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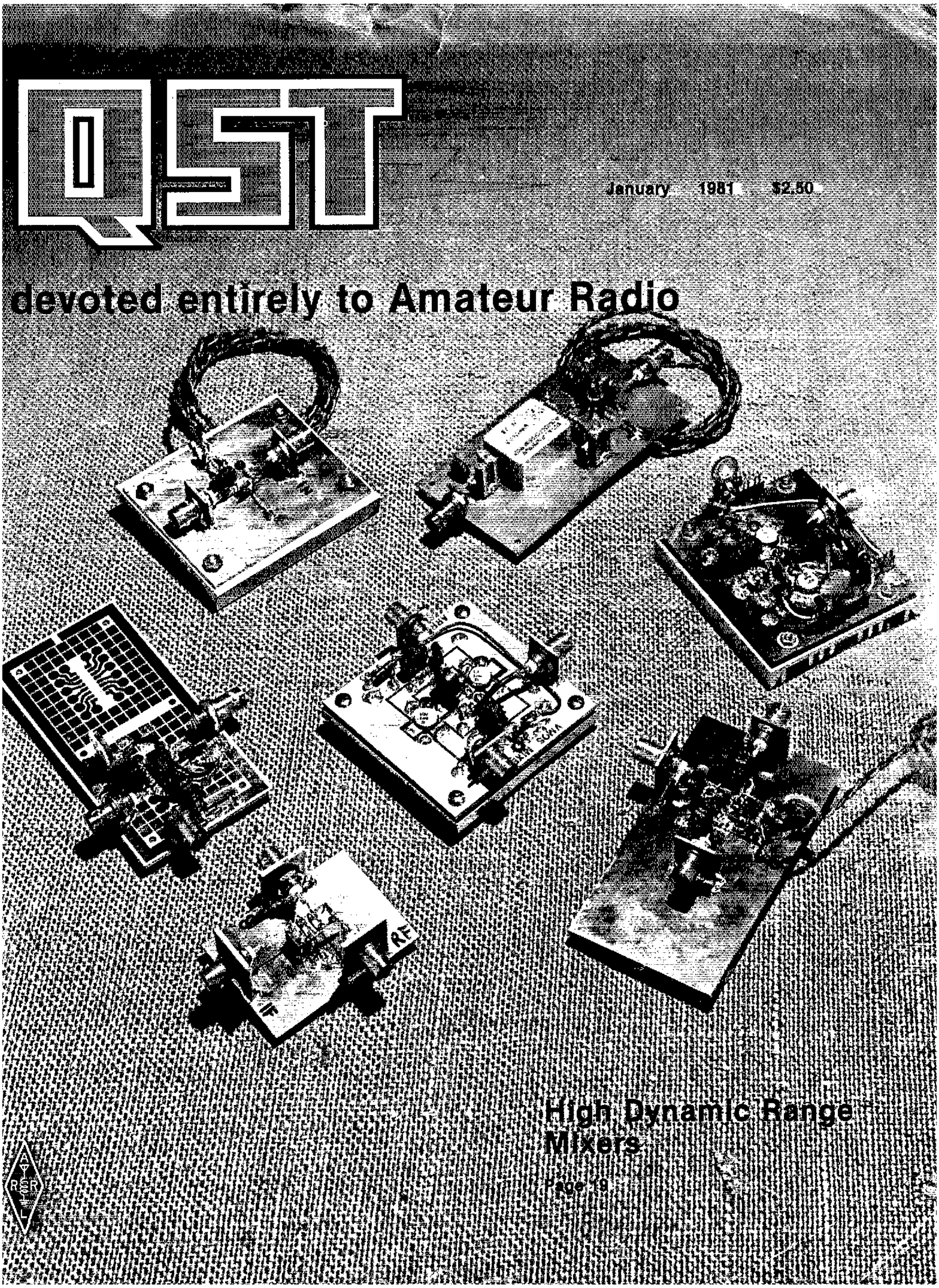
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THE COVER

VMOS power FETs, diode-rings and some ICs make excellent strong-signal mixers. A two-month ARRL lab program provided some revealing intercept numbers. See page 19.

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Low-Cost Conversion of the Robot 400 to Color

Take an existing Robot 400, add another memory board and a simple encoder and you've got color SSTV!

By Dr. Don C. Miller,* W9NTP

These "full-color" SSTV pictures were made by transmitting and receiving only two colors on 20 meters. Jack Berman, W1BGW, is the originator of two of these pictures while Ken Carpenter, WD5BRG, sent the picture of our colorfully feathered friend. Don Miller, W9NTP, supplied the photos of the pictures received at his station.

Over the years, I've experimented with many systems for transmitting color slow-scan television (SSTV). Several successful methods may be utilized, but many are too complicated for the average SSTVer to contemplate. It is for this reason that the conversion of a commercial scan converter was undertaken.

Color video is a complicated entity and has technical limitations even in fast-scan NTSC (National Television Systems Committee) systems. Slowed-down versions of the NTSC system are feasible and experimenters such as Mike Tallent, W6MXV, have spent considerable time working on them. After all areas were explored, it was decided that the best place to start in color SSTV was one which would get as many stations operational as easily as possible.

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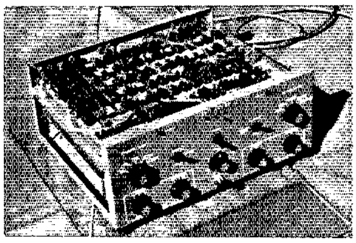
Which Color System To Use?

Color TV pictures can be produced in a variety of ways. The most natural colors can be reproduced if three sources of video are provided whose images have been subjected to three filters which pass different spectral frequencies. Commercial color TV encoders encode these three simultaneous signals into a luminance signal (called the Y signal) and at least two color difference signals. Color pictures can also be produced using only two sources of video which have been derived from scenes viewed through two different spectral filters (filters different from those used in the three-color system). I have designed and built both types of systems and can say the accuracy of color reproduction from a three-color system is superior to that produced from a two-color system. However, other considerations must be taken into account when assembling an SSTV station.

In many demonstrations of TV systems I've seen, the real problem of video transmission has not been addressed. Of course, color can be transmitted over three cables or over a radio propagation path using a bandwidth three times that of a black-and-white TV signal. For amateur use, cables are obviously out of the question and the wider transmission bandwidth is not permitted by FCC regulation, so some other method must be found. This leaves only two other possibilities. The first, quadrature modulation, is the most acceptable, but has not been sufficiently explored technically to produce a workable system. Much like the present NTSC fast-scan commercial method, it would require the development of complicated new gear at both ends of the transmission path. The other possibility is



The modified Robot 400. A second memory board has been mounted inside the scan converter. The toggle switch is mounted in the area formerly occupied by the Robot label. Portions of the NTSC encoder board (available from the author) and another memory board are also shown.

that of time multiplexing. In the early days of TV, field-sequential TV almost made it to our living rooms. Remember the CBS system? It was found that this system could be used for color SSTV since there is no problem with flicker and storage, for the images can be provided by means of digital memories. The price paid for using this transmission method is that more *time* is required, but bandwidth is conserved.

Where Do I Get A Color SSTV Camera?

In order to be practical, a system must not be too costly. The time-multiplexing system makes it possible to use a simple color camera exhibiting perfect registration and a high video signal-to-noise ratio with low light levels. Later, I'll discuss recent developments that make it possible to use a commercial color camera for color SSTV. The lowered prices on out-of-date, striped vidicon cameras now make this a desirable economic choice.

We start with an operating black-and-white Robot 400 SSTV system. The cost of converting the black-and-white camera is negligible. Two color filters are required. Cyan and magenta are best, but the color SSTVer should plan on experimenting with various color filters. Do not buy expensive filters unless you are a color expert. Inexpensive filters can be made from Christmas decoration material. A second memory board is obtained and installed in the Robot 400. The filters are alternately held in front of the camera lens while the two images are separately loaded and stored into the two memories of the converted Robot 400 digital scan converter. (Those who feel manual operation is too primitive can employ a color wheel.) A cyan picture is transmitted by holding the proper filter in front of the camera and pushing the "snatch" button. This picture can now be transmitted in the next 8 seconds. A magenta picture is then similarly stored and transmitted. (Such a system was demonstrated several years ago at the Dayton Hamvention and created a sensation.) The total time of transmission is 16 seconds. (You can easily design a system in which the entire content of the two memories can be read out automatically, one field at a time). Practical considerations dictate that several transmissions of each color be made when using our crowded hf bands. This two-color system is not claimed to be superior to a three-color system, but the time of transmission is minimized and it is accomplished simply by modifying an existing piece of popular commercial equipment. Two additional memories cannot be placed into the cabinet of the Robot 400, but nothing should prevent the reader from adding one board inside and another outboard for future experimentation with the more-complicated quadrature or line-sequential system now under development.

Additional Memory Board Installation

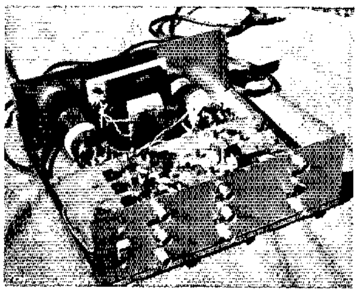
Performing this modification on a new unit will void the manufacturer's warranty. It will not hurt the resale value, however, because the connections are made either to the IC pins on top of the board or to the underside on the solder pads. If it is ever desired to restore the Robot 400 to its former appearance, it can be done in a few minutes without any scars. A modified '400 is shown in the photograph.

Step-by-step instructions for the procedure are not given here. The board, complete wiring diagrams, and other details are available at cost from the author.[1] Readers in foreign countries may find it practical to write for the negative artwork.

It is necessary that the reader understand the principle of the addition of the second memory. A block diagram is shown in Fig. 1. The timing circuitry of the Robot 400 remains unaltered. All that has been done is to add a complete 8-K (65,536 bit) memory that is multiplexed with the original memory in the scan converter. Examination of the original schematic diagram of the memory will show that certain designations such as CHIP ENABLE, CHIP SELECT, DATA IN and WRITE are the important inputs to the memory. The outputs need be multiplexed so that each memory can be fed through the slow-scan fm oscillator. In order to make sure that the loading is not exceeded, the inputs to the two memories were isolated by buffers. Input data is fed to both memories in parallel and the WRITE lines are provided with a separate driver so that the multiplexing function can be performed easily without fear of loading problems.

If desired, the new fast scan output of the added memory board can be brought out to an output jack installed on the back panel of the Robot. Several output jacks

[1]Notes appear on page 13.



A completed NTSC color encoder. It features both a composite video output and an rf output for attachment to the antenna terminals of any color television set.

already present are rarely used, so it is possible to modify and use one of these without making any additional holes in the back panel.

Removing the Robot label from the front panel exposes two holes. These are used to mount a red and a green LED indicator. A small switch is mounted between these two LEDs. The operator loads the picture into the memory of choice by toggling this switch. The slow-scan information outputs through an analog IC switch under transmit conditions. Again, the position of the small switch between the red and green LEDs determines which color is being transmitted through the internal 4066 analog switch.

Monitors and an Encoder

When I first designed this modification, the system operated with three memories. It immediately became apparent that some method of viewing the color image would be needed — an RGB (red, green, blue) monitor. For those of you not familiar with this type of color monitor, it is one which has direct inputs to each of the three color guns. What is stored in each of the memories is fed directly to the correct gun. The only other alternative is to build an NTSC encoder to permit display on an NTSC monitor.

Again, a problem of economics comes up; both the RGB and NTSC monitors are expensive. The encoded monitor is more obtainable now since fast-scan video tape recorders (VTRs) are generally available, but a closer look will show that most home-type VTRs output rf to an existing television set tuned to a particular TV channel. Fortunately, the 1889 IC has become available and that seems to solve all the problems. Fig. 2 is a schematic diagram of an NTSC encoder which was inspired by another circuit.[2] This encoder has three inputs. Each input is clamped to the black level and fed to the encoder chip. It is not necessary to have clamping for the scan converter (Robot

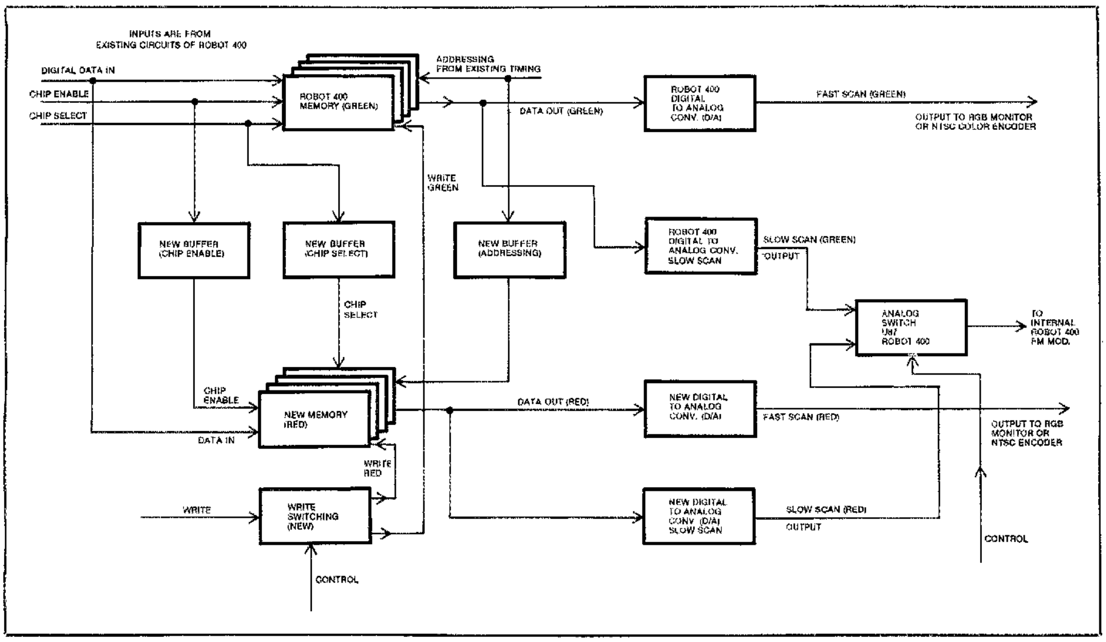


Fig. 1 — A block diagram of the Robot 400 two-color SSTV conversion.

conversion), but if inputs from three black-and-white cameras for color or overlays are to be used, it is necessary to ensure that the black levels are equal. I recommend that the clamping be retained.

The encoder board is placed in a separate box; it isn't needed if an existing TV set is modified for RGB inputs. An inside view of the encoder is shown in the photograph.

The NTSC system requires that each of the three signals supplied have a ratio of 0.59/0.3/0.11 to give the proper color fidelity; the resistors in the encoder perform this task. The output of the 1889 IC is either a video signal or a modulated rf signal at a television channel frequency chosen by the constructor (usually channel 2 or 3).[3]

The foregoing assumes that the encoder will have three inputs to encode. Our Robot 400 conversion has only two outputs. I found that the color blue is not very important in a TV picture. In some cases, it can be added as "dc." Experiments have been conducted combining some red and green and using this for the blue signal; the encoder board performs that function.

Much of the accuracy of color reproduction depends upon the filters used at the transmitting station as well as the adjustment of the receiving station color receiver circuitry. No standardized levels yet exist among color SSTVers. Remember how the spacecraft pictures of Mars were standardized by sending back a picture of the American flag on part of the spacecraft? This same method is used by SSTV operators. Pick a subject that has colors familiar to the receiving operator and include this as a part of your overall picture. You'll be surprised at the accuracy of the reproduction.

Summary

The future still holds the possibility of many improvements. With the availability of fast-scan color cameras, it is now possible to feed the output of your color camera into a color TV receiver through an rf encoder and modify the TV set to have RGB outputs. These three outputs can be connected to two or three memory scan converters. This provides "frozen" color SSTV shots. With the filter method, only still subjects may be used because of the time delay encountered between the filter positioning when loading the memories.

The 16- or 24-second transmission time is the one remaining problem. This may be solved by remembering that only the Y, or luminance, channel need have high resolution in any system, fast- or slow-scan TV. With the two-memory conversion just described, one memory can be loaded with the 128 × 128-line resolution luminance signal and the other memory with a 64- × 128- or 128- × 64-line color picture of the R-Y and B-Y information. This makes the difference colors only half the resolution of the luminance channel. The receiver can accept the two transmissions and demultiplex them over a 16-second interval for a three-color image or the sender can encode them into a quadrature system not unlike the 3.58 MHz system used for fast scan. The frequencies would be scaled down for slow-scan transmission. This last system would provide three-color SSTV in an 8-second time frame.

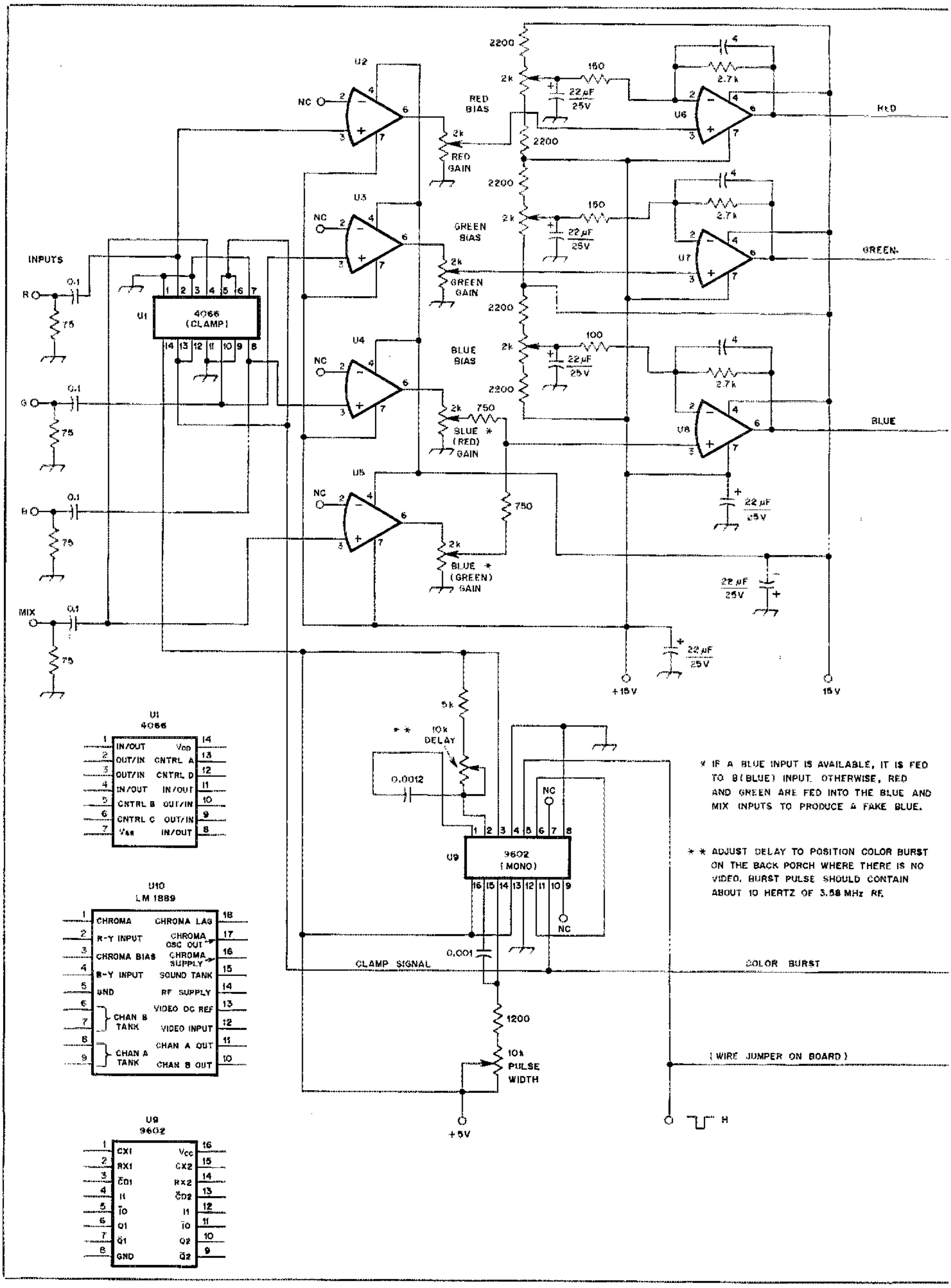
I regularly operate the SSTV net that meets each Saturday on 14.230 MHz at 1800 UTC. Call in and start looking at the transmissions of *color* SSTV!

Notes

[1][Editor's Note: The ARRL and *QST* in no way warrant this offer.]

[2]Trottier and Matic, "Signal Encoder Generates Composite Color," *Electronic Design Notes*, August 20, 1978.

[3][Editor's Note: A device which produces a video-modulated, radio-frequency carrier on frequencies allocated for television broadcasting is defined in §15.4(m) as a Class I TV device, and requires FCC type approval before it can be used. Type-approval procedures are described in Subpart J of Part 2 of the FCC rules. Technical specifications for a Class I TV device are given in §§15.401 to 15.423 of the rules. An alternative to type approval might be obtaining Special Temporary Authority for operation in a unique type of station under §15.2(b) of the rules. Docket 79-244 proposes to relax these requirements.]


INPUTS
R
G
B
MIX
0.1
75
U1
4066
(CLAMP)
U2
U3
U4
U5
NC
RED BIAS
GREEN BIAS
BLUE BIAS
RED GAIN
GREEN GAIN
BLUE * (RED) GAIN
BLUE * (GREEN) GAIN
2200
2k
150
100
750
2.7k
22 µF 25V
U6
U7
U8
RED
GREEN
BLUE
+15V
15V
5k
** 10k DELAY
0.0012
U9
9602 (MONO)
0.001
CLAMP SIGNAL
COLOR BURST
1200
10k PULSE WIDTH
+5V
(WIRE JUMPER ON BOARD)
H
* IF A BLUE INPUT IS AVAILABLE, IT IS FED TO B(BLUE) INPUT. OTHERWISE, RED AND GREEN ARE FED INTO THE BLUE AND MIX INPUTS TO PRODUCE A FAKE BLUE.
* * ADJUST DELAY TO POSITION COLOR BURST ON THE BACK PORCH WHERE THERE IS NO VIDEO. BURST PULSE SHOULD CONTAIN ABOUT 10 HERTZ OF 3.58 MHz RF.
U1 4066
IN/OUT
OUT/IN
CNTRL B
CNTRL C
Vss
VDD
CNTRL A
CNTRL D
U10 LM 1889
CHROMA
R-Y INPUT
CHROMA BIAS
B-Y INPUT
GND
CHAN B TANK
CHAN A TANK
CHROMA LAG
CHROMA OSC OUT
CHROMA SUPPLY
SOUND TANK
RF SUPPLY
VIDEO DC REF
VIDEO INPUT
CHAN A OUT
CHAN B OUT
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CX2
RX2
CD2
Q2

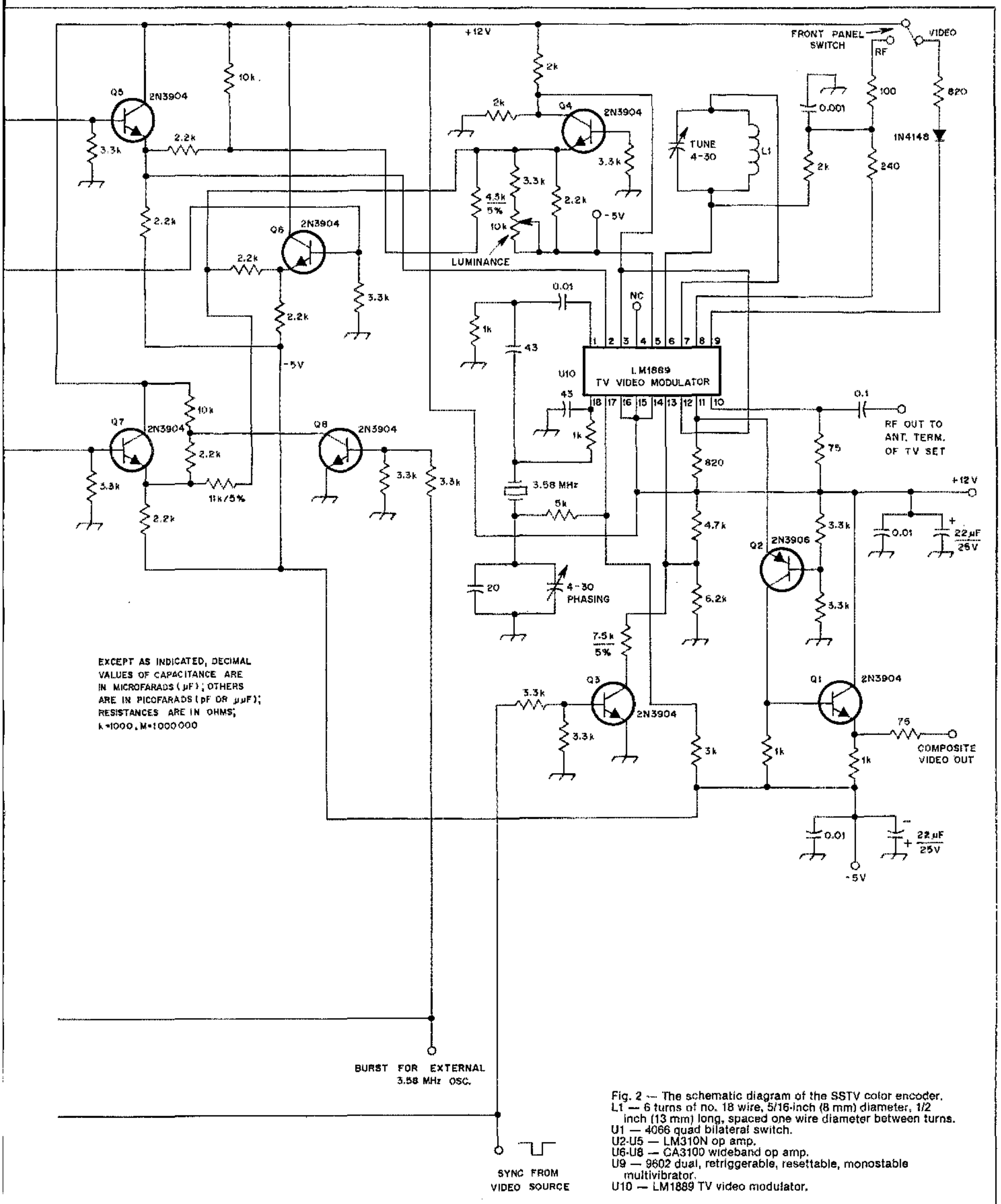

Fig. 2 — The schematic diagram of the SSTV color encoder.
L1 — 6 turns of no. 18 wire, 5/16-inch (8 mm) diameter, 1/2 inch (13 mm) long, spaced one wire diameter between turns.
U1 — 4066 quad bilateral switch.
U2-U5 — LM310N op amp.
U6-U8 — CA3100 wideband op amp.
U9 — 9602 dual, retriggerable, resettable, monostable multivibrator.
U10 — LM1889 TV video modulator.

Heat Sinks†

Buying an air conditioner for your solid-state rig? Perhaps all you need is a correctly sized heat sink. At last, heat-sink design theory revealed!

By G. C. Oxley,* G8MW

The rating of all electrical equipment is determined by its working temperature. If the apparatus gets too hot then insulation may catch fire or melt, conductors expand and semiconductor junctions can be destroyed. In the specific case of semiconductors the device is usually kept cool by using a heat sink. Keeping the temperature of semiconductor devices within the specified limits is also important because their operating characteristics alter with changes in temperature. This is particularly important with Zener diodes, Class B amplifiers and temperature-limited voltage regulators.

The heat sink loses heat to its surroundings by convection, radiation and conduction. Mounting the heat sink vertically, so as to give as good a flow of air as possible, will help the convection of heat. The larger the volume of metal, the more heat it will absorb; but the most important factor is the surface area of the heat sink. This area can be increased by adding "radiating" fins. When natural convection takes place the rate of heat loss in a constant-temperature enclosure is proportional to θ,[1,2] where θ is the temperature excess over the surroundings. Loss of heat by radiation can be enhanced by painting the heat sink matte black or by anodizing.

A rough comparison of the ability of some metals to conduct heat is given in Table 1. When cost and ease of working are considered, aluminum comes out best; but copper, zinc and brass can all be used, and these metals are easily soldered (plumbers' solder). The working temperature of the device and the power that it needs to dissipate must be known before a heat sink can be designed. Considerations of cost, weight and space will require the size of the heat sink to be kept to a minimum.

The opposition to a body losing heat is called its thermal resistance. This is usually denoted by θ and is expressed in ° C/watt.

Rectifier diodes, large Zener diodes and transistors dealing with more than about 0.5 W are often provided with heat sinks in order to achieve a higher power output. A rule-of-thumb value for the working temperature of silicon junctions is approximately 150° C, and for germanium junctions 75° C.

The rating of rectifier diodes is often related to the temperature of the stud (bolt) T_S. Fig. 1 shows that the output current of this diode must be halved if the temperature T_S rises from 50° C to 100° C.

Table 1
Heat Conductivity of Some Metals

Silver (Ag)	100	Brass	25
Copper (Cu)	80	Iron (Fe)	15
Aluminum (Al)	40	Lead (Pb)	8
Zinc (Zn)	30		

Examples Using Diodes and Voltage Regulators

A rectifier diode has a forward voltage drop of 1 V when delivering a current of 5 A. The stud temperature must not exceed 80° C when the rectifier is dissipating 5 W. Let the air (ambient) temperature

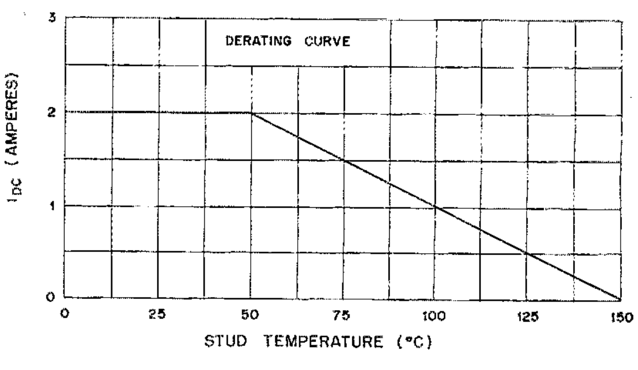

Fig. 1 — Diode rating related to stud temperature.

*Osterwald, Littlemoor, Ashover, Chesterfield, Derbyshire, England

†Adapted from an article of the same title in *Radio Communication* (RSGB), December 1978.

[1]References appear on page 18.

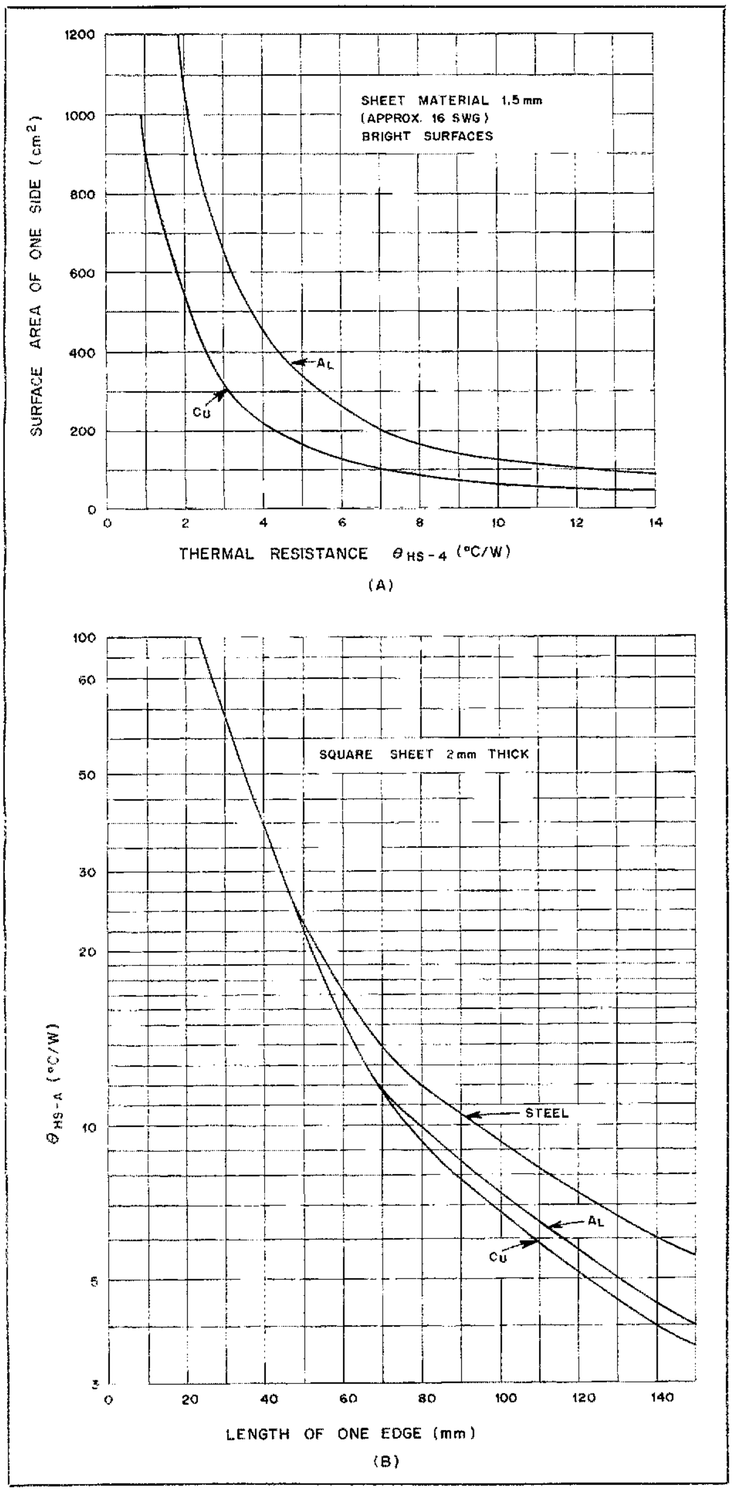

Fig. 2 — At A, thermal resistance related to surface area. At B, graph showing reduced importance of area and material at higher thermal resistance.

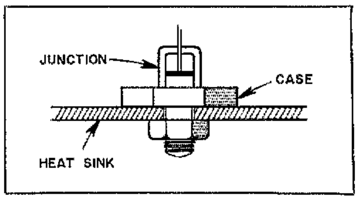

Fig. 3 — Diode rectifier mounted on heat sink.

inside the rectifier compartment be T_A = 50° C, then

$$\frac{T_s - T_A}{P_D} = \frac{80° - 50°}{5W} = 6° \text{ C/W}$$

From the curves, Fig. 2, an aluminum heat sink would need to be approximately 260 cm^2 in area of one side. The dimensions of a square heat sink would be $\sqrt{(260/2)}$ by $\sqrt{(260/2)}$ = $\sqrt{130}$ by $\sqrt{130}$, and a 12-cm by 12-cm piece of 1.5-mm aluminum sheet would be suitable. Painting the sheet with matte black paint would give an added safety margin of about 20 percent.

Manufacturers often draw heat-sink characteristics on logarithmic graph paper, the result being nearly a straight line. Fig. 2A shows the rapid increase in area needed as the thermal resistance falls below 5° C/W or so, while Fig. 2B shows that the area and material become of less importance above 30° C/W.

Fig. 3 shows a diode rectifier mounted on a heat sink. Heat must be conducted away from the junction to the case, and this path has a thermal resistance of $\theta_{J\text{-}C}$° C/W. From the case to the heat sink the resistance is $\theta_{C\text{-}H}$, and from the heat sink to the surroundings $\theta_{HS\text{-}A}$. Adding these together:

$$\theta_{J\text{-}A} = \theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}$$

The same conditions apply also to transistors and voltage regulators. Compact and cheap voltage regulators are now available, and best results are obtained by using adequate heat sinks.

For a regulator required to supply 3 A at 12 V, the input voltage will be about 14.5 V, but to allow for ac line voltage variations, and transformer and rectifier tolerances, this input may reach 17 V. At maximum output the regulator must dissipate 5 × 3 = 15 W. If T_A = 50° C and T_j = 150° C:

$$\theta_{J\text{-}A} = \frac{150° - 50°}{15 \text{ W}} = 6.7° \text{ C/W}$$

$$\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 6.7° \text{ C/W}$$

$$\theta_{HS\text{-}A} = 6.7 - \theta_{J\text{-}C} - \theta_{C\text{-}HS}° \text{ C/W}$$

The manufacturer of one such regulator gives the value of $\theta_{J\text{-}C}$ as 3° C/W. A figure for the value of $\theta_{C\text{-}HS}$ can range from 0.1° C/W to 0.5° C/W, depending

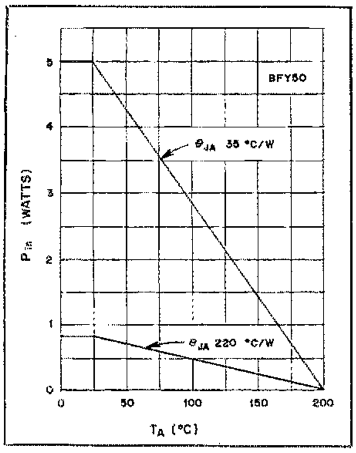

Fig. 4 — Derating curves of a BFY50.

on whether an insulating washer and bushings are used and upon good surface contact, aided by a thermal compound such as silicone grease. If a figure of 0.3°C/W is chosen:

$\theta_{HS\text{-}A} = 6.7 - 3 - 0.3 = 3.4°$ C/W.

From Fig. 2, an aluminum plate approximately 17-cm square would be suitable as a heat sink.

Examples Using Transistors

BFY50 [equivalent to 2N1613 — Ed.]: If the temperature of the case can be kept below 100° C then the power dissipated can be 2.86 W. $\theta_{J\text{-}A}$ is quoted as 220° C/W.

$$P_D = \frac{T_J - T_A}{\theta_{J\text{-}A}} = \frac{220° - 25°}{220°\ C/W}$$

$$= \frac{175}{220} = 0.8W$$

This is the power which a BFY50 will handle in surroundings having a temperature not exceeding 25° C. The derating curves are given in Fig. 4. Let the power dissipated be 2 W.

$$\theta_{HS\text{-}A} = \frac{200° - 50°}{2\ W} - \theta_{J\text{-}C} - \theta_{C\text{-}HS}$$

$$= 75\text{-}35\text{-}1 = 39°\ C/W$$

Because this transistor has a TO-5 can, a rather higher figure is chosen for $\theta_{C\text{-}HS}$. Note case is connected to collector.

BLY85, vhf transistor [equivalent to 2N5589 — Ed.]: Let P_D = 5 W

$$\theta_{J\text{-}A} = \frac{150° - 50°}{5\ W} = 20°\ C/W$$

$$\theta_{HS\text{-}A} = 20\text{-}\theta_{J\text{-}C}\text{-}\theta_{C\text{-}HS}$$

$$= 20 - 12.5 - 0.5 = 7°\ C/W.$$

The data sheet gives $R_{th(J\text{-}mb)}$ instead of $\theta_{J\text{-}C}$. The term "mounting base" is used instead of "case." The torque applied to the nut on the fixing stud is quoted as between 7.5 kg/cm and 8.5 kg/cm. Tight, but not too tight.

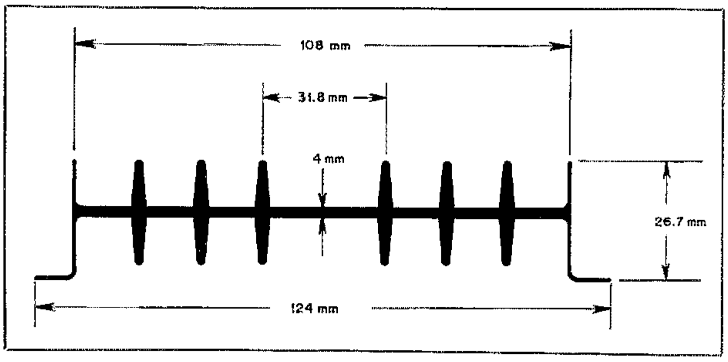

Fig. 5 — Cross-section of a manufactured heat sink.

Practical Considerations

A typical manufactured heat sink is shown in cross section in Fig. 5. Data supplied by the manufacturer indicates that a 100-mm length has a thermal resistance of 2.1° C/W, with the fins vertical in free air. For a length of 100 mm the performance is shown in the graphs of Fig. 6. For a dissipation of 25 W with $T_{HS}\text{-}T_A$ = 50° C,

$$\theta_{HS\text{-}A} = \frac{50}{25} = 2°\ C/W.$$

Care should be taken to make sure that the surface of the heat sink is as smooth and flat as possible. Apply the correct fixing pressure to the securing nuts and bolts, and use a thermal conducting grease. When no insulating washers are needed use bolts or screws which fill the fixing holes and use flat washers under the nuts. If the heat sink must be mounted horizontally its size should be increased by a factor of 1.3.

Home-Made Heat Sinks

Details are given in the handbooks. Copper-clad board can be used; if clad on both sides, the copper should be bonded. Transistors with TO-5 cans are best sunk into an 8.5-mm diameter hole drilled into the sink. Aluminum or brass vanes from old tuning capacitors, as well as discarded aluminum sole-plates of smoothing irons, can be adapted.

The writer wishes to thank Marston Excelsior Ltd., STC, Texas Instruments, Lambda Electronics and Mullard for technical information.

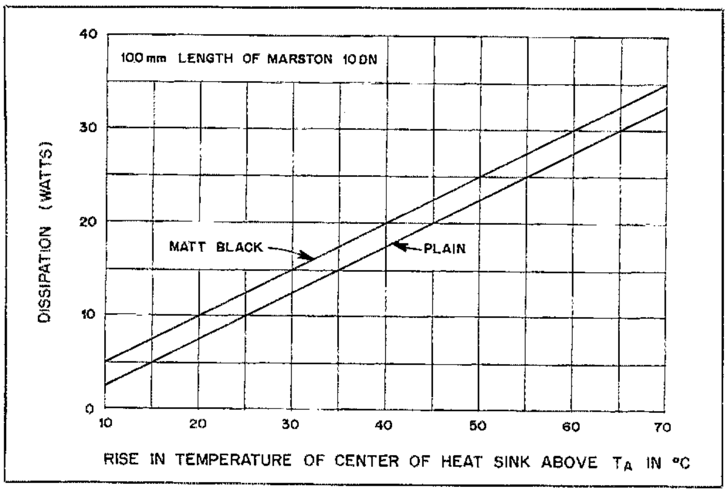

Fig. 6 — Performance graph of a manufactured heat sink, 100-mm length.

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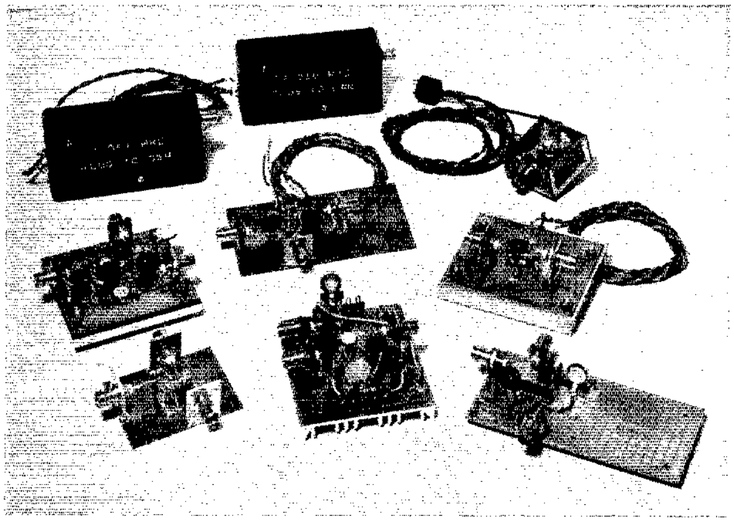
[1] Hall, "How to Solve Transistor Heat Sink Problems," *Ham Radio*, January 1974.

[2] Kennedy, "Low-power Transistor Transmitter," *Wireless World*, October 1968.

Modern Receiver Mixers for High Dynamic Range



The VMP4 VMOS offers a new approach to mixer design. For quality communications equipment it provides improved port-to-port isolation and relatively high immunity to strong in-band and out-of-band signals.

By Doug DeMaw,* W1FB and George Collins,** ADØW

Designers and users of modern communications receivers and transmitters are necessarily interested in high dynamic range and port-to-port isolation in the mixer stages of the equipment. A quality communications receiver for medium- or high-frequency band use will exhibit high dynamic range in order to provide relative immunity to strong in-band or out-of-band signals. Furthermore, the system should be relatively free of spurious responses that cause "birdies" across the receiver tuning range.

Acknowledging the importance of gain distribution and noise figure in the early stages of a receiver, we concentrate, therefore, on the mixer performance. In a typical quality design of the day we try to ensure a "crunch-proof" status for the rf amplifier, mixer and post-mixer amplifier. For the most part, this requires that each of those stages be capable of handling a substantial amount of signal power without gain compression or undue IMD products being generated. It is not unusual to find a VMOS power FET or a large CATV (cable television) type of bipolar transistor being used as an rf amplifier ahead of the mixer. A VMP4 VMOS device or a 2N5109 bipolar transistor can be used to obtain high dynamic performance in an rf amplifier. The same or similar devices are often used as post-mixer broadband amplifiers in high-performance communications receivers.[1,2]

Our objective is to select a mixer that has sufficient port-to-port isolation to minimize the effects of LO energy appearing in the mixer output. Similarly, the signal energy should be well suppressed at the remaining ports of the mixer. Furthermore, if the mixer requires a high level of LO power to provide optimum performance, difficulty may be encountered in keeping the LO energy isolated from the other circuits in the receiver. Our choice, therefore, must be one that involves a minimum amount of trade-offs while ensuring good mixer performance.[3]

Mixer Options

The choice between passive and active mixers in a given design should be based on performance objectives, with consideration of the circuitry that precedes and follows the mixer. A singly or doubly balanced mixer is preferable to a single-ended mixer in the interest of isolation between the ports. The doubly balanced version will afford the best performance in that respect.

The active mixer will yield conversion gains of less than unity to as great as 20 dB, depending upon how it is used. Perhaps the least acceptable of the better mixer options is a pair of small-signal, dual-gate MOSFETs of the 40673 family. Many communications receivers use such devices in a broadband, singly balanced arrangement. Although this may be cost-effective to the manufacturer, high dynamic range will be hard to achieve without a sacrifice in noise figure at the higher frequencies. If an rf amplifier is used to improve the noise performance, care must be taken to keep the gain only

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[1]References appear on page 23.

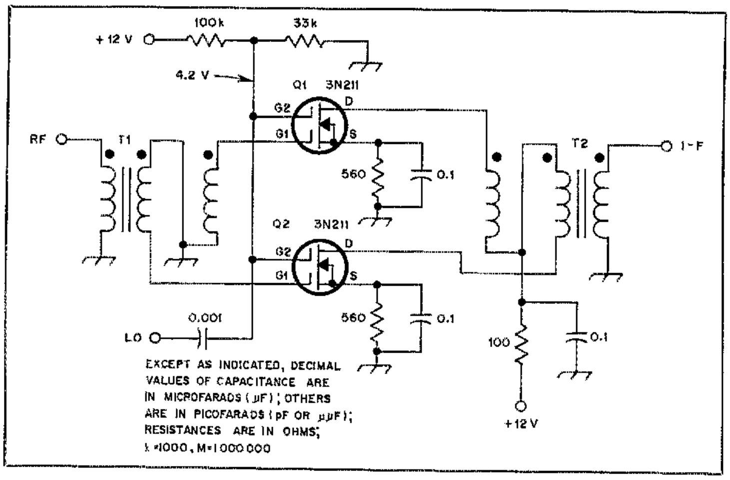


Fig. 1 — Reference mixer that uses small-signal dual-gate MOSFETs in a broadband, singly balanced setup. Conversion gain is −5 dB because of the low terminal impedances and broadbanding. With an LO injection of 8 volts pk-pk and an input signal level of −10 dBm PEP, the third-order output intercept is +17 dBm. Gate bias and LO injection has been optimized. Narrowbanding and careful impedance matching would yield conversion gains up to +15 dB.

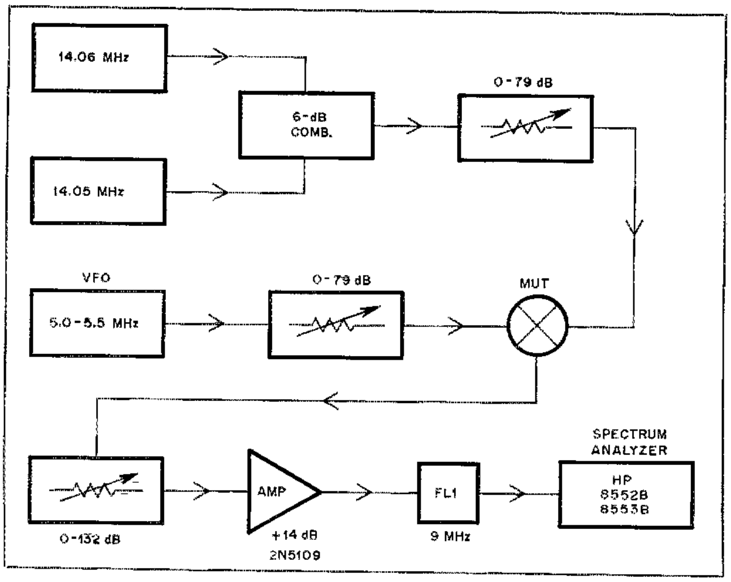


Fig. 2 — Block diagram of the test fixture used in evaluating the mixers treated in this article.

high enough to ensure the desired receiver noise figure. Too much gain will cause the mixer to collapse in the presence of strong signals. Most receivers that use small-signal FETs in a singly balanced scheme (Fig. 1), and with a MOSFET rf amplifier ahead of the mixer, exhibit an IMD characteristic of 80 to 85 dB if the design has been done with care. A gain compression of 1 dB occurs between 115 and 125 dB on the average, referenced to the receiver MDS (minimum discernible signal). A receiver with these characteristics might be entirely acceptable in some signal environments. But much greater dynamic range is necessary in high signal-density locations, such as shipboard and in large communications centers where transmitters are operating on several frequencies simultaneously.

Active mixers can be valuable in terms of conversion gain, with narrow-band types yielding the higher gain figures. The usual trade-off between bandwidth and gain must be accepted when using broadband mixers. The amount of conversion gain desired will depend on the filter losses before and after the mixer, and the available overall gain after the mixer.

Passive mixers of the diode-ring, doubly balanced variety are capable of excellent dynamic range and port-to-port signal isolation. The shortfall is, of course, fairly high LO power requirements (+7 to 15 dBm) and a conversion loss on the order of 8 dB. It is almost mandatory to employ an rf amplifier ahead of the diode-ring mixer to provide a low noise figure. A diplexer may be used after the mixer to ensure a 50-ohm termination at all frequencies, thereby aiding the IMD characteristic.[4] If the i-f filter has a high insertion loss (10 dB for most mechanical filters), a post-mixer, large-signal amplifier is worthwhile. It can be terminated by a 50-ohm pad of specified attenuation to ensure a constant load and to protect the i-f filter from damage when very high signal levels are present at the receiver input.

It is apparent from the foregoing discussion that a lot of decision making is necessary when deciding what mixer to use. Whatever the choice is, high dynamic range should be the criterion. This can be achieved with passive or active mixers. The remainder of this article addresses various mixers and their performance characteristics. The laboratory test procedure used by the authors is also discussed.

Mixer Evaluation Method

Two-tone tests of the various mixers were performed with a signal separation of 10 kHz at 14.050 and 14.060 MHz. A +8 dBm output level was available from each spectrally clean, crystal-controlled generator. A 6-dB combiner followed the two generators. Output from the combiner was routed through a Tektronix 2701 attenuator (0 to 79 dB), then to the mixer under test (MUT).

LO power was generated by a Trio-Kenwood 5-MHz VFO, to which filtering and additional amplification was added. The LO source delivered +16 dBm. A second Tektronix 2701 attenuator was connected between the LO source and the MUT LO port.

I-f output from the mixers was routed through an HP 355C/D attenuator (0 to 132 dB) to a broadband class A 2N5109 +14-dB amplifier which had a +40 dBm output intercept. A 2.4-kHz bandwidth KVG 4-pole crystal-lattice filter with an IL (insertion loss) of −5 dB followed the post-mixer amplifier. Output from the filter was supplied to an HP 8553/8552B spectrum analyzer through a 500- to 50-ohm matching transformer. Other broadband transformers were used to provide a proper interface between the test modules and MUTs. Those transformers are not shown in the test-setup block diagram of Fig. 2. A 7-pole, T-section Chebychev low-pass filter was used at the output of the 2N3866 broadband post-LO amplifier to ensure that all LO harmonics were 70 dB or greater below peak LO output.

Plessey SL6440C IC Mixer

A recent product to the IC market is the Plessey SL6440C programmable high-level mixer. It is advertised as having a +30 dBm output intercept point and a +15 dBm compression point (1 dB). The internal circuit of the IC had not been revealed at the time this article was written, but it is presumed that the inner workings are not too unlike those of the Motorola MC1496G, with the exception of greater dissipation capability for the SL6440C. The manufacturer rates the mixer as having a −1 dB (typical) conversion gain when the IC is terminated in 50 ohms. In our tests a 200-ohm termination was used at the input and output of the IC, yielding a conversion gain on the order of +8 dB maximum.

Fig. 3 contains the circuit of the SL6440C as it was configured for laboratory analysis. R1 was used to adjust the quiescent current of the mixer. Table 1 shows the test results at various LO and signal-input levels. The spectral displays of Fig. 4 show the LO and LO harmonics to i-f-port isolation (A). With 0 dBm of LO input power the isolation was 29 dB. The 2f LO isolation was measured at −72 dB.

Spectral photograph B of Fig. 4 shows the rf port to i-f port isolation as being 48 dB when the LO level was 0 dBm and the rf-input level was −10 dBm, PEP. Photograph C is the two-tone output of the mixer. Table 2 contains data on conversion gain, intercept numbers and port isolation with various I_p amounts. These data were compiled with an LO injection of 0 dBm and an rf input of −5 dBm.

One might conclude from the foregoing test results that the Plessey SL6440C is indeed a worthy device which is capable of providing high dynamic range without conversion loss. The I_p values used in these tests were the maximum safe levels

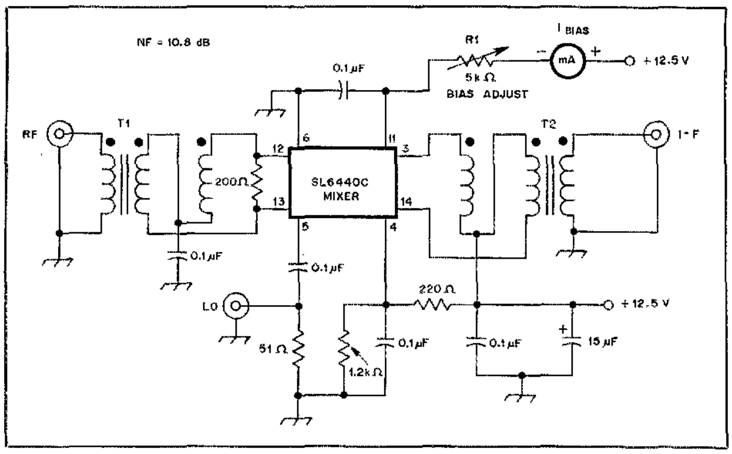


Fig. 3 — Test circuit for the Plessey SL6440C mixer IC.

Table 1

Test Results at Various LO and Signal-Input Levels

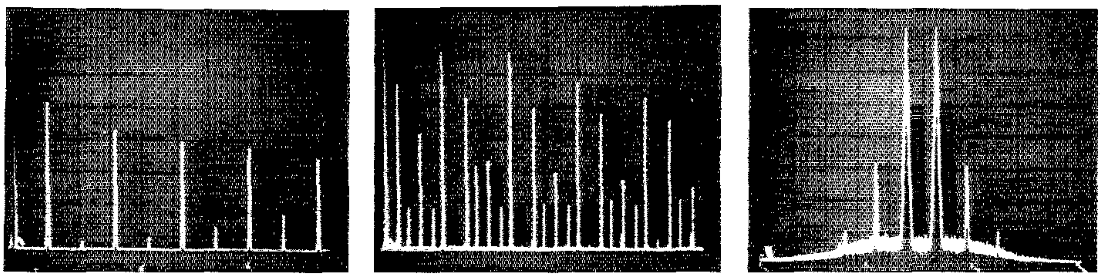
LO Level (dBm)	*Input Level (PEP, dBm)*	*Third-Order Output Intercept (PEP, dBm)*	*Conversion Gain (dB)*
0	+3	24	7
0	0	29	8
0	−5	31	8
0	−10	31	8
0	−15	29	8
−3	+3	25	7
−3	+1	28	8
−3	0	29	8
−3	−5	30	8
−3	−10	31	8
−3	−15	30	8
−10	+2	23	7
−10	0	29	8
−10	−5	31	8
−10	−10	31	8
−10	−15	29	8
−15	+2	25	7
−15	0	29	8
−15	−5	31	8
−15	−10	31	8
−15	−10	31	8
−15	−15	29	8

Table 2

Data on Conversion Gain, Intercept Numbers and Port Isolation

I_p Current (Pin 11, mA)	*Conversion Gain (dB)*	*Third Order Output Intercept (dBm)*	*LO-to-RF Isolation (dB)*
5.0	5.5	18	27
5.5	6.0	19	27
6.0	6.5	20	27
6.5	7.0	21	27
7.0	7.0	22	27
7.5	7.0	23	27
8.0	7.0	24	27
8.5	7.0	25	27
9.0	7.5	26	27
9.5	7.5	26	27
10.0	7.5	27	27
10.5	7.5	28	27
11.0	7.5	28	27
11.5	8.0	29	27
12.0	8.0	29	28
12.5	8.0	30	28
13.0	8.0	31	28
13.5	8.0	31	28

LO input = 0 dBm. Rf input = dBm



(A) (B) (C)

Fig. 4 — Spectograph A shows the LO suppression at the i-f port of the SL6440C with no rf signal applied. LO injection is 0 dBm. Center frequency is 25 MHz, bandwidth is 100 kHz, vertical scale is 10 dB/div. and horizontal scale is 5 MHz/div. Display B shows the output spectrum with 0 dBm of LO power and −10 dBm of rf signal applied to the mixer. Analyzer bandwidth in this example is 30 kHz. Two-tone output is displayed at C with the vertical scale being 10 dB/div. and the horizontal scale at 10 kHz/div. Center frequency is 9 MHz and bandwidth is 0.3 kHz.

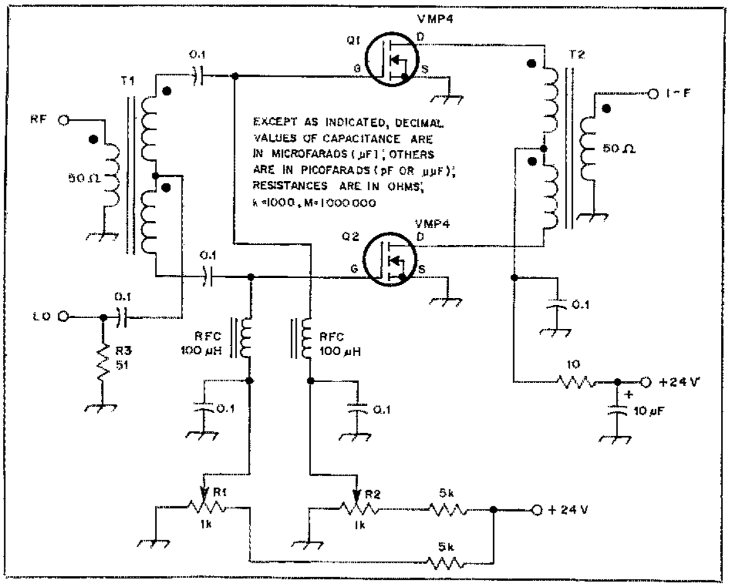


Fig. 5 — Circuit for the VMOS power FETs in a singly balanced arrangement. Split dc feed to the gates was used to provide dynamic balance.

Table 3

Results with Various Levels of Gate Voltage and Drain Currents

LO (dBm)	Rf Input[1] (dBm)	Gain (dB)	I_D[2] (mA)	Gate[3] Volts	Third O.I. (dBm)
+16	+8	15	75	1.0	42.5
+16	+5	15	63	1.0	43.5
+16	+2	15	56	1.0	44.0
+16	−1	15	54	1.0	44.0
+16	−4	15	52	1.0	45.0
+16	−7	15	52	1.0	*
+16	+8	16	115	1.5	42.0
+16	+5	16	105	1.5	44.0
+16	+2	16	100	1.5	45.0
+16	−1	16	97	1.5	45.0
+16	−4	16	96	1.5	44.5
+16	−7	16	96	1.5	*
+16	+8	16	180	2.0	39.0
+16	+5	17	170	2.0	42.5
+16	+2	17	165	2.0	43.0
+16	−1	18	160	2.0	44.5
+16	−4	18	160	2.0	43.0
+16	−7	18	160	2.0	43.0

*IMD products below measurement system noise floor.
[1]All signal levels referenced to PEP.
[2]Total current.
[3]Both gates at same voltage.

of dc current without heat sinking the IC. A package limitation of 1.2 watts is specified for temperatures up to 25° C, with derating set at 8 mW/° C above 25° C. Maximum program current is 50 mA.

Singly Balanced VMOS Power FET Mixer

The VMOS power FET has characteristics that suggest its ability to perform well in a high-level balanced mixer circuit. For this reason it was included in the mixer evaluation program to determine how it would compare to other high-level mixers. A pair of VMP4 vhf devices was selected for testing in a singly balanced mixer. Other VMOS devices, such as the VN66AK, should offer nearly comparable hf-band performance at lower cost. The VMP4s were chosen mainly because they could be adapted easily to heat sinking, owing to the strip line package format.

Fig. 5 contains the test circuit used by the authors. The rf and LO signals were applied to the gates of the FETs, permitting the sources to be grounded. Earlier tests of the same FETs in a circuit recommended by a manufacturer (rf signal injected on the sources and LO injection on the gates) yielded substantially degraded mixer performance. Instability was also manifest when the forward gate voltage was increased beyond 1.9. Stability could not be obtained without excessive resistive loading of the broadband transformers, so the circuit was abandoned in favor of the one in Fig. 5. Bias controls R1 and R2 were included to help establish dynamic balance of Q1 and Q2. R3 was added to establish a known impedance at the LO injection point during laboratory analysis. Without the resistor, the port impedance is in excess of 500 ohms.

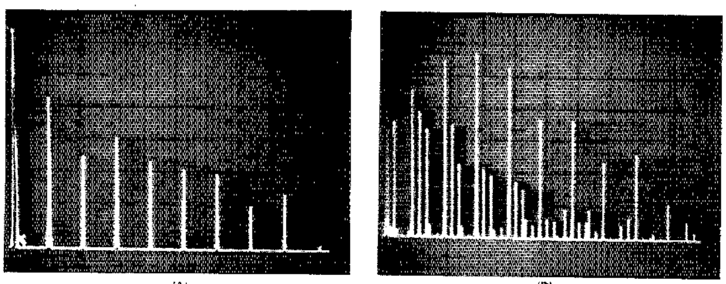
Table 3 shows the results obtained with various levels of gate voltage, rf-signal input and quiescent drain currents. LO injection was maintained at +16 dBm. It can be seen that a variety of operating conditions yielded good output intercepts. The resultant conversion gain is somewhat higher than is desired for most receiver applications. If this circuit is used it will probably require inclusion of an attenuator pad after the mixer to tailor the effective gain to a suitable level for the stages that follow the mixer.

As one would suspect, port isolation follows the format that is common to singly balanced mixers. With the circuit of Fig. 5 the isolation was 38 dB when R1 and R2 were adjusted for best suppression of the output responses. This condition was realized when one gate had 2 volts and the other had 1.85 volts. Fig. 6 shows the spectral output of the mixer under a balanced condition. Photograph A shows the LO isolation and photograph B illustrates the LO and rf isolation.

The authors have concluded that VMOS power-FET mixers are worth considering when high dynamic range is desired (without concern for the high values of quiescent drain current in a 24- to 28-volt dc type of system). It follows that a quad of power FETs in a doubly balanced mixer circuit would offer improved performance over that provided by the mixer in Fig. 5.

High-Level Diode-Ring DBM

If the designer is willing to accept a trade-off between dynamic range and conversion gain, the doubly balanced diode-ring mixer is worthy of consideration. Our



(A) (B)

Fig. 6 — Spectral display A shows the LO/i-f port isolation for the VMP4 balanced mixer with +16 dBm of LO injection and no rf signal applied. Spectrograph B reveals the rf/i-f isolation with +16 dBm of LO power and 0 dBm of rf signal input.

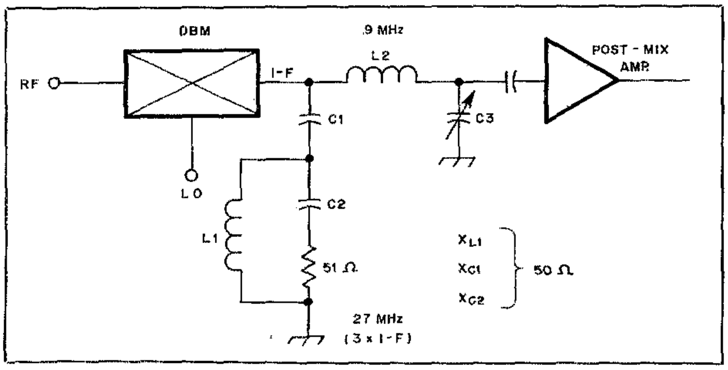


Fig. 7 — Method for adding a diplexer to the output of a diode-ring mixer to enhance the IMD performance. The high-pass network is terminated in 51 ohms and is designed for 3 × i-f. An L network provides an impedance match between the mixer output (50 ohms) and the input of the post-mixer amplifier.

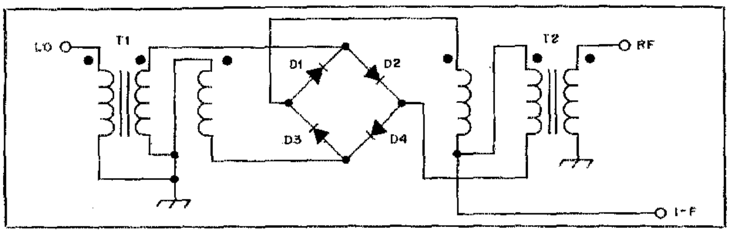


Fig. 8 — Diagram of the SRA-1H diode-ring, high-level mixer used in the performance tests.

Table 4

Test Results for the SRA-1H Diode-Ring High-Level Mixer

LO (dBm)	RF (dBm, PEP)	I-f (dBm, PEP)	Gain (dB)	Third-Order O.I. (dBm, PEP)
+9	+8	0	−8	+19.0
+9	+5	−2	−7	+22.0
+9	+2	−5	−7	+23.5
+9	−1	−8	−7	+24.5
+9	−4	−11	−7	+26.5
+9	−7	−14	−7	*
+12	+8	+1	−7	+25.0
+12	+5	−2	−7	+26.0
+12	+2	−5	−7	+27.0
+12	−1	−8	−7	+27.0
+12	−4	−11	−7	*
+12	−7	−14	−7	*
+15	+8	+1	−7	+30.0
+15	+5	−2	−7	+30.0
+15	+2	−4	−6	+31.0
+15	−1	−7	−6	+31.0
+15	−4	−10	−6	*
+15	−7	−13	−6	*
+17	+8	+1	−7	+33.0
+17	+5	−1	−7	+33.5
+17	+2	−4	−6	+33.0
+17	−1	−7	−6	+31.0
+17	−4	−10	−6	*
+17	−7	−13	−6	*

*Measurement limited by post mixer/filter IMD.

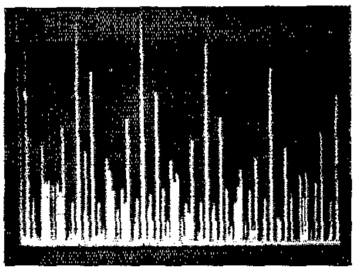


Fig. 9 — Output display of the SRA-1H high-level, diode-ring mixer with an LO power of +17 dBm and an rf signal input of +8 dBm. The large number of spurs emphasizes the importance of filtering at the mixer output.

tests included an analysis of the Mini-Circuits Lab SRA-1H DBM module. The test setup was essentially the same as for the previous mixers treated in this article. Tests were conducted with and without a diplexer connected to the mixer output. The results were essentially identical, since the test-setup terminations provided the desired 50-ohm port characteristic. In an actual receiver where absolute source-impedance levels are not always known, a diplexer of the type shown in Fig. 7 can be beneficial in providing the mixer with a 50-ohm termination at all frequencies. The high-pass branch of the diplexer is resonant at approximately three times the i-f. Improvements of 2 to 3 dB in mixer IMD are not uncommon when a diplexer is added to a ring mixer.

Test results for the SRA-1H (Fig. 8) are listed in Table 4. The conversion-gain spread follows the predicted amount, ranging from −6 to −9 dB over an LO injection excursion of +6 to +17 dBm. A spectral display of the mixer output is shown in Fig. 9. Owing to the LO power needed for this mixer it became necessary to make one change in the test setup used for the other mixers discussed here: The 2N3866 post LO amplifier was followed by an MRF-511 CATV transistor to elevate the available LO power to +27 dBm. The second harmonic from the LO source was measured at greater than 50 dB below the peak power of the fundamental.

Summary

The implications of the test results in this article are that large-signal devices provide high dynamic-range numbers when careful attention is given to biasing and LO levels. Certainly, a receiver is only as good as its mixer in terms of large-signal accommodation. Schottky ring mixers still offer a good compromise between dynamic range and moderate LO injection power. The penalty is in conversion loss, but a major advantage is seen in the passive feature of the diode-ring mixer, since the device does not impose dc current drain on the power supply.

The Plessey SL6440C high-level mixer IC offers the advantage of having excellent dynamic range, conversion gain and moderate dc current requirements. The LO-injection level is significantly lower than that required for a diode-ring mixer, and the package format lends itself well to the design of miniature equipment.

VMOS power FETs open the door to very high dynamic-range numbers at the cost of bulk and high dc-current requirements. LO-injection requirements are fairly high, and heat sinking of the active devices is necessary. Owing to the relatively high amplitude of the mixer-output spurs, a doubly balanced VMOS mixer would be preferable to a singly balanced version. The VMOS balanced mixer may not, in many instances, be cost-effective unless low-priced VMOS FETs are used in preference to the VMP4s specified in this article. The latter are in the $20 price class when purchased in single-lot quantity.

Indications are that small-signal devices, such as the 40673 and 3N211, are poor choices when high dynamic range is a design criterion. They are entirely acceptable for use in many low- and medium-cost hobby and entertainment receivers where high signal levels are not a problem. QST

References

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[2]DeMaw, "His Eminence, the Receiver, *QST*, June 1976.
[3]Elliott, "The Real World of High-Performance Receiver Design," *Session 5 Preprint*, IEEE ELECTRO/80. Boston, Massachusetts.
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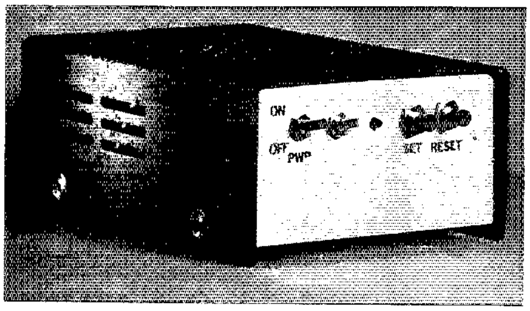
The ARES Standard-Tone Alert System

This new concept of Amateur Radio alerting in times of serious emergencies offers superior performance and reliability. It's being proposed as a national standard.



By Frank Jaeger,* WA9SQN

Several tone alert systems have been developed for use by ARES and other Amateur Radio emergency groups.[1,2,3] Some have been based on a single tone being transmitted to "unmute" receivers and warn of emergency situations, while others have used commonly available Touch-Tone signals that may be initiated by anyone having a tone pad.

In an attempt to find a satisfactory system to use in central Wisconsin, both approaches were developed. When they were presented to the Wisconsin Valley Radio Association (WVRA), lengthy discussion indicated both had validity. It was also noted that no standard system exists; each group uses its own method and frequency. This can be a burden on operators who monitor several frequencies.

WVRA adopted a combination of the two systems and proposed it as a national standard. Subsequently, this concept was adopted by the Rib Mountain Repeater Association and endorsed by the Wisconsin Association of Repeaters as the standard in Wisconsin. Basic information appeared in the "FM/RPT" column in December 1979 *QST*.

The ARES Standard-Tone Alert System uses a Touch-Tone zero transmission of five seconds or longer to alert monitoring stations to lower levels of urgency. Included are auto accidents, fires, car failures, weather watches and similar incidents. Decoders are to respond in three seconds with the remaining tone transmission being an audible alert signal.

Any amateur may initiate the Touch-Tone "0" alert. Rules, as such, are broadly defined to allow the user latitude. The individual must determine (or groups may set guidelines) which situations warrant the tone.

Decoders are equipped with provisions to defeat the Touch-Tone "0" portion, as some operators may not wish to listen for such calls. All operators are urged to monitor for the call when severe weather is forecast, however.

The ARES emergency tone warns of utmost urgency and should be used *only* for severe thunderstorm and tornado warnings or situations requiring the agency being served to go to its highest state of alert. The standard NOAA weather alert frequency of 1050 Hz is used. It should be initiated *only* at the direction of the District Coordinator or assistant, or an official of the agency being served. All decoders should respond.

A suggested procedure is to have ARES and other vhf nets use a Touch-Tone "0" transmission to initiate net sessions and include a test of the ARES emergency tone during the session. This not only ensures that decoders are working properly, but also accustoms listeners to the alert signals.

When it is used with a scanner, locking the receiver on the tone alert channel is advised. A call would be missed if the scanner is on another channel when the alert is sounded.

It should also be noted that the ARES Standard-Tone Alert System does not outmode all other systems. Decoders currently in use, which are based on the NE567 IC, can easily be tuned to the 1050-Hz alert and used by operators wishing to respond only to the ARES emergency tone.

How the Decoder Works

Although the decoder appears complex, it is not. Fig. 1 is a simplified block diagram showing logic levels needed to decode a valid tone. Figs. 2 and 3 are the schematic diagrams.

An automatic level control using a dual operational amplifier limits the audio signal applied to three NE567 tone decoders. Back-to-back diodes could be used on the input to provide hard limiting but the op amp permits a wider range of receiver output settings. A fixed value of 47 kΩ for R1 is suitable for most applications but a 50-kΩ or 100-kΩ potentiometer may be substituted and thus provide a means for varying the alc output.

Only one of the three decoders is shown in the schematic diagram. The circuits for all three are identical — they are basically the standard NE567 configurations that have been discussed in many articles. One decoder is tuned to each frequency in the unit, either 1050 Hz or the Touch-Tone "0" frequencies of 941 and 1336 Hz.

Decoder output is a digital signal, either high when off or low when a valid tone is decoded. U5A and U5B are 3-input NOR gates that select which tones will be acknowledged. U5A requires that U3 and U4 must both be low and S1 closed to decode Touch-Tone "0." U5B needs a low on U2 and S2 closed to acknowledge a 1050-Hz signal.

The decoder may be wired for constant recognition of either tone as shown in the schematic and parts diagrams. For

[1]Notes appear on page 27.

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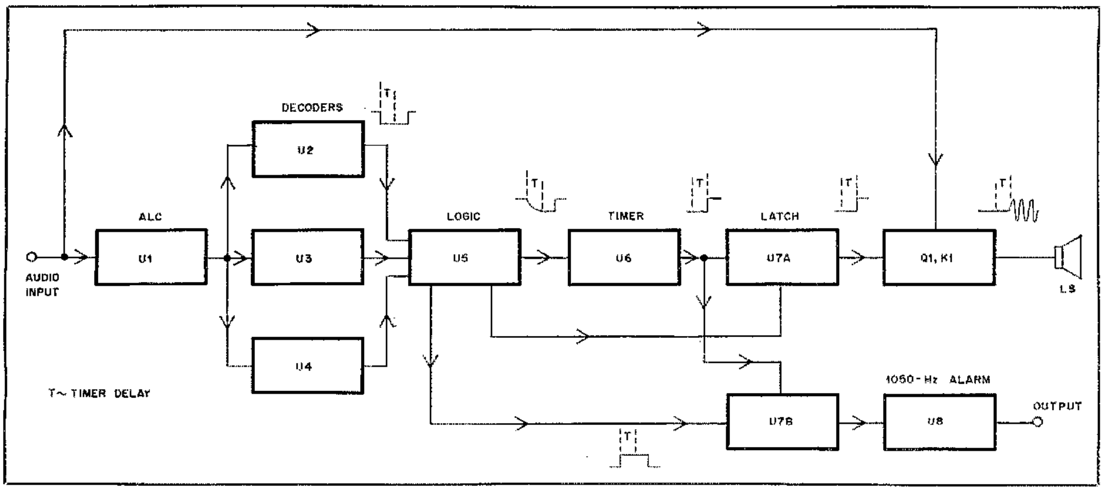


Fig. 1 — Block diagram for the ARES Standard-Tone Alert System.

decoding Touch-Tone "0," omit R5 and S1, eliminate the +5-V lead to pin 8 of U8 and ground pin 8. Similarly, R6, S2 and the lead from pin 1 of U5 to pin 8 of U3 should be omitted and pin 8 of U3 grounded for constant recognition of 1050 Hz. Since the ARES Standard-Tone Alert System depends on *all* decoders responding to the ARES emergency tone, it is recommended that decoders be wired for constant decoding of 1050 Hz.

Normally, the output of U5C, another 3-input NOR gate, is high and switches low when either tone is decoded. The voltage on the 4.7-μF capacitor at pin 2 of the timer begins to decay through the 680-kΩ resistor. When the voltage at pin 2 reaches 1/3 of the supply voltage, the timer output at pin 3 is triggered high.

Timer reset after short tone bursts is accomplished by recharging the capacitor to two-thirds of the Vcc through D1 and the 1-kΩ resistor. That resistor limits the initial surge current which the CMOS gate must sink.

Because of internal characteristics, the NE555 time period is independent of supply voltage. Delay time is proportional to the value of the discharge resistor, about three seconds for 680 kΩ.

Latch Circuits

Decoder output is controlled by U7, a CD4013 dual-D flip-flop. The timer output is applied directly to both units at pins 3 and 11. Data input pin 5 is tied to U5A for Touch-Tone "0" and pin 9 is tied to U5B for the ARES emergency tone.

Both latches function identically, with Q outputs (high when triggered). These are pins 1 and 13 and inverted Q outputs at pins 2 and 12.

Reset pins 4 and 10 provide the means to override the triggered inputs manually. The set switch, S3, is applied only to U7A and may be used to activate the receiver speaker.

Outputs

Several output variations have been tried but the relay shown has proven the most versatile. Driver transistors may be switched from either latch section. If the decoder speaker alone is to be keyed by either tone, the collectors of both transistors, Q1 and Q2, may be connected in parallel.

The relay may be energized in the standby (muted) mode by connecting the 39-kΩ bias resistors to pins 2 and 12. When the decoder is used with a battery receiver, this arrangement provides a fail-safe situation as the speaker will be enabled should power be lost. Alternatively, the relay may be enabled when the latch is triggered by connecting the resistors to pins 1 and 13.

Fig. 2 contains an alarm that may be triggered by the ARES emergency tone. The circuit, using an NE555 timer as an astable oscillator, is turned on by applying the Q output of U7B to the reset input of U8.

Using the configuration shown, with the relay energized during standby, the alarm will sound until manually reset or a Touch-Tone "0" signal is received. The speaker may then be enabled by pressing the SET button or by simply shutting off the decoder power.

The alarm and driver transistor may be used simultaneously. The author uses this transistor to activate a recorder to tape weather watches automatically.

Power Supply

Power for the ARES tone-alert decoder can be supplied by a small ac supply or from an 8- or 10-cell battery pack. Current demand is about 40 mA with the relay energized. Fig. 3 shows a 5-volt regulator circuit which is included on the circuit board.

An ac supply is recommended, for the unit normally will not be used with portable or mobile equipment. In all but the fewest foreseeable situations, an alert will have been sounded before commercial power is lost. A 9- or 12-volt dc output battery eliminator (the type that plugs into an ac outlet) is ideal.

Construction Hints

While point-to-point wiring could be employed, the decoder lends itself well to circuit-board construction. Several boards have been used during development and testing, the most recent of which is shown in Fig. 4.

The layout is rather dense but the result is a compact unit that could be installed in many receivers. The unit is intended as an outboard device to be plugged into the extension-speaker jack, however. A Radio Shack no. 270-252 enclosure makes a neat package.

All polarized capacitors except the electrolytics are dipped solid tantalum to provide good stability for the decoder and timer circuits. The variable resistors are multiturn Trimpots for both stability and ease of tuning.[4]

Alignment

Two methods can be used to tune the unit. In either case the following frequencies are used:

U2: Tune R2 to 1050 Hz. R_A = 8.2 kΩ
U3: Tune R3 to 941 Hz. R_A = 9.1 kΩ
U4: Tune R4 to 1336 Hz. R_A = 6.8 kΩ

Tuning is easily accomplished using a frequency counter. By attaching the counter at the test points (TP), the free-running frequency of each decoder can be read and adjusted by the variable resistor.

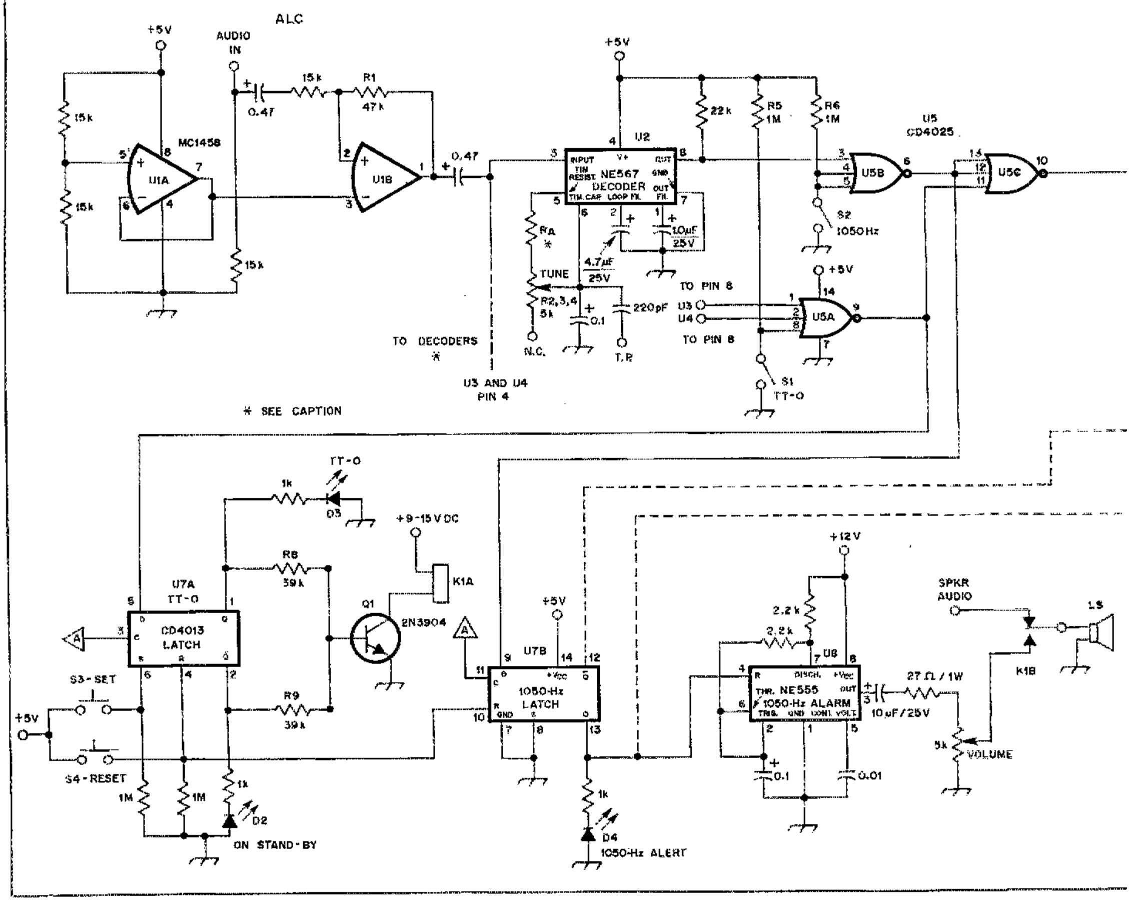


Fig. 2 — Circuit diagram for the Standard-Tone Alert System. Reliable, fail-safe operation is attained by this design. The tone alarm will sound regardless of the state of the latches. The alarm draws about 75 mA, depending on the speaker impedance. Up to 15 V dc unregulated for the alarm is acceptable. Operating voltages for K1 and K2 (Radio Shack relays no. 275-003) may be obtained from a 9- to 15-V unregulated supply. K2 and Q2, indicated by dashed lines, form an optional feature for keying an external device. Decoder circuits for U3 and U4 (omitted for drawing simplification) are identical to the decoder circuit for U2. Capacitors marked + are tantalum. All others are ceramic disc. Except as shown, resistances are 1/4 watt. A 27-ohm resistor in series with the 5-kΩ Trimpot prevents overheating the 555 (U8) in the alarm section. It may be eliminated if the supply voltage is 12 V or less.

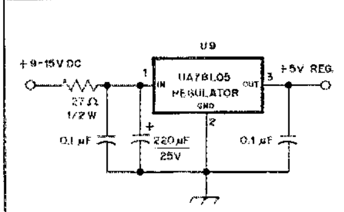


Fig. 3 — Diagram for the voltage regulator found on the circuit board. A 78L08 regulator may be used if the supply voltage is raised to between 12 and 15 V dc, the maximum Vcc is governed by the NE567 chips, rated at + 10V.

Checking the unit against a tone pad and a good source of 1050 Hz will verify tuning.

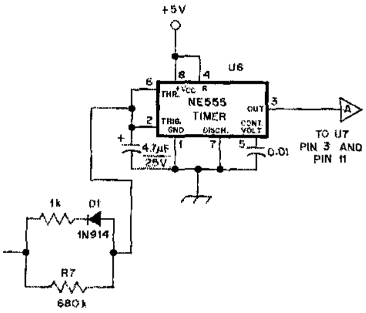
If no counter is available, a signal source and a VOM may be used. The voltage at pin 8 of the NE567 is at or near zero when the decoder is tuned to a frequency being injected at the audio input to the decoder. The center of the voltage null must be determined by setting the Trimpot for a reading midway between the edges of the null.

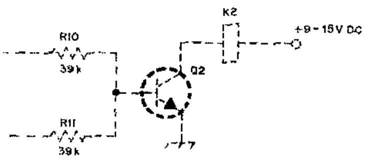
A stable source must be applied for each tone. The two Touch-Tone frequencies may be generated using a standard tone pad. Pressing two keys *simultaneously* in the bottom row will encode only 941 Hz while any two keys in the center column will yield only 1336 Hz.

Operation

As has been suggested, general net operations or situations of lower urgency should be initiated with a Touch-Tone "0" transmission. The ARES emergency tone is reserved for severe conditions.

Once the decoder is triggered by a Touch-Tone "0" alert, subsequent transmission of the ARES emergency tone will reverse the state of the latches, switching the speaker from the receiver audio line to the alarm. Thus, the alarm will sound regardless of latch state and an operator will be alerted even when out of speaker range.





EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k=1000, M=1000 000

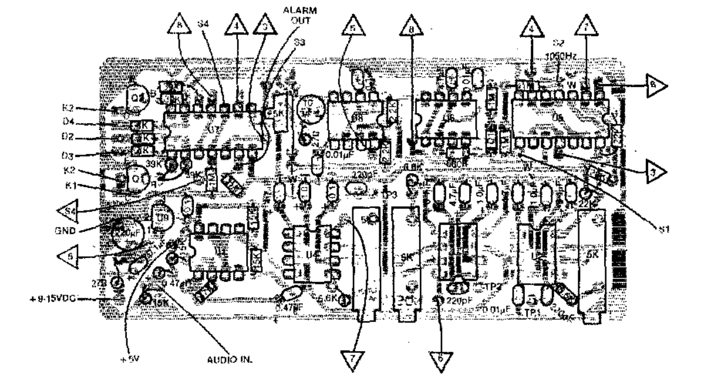


Fig. 4 — Parts placement guide for the ARES Standard-Tone Alert System. Components are placed on the non-foil side of the board; the shaded area in this view represents an X-ray view of the copper pattern. Decimal-value numbers alone represent capacitance in microfarads. Whole-number values with no units represent resistance in ohms; k = 1000. W = jumper wire. (The etching pattern appears in the "Hints and Kinks" section of this issue.)

Termination of the severe condition alert may be effected by transmitting a Touch-Tone "0" for a few seconds. Alarms that have not been answered will be shut off and the speaker connected to the receiver audio line, while others will be unaffected.

Note, however, that this procedure is effective only when the Touch-Tone "0" section of the decoder has been enabled. The alarm will continue to sound if the Touch-Tone "0" section has been disabled by opening S2.

Security for The ARES Emergency Tone

All alerting systems rely on operators who commit themselves to monitoring a given frequency. If the alerting tone is falsely triggered a few times, operators may shut down their receivers and thereby defeat the system. Consideration must be given to the security of the ARES emergency tone.

A simple 1050-Hz encoder can be built from an NE555 timer IC but the same simplicity also lends itself to easy duplication and possible abuse. Other than operator education, little can be done to prevent false alarms through simplex transmission. Two schemes can be employed, however, to thwart abuse through repeaters.

A 1050-Hz filter on the repeater receiver will prevent unauthorized tones from being transmitted through the machine. The actual alerting tone can then be generated at the machine and accessed through a code given only to authorized personnel.

A 1050-Hz decoder and delay would allow switching the filter into the audio circuit, thus allowing voice and short tone transmissions to pass normally. But sufficiently narrow filters can be built to eliminate the 1050-Hz tone without distorting normal audio.

A two-tone encoder can be used on repeaters with no Touch-Tone facilities. The 1050-Hz signal is paired with another tone chosen by the ARES group and given only to authorized operators. An exclusive OR circuit may be used to either disable the COR or transmitter audio when only one of the tones is decoded. A delay should also be used in this design and a filter added to remove the second tone.

The first method is preferred, as it does not rely on initiation of the ARES emergency tone on the primary repeater frequency. Information may be obtained from the author.

Conclusion

The ARES Standard-Tone Alert System gives versatility and security that has been sorely lacking in Amateur Radio emergency alerting. Adopted as a national standard, it also requires the operator to maintain one decoder while monitoring several systems.

By encouraging full-time monitoring of emergency frequencies, the system provides reliable call-up, particularly at times when only the outdated telephone tree would be effective. As with any system, success depends on the user. Neither tone should be transmitted without a valid reason. The responsibility is yours.

I wish to thank the members of the Wisconsin Valley Radio Association for the ARES standard-tone alert concept and the many radio amateurs in central Wisconsin who gave suggestions and support. Special thanks to Bob, WA9UTC, for the accompanying photo. QST

Notes

[1]Kraman, "Single-Tone Decoders" *Ham Radio*, August 1978, p. 70.
[2]Paquette, "A Time Delayed Tone Decoder" *QST*, February 1977, p. 16.
[3]Wetzel, "Tone-Alert Monitor" *Ham Radio*, August 1980, p. 24.
[4]Kits including board-mounted parts, drilled and plated circuit boards, plus instruction booklet are available from the author for $29.50 in single quantities. Circuit boards and quantity prices are also available. For details send an s.a.s.e. to Frank Jaeger, Route 2, Box 134, Merrill, WI 54452. The ARRL and *QST* in no way warrant this offer.

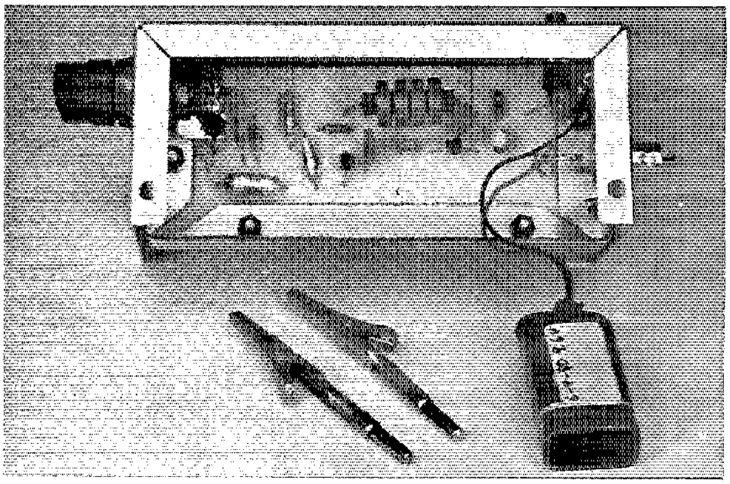
[Editor's Note: Attention is called to the article "Tone-Alert Decoder," written by Harold C. Nowland, W8ZXH, and Stan Briggs, W8MPD, which appears in *Ham Radio*, November 1978, pp. 64-65.]

The L-Meter

Need a better technique for measuring inductance? This unit is L-ementary but accurate.

By Alf Reinertsen,* WA2TNG

Inductance-measurement techniques using a GDO or impedance bridge are well known. But some GDOs (like mine) have poor frequency resolution and a limited range of inductance measurements. Purchasing a more accurate bridge or GDO was out of the question; it would have put a dent in my wallet. I needed a device that provided high resolution and good accuracy, was capable of measuring inductance values of 1 mH to 0.05 μH, and was inexpensive, too.



A homemade aluminum bracket secures the L-meter pc board to the inside of the enclosure. L1 may be seen at the left of the photo between the banana jacks and pc board. L2 is the rf choke in the center. R3 is hidden by the body of the choke. The battery is held in place within the other half of the box by means of a homemade aluminum clip.

The "Obvious" Solution Circuit

Constructing an L-meter that satisfied my requirements seemed simple: Just put the inductor in an oscillator circuit, measure the resultant frequency and calculate the inductance. The initial circuit I tried used a Colpitts oscillator followed by a buffer stage to isolate it from the counter. However, the low-end of the measurement range was limited to 1.4 μH. Why? After much trial and error, many trips to the book shelf and "exercising the gray matter," I learned why.

The circuit shown in Fig. 1 works just fine — if: the rf choke (L2) is larger than the largest inductor you wish to measure and the effective series resistance of the capacitor path (C1, C2, C3) is kept low. The reason for the latter is obvious if you determine the current that actually flows through the capacitive path, effectively 100 pF. At 30 MHz, the current will be 40 mA with 2.1 V present. Ceramic disc capacitors had been utilized in the original circuit and since they were used extensively in the literature I'd read, they were the last components I suspected. Upon close examination, I found they exhibited an effective series resistance of 7 ohms and created losses in the tank circuit, which

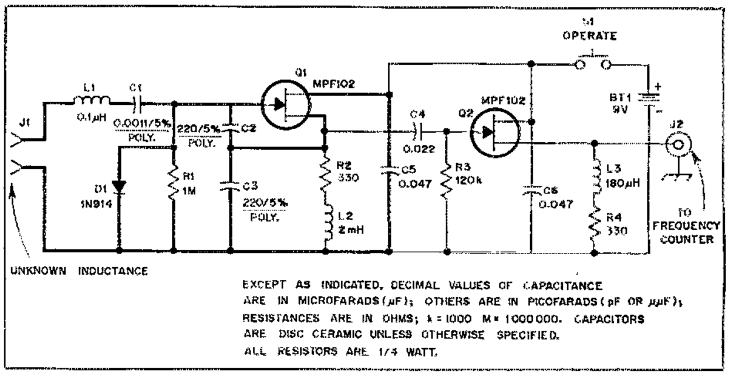


Fig. 1 — Schematic diagram of the L-meter. L1 consists of 7 turns of no. 24 enameled wire on an Amidon T-37-12 core. L2 is a pie-wound phenolic core rf choke. A dual banana jack is used at J1 while J2 is a BNC chassis-mount connector.

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prevented oscillation beyond 12 MHz. The problem was resolved by using polystyrene capacitors that have an effective series resistance of less than 1 ohm at 30 MHz.

Construction

The unit is constructed in a 3- × 5- × 2-inch (76- × 127- × 51-mm) aluminum box. A pc-board layout is shown in Fig. 2. Toroid L1 has been added to compensate for lead inductance in the circuit and keep the readout within the range of a 30-MHz frequency counter. Layout is not critical as long as the heavy leads shown in Fig. 1 are kept short and components are placed to avoid unwanted feedback. C2 and C3 determine the overall accuracy of the unit, so two 5% or 1% 220-pF capacitors should be used. Such capacitors are inexpensive. In fact, the entire unit should cost less than $12 if you use some parts from your junk box and it can be constructed as a weekend project.

A 9-V battery is used to supply power through a momentary push-button switch. With a total battery drain of 8 mA, the battery should last for thousands of measurements. The unknown coil is attached to the unit by means of a pair of 5-way binding posts. By mounting alligator clips in banana plugs, you can attach small coils readily and quickly.

Calibration

The calibration procedure consists of finding and subtracting the circuit inductance from the total oscillator inductance to determine the value of the unknown inductor. Connect the L-meter to a 30-MHz frequency counter and place a shorting stub across the binding posts. Depress S1, note the reading of the frequency counter and compute the circuit inductance using this equation:

$$L_o = (15.915/f_{MHz})^2 - 0.015$$

Record this value as Lo-JACK — inductance of the oscillator when using the jacks. Repeat the procedure with a shorting stub across the ends of the alligator clips and record this as Lo-CLIP — inductance of the oscillator when using the clips. These inductance values should be marked on the L-meter using Dymo labels or other means.

Operating Procedure

To use the L-meter, attach the coil to be measured, depress the switch and record the frequency of oscillation. Determine the inductance value by using a calculator or the charts in the 1981 ARRL *Handbook* (page 16-22, Fig. 42). When calculating, use the following formula:

$$L_{\mu H} = (15.915/f_{MHz})^2 - L_o$$

For readout values of less than 5 MHz, Lo has little impact and may be omitted. If the Handbook method is employed, use the LC chart to convert the frequency to total inductance, then subtract Lo to obtain the correct value of the unknown inductance.

The L-meter was evaluated by measuring several rf chokes, rf coils and toroids of known value. In every instance, the measured values were within 5% of the known. Two of the coils were checked on a General Radio bridge and found to be within 1% of the indicated L-meter value. That was a pleasant surprise!*

The unit is relatively insensitive to changes in battery voltage. From 15 to 3.5 volts, the inductance values varied only 0.2%. A 5° F (3° C) change in room temperature affected the readings by less than 0.1%.

I'm certain you'll find the L-meter to be as useful as I have. The experience of building your own test equipment is very rewarding. QST

*[Editor's Note: A check in the ARRL lab showed the inductance values found by means of the L-meter were within 5% of those obtained with a Hewlett-Packard 4342A Q-meter. In some instances, agreement was within 1.5%.]

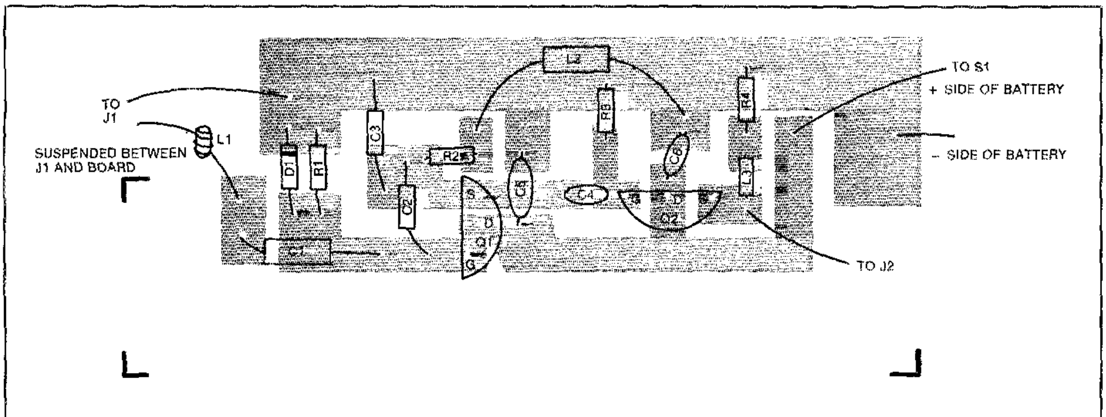


Fig. 2 — Component layout of the L-meter as viewed from the component side of the board. The etching pattern appears in the "Hints and Kinks" section of this issue.

Strays

SNOWFLAKE MADNESS

☐ The Michigan Technological University ARC and the Copper Country Radio Amateur Association, in association with the Copper Country Chamber of Commerce, will issue a certificate to all amateurs who contact any station in Copper Country between 0000 UTC, February 2, and 0000 UTC, February 9. Suggested frequencies are 3.705, 3.975, 7.085, 7.105, 7.285, 14.085, 14.305, 21.085, 21.185, 21.385, 28.185 and 28.385 MHz. On cw listen for CQ WINTER CARNIVAL. Send your QSL with two 15-cent stamps to Debbie Nietzke, WD8JPX, 2005D Woodmar Dr., Moughton, MI 49931.

I would like to get in touch with . . .

☐ other amateurs who want to design and apply digital, tone and other controls to railroad models. Temple Nieter, W9YLD, 707 Sheridan Rd., Evanston, IL 60202, Tel. 312-475-4408.

☐ anyone interested in organizing a national conference of blind radio amateurs and friends. Contact (in braille or print) The Hadley Radio Association, 700 Elm Street, Winnetka, IL 60093.

The Poly-Tower Phased Array

Got a small lot and want a big signal? With this system, you can boost the performance of a 180-watt transceiver on 10 through 40 meters at a modest cost.

By Bob Hickman,* WB6ZZJ

To most hams on a budget, the cash outlay for a transceiver is a large expenditure. After that, little remains in the family treasury that can be used to purchase an antenna . . . if the family is to continue to eat three meals a day!

For the rural ham, the problem is simple: Just erect a sloping V or some other low-cost wire antenna. If you live on a 60-foot city lot and are surrounded by neighbors, however, low-cost wire antennas become a real challenge.

The City Dweller's Plight

Many city-dwelling hams solve their antenna problem by building or buying a quarter-wave vertical antenna. I've spent a lot of time operating successfully with this type of antenna during 24 years in the navy. But I hasten to point out that there is a marked difference in performance between a quarter-wave vertical antenna operating over seawater and one placed on a small city lot over an inadequate or nonexistent radial system and surrounded by buildings.

In reality, the city dweller with the quarter-wave vertical is often faced with the following choices: Put the antenna on the ground out of sight where it looks good (and have most of the radiated energy absorbed by surrounding objects), or put it in the air, clear of surrounding objects. The latter is the better choice, but now that the antenna is above ground, a spider web of ground plane wires is visible. At 40 meters, these wires should be over 30 feet long.[1] Even if space is available, the results of your efforts are frequently referred to as an eyesore by the XYL and other helpful (?) persons.

Not liking either previously mentioned choice and not wanting to "bulldoze" with a linear amplifier, I turned to the center-fed vertical dipole. The center of this antenna (from which most of the rf is radiated) clears many surrounding objects and the antenna enjoys a few decibels of gain over the quarter-wave vertical. With the center-fed vertical dipole, operating performance of my station improved immediately and there was motivation to make a multiband phased array of center-fed vertical dipoles to achieve even greater performance. But a simple, cost-effective method of making these dipoles had to be found.

One afternoon, the XYL (the eyesore expert), our two harmonics, Bob Jr., WB6CWT, Chuck, WA6CWQ and I were brainstorming the problem. I suggested an antenna using no. 12 house wire run through 1/2-inch PVC plastic sprinkler pipe, but this idea was dropped because the PVC got too shaky when it was stacked and traps would be required for multiband operation. We explored several other avenues, but kept returning to the PVC idea because of the low cost, simplicity and availability of supplies. Finally, we decided to make a tower of PVC and run no. 12 wire down each leg of the tower to form a multiband dipole.

Several scraps of schedule 125, 1/2-inch PVC pipe were made into an equilateral triangle to test the idea. The increased strength of the triangulated PVC was convincing and the XYL was even impressed with the appearance, so supplies were hastily gathered. With Bob Jr. and Chuck cutting out spacer triangles from cedar fencing planks, construction of the first poly-tower began.

Poly-Tower Construction

Throughout the years of building antennas, I have frequently been frustrated trying to locate materials listed in the respective articles, or, upon locating the materials, finding that the cost was prohibitively high. The materials used in constructing the poly-towers are not only readily available, but are also low in cost. A poly-tower can be built for less than $20. The four poly-tower phased array, including phasing unit and all coax runs,

*7043 Lemonwood La., Lemon Grove, CA 92045

[1]Notes appear on page 34.

Table 1

Materials Required for One Poly-Tower

10 — 10-foot lengths of schedule 125 (or 40) 1/2-inch PVC sprinkler pipe (see note 1).
3 — 1/2-inch PVC tees.
9 — 1/2-inch PVC caps.
6 — 1/2-inch PVC connectors.
6 — 1/2-inch electrical conduit fasteners (see note 2).
3 — 8-inch lengths of 1- × 2-inch lumber.
34 — 6-inch equilateral cedar triangles (see note 3).
1 — 20-foot length of 2- × 4-inch lumber.
70 feet — No. 12, single-conductor, insulated electrical wire.
Misc. — Epoxy cement, PVC cement, white paint, mounting hardware.

Notes

1) Nine of the 10-foot lengths are used for the poly-tower legs. Three of the 10-foot lengths are cut in half to provide six, 5-foot lengths for use as described in the text. The tenth length of PVC is used to make short lengths to reinforce the poly-tower at the PVC pipe junction points and to close the PVC tees.
2) The 1/2-inch fasteners marked "EMT" are too small for the 1/2-inch PVC pipe.
3) Normally, three triangles can be cut from each foot of a cedar fencing plank. Therefore, 34 equilateral triangles can be cut from two 6-foot or three 5-foot planks.

Table 2

Dipole Wire Lengths for One Poly-Tower

10 meters	7 ft 8 in.
15 meters	11 ft 1 in.
20 meters	15 ft

Note: The lengths specified above are one-half the total dipole length that should be cut and placed in each half of the poly-tower (see text).

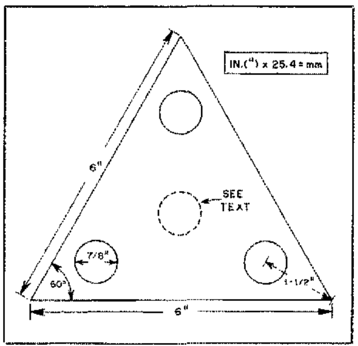


Fig. 1 — The equilateral triangular braces for the poly-tower are cut from cedar planking as described in the text.

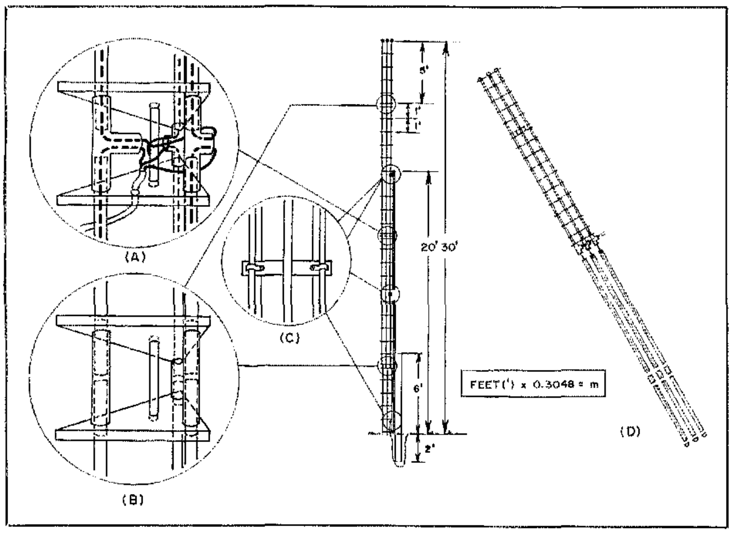


Fig. 2 — This drawing shows some essential details of poly-tower construction. At A, the joining of the dipole wires. Structural strengthening details are shown at B. The electrical conduit fasteners and cross-bracing is evident at C. Basic assembly of the poly-tower legs and dipole wires is shown at D and described in the text.

was constructed for approximately $150.

Table 1 contains a list of materials required to construct one poly-tower. A word of caution: When selecting schedule 125, 1/2-inch PVC pipe, be aware that some brands on the market are not suitable for making poly-towers. A simple test will help you determine the suitability of PVC pipe. Take the end of the pipe between your thumb and index finger and squeeze the pipe. If the end of the pipe collapses under moderate pressure, you don't want it!

Preparing the Spacer Triangles

Equilateral triangles with 6-inch sides are cut from 6-inch-wide cedar fencing planks (see Fig. 1). These planks are rough cut, and rarely measure exactly 6 inches, but this doesn't matter — just cut the planks you get into equilateral triangles. A mitre box makes cutting the cedar triangles easier and results in neater-looking pieces. Or the triangles can be marked out on the planks and then cut out with a hand saw.

Drilling the holes in the cedar triangles requires some care. If there is no means of drilling reasonably straight holes, difficulty will be experienced when trying to thread the PVC pipe through tandem sections. The drill press sold at many hardware stores, in combination with a 1/4-inch electric drill, will prove most satisfactory for this job.

A 7/8-inch wood bit will bore a hole that makes a nice fit for 1/2-inch PVC pipe. A fourth hole should be drilled through the center of six of the cedar triangles as shown in Fig. 1. This fourth hole accommodates a short length of 1/2-inch PVC pipe at the tower junction points to provide additional strength.

Putting It Together

PVC cement is used to bond all PVC fittings. Epoxy is used to join the cedar triangles to the 1/2-inch PVC pipe. See Fig. 2 for triangle placement. Use of 5-oz cans of epoxy is recommended, as you'll go broke before you finish the job if you use the squeeze tubes.

Start cementing the cedar triangles, beginning with the middle PVC tees of the tower and work to the end, completing the upper 15 feet of the tower. Then fit one half of the dipole wires into the completed upper half of the tower and their counterparts into the loose 10-foot lengths of PVC pipe of the lower half of the tower, as shown in Fig. 2D. Dipole wire lengths are listed in Table 2.

Cement the lower 10-foot lengths of PVC pipe to the respective tees with PVC cement and continue epoxying the cedar triangles to the pipe. When the first 10 feet of the lower tower half is completed, stuff the dangling ends of the 15- and 20-meter dipoles into the adjoining 5-foot lengths of pipe. Secure these 5-foot lengths to the tower with PVC cement, then proceed to epoxy the remaining cedar triangles to the PVC pipe.

Unless fast-setting epoxy is used, a lot of patience is required to get the triangles in the right place. One method employed is to cement just a few triangles at a time and let the epoxy harden before moving on. Another equally satisfactory method is to just tack each triangle with epoxy and let it cure. After the tacks harden, you can make other applications of epoxy to strengthen the junctures without having the triangles shift position.

Six PVC caps are used to close both ends of the poly-tower. Three PVC caps and a short length of 1/2-inch PVC pipe are used to seal the PVC tees at the center of the poly-tower. Prior to sealing the tees, two small holes are drilled into each PVC cap and the dipole wires are brought out through these holes. Use a sealing compound around the exit points of the wires to prevent moisture from entering the poly-tower. All the upper wire halves are connected together and to the center conductor of the coaxial transmission line. Similarly, all the lower dipole wire halves connect together and to the shield braid of the transmission line.

Erecting the Poly-Tower

The completed poly-tower is light enough to be lifted by one hand, so getting it into the air is easy. The schedule 125, 1/2-inch PVC poly-tower will not freestand without a supporting structure. Initially, two-thirds of the tower height was supported by a 2 × 4 piece of lumber. After a year of testing in winds of 50 to 60 mi/h, I concluded that this amount of support may be unnecessary. If the thicker-walled schedule-40 pipe is used, even less support will be required. Additional study is required to determine the minimum supporting height required for the poly-tower. Supporting it to a height of 20 feet should, however, provide a tower that will weather a lot of storms.

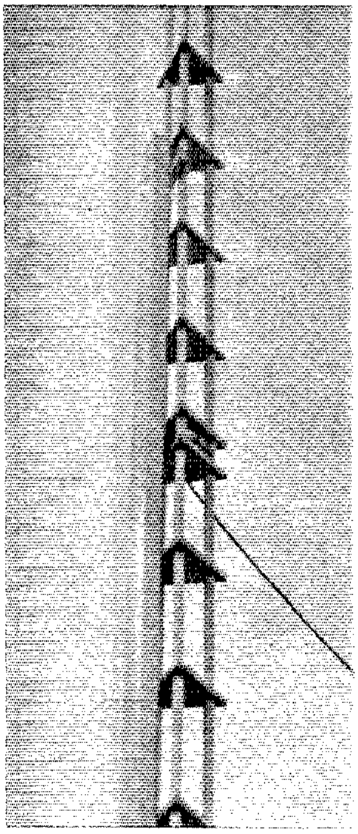
Since the poly-tower is wider than the standard 2 × 4 piece of lumber, three strips of 1 × 2 lumber were bolted to the 2 × 4 piece and the poly-tower fastened to these strips with 1/2-inch electrical conduit fasteners, as shown in Fig. 2C. Two of the 2 × 4 supported poly-towers used in the phased array were fastened to the back of the house with 1/4-inch lag screws, and two were secured to 8-foot lengths of 4 × 4 lumber buried in 24 inches of concrete.

Phasing and Tuning the Array

The electrical arrangement of the phased array draws extensively from the work of others. Electrically, the poly-tower phased array is an adaptation of that designed by Atchley, Stinchelfer and White.[2]

The four poly-towers are arranged in a 12-foot square. Phasing line lengths for each band, shown in Table 3, were adjusted for optimum performance at the 12-foot spacing in accordance with the data compiled by Lawson.[3]

Several cost and space economies were made possible by designing for low-power, multiband operation. RG-58U and RG-59U coaxial cables were used in place of RG-8/U and RG-11/U for transmission and phasing lines. This permitted all phasing lines to be coiled on an 18- × 24-inch board and fitted under the operating table in an area 3-1/2 inches deep. Smaller resistors than those



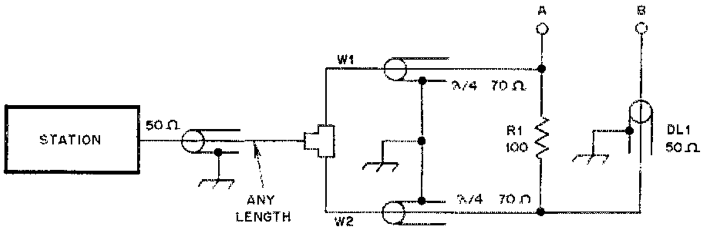
A portion of one of the poly-towers showing the method of bracing used.

Table 3

Phasing Line Lengths for DL1, DL2 and DL3

	Degrees	Length
10 meters	−80	5 ft 2 in.
15 meters	−110	9 ft 6 in.
20 meters	−130	16 ft 8 in.
40 meters (DL1 only)	−135	34 ft 8 in.

Note: Refer to Fig. 33, page 20-14, of the *ARRL Handbook* (1979 or 1980 edition). DL1, DL2 and DL3 lengths are modified in accordance with Table 3. Other values in the referenced diagram remain unchanged. One complete phasing unit is required for each band. The diagram of Fig. 33 is modified as follows for 40-meter operation:



RG-58/U was used for DL1, DL2 and DL3. RG-59/U was used for W1 through W6 of Fig. 33. The velocity factor for both types of coaxial cable is 0.66

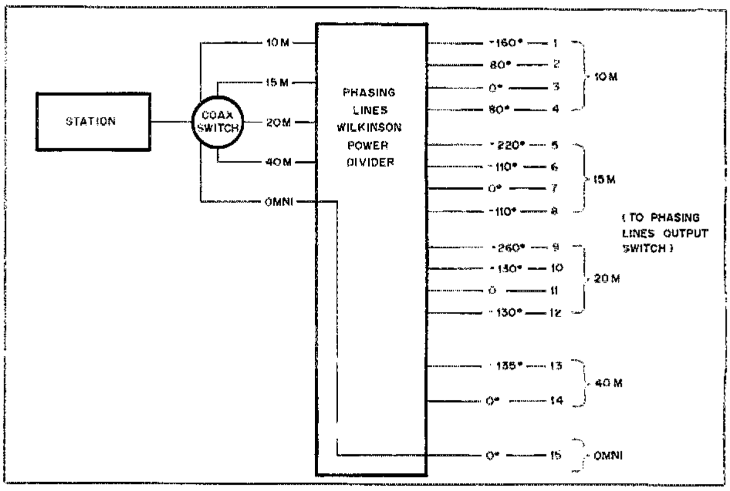


Fig. 3 — The overall diagram of the poly-tower phased array system.

specified in *The Radio Amateur's Handbook* were used for the Wilkinson power divider. Four 390-ohm, 5-watt carbon resistors were paralleled to provide the called-for 100 ohms at each power divider junction. Similarly, ten 1-kΩ, 2-watt carbon resistors can be used with satisfactory results if 5-watt carbon resistors are not readily available. Terminal strips rather than expensive coax fittings were used at the power divider junctions. The common ground for the coax braids was provided by lining the mounting board for the phasing lines with extra-heavy-duty aluminum foil. Then the entire board was enclosed using the same foil and aluminum tape.

The three switches that replace *The Radio Amateur's Handbook* array relays are mounted on the bottom of the phasing lines board. A coax switch was used to transfer the transmitter output to the input of the phasing lines for the desired band. Four coax fittings were installed on the rear panel of a 4- × 6- × 5-inch aluminum box. Two, four-wafer switches were bought from a local supplier of surplus equipment and mounted within the box. One of the switches has six positions. This switch is used to connect the output of the phasing lines to the direction-selection switch. Four positions are used for the 10- through 40-meter bands. Of the remaining two positions, one is used to select single-antenna operation. This is especially desirable for periodically checking the "health" of each antenna. The sixth position is used to ground all four antennas in the array.

The second four-wafer switch is the direction-control switch, which ideally, should incorporate 90-degree indexing. Such a switch was not available, so I settled for a five-position switch. This permits switching through all quadrants and returning to the starting quadrant at the fifth position. Figs. 3 and 4 show the wiring arrangement of the three switches.

Transmission line lengths must all be the same. Significant differences in length will alter the operation of the array. The lines should be cut to lengths specified in *The ARRL Antenna Book* to reduce line currents.[4]

To keep the transmission lines as close to right angles as possible for as great a distance as possible, the lines were run through the attic from the front to the rear of the house, then out to the antennas through an attic air vent.

Operation on 40 Meters

Only two diagonally opposite poly-towers are used at any time on 40 meters. Inoperative towers are grounded. The resistance of the poly-towers at 40 meters is about 12 ohms, so two identical L networks are used to tune the phased towers. These networks are enclosed in a 4- × 8- × 6-inch aluminum box. The networks are separated by a Masonite panel covered with heavy-duty aluminum foil that is fastened to the box with L brackets. Because of the proximity of the poly-towers to each other on 40 meters, tuning is a little critical. If it is desired to work both the cw and phone portions of the band, it will be necessary to provide some means to alter the tuning of each L network. Only cw operation is used here on 40 meters, so no such provision was made.

L Network Tune-Up Procedures

Tune the transceiver into a 50-ohm dummy load on 40 meters, then reduce the transmitter output to zero. Connect an SWR meter to the transmitter side of one of the L networks. Increase transmitter output power just enough to obtain a reading on the meter at its most sensitive setting. Adjust both L networks simultaneously and identically for a low SWR reading (below 2:1). When this has been done, check the second L network SWR. If it is essentially the same as that of the first, you're in business.

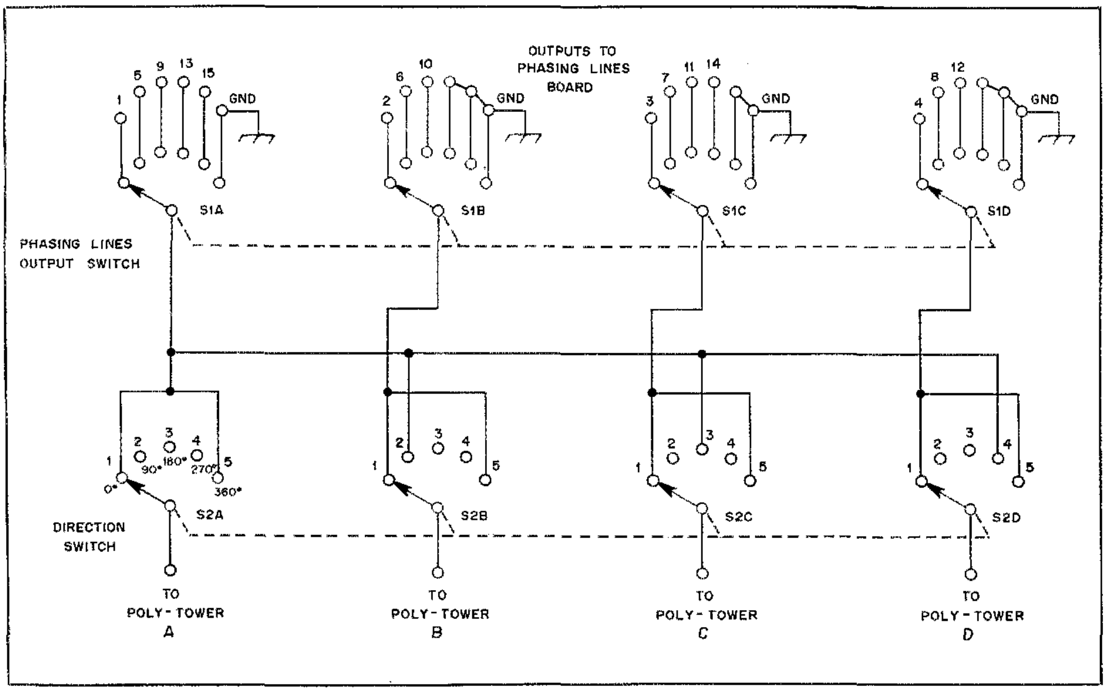


Fig. 4 — The wiring diagram for the phasing lines output and direction switches is shown here. The interconnection chart shown is to be used when wiring switch S2; only the first set of interconnections is shown for clarity. The direction switch interconnections are:

S2A-1,5 to S2B-2 to S2C-3 to S2D-4
S2B-1,5 to S2C-2 to S2D-3 to S2A-4
S2C-1,5 to S2D-2 to S2A-3 to S2B-4
S2D-1,5 to S2A-2 to S2B-3 to S2C-4

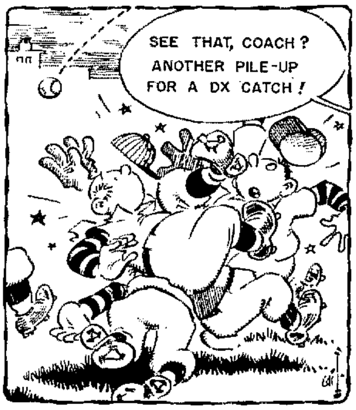
The exact component values of the L networks will depend on transmission-line lengths and other factors. A 365-pF receiving-type capacitor should be adequate to tune a single poly-tower. When phasing two towers, however, the required capacitance may exceed 1000 pF. Silver mica capacitors may be added in parallel with the 365-pF variable to achieve a matched condition. After the L networks have been tuned, fixed-value capacitors may be substituted for the variables.

General Notes

The poly-tower is not as sharply resonant (except on 40 meters) as normal wire antennas. As a rule, 20, 15 and much of 10 meters can be covered with a low SWR. The broadband effect of the poly-tower antenna is attributed to the multiband dipole arrangement and the placement of the dipoles inside the PVC legs of the poly-tower.

Occasionally, climatic conditions will cause a rise in SWR on one or perhaps two bands. When this occurs, the reflected power is absorbed by the power-divider resistors. The 5-watt resistor combinations have been more than adequate to handle these occasional SWR excursions.

If for some reason the resonant frequency of one or more of the dipoles in the poly-tower should be far enough removed from the desired frequency of operation to cause a constantly high SWR, the frequency of that dipole can be shifted by methods outlined in the *Antenna Book.*



Do you have to sit on the sideline or are you able to participate in the action?

How Does It Perform?

The real test of an antenna does not come when the band is open, but rather when conditions are marginal. Under marginal band conditions, do you have to sit on the sideline, or are you able to participate in the action? The poly-tower phased array has taken me off the sideline and put me into the action during such times.

The array has been in operation for over a year now. The following general observations have been made while running approximately 150 watts into the array: On 40 meters, the antenna appears to provide performance equal to that of operating with a linear amplifier and using an inverted V or quarter-wave vertical antenna; On the 10- through 20-meter bands, the performance is as good as (and often better than) operating "barefoot" with a triband beam at 50 feet. Naturally, 150 watts and a poly-tower array does not match the performance of a linear amplifier feeding a mammoth monobander at 70 feet!

If you are living on a small city lot and have a limited amount of money to spend for your hobby, the poly-tower phased array offers a cost-effective way to add to you operating enjoyment. As a start, you can assemble one tower and achieve an immediate improvement over a quarter-wave vertical stuck into the sand. As time permits, build additional poly-towers and enjoy the pure pleasure of instant beam switching. QST

Notes

[1]Feet × 0.3048 = meters
inches × 25.4 = millimeters.

[2]*The Radio Amateur's Handbook*, fifty-seventh edition, p. 20-13.

[3]Lawson, "Simple Arrays of Vertical Antenna Elements," *QST*, May 1971.

[4]*The ARRL Antenna Book*, thirteenth edition, p. 197.

Strays

TA PROFILES

☐ For services rendered as an ARRL Technical Advisor since 1978, we extend our gratitude to Edwin S. Oxner, KB6QJ. His professional area of expertise is field-effect transistors (JFETs, MOSFETs and VMOS). He has written many amateur and professional articles on this subject. Ed has also given several excellent technical papers at ARRL-organized IEEE seminars and ARRL conventions.

Ed was first licensed in 1952 as W9PRZ and now holds an Advanced class license. Beside his sheer enjoyment of QSOs, both phone and cw, he is also interested in astronomy, archaeology (Near Eastern) and Semitic languages. He resides in San Jose, California, is a member of the Santa Clara Valley Repeater Society and has been a senior member of IEEE since 1947.

Ed received his BSEE and BSRE from Tri-State University. He is listed in *Who's Who in the West* and *Who's Who in Finance and Industry*. Ed is employed as the senior engineer for Siliconix Incorporated. — *Marian Anderson, WB1FSB*

TA Ed Oxner, KB6QJ, wearing his usual friendly smile.

STILL GOT SOME SPARK LEFT?

☐ Were you operating a spark rig when you obtained your first amateur license? Amateur spark became obsolete about 1924 and was made "officially" illegal in 1927.

Ralph Hasslinger, W2CVF (ex-2CVF) is spearheading the formation of a very informal organization of ex-spark operators — no constitution, politics, membership fees, dues or assessments — just a group that pioneered the development of the hf bands. If you can remember the nostalgic aroma of ozone and want to become a member of this group, contact Ralph at 28 Warren Pl., Glen Rock, NJ 07452.

I would like to get in touch with . . .

☐ Dave, in Sacramento, who worked PAØLH with an FT-7, QPR, in the spring of 1980. I have the FT-7 modification he was looking for, but have been unable to locate him through the call sign WA6JSA. L. Tysma, PAØLH, 1 Wiersmajof 29, 9203 RG Drachten, The Netherlands.

• *Basic Amateur Radio*

The (Not Quite) Ultimate Dummy Load

What has 66 resistors, dissipates 132 watts, is easy to construct and is educational? This dummy load may be the answer to what to do with the box of resistors Aunt Millie gave you for Christmas.

By Peter O'Dell,* AE8Q

That will never fly. I'd be surprised if that thing works above 20 meters. You're kidding!

Such was the chorus of support I received as I announced my intention to build a large dummy load from 2-watt, carbon-composition resistors. I must admit that I wasn't so sure that it would work myself, but I am a rather stubborn type who has to prove things for himself.

A dummy load is simply a resistive device that should be much better at generating heat than propagating rf energy (Fig. 1). The first dummy load I had was a 100-watt electric light bulb. Don't laugh; it worked. It was a good visual tuning indicator and the tube finals didn't seem to mind that it probably was not exactly a 50 Ω load. I've never tried one with a rig that has solid-state finals, but it should work with them, up to maybe 10 meters or so. If a light bulb presents such a good match, why do people use anything else? Ask some people who have been around for a few years. One staff member recalls working another station about 10 to 15 miles away with 30 watts into a light-bulb "dummy load." In fact, light bulbs are better signal radiators than the "antennas" that some hams use.

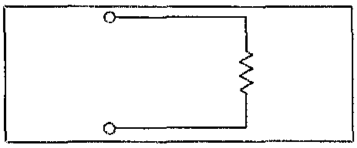
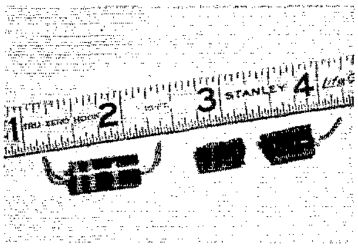
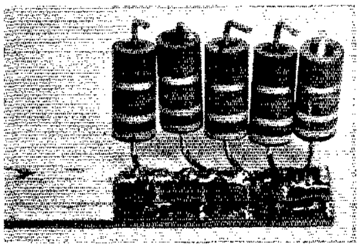


Fig. 1 — A dummy load consists of nothing more than a resistive device with two terminals. It converts the rf energy coming into it on the transmission line to heat.

*Basic Radio Editor



How do you spot a 2-watt carbon resistor? If it is a little over 1/2 inch (13 mm) long, then it is the right wattage. If you are not sure if it is carbon, take a blunt object and smash the resistor. A carbon composition resistor will look something like the pieces on the right when broken open; a wire-wound resistor will have wire inside (naturally).



Construction technique for assembling resistors. A bead of solder is run lengthwise along both edges of the pc board. In our case the leads of the resistors were precut and bent in the shape shown, resulting in a simple procedure for mounting. If your resistors have long, straight leads, it may be advantageous to adopt a different construction technique.

Besides radiation characteristics, the other important considerations for a dummy load are that it present something near a 50 Ω load and that it not be reactive. In other words, it should be a "pure" resistance. Obviously, there must be some kind of conductor that connects the transmission line to the resistor. For the lower frequencies, these conductors or leads are of relatively minor concern; but as we move toward the very-high frequencies the leads begin to act like inductors or capacitors, depending upon their size and location. Therefore, a dummy load that looks like a pure resistance to an 80-meter transmitter may look like a resistor in series with an inductor or capacitor to a transmitter operating at 10 meters. This effect will become more pronounced as the frequency is increased.

If we are talking about enough 2-watt resistors to handle the output of a typical hf transceiver of 100 watts or so, then we are also talking about several leads to several resistors. Without experimenting, it is quite reasonable to *assume* that the composite load will be quite reactive. Hence, the justifiable skepticism that greeted my idea.

Two By Two

What happens to the resistance and power-handling capabilities of resistors in parallel? Let's take a look at the case where we are dealing with only two resistors (Fig. 2). As depicted in Fig. 2A, the total resistance of two resistors in parallel is equal to the reciprocal of the sum of the reciprocals of the individual resistors. Let us suppose that we have the situation that is depicted in Fig. 2B. R1 is 100 Ω and R2 is 150 Ω; both resistors are

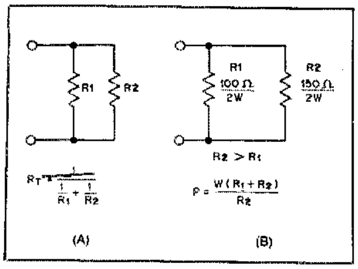


Fig. 2 — A shows two resistors in parallel and the formula for calculating the resistance of the circuit. The diagram and formula at B show what happens when resistors of unequal value are wired in parallel.

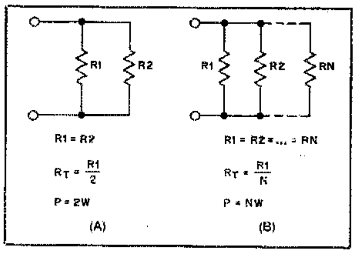


Fig. 3 — Using resistors of the same value, we can maximize the ability to safely dissipate heat. B shows the simple formulas that can be used to calculate the total circuit resistance and the effective wattage when equal-value resistors are used.

2-watt carbon composition. The reciprocal of 100 is 0.01; the reciprocal of 150 is 0.0067. The sum of these two numbers is 0.0167, which produces a reciprocal of 60 (ohms) for the effective resistance of the circuit. How much power can safely be dissipated by these two resistors in parallel? If you said 4 watts because both resistors are of the 2-watt size and, therefore, the power-handling ability should be the sum of the two, think again.

Each resistor by itself can handle 2 watts. But how is this power level determined? Power is equal to the voltage times the current. Since the two resistors are in parallel the voltage across one will always be the same as the voltage across the other. However, the current through each individual resistor is equal to the voltage divided by the resistance of that resistor. Thus, more current will flow through the lower value resistor for any given voltage across the resistors. Because that resistor has more current flowing through it, it will reach its level of maximum safe dissipation (2 watts in this case) before the other resistor reaches its maximum safe level. The formula for calculating the total safe power dissipation level (P) of two resistors in parallel is given in Fig. 2B. R2 is assumed to be larger than R1 and both resistors have the same wattage rating (W). This formula can be derived from Ohm's Law by simple algebraic manipulation. (I bet there are three or four of you who would enjoy deriving it.)

If we insert the values given in the example in Fig. 2B, we find that the total safe power dissipation is only 3.33 watts. If we are interested in maximizing the power dissipation for the fewest number of resistors, then intuitively we will want to use resistors of equal wattage and resistance.

The More the Merrier

Fig. 3 depicts what happens when we parallel 2 or more resistors of equal resistance and equal wattage. In this special case, the resistance of the circuit R_t is equal to one-half the resistance of one of the resistors. The formula for this relationship can be derived from the more general formula for resistors in parallel by simple algebraic manipulation. (Is anyone interested in staying after class and working out the math involved?) The safe power dissipation is equal to twice the wattage rating of the individual resistors.

This relationship can be extended to three or more resistors, as depicted in Fig. 3B. The resistors are numbered sequentially with N being the number of the last resistor in the chain. Again, all resistors are equal in resistance and wattage. Can you derive the formulas for the total resistance (R_t) and the total wattage (P)?

If we use three equal resistors, we find that the resistance of the three in parallel will be equal to one-third the resistance of the individual resistors and that the power rating will be tripled. If we go to four resistors, the total resistance will be one-fourth and the power rating will be four times that of the individual resistors. We can extend this relationship as far as we need to.

Suppose that we want to build a 50 Ω load from 2-watt resistors. The load will be required to handle the output power of our typical transmitter (120 watts maximum). We will be using equal-value resistors to minimize the number of resistors needed to safely dissipate the required amount of power. Therefore, we will need at least 60 of them (120 watts divided by 2-watt resistors equals 60 resistors). Plugging values into the formula in Fig. 3B and solving for R1, we find that the resistors must be 3000 Ω each to give us a total resistance of 50 Ω. On the other hand (and more likely in reality), if we had a stock of 3000-Ω resistors, we could calculate the number needed to make a 50 Ω load by dividing 3000 Ω by 50 Ω.

What for Watts

Throughout this article we have been talking about 2-watt resistors. The reason is that the largest stock-value wattage for carbon-composition resistors is usually 2 watts. Larger wattage resistors are often available, but they almost invariably are wire-wound. These resistors are pretty much what the name implies — a precise length of high-resistance wire wound into a coil and encased in some heat-conducting package. Because of the construction, wire-wound resistors are totally unsuitable for dummy loads; they're highly reactive.

Where do you get 2-watt carbon composition resistors these days? You probably won't find them at your local CB-supply house or discount store. You will find them at large industrial electronic supply houses, but the cost may be prohibitive. I checked the catalog of a national distributor (with a $25 minimum purchase) and found that they sell 2-watt resistors for about $12 per hundred. Such pricing is reasonable if several individuals go together and buy enough to exceed the minimum order. If it turns out that this is the only way that you can obtain enough resistors to build one dummy load and you have no one to share the costs with, it will cost you less to buy a commercial dummy load or kit. Probably the best source for the resistors is a hamfest flea market. I have often seen bags of resistors of the same value go for $2 or less at these gatherings.

Here is where knowing the formulas that we developed earlier will help you. Surplus dealers will not likely have a wide range of values to choose from. It will be incumbent upon you to do a little mental arithmetic and decide which value resistors are suitable for use and which are not, in addition to the number needed.

Table 1

Resistor-Capacitor Color Code

Color	*Significant Figure*	*Decimal Multiplier*	*Tolerance (%)*	*Voltage Rating**
Black	0	1		
Brown	1	10	1*	100
Red	2	100	2*	200
Orange	3	1,000	3*	300
Yellow	4	10,000	4*	400
Green	5	100,000	5*	500
Blue	6	1,000,000	6*	600
Violet	7	10,000,000	7*	700
Gray	8	100,000,000	8*	800
White	9	1,000,000,000	9*	900
Gold	-	0.1	5	1000
Silver	-	0.01	10	2000
No Color	-		20	500

*Applies to capacitors only

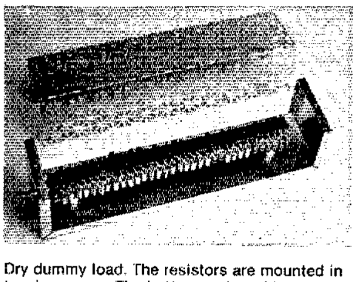
Since carbon-composition resistors are marked with the standard color code (Table 1), you may want to memorize it or carry a copy with you (a full explanation of the color code can be found in chapter 17 of *The 1981 Radio Amateur's Handbook*, available from ARRL for $10). Carbon-composition resistors are usually tubular in construction, with the value of the resistor specified by the color code; wire-wound resistors are customarily encased in oblong, box-like structures, with the value of the resistor printed on the top. If there is any doubt about what kind of resistors you have, it would be advisable to break one apart and see what is inside.

Wet vs. Dry

As can be seen from the accompanying photographs, we have constructed the dummy load in two different formats. The enlongated version is meant to be used as an air-cooled (dry) dummy load. The heat dissipated in the resistors of the dummy load is transferred to the air around the load by convection. If the duty cycle is less than 100%, the power rating of the dummy load can be exceeded. A rule of thumb is that if the resistors become too hot to touch (don't key the transmitter while touching them!) then you should reduce the power level, the duty cycle or both. A perforated cabinet may be constructed to further reduce any incidental radiation.

The second version of the dummy load is shown attached to a paint-can lid. A significant improvement in the transfer of heat can be accomplished by immersing the dummy load into an oil bath. Thus, a dummy load that would be rated for 100 watts dry may be able to withstand several hundred watts for a minute or two if submerged in oil. The best oil to use is transformer oil, which you may be able to obtain from your local utility company. If local hams are employed by the utility, check with them. Be wary of transformer oil that individuals may have had for several years because it may be contaminated with PCB, a highly toxic substance. If you have no luck with transformer oil, you may want to use mineral oil. Purchased in a drug store, mineral oil can cost up to $3 per pint. The reason for the high cost is that the product has been certified as fit for human consumption and it may carry the label of a major pharmaceutical house. Veterinarians have used quantities of mineral oil to treat horses, cattle and other large animals for years. A check with local veterinarians specializing in large animals indicated that mineral oil should be available from this source for about $5 to $10 per gallon. (It may be less embarrassing as well as less expensive to buy a gallon of mineral oil from the veterinarian.)

Over the years hams have used various other oils as a coolant in dummy loads.



Dry dummy load. The resistors are mounted in two long rows. The bottom pc board is mounted to two standoff insulators. The enclosure was specially constructed in the ARRL lab to fit the dummy load. Any metal cabinet that the dummy load will fit in will serve to reduce incidental radiation and to prevent possible accidental contact when the transmitter is being keyed.

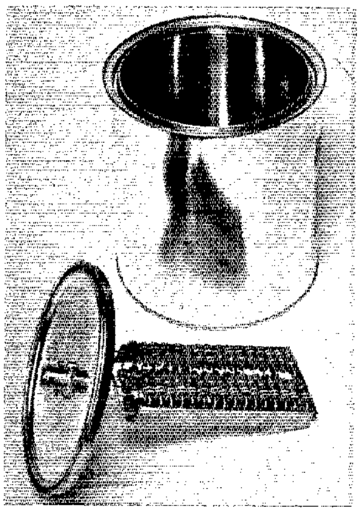
Most of these oils, including motor oil and cooking oils, have a considerably lower flash point than transformer oil or mineral oil. We advise you to err on the side of caution in this matter — one accidental fire could easily cost 20 times the saving of using a less costly oil.

Whether to build wet or dry is a choice each builder will have to decide. A dry dummy load is certainly less messy and easier to build. Also, there is no need to scrounge for an empty paint can and oil to fill it. On the other hand, a dry dummy load will not handle nearly as much power.

Putting It Together

The 3300-Ω resistors I used were a portion of a large donation of parts from a member. Each resistor came with the leads clipped short and bent as shown in the photograph. My first thought was to drill equally spaced holes through the circuit board and mount the resistors with the shortest possible leads. Common sense [read: laziness — Ed.] intervened and I decided to solder the resistors directly to the circuit board without straightening them or drilling the holes. Two strips of double-sided circuit board, 1-inch wide by whatever length necessary, are used if the dry dummy load is to be constructed. You will need three strips half as long if the wet format is chosen. The outer copper laminations are not connected. We are not sure what the effect will be to use single-sided pc board — we ran out of resistors before we thought of trying it that way. One side of the bank of resistors is connected to the center pin of a coax connector and the other side is attached to the ground side. Make the connecting leads as short as possible.

Once the dummy load has been built, attach an SWR indicator and transmitter and check the SWR of the dummy load. On both models constructed in the lab we showed an SWR no greater than 1.1 to 1, 80 through 10 meters. Incidentally, we used a reactance bridge to double check



The wet dummy load. In this format the length has been halved by constructing with two sets of two rows each. A small pinhole is punched in the top of the can to allow the can to "breathe." The can shown was obtained from a chemical supply house. If you have available a paint can that has been emptied it should work — be sure to clean out the paint before adding the oil. Some paint and hardware stores that buy paint in bulk may be willing to sell you a new, clean paint can.

the figures obtained from the SWR bridge and found no discrepancy. At 2 meters we found that the dry dummy load had an SWR of 1.8 to 1 and the wet one had an SWR of 2.6 to 1. While it may not be suitable for vhf work, this design is perfectly adequate for hf.

Lessons to Be Learned

I am not one who advocates building anything and everything just for the sake of building it — particularly if the end result is not better and less expensive than something that can be bought. (The SWR figures on this dummy load are not as good as those of most commercial dummy loads, especially at vhf.) You are justified in building this if you happen to have enough resistors around, you know where you can get them cheap or you want to do it as a group project and go for a quantity discount.

This project demonstrates the value of knowing the most basic fundamentals of electronics — and being able to recognize what is significant and what is not. If you know the fundamentals, you will be in a better position to make use of the bargains that you encounter at flea markets and surplus houses. If you know the fundamentals of electronics, you will be able to make do in an emergency whether you have the exact replacement part or not. If you don't know the fundamentals of electronics, now is the time to start learning them.

Product Review

Conducted By Paul K. Pagel,* N1FB

ICOM IC-2A 2-Meter Hand-Held Transceiver

ICOM's contribution to the world of synthesized, 2-meter hand-held transceivers is the rugged, compact IC-2A. With the Touch-Tone pad installed, it is called the IC-2AT. ICOM provided Hq. with one of the first production models, and in the seven months I have operated this transceiver, it has undergone a lot of rugged use and given no problems.

What do I mean by rugged use? How about clipping it on my belt for monitoring the local repeater while bicycling the 12 miles from home to League Hq. and back two or three times a week during this summer? Or using it to keep in touch with civilization while climbing Mount Katahdin, Maine's tallest mountain, and camping at Baxter State Park? (I wish *I* were as unaffected by that mountain climb as the hand-held was. Whew!) On top of that, I lent it to K1FHN, who used it to get onto 2-meter fm for the first time. The little ICOM saw no rest that month! Believe me, this rig was *not* babied. Yet, it performed flawlessly. On-the-air reports gave it high marks for overall signal intelligibility and clarity.

The best thing going for this rig, in my opinion, is its small size and light weight. The rig is so light it's easy to forget you're carrying it until someone breaks the squelch.

Metamorphosis: IC-2A Becomes IC-2AT

The unit ICOM sent to Hq. was the IC-2A because, at that time, production models of the IC-2AT were not available. A few months later however, ICOM sent a new case front, including the Touch-Tone pad, allowing me to change the IC-2A into an IC-2AT. This required only the removal of six screws and disconnection of the wires to the speaker and microphone. The case front with the Touch-Tone pad was installed by plugging in the Touch-Tone connections and soldering the wires for the speaker and microphone. The whole procedure took about 10 minutes. For those of you who purchase the IC-2A and then decide to retrofit your rig with the pad, you may order the 2A-TTN from your ICOM dealer.

The ICOM factory tests and adjusts the tones for the IC-2AT. However, retrofitting the IC-2A with the Touch-Tone pad required a minor adjustment of the tone level to get the autopatch on the local repeater to accept the tones. This was a simple matter of adjusting R77. Page 19 of the owner's instruction manual shows where this potentiometer is located. The tone frequencies were measured in the ARRL lab and were found to be within 0.7% of the standard, an extremely accurate figure.

I used the standard IC-BP3 NiCad battery pack and BC-25U wall charger exclusively and found the IC-BP3 to be adequate for most of my needs, though there were a few times when longer battery life would have been nice. The radio has a small, red transmit/battery indicator that is illuminated while transmitting.

*Assistant Technical Editor

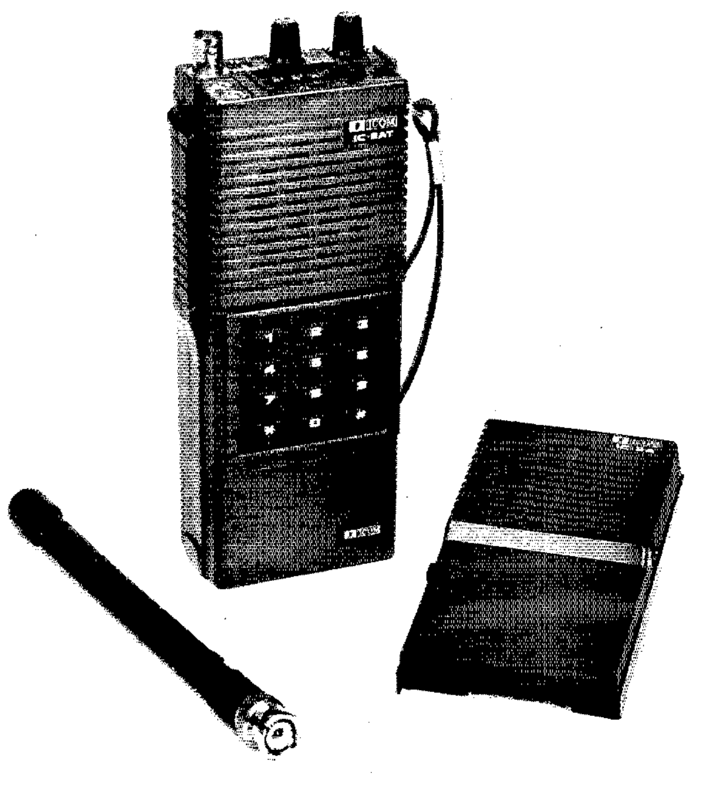


Fig. 1 — The IC-2AT. A BNC antenna connector permits rapid and positive antenna connections to be made. The flexible antenna is a part of the standard package. To the right of the transceiver is the original case front. Conversion from the IC-2A to IC-2AT is discussed in the text.

Table 1

IC2A/AT Battery Packs

Battery Pack Model	*Height*	*Charger Required*	*Batteries*	*Voltage*	*Typical Output (in watts)*	*Dealer's Suggested Retail Price*	*Brief Description*
IC-BP2	1.5 in. (39 mm)	BC-30	N-425 AR	7.2	1.0	$34.50	Low voltage/ high capacity
IC-BP3	1.5 in. (39 mm)	BC-25 or BC-30	N-250 AA	8.4	1.5	$27.50	Standard voltage/ standard capacity
IC-BP4	1.9 in. (49 mm)	 BC-30	UM-3 N-450 AA	9.0 7.2	1.5 1.0	$9.50 (no cells included)	Holder for dry cells or NiCads
IC-BP5	2.4 in. (60 mm)	BC-30	N-425 AR	10.8	2.3	$47.50	High voltage/ high capacity

Note: The BC-25 is a wall charger and is supplied as standard equipment with the transceiver. A drop-in charger, the BC-30, is optional and sells for approximately $70.

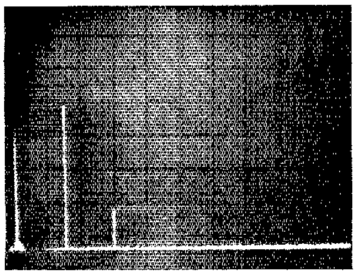


Fig. 2 — A spectral photograph of the IC-2A/AT output. The fundamental signal has been reduced in amplitude some 30 dB by means of notch cavities; this prevents analyzer overload. The second harmonic is shown approximately 62 dB below peak fundamental output. Vertical divisions are 10 dB; horizontal divisions are 100 MHz. Power output was 2.5 watts at a frequency of 146.52 MHz. Tests were performed in the ARRL lab. The IC-2A/AT complies with current FCC specifications for spectral purity.

ICOM IC-2A Serial no. 11501169

Manufacturer's Claimed Specifications	*Measured in ARRL lab*
Frequency coverage: 144.000-147.995 MHz	Same
Frequency resolution: 5-kHz steps, 800 channels.	Same
Frequency control: Digital PLL synthesizer, with thumbwheel switches.	
Antenna impedance: 50 ohms, unbalanced; no VSWR protection claimed.	
Power supply requirements: 8.4 V dc	
Dimensions: 4.6 × 2.6 × 1.4 inches (117 × 65 × 35 mm) HWD without battery pack. IC-BP3 pack dimensions: 1.9 × 2.6 × 1.4 inches (49 × 65 × 35 mm) HWD.	
Weight: 16.6 oz (470 g) including IC-BP3 and flexible antenna.	
Transmitter output power: High — 1.5 W, low — 0.15 W at 8.4 V dc.	High — 2.5 W, low — 0.5 W
Receiver: Double-conversion superheterodyne.	
Intermediate frequencies: 1st — 10.695 MHz; 2nd — 455 kHz.	
Sensitivity: > 26 dB S + N + D/N + D at 1 μV; < 0.5 μV for 20 dB noise quieting.	

If the light fails to go on, the battery voltage is too low. Bringing the BP3 back up to full charge takes 15 hours. However, optional battery packs have more capacity and can be quick-charged in 1 to 1-1/2 hours with the BC-30 drop-in charger.

Four different battery packs can be used with the IC-2A/AT (see Table 1). The hand-held's receiver is self-regulating; however, the transmitter will draw more current from the higher voltages. This means a higher-voltage battery pack will deliver more output. Each battery pack, with the exception of the BP-4, is a sealed NiCad battery. The BP-4 is actually a battery holder for six AA-sized cells. This case will accept dry cells, zinc or alkaline, for 1.5-W output, or NiCad cells for 1-W output.

The BC-30 drop-in charger is necessary to charge any NiCad battery pack except for the CO-3. The BP-3 can be charged with either the wall charger or the BC-30. However, the other battery packs, including the BP-4 if loaded with NiCad cells, must use the BC-30. The BC-30 drop-in charger is a "smart" charger. If you drop in the hand-held with any of the battery packs, the notches on the bottom of the pack identify it for the charger and it will supply the right voltage and current. The BC-30 has a heat-sensing device that makes use of the fact that a fully charged NiCad cell's temperature elevates once it reaches a full charge. When it senses the temperature elevation, the BC-30 knows the NiCads are fully charged and shuts down. It takes the BP2, BP4 (with NiCad cells) and BP-5 about 1 to 1-1/2 hours to charge. Though the BP-3 can be charged with the drop-in charger, it still takes 15 hours.

The battery life varies with the battery pack being used. According to ICOM, the BP3, the standard NiCad battery pack, should last for approximately 100 minutes of continuous use. This assumes a duty cycle of 3:1, i.e., three minutes of reception for every one minute of transmission. My experience seems to bear this out. Of course, a squelched receiver draws less current (20-mA) than an active receiver (130 mA), so expect longer battery life if monitoring a quiet repeater or simplex channel.

On-the-Air-Operation

Most of the operating controls are located on the top of the hand-held. The ON/OFF switch is a little unusual because it is a small slide switch separate from the VOLUME control knob. Whenever I handed the rig to a friend, he or she would invariably twist the VOLUME control knob in an attempt to turn it on. The ON/OFF switch is clearly marked so you can chide your friends for being so impetuous! Actually, I like the separate ON/OFF switch because it saves the trouble of readjusting the volume whenever the transceiver is turned on. The other controls: VOLUME, SQUELCH and FREQUENCY SELECTION thumbwheel switches are in a convenient configuration. There is also a 5-kHz SHIFT switch located next to the ON/OFF switch to add 5 kHz to the frequency displayed. On the back of the radio there is a small depression where there are three more slide switches. The switches are, from top to bottom, HIGH/LOW POWER, SIMPLEX/DUPLEX and a +600/−600 TRANSMITTER FREQUENCY OFFSET. It works very well. You select your receiver frequency with the thumbwheel switches on the top and then relate your transmit frequency to it using the controls on the back. A friend criticized the separate SIMPLEX/DUPLEX and +600/−600 switches, saying these functions could have been incorporated into one three-position switch. I think he is a little too picky.

The only serious problem I had with this rig is that everyone wanted to borrow it! Fortunately, the radio is modestly priced so one can seriously say "go out and buy one of your own." It's light, rugged and compact — a lot of radio for the money.

ICOM supplies a 29-page instruction manual, a schematic diagram and a board layout sheet with each transceiver. The instruction manual is of excellent quality. It has a trouble-shooting section, but it is confined to possible operator errors. All in all, I give the instruction manual high marks for completeness, understandability, and good diagrams and pictorials.

The Package

The basic package includes the following: BP-3 battery pack, BC-25 wall charger, flexible antenna, belt clip, carry strap, earphone and a couple of extra earphone and microphone plugs. The flexible antenna has a standard BNC connector for quick installation and disconnection. Besides the optional battery packs already mentioned, a number of other accessories are available. The IC 2A/2AT is available from: ICOM, 3337 Towerwood Dr., Suite 307, Dallas, TX 75234. Price class: IC-2A $230; IC-2AT, $250; 2A-TTN, $30. — *Dale Clift, WA3NLO*

BIRD MODEL 6736 TERMALINE WATTMETER

☐ The 6736 combines a high-power, highly accurate, 50-ohm termination with a multirange wattmeter to provide power measurements up to 1000 watts in the 1.5- to 35-MHz range. Two units make up the 6736: a 50-ohm termination (a Bird Model 8251 that has been fitted with a 50-ohm line section and voltmeter cartridge) and a three-range meter unit. The two units are connected by a 43-1/3-inch (1100-mm) length of shielded cable (RG-58/U. The cable is attached to the termination with a screw-on connector so that the units may be separated.

It should be noted that while the frequency range of the 6736 is 1.5 to 35 MHz, the termination can be used as a 50-ohm load to 2.5 GHz. Full-scale power ranges of 50, 250 and 1000 watts are available on the model 6736; a fourth position of the range switch shorts the meter movement for protection during transit. Accuracy is 5% of full scale. The input connector is a Bird quick-change type that permits easy interchange so that any of the standard type connectors can be used. Though the model 6736 is normally supplied with a female type LC connector, changing to a type N connector takes less than a minute. It is also possible to

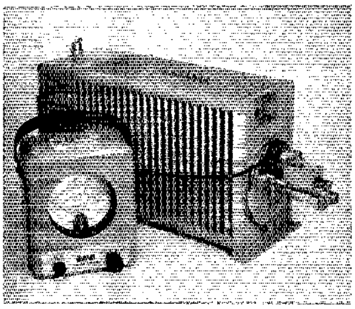


Fig. 3 — The 6736 combination shown here is only one of a number of combinations available from Bird. A multirange wattmeter eliminates the need to change slugs.

remove the voltmeter line section and place the input connector directly on the termination if desired. Both the meter unit and the termination are fitted with carrying handles for convenience. The termination unit requires 1.1 gallon (4 liters) of coolant oil (supplied by Bird) and comes with a vent plug to prevent leakage while moving the unit. Comparison to a laboratory reference meter (a Bird model 43) showed that the 6736 meets the manufacturer's specification for accuracy. There are four other Termaline wattmeters in the model 6730 series, covering power levels from 250 to 2500 watts and frequency ranges to 1 GHz. The price class for the model 6736 is $625. It is available from the Bird Electronic Corp., 30303 Aurora Rd., Cleveland OH 44139. — *George Collins, AD0W*

TELEX/HY-GAIN HDR-300 HEAVY DUTY ROTATOR

☐ In a word, the HDR-300 is *hefty*. This unit, weighing in at 27 lb (12.2 kg), is designed to support a vertical load of 500 lb (227 kg) and rotate an antenna with a projected wind surface area of 25 ft^2 (2.3 m^2) when mounted inside the tower. The antenna in use at W1SE at the time the rotator was tested was a large, six-element tribander with a 32-foot (9.8 m) boom. This 75 pound (34 kg) antenna hardly taxed the capability of the HDR-300, which operated as if it had no load upon it.

Telex/Hy-Gain recommends that the minimum outside tower width be 11.5 inches (292 mm). The top section of the tower at W1SE is just 11 inches (279 mm). This, and the fact that the HDR-300 mounts *beneath* the rotator mounting plate, at first made it impossible to mount the rotator and have it clear the tower bracing. The job was finally done on the fourth try by *inverting* the mounting plate, permitting the rotator housing to clear the tower bracing. If one has a tower with the recommended minimum-width face, or larger, no problem should be encountered. Earlier, some difficulty was experienced in determining the location of the holes to mount the rotator to the mounting plate. The required spacing is not the same as the HAM-II holes that were already there. Though a template is provided, its use is limited to two sizes of Hy-Gain towers. The second, and successful, effort at alignment of the rotator to the mounting plate was "eyeballed." Other size mounting plates, for other towers, might prove easier — or produce similar problems. As a suggestion, Hy-Gain might consider a template marked with the holes of other popular rotators. Then it would be a snap. Once these mechanical problems were solved, there were no others.

Control Unit

The nicely styled, functional HDR-300 control console is provided with a convenient digital readout accurate to ±1°. The 21 lb (9.52 kg) console, supplies 24 V ac for the rotator motor, 5 V dc for the azimuth potentiometer, and converts the analog voltage received from this potentiometer for input to the three 7-segment LEDs that display the digital azimuth readout. Both transformers are factory wired for 117 V ac, but may be re-strapped for 235 V ac operation.

Just above the ROTATE switch lever is a rocker-type switch labeled BRAKE, with FREE and LOCK positions. The switch must be moved to the FREE position before the rotator may be activated. In the LOCK position, power is removed from the ROTATE switch. Thus, the brake is not released automatically as one rotates the antenna, and then automatically applied as rotation power is removed. The antenna is free to coast to a stop as it nears the end of rotation. A simple idea, but Telex/Hy-Gain will be thanked many times by amateurs for this thoughtful feature. It is possible to lock the rotator *when* one wants it locked: Just push the BRAKE rocker-switch to LOCK. In addition, should one forget to push the BRAKE switch to LOCK at the end of an operating period, pushing the POWER switch to off automatically locks the brake on the rotator. Both the BRAKE and POWER switches are illuminated, so it is difficult to ignore them.

In addition to the operating convenience provided by the digital readout, the brake-release feature offers a degree of safety and protection. This feature, in which the operator independently activates the brake, is designed to reduce the effects of torsional forces on a tower caused by instant deceleration when a large antenna is brought to a stop. After a few attempts, one is able to release the ROTATE lever slightly before the desired antenna position is reached, thereby permitting the antenna to coast to a stop. The desirability of coasting a large antenna to a stop before brake application is an idea that appears to have escaped the minds of most rotator manufacturers. Here is one manufacturer who has heard and answered this need with the HDR-300.

The manufacturer does not recommend operation of the rotator at its rated capacity in winds above 50 mi/h (80.5 km h). However, Telex/-Hy-Gain says it is possible as long as certain precautions are taken. (1) Always allow the antenna to coast to a stop before locking the brake. (2) Always keep the brake locked when the rotator is not being turned. (3) Avoid rotating near the ends of rotation. Do not depend on the limit switches to stop rotation of a large antenna in strong winds. The manufacturer also suggests that the above precautions be followed when rotating even medium-size antennas in light winds. The life of the rotator will be prolonged.

The HDR-300 is manufactured by Telex/Hy-Gain, 8601 Northeast Highway 6, Lincoln, NE 68505. Price class: $500. — *Lee Aurick, W1SE*

AEA KT-1 KEYER/TRAINER

☐ Do you avoid reading keyer reviews because some arrogant cw hotshot starts off by telling you how easy it is to rag chew at 40 wpm when you have trouble at 10 wpm? I'm not a cw hotshot; in fact, I struggled to get through the FCC code exams. My first three contacts were so disastrous that I dropped out of the hobby for five years! This wouldn't have happened had the KT-1 been available.

Besides being a full-feature keyer, the KT-1 is also a trainer. The trainer has approximately 24,000 characters stored in its memory. The operator can choose from among 10 fixed and 1 random starting points. So far it doesn't sound much different than a tape recorder with a cassette, but there is more — a lot more! I suspect that the designer had flexibility in mind as the utmost consideration when the circuit was developed.

The trainer can be set up to "spit out" the code at one constant speed or to start at a slow speed and build up to a fast speed (starting speed, ending speed and duration of speed change are all user programmable). The user has the option of choosing "slow" or "fast" code. Slow code employs the standard timing of dits, dahs and spaces, at whatever code speed.

"Fast" code is also known as the Farnsworth method. Characters are generated at a higher speed, but the spacing between letters is increased so that the overall speed is slow. For example, on speeds below 13 wpm, W1AW generates the characters for code practice at a 13-wpm rate, but the spacing between the characters is increased so that the rate of words per minute actually sent is that specified by the schedule. Above 13 wpm, W1AW sends code practice using slow code. The KT-1 user can

Fig. 4 — On first inspection, the outward appearance of the KT-1 gives no indication of its capabilities. Inside this 1-3/4 × 2-1/2 × 5-inch (44 × 63 × 127 mm) housing hides a tremendous amount of electronic sophistication.

program it for any speed up to 99 wpm, which means that those of us in the midrange of ability can use the Farnsworth method to help us increase our speed more rapidly. Try to find a tape recorder that will do that!

I don't know if everyone struggling to learn the code or increase speed (for a code test?) will find the KT-1 helpful, but I certainly have. For years I have been listening to cw hotshots talk about hearing characters and words instead of individual dits and dahs; I had been pretty skeptical that I would arrive at that blessed condition. Thanks to the KT-1 and the Farnsworth method I am getting there. My procedure has been to set the finishing speed (that sets the rate at which the character is generated) at 35 wpm and the beginning speed at 10 wpm. (Don't get me wrong; I wouldn't classify myself as a cw hotshot now, but I am a lot better than I was.)

The keyer portion has all the features (and more) that we expect in a modern piece of equipment. It can be used as an iambic keyer with dit-only memory, dah-only memory and with or without both. For anyone so inclined, the dah input can be turned into a straight-key input, which allows the KT-1 to be used as a straight key or a bug. At initial power up, the dit-space ratio is set at 1.0 to 1. The user can program the KT-1 for any ratio between 0.5 and 1.5 to 1. The dah-space ratio is set to 3.0 to 1 at power up, but the user can select any ratio between 2.0 and 4.0 to 1.

Even though I am exposed to miniaturized, computerized equipment on a daily basis, it never ceases to boggle my mind when I see so much crammed into something so small! The KT-1 has two ICs (about 23,000 transistors in one), six diodes and five discrete transistors. The only knob on the KT-1 is a dual function ON/OFF and VOLUME control for the sidetone (the tone frequency is selected from the keyboard). All programming is by means of the 12-key pad. Some of you may suspect that the KT-1 is difficult to operate because of all the features that I have described as "programmable." Just the opposite is true. The KT-1 is simple to use after you read the manual. AEA has devoted enough time and effort to produce a manual that is complete, accurate and easy to understand. A few minutes of off-the-air practice should be enough to provide most any amateur enough "programming skill" to operate the KT-1 successfully.

The KT-1 has been designed with a bipolar keying output that will handle either positive or negative keying without modification. It should work with any modern transmitter. I found it quite enjoyable to unplug the KT-1 from my Drake TR-4C and then plug it into a Kenwood TS-130 without having to alter anything. The operating manual mentions that there are a few transmitters that the KT-1 will not key. A simple modification (which involves shorting out one of the diodes in the keyer) will overcome this difficulty. This modification will make the keyer inoperable for negative keying; however, it should never be necessary to resort to an external reed relay with the KT-1, as is the case with some other keyers on the market.

The KT-1 should be of interest to those amateurs (and would-be amateurs) who are struggling to improve their code speed, those who teach Amateur Radio courses and those looking for an extremely versatile keyer. Price class is $130. Additional information on this keyer and other products can be obtained from AEA, Inc., P. O. Box 2160, Lynnwood, WA 98036. — *Peter O'Dell, AE8Q* QST

New Books

☐ *From Beverages Through OSCAR — A Bibliography*, by Rich Rosen, K2RR/Ø. Published by Rich Rosen, 6043 W. Maplewood Dr., Littleton, CO 80123. Softcover edition or topical booklet form, 8-1/2 × 11 inches, 620 pages. Book price is $24.95 plus $2 handling; individual sections by subject are $2 each plus 50 cents handling.

No longer is it necessary for the amateur or engineer to become buried in a landslide of assorted publications while looking for an obscure and forgotten article of interest. Rosen's in-depth bibliography spans in chronological form a 65-year period during which pertinent data were published in 288 different magazines, journals and publications — including the amateur and professional magazines.

This massive and complete bibliography references 30,000 articles on Beverage antennas, Yagis, receivers, preamps, oscillators, filters, ssb, lasers and 84 other subjects of amateur and commercial interest. Although the complete listing cost $20 and the individual sections sell for $2, one can also order larger subject volumes (up to 2378 entries) for $5 plus $1 handling.

The author invested four years of his spare time in compiling this enormous file of data and getting it into proper order for publication. He calls it a true "labor of love," and has read every issue of *QST* since 1945 (plus *CQ, Ham Radio, 73* and others) in order to gather the necessary information. Rosen is not only an active radio amateur, but is a professional engineer with extensive industrial experience. He is thus well qualified to have selected the best of the published material. Rosen also is editor of the trade journal, *RF Design*, of Denver, Colorado. This reviewer feels that Rosen's work will represent an important part of any active amateur's technical library. The review copy will be extremely useful here at League hq. — *Doug DeMaw, W1FB*

☐ *Interrelated Integrated Electronics Circuits for the Radio Amateur, Technician, Hobbyist, and CB'er*, by Robert M. Mendelson. Published by the Hayden Book Company, Inc., Rochelle Park, New Jersey, 1979. Softcover, 6 × 9 inches, 121 pages, $6.95.

If you fit into any one (or more) of the categories named in the title, you'll enjoy this project book. It contains approximately 25 different circuits, many of which are interrelated (note the title again) and can therefore be tackled in building-block fashion if desired.

Starting with six power-supply-oriented projects, the reader/constructor progresses to an audio mixer, two-tone generator, ssb detector, high- and low-pass filters and band-pass and notch filters using linear CMOS circuitry. Resistance boxes, a Wheatstone bridge and a passive attenuator are next. The instruments section contains information for, among others, a multipurpose rf detector, portable digital voltmeter, battery-operated frequency counter and a capacitance meter. Then, for fun and games, there are electronic dice and digital roulette.

My first impression of the book was its neatness. It's easy to read, with clear photographs and distinct parts overlays. It is evident that care was taken in the construction of the complete units shown in the photographs as they are all "well-groomed," presenting a professional appearance.

Circuit operation is discussed briefly in everyday language. While most circuits described are shown using pc-board construction (there's an appendix with complete pc layouts), there's no reason why perf-board construction cannot be used.

Be sure to read the preface pages, as they contain some general rules that apply to the construction of all the projects presented. Parts procurement should not be a problem, as most of the components are readily available. You'll note that most of the project enclosures appear to have come from the shelves of a Radio Shack outlet. Although the author cautions that some of the latest IC types may have to be obtained from an RCA distributor, this should not be a deterrent since there are some 300 such distributors nationwide. In all, I'd have to rate this book a cut above many of the project books I've seen. — *Paul K. Pagel, N1FB*

☐ *Modern Electronic Circuits Reference Manual*, by John Markus. Published by McGraw-Hill Book Co., New York, NY 10020. Hard-cover edition, 8-3/4 × 11-1/2 inches, 1238 pages including index, $44.50.

The John Markus name certainly must stand out in the minds of many amateurs and engineers, for Mr. Markus has been writing compendium-style circuit books for many years. I recall vividly how, during my early and lean years as a professional engineer, a gift of the John Markus/Vin Zeluff book, *Electronics for Communications Engineers* (McGraw-Hill 1952), became an important source of practical circuit information. By today's standards, the book would be a dismal addition to one's technical library, since it deals exclusively with vacuum-tube circuits (FETs that glow?). The current John Markus book treats practical circuits that employ semiconductors. It is perhaps the largest book of its kind that I have had the occasion to heft. One almost needs to have muscles in his shirt sleeves to carry this volume around: It weighs 8 pounds, 5 ounces!

Although the book seems to be aimed at the professional community of engineers and technicians, it is a radio amateur's cornucopia of practical data. The more than 3600 circuit diagrams have been harvested from the pages of *QST, Ham Radio, Wireless World, CQ* and *73*. Other material has been gleaned from such publications as *Byte, Kilobaud, EDN, Electronics* and other trade journals. All manner of practical circuits are represented, including rf, audio, digital and logic. There are even QRP rigs, burglar alarms, TV circuits, test equipment and temperature-control circuits. You name it; Marcus has it!

The only original writing found in the book is seen in the captions, which in capsule form tell what each circuit is and where to find the original article. The complete address of each of referenced publication is given at the beginning of the book.

If you have $44.50 to invest in an interesting and useful reference book, this may be the next publication to add to your Amateur Radio library. Better get a small red wagon to pull it in when you go from one point to another! — *Doug DeMaw, W1FB*

Technical Correspondence

Conducted by
Jerry Hall,* K1TD

The publishers of QST assume no responsibility for statements made herein by correspondents.

MY EXPERIENCE WITH SOLAR POWER

☐ I have used my Heathkit HW-8 for more than one year entirely on energy collected from the sun. I use a solar panel that is rated at 12 volts, 300 mA, containing 32 solar cells. It sits in a southeast window at a 50° angle. The panel is connected to a 12-volt lead-acid auto battery in the basement. I use the HW-8 in the room next to the solar panel. It is best not to have the rig too close to the panel or the rf energy will destroy the blocking diode in the panel. There has to be a diode in the panel circuit or the battery will discharge back through the panel when the sun is not shining. I have made more than 250 QSOs without using any commercial power. This gives me a kind of self-satisfied feeling when I hear our fearless leaders telling us to save hydro.

I have another panel that powers lights in the garage; it is rated at 14.7 volts, with 36 cells. (Sealed-beam lamps with one element burned out are easy to get at any service station or garage, for taking them away.) I think the bigger panel is the better value. Both my panels came from Edmund Scientific; they were manufactured by Solarex of Rockville, Maryland. In all my solar-powered contacts I have never run across another solar-powered station or anyone who has worked another such station. It is easy to set up a QRP station on solar power, so I will be looking harder than ever now. Hope to see *you* soon. — *McRae McNaughton, VE3EQQ, 230 Ontario Rd., P. O. Box 507, Mitchell, ON N0K 1N0*

SAFETY AGAINST ELECTRIC SHOCK

☐ How many times have you worked on a piece of electrical equipment and received an uncomfortable shock? After further checks, you may have realized it was "normal" ac leakage to ground, which sometimes must be tolerated with line-to-chassis bypass capacitors. Have you ever wondered how much leakage was acceptable? Where do you draw the line? And how can you measure such leakage?

*Technical Editor, *QST*

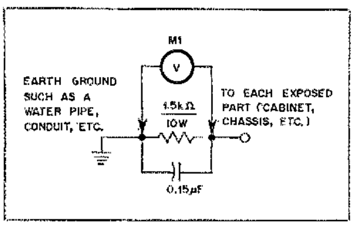


Fig. 1 — Measurement setup for determining ac leakage. M1 must have a sensitivity of 5-kΩ per volt or greater, and the capacitor must be nonpolarized. A measured ac voltage greater than 7.5 indicates a potential shock hazard.

Well, the Consumer Electronics Group of the Electronic Industries Association (EIA) has a guideline designed to be used by radio and TV service technicians. This covers their service obligation always to deliver a safe unit to the user. You should always be conscious of the safety aspects of each piece of equipment, and never be tempted to ignore any of them. The guideline covers the following.

AC Leakage Test

Do not use an isolation transformer during this test. Use an ac voltmeter having 5 kΩ per volt or more sensitivity in the manner shown in Fig. 1. Connect a 1.5-kΩ, 10-W resistor paralleled by a 0.15-µF nonpolarized capacitor between a known good earth ground and the exposed metallic parts, one at a time. Measure the ac voltage across the combination resistor and capacitor. Reverse the ac plug and repeat the voltage measurements for each exposed metallic part. A potential as much as 7.5 V rms is permitted. (This corresponds to 5 mA ac.) The lower the measured value, the better. Any value exceeding the 7.5-V limit should be corrected immediately, as a defect is indicated. This is a potential shock hazard and may lead to death.

As amateurs, we often have contact with gear that should pass the above test. If the leakage is too high, we probably should look deeper into the cause, and naturally find a remedy. For extra protection, we should always ground all equipment — with a separate ground wire — to insure against any possible shock hazard. Remember, you do not want to find out your equipment is a shock hazard when you are making antenna connections at the top of your tower or on your wet lawn! — *Thomas R. Rosica, W2GIR, 125 Grandview Ter., Batavia, NY 14020*

COMMON FREQUENCIES FOR UHF AND HIGHER

☐ For some 10 years the use of 2304.0 MHz for weak-signal work has been employed because of several advantages realized: 2304 is 16 times 144 MHz. The British hams have also suggested using other frequencies in the uhf spectrum, 3456 MHz for example. See Table 1.

The use of a common frequency of 1080 MHz for receiving converters would reduce the stages needed for 2304- and 3456-MHz reception, as follows:

1080 MHz × 2 = 2160 MHz (144 MHz i-f from 2304 MHz)

1080 MHz × 3 = 3240 MHz (216 i-f from 3456 MHz)

These intermediate frequencies would permit using 144- and 220-MHz converters for reception of 2.3- and 3.4-GHz signals. — *Paul M. Wilson, W4HHK, ARRL TA, P. O. Box 73, Collierville, TN 38017*

Table 1

Suggested Crystal-Controlled Frequencies with a Common Lower Frequency

Frequency Relationship	*Band (MHz)*
1152 MHz × 2 = 2304 MHz	2300-2450
1152 MHz × 3 = 3456 MHz	3300-3500
1152 MHz × 5 = 5760 MHz	5650-5925
1152 MHz × 9 = 10,368 MHz	10,000-10,500

Q VERSUS BANDWIDTH

☐ One concept that I was confronted with some years ago was the simple relationship of bandwidth and Q. Generally, one almost takes for granted that bandwidth and Q are related only to the well-accepted 3-dB level. That is, we accept the 3-dB bandwidth as representing the calculation of Q. The problem then presents itself: What does one do when he wishes to consider a bandwidth or Q based on a different attenuation level, say the 1-dB bandwidth?

This concept is not original: It has been written up in the ITT *Reference Data for Radio Engineers* for many editions. Perhaps for amateurs it is new. The formula given in that reference is

$$\frac{\Delta F}{F_o} = \frac{1}{2Q}\sqrt{\left(\frac{E_o}{E}\right)^2 - 1}$$

where the ratio E_o/E is the reciprocal of the voltage for the dB. For example, let's consider the 3-dB bandwidth. For 3 dB the voltage ratio is 0.707; the reciprocal is 1.4144, so, using the foregoing equation we obtain the well-known expression

$$\frac{\Delta F}{F_o} = \frac{1}{2Q}\sqrt{1.4144^2 - 1} = \frac{1}{2Q} \bullet 1$$

or,

$$\frac{\Delta F}{F_o} = \frac{1}{2Q}$$

In the *Reference Data* book the expression ΔF is not bandwidth, but is what amounts to one half the bandwidth, so the equation for the 3-dB "Q" reduces to

$$\frac{BW}{F_o} = \frac{1}{Q} \text{ or, } Q = \frac{F_o}{BW}$$

Now, if one wishes to determine the 1-dB bandwidth characteristic, simply substitute the reciprocal of the 1-dB voltage ratio (1.122) into the equation and crank away. Simple?

I found this approach valuable when I designed a synchronously tuned, three-stage wideband amplifier. Maybe there are easier ways, or maybe not. — *Ed Oxner, KB6QJ, ARRL TA, Siliconix Incorporated, Santa Clara, CA 95054*

MORE 28-MHZ LONG-DELAYED ECHOS

☐ More than a dozen possible LDEs were recorded on 28 MHz at VE2AEJ/3 during the fall/winter seasons of 1979/80 and details are available on request. However, the purpose of this short note is to mention that conditions for LDEs seemed particularly good during

November 1979, with possible echos being received on November 6, 8, 12, 13 (a double echo and a single echo) and 19 (a triple echo), all at about 0200 to 0300 UTC. Noting that 6-meter DX conditions were especially good according to "The World Above 50 MHz" on November 5 to 8 and to November 16 to 19, I suggest it might be worthwhile for anyone interested in listening for LDEs this winter to monitor 50 MHz.

Enough 28-MHz LDEs have now been analyzed to show that some of the echo delay times are not always integral multiples of the round-the-world (RTW) travel time of 138 ms (see Goodacre, *QST*, May 1980, pp. 14 to 16). However, the two main time "quanta" which show up in the 1979/80 delay times are 124 and 152 ms, the latter having been observed some years ago in 50-MHz data. Curiously enough, the arithmetic mean of these two numbers is the RTW travel time of 138 ms. By the way, anyone recording LDEs should provide timing calibration by also recording WWV or CHU either simultaneously or before and after the event.

Please note that the time of observation of echo B in my May 1980 *QST* article on 28-MHz LDEs is in error. The correct time is 0100 UTC November 18, 1978; I originally made a mistake in converting from 12-hour to 24-hour time.

My thanks go to Mr. Howard Lorenzen, W7BI, for his initial encouragement to study LDEs and to Dr. Mike Villard, W6QYT, for suggestions as to how to improve my experimental technique. These will be put into effect this fall/winter season. — *Alan Goodacre, VE2AEJ/3, 1286 Woodside Dr., Ottawa, ON K2C 2G9 Canada*

ANTENNA AND TRANSMISSION-LINE QUIZ

☐ Check your understanding of the performance of antennas and transmission lines with this quiz. The information was prepared by Richard C. Fenwick, K5RR, ex-W5KTR, for appearance in *QST* in 1965. Mr. Fenwick is now Vice President, Electrospace Systems, Inc., Richardson, Texas. Arising from questions asked at radio-club talks, it covers a lot of ground, ranging from things every amateur *should* know to points that will require real thought. This information appeared in *QST* for July 1965. Answers appear in August 1965 *QST* and will be republished next month.

True or False?

1) VSWR at the input to a transmission line is normally the same as that at the load.

2) VSWR on a transmission line is normally different when receiving than when transmitting.

3) VSWR is the ratio of maximum voltage to minimum voltage on a transmission line.

4) "Reflected power" from an antenna is absorbed in the transmitter final tube and matching circuitry.

5) Feeding a horizontal half-wave dipole directly with coax cable normally results in serious feed-line radiation.

6) Transmission-line loss is independent of the VSWR on the line.

7) The loss in 100 feet (30.5 meters) of RG-8/U coax is less than 2 dB in any of the hf bands below 30 MHz if the VSWR is less than 4:1.

8) A perfectly balanced open-wire transmission line will not radiate.

9) Symmetrical radiation patterns cannot be obtained from a beam antenna unless it is fed through a balun or with a balanced transmission line.

10) There is seldom any justification for reducing the transmission-line or antenna VSWR below 2:1.

11) Coaxial transmission line is preferable to open-wire line for feeding a simple dipole antenna which is to be used on several amateur bands.

12) A Transmatch or "antenna tuner" can be used at the transmitter to reduce the VSWR on the transmission line running to the antenna.

13) The gain of a half-wave dipole antenna can be increased by more than 6 dB by placing it in front of a flat screen reflector.

14) A 5-element 20-meter Yagi on a 48-foot boom can be expected to give more than 3 dB gain over a 3-element Yagi on a 24-foot boom.

15) For all practical purposes a single ground rod is as good as a system of many quarter-wave radials on a quarter-wave vertical monopole antenna.

16) There is no point in using ground radials longer than a quarter wavelength on a quarter-wave vertical monopole antenna.

17) A 40-meter horizontal half-wave dipole 70 feet above average ground has greater gain than a quarter-wave vertical monopole with many quarter-wave ground radials.

18) High antenna efficiency is less important for receiving than for transmitting.

19) The gain of an inductively loaded quarter-wave dipole can be within 1/2 dB of the gain of a half-wave dipole.

20) The bandwidth of a half-wave dipole is greater than that of a half-wave folded dipole.

21) Ground radials on an hf vertical monopole antenna can be buried several inches deep without seriously affecting antenna performance.

22) The gain of a vertically polarized antenna at hf is significantly greater if the antenna foreground is sea water rather than ground.

24) A horizontal half-wave dipole is nearly 100% efficient if mounted at least a quarter wave above ground.

25) A vertically polarized antenna should be used for best results at hf when working DX stations using a vertical antenna.

26) Vertically stacked Yagis may give no improvement in signal-to-noise ratio over a single Yagi when used for receiving.

27) The gain of two vertical monopole antennas side by side can be greater than 3 dB over the gain of a single monopole.

28) The presence of the ground increases the maximum gain of an antenna elevated above ground by up to 3 dB relative to what it would be if the ground were not present.

29) The gain at beam maximum of a horizontal half-wave dipole is independent of the height of the dipole, considering 100% overall radiation efficiency.

30) A half-wave folded dipole gives at least 2 dB gain over a half-wave dipole. QST

Feedback

☐ In "Modern Design of a CW Filter Using 88- and 44-mH Surplus Inductors," December 1980 *QST*, the formula in the caption under Table I should read:

$F_{3dB}/F_{Ap} = 1.248$

Fig. 1A should appear as shown here. On page 17, first column, 23rd line from the bottom, the text should read: "when the headset *or* speaker." Page 18, first column, the fifth line under *Conclusion* should read: "are certainly still *applicable* to." In the second column, near the center of the page, Eq. 1 should read:

$(1)\ \rho = (1 - 0.1^{0.1Ap})^{0.5}$

and Eq. 3a should be:

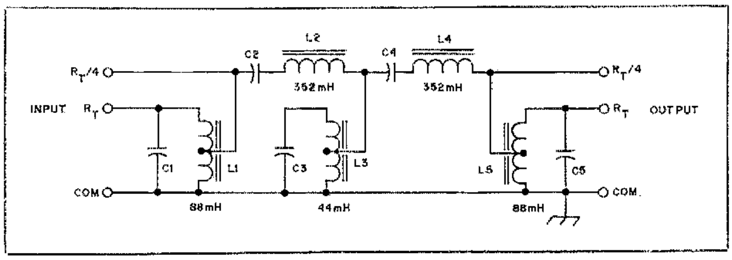
$(3a)\ \varepsilon = (10^{0.1Ap} - 1)^{0.5}$

☐ In the schematic diagram of the "Smart Push-to-Talk Circuit" on page 39 of December 1980 *QST* the 1-MΩ resistor connected to pin 3 of U1 should be labeled R2 to correspond with the text.

☐ Jack Hardcastle, G3JIR, author of the article, "Ladder Crystal Filter Design" appearing in November 1980 *QST*, advises that correspondents should use his new address: 8 Norwood Grove, Rainford, St. Helens, Merseyside, WA11 8AT, England.

☐ The snowy scene on the December cover is the home QTH of K1NH, not W1NH as the cover blurb misstated. Our apologies, Bill.

☐ Arthur S. Westneat, W1AM, Newmarket, New Hampshire, and Peter R. D. Munroe, WB1DQC, Holliston, Massachusetts, were mistakenly listed as Silent Keys in December 1980 *QST*. Our apologies for this error. QST



Corrected schematic diagram of a 5-resonator cw filter.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

N6AZL STATION CONSOLE

☐ A cabinetmaker would have hysterics looking at it. In fact, three of them told my son Scott, N6AZM, who assisted in the project, that it couldn't be done my way. However, as a stubborn accountant-wood-butcher type, I proceeded to do it anyway.

The gimmick is the surfacing. Instead of using bare wood, wood-toned stain or paint as a covering for plywood, I wanted something different. Formica was too expensive, so I settled on a melamine-coated, Masonite-like hardboard product with a thin covering of plastic. Mine is stamped "Made in Brazil" but similar products must be made elsewhere. The 4- × 8-foot (1.2- × 2.4-m) or 5- × 5-foot (1.5- × 1.5-m) sheets are sold in home-improvement stores as shower stall or tub wall coverings. I bought two 5 × 5 sheets for $8 each. This material does not warp, shrink, swell, chip or peel. It can be sawed, filed, planed, sanded or whittled.

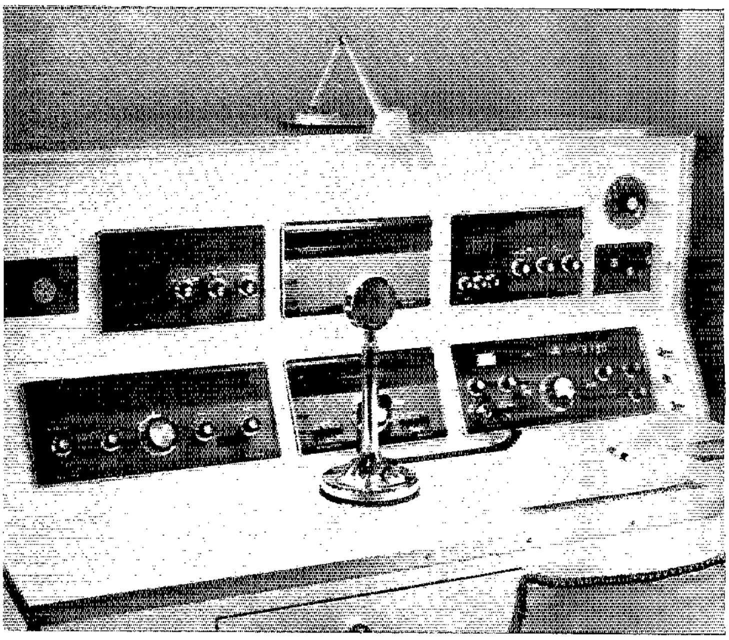
If you already have a satisfactory bench or table for your rig, these sheets could be adapted by making cut-outs for the equipment faces. This alone would eliminate those dark, gaping holes and hide the tangled mass of cables and wires that are necessary at even the simplest station.

The framing of my console consists of 3- × 3-inch (76- × 76-mm) corner posts, equipment shelf bracing and footrest. For the top and desk any grade of 3/4-inch (19-mm) plywood is satisfactory inasmuch as it will be covered. The front panels and equipment shelves are made with 1/2-inch (13-mm) plywood.

I designed the lower panel for a 25-degree slope. The Masonite covering the instrument panels is not glued to the plywood, although it could have been. It fits nicely and is held in place by friction along the edges. Vertical instrument panels are screwed from the side on the outside of the covering for easy removal. Screws do not show from the front. The desk drawer, ready made, is from a modular set of shelves.

The remaining hardboard is glued to the "ply" with standard wall panel adhesive. Corners were beveled with my new saber saw. (What a chore!) Aluminum corner mouldings prevent dents and cover mistakes. An acrylic-plastic desk top is surrounded by standard moulding. Casters are under the corner posts. For easy turning these should have a fairly large diameter.

My XYL, Helen, constructed the Heathkit equipment shown in the photograph. She knows nothing about electronics and has yet to master 5 wpm. But she taught herself to solder years ago and everything she builds works like a dream. Maybe if she got a license I would never be allowed time to sit down in front of this thing. Hmm! Maybe I shouldn't encourage her so much. Helen, turn off the cassette . . .you'll never learn the difference between *A* and *N*! — *Bill Sheppard, N6AZL, San Jose, California*



This well-arranged station console is the handiwork of Bill Sheppard, N6AZL, of San Jose, California. Bill proudly explains that credit for the faultless construction of the Heathkit equipment in the console goes to his wife, Helen. A goose-neck boom, mounted on the upper front panel, has recently replaced the D-104 microphone desk stand in order to avoid desk-top clutter. *(photo by WA6WNU)*

10-METER ADAPTATION FOR DRAKE L7

☐ Owners of Drake L7s can benefit from the following 10-meter adaptation. Proceed with the following steps while using the owner's manual for reference.

Replace the low-pass filter with a short piece of RG-58 coaxial cable. Later models have a shorting path on the low-pass filter board identified by empty terminal lugs at the input and output. On these units simply switch the input and output coaxial-cable center conductor to these empty terminals. (*Do not short* the input to the output of the low-pass filter. Doing so does not remove it from the circuit.)

Removal of the band stop from the band switch is the next step. On early models this was a removable stop located on the back side of the index of the band switch and may be found at the rear of the input matching filters. Use a sharp, pointed tool to rotate the nut on the stop and then extract the stop.

On later models, the band-switch stop is a bracket mounted on the bottom plate behind the input matching filters. Remove two sheet metal screws and sheet metal band stop.

Add two 68-pF DM19 or DM20 mica capacitors to the input coil assembly. One is wired to the jumper across the input wafer. The other is connected to the input side of the 15-meter input coil. With the linear amplifier placed upside down, observe that the 15-meter coil is the one farthest toward the back and on the left. The input side is the bottom end (closest to the clip).

Retuning of the 15-meter input coils may be necessary. Use the input-coil adjustment procedure outlined in the manual. There is no tuning for 10 meters. — *Jeem Newland, WB8RXI, Miamisburg, Ohio*

TEFLON FOR PREVENTING ICE BUILD-UP ON ANTENNAS

☐ As another approach to applying Teflon to beam elements to avoid ice build-up ("Hints and Kinks," March 1980) one might try Teflon Coating Product no. 82808 sold in 16 oz. spray cans by H. W. Chesterton Co., Middlesex Industrial Park, Stoneham, MA 02190. The maker claims it contains an acrylic carrier and provides a slippery coating for surface protection and lubrication. It is resistant to water, mild acids and alkalies. The price of a can is about $5. — *John H. Ferguson, W1IIM, Wayland, Massachusetts*

*Assistant Technical Editor

HW-8 IDEAS

☐ I wish to report a method of eliminating parasitic oscillation in a Heathkit HW-8 transceiver. Although Doug DeMaw has implied that the spurious radiation from this source is weak enough to satisfy the FCC rules (April 1979 *QST*, p. 18), I still consider it ethically and esthetically unsatisfactory to operate the transmitter without silencing this unnecessary noise.

The direct current bus lines to the band-switching diodes for the three bands which are not selected, support the relaxation oscillations in the audio-frequency range when the key is down and the transmitter is on the air. The amplitude of these oscillations depends upon the positions of the receiver preselector and rf gain controls and may become large enough to be heard in the headset, in spite of the muting circuit and sidetone. They are probably the cause of the spurious radiations referred to above.

I have completely eliminated these oscillations in my HW-8 by providing back bias to turn off the bandswitch diodes which are supposed to be off. There are surely many ways this could be done. I did it by lifting the grounded ends of resistors R81, R84, R87 and R91 from the circuit board. These are then connected to a C battery as shown in Fig. 1. A TN94 serves to disconnect the battery when the HW-8 is not in use. The drain is about 0.2 mA so that I expect long life for this bias supply. My HW-8 is now clean and quiet but otherwise operates exactly as before. — *James E. Gray, WØGNV, Boulder, Colorado*

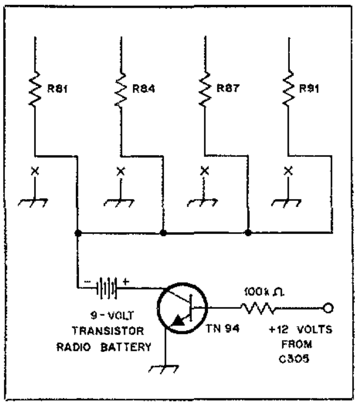


Fig. 1 — Lifting the four resistors shown above from ground and connecting them to a battery in series with a TN94 or any small npn silicon audio transistor will prevent unwanted oscillation that may occur in some HW-8 transceivers.

☐ My version of the K6TG HW-8 RIT modification, in use for over two years without problems, does not require drilling holes or cutting the foil of the main circuit board. R36A and C55A (see Fig. 2) replace R36 and C55 on the main board. D11A replaces D11. C101 is mounted on the foil side of the main board. R103 may be mounted between the load control and the rf-output meter if a miniature potentiometer (type MLC-14L, Burstein and Applebee no. 14A937-7) is used.

S101 can be mounted at the left of the preselector control in the spot indicated by *CQ* (October 1977) for an RIT potentiometer. Two other locations are the top cover, mentioned by *CQ*, or the back of the set as suggested by the K6TG RIT modification. Power can be obtained from ZD1 or ZD101. Parts are mounted on a Radio Shack pc board like the K6TG RIT.

The dial calibration on my HW-8 varied as much as 5 kHz whenever I switched between power supplies until I made the following change to regulate the supply voltage for the crystal oscillator. Remove the wire from point D on the main board. See part B of Fig. 2. Install one end of a 27-ohm resistor (1/4 W) at point D. Connect the removed wire to the other end of the resistor. Solder two 6.2-V, 1-W Zener diodes together in series, connecting the cathode to pin 8 of SW4 and the anode to pin 4 of SW4 (the 21-MHz bandswitch). I shall be glad to help anyone who tries this modification. — *John Lock, WB5WOQ, Wichita, Kansas*

ELIMINATING SB-102 FREQUENCY JUMP

☐ After using my SB-102 in favorite portions of each band over a long period of time, I began to hear crackling accompanied by sharp jumps in frequency as I attempted to zero in on a signal. I even received reports of having a signal in spots that were not desired.

I cured the problem by carefully peeling off the piece of adhesive-backed foil on the top of the LMO and spraying each end of the variable capacitor with a nonpetroleum contact cleaner. Two drops of light gun oil were then placed on each bearing.

Try this idea if your SB-102 has developed a similar behavior. You will help maintain the value of your set by carefully removing and replacing the foil. — *Lynn A. Deppen, N3IN, ex-WA3VHV, Lykens, Pennsylvania*

TOWER-STATIC CURE

☐ After erecting my antenna atop a new Rohn tower, I unhappily found an annoying amount of static bothering reception. After some thought and investigation, I found that my Ham IV rotator lacked proper electrical contact between mast and tower. There is no thrust bearing in my tower assembly. A shorting strap between the mast and tower cured the problem. The strap is just long enough to permit a ±180-degree rotation. — *Jim Scarbrough, WD5FIP, Houston, Texas*

STICKING RELAYS

☐ Sticking relays have always been annoying. Although this may be an old remedy, it works. Just cement a piece of very thin clear plastic to the pole piece to prevent intimate contact between the armature and the pole piece. — *J. O. Myers, W2SVJ, Neptune, New Jersey*

EXTENDING BATTERY LIFE

☐ Extra life for your flashlight, lantern and QRP rig batteries can be had by storing them in your freezer. — *Glenn Jacobs, WB7CMZ, Eagar, Arizona*

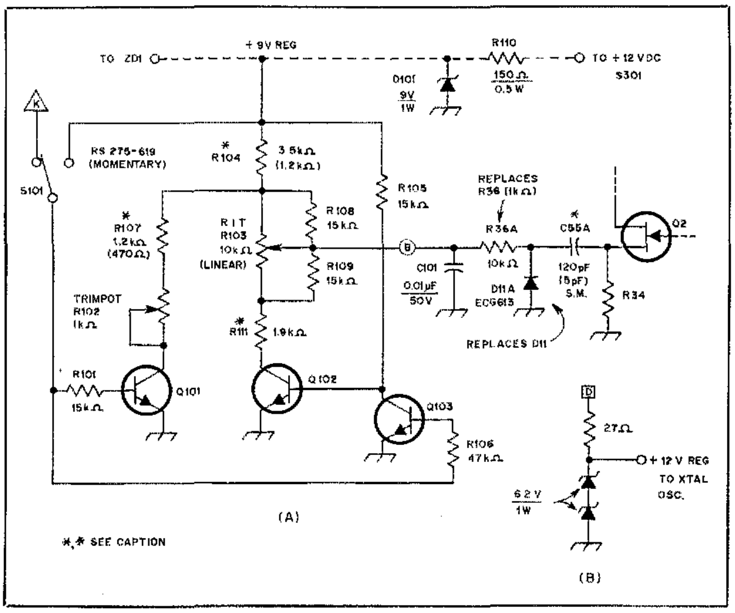
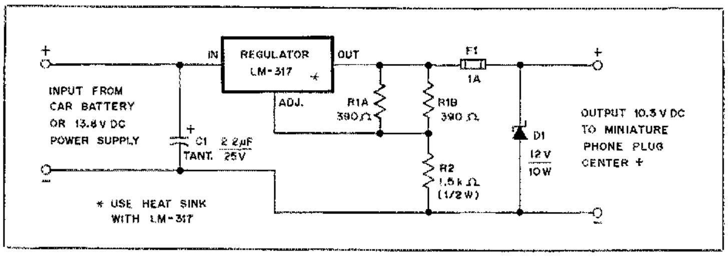


Fig. 2 — An RIT modification for the HW-8 provided by John Lock, WB5WOQ. This is an adaptation of the RIT circuit described by Ben Saylor, K6TG, in July 1977 *QST*. Also see January 1978 *QST*, p. 40; March 1978 *QST*, p. 36; and December 1978 *QST*, p. 38. The circuit is built on a Radio Shack board (RS-276-024). Values marked (*) may be adjusted to tailor the range. Those values shown in parentheses are minimum for proper operation. The value of R111 (#) may be varied or eliminated to adjust the RIT range. Q101-Q103, incl., are 0.3- to 0.5-W switching transistors (ECG123A, RS2016, or 2N3860). Dashed lines show optional power control circuit. Regulation of the oscillator supply voltage is provided by the circuit at B above. Resistance values are 1/4 watt except for R110 (150 Ω), which is 1/2 watt.



Diodes have a voltage drop of 0.6 to 0.7 V. To supply a nominal 9.6 V to the S-1, the external voltage would have to be 10.3. In a straightforward design, an LM-317 voltage regulator easily delivers the 10.3 V. Overvoltage protection is a must and is provided by a 1-A fuse and a 12-V, 10-W Zener diode. This device can work with input voltage from the car battery or any 13.8-V power supply. Terminate the output in a miniature phone plug. Turn off the battery, plug the ac line in and don't worry about running out of power! — *Henry Schickler, W2ICW, Whitestone, New York*

EXTERNAL POWER FOR THE TEMPO S-1

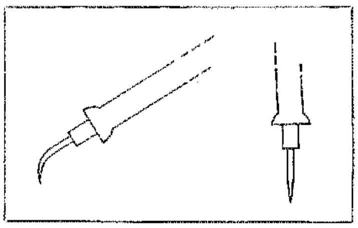
☐ The Drake TR-22C is a great little 2-meter machine. Its best feature is versatility — it operates from its own batteries, the car battery or a power supply. The Tempo S-1 is an even better little machine. It, too, can operate from its own batteries, the car battery or a power supply. How? Just use a switch to disconnect the negative side of the battery and feed the external power through the existing charger jack. A slide switch is ideal for this purpose.

Remove the cover of the S-1. Replace the screws to hold the circuit boards in place while handling. Carefully unplug and remove the battery pack. Mark the right-hand side of the case at the battery compartment for the switch hole. The hole can be made easily with the help of a small drill and a small flat file. Try to get a smooth, snug fit. Put a drop of glue on the ears of the switch and press it firmly from inside the case. Unsolder the black lead from the battery pack. Connect this lead to the center pole of the switch. Solder a new black lead to the battery pack and then connect it to one of the other poles of the switch. Press the poles down flat and cover the switch with a piece of tape. The battery pack and cover can now be replaced.

The diagram and examination of the S-1 show a diode in series with the charger input.

OLD TIMER'S NOTEBOOK: HINTS FOR THE WORKSHOP

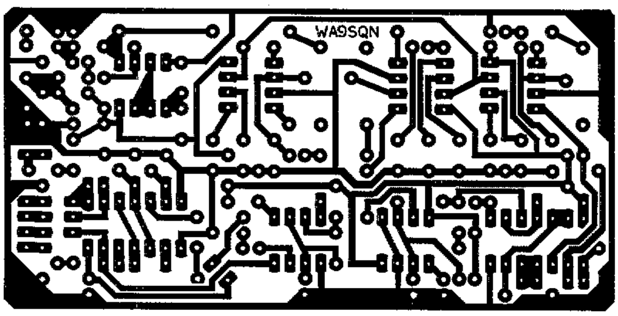
☐ Not everyone likes to use a pencil iron with a curved tip. However I find it much easier to use than a straight tip.

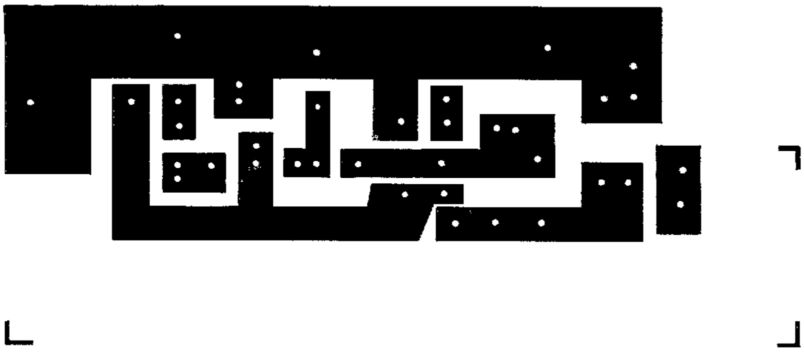


To avoid burning wiring or small parts when working in cramped areas of equipment, aluminum foil can be used as a soldering aid. Place it near the wires or parts that could be touched by the tip of the soldering iron or gun. — *Antonio G. O. Gelineau, W1HHF, ex-W1BHR, W4LEQ, KP4FN, TG9AG, Burlington, Vermont*

TRI-YAGI ADDENDUM

☐ The author of "A Tri-Yagi for 50 MHz," (June 1980 *QST*) in response to inquiries, advises that the distance from the driven element to the vertical boom supporting the trigonal reflector is 35 inches (889 mm).





Etching patterns for construction projects in this issue. The upper pattern is for the Standard-Tone Alert System (see Fig. 4, page 27 of this issue), and the lower pattern is for the L-meter (see Fig. 2, page 29). Black represents copper; both boards are single sided. The patterns are shown at actual size from the foil side of the board.

License Renewal Information

1) Attach a photocopy, or the original, of your license to the FCC Form 610 (available from ARRL hq.; s.a.s.e. please).

2) Mail to FCC, Box 1020, Gettysburg, PA 17325.

3) Retain copies of everything, if possible, as proof of filing before expiration. If you file before the license expiration date, you may continue to operate beyond the expiration date and until the new license arrives. After expiration, there is a one-year grace period under which you may still renew and keep your call sign without retesting, but you must wait until the new license arrives to operate. There is also a five-year grace period under which you may still renew; however, after the initial one-year period, you will be issued a new license with a new call sign. After this five year grace period expires, you must be re-examined for a new license. Normally, application should be made approximately 90 days before expiration; however, renewal can be applied for at any time during the term of the license.

4) If you are simply modifying your license (change of address, for example), you must fill out the Form 610; a letter is no longer sufficient. Incidentally, your license will also be automatically renewed at this time.

5) If you have any questions or problems, drop a note to the Membership Services Department, ARRL.

Table 1

The "Considerate Operator's Frequency Guide"

Some frequencies that are generally recognized for certain modes or certain activities:

1800-1810 kHz	cw, DX calling	21.09-21.10 MHz	RTTY
1825-1830 kHz	"DX window" (no W/VEs)	21.34 MHz	SSTV
3610-3630 kHz	RTTY	28.09-28.10 MHz	RTTY
3845 kHz	SSTV	28.68 MHz	SSTV
7090-7100 kHz	RTTY	28.30-29.50 MHz	Satellite downlinks
7171 kHz	SSTV	29.52-29.58 MHz	Repeater inputs
14.08-14.10 MHz	RTTY	29.60 MHz	FM simplex
14.23 MHz	SSTV	29.62-29.68 MHz	Repeater outputs

(In addition, on 20 meters in particular, the low end of the U.S. phone segment is reserved for DX, the high end for traffic, and ragchewing in between. The dividing lines are not definite, however.) Radio Control R/C Channels: 53.1, 53.2, 53.3, 53.4, 53.5, 53.6, 53.7 and 53.8 MHz.

U.S. Amateur Frequency and Mode Allocations

Power Limits: All U.S. amateurs are limited to 250-watts dc input in the Novice segments. On all other segments, with certain exceptions in the 160-meter and 420-MHz bands, 1-kilowatt dc input is permitted. Also, there are erp limitations for stations in repeater operation. (See 97.67, FCC rules.) At all times the power level should be kept down to that necessary to maintain communications. (Revised as of December 6, 1980)

Bandwidth Limitations

FREQUENCY (OR PHASE) MODULATION: On frequencies below 29.0 MHz, the bandwidth of F3 emission shall not exceed that of an A3 emission having the same audio characteristics.

TELEVISION: On frequencies below 50 MHz, the bandwidth of A5 and F5 emissions shall not exceed that of an A3 single sideband emission. Between 50 and 225 MHz, single sideband or double sideband A5 may be used and the bandwidth shall not exceed that of an A3 single sideband or double sideband signal respectively. The bandwidth of F5 emission shall not exceed that of an A3 single sideband emission. Below 225 MHz, A3 and A5 emissions may be used simultaneously on the same carrier frequency provided the total bandwidth does not exceed that of an A3 double sideband emission.

DIGITAL TRANSMISSION:

(a) *International Telegraphic Alphabet No. 2 (Baudot code)*. When using frequency-shift keying, the shift shall be less than 900 Hz. With audio frequency-shift keying, the highest fundamental modulating frequency shall not exceed 3000 Hz and the audio frequency shift shall be less than 900 Hz.

(b) *American Standard Code for Information Interchange (ASCII)*. F1 emission shall be utilized on those frequencies between 3.5 and 21.25 MHz where its use is permissible, and the sending speed shall not exceed 300 bauds. F1, F2 and A2 emissions may be utilized on those frequencies between 28 and 225 MHz where their use is permissible and the sending speed shall not exceed 1200 bauds. F1, F2 and A2 emissions may be utilized on those frequencies above 420 MHz where their use is permissible and the sending speed shall not exceed 19.6 kilobauds.

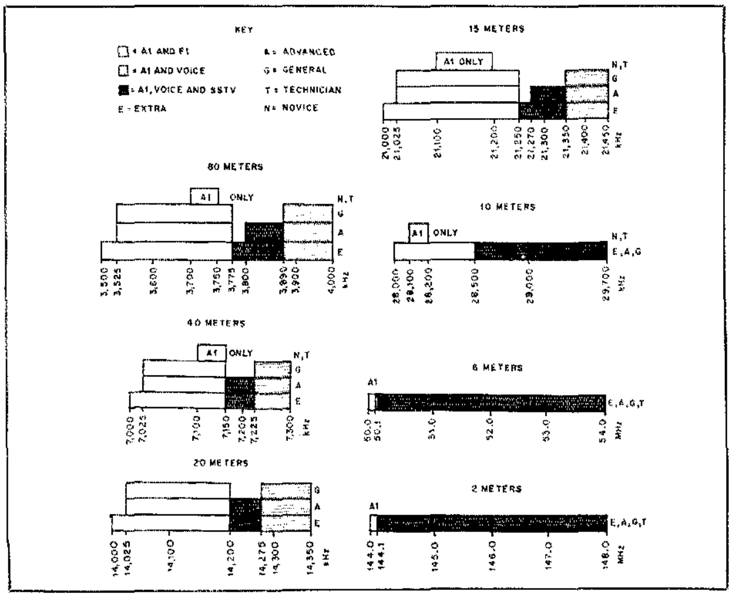
The code must conform to the American Standard Code for Information Interchange (ASCII) as defined in American National Standards Institute (ANSI) standard X3.4-1968. See §97.69 of the Amateur Rules.

ALL MODES: The carrier frequency plus modulating frequencies must be contained within amateur allocations and within appropriate subbands.

NOTE: Some amateur bands are shared with other services. Some geographical limitations exist for the 420-MHz band. For details, and for information on specialized modes, see *ARRL License Manual*. For information on repeaters, see the *License Manual* and *Repeater Directory*.

160 METERS: Extra, Advanced and General may use some segments at 1.8-2.0 MHz. Limitations are on a geographical basis; see *License Manual* or request form MS/G-7 from ARRL hq.

Other — All modes, except as noted.



Extra, Advanced, General, Technician

MHz	*GHz***
220-225*	10.0-10.5*
420-450*	24.0-24.25
1215-1300*	48.0-50.0
2300-2450	71.0-76.0
3300-3500	165.0-170.0
5650-5925	240.0-250.0
	All above 300

*Pulse not permitted.
**1 GHz = 1000 MHz.

MAJOR ARRL OPERATING EVENTS AND CONVENTIONS — 1981
(Check *QST* monthly for updates)

JANUARY

1	Straight Key Night
1-4	*SAROC (Las Vegas)**
3-4	CD Party, phone
7	West Coast Qualifying Run
10-11	CD Party, cw
11	*ARRL Hamfest (Oak Park, MI)*
12	W1AW Qualifying Run
17-18	VHF Sweepstakes
17-18	*ARRL Hamfest (Sarasota, FL)*
25	*ARRL Hamfest (Arlington Heights, IL)*
27	W1AW Qualifying Run
31-February 8	Novice Roundup

FEBRUARY

5	West Coast Qualifying Run
7-8	*Florida State Convention (Miami)*
10	W1AW Qualifying Run
14	Frequency Measuring Test
21-22	International DX Contest, cw
21-22	*ARRL Hamfest (Vero Beach, FL)*
25	W1AW Qualifying Run

MARCH

1	*ARRL Hamfest (Davenport, IA)*
4	West Coast Qualifying Run
7-8	International DX Contest, phone
11	W1AW Qualifying Run
13-15	*ARRL National Convention (Orlando, FL)*
21	*ARRL Hamfests (Sioux City, Iowa and Flemington, NJ)*
21-22	*ARRL Hamfests (Ft. Walton Beach, Florida and Lafayette, LA)*
26	W1AW Qualifying Run
28-29	*ARRL Hamfest (Kearney, NE)*
29	*ARRL Hamfest (Mentor, OH)*

APRIL

2	West Coast Qualifying Run
4	*ARRL Hamfest (Columbia, MO)*
4-5	*ARRL Hamfest (Little Rock, AK)*
4-5	CD Party (open), phone
11-12	*Missouri State Convention (Kansas City)*
11-12	CD Party (open), cw
11-12	EME Contest (part 1)
16	W1AW Qualifying Run
24-26	*Dayton Hamvention (Dayton, OH)**
25-26	*Mississippi State Convention (Jackson)*
25-26	*West Indies Section Convention (Dorado, PR)*
26	W1AW Qualifying Run

MAY

6	West Coast Qualifying Run
8	Frequency Measuring Test
9-10	EME Contest (part 2)
11	W1AW Qualifying Run
15-16	*Atlantic Division/NY State Convention (Rochester, NY)*
15-17	*Pacific Division Convention (Fresno, CA)*
16-17	*Southeastern Division Convention (Birmingham, AL)*
28	W1AW Qualifying Run

JUNE

4	West Coast Qualifying Run
5-7	*ARRL Hamfest (Dallas, TX)*
5-7	*Northwestern Division Convention (Seaside, OR)*
9	W1AW Qualifying Run
13-14	VHF Contest
20-21	*Georgia State Convention (Atlanta)*
23	W1AW Qualifying Run
27-28	Field Day

JULY

1	West Coast Qualifying Run
8	W1AW Qualifying Run
11-12	IARU Radiosport Championship
22	W1AW Qualifying Run
24	*West Gulf Division Convention (Oklahoma City, OK)*

AUGUST

6	West Coast Qualifying Run
8-9	UHF Contest
13	W1AW Qualifying Run
23	W1AW Qualifying Run

SEPTEMBER

2	West Coast Qualifying Run
12-13	VHF Contest
12	Frequency Measuring Test
14	W1AW Qualifying Run
19-20	*New England Division Convention (Hartford, CT)*
23	W1AW Qualifying Run

OCTOBER

1	West Coast Qualifying Run
2-4	*Texas State Convention (Houston)*
3-4	*Midwest Division Convention (Salina, KS)*
9-10	*Southwestern Division Convention (Scottsdale, AZ)*
10-11	*Delta Division Convention (Memphis, TN)*
10-11	CD Party, phone
11-12	CD Party, cw
13	W1AW Qualifying Run
17-18	Simulated Emergency Test
25	W1AW Qualifying Run

NOVEMBER

5	West Coast Qualifying Run
7-8	Sweepstakes, cw
11	W1AW Qualifying Run
13	Frequency Measuring Test
21	W1AW Qualifying Run
21-22	Sweepstakes, phone

DECEMBER

2	West Coast Qualifying Run
4-6	160-Meter Contest
10	W1AW Qualifying Run
12-13	10-Meter Contest
29	W1AW Qualifying Run

*Not an ARRL event

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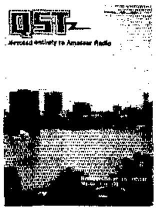
THE COVER



Tired of winter's chill? The 1981 ARRL National Convention/Orlando Hamcation, to be held March 13 to 15, should have enough activity to thaw out all who make their way to Orlando. Details appear in January 1981 *QST*, page 54.

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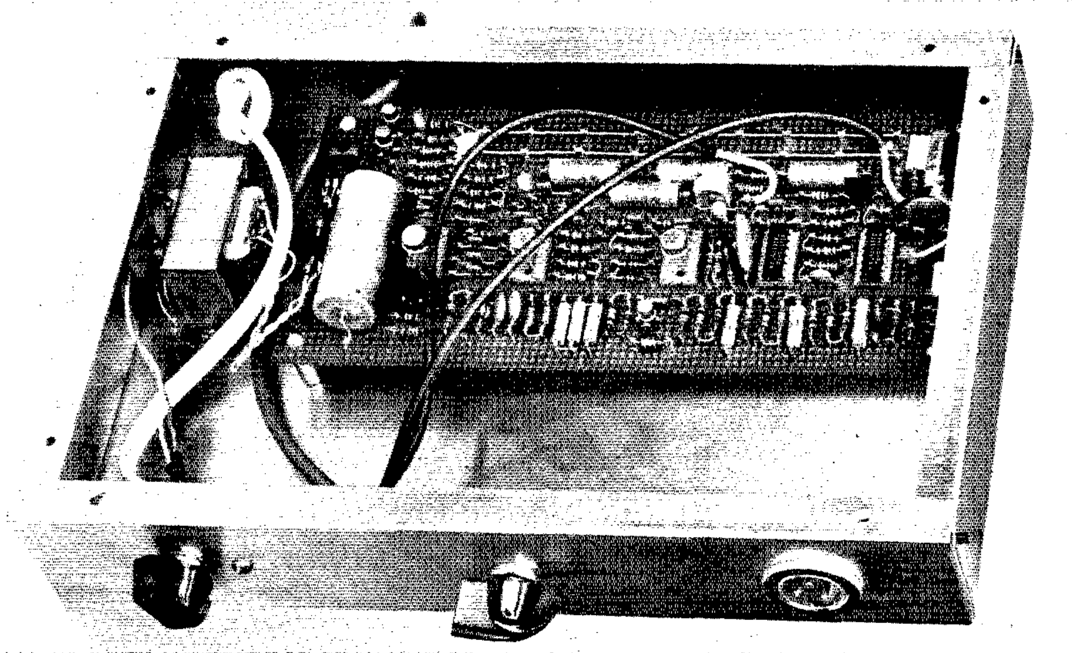
Audio Processor Using RF Clipping

For extra clout to break through QRM or catch that rare DX, add this state-of-the art speech processor to your station lineup. It can make the difference!

By William A. Stein,* KC6T



Many of the new hf transceivers are equipped with speech processors using an rf clipper. When properly applied, this method provides excellent "talk power" with low distortion. In addition to giving that extra punch for getting through DX pileups, the processors do much to iron out speech variations. As a result, copying at the other end of a QSO is easier. The numerous fine pieces of equipment in use today which lack this feature would benefit from an outboard speech processor.

The objective of any homemade speech-processor project should include a unit that can be constructed and adjusted without the requirement for exotic test equipment, since this equipment is generally beyond the reach of most amateurs. The design described in this article has one internal adjustment, one external gain control and one ON/OFF switch. Although other internal adjustments could be added to improve sideband generation, they have been eliminated in the interest of simplicity. This has been done without degrading the overall performance of the processor.

A Processor That Generates an SSB Signal

The rf clipper, shown schematically in Fig. 1, generates a single-sideband signal at approximately 500 kHz. Single sideband is generated by a phasing technique[1] employing two quad operational amplifiers[2] and two doubly balanced modulator/demodulator units.[3] After generation, the sideband signal is buffered and clipped by means of a pair of transistors. The output from the clipper is the input to the doubly balanced modulator/demodulator mixer that serves as a product detector. A section of the quad op-amp buffers the signal that emanates from the detector. Processed audio is then fed to the transceiver through the microphone jack.

The signal from the microphone input is amplified by U1A, which drives two

*10823 Bismarck Ave., Northridge, CA 91326

[1]Notes appear on page 14.

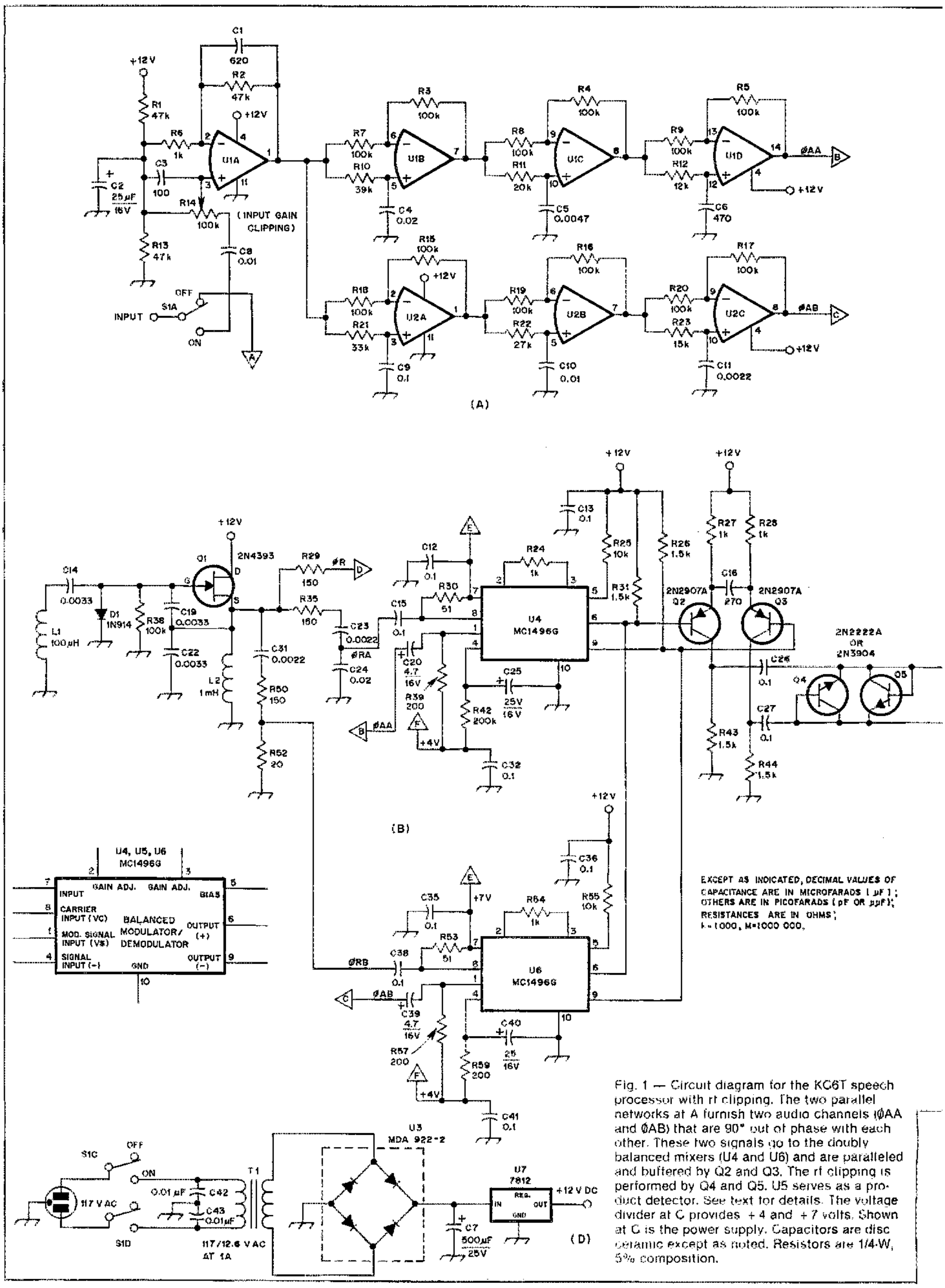
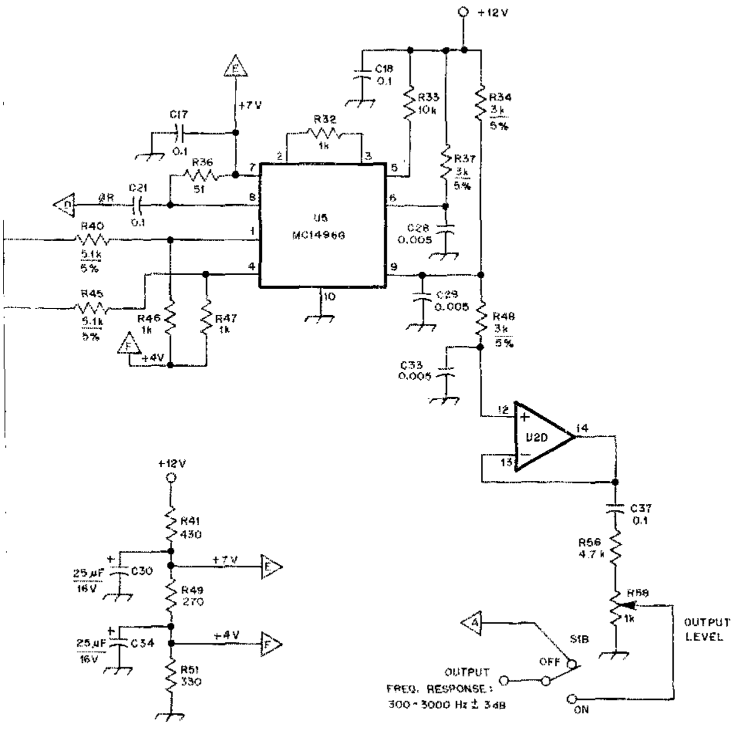


Fig. 1 — Circuit diagram for the KC6T speech processor with rf clipping. The two parallel networks at A furnish two audio channels (ØAA and ØAB) that are 90° out of phase with each other. These two signals go to the doubly balanced mixers (U4 and U6) and are paralleled and buffered by Q2 and Q3. The rf clipping is performed by Q4 and Q5. U5 serves as a product detector. See text for details. The voltage divider at C provides +4 and +7 volts. Shown at C is the power supply. Capacitors are disc ceramic except as noted. Resistors are 1/4-W, 5% composition.

C1 — 620 pF.
C2, C25, C30, C34, C40 — 25-μF, 16-V electrolytic.
C3 — 100 pF.
C4, C24 — 0.02 μF.
C5 — 0.0047 μF.
C6 — 470 pF.
C7 — 500-μF, 25-V electrolytic.
C8, C10, C42, C43 — 0.01 μF.
C9, C12, C13, C15, C17, C18, C21, C26, C27, C32, C35-C38 incl., C41 — 0.1 μF.
C11, C23, C31 — 0.0022 μF.
C14, C19, C22 — 0.0033 μF.
C16 — 270 pF.
C20, C39 — 4.7-μF, 16-V electrolytic.
C28, C29, C33 — 0.005 μF.
D1 — Silicon fast switching diode, 4 nanosec., 100 PRV, 1N914 or equiv.
L1 — 100-μH inductor (Nytronics Wee-100 or equiv.).
L2 — 1-mH inductor (J. W. Miller no. 4652 or equiv.).
Q1 — Silicon n-channel junction field-effect transistor, 2N4393 or equiv.
Q2, Q3 — Silicon pnp annular hermetic transistor, 2N2907A or equiv.
Q4, Q5 — Silicon npn annular hermetic transistor, 2N2222A, 2N3904 or equiv.
R1, R2, R13 — 47 kΩ.
R3-R5, incl., R7-R9, incl., R15-R20, incl., R38 — 100 kΩ.
R6, R24, R27, R28, R32, R46, R47, R54 — 1 kΩ.
R10 — 39 kΩ.
R11 — 20 kΩ.
R12 — 12 kΩ.
R14 — 100-kΩ linear-taper potentiometer.
R21 — 33 kΩ.
R22 — 27 kΩ.
R23 — 15 kΩ.
R25, R33, R55 — 10 kΩ.
R26, R31, R34, R44 — 1.5 kΩ.
R29, R35, R50 — 150 Ω.
R30, R36, R53 — 51 Ω.
R34, R37, R48 — 3 kΩ.
R39, R57, R59 — 200 Ω.
R40, R45 — 5.1 kΩ.
R41 — 430 Ω.
R42 — 200 kΩ.
R49 — 270 Ω.
R51 — 330 Ω.
R52 — 20 Ω.
R56 — 4.7 kΩ.
R58 — 1 kΩ Trimpot.
S1 — 4pst rotary.
T1 — 117/12.6 V, 1 A (Triad F-70X or equiv.).
U1, U2 — Quad operational amplifier, 3403P Fairchild or equiv.
U3 — Rectifier assembly MDA 922-2, Motorola or equiv.
U4, U5, U6 — Balanced modulator-demodulator, Motorola MC1496G or equiv.



(C)

parallel networks composed of U1B through U1D and U2A through U2C. These two parallel networks provide two audio channels (ØAA and ØAB) 90° out of phase with one another over the audio range of interest. A Clapp oscillator (Q1) provides an rf carrier at approximately 500 kHz. The output of this oscillator is phase shifted by two R-C networks to produce a pair of rf signals that are out of phase by 90° (ØRA and ØRB). The oscillator also provides a carrier signal for use in the product detector (ØR). The two audio signals and two rf signals go to a pair of integrated doubly balanced mixers (U4 and U6) to generate an ssb signal. The outputs of U4 and U6 are paralleled and buffered by a pair of transistors (Q2 and Q3).

These transistors drive an rf clipper composed of "super-diodes," transistors and Q4 and Q5.[4] A super diode is formed when the base and collector of a transistor are connected so that the device exhibits a steep knee in the forward transfer characteristics. As a result, the clipped ssb signal is then passed to a product detector (U5) along with the rf carrier from oscillator Q1 (ØR). The output of this product detector is filtered and buffered by one section of the quad op-amp (U2D) and output at potentiometer R58. The frequency response of the unit, as shown, is 300 Hz to 3 kHz. If desired, some of the low-frequency response can be eliminated by changing C8 to 0.005 μF and C37 to 0.033 μF. With these modifications, the frequency response is approximately 600 Hz to 3 kHz.

Layout Care Required

Construction of this processor required layout care since radio frequencies (although they are quite low) are involved. I constructed the first model on a perforated board with push-in terminals and had no stability problems. The bypass capacitors shown at U3, U4 and U5 (C12, C13, C25, C32, C36, C40 and C41) should all be placed physically close to these integrated circuits. When the circuit board is completed, it should be packaged in a relatively rf-tight box. I used a 7 × 11 × 2-inch (178 × 279 × 51-mm) chassis box with a bottom cover. To eliminate rf feedback to the processor when the station is on the air, C42 and C43 are required.

Adjusting the Processor

In adjusting and using this processor, as with all electronic devices, the rule to apply is "if a little works great, don't use a lot." With this advice in mind and a few basic instruments on hand, adjustment of the processor should be completed without difficulty. Those instruments include your transceiver, a dummy load and some method of observing the alc action when setting the microphone gain control. Most transceivers have a metering position for observing alc performance.

The procedure I've outlined in this article refers to the steps I took in adjusting the processor and my Yaesu FT-101B. After normal tune-up into a dummy load adjust the microphone gain control for comfortable audio. Set the gain so that the alc meter will barely move off the pin with a steady input signal such as the sound "OHHHH" or with a steady whistle. Current in the plate circuit will approach its key-down value, so this portion of the adjustment should be done rapidly. Turn on the processor (which disconnects the microphone from the transceiver input jack and connects the processor). Turn the internal adjustment (R58) to approximately midposition. Turn the input gain control (R14) to maximum clockwise position. Use the same microphone-input technique and adjust the output level (R58) until the alc meter barely moves off the peg. Do not change the microphone gain-control setting on the transceiver. This completes the adjustment procedure. Reinstall the bottom of the chassis box.

Although the unit is capable of a considerable amount of compression (rf clipping), use of the device in this manner produces a very harsh-sounding received signal which is not necessary. In fact that is not desirable. Operation of the unit with the gain control fully clockwise, for example, will cause all background noise in the shack to drive the transmitter excessively, detracting from the legibility of the received signal. With the processor switch off and the microphone connected normally, speech levels that cause the alc meter to bounce slightly off the peg will cause an average indicated plate current that is 30% to 40% of the key-down plate current. If it were possible to hold your audio input to the microphone relatively constant at this level, any further increase in microphone gain would not produce an increase in S-meter reading at the distant receiver.

The processor will assist in maintaining this even level. When used properly, it can be left in the microphone circuit even for local QSOs under ideal conditions. The input gain-control setting should be readjusted such that the average value of plate current increases from its normal 30% to 40% of the key-down flow to about 60% of the key-down level.

I found that the proper input gain-control setting for my microphone and voice is at the 10:30 position. On-the-air checks with the transmitter and processor gain controls adjusted as described have produced very satisfactory reports. This processor, as with others, allows the operator to set the microphone gain control for minimum drive (minimum grid current) and yet attain a considerable increase in talk power without increasing bandwidth and splatter.

If you're a dedicated DXer but have yet to include processing at your station, this device may give your signals longer arms. Good luck with the rare ones! QST

Notes

[1]Dickey, *Electronics Designers Casebook, 1979,* catalog 14-D (prepared by editors of *Electronics* Magazine), p. 129. See "Outputs of Op-Amp Networks Have Fixed Phase Difference."

[2]*Linear Integrated Circuits, 1976,* Fairchild Semiconductors, p. 12-166.

[3]*Linear Integrated Circuits Data Book, Third Edition,* Motorola Semiconductor Products, Inc., p. 8-416.

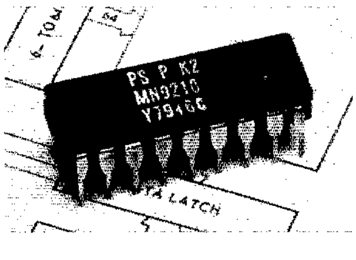
[4]Any bipolar trnsistor with base and collector connected exhibits diode characteristics between the base/collector and emitter terminals, but the "knee" in the forward direction is much sharper than the forward knee of most small signal diodes, i.e., the forward resistance during conduction is reduced.

New Products

PLESSEY SEMICONDUCTORS EAROM

☐ A TTL/CMOS-compatible, 256-bit (64 × 4) nonvolatile EAROM is now available from Plessey Semiconductors. The MN9210 is a member of the family of NOVOL logic products, which guarantee data retention of one year in the absence of applied power if the temperature is maintained within the range of −40 to +70° C.

The device is housed in an 18-pin DIP package and has latching data and address inputs and three-state outputs on the data lines. It features six address inputs, four data I/O lines, a read/write control line, a strobe control line, two chip-select control lines, three power-supply pins and an external capacitor connection. According to the manufacturer, any word may be programmed independently without disturbing the rest of the stored data. Further information may be obtained from Plessey Semiconductors, 1641 Kaiser Ave., Irvine, CA 92714. — *Paul K. Pagel, N1FB*



NEW ZENITH HIGH-PASS FILTER

☐ Zenith Radio Corporation has announced the availability of a new TV high-pass filter. According to the manufacturer, this filter is designed to suppress TV interference caused by paging systems and commercial, CB, police and Amateur Radio transmitters operating at 52 MHz and below. The filter (part no. A-8477) has TV F-type connectors and is installed directly at the rear of any 75-ohm-input Zenith receiver without the use of adapters or the need for soldering. It is 2 × 2 × 1 inches (51 × 51 × 25.4 mm) in size and provides up to 80 dB of attenuation below 52 MHz with an insertion loss of less than 1.5 dB. It is available through Zenith distributors and sold to consumers at Zenith dealers. — *Paul K. Pagel, N1FB*

MOTOR-SPEED REGULATOR IC

☐ National Semiconductor Corporation has announced a low-cost motor-speed regulator for low-voltage dc motors. The LM1014 is a monolithic IC which has remote stop (pause) and output short-circuit protection. The user may program the IC for variations in temperature by means of four externally set temperature coefficients. Designed primarily for use with cassette tape recorders, the LM1014 is sure to find use in other categories. According to the manufacturer, the LM1014 can operate from a wide power-supply voltage range (+5 to +20 volts) and achieves excellent speed regulation under a variety of torque and temperature environments.

Requiring four external resistors and a pnp pass transistor for motor connection, the circuit can accommodate a wide range of motor conditions. Motor speed is controlled with a negative-output impedance voltage regulator, whose impedance is a function of the four external resistors. Should the output current exceed a preset limit, the base drive to the external pnp transistor is switched off automatically, requiring the supply voltage to be reconnected to start up the motor. — *Paul K. Pagel, N1FB*

SWITCHCRAFT "FLIP-FLOP" PUSH BUTTONS

☐ Switchcraft has announced the TDW-F "Flip-Flop" series of push buttons designed for use with the Switchcraft Tini DW Multi-Switch switches. These push buttons provide an unusual lighted effect even though no electrical energy is used. There are no lamps to replace, no heat is generated and no extra internal switching is required.

According to the manufacturer, an internal flip-flop mechanism is used in conjunction with colored indicator panels (with or without legends), which makes the push buttons appear to change color. With the switch in the IN position, one color background shows through the clear front window; in the OUT position, another color display appears. Any of six bright colors — red, black, green, blue, yellow or white — may be selected. There's also a wide variety of both standard and special letters and symbols available for use with the push buttons. Further information may be obtained from Switchcraft, Inc., 5555 No. Elston Ave., Chicago, IL 60630. — *Paul K. Pagel, N1FB*

Antenna Modeling Program for the TRS-80

With this information and a Level II TRS-80 you can model hundreds of different antenna arrays. Enter data at the keyboard, then sit back and watch the computer plot the pattern.

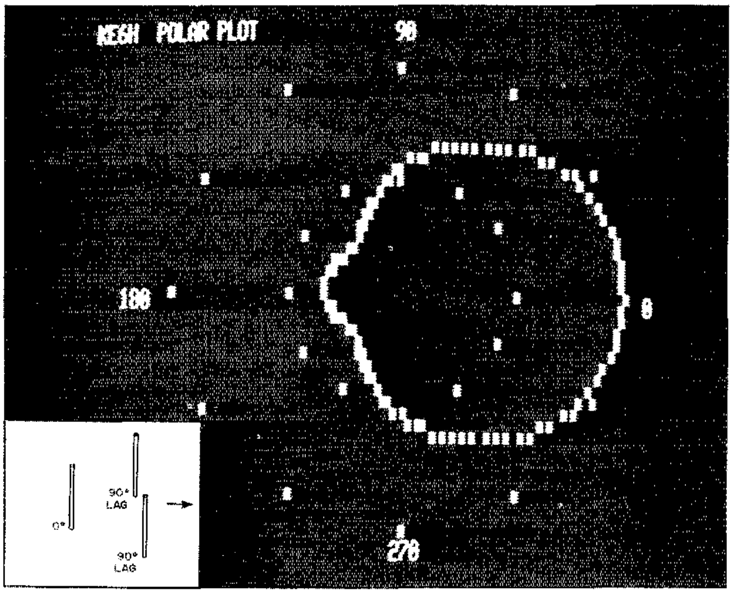
By Larry D. May,* KE6H

Antenna design seems to capture the interest and wonder of most hams at some time in their involvement in Amateur Radio. I had wondered for many years about the effects of modifying the spacing and phasing of antennas. This finally led me to read through *The Radio Amateur's Handbook*, *The ARRL Antenna Book*, and all the antenna engineering books I could find in the technical library at one of the universities nearby. While reading I came to a hazy conclusion: It should be possible to determine the relative field strength at any set of points equidistant from the array model, just by knowing the amplitude and phase of excitation of each dipole in the array and the orientation of the elements.

Determining this relative field strength should be simply to sum the instantaneous amplitudes of the rays of rf arriving at any given point from each element. The sum would conceivably be affected by the phase difference of arrival of each ray and their initial amplitudes relative to the other elements.

The phase would be affected conceivably by the physical spacing in wavelengths of the elements, and it would be modified by the simple angle effect to the summation point. The phase would also be affected by any radiation phase differences such as those caused by transmission-line delay time in the driven case or reactance delays in the parasitic case.

The amplitudes would be affected conceivably by the power delivered to each dipole element as well as by the radiation response: omnidirectional perpendicular to the axis of each element, and sinusoidal around the plane slicing lengthwise



TRS-80 pattern plot for the "Atchley" array.[1] This is a triangular arrangement of vertical elements spaced 0.288 λ and phased as indicated in the inset. *(All computer-screen photos courtesy of Jerry Hall, K1TD)*

through the axis of the element. All arrays would conceivably be broken up into an arbitrary reference dipole and secondary discrete dipoles.

I then set out to develop a program that would perform these calculations. When the program was completed I compared the results to standard known simple radiation patterns and was happy to find an excellent fit. I then checked some very complex arrays and was amazed at the fit. I went on to try all the various antenna configurations I had been curious about and came out with an understanding of antennas that I had never thought possible. The program had given me a quantum jump in my understanding of the effects of changing parameters of an antenna array; I could make changes in the computer model in seconds and see the effect it produced on the CRT. I could freely experiment with the number of

*8466 Abilene Ter., La Mesa, CA 92041

[1]Notes appear on page 19.

elements, spacing, boom length, phasing, transmission-line effects, polarization, stacking effects, collinear effects, and effects of nonstandard complex array configurations.

I developed two versions of the program, one for 4 K Level II systems, which allowed synthesis of 10-element arrays, and another, more complete, version that requires at least 16 K. That version permits synthesis of up to 128-element arrays and provides greater ease in modifying the array model and more options. The 4 K program, written in BASIC language, is presented in Table 1. Because of page-space limitations, the larger, more flexible 16 K program cannot be presented here. Information is available from the author, however.[2]

Running the Program

The program of Table 1 is based on the phase-vector summation of ideal half-wave dipoles as seen from a great distance. The factors that affect real antennas are very complex but this program allows you to see a good representation of the approximate field pattern that you would see from a real antenna. You can experiment with various combinations of elements — changing the number, the position, the spacing, the excitation level and the phase of the elements.

I hope you will gain insight into what is at play in antenna arrays from your use of these programs and, additionally, that you will enjoy the fascination of seeing displayed before you the unique field pattern of a whimsically conceived array. You can play with a simulation of your nearby 50 kW radio station towers, try an interferometer cross array for radio astronomy, or you can consider trade-offs in how you should stack your Long Johns for satellite tracking.

The half-wave dipole plays a very important role in most antenna designs. The

Table 1

Listing for the KE6H Polar Plot Modeling Program

```
10 CLS:PRINT" KE6H POLAR PLOT MODELING PROGRAM 4K": PRINT
15 INPUT"POLARIZATION = V OR H";P$: IFP$ = "V"ORP$ = "H"THEN2ØELSEGOTO15
20 INPUT"% FULL SCALE OF REF ELEMENT = ";A1:A1 = A1*.4:N = 1:GOTO9Ø
25 PRINT
30 N = N + 1:PRINT"ELEMENT NO = ";N:N2 = N
4Ø INPUT"% FULL SCALE";A(N,1):B(N,1) = A(N,1)*.4
50 INPUT"SPACING IN WAVELENGTHS";A(N,2):B(N,2) = A(N,2)*6. 28319
60 INPUT"ANGLE TO ELEM FROM REF (DEGREES)";A(N,3):B(N,3) = A(N,3)*.Ø174533
70 INPUT"PHASE DELAY (WAVELENGTHS)";A(N,4):A(N,4) = A(N,4):B(N,4) = A(N,4)*6. 28319
90 INPUT"MORE ELEMENTS (Y OR N)";T$
100 IFT$ = "Y"THEN25
105 IFT$ = "N"THEN14Ø
110 PRINT"TRY AGAIN":GOTO9Ø
140 INPUT"VERIFY DATA (Y OR N)";T$
145 N = 2
150 IFT$ = "Y"THENGOSUB5Ø5:GOTO165
160 IFT$ = "N"THEN165ELSEPRINT"TRY AGAIN":GOTO14Ø
165 CLS
200 FORI = 1TO2:FORO = ØTO11:W = O*3Ø
210 X = (4Ø/I)*COS(W*.Ø174533) + 62
220 Y = ( - 2Ø/I)*SIN(W*.Ø174533) + 24
230 SET(X,Y):NEXTO:NEXTI
260 PRINT@517;" 180 ";:PRINT@564, " Ø ";
265 PRINT@99Ø,"270";:PRINT@30,"90";
270 PRINT@Ø,"KE6H POLAR PLOT";
300 FORQ = 1TO108:Z = Q*.0581777:GS = 0:G2 = A1:G3 = Ø
305 FORN = 2TON2
310 G1 = B(N,2)*COS(B(N,3) - Z) - B(N,4):IFP$ = "H"THEN34Ø
320 G2 = G2 + B(N,1)*COS(G1):G3 = G3 + B(N,1)*SIN(G1)
330 NEXTN:GT = (G2↑2 + G3↑2)↑.5:GOTO37Ø
340 G2 = B(N,1)*SIN(Z):G3 = G2*COS(G1)
350 GS = GS + G3:NEXTN:GT = ABS(GS + A1*SIN(Z))
370 X = GT*COS(Z) + 62:Y = .5*( - GT)*SIN(Z) + 24
380 PRINT@40,"";:PRINTUSING"######.#";Q*3. 33333;GT*2.5;
385 IFY<2ORY>46THEN4ØØ
390 IFX<2ORX>126THEN4ØØ
395 SET(X,Y)
400 NEXTQ
405 PRINT@4Ø,"";:INPUT"VERIFY DATA (Y OR N)";T$
410 IFT$ = "Y"THENGOSUB500
420 RUN
500 N = 2
505 CLS:PRINT"A1 = ";A1*2.5;"% FULL SCALE"
510 GOSUB700:PRINT"A";N$" = ";A(N,1);"% FULL SCALE"
520 PRINT"S";N$;" = ";A(N,2);"WAVELENGTH OR ";B(N,2);"RADIANS"
530 PRINT"P";N$;" = ";A(N,3);"DEGREES OR ";B(N,3);"RADIANS"
540 PRINT"D";N$;" = ";A(N,4);"WAVELENGTH OR ";B(N,4); "RADIANS"
560 GOSUB6ØØ
562 INPUT"CONTINUE (Y OR N)";T$
565 IFT$ = "Y"THEN57Ø
567 RETURN
570 N = N + 1:IFN>N2THENRETURNELSECLS:GOTO51Ø
600 PRINT"WHERE":PRINT"A = SCALE":PRINT"S = SPACING"
610 PRINT"P = ANGLE TO ELEM FROM REF":PRINT"D = DELAY"
620 RETURN
700 N$ = STR$(N):IFLEN(N$) = 2THENN$ = RIGHT$(N$,1)ELSEN$ = RIGHT$(N$,2)
710 RETURN
```

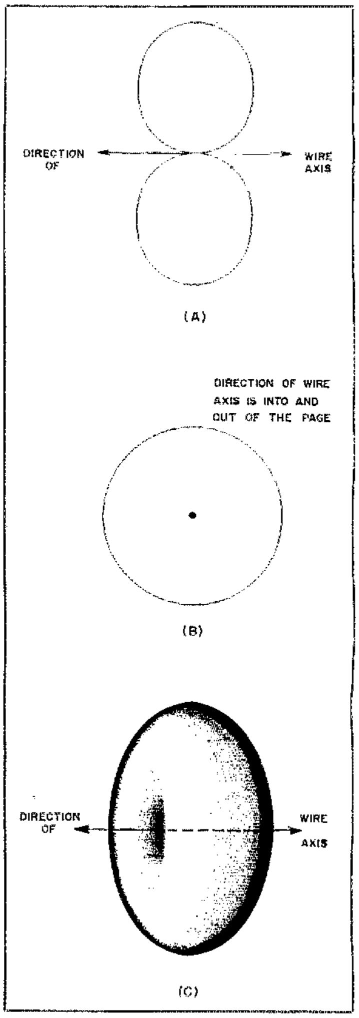


Fig. 1 — Radiation patterns for a dipole antenna. At A is the horizontal case, from a broadside view of the conductor. Visualize a horizontal slice removed from the center of the solid or three-dimensional pattern at C. At B is the vertical case, as if a vertical slice were removed from the center of the solid pattern at C.

dipole radiates a field such that if all points of equal intensity were graphed you would see a shape similar to a doughnut surrounding the dipole. See Fig. 1. The following exercises will allow you to see vertical and horizontal slices of this doughnut-shaped field. Later you will see vertical and horizontal slices of the field patterns of some of the elementary combinations of dipoles, to give you a base from which to expand your experimentation.

When you run the program of Table 1, the display should read KE6H POLAR PLOT MODELING PROGRAM 4K on the top line and then POLARIZATION = V OR H? With this program, type the data on the keyboard and then press the ENTER key, so the computer will act on the entry. Be sure to key data in carefully, as some machines are subject to key bounce.

Vertical Dipole

For our first exercise let's examine the pattern of a vertical dipole. Enter the information shown in small capital letters below in response to questions from the computer.

POLARIZATION (V OR H)?	V (vertical)
FULL SCALE OF REF ELEMENT = ?	100 (for % base current)
MORE ELEMENTS (Y OR N)?	N (for no more elements)
VERIFY DATA (Y OR N)?	N (no desire to double check)

The computer will then display two concentric rings of dots, spaced 30 degrees around the circles. These circles represent 50% and 100% of full scale. Major angles are displayed in conventional polar-coordinate form, with 0 degrees at the right side of your screen and increasing values in a counterclockwise direction.

Your computer will then proceed to calculate field intensities at 3.3° intervals around your hypothetical dipole. The dipole is not visible, but is theoretically located at the center of your screen, as if you were looking down at the vertical antenna on your roof from many miles up. What you see in the plot are points of equal field intensity about a vertical dipole, e.g., the slice normal to the wire. See Fig. 1B. The pattern is circular.[3] As the computer is plotting the values, they are also displayed in the upper-right corner of the screen — the angle in degrees and the percent of full scale. When the plot is completed, VERIFY DATA (Y OR N)? will appear in this area. Entering Y will display the parameters you entered on the keyboard, and entering N will clear the computer for a new pattern.

Horizontal Dipole

Now let's take a look at the field about a horizontal dipole.

POLARIZATION (V OR H)?	H (horizontal)
FULL SCALE OF REF ELEMENT = ?	100
MORE ELEMENTS (Y OR NO)?	N
VERIFY DATA (Y OR NO)?	N

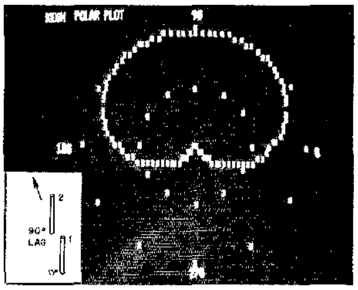


Fig. 2 — The cardioid pattern for a pair of vertical elements spaced 0.25 λ and phased as indicated in the inset.

Again the concentric circles and major angles appear. And you are now observing the field pattern around a horizontally polarized dipole at the center of your screen. It's as if you were looking down on it from many miles up, or like standing a doughnut on its edge, slicing it in half and looking down at the cross section. See Fig. 1A and the photo directly below.

Two-Element Vertical

The first requirement of a communications antenna is to capture and radiate energy, but an often equally important feature is to be able to null out unwanted signals that are on the frequency during reception. The dipole and many other antennas have deep null points that can be used by aiming them at the unwanted station — provided it is at a different angle from you than the desired station. The signal strength of the desired station may fall off somewhat but we hope not nearly as much as the undesired station. Now let's try two elements. See Fig. 2.

POLARIZATION (V OR H)?	V
FULL SCALE OF REF ELEMENT = ?	50 (for % base current for element 1)
MORE ELEMENTS (Y OR N)?	Y

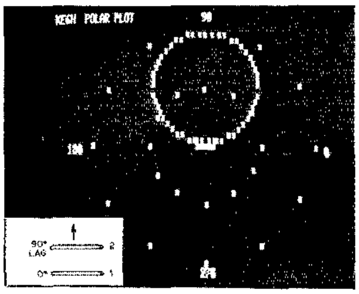


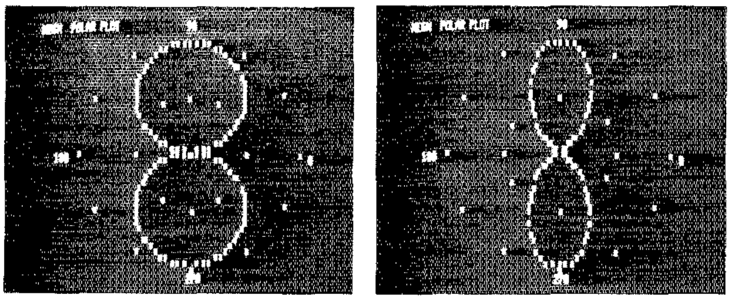
Fig. 3 — Horizontal pattern for a pair of dipoles spaced 0.25 λ and phased as shown in the inset.

And for element no. 2:

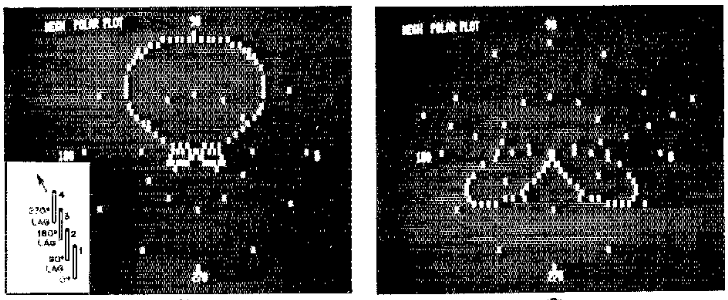
% FULL SCALE?	50 (% base current for element 2)
SPACING IN WAVELENGTHS?	.25 (for 1/4 λ)
ANGLE TO ELEM FROM REF (DEGREES)?	90 (position of elem 2 relative to elem. 1)
PHASE DELAY (WAVELENGTHS)?	.25 (for 90° phase lag at elem. 2)
MORE ELEMENTS (Y OR N)?	N
VERIFY DATA (Y OR NO)?	N

This configuration produces a pattern with a large single lobe and a deep null 180° from the main lobe. This is called a cardioid pattern. The display you should have is pictured in Fig. 2.

I suggest you try playing a little at this point with various spacing and phasing arrangements. Note that this program uses a positive number to indicate a phase lag in the drive to element 2, referenced to element 1. For a phase lead, enter a negative value into the computer. You will have to start afresh each time and reenter all parameters as you have just done. Sketch the pattern you get from each case and



The TRS-80 representation of the pattern of a horizontal dipole, left, and the bobtail curtain, right. (The bobtail curtain is described on page 300 of *The ARRL Antenna Book, 13th Edition.*) In plotting the bobtail curtain pattern, it was assumed the current in the center element was twice that in each end element. Numerous other current distributions can be simulated with ease.



(A) (B)

Fig. 4 — At A, the pattern of the vertical end-fire array shown in the inset. Adjacent elements are spaced 1/4 λ apart. By entering larger "full-scale" values for the elements, the magnified pattern at B results, giving better definition of the minor lobes.

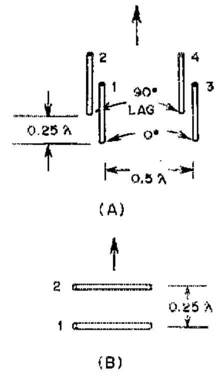


Fig. 5 — A 4-element broadside stacked array. At A is the configuration for the vertical case. At B, for the horizontal case, element 3 is hidden by element 1 and element 4 is hidden by element 2.

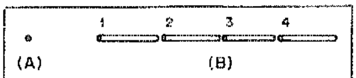


Fig. 6 — The vertical representation of four collinear vertical dipoles is shown at A. The pattern plot is the same as for a single vertical dipole — omnidirectional. The plot for the horizontal case at B, however, will show the "doughnut" of Fig. 1 is considerably flattened, and four minor lobes appear.

write the parameters next to each sketch. You may be exploring what to you are unknown waters. You are at the helm for this voyage, and what you learn is limited primarily by your desire to explore.

After you explore the 2-element driven phased array for a while you will probably come to the following generalities: (1) Increasing the phase up to 1/2 λ (180°) has the effect of squeezing out the forward lobe and increasing the size of the aft lobe, and (2) increasing the spacing has the general effect of increasing the number and size of the secondary lobes.[4]

Horizontal Patterns

The horizontal patterns of your 2-element arrays can be seen by selecting H instead of V and otherwise using all the same parameters. Note that the reference element, number 1, has been arbitrarily fixed in the horizontal mode in the 0-180° direction. If you want to place the next element in front of the reference element, it should be positioned at 90°. See Fig. 3, which shows the horizontal pattern when element 2 is spaced 0.25 λ and delayed 90° from element 1.

The pattern pictured in Fig. 3 may actually be considered as representing either of two antenna systems. First, if the two elements are vertical half-wave dipoles, this is a free-space pattern. To best understand the presentation for such an array, visualize that the screen is rotated 90° clockwise, so the major lobe goes to the right. For 1/4 λ vertical elements mounted on the ground or over a counterpoise, the pattern would be represented by the upper half only of the display on the screen (after 90° rotation).

Second, the display also represents the azimuthal pattern of a pair of horizontally polarized dipoles in a horizontal plane. It's as if the dipoles were parallel to the ground, no. 2 in front of no. 1, and you were viewing them from many miles up. These field patterns that you are seeing are not perfect, but will give you a good feeling for what happens for various arrangements and combinations of dipoles.

I hope you have now become aware of the basic entry schemes, so for simplicity all further parameter changes will be given in tabular format.

End-Fire Array

Try this end-fire array (vertical polarization), shown in Fig. 4.

Elem.	%	Spacing	Pos. Angle	Phase
1	25	—	—	—
2	25	.25	90	.25
3	25	.5	90	.5
4	25	.75	90	.75

Notice that the phase delay is set to equal the spacing for the end-fire array. The pattern you should see for this array is pictured in Fig. 4A. You'll note that there are minor lobes at the rear of the array, but because of the lack of fine resolution in the display, their exact shape is not easy to discern. You can expand or magnify the pattern easily. Just enter a larger percentage for the "full-scale" values without changing any other information. Enter the information as above, but now use 80% instead of 25% of full scale for each element. The resulting pattern, Fig. 4B, is enlarged 3.2 times and behold, you have the resolution you wanted in the minor lobes. The off-scale values simply are not plotted, even though they are calculated and displayed during execution of the program. To examine the minor lobes of various arrays you can use different full-scale percentage values to give the degree of magnification you desire.

Broadside Stacked Array

All the elements of the array do not have to lie in the same plane. The program will handle stacked arrays with the same ease. To illustrate this point, plot the pattern for the broadside stacked array of Fig. 5A (vertical polarization).

Elem.	%	Spacing	Pos. Angle	Phase
1	25	—	—	—
2	25	.25	90	.25
3	25	.5	0	0
4	25	.559	26.565	.25

In this array the spacing between elements 1 and 2 is 0.25 wavelength, as is the spacing between elements 3 and 4. We are stacking them 0.5 wavelength apart and feeding them in phase with each other. We can determine the spacing and position of elements 2 and 3 easily, but element 4 must be found by using a calculator:

$$S = \sqrt{X^2 + Y^2} = \sqrt{0.5^2 + 0.25^2}$$
$$= 0.559 \text{ wavelength}$$

$$P = \arctan(X/Y) = \arctan(0.25/0.5)$$
$$= 26.565°$$

where

S is the spacing in wavelengths

P is the position angle in degrees

This antenna yields a pair of cardioid patterns added together or summed. The horizontal equivalent for this antenna can be entered as follows (horizontal polarization). See Fig. 5B.

Elem.	%	Spacing	Pos. Angle	Phase
1	25	—	—	—
2	25	.25	90	.25
3	25	0	0	0
4	25	.25	90	.25

Notice that in the horizontal case, elements 3 and 4 superimpose and appear to be at the same location as elements 1 and 2 when looking down on the array. This is portrayed in Fig. 5B.

Collinear Stacked Array

The vertical collinear array of Fig. 6A is simply a vertical stacking of vertical dipoles end on end and all fed in phase. As in the case above, all the elements superimpose and appear to be at the same location. In this case the field geometry would appear to be the same as that of a single dipole, but the horizontal case (Fig. 6B) will show that the doughnut has been flattened considerably.

Elem.	*%*	*Spacing*	*Pos. Angle*	*Phase*
1	25	—	—	—
2	25	.5	0	0
3	25	1	0	0
4	25	1.5	0	0

Parasitic Arrays

Yagi antennas are similar to driven endfire arrays in that the moving wavefronts must reinforce each other in the forward direction. In the driven case this can be accomplished by delaying the drive to the elements by the same amount as the spatial delay. In the case of the Yagi, however, you have no transmission line that you can adjust. Instead, the wavefront strikes and excites each parasitic element. The phase of the reradiated energy depends on the tuning of the parasitic element; if it is tuned to the excitation frequency, the radiation is in phase with the excitation wave. The energy is delayed if the parasitic element is tuned below the excitation frequency, and advanced if tuned above. [If there are more than two elements in the parasitic array, the situation is complicated by interaction. Radiation from other parasitic elements combines with that from the driven element, and the resultant provides overall excitation for a given parasitic element. — Ed.] It was not possible to make provisions for treating parasitic arrays in the 4 K program, but provisions are included in the 16 K version mentioned earlier.

You should now be able to construct any configuration of driven dipoles on your TRS-80-II in either vertical or horizontal polarization and see the resultant field pattern on your screen. This places you in a unique position, as you now have the means for true exploration in an area that has previously been enjoyed by only a select group of antenna specialists. Consider trying to duplicate all the possible plots with real antennas on your roof or in your backyard. In the next few hours you may very well try out an entire antenna farm by computer simulation.

If you want to build and test a real antenna from your computer model you will need to know something about transmission lines, wavelength conversion, impedance matching and construction techniques. I would recommend *The Radio Amateur's Handbook* or *The ARRL Antenna Book* as references. QST

Notes

[1]Atchley, "Updating Phased-Array Technology," *QST*, August 1978. See Fig. 3, p. 24.

The author offers recordings of both the 4 K and the 16 K program versions, along with a "short course" explaining use of the programs. To help cover costs for materials, handling and shipping, send $6 for both programs on cassette tape, $10 for both programs on mini-disc, and $5 for the short course if you live in the U.S. [The ARRL and *QST* in no way warrant this offer. — Ed.]

[3]If the pattern is an ellipse rather than a circle, you can correct this situation either in hardware or in software. Size adjustments may be touched up in the monitor, and it may also be necessary to adjust sweep linearity. For software adjustment, modify the following statement numbers as necessary: 210 and 220, to modify the value of I; 260 and 265, to modify the PRINT@ positions; and 370, to modify the values of either or both X and Y.

[4][Editor's Note: A direct comparison of the *sizes* of different patterns cannot be used for determining the gain of one antenna system over another, even though both patterns were derived by using the same base-current values. Through mutual coupling, current flowing in one element will induce a current (and therefore a voltage) in the other element, and vice versa, affecting the total radiation from a given element. Although the program does not take this factor into account, the *shapes* of the patterns are reliable. The gain, however, *is* related to directivity; i.e., an antenna with a very broad major lobe will have less gain than one with a thin or narrow major lobe.]

Combined Vertical Directivity

You need a low radiation angle for DX and a high angle for short skip. Most of us shoot for maximum antenna height and hope for good results, but you may have more control over the angle than you think!

By W. B. Bachelor,* AC3K

The angle of radiation in the vertical or elevation plane from an antenna is of extreme importance in hf radio communications because it profoundly affects the signal strength at various skip distances. Height above ground is the dominant influence on the radiation angle from a horizontal antenna. The height of most amateur installations is severely limited, but the general rule has always been "the higher the better." This article shows how to calculate the vertical radiation patterns for antennas at various heights. A mathematical derivation of the method is included for completeness, but the resulting patterns should interest anyone who must operate with a height-restricted antenna.

Setting it Up

The ARRL Antenna Book shows the combined vertical plane radiation patterns for two antenna situations and states that the actual patterns in the presence of ground may be found for other cases by multiplying the free-space pattern by the given ground reflection factors.[1] If the free-space radiation patterns can be expressed mathematically, the vector summation of the direct and reflected rays can be readily calculated.

The free-space patterns are assumed to be of the form

$$p = k \cos^{N} \theta \qquad \text{(Eq. 1)}$$

where p is the field-strength magnitude, θ

*P. O. Box 10393, Oxon Hill, MD 20021

[1]*The ARRL Antenna Book*, thirteenth edition, pp. 55, 144 ($5 postpaid from ARRL).

BASIC Programs for Calculating Vertical Radiation Patterns

Although the author's radiation patterns were of very high quality, they weren't in a format suitable for direct reproduction. To obtain smooth, accurate curves required plotting field-strength values in one-degree increments — a task not relished by the editor and his modest TI-30 calculator. A TRS-80 microcomputer system came to the rescue in producing the graphs in this article. While not nearly as sophisticated or flexible as May's program elsewhere in this issue, the short special-purpose routines listed here served their intended function very well. If the listings appear somewhat inefficient, it's because the information had to fit on the narrow surplus TTY paper that was in the line printer. Computer enthusiasts can easily modify the programs to accommodate antennas and heights not treated in the article, or simply to optimize paper usage.

```
1Ø CLS:LPRINT"FREE-SPACE VERTICAL
 RADIATION PATTERNS"
2Ø LPRINT" "
3Ø LPRINT" "
4Ø LPRINT" "
5Ø LPRINT"ELEVATION ANGLE,    COS↑Ø.5",
 "COS","COS↑1.5","COS↑2","COS↑3",
 "COS↑5"
52 LPRINT"    DEGREES"
54 LPRINT" "
56 LPRINT" "
6Ø FORA=ØTO89:Z=COS(A*.Ø174533)
7Ø B=Z↑.5:C=Z↑1.5:D=Z↑2:E=Z↑3:F=Z↑5
8Ø LPRINTA,B,Z,C,D,E,F:NEXTA
```

```
1Ø CLS:LPRINT"VERTICAL RADIATION
 PATTERNS FOR ANTENNAS HAVING"
13 LPRINT"VERTICAL DIRECTIVITY OVER A
 PERFECT REFLECTOR"
14 LPRINT" "
16 FORL=.25TO.75STEP.125
18 LPRINT"ANTENNA HEIGHT ABOVE
 REFLECTOR:_"L" WAVELENGTH"
2Ø LPRINT " "
22 LPRINT" "
24 LPRINT" "
3Ø LPRINT" "," ","FREE-SPACE
 DIRECTIVITY FACTOR"
4Ø LPRINT" "
5Ø LPRINT"ELEVATION ANGLE,    COS↑Ø.5",
 "COS","COS↑1.5","COS↑2","COS↑3",
 "COS↑5"
55 LPRINT"    DEGREES"
57 LPRINT" "
6Ø FORA=ØTO89:Z=COS(A*.Ø174533):
 M=SIN(A*.Ø174533)
8Ø B=Z↑.5C=Z↑1.5:D=Z↑2:E=Z↑3:F=Z↑5
9Ø G=ABS(COS((3.14159)*(.5-(2*L*M))))
1ØØ K=B*G:N=Z*G:O=C*G:P=D*G:Q=E*G:
 R=F*G
11ØLPRINTA,K,N.O,P,Q,R:NEXTA
12Ø LPRINT" "
122 LPRINT" "
124 LPRINT" "
126 LPRINT" "
13Ø LPRINT"VERTICAL RADIATION PATTERN
 FOR ANTENNA HAVING NO FREE-SPACE
 VERTICAL DIRECTIVITY"
135 LPRINT" "
14Ø LPRINT"ELEVATION ANGLE,"," ",
 "NORMALIZED FIELD STRENGTH"
142 LPRINT"    DEGREES"
144 LPRINT" "
15Ø FORA=ØTO89:M=SIN(A*.Ø174533):
 G=ABS(COS((3.14159)*(.5-(2*L*M))))
16Ø LPRINTA," "," ",G:NEXTA
162 LPRINT" "
164 LPRINT" "
166 LPRINT" "
17Ø LPRINT" ":NEXTL
```

— *George Woodward, W1RN*

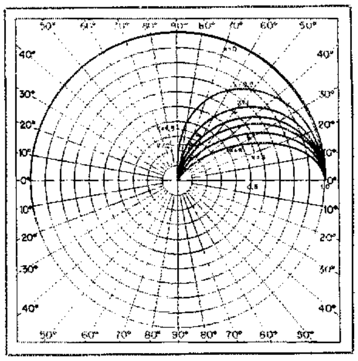


Fig. 1 — Free-space vertical radiation patterns for antennas having various degrees of vertical directivity. These curves are generated by the equation $p = \cos^x \theta$. Only one quadrant is plotted because the graphs are symmetric about the horizontal axis. An antenna with no free-space directivity has a pattern that coincides with the outer edge of the graph.

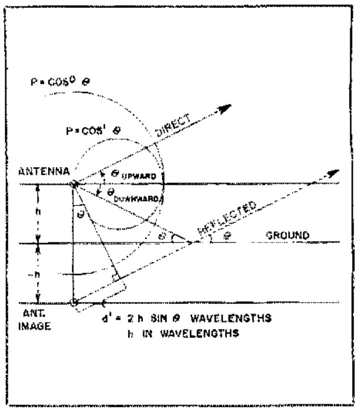


Fig. 2 — This drawing shows how the ground-reflected ray is delayed with respect to the direct wave.

is an angle with respect to the horizontal, x is an assigned exponent corresponding to the vertical directivity, and k is a constant coefficient related to the gain owing to beam formation. The patterns are horizontally directed and are symmetrical about the horizontal axis in both magnitude and phase.

Six $\cos^x \theta$ free-space vertical radiation patterns are graphed in Fig. 1. The antenna is at the origin, or pole, of the coordinate system, radiating at zero degrees to the right. When x = 0, the pattern is a circle centered at the antenna. A dipole exhibits this type of pattern. As x increases, the pattern narrows. These patterns are significant for illustrating the effect of free-space vertical directivity on the combined (direct and reflected) radiation pattern. The gain coefficient, k, has been set to one for each case to normalize the patterns to full-scale on the graph. This procedure ensures clarity by preventing the plots from intersecting. The maximum signals of real antennas, however, would be increased by the gain realized as the beamwidth is decreased.

Ground Reflections

Fig. 2, depicting the delay, d, of reflected signals is a detailed version of Fig. 2-21 in *The ARRL Antenna Book.* The reflected ray travels farther than the direct ray by the distance d′. θ is the radiation angle under consideration. If the antenna height, h, is expressed in wavelengths above ground (and below ground for the image antenna), by geometry, the angles marked θ are equal, and $\sin \theta = d'/2h$, or

$$d' = 2h \sin \theta \text{ in wavelengths, or} \qquad \text{(Eq. 2)}$$

$$d = 4\pi h \sin \theta \text{ in radians} \qquad \text{(Eq. 3)}$$

The quantity d, therefore represents the angle of delay in radians.

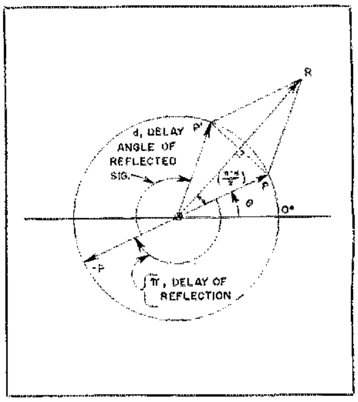


Fig. 3 — The magnitude of the radiated signal at some distant point is the vector sum of the direct and reflected waves. The mathematics are developed in the text.

Fig. 3 is a diagram of the vector addition of the direct and reflected rays. The phases of each pair of plus and minus θ-angle signals are equal in this symmetrical pattern. However, the reflected wave suffers two additional delays: d, resulting from its extra travel distance, and 180° or π radians caused by the reflection.

In Fig. 3 a direct ray is labeled p, and its opposite, which is delayed π radians is labeled −p. The space delay angle d added to reflection reversal fixes the phase of the reflected signal p′ with respect to the direct ray. Since lossless reflection is

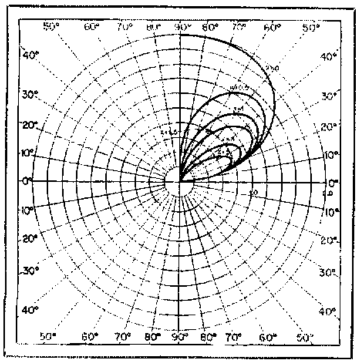


Fig. 4 — Vertical radiation patterns of antennas having various degrees of directivity installed 1/4 wavelength above perfect ground. These patterns have been scaled so as not to overlap. In reality, an antenna having a free-space directivity factor of $\cos^5 \theta$ would show considerable gain over one having no directivity (x = 0). Full scale on the relative amplitude (radial) axis is normalized to 2.0 to emphasize the doubling of the maximum field strength when the ground reflections combine with the direct rays.

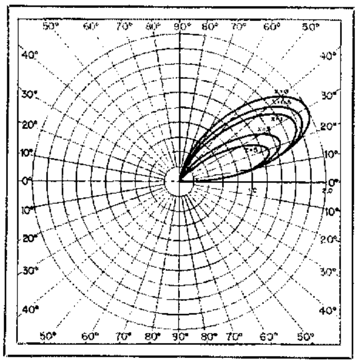


Fig. 6 — Radiation patterns for antennas 1/2 wavelength above ground. The low angles and lack of secondary lobes make this height desirable for DXing.

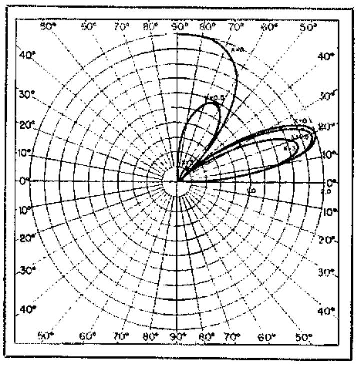


Fig. 8 — At 3/4 wavelength, the high-angle lobes are a nuisance to the DXer, who is likely to use an array having at least modest directivity. However, if one's operation is a casual combination of DXing and short skip, a dipole at this height might be the ideal antenna.

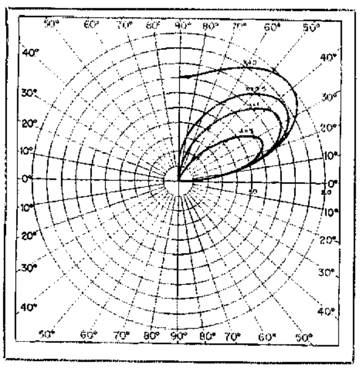


Fig. 5 — Some patterns for an installation height of 3/8 wavelength. Note that the dipole pattern (x = 0) no longer fires straight up, and all of the major lobes peak at lower angles than when installed at 1/4 wavelength.

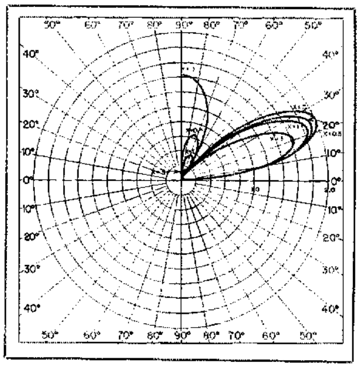


Fig. 7 — Raising the antenna to 5/8 wavelength further lowers the first lobe, but introduces a minor high-angle lobe. This secondary lobe is much less significant for a highly directive array than for a dipole.

assumed, the magnitudes of p′ and p are equal, and the diagonal, R, of the parallelogram is the vector sum of p and p′. The magnitude of R may be calculated by drawing the other diagonal, forming four right triangles, and noting that

$$\cos \frac{\pi - d}{2} = \frac{R}{2p} \text{ or}$$

$$R = 2p \cos \left(\frac{\pi}{2} - \frac{d}{2}\right) \qquad \text{(Eq. 4)}$$

Substituting Eq. 3 into Eq. 4 gives

$$R = 2p \cos \pi \left(\frac{1}{2} - 2h \sin \theta\right) \qquad \text{(Eq. 5)}$$

Substituting Eq. 1 into Eq. 5, and setting k = 1 gives

$$R = 2 \cos^x \theta \left[\cos \pi \left(\frac{1}{2} - 2h \sin \theta\right)\right] \qquad \text{(Eq. 6)}$$

R, the magnitude of the combined direct and reflected signals at large distances from the antenna, is computed by assigning values for the antenna height h and the exponent x of the free-space directivity equation, then for these two conditions introducing values of θ starting at zero and solving for the corresponding values of R. An inexpensive trigonometric calculator will solve Eq. 6, but the author used a programmable TI-59 to plot his original graphs.

Calculated Patterns

Figs. 4 through 8 show the calculated plots of the vertical radiation patterns of Fig. 1 combined with their lossless reflections. The effect of imperfect ground is to broaden the lobes and fill in the nulls. Antenna heights range from 1/4 to 3/4 wavelength.

These plots show that as the free-space vertical beamwidth decreases (exponent x becomes larger) the maximum radiation occurs at lower angles. At the lower heights a little directivity produces a considerable lowering of the combined patterns. For example, with a height of 1/2 wavelength (Fig. 6) the maximum radiation would occur at about 30° for an antenna having a circular free-space pattern such as a dipole (p = 1), and approximately 23° for one having a p = $\cos^{2.4} \theta$ pattern. The 2.4 exponent value can be located in Fig. 6 by interpolating between the x = 1 and x = 3 curves. Such a pattern closely resembles that of a 2-element end-fire array in Fig. 4-23 of *The ARRL Antenna Book*. If this antenna were to radiate the same total power as would be radiated by the circular pattern (p = 1), then the combined radiation pattern would show not only lower angles, but also higher magnitudes. This results because the combined beamwidth decreases with vertical free-space beamwidth; thus, in a constant-power situation, gain shows in the major lobe.

It appears that, to some extent, antenna height can be traded for vertical directivity. At greater heights the effect is less pronounced. For example, at 3/4 wavelength the vertical pattern used above (p = $\cos^{2.4}$ θ) would lower the maximum radiation from 19.5° only to 17.4°. QST

Vertical Array Analysis

You can determine the radiation pattern of an experimental phased array before building it. A computer helps, but you can get the same results with a ruler and protractor.

By Walter J. Schulz, Jr.,* K3OQF

Many articles on vertical antenna array construction have appeared in the Amateur Radio literature. However, little information has been published on the formation and analysis of the radiation patterns for such arrays. The simple vector methods presented in this article will enable anyone to graphically construct radiation patterns using only a compass rose and a ruler. For faster, more precise plotting, an HP-33E calculator program is given in the appendix. A short BASIC computer program, listed in the sidebar, will generate a printout from which a pattern can be graphed.

Vector Foundations

The fundamental assumption used in evaluating radiation patterns is that a single vertical antenna element is an isotropic, or point source. When looking down on the element, this assumption is sufficiently valid for amateur purposes — a single vertical element produces an omnidirectional pattern in the horizontal or azimuthal plane. The field intensity in any direction from an antenna element can be represented by a vector.

Two systems of vector notation are illustrated in Fig. 1. In part A, the vector is identified by its rectangular coordinates or components (x, y), which are the lengths of the vector projections on the coordinate axes. Defining ϕ as the angle the vector makes with the positive y axis, and R as the length (magnitude), the x and y coordinates can also be expressed as Rsin ϕ and Rcosϕ, respectively. By the Pythagorean Theorum,

$$R = \sqrt{x^2 + y^2} = \sqrt{\sin^2\phi + \cos^2\phi}.$$

The vector is identified by its polar form

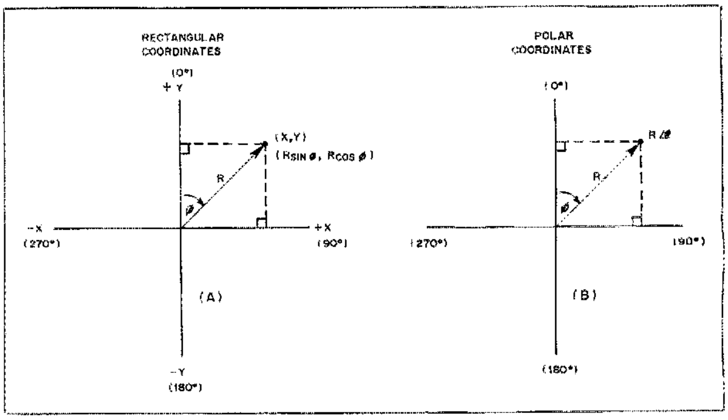


Fig. 1 — Two methods for identifying a vector. The rectangular or Cartesian coordinate system is given in A, and polar notation is illustrated in B.

R $\angle\phi$ in Fig. 1B. Note that ϕ is measured clockwise from the positive y axis. If the positive y axis points north, the angle ϕ corresponds to an azimuthal bearing on a compass. A more typical mathematical convention defines ϕ as the angle the vector makes with the positive x axis measured counterclockwise.

Forming the Pattern

When two or more vertical elements, each having an omnidirectional azimuthal pattern, are arranged in some physical pattern and excited from a common source, the combined radiation pattern shows some directivity. The lobes and nulls are a result of wave reinforcement in some directions and cancellation in others. The radiation pattern is directly dependent on the time delay caused by the physical separation between the elements. Further control can be exercised by delaying the electrical excitation of one element with respect to another. This phase delay can be introduced by means of a transmission line or a lumped-constant network.

To determine the directional characteristics of an array, construct a coordinate system and locate the element that leads in phase (is excited first or has no delay) at the origin. This is the reference element from which all distances and delays are measured. The other elements (represented as point sources) are then located in their physical configuration using any convenient scale. Staying within the first (upper right) quadrant and placing elements on the coordinate axes where possible will simplify the calculations.

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At any specific compass heading, each element will contribute a vector to the array pattern given by

$$E = S\cos(\theta - \phi) + \psi,$$

where

- S = spacing in degrees from reference element
- θ = azimuth angle (compass heading) in degrees
- ϕ = angular position of element with respect to positive y axis
- ψ = excitation phase with respect to reference element.[1]*

The reference element is assigned a field strength of unity, and, from the definition just given, an angular component of zero. The array vector magnitude (field strength) corresponding to a particular heading is found by summing the individual element vectors. To do this graphically, draw a set of coordinate axes and assign zero degrees to the positive y axis. Starting at the origin, draw a vector having length one (any convenient linear measurement unit) coincident with the positive y axis. At the tip of this reference vector establish a new set of coordinate axes. Using a compass rose (or protractor) and a ruler, start the vector for the next element at the new origin (head of the reference vector). Measure positive angles clockwise from the y (or new vertical) axis and negative angles counterclockwise. In the same way, construct each element vector in succession. It doesn't matter in which order you draw the vectors, but some orders may be more convenient than others.

To find the array field strength draw a vector from the tail of the reference vector to the head of the final vector and measure its length. This length is the field strength at a particular value of θ (azimuth heading); to graph the complete radiation pattern repeat the process for several values of θ, plot the points on polar paper and connect them. The process can be quite tedious if fine resolution is required.

A trigonometric table or slide rule can be used to obtain the cosine values, or they can be punched up on a modest calculator such as the TI-30. If you use the calculator, you can avoid most of the pencil work except plotting the actual pattern. Here's how: First, find the value of the angular component of the vector, take its sine and multiply by the magnitude. This is the x component of the vector. Repeat this process using the cosine function to find the y component. Find the rectangular components of each vector [don't forget the reference element — its components are (0,1)]. Total the x values and square the result. Do the same for the y values. Now add the two squares and take the square root of the sum to get the relative field strength of the array for that azimuth value. It's a fair amount of punching, but it's faster than drawing vectors.

A more sophisticated calculator can speed up the process considerably — see the simple program at the end of this article. The author has also published a more comprehensive program.[2]

Some Examples

To illustrate the technique, let's apply it to four antenna systems commonly used by radio amateurs. We'll begin with the classic two-element broadside and endfire arrays and progress to some more exotic multielement designs. The elements in these arrays are excited with equal power, so the magnitude components of the individual field-strength vectors can be normalized to unity. Keep in mind that this isn't always the case — the bobtail curtain is an example of an array having unequal power distribution.[3] Our calculations require the element spacing to be expressed in degrees. Construction articles for amateur arrays typically specify the spacing in wavelengths. To convert wavelengths to degrees, multiply by 360.

The radiation patterns constructed from the vector magnitudes have the proper shapes — that is, the amplitude relationship between any two points is correct. Therefore, one can measure front-to-back and front-to-side ratios directly from the pattern. Also, one might expect the array magnitude vector to be equal to the numerical gain over a single element. Unfortunately, it isn't that simple, because we've neglected the effect of mutual currents induced by the coupled elements. These currents can increase or decrease the array gain. To account for this effect would complicate the calculations beyond the usefulness of the simple technique used here. Therefore, we'll be content with exploring the directional characteristics without attempting to quantify the forward gain.

Two-Element Broadside Case

Illustrated in Fig. 2A, this system consists of two verticals spaced a half wavelength (S = 180°) and excited in phase (ψ = 0). The field-strength vector for each element is given in polar form. To investigate the combined field strength broadside to the array we set θ = 90°. Since the cosine of 90° is zero, the angular component of vector 2 is zero. Therefore, the vectors have the same direction and their magnitudes can be added directly as shown in Fig. 2B. Since the resultant field intensity has a relative magnitude of 2 with respect to a single element, the array has an apparent gain of 2 at 90° azimuth. The cosine of 270° is also zero, so the array provides the same gain at that heading as well. Plugging successive values of θ into the formula will yield magnitude values

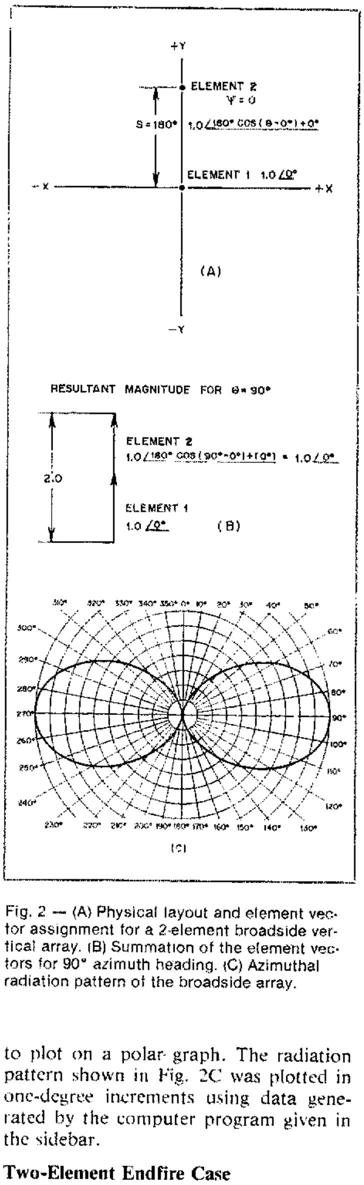

Fig. 2 — (A) Physical layout and element vector assignment for a 2-element broadside vertical array. (B) Summation of the element vectors for 90° azimuth heading. (C) Azimuthal radiation pattern of the broadside array.

to plot on a polar graph. The radiation pattern shown in Fig. 2C was plotted in one-degree increments using data generated by the computer program given in the sidebar.

Two-Element Endfire Case

Two elements spaced a quarter wavelength (S = 90°) and excited in phase quadrature (ψ = −90°) form the simplest unidirectional vertical array. The value for ψ is negative, indicating that the excitation of element 2 lags that of the reference element. Fig. 3A depicts the physical arrangement of the elements and identifies the vectors. Equal power distribution is assumed here, but this condition isn't realized in typical amateur installations because one element induces current in the other, making the radiation resistances unequal. The effect of this imbalance is to degrade the front-to-back ratio.[4] The vector addition for θ = 0° is

[1]References and Editor's Note appear on page 25.

Plotting Radiation Patterns

While the graphical vector method outlined by Schulz can be used to plot the pattern of any phased array, the procedure is rather time consuming (and paper consuming) when applied to large arrays or when fine resolution is required. The calculator program given in the appendix will greatly enhance the speed and accuracy of the exercise. A logical extension of the technique is to use a computer to calculate and print the azimuth and field-strength values. Mitchel and May have taken this idea one step further with programs written to plot patterns on a CRT terminal.[7,8]

Those programs are quite complete, but also quite long if one needs only to analyze the simple arrays used by most amateurs. Listed below are the programs used to generate the data for the antenna patterns printed in the accompanying article. The routine first calculates the relative field strength using the formulas already given and then divides all the values by the maximum field strength to normalize the major lobe to full scale on the polar graph. A complete listing is given for the two-element broadside program; for the other programs, only those lines that differ from the broadside program are listed.

The amplitude values plotted correspond to the field strength (voltage) some distance from the antenna, and the amplitude scale is linear. Many amateurs would be interested in seeing the amplitude plotted in decibels. To obtain the field strength in decibels (with respect to the major lobe) and any heading, take the common logarithm of the normalized field strength value and multiply by 20. This operation could be incorporated in the computer program using only one or two instructions. The data thus obtained is most useful to amateurs when plotted on the scale designed by Hall.[9]

```
10 CLS:LPRINT" ", "RADIATION PATTERN OF
   2-ELEMENT BROADSIDE VERTICAL ARRAY"
12 LPRINT" "
14 LPRINT" "
16 LPRINT" "
20 LPRINT"AZIMUTH, DEGREES","RELATIVE
   FIELD STRENGTH", "NORMALIZED FIELD
   STRENGTH"
22 LPRINT" "
24 LPRINT" "
30 FORX=0TO359:Q=.0174533:L=X*Q
40 A=180*Q*COS(L)
50 B=COS(A):C=SIN(A)
60 D=((B+1) ↑2+C ↑2) ↑.5
70 E=D/2:LPRINTX," ",D," ",E:NEXTX

10 CLS:LPRINT" ","RADIATION PATTERN OF
   2-ELEMENT ENDFIRE VERTICAL ARRAY"
40 A=90*Q*COS(L)-(90*Q)

10 CLS:LPRINT" ","    RADIATION PATTERN
   OF W1CF 3-ELEMENT ARRAY"
40 A=104*Q*COS(L-(60*Q))-(90*Q)
50 B=104*Q*COS(L-(120*Q))-(90*Q):
   C=COS(A):D=COS(B)
60 E=SIN(A):F=SIN(B):G=((C+D+1) ↑2
   +(E+F) ↑2) ↑.5
70 H=G/3:LPRINTX," ",G," ",H:NEXTX

10 CLS:LPRINT" ","    RADIATION PATTERN
   OF W1CF 4-ELEMENT ARRAY"
40 A=90*Q*COS(L-(90*Q))-(90*Q)
50 B=127*Q*COS(L-(45*Q))-(180*Q):
   C=90*Q*COS(L)-(90*Q)
60 D=COS(A):E=COS(B):F=COS(C):
   G=SIN(A):H=SIN(B):I=SIN(C)
65 K=((D+E+F+1) ↑2+(G+H+I) ↑2) ↑.5
70 P=K/3.78987:LPRINTX," ",K," ",P:NEXTX
```

— George Woodward, W1RN

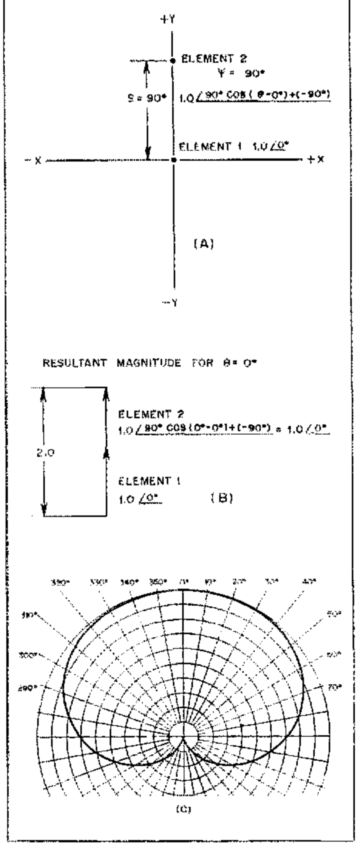

Fig. 3 — Two-element end-fire array. The array configuration and vector assignment are given in A. B is the vector summation for 0° azimuth heading. The array produces a cardioid radiation pattern, plotted in C.

shown in Fig. 3B. At this heading the array gives maximum gain over a single element. Setting $\theta = 180°$ yields an angular component of 180° for vector two, which exactly cancels (in the ideal case) the radiation from the reference element in that direction. The major lobe of any unidirectional array fires through the phase-lagging element. Fig. 3C is the radiation pattern of the ideal two-element unidirectional array.

W1CF Tri-Element Case

Increasing the number of elements allows greater flexibility in beam formation and steering as well as higher gain. Atchley proposed the systems in this example and the next for 80-meter DXing.[5] The array is composed of three elements arranged in an equilateral triangle as illustrated in Fig. 4A. The altitude of the triangle is placed along the x axis for convenience. Each leg is 0.288 wavelength long (S = 104°), and elements 2 and 3 lag the reference by 90° ($\psi = -90°$). Because this array uses nonzero values of ϕ, the vectors must be set up carefully and the calculations are somewhat more tedious. The radiation from all three elements is in phase when $\theta = 90°$. As shown in Fig. 4B, the apparent azimuthal gain at this angle is 3. The pattern is drawn in Fig. 4C. Notice that the array exhibits wide azimuthal coverage, but that the front-to-back ratio is only 9.6 dB and the best lobe-to-null ratio is only 11.6 dB.

W1CF Four-Element Case

This array consists of four elements arranged in a square one quarter wavelength per side as diagramed in Fig. 5A. For elements 2 and 4, S = 90°. The spacing for element 3 is the diagonal of the square. The phasing (ψ) is $-90°$ for elements 2 and 4, and $-180°$ for element 3. Element 2 has an angular position (ϕ) of 90°, and for element 3, $\phi = 45°$. Rusgrove has described a 40-meter version of this antenna system.[6] Equal element excitation is forced by means of Wilkinson power dividers, so the actual performance of this antenna will closely approximate the theoretical predictions. Maximum field intensity occurs at 45° azimuth, and the vector summation for this angle is performed in Fig. 5B. Note that the construction has been simplified by adding vectors 3 and 4 in reverse order. Fig. 5C gives the radiation pattern of the 4-element array. The half-power beamwidth (where the field-strength voltage drops to 0.707 of full scale) is about 97°. A front-to-back ratio of 25 dB is achieved, with deep nulls on either side of the back lobe.

Appendix

HP-33E Manual Program for 2-Element Vertical Array

1) Azimuth, element position, element spacing and element phasing are expressed in degrees.

2) After each azimuthal magnitude calculation the memory must be cleared. Turn the calculator off and on again to ready the unit for the next calculation.

3) Line 8 displays magnitude answer.

4) Key g Deg before beginning calculation.

Manual Key Sequence

Line	*Data*	*Operation*	
1	Azimuth	[enter]	
2	element position	[minus]	[f cos]
3	spacing	[×]	
4	electrical phase	[plus]	[enter]
5	magnitude	[f→R]	[Σ+]
6	0	[enter]	
7	1,0	[f→R]	[Σ+] [RCL 5] [enter] [RCL 3]
8		[g→P]	[r/s] answer

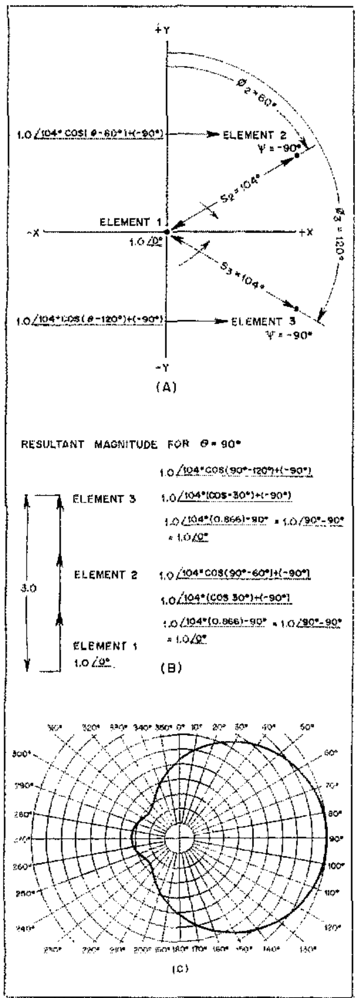

Fig. 4 — The 3-element W1CF array. A illustrates the triangular arrangement and vector specification. At $\theta = 90°$ the radiation from all elements is in phase, as diagramed in B. The pattern is given in C. As in all unidirectional phased arrays, the major lobe fires through the lagging elements.

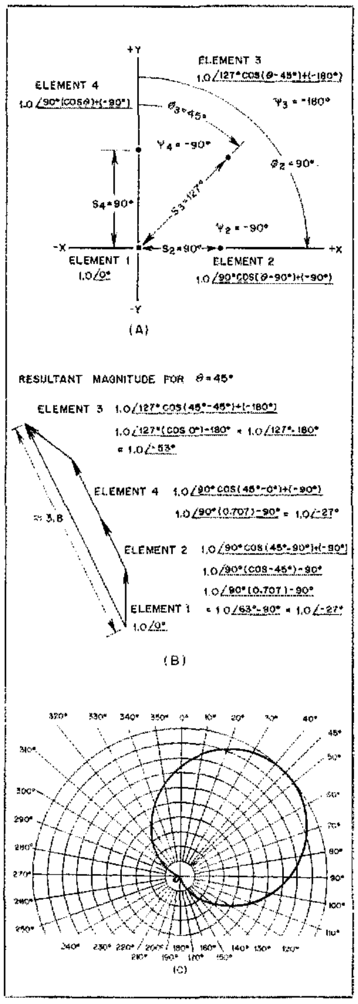

Fig. 5 — The square shape of the W1CF 4-element array allows the elements to be represented on the coordinate axes and in the first quadrant, shown in A. The radiation from all four elements is not phase-coincident for any azimuth heading, but the nearest approach to this condition occurs at $\theta = 45°$, as shown in B. The radiation pattern, plotted in C, shows good directivity.

*Editor's Note: The author's original manuscript (and reference 1) assign negative values to the spacing, S. The mathematical justification for this notation is that S really represents the time a space wave arrives at a secondary element with respect to the excitation of the reference element. Since the wave arrives *after* it has been radiated by the reference, the time can be rendered as a negative number. However, this definition causes the plotted patterns to have an apparent firing direction 180° from the true major lobe. To reconcile the formula with the real-world radiation patterns, the editor has used positive numbers for element spacings. The patterns given in Figs. 2 through 5 are correct. This can be verified intuitively by sketching a two-element system having quarter-wave spacing and quadrature phasing, and analyzing the response from each end.

References

[1]Smith, *Directional Antennas*, Smith Electronics, Inc., 1969, p. 2-1-23.

[2]Schulz, "HP41-C Tweaks Vertical Antenna Arrays," *Electronics*, January 17, 1980.

[3]Orr, *Radio Handbook*, twenty-first edition, Editors and Engineers, p. 28-13.

[4]Lewallen, "Notes on Phased Verticals," Technical Correspondence, *QST*, August 1979.

[5]Atchley, Stinehelfer and White, "360°-Steerable Vertical Phased Arrays," *QST*, April 1976.

[6]Rusgrove, "A 360° Steerable Vertical Phased Array for 7 MHz," *The Radio Amateur's Handbook*, fifty-eighth edition, ARRL, p. 20-15.

[7]Mitchel, "Antenna Engineer — Predict Performance of Phased Arrays with a TRS-80," 73, May 1980.

[8]May, "TRS-80 Antenna Modeling Program," *QST*, February 1981.

[9]Hall, "The New Look for *QST*'s Antenna Patterns," *QST*, July 1980.

Strays

In all seriousness, the new ARRL flag is now available to members. Central Division Vice Director K9EN introduced it at a club meeting in Madison, Wisconsin. Details on how you can obtain one (or more) are in October 1980 *QST*, page 9. The sizes are slightly different than those mentioned in *QST*, though — the large flag ($21) is about 3 × 5 feet, while the small one ($15) is about 2 × 3 feet. (*photo courtesy K9ZZ*)

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Atlantic Division Director Jesse Bieberman, W3KT, appears pleased with events at the recent 25th Annual York County (Pennsylvania) hamfest. Left to right are Vice Director W3ABC, W3KT, W3AXC and W3AMQ.

I would like to get in touch with . . .

☐ amateurs who are or have been employees of CBS or CBS-owned stations. I am compiling a list of CBS hams. — Bob Oswald, WA2AIW, 524 W. 57th St., New York, NY 10019.

☐ Chicago-area amateurs who are interested in a 2-meter a-m calling/working channel on 144.4 MHz. Edgar Reihl, WA9ULU, 545 Ridge Rd., Wilmette, IL 60091 (s.a.s.e. appreciated).

What Your Wattmeter Really Reads

Your wattmeter's power readings most times are not a true indication of the power actually delivered to the load. Learn how to correctly interpret those readings.

By J. T. Kroenert,* WA1YTC

The reflectometer-type wattmeters are the only economical instruments available to the radio amateur for measuring rf power. As such, they are invaluable. The devices are not true power meters, however. The power reading is only true when the load is a pure resistance having a value the same as that used at the factory for calibration. The readings must be carefully interpreted when the load is anything other than this value.

A misconception often heard concerns the role of "reflected" power. Even equipment designers are guilty of perpetuating this misconception at times. Under key-down conditions, the source (transmitter) does not recognize the existence of such a quantity as reflected power. The source simply delivers some actual power, P_A, to some load impedance, Z_L, as shown in Fig. 1. If a true rf wattmeter were available, it would have only one scale — actual power. It could not provide a reflected power reading.

This discussion analyzes the Heathkit HM-102, which is functionally the same as the Drake wattmeters, the Swan WM-2000 and others using a current transformer to sample the load current. The Bird uses a different scheme to sample the transmission line, but the result is the same. The remarks, curves and formulas apply to all these meters.

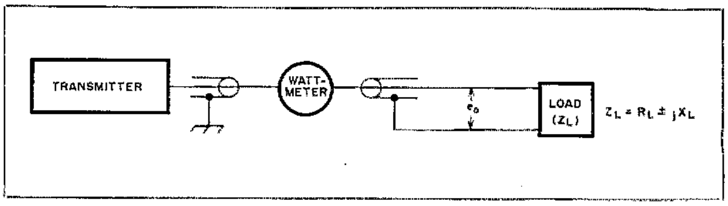

Fig. 1 — The transmitter supplies power via the wattmeter to a load impedance, Z_L. The voltage developed across the load impedance is e_o. The wattmeter reading is then obtained from the values of e_o and Z_L.

Actual Power

Actually none of the reflectometer types of wattmeters measure power: The meter scale is marked in watts, but the meter deflection is not truly dependent on the power delivered to the load. A true wattmeter would measure the power into the load regardless of the impedance of the load. Let's use an example, illustrated in Fig. 1. The transmitter supplies power through the wattmeter to the load impedance Z_L, which has both resistance, R_L, and reactance, $\pm jX_L$. Knowing the voltage across the load, e_o, and the impedance, Z_L, the actual power in the load, P_A, can be calculated. (This is Eq. 18 from the appendix.)

$$P_A = \frac{e_o^2 R_L}{|Z_L|^2} = \frac{e_o^2 R_L}{R_L^2 + X_L^2} \qquad \text{(Eq. 1)}$$

Let us compare this actual power, P_A, with the forward power reading, P_F, of your wattmeter. Eq. 16 from the appendix gives the forward power reading, P_F, as:

$$P_F = \frac{e_o^2}{4R_o}\left|1 + \frac{R_o}{Z_L}\right|^2$$

$$= \frac{e_o^2}{4R_o}\left(\frac{[R_o + R_L]^2 + X_L^2}{R_L^2 + X_L^2}\right) \qquad \text{(Eq. 2)}$$

The two formulas are not equal for all values of $R_L \pm jX_L$, so the forward power reading is not always an indication of the actual power. Note the presence of the new quantity, R_o, in the P_F formula. R_o is the value of pure resistance (usually 50 or 52 ohms) that the manufacturer uses as a load when the wattmeter is calibrated. If the load impedance is equal to R_o, then

$$P_A = \frac{e_o^2}{R_o} \qquad \text{(Eq. 3)}$$

and

$$P_F = \frac{e_o^2}{R_o} \qquad \text{(Eq. 4)}$$

Eqs. 3 and 4 show that your wattmeter reads actual power on its forward power scale only when the load impedance is a pure resistance equal to R_o.

There are two ways to obtain the value of actual power when the load impedance does not equal R_o. If your wattmeter reads both forward and reflected power, subtract the reflected power reading from

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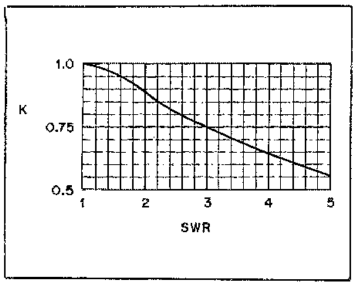


Fig. 2 — The actual load power is obtained by multiplying the forward power reading by the factor K from the curve. As the SWR reading increases from 1.0, the value of K decreases from 1.0.

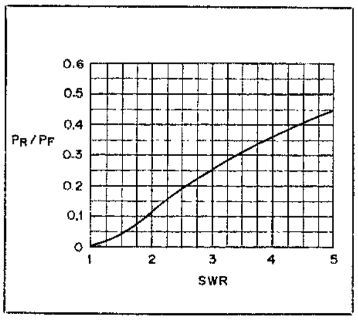


Fig. 3 — This curve shows the ratio of the reflected power reading to the forward power reading as the SWR increases from 1 to 5.

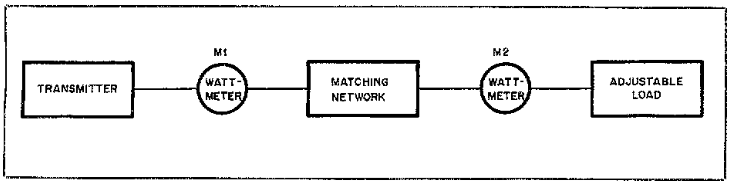


Fig. 4 — This test setup is used to illustrate the proper interpretation of the reflected power readings.

the forward power reading.

If your wattmeter reads forward power and SWR, multiply the forward power reading by a factor, K: Actual Power = K × "forward" power reading. Values of K for SWR readings from 1 to 5 are given in Fig. 2. For example, with an SWR of 3.0, K is 0.75. The actual power is only 75% of the "forward" power reading.

Forward and Reflected Power Readings

In the forward power position the meter reads a voltage which is the phasor sum of two voltage components. One component is a fraction of the load voltage and the other component is a voltage proportional to the load current. The circuitry is set up to make these two components equal when the load is R_0. The meter scale is then marked in watts delivered to R_0. The detailed formulas are contained in the appendix.

In the reflected power position the meter reads a voltage which is the phasor difference of two voltage components. One component is a fraction of the load voltage and the other component, proportional to the load current, is subtracted. These two components are equal when the load is R_0, and when they are subtracted the result is zero — no reflected power. When the load differs from R_0, the current component no longer cancels the voltage component, so some reflected power is indicated on the meter.

If the meter-circuit sensitivity is the same as for forward power, then the same scale markings are used. Some meters may increase the meter-circuit sensitivity to provide a more expanded scale for reflected power. Basically, the reflected power reading is a measure of how much the load impedance differs from R_0. The formula for the reflected power reading, Eq. 17 in the appendix, is difficult to interpret generally in any other way.

Some meters have an SWR scale instead of, or in addition to, a reflected-power scale. Such a meter measures SWR exactly the same way that it measures reflected power. The circuit is exactly the same — the voltage component proportional to load current is subtracted from the voltage component proportional to load voltage and rectified to give the meter reading. Only in this case the meter scale is marked in SWR instead of reflected power. To permit the use of low power for SWR measurement, practically all meters provide a higher sensitivity in this mode. Using the sensitivity adjustment, the forward power is set to full scale and the same sensitivity retained for the SWR measurement. Thus the SWR reading is obtained from the ratio of reflected to forward power. Fig. 3 is a plot of the ratio of reflected to forward power vs. SWR. Note on the curve that when the SWR is 3.0, the ratio of reflected to forward power is 0.25. Also note on your meter that 25% of full scale power is midscale and that the SWR = 3 mark is also midscale. The formula for the relationship is given in the appendix as Eq. 24.

The basic quantity measured is again a difference between the load impedance and R_0, not SWR. It is converted to SWR by the meter, which assumes that the load should have a characteristic impedance equal to R_0. No transmission line is even required to produce an SWR reading on such a meter. Put a capacitor or inductor in series with your dummy load and measure the SWR. An SWR reading greater than 1.0 will be obtained because the load is no longer R_0. The only true way to determine SWR is by measurements along the line, as discussed in Ref. 1. This is not possible with short lines and impractical with coaxial lines, so the meter provides the most practical way of estimating SWR. Ref. 1 is highly recommended for its discussion and illustrations of the readings that occur when a line having a characteristic impedance other than R_0 is used.

The Reality of Reflected Power

The reflected power reading is not true power. This can be illustrated by performing the experiment shown in Fig. 4. With the power into the load held constant at 100 watts, note the readings of M2 as the load impedance is changed. With each different impedance, the matching network is readjusted to make the readings of M1 constant. The transmitter does not require any adjustment since its load is a constant R_0 as indicated by the SWR = 1 ($P_R = 0$) reading of M1. Therefore, the transmitter constantly delivers 100 watts to the matching network. If there are no losses within the matching network, 100 watts is delivered to the load. Let the load assume various impedance values which result in SWR readings on M2 of 1, 2, 3, 4 and 5. The corresponding readings of forward and reflected powers for each SWR can be obtained using the curve of K vs. SWR in Fig. 2. The results are shown in Table 1. As the SWR reading increases, both P_F and P_R increase, but the difference always stays fixed at the value of *actual power.* The reflected power cannot be considered as power returned to the matching net-

Table 1

Wattmeter Power Readings Vs. Actual Power for SWR Values of 1 to 5.

SWR	*K*	P_F	P_R	P_A
1	1.0	100	0	100
2	0.89	112	12	100
3	0.75	133	33	100
4	0.64	156	56	100
5	0.55	182	82	100

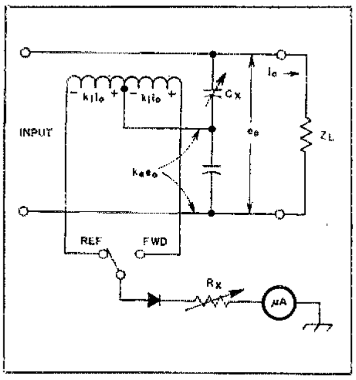


Fig. 5 — A functional representation of a typical rf wattmeter circuit. Only the components necessary for the discussion are shown. The center-tapped coil is on a toroid core.

work because the matching network has no losses. Just consider reflected power as the correction factor to convert the forward power reading to actual power.

If you have a long transmission line and transmit a short pulse, a distinct reflection pulse will be produced if the line is misterminated. If the load impedance does not equal the characteristic impedance of the line, a voltage pulse will be reflected at the load and travel back down to the sending end. In fact, this method is used to locate a failure (a gross mismatch) in transmission lines by measuring the travel time of the reflected pulse and converting the time to distance along the line.[2] In Amateur Radio communications, the key-down time is so long that all the reflections reach a continuous, or steady-state, condition. With a steady-state condition, the forward and reflected components cannot be separated. The load can be evaluated only as an impedance; this is basically what our wattmeters do. Reflections are real, but the concern some amateurs have about reflected power is unwarranted. Reflected power is not power rejected by the load which could otherwise be used, nor is it necessarily power which is returned to be dissipated in the transmitter.

I hope the preceding discussion has explained the readings of the reflectometer type of wattmeter and has led to the proper interpretation of the readings. I did not include the further expansion of a load impedance into a transmission line plus antenna. Consult Ref. 1 for a detailed discussion of how the load impedance is determined by the antenna and transmission line. QST

References

[1] Cebik, ... "The Imperfect Antenna System and How It Works," *QST*, July 1979.

[2] Inchem, "An Inexpensive Time-Domain Reflectometer," *QST*, March 1973.

Appendix

The functional circuit of the wattmeter is assumed to be as shown in Fig. 5. The current-sampling transformer develops a pair of voltages, $k_i i_o$, proportional to the load current, i_o. The capacitive voltage divider across the output provides an output voltage sample, $k_e e_o$, to the center tap of the current-sampling transformer. Assume instantaneous polarities are as marked in the figure. The sampled forward voltage, e_f, is the sum of two components.

$$e_f = k_e e_o + k_i i_o = e_o\left(k_e + \frac{k_i}{Z_l}\right) \qquad \text{(Eq. 5)}$$

and the sampled reflected voltage, e_R, is the difference of the two components.

$$e_R = k_e e_o - k_i i_o = e_o\left(k_e - \frac{k_i}{Z_l}\right) \qquad \text{(Eq. 6)}$$

The first step is the adjustment of the relative values of k_e and k_i to make the reflected voltage, e_R, equal to zero when the load, Z_l, is the design value, R_o. If $Z_l = R_o$, then

$$e_R = 0 = e_o\left(k_e - \frac{k_i}{R_o}\right) \qquad \text{(Eq. 7)}$$

Therefore, after adjusting C_X,

$$k_e = \frac{k_i}{R_o} \text{ or } k_i = k_e R_o \qquad \text{(Eq. 7a)}$$

Substituting $k_e R_o$ for k_i in Eqs. 5 an 6 yields

$$e_f = e_o k_e\left(1 + \frac{R_o}{Z_l}\right) \qquad \text{(Eq. 8)}$$

and

$$e_R = e_o k_e\left(1 - \frac{R_o}{Z_l}\right) \qquad \text{(Eq. 9)}$$

With the switch in the e_f position, adjust R_X to make e_f full scale on the meter, and then switch to e_R. The meter reading of e_R (as a fraction of full scale) is then the reflection coefficient, RC.

$$\frac{|e_R|}{|e_f|} = \frac{k_e e_o\left|1 - \frac{R_o}{Z_l}\right|}{k_e e_o\left|1 + \frac{R_o}{Z_l}\right|} = \frac{\left|1 - \frac{R_o}{Z_l}\right|}{\left|1 + \frac{R_o}{Z_l}\right|} \qquad \text{(Eq. 10)}$$

Since the reflection coefficient, RC, is related to the standing-wave ratio, SWR, as

$$|RC| = \frac{SWR - 1}{SWR + 1} = \frac{|e_R|}{|e_f|} \qquad \text{(Eq. 11)}$$

The meter scale is calibrated by assuming values for SWR and calculating the relative meter deflection, e_R/e_f, to determine the position of the scale marks.

For the calibration of the forward power scale, the meter will be calibrated using R_o as the load. Under this condition $Z_l = R_o$ and the forward voltage becomes

$$e_{f\,Z_l} = e_o k_e\left(1 + \frac{R_o}{R_o}\right) = 2e_o k_e \qquad \text{(Eq. 12)}$$

Since the power is proportional to e_o^2 and thus e_f^2, let the forward-power meter reading, P_f, be e_f^2. Thus, the forward power reading is

$$P_f = e_f^2 = 4e_o^2 k_e^2 \qquad \text{(Eq. 13)}$$

Equating the meter reading, P_f, to the actual power with $Z_l = R_o$ gives the value for k_e.

$$P_f = \frac{e_o^2}{R_o} = 4e_o^2 k_e^2 \qquad \text{(Eq. 14)}$$

and

$$k_e^2 = \frac{1}{4R_o} \qquad \text{(Eq. 14a)}$$

Squaring Eq. 8 so that P_f can be obtained for all values of Z_l

$$P_f = e_f^2 = e_o^2 k_e^2\left|1 + \frac{R_o}{Z_l}\right|^2 \qquad \text{(Eq. 15)}$$

and substituting $1/4R_o$ (from Eq. 14a) for k_e^2

$$P_f = e_f^2 = \frac{e_o^2}{4R_o}\left|1 + \frac{R_o}{Z_l}\right|^2 \qquad \text{(Eq. 16)}$$

Eq. 16 gives the forward power reading for all values of R_o and Z_l. Note that when $R_o = Z_l$, $P_f = e_o^2/R_o$, the correct value for the matched condition. Using the same procedure, the reflected power reading is

$$P_R = e_R^2 = \frac{e_o^2}{4R_o}\left|1 - \frac{R_o}{Z_l}\right|^2 \qquad \text{(Eq. 17)}$$

Of primary interest is the actual power, P_A, which is delivered to the load. Assuming that the load impedance has both resistance and reactance, $R_l \pm jX_l$, the current, i_o, in the load impedance is $e_o/|Z_l|$. The power absorbed by the load is the square of i_o times the resistive portion of the load impedance, R_l.

$$P_A = i_o^2 R_l = \frac{e_o^2 R_l}{|Z|^2} = \frac{e_o^2 R_l}{R_l^2 + X_l^2} \qquad \text{(Eq. 18)}$$

If $R_l \pm jX_l$ is substituted for Z_l in Eqs. 16 and 17 (P_f and P_R), the following results are obtained:

$$P_f = \frac{e_o^2}{4R_o}\left|1 + \frac{R_o}{Z_l}\right|^2 = \frac{e_o^2}{4R_o}\left|\frac{(R_l + R_o) \pm jX_l}{R_l \pm jX_l}\right|^2$$

$$= \frac{e_o^2}{4R_o}\left(\frac{R_l^2 + 2R_l R_o + R_o^2 + X_l^2}{R_l^2 + X_l^2}\right) \qquad \text{(Eq. 19)}$$

$$P_R = \frac{e_o^2}{4R_o}\left|1 - \frac{R_o}{Z_l}\right|^2 = \frac{e_o^2}{4R_o}\left|\frac{(R_l - R_o) \pm jX_l}{R_l \pm jX_l}\right|^2$$

$$= \frac{e_o^2}{4R_o}\left(\frac{R_l^2 - 2R_l R_o + R_o^2 + X_l^2}{R_l^2 + X_l^2}\right) \qquad \text{(Eq. 20)}$$

If P_R (Eq. 20) is subtracted from P_f (Eq. 19), the result is the same expression for P_f that was obtained in Eq. 18.

$$P_f - P_R = \frac{e_o^2 R_l}{R_l^2 + X_l^2} = P_A \qquad \text{(Eq. 21)}$$

Thus, the actual power is always equal to the forward-power reading minus the reflected-power reading — for all values of load impedance.

If Eq. 11 is squared and substitutions made from Eq. 16, 17 and 19, the actual power can be obtained in terms of forward power and SWR readings.

$$P_A = kP_f \qquad \text{(Eq. 22)}$$

where

$$k = \frac{4(SWR)}{(SWR + 1)^2} \qquad \text{(Eq. 22a)}$$

Solving Eq. 11 for SWR,

$$SWR = \frac{|e_f| + |e_R|}{|e_f| - |e_R|} \qquad \text{(Eq. 23)}$$

$$= \frac{\sqrt{P_f} + \sqrt{P_R}}{\sqrt{P_f} - \sqrt{P_R}} \qquad \text{(Eq. 24)}$$

$$= \frac{1 + \frac{\sqrt{P_R}}{\sqrt{P_f}}}{1 - \frac{\sqrt{P_R}}{\sqrt{P_f}}} = \frac{1 + \sqrt{\frac{P_R}{P_f}}}{1 - \sqrt{\frac{P_R}{P_f}}} \qquad \text{(Eq. 25)}$$

Circuit Boards From Scratch

Want to add the "professional touch" to your next construction project? This article takes the neophyte step-by-step through the "positive" process for pc board fabrication.

By David R. Malley,* K1NYK

The recent increased interest in "rolling your own" construction projects has prompted many hams to start making their own printed-circuit boards. Although point-to-point wiring is sufficient for many circuits, the use of copper-clad circuit boards offers convenience, professional appearance, and ease of testing and repair, if necessary.

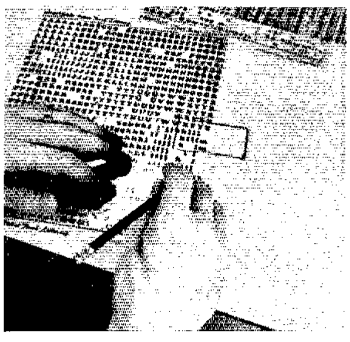
Recently, I needed to replace a diode in the rf output metering circuit of an older transceiver. After an hour or so of guessing where the wiring harness went, I found the diode quite a distance from the meter itself. This would have been a lot simpler with today's equipment that uses plug-in boards, of course. If you feel turned off to the idea of actually making these boards yourself, just read on for a while. You will probably find that it's really not difficult or beyond your ability. Remember how you felt about being able to learn Morse!

Picture Perfect

This article will deal with photo-etching and derivative methods, although you might be interested to know that silk-screening techniques are also available. There are several basic ways of making printed-circuit (pc) boards, and it turns out that printing has nothing to do with any of them! The differences between methods lie in how the acid resistant (resist) material is applied to the copper-plated board.

A simple circuit can be hand drawn on the pc board using dry transfers or resist pens. These methods allow direct etching to obtain the needed pattern without any exposing or developing steps. Many magazine construction articles offer a full-scale drawing of the copper side of the board with black representing the copper pattern that remains after etching is complete. This drawing makes the production of sophisticated layouts relatively straightforward, especially when several pc boards are necessary, as in a club project. A photographic positive or negative can be produced on a clear piece of thick plastic (transparency) from this artwork.

One positive method seems to be more popular because the transparency can be made several different ways. If you do not have access to photographic equipment and wish to avoid the expense of a commercial photographer, several companies offer products that transfer the magazine sketch directly to a clear plastic sheet. The transparency can also be made by passing the original page (preferably a quality copy) through a Thermofax machine. However, my limited experience with this machine indicates that the resulting positive often lets the ultraviolet (UV) exposure light through where it shouldn't, which ruins the final product. The



Dry-transfer letters can be used to add a personal touch to the circuit board. Some circuit patterns are also available in this format.

negative transparency can only be made photographically.

It is easy to photoetch your call, magazine article date or whatever by applying dry transfer letters and numbers on the photographic *positive*. If your method involves direct application of the resist, the above information can be applied using run-on resist-type letters and numbers.

Positively Clad

A short explanation of the difference between positive and negative photoetching might be in order at this point. In the positive process, after applying the resist to the board to be etched, the transparency is placed on top of the board and the combination exposed to a UV source. The light chemically changes the resist coating wherever the clear areas of the plastic film are. This allows the liquid developer to dissolve the resist coating. When the pc board is then etched, the copper is removed in the areas where the resist was removed.

As you might guess, somewhat the opposite occurs with the negative process. Here, light hitting the resist-sensitized board makes the coating resistant to the developer and the etchant because of the different chemical character of the negative resist.

Copper-clad (one- or two-sided) boards are available from several sources including mail-order and industrial supply outlets. These hobby products are available bare or presensitized with either type of resist. The coated boards are packaged in a black opaque plastic bag since they are light sensitive. It's a good idea to store these where the bag won't accidentally be opened. The presensitized boards are naturally more expensive and also are more difficult to locate in larger

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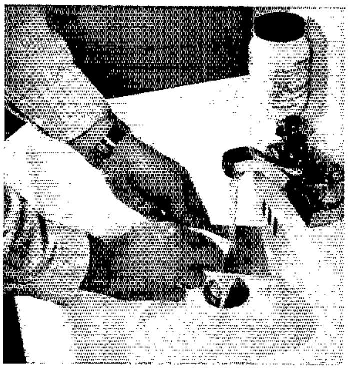
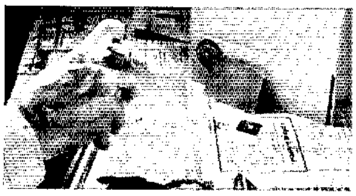


It is essential that the board be thoroughly cleaned before applying the photo-sensitive resist agent. After cleaning with a mild household abrasive cleanser, rinse under warm water for a few seconds to ensure that all traces of the cleaning agent have been removed.



Once the board is clean, handle it by the edges and immediately spray with the sensitizing agent. This is a rather messy process; use newspapers for a mat and take other precautions as you see fit.

sizes (over 6 × 6 inches or 150 × 150 mm). Consequently, I generally use the bare boards and apply a positive resist coating from a spray can sold under the GC Electronics label. Large, unetched pc board trimmings may often be obtained at low or no cost from local photoetching companies. This combination results in producing most circuit boards for under a dollar since the developer and etching chemicals are reusable many times. For those who prefer the negative method, presensitized boards and spray cans are available.

Tricky and Sticky

Taking advantage of these cost-saving techniques naturally involves being able to apply the resist correctly. This step is not as simple as using a can of spray paint. However, applying a few easy tricks should make your efforts successful.

Once you have obtained the positive, it is time to prepare the board itself. The easiest way to cut the circuit board to size seems to be with a hacksaw, assuming a large shear is unavailable. Glass epoxy boards are the better material from the end-use standpoint, although they are quite difficult to cut. Phenolic materials have a tendency to chip at the corners. These characteristics tend to discourage cutting with tools such as coping saws or paper cutters.

Proper cleaning is one of the essential steps in the process. You need a surface that water will roll off of rather than bead up on. You may have heard the term "water break-free" applied here. Some light abrasive cleaning goes a long way; I generally use a household silver-cleaning paste. Powdered household cleaners (e.g., Comet, Ajax, etc.) also work well. In either case, the pc board should be subsequently washed in soapy water and rinsed well. Now let it air dry while it stands up on a lint-free cloth (terry towel). Paper towels are bad news since they leave lint on the board. The presence of "enough" dust will cause the resist spray to bead up and form a poor coating just as if the board had not been cleaned at all. It's wise to handle the board by its edges or with rubber gloves to avoid fingerprints after cleaning. (I might suggest some discretion at this point to avoid any possibility of your spouse suggesting that you wash the dishes.)

A few tricks in applying the spray resist make a large difference in the quality of the finished product. Concerns over the ozone content of our atmosphere have rightfully prompted discontinuing the use of fluorinated-hydrocarbon propellants. However, this seems to have caused some difficulties in getting resist cans to spray properly. In spite of this, it's easy to be at peace with nature and still apply the coating. This involves warming the bottle in hot water for half a minute or so, followed by a minute or more of shaking prior to spraying.

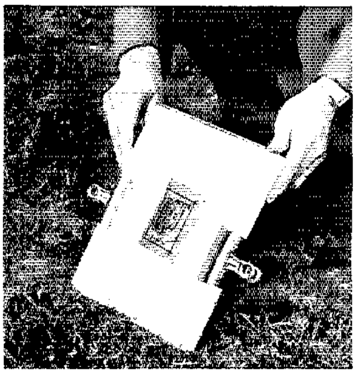
While you are spraying, the board should be in a near vertical position with the can about 12 inches away. Spray the work-piece with smooth horizontal strokes until it has been completely covered. Then lay it right down flat to keep the resist from flowing off the surface. It is important to put the board on a level surface to prevent uneven coating. A thin coating on one side might not stand up against the developer or etching solutions. I find it is important to apply a light to medium coating, let the board dry eight hours or so and apply a second coating. Applying the second coating at right angles to the first spraying direction will ensure good coverage.

The drying process may be reduced to about an hour by following the oven-drying directions on the label of the spray can. If you use the kitchen oven for this, remove the light bulb before putting the board in and be prepared for some lingering odors. Remember that the board is light sensitive once it starts to dry. Safe handling from here on involves working under a yellow bug light or equivalent.

Contact

You will need a way to hold the artwork

After coating the board with the sensitizing agent, move it to a convenient, warm, dry and dark place for several hours to let it dry thoroughly. As soon as the agent is sprayed onto the board, it is light sensitive; handle by the edges and avoid direct light.



Exposing the photosensitive board. The homemade contact printer consists of a sheet of glass that holds the positive and the circuit board in place. A sheet of Styrofoam and a rigid sheet of fiberboard serve as the backing. The large paper clips hold the printer together.

tightly against the copper-clad board to keep light from getting underneath the transparency and undercutting the pattern. Contact printers are commercially available for this purpose, but the one shown in the photo is just as effective and costs under a dollar. Paper clamps are used to press the board and artwork together between the glass plates. The styrofoam provides some cushioning to protect the glass.

Photoetching could turn out to be your first solar-powered project! That is, if you use sunlight to expose the resist. The sun is a strong source of UV radiation and sure beats buying a special $35 light. It is important to expose the board during periods of bright sunlight, as cloudy or hazy days are less satisfactory. Of course, if you live in New England as I do, you may have to wait to get a sunny day!

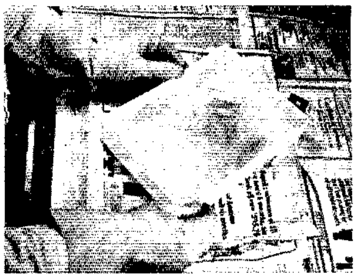
My experience indicates that the board should be exposed for longer times than usually specified in the commercial literature. I typically use about a 15-minute sunlight exposure. Shorter times seem to incompletely polymerize (chemically convert) the positive resist. This ultimately results in not being able to remove all of the unwanted copper. The longer exposure time is one factor in why the Thermofax positives don't seem to work out satisfactorily.

The developer you use should be the one supplied by the same company that made the resist itself. This avoids incompatibility problems and variations in solution concentrations. You probably have realized by this point that the type of developer used (positive or negative) must match the resist type used. As with the exposure step, my best results are obtained with longer developing times than those in the manufacturer's literature. A three- to four-minute time seems satisfactory for the positive spray resist. Part of the reason for the longer time is that two resist applications were applied to the copper clad board.

It's What Develops That Counts

The board should be immersed coating side up in a developer and gently moved back and forth for the time mentioned. After the first 1 to 2 minutes, lightly brush the board's surface with a cotton swab to help remove the unwanted coating. Remove the board from the solution and wash it gently under cold and then warm water for a minute or so. Now the board is no longer light sensitive and the complete circuit should be visible. Any minor breaks in the pattern can be repaired easily at this point with a resist pen. In case there happens to be a lot of bad areas, the board can be solvent cleaned (acetone, lacquer thinner, etc.) and recoated. Positive developers can be used and stored in plastic or glass containers, and rubber gloves are recommended when using them.

Ferric chloride is the most common etchant used for this work. Although this chemical will not burn the skin, it can



With the etching process nearly completed, the circuit is clearly visible. Notice that the author is protecting his hands from the etchant by wearing rubber gloves.

stain it, so gloves are a good idea. Plastic or glass trays and bottles can also be used safely with ferric chloride. I place the tray of etchant in a sink filled with shallow water since this allows the board to be washed easily. The etchant level should be about 1/4 inch above the board, which is placed copper side up. Gentle agitation is used to wash away the dissolved copper. When all the unwanted copper has been dissolved, the board should be promptly removed and well rinsed. A new bottle of etchant normally takes about 10 to 15 minutes to do its job and can etch several boards before being discarded.

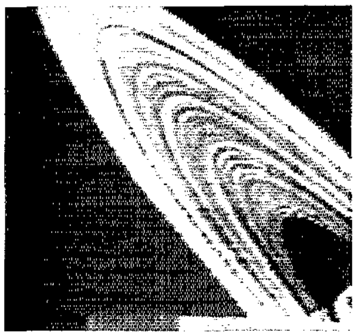
A no. 60 or 66 drill bit will work well for nearly all component lead holes and serves as a good pilot drill for the larger holes (such as ac line cords). These drills should only extend about 1/4 inch past the chuck to keep them from breaking. High-speed drill motors are best but good results can be obtained with either hand or portable drills. Note that the copper pattern on the board is still covered with the resist, which must be removed before soldering. Rubbing alcohol will work nicely. I find that rubbing the pattern lightly with a steel wool pad also helps the solder flow well.

There are several techniques that will keep the copper pattern from tarnishing with time. Sometimes this can become a problem if you're working with rf circuits. A rather tedious method is to tin the entire pattern with solder; the simplest method involves spraying the completed and tested circuit using spray cans available commercially for this purpose. The drawback with the latter technique is that any eventual repairs will necessitate removing all of the sprayed material wherever soldering is to be done. Immersion tin plating can resolve these problems; the solution involved is available from most industrial supply outlets. A word of caution, however: This chemical can cause severe burns. If you are unfamiliar with handling such materials, I would suggest one of the alternate methods.

Closing Comments

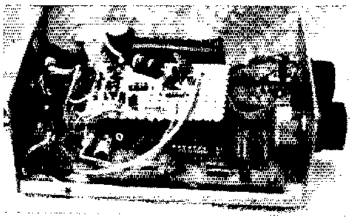
There you have the ingredients for producing a professional-looking circuit board for your latest project. As mentioned at the beginning of the article, it isn't a difficult task. And once you try it, I doubt that you will want to go back to the old point-to-point method for anything but the simplest of circuits. Home construction has been growing by leaps and bounds lately and pc board fabrication seems to be a part of the reason for it. I hope that this article has helped to reduce any hesitation you may have had to jump in and enjoy this aspect of Amateur Radio. Good luck! QST

Strays



While most of the world had to wait to get a glimpse of Saturn, amateurs worldwide were viewing slow-scan television pictures of live Voyager 1 transmissions moments after they beamed in to scientists at the NASA Jet Propulsion Laboratory in Pasadena, California. The SSTV pictures, like these received at ARRL's operators' club station, W1INF, were sent out by members of the JPL ARC, W6VIO, on 20, 15 and 10 meters at 14.235, 21.340 and 28.680 MHz to commemorate the Voyager 1 flyby of the ringed planet in mid-November. From left to right: JPL club station SSTV CQ; a view of Saturn showing two of the planet's 10 moons, Tethys and Dione (lower left), and a close-up of Saturn's intricate sets of rings.

Accu-Control — A QSK System for the Kenwood TS-820/R-820 Twins



Smooth and fast, this QSK system is adaptable to other equipment combinations as well. It's a sure-fire way to add to your cw operating enjoyment!

By Michael R. Joyce,* N6ML

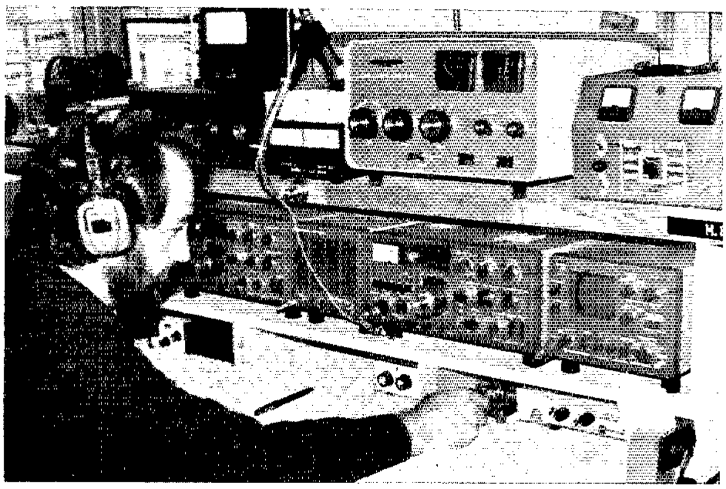
The Kenwood TS-820S is one of the more popular, dependable and admired rigs produced in the history of Amateur Radio. A testament to the TS-820 design is that few modification articles for it have been published. On-the-air reports leave the impression that this rig can do everything an amateur desires an hf rig to do, except . . .

Kenwood must have sensed that for a few serious amateurs, a high-quality transceiver alone would not be enough. The R-820 receiver was developed to fill that gap. Lab tests show that it is certainly one of the finest receivers ever marketed for the amateur fraternity.[1] The R-820, compatible with the TS-820, can do everything an amateur desires an hf receiver to do except . . .

"Well, except what?" Except there are no provisions for full-break-in operation (QSK) with either the transceiver alone or the transceiver/receiver combination. In fact, a Kenwood representative in California informed me that Kenwood considered QSK very difficult to implement and not an essential feature for the average amateur. So there was no justification for the additional work involved in adding QSK. The Kenwood representative had no QSK modification suggestions for the '820 twins.

What is QSK?

At this point, a definition of QSK is in order. My research of Amateur Radio literature of the last 25 years, and testing of commercially manufactured equipment designed for QSK, revealed a great disparity with regard to QSK parameters. For the purpose of this presentation, QSK shall be defined as the ability to hear one dash of S1 strength (as measured on the R-820 S meter) while transmitting a continuous string of dots at 30 wpm. Terms such as semi-break-in, slow QSK and VOX break-in shall be considered contradictions or misnomers. The system shown here is designed to permit QSK operation with the '820 twins in a full-



With Mike at the key [uh-oh! — Ed.], the Kenwood twins are ready for action. QSK? R BK.

*2234 Shelby Dr., Melbourne, FL 32935

[1]Notes appear on page 36.

transceive configuration.

System Requirements

To achieve QSK operation, a modern amateur station must meet the following requirements: The transmitter has to be free of clicks, chirps and backwave; it must not generate "white noise" and, preferably, the final amplifier(s) will be biased to cutoff (zero plate current). The linear amplifier must also comply with the biasing and "white noise" requirements demanded of the transmitter. The receiver must be able to recover immediately from muting and/or overload caused by the operation of the nearby transmitter. A sidetone monitoring system is desirable. Lastly, the T-R switch must switch the receiver into and out of the transmission line circuit immediately, not affect signal strength and, preferably, be silent in operation.

The Transmitter

Although the TS-820 has excellent cw keying, a backwave is present on the 20-, 15- and 10-meter bands, and the final amplifiers draw a resting plate current of 55 mA. The usual argument for biasing the final amplifiers to cutoff is that it eliminates "white noise" generated by the heat in the tubes. During tests at N6ML, no perceptible noise was detected from a variety of commercial and homemade transmitters and amplifiers that drew idling plate current; all had solid-state rectification in the power supply. It would initially appear that cutoff biasing to eliminate "white noise" is today more a matter of style and is more academic than absolute necessity. Not so! Two definite advantages are to be obtained: A reduction in the amount of heat produced (adding to tube life) and attenuation of backwave. By installing a transistor switch in the TS-820 to key the screen voltage of the final amplifiers, the plate resting current is reduced to zero (as read from the front panel meter) and the backwave is eliminated.[2]

The Linear Amplifier

The linear amplifier used at N6ML is a Heath SB-220 modified by adding electronic bias switching and a STANDBY/VOX-PTT CONTROL/TRANSMIT switch (see Fig. 1).[3,4,5] The electronic bias switch provides all of the benefits stated by Bryant. Previous articles described the usefulness of the STANDBY switch addition to the '220. This is further enhanced by providing an extra switch position, TRANSMIT, whereby the linear amplifier control relay is energized continuously and independently of the TS-820. This frees the TS-820 relay to be used to control the station Accu-Keyer during tune-up and ssb operation.

The Receiver

The R-820 has an excellent i-f derived, fast-attack agc system, but recovery is too slow for QSK. Receiver muting is accomplished by applying a negative bias to gate 2 of the dual-gate MOSFETs used as the rf and i-f amplifiers and mixers (see Fig. 2). For the receiver to be muted, the TS-820 T-R relay must be activated. This in turn switches 12 volts dc to activate RY1 in the R-820, removing the 9 volt source on line RLR and causing line RB (the biasing line of the MOSFETs) to go negative.

To monitor sending, the operator engages the MONITOR switch, which activates RY2. RY2 disconnects the antenna from the receiver, connects a dummy load to the receiver input, the partially activates the receiver by turning on the i-f amplifiers while maintaining the rf amplifier, buffer amplifier and first mixer at cutoff. Jack Gachesa, W6SCH, contends that the R-820 would be a good candidate for the "Relay Hall of Fame"! A transistor switch must be added to replace the slower mechanical relay to meet our QSK requirements. Although the operating and service manuals of the R-820 make no mention of providing a sidetone input, pin 15 of the remote connector (ST-1) serves this purpose.

The T-R Switch

T-R switching can be handled effectively by a vacuum or reed relay system,[6,7,8] conventional electronic T-R switch,[9,10] PIN diodes[11] or diode switching.[12,13,14] All of the above methods were tried at N6ML, excluding the PIN diode switch.* The method used is a diode switch based on designs by Hildreth and Hitchcock. This method offers the following features: It is quiet; it involves no amplification or rf rectification; it is inexpensive; it provides excellent isolation; it eliminates the need for modification to the linear amplifier (if used) or transceiver; it is installed at a low rf voltage point in the system; it can be used with a separate receiving antenna; it is easily controlled by the logic circuits of modern keyers; and it is compact.

Control System

Muting the receiver, keying the screen voltage of the transceiver and activating the T-R switch requires a control system. The Accu-Keyer seemed to be the logical (no pun intended) choice.[15] In keeping with the various "monickers" of changes and accessories for the Accu-Keyer (Accu-Memory, Accu-Stop), I call this QSK feature Accu-Control. The control board addition to the keyer is shown in the top photo on page 32.

The basic Accu-Keyer circuitry is unchanged; an internal ac-operated power supply is used at my station. See Fig. 3. A

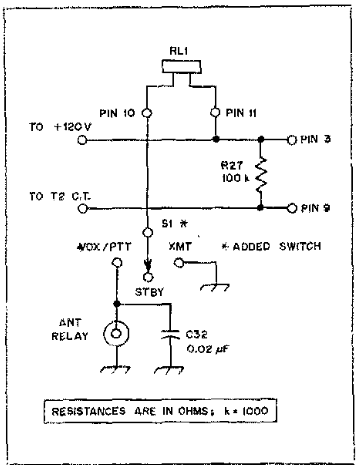


Fig. 1 — The Heath SB-220 linear amplifier is modified to include bias switching (not shown here — see text) and a standby switch. The switch is a Radio Shack spdt center-off type (275-653). Component designations are those of the manufacturer. Pin numbers are those of RL1.

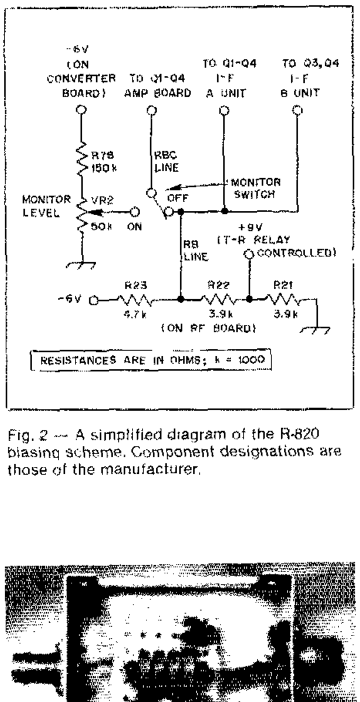
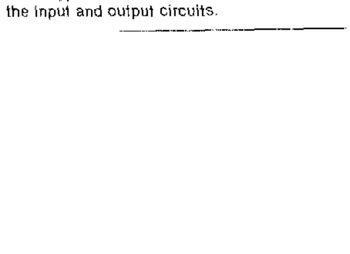


Fig. 2 — A simplified diagram of the R-820 biasing scheme. Component designations are those of the manufacturer.



The simple T-R switch is enclosed in a small utility box. To prevent incorrect cabling, different types of coaxial connectors are used for the input and output circuits.

*Editor's Note: An article related to PIN diode T-R switching is planned for appearance in the March issue of QST.

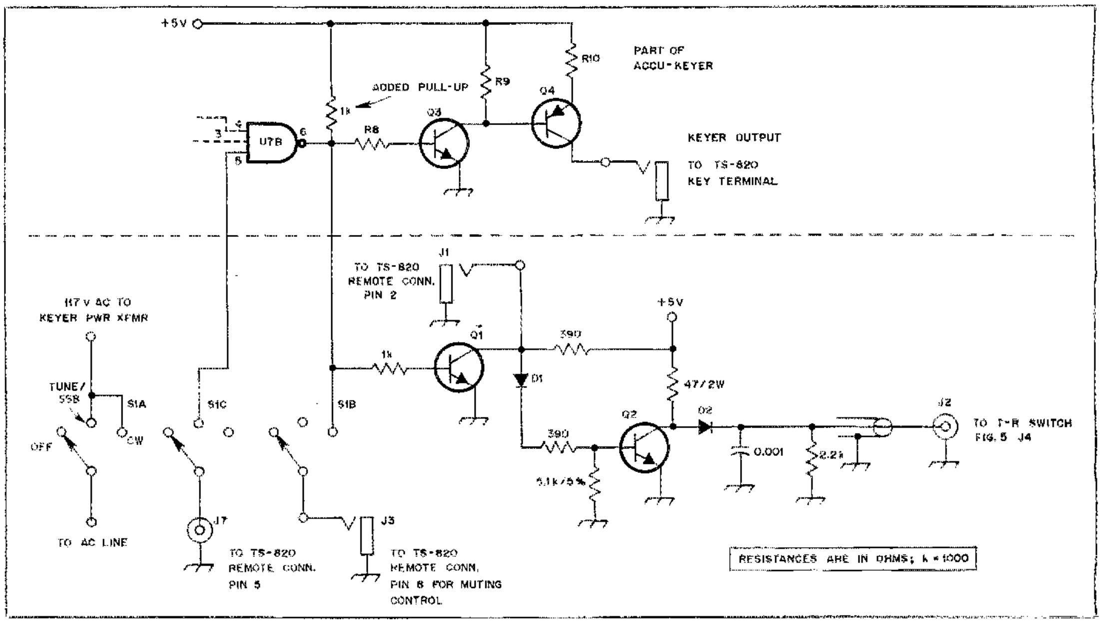


Fig. 3 — The Accu-Control circuit. The portion of the circuit above the dashed line is part of the original Accu-Keyer circuitry. A 1 kΩ pull-up resistor is added between the junction of U7B and R8 and the +5 volt line. All resistors are 1/2 watt unless otherwise specified.
D1, D2 — Silicon, 1 A, 600 PIV, 1N4004 or equiv.
J1, J3 — Miniature jacks.
J2, J7 — Phono jacks.
Q1 — Silicon npn switching bipolar transistor, 500 mW, 2N2222A or equiv.
Q2 — Silicon npn audio power bipolar transistor, 50 W, TIP31 or equiv.

3-pole, 3-position rotary switch (S1) replaces the ON/OFF toggle switch. S1A turns on the power supply during TUNE/SSB and CW conditions. S1B provides control of the receiver muting switch; when S1 is in the OFF or TUNE/SSB position, the receiver muting function is relay controlled. S1C grounds the manual key input to U7B pin 5 in the TUNE/SSB position through the TS-820 relay. A 1 kΩ pull-up resistor is added at the output of U7B pin 6. Q1 is used as an inverter. In the Accu-Keyer, U7C is unused and could replace Q1 if desired.

As shown in Fig. 4, Q3, Q4 and Q5 form the final-amplifier screen-voltage switch. When Q3 conducts during key up (Q4 and Q5 off), the 100 kΩ collector resistor reduces the screen voltage to +4 volts. When Q3 is turned off, Q4 is self-biased, turning Q5 on. Note that when this screen switch is disconnected from Q1 control, the switch self-biases and the TS-820 operates as though it were unmodified; ideal for operation of the transceiver alone.

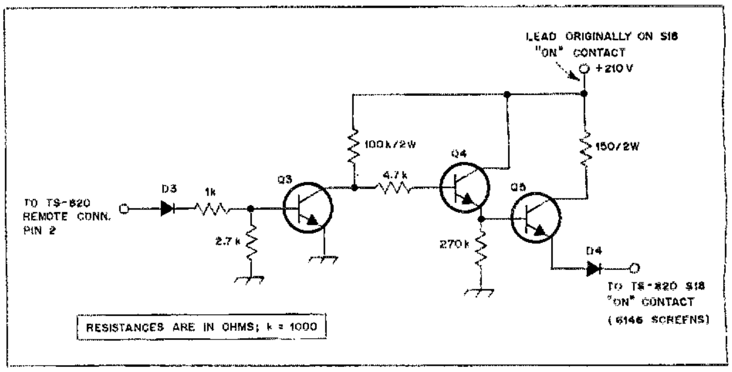


Fig. 4 — A solid-state screen switch for the TS-820 power-amplifier tubes. D4 is necessary only if the screen-switch circuitry is mounted outside the TS-820 chassis and cabled into the screen circuit; it acts as a safety device to prevent damage should the cables be reversed. All resistors are 1/2 watt unless otherwise specified.
D3, D4 — Silicon, 1A, 600 PIV, 1N4004 or equiv.
Q3-Q5, incl. — Silicon npn high-voltage audio power bipolar transistor, 300 V, MJE340 or equiv.

Q1 of Fig. 3 also controls the T-R switch of Fig. 5. When Q1 goes low, Q2 is turned off. This forward-biases D5, placing the junction of the choke, diode and two capacitors virtually at rf ground. This grounds the antenna-input circuit to the R-820. Diodes D6, D7 and D8 provide protection in case the biasing system fails. During initial testing, the logic control was not connected because of an operator oversight; no damage was sustained in the presence of 700 watts of rf power output!

QSK muting is performed by a switch (Fig. 6) composed of Q6 and Q7. Q7 is self-biased on through a 10 kΩ resistor, permitting +9 volts from the RLR line to bias the receiver to the operating mode via the RB line. When a logic voltage greater than +3 volts appears, the base of Q6 becomes positive with respect to the emitter and Q6 saturates. The base of Q7 is now negative with respect to its emitter and Q7 is off. When the logic voltage drops to less than +3 volts, Q6 turns off and Q7 turns on. This action is delayed 6 ms by the time constant of the RC network in the base lead of Q7. The receiver

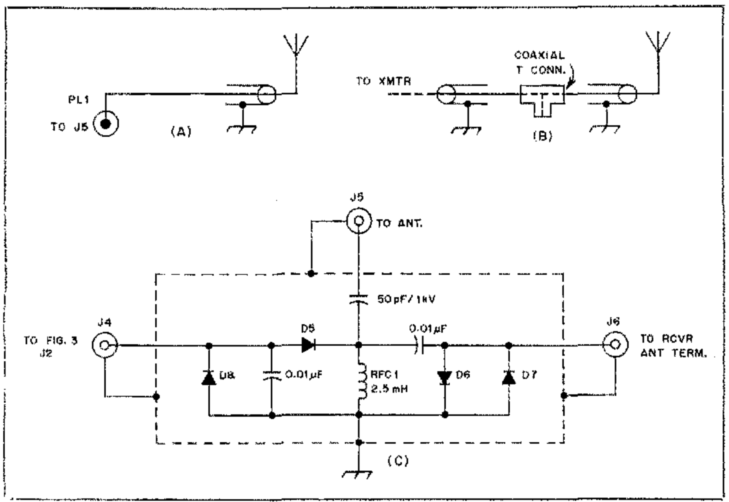


Fig. 5 — The T-R switch. At A, interconnections for using separate antennas on the receiver and transmitter. For use with a common antenna, the connections shown at B should be used.
D5-D8, incl. — Silicon, 1A, 600 PIV, 1N4004 or equiv.
J4 — Phono jack.
J5 — Type N or UHF chassis connector to mate with T connector.
J6 — Type BNC (or other) chassis-mount connector chosen to prevent confusion with J5 when interconnecting units.

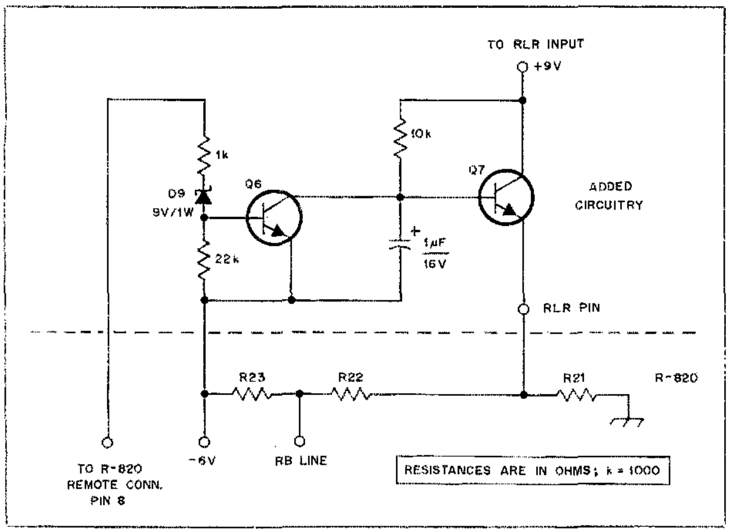


Fig. 6 — The R-820 muting switch. Components below the broken line are part of the R-820. All resistors are 1/2 watt.
D9 — 9-V, 1 W Zener diode (Radio Shack 276-562 or equivalent).
Q6, Q7 — Silicon npn switching bipolar transistor, 500 mW, 2N2222A or equiv.

is muted before rf is generated by the transceiver and remains so until a few milliseconds after the rf disappears. Since the cutoff bias is not applied to the agc bus, the S-meter needle rests in the S0 position. The resulting receiver muting action is the fastest and smoothest ever experienced at my station.

Construction

No drilling or defacing of the '820 twins is necessary. By disconnecting leads from the terminal connectors in accordance with the manufacturer's instructions, circuits are installed using wire-wrap techniques on the connector pins and leads. This procedure makes it easy to return the twins to their original condition when trade-in time arrives.

Perfboard and point-to-point wiring may be used during construction. Terminal pins simplify board-to-board connections. The control board is stacked above the main Accu-Keyer board and they are housed in a Radio Shack chassis (270-252). The T-R switch board is mounted in a 2-3/4 × 2-1/8 × 1-5/8-in. (70 × 54 × 44-mm) box (Radio Shack 270-235) and attached to the SB-220 rf output connector by means of a coaxial T connector.

TS-820 Modifications

While this QSK system works just as well in the VFO transceive mode, factory-documented modifications for full transceive operation and anti-VOX operation with the R-820 should have been made previously. The screen switch board is placed beneath the final amplifier board of the TS-820. It is inserted into the final amplifier screen circuit at the +210 V terminal of the screen voltage ON/OFF switch (S18), which is located on the rear panel of the TS-820. Control wiring for the screen switch is brought in from an unused pin on the 8-pin accessory socket. Installation of a sidetone output jack is required. See Fig. 7.

If you do not wish to drill a hole in the rear panel of the TS-820, the RTTY input jack may be unscrewed and taped up, and a closed-circuit phone jack installed there. I preferred to drill a small hole next to the ac power connector, and installed a miniature closed-circuit jack there. The shielded leads to and from this jack may be either tack-soldered to the proper points or wire-wrapped on the pins of the card. Be sure to remove one end of cable ST from the circuit. Installation of the foregoing circuitry does not affect final-amplifier neutralization or any other transceiver adjustments.

R-820 Modifications

The FAST agc time constant must be speeded up. This can be accomplished by tacking a 180 kΩ resistor in parallel with R40 on the IF-B board. There are two alternatives that provide greater control. The first is to replace R40 with a 5 MΩ potentiometer in series with a 50 kΩ resistor; then mount it in place of the VFO/FIXED CHANNEL switch on the front panel. The VFO/FIXED CHANNEL switch may be taped up and tucked out of the way until you are ready to restore the receiver to its original condition. The other alternative is to use the VFO/FIXED CHANNEL control to switch in various fixed resistances as shown in Fig. 8. This is the method used in my receiver.

Transceive operation and muting control require the following modifications:

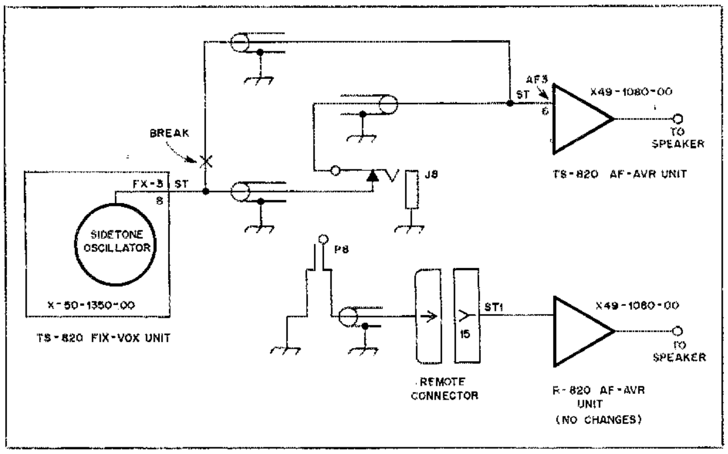


Fig. 7 — Sidetone-oscillator modification for the TS-820. J8 and P8 may be a compatible miniature jack and plug or standard 1/4 in. (6.4 mm) types if the TS-820 RTTY jack mounting hole is used; see text.

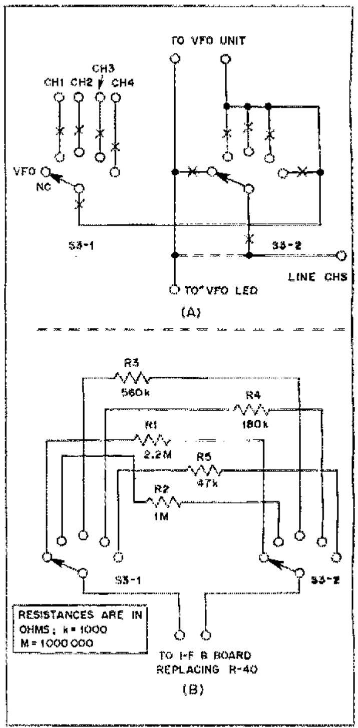


Fig. 8 — A diagram of one alternative method of modifying the R-820 VFO/FIXED CHANNEL switch. At A, the connections are broken at the points marked X. Fixed-value resistors are then connected between the various switch positions as shown at B. Resistors are 1/2 watt. The switch designation is that of the manufacturer.

1) Remove the lead going to MRL-4 on the converter board. This deactivates relay RL-2.

2) On the relay board, short pins 2 and 3 together by wrapping a wire around them and reinserting connector RL-3. (These pins are designated TCB-2 and RCB-3.) This action defeats the STANDBY function while in the MONITOR mode.

The muting switch is installed on a 2 in. (51 mm) spacer next to the rf amplifier board. A wire is soldered to pin 8 of the remote connector and to the logic input of the board. A connection is wire-wrapped to pin 3 (−6 V) of the rf amplifier board and then soldered to the −6-V input of the switch. The RLR wire is removed from the connector according to Kenwood instructions. This wire is then connected to the RLR input of the switch. The RLR output of the switch is wire-wrapped to the RLR pin of the rf amplifier board.

Operation

For ssb operation of the '820 twins, place the Accu-Keyer in the TUNE/SSB position, the linear amplifier (if used) in the TRANSMIT position and the MONITOR switch of the R-820 off. Your on-the-air ssb signal may be monitored by means of the TS-820 monitor function.

Cw QSK operation of the twins is accomplished by placing the Accu-Keyer in the ON position and the TS-820 in TRANSMIT (note the absence of a plate-current indication on the meter). The R-820 may be switched to either TRANSCEIVE or SEPARATE. In the TRANSCEIVE position, the VFO SELECT switch operates as follows: NORM — TS-820 VFO: RX — R-820 VFO; TX — TS-820 VFO; and REV — R-820 VFO. In the SEPARATE position, each unit uses its own VFO. Finally, place the MONITOR switch of the R-820 in the on position and the AGC switch to the FAST or OFF position.

VOX keying is obtained by putting the twins into the QSK mode, except the TS-820 should be in the VOX mode and the R-820 MONITOR switch should be turned off. During such operation, the VFO SELECT switch operates normally.

Comments

QSK operation of the '820 twins is incredibly smooth and fast-acting. The Accu-Control can be used with other rigs such as the Collins S-line (with the 32-S transmitter modified) and the Drake 4-line (no modifications necessary).[16] Additionally, the TS-520 (S, SE) used in VFO transceive with the R-820 works beautifully — don't forget to key the screens of the '520.

It's a good idea to purchase the TS-820 and R-820 service manuals; they may be ordered directly from Kenwood.[17] The operating manuals leave out much detail that is useful to the tinkering amateur. Addition of the sidetone output to the TS-820 is useful — it permits greater flexibility when using the TS-820 on cw with an external receiver.

The filter complement of my R-820 consists of the 500 Hz and 250 Hz second-i-f filters and the standard 2.4 kHz ssb filter in the first i-f. As a substitute for the Kenwood first i-f 500 Hz cw filter, I use the 400 Hz filter sold by the Fox-Tango Club.[18] My R-820 has a continuously variable i-f bandwidth tuning range from 100 Hz to 2.4 kHz.

I would like to thank Jack Gachesa, W6SCH, for his fatherly patience and technical advice. Thanks also go to Art Brittingham, W4MPT, for his constant reminder that "a lot of good will come from this!" QST

Notes

[1]Rusgrove, "Trio-Kenwood R-820 Receiver," *QST*, July 1979.
[2]Wade and Hallock, "CW Break-In for the Collins S-Line," *QST*, September 1970.
[3]Bryant, "Electronic Bias Switching for RF Power Amplifiers," *QST*, May 1974.
[4]Gleszer, "Upgrading Your SB-220 Linear Amplifier," *QST*, February 1979.
[5]Rolek, "For the SB-220," Hints and Kinks, *QST*, July 1979.
[6]Pluess, "A Fast QSK System Using Reed Relays," *QST*, December 1976.
[7]McKinley, "A New High-Powered Keyed Antenna Relay," *QST*, August 1967.
[8]Klinman, "A Vacuum Relay-TTL QSK Antenna Switch," *CQ*, July 1976.
[9]Rusgrove, DeMaw and Grammer, "Transmitting Accessories," *Understanding Amateur Radio*, 1977 edition.
[10]*The Radio Amateur's Handbook*, 1980 edition.
[11]Boomer, "Pin Diode Transmit/Receive Switch for 80-10 Meters," *Ham Radio*, May 1976.
[12]Hildreth, "More on Instant Voice Interruption," *QST*, June 1972.
[13]Hitchcock, "Syllabic VOX System for Drake Equipment," *Ham Radio*, August 1976.
[14]Hildreth, "Syllabic VOX System for the Collins S-Line," *Ham Radio*, October 1977.
[15]Garrett, "The WB4VVF Accu-Keyer," *QST*, August 1973.
[16]Klinman, "Full Break-In With the Drake T4XC-R4C Using the Vacuum Relay QSK," *CQ*, March 1980.
[17]Trio-Kenwood Communications, Inc., 1111 West Walnut, Compton, CA 90220.
[18]Box 15944H, West Palm Beach, FL 33406.

Add-Ons for Greater Dipper Versatility

Your dip oscillator may be in for a new ball game! These simple gimmicks and gadgets extend its usefulness and improve dial accuracy.

By Robert H. Johns,* W3JIP

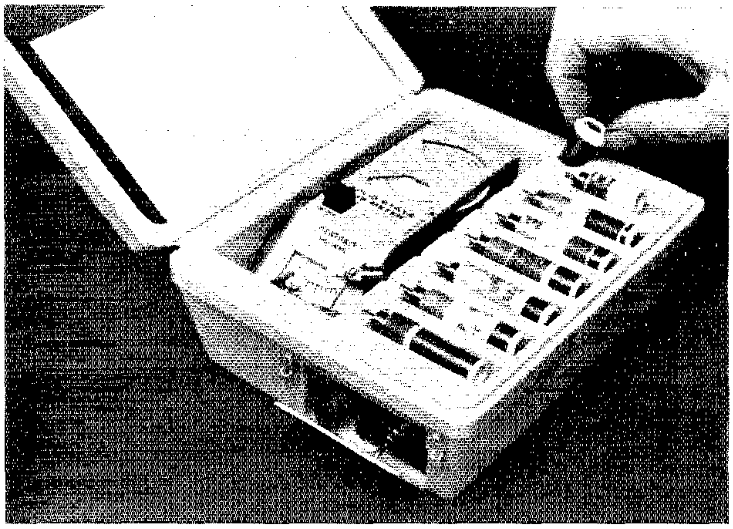
Simple accessories can be added to your dip oscillator for increased usefulness. They do not require any modification of the basic instrument. All are "outboard additions" that complement the original equipment by providing improved dial accuracy and a means for capacitance coupling to inaccessible circuits. Furthermore, the add-ons make tuning easier by slowing the dipper tuning rate, an advantage when the device is performing as a signal generator. Another benefit is provision of convenient connections and components for measuring inductance and capacitance.

The accessories described apply directly to the Heathkit HD-1250 dip meter. The ideas, however, may be applied to other models, too.

Accuracy

I found the dial calibration surprisingly accurate, especially for a kit. Dipper scales are never exact, and no one expects them to be. As I prepared a chart of how many kilohertz to add or subtract from the dial indication, I noticed that each amateur band required the use of a different coil except for 15 and 20 meters. The thought came to mind, "Why not adjust each coil so that it is 'right on' for the bands where the dipper is used most?" Not wishing to modify the coils themselves (they are nicely encased in plastic), I trimmed the inductance of each by the addition of tiny amounts of core material, either powdered ferrite or chips of copper.

First, I listened to the dipper on a calibrated receiver to determine the correction needed. If the dipper indicated 6.9 MHz when the receiver is getting the signal at 7.0 MHz, the coil is too small



The case of the Heath HD-1250 dip meter has plenty of extra space for accessories that belong with the dipper. A photocopy of the *Handbook* "L and C vs. frequency" graph is taped to the lid. Loose wire additions such as the capacitance probe and the phono jack are tucked in the instrument compartment. The door cut in the side permits access to the space under the coil tray for the plastic box and other coils. Solder lugs held by small hardware hold the door closed. The 5-μH standard coil has a plastic hat, white silicone rubber caulking compound, which prevents it from slipping through the mounting hole to the right of the dipper coils.

(too much C needed to resonate it at 7.0 MHz). This means a little more inductance needs to be added, which can be done by inserting pieces of ferrite from a junk-box coil. See Fig. 1. Use a hammer or pliers to break up the ferrite. Before adding the ferrite powder, plug the coil with some sort of plastic that will harden. Fill to a depth of 10 mm (0.4 inch) inside the coil form. Silicone rubber caulking or bathtub sealant has good electrical properties. Either makes a good embedding medium for the ferrite and can be dug out of the coil form if you later decide to remove it. As you add powder and little bits of ferrite, they stick in the silicone. You can follow the frequency change with your receiver and add inductance until both read the same frequency. Make sure that the dipper coil is plugged all the way into its socket since the capacitance involved at this point is part of the tuned oscillating circuit. Otherwise, a little slip will throw off the exact calibration you are aiming for.

Should the coil be too large (the dial

*R. H. Johns-Scientific Instruments, 3379 Paper Mill Rd., Huntingdon Valley, PA 19006

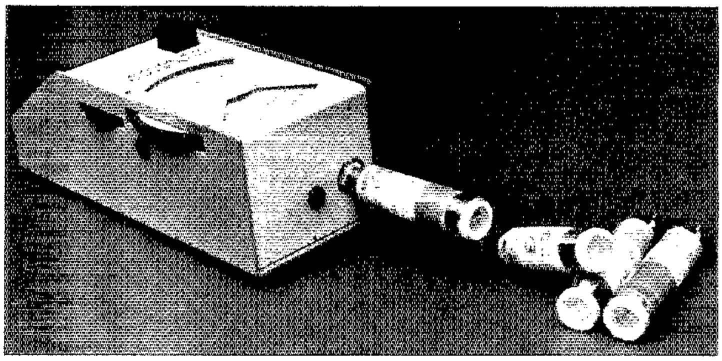


Fig. 1 — The Heath dip meter with plug-in coils. The silicone rubber that may be seen inside the coil has ferrite dust or copper chips embedded in it to trim the coil's inductance so that the dipper reads correct frequencies on amateur bands.

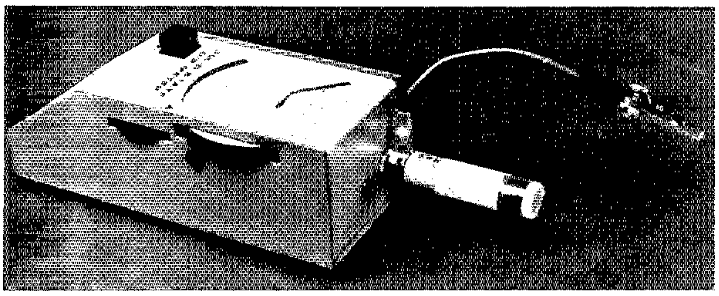


Fig. 2 — The capacitance coupling probe. The clip lead is connected to the circuit under test and is coupled to the dip meter through the small capacitance between the insulated collar and the phono plug of the coil.

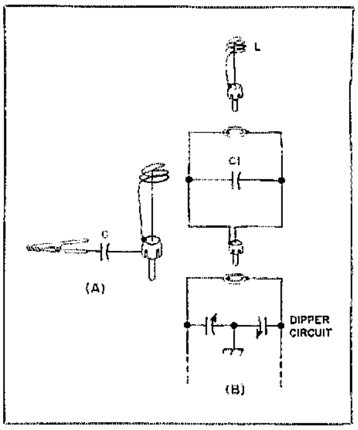


Fig. 3 — At A is shown the coupling capacitor, C, connected between the clip and the coil. Actually, this capacitor is simply the capacitance between the phono plug outer sleeve and the aluminum collar that fits around it but doesn't touch it. At B, a 150-pF or 100-pF capacitor, C1, is connected in parallel with the plug-in coil, L, and also the balanced tuning capacitors inside the dip meter. The capacitors are mounted in a plastic box and connections made by plugging the box in between the coil and the dipper.

indicating 7.1 MHz when the receiver is set at 7.0 MHz), the inductance may be decreased by placing small chips of copper in the coil. Each one acts as a shorted turn of a transformer secondary where the dipper coil is the primary. Cut pieces about a millimeter (0.04 inch) long from heavy copper wire and add them a few at a time to the silicone plug in the coil form. When enough core material has been added to a coil, squeeze some additional silicone into the coil form to cover and secure it. The silicone will set overnight and is easier to trim with a sharp knife than by trying to smooth out the uncured sticky stuff.

There is a little compromise concerning the 15/20-meter coil. That compromise in calibration amounts to the width of a calibration line. In other words, the calibration is about 1 mm (0.04 inch) off. That's very good, however.

Capacitance Coupling

After reading the recent article by Fred Brown, W6HPH,[1] I thought that I would try capacitance coupling to an unknown circuit as he describes. I agree with his conclusion that it works very well. I'm sorry that I did not know about this years ago! With capacitance coupling, you can dip an unknown circuit without having to place the dipper physically next to it so that the coils couple magnetically. The unknown can be a toroid or an LC circuit below a chassis or in a tight place. A single wire is clipped to the unknown and then lightly coupled (a few picofarads) to one side of the dipper tank circuit. A "no-holes" modification for the Heath dipper is accomplished by wrapping a turn or two of the insulated single wire around the outer surface of the phono plug of the dipper coil. This outer surface of the phono connector is not a ground. Rather, it is one side of the balanced oscillator circuit.

A more stable capacitance probe is shown in Fig. 2. An aluminum ring is bent and shaped to be a snug slip fit around the phono plug. The single wire is connected and black electrical tape wrapped around the ring for insulation. The capacitance between this ring and the phono plug is enough to couple the unknown circuit to the dipper so that a nice dip is observed at resonance. The ring may be cut and bent from aluminum sheeting, but I made the one shown from aluminum tape of the type sold in automotive stores. It can be cut with scissors, works easily and can be folded into layers to become as thick as desired. There are many uses for it in the ham shack.

This capacitance probe also provides uniform coupling to a circuit when measuring its Q, as suggested in the Heath manual. In brief, one measures the rf voltage across the test circuit and notes the change in frequency between the 3-dB-down points, where the voltage falls to 0.707 times the peak voltage. The Q of the unknown circuit is equal to the center frequency divided by the bandwidth. This measurement of Q with a dipper was new to me. It works out very well, provided that the coupling between the dipper and the unknown circuit is kept constant. The bandspread provided by the next circuit addition is also a help in measuring the 3-dB bandwidth since these frequencies are quite close together for high-Q circuits in the hf range.

Signal Generator

Although use of a dip meter as a signal source for an impedance bridge or as a signal generator in receiver work is common, the fast tuning rate is a handicap. It is tricky to get a dipper to stop in the passband of a receiver. Since the amateur bands are at the low end of the tuning ranges of the Heath dipper, a simple way to slow down the tuning rate is to add a capacitor in parallel with the tuning capacitor in the dip oscillator as shown in Fig. 3. No change need be made to either the dipper or the coil if the capacitor is placed between them. Placement must allow the coil to be plugged into the capacitor box and the capacitor box plugged into the instrument. With the 150-pF

[1]Brown "A 1980 Dipper," *QST*, March 1980, p. 11.

padder in the circuit, the normal tuning range of the dipper from about 15 pF to 70 pF becomes about 165 to 220 pF. Accordingly, the frequency of the oscillator is both lower for a given coil and does not change over such a wide range. The green coil of the Heath dipper, which tunes from 12.5 to 26 MHz, oscillates from 6.7 to 7.7 MHz with the 150-pF capacitor in parallel with it. This capacitor serves to spread out the bands, 160 through 10 meters. The 50-pF capacitor gives 15- and 17-meter coverage with one coil and 30-meter coverage with another.

Capacitors, phono plugs and jacks are mounted in a small plastic box with the bandspread calibrations shown on the outside (Fig. 4). The calibrations are marked on colored tapes (Radio Shack 64-2340) that correspond to the colors of the coils. Which way to plug the box in is taken care of by the calibration scales; when you read the 40-meter scale, the box is plugged in with the proper capacitor connected.

The oscillator stalls at the high ends of the 160- and 80-meter ranges, probably from lack of feedback. This is easy to recognize, for the meter drops to zero and restricts the ranges only a little.

With the modification indicated, the dipper signal is easy to tune in on a receiver. Also, the Δf for Q measurements in or near the ham bands is easier to estimate from the bandspread scales, despite the inaccuracies in reading the calibration through the logging scale. The measurement of the rf voltage across the unknown circuit is made easier by using a digital voltmeter and a simple probe. The

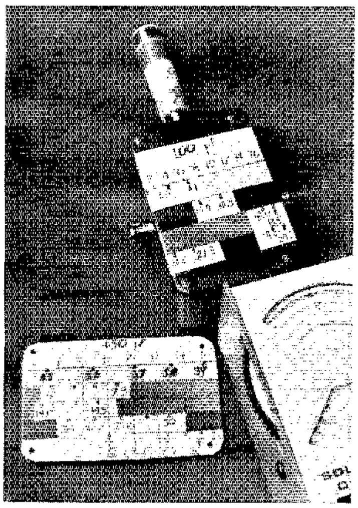


Fig. 4 — The 100-pF bandspread capacitor is connected between the coil and the dipper and the bandspread scales are taped on the plastic box. To use the 150-pF capacitor, the box is turned over and rotated 90°, and the other set of phono connectors is used.

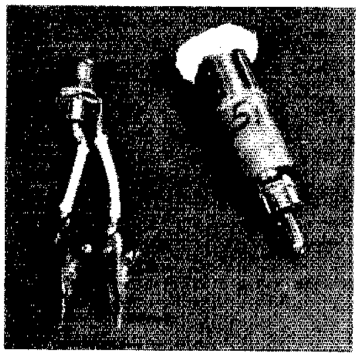


Fig. 5 — Accessories for measuring inductance and capacitance. The phono jack with clip leads will connect to the 100-pF standard in the plastic box and clip onto the unknown inductance. After locating the resonant frequency with the dipper, the value of the unknown coil may be read from charts in the ARRL *Handbook*. The standard 5-μH coil is about the same size as the dipper coils and can be plugged into the phono jack for connection to an unknown capacitor.

0.1 millivolt sensitivity of these instruments makes this job a snap!

Measuring Unknown Coils and Capacitors

The box with a 50-pF capacitor inside fits right in with the graphs and the methods outlined in the measurements chapter in the ARRL *Handbook*. Unknown coils may be measured by connecting them to the 50-pF capacitor in the box via a phono jack equipped with short clip leads as in Fig. 5 and the resonant frequency of the combination found with a dipper. The graph of inductance vs. frequency for this capacitor will furnish the inductance of the unknown coil with no calculation.

Any of the dipper coils can be used as a standard in finding the capacitance of unknown capacitors; their inductance is given in the manual. This can get confusing, since the standard coil that is plugged into the phono jack and connected to the unknown capacitor is sometimes needed in the dipper to scan for the resonant frequency. I prefer to make up a small 5-μH standard that can be stored in the plastic dipper box along with other accessories. It could have been put in the plastic box, but I was afraid of stray coupling and false resonance. The small coil in Fig. 5 is wound on a length of half-inch PVC tubing which is obtainable from the plumbing department of many hardware stores. A good phono plug (Radio Shack no. 274-339) fits snugly in this tubing.

It should be clear that any of these additions to your dip meter could be made independently of the others and according to your interests and needs. The dipper is one of the most useful devices in the shack and it can become even more versatile! QST

Strays

TA PROFILES

☐ We are pleased to have Jim Stewart, WA4MVI on our team of ARRL Technical Advisors, serving as our radio propagation/predictions and EME specialist. In 1978 Jim had a book published on this subject, entitled *VHF Radio Propagation*.

First licensed at age 15, Jim presently has an Extra Class license, and is the proud holder of a WAS certificate on 6 and 2 meters, plus a WAC certificate on 2 meters. His principal interests in Amateur Radio include EME, vhf/uhf, propagation, radio astronomy and OSCAR programs. He is also involved in flying, skiing and sports cars.

As a chemistry major, Jim received his BS degree from Lander College. He resides in Hendersonville, North Carolina, and is employed in air traffic control and as a commercial pilot. — *Marion Anderson, WB1FSB*

TA Jim Stewart, WA4MVI

HAPPY BIRTHDAY AMSAT-OSCAR 8!

☐ March 5 marks the completion of three years of successful operation for AMSAT-OSCAR 8. The satellite will have provided flawless service to Amateur Radio operators, students and science teachers worldwide during 15,280 orbits.

To commemorate this anniversary, ARRL will issue a special QSL card. During the period March 1 through 7, send a signal-reception report to AMSAT-OSCAR 8 Third Anniversary, ARRL Club and Training Dept., 225 Main St., Newington, CT 06111. Provide as much information as possible, including calls heard, telemetry and frequency. Check the OSCAR Operating Schedule elsewhere in this issue or write ARRL Hq. for details on how to listen for AMSAT-OSCAR 8. — *Bernie Glassmeyer, W9KDR, ARRL Satellite Coordinator*

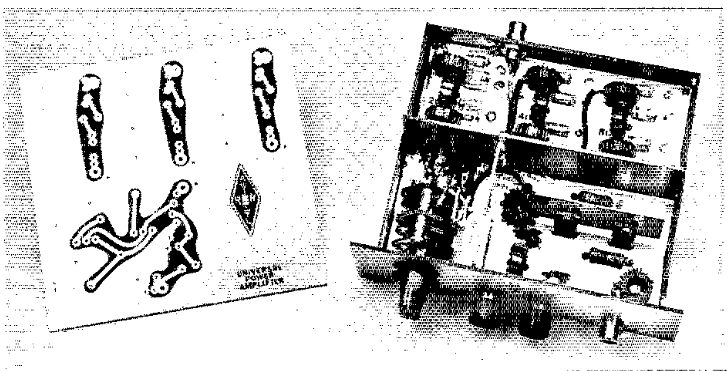
• *Basic Amateur Radio*

The Basic "Nonlinear" Amplifier

Has QRM put the skids under your QRP activity? Here's a 6 dB booster for the Universal Transmitter and other 2 watt QRP rigs.

By Doug DeMaw,* W1FB and Peter O'Dell,** AE8Q

Years ago coauthor O'Dell was fond of spicy food — in particular, *hot* spicy food. He often used the phrase, "the hotter the better." Then his father introduced him to some home-grown peppers; after two mouthfuls O'Dell decided that discretion is the better part of valor and thereafter modified his statement about hot, spicy food. When he returned home, his father insisted on sending along several cans of the peppers. One can was promptly given to friends who were hosting a New Year's Eve party. The brother-in-law of the host had the reputation for exhibiting many of the characteristics of a cross between a horse and a donkey — he was a self-made man. At the party he boasted that he liked hot things. How hot? The hotter the better, of course. As the host retreated to the kitchen to get something "special" for him, several others exchanged knowing glances.



Circuit board for amplifier and completed project. Notice that precautions have been taken to isolate the input from the output.

After the first mouthful, the guest's face became flushed and tears streamed down his face. But he kept right on eating the peppers and insisting he liked them. He spent the rest of the evening drinking large quantities of soda-pop and whispering "excuse me."

A Sense of the Appropriate

Some operators are dedicated to using *very low* power all the time, and reject the idea of running more than 1 or 2 watts, no matter what the conditions are. This is called "QRP," and is satisfying to some skilled operators. But Amateur Radio is a pastime some people enter with a relatively low level of skill — both technical and operating. Most continue to develop these skills by mastering increasingly difficult or more complex tasks. Running no more than a watt or two is difficult for the new operator. For a new operator to decide that it is never warranted to run more than 2 or 3 watts is a little like our friend with the peppers. He may be able to do it, but chances are he really won't enjoy himself! It is sometimes more fun to recognize our limits and then make the best of them and the circumstances.

The opposite end of the scale from the fanatic who insists on running QRP when conditions do not warrant it is the lid who fires up his 2 kW amplifier to chat with Charlie who lives five blocks away. FCC rules require that amateurs use no more power than necessary to maintain reliable communications. After some on-the-air experience, you will develop a sense of the appropriate. If conditions are poor, your skills are not quite up to par or you don't have a good antenna system, you will probably want to switch on the amplifier. On the other hand, if conditions are good, QRM is light and you can maintain reliable communications, you should turn the amplifier off. You will keep the QRM down and save energy as well!

DB, Gain and Confusion

An area of confusion concerning amplifiers is *gain*. Is a signal that is four times more powerful four times better? Usually, the gain of an amplifier or antenna or other device is expressed in decibels (dB). The decibel, which was originally formulated for audio work, is based on logarithms because it was discovered that

*Senior Technical Editor, ARRL
**Basic Radio Editor

the human ear has a logarithmic response. If a person thinks a 40 watt sound is twice as loud as a 10 watt sound, then he will think that a 400 watt sound is twice as loud as a 100 watt sound. In other words, it is the ratio that is important and not the absolute values of the two sounds.

A complete discussion of decibels is beyond the scope of this article, but there are a few simple relationships that we can work with. A 1 dB increase is that ratio at which a person will notice that there has been a change. If we double the power present in a signal, that is a 3 dB increase. If we double it again, it will be a 6 dB increase (3 dB + 3 dB). Decibels add, so don't fall into the trap of trying to multiply them. We once heard an operator on the air talking about his pair of stacked 11-element Yagis for 2 meters. He said they provided him with 26 dB of gain. Upon further questioning we found that he had arrived at this truly amazing figure by noting that one of the beams by itself was rated at 13 dB. Therefore, he concluded that two of them stacked together must give 26 dB of gain. If everything was optimum, the most our friend could have hoped for by doubling the size of his antenna was approximately 3 dB gain over one of the antennas by itself. There is a big difference between 16 dB and 26 dB!

These same limiting principles hold for amplifiers as well. Going from 500 W to 1000 W will result in a 3 dB gain in your signal. Figuring the trade-offs between increased expense and increased payoff (dB) is often downright frustrating. We have opted to build an amplifier for this project that will give us a 6 dB gain over our 2 W transmitter by itself. In other words, we will double our output from 2W to 4W for a 3 dB gain, and then we will double the 4 W to 8 W for the second 3 dB increase, yielding a total gain of 6 dB. This is a good compromise in terms of noticeable improvement in signal strength, cost and availability of components.

Linear vs. Nonlinear

Even those with only a modest understanding of the technical side of things find the contemporary misuse of the word "linear" humorous and sometimes embarrassing. An amplifier is a device that increases the power of a signal. If the amplifier is linear, the output signal will be a large-scale version of the input signal — sort of like a photographic blowup. If the amplifier is nonlinear the output signal will probably occur at the same frequency as the input signal, but the envelope (shape) of the output will not necessarily correspond to the input — that is, it will be somewhat distorted.

If the output of a "nonlinear" is distorted, then it must be useless, right? Wrong! For cw communications, the receiving operator needs to know whether the signal is on and for how long, not whether it is an exact replica of the signal that came out of the oscillator or driver stages. This kind of distortion is irrevelant for fm communications also.

The most common type of nonlinear amplifier is the Class C amplifier. The other types of amplifier commonly used in radio circuits are the Class A, Class AB and Class B. Assuming they are properly connected, these last three will operate as linear amplifiers. A Class A amplifier conducts during 100% of each cycle. A Class B amplifier conducts for 50% of the cycle; linearity is usually achieved by using two devices (one for each half of the cycle) and summing their output. A Class C amplifier conducts for only about 30% of the cycle — hence the distortion to the envelope of the signal.

The major advantage of a Class C amplifier is in terms of efficiency. Efficiency (expressed as a percentage) is the ratio of power out of a circuit to dc power into it. For instance, if the output of an amplifier was 10 watts and the dc input power (not driving power) required to operate it was 20 watts, the efficiency would be 10 divided by 20 multiplied by 100, or 50%. Input power here refers to the dc voltage and current taken from the power supply. Class C amplifiers can have an efficiency in excess of 70%, while linear amplifiers seldom display more than 60%.

A nonlinear amplifier can be more practical if the output signal is not required to be an exact replica of the input signal, which is the case with cw and fm.

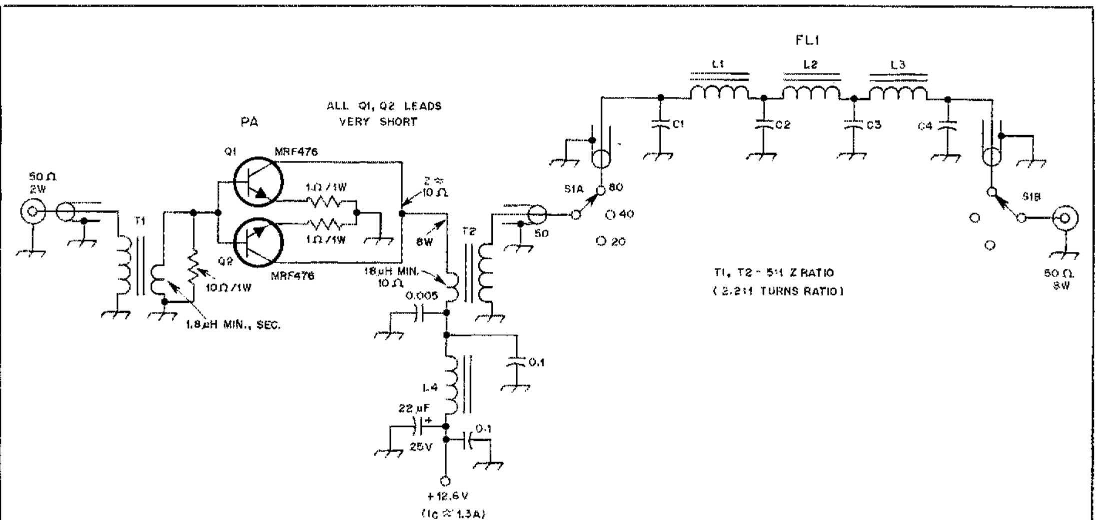


Fig. 1 — Schematic diagram of the amplifier. Capacitors are disc ceramic, except those with polarity markings, which are electrolytic. Resistors are 1-watt carbon-composition types. Parts values for the components of the filter sections can be found in Table 1.

L4 — 8 turns of no. 20 enam. wire on an Amidon Associates FT-50-43 ferrite toroid.

Q1, Q2 — Silicon npn rf bipolar transistor, 10 W, Motorola MRF476 or equiv.

T1 — Broadband toroidal transformer, 5:1 impedance ratio. Primary contains 11 turns of no. 22 enam. wire on an Amidon Associates FT-50-61 toroid core. Secondary consists of 5 turns of no. 22 enam. wire over the primary winding.

T2 — Broadband toroidal transformer, 5:1 impedance ratio. Primary consists of 5 turns of no. 20 enam. wire wound on an Amidon Associates FT-82-61 toroid core. Secondary consists of 11 turns of no. 20 enam. wire over the primary winding.

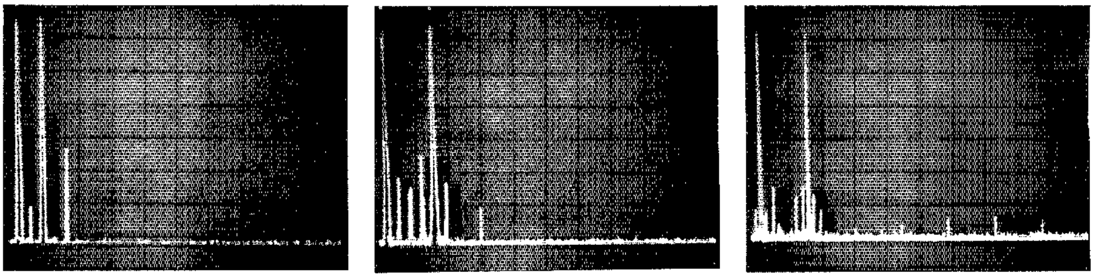


Fig. 2 — Spectral display of the amplifier for each band of operation, 80, 40 and 20 meters, left to right. At full power output all spurious emissions are more than 40 dB down from peak power. Vertical scale: 10 dB per division. Horizontal scale: 5 MHz per division for 80 and 40, 10 MHz for 20. The amplifier complies with current FCC spectral purity requirements.

A-m signals (including ssb) require a linear amplifier. The misuse of the term linear seems to have started with the CB service; most of the users talk about "linears." Unfortunately many of the illegal amplifiers purchased by operators in this service (which is confined to a-m types of signals) are in reality Class C amplifiers,[2] far from being linear. Although some vhf amplifiers can be operated either Class C or Class AB by throwing a switch that changes the bias, the vast majority of these amplifiers in service are Class C only, which is all that is needed for fm operation. Common amateur parlance lumps them all together wrongly as "linears." Depending on the circumstances, this malapropism can be either humorous or embarrassing.

How the Circuit Operates

Our objective in building this amplifier is to boost the power of the QRP transmitter described in December 1979 *QST*.[1] Of course, this amplifier will work with other low-power rigs, provided no more than 2 watts of drive is applied (e.g., the Heathkit HW-7 and HW-8 transceivers).

We want not only to boost the power, but to have an amplifier that is stable, reliable and low in harmonic output. This has been achieved through careful circuit layout, short leads and the use of broadband circuits.

T1 of Fig. 1 is a broadband toroidal transformer that gives us a 2.2-to-1 turns or voltage ratio. This can be converted to an impedance (Z) ratio by simply squaring the numbers. Hence, Z ratio = 2.2^2 or 4.84:1. This is close enough to the desired 5:1 impedance transformation we need to go from a 50 ohm driving source to a Q1/Q2 base impedance of roughly 10 ohms. A slight mismatch will not spoil the amplifier performance. Rather, it will reduce the drive reaching the bases of the amplifier transistors. The result is reduced output power from the amplifier. With the turns ratio specified for T1, the maximum safe power for the two transistors is realized when 2 watts of drive is applied to T1. The 10-ohm resistor across the T1 secondary winding helps to stabilize the amplifier by lowering the Q (quality factor) in that part of the circuit.

Each emitter (Q1 and Q2) is returned to ground via a 1-ohm resistor. This helps to ensure that one transistor doesn't "hog" the current and have its power rating exceeded. We can think of these components as "equalizing" or "balancing" resistors. Since they are not bypassed for rf, they cause the amplifier to be slightly *degenerative* (degenerative feedback), which causes a small but not significant power loss. Emitter bias in a Class C solid-state amplifier aids the Class C conduction angle, however, thereby (in theory) improving the amplifier efficiency.

The impedance of the Q1/Q2 collectors in parallel is approximately 10 ohms at 8 watts of output. This is approximated by

$$Z_o = \frac{V_{cc}^2}{2P_o}$$

where Z_o is the collector impedance in ohms, V_{cc} is the collector-to-emitter voltage and P_o is the amplifier output power.

T2 is another broadband transformer that transforms the 10 ohm collector impedance to 50 ohms, thereby providing a proper match to the 50 ohm harmonic filters (FL1). L4 is a decoupling choke that is used in combination with the four associated bypass capacitors to prevent amplifier rf energy from following the +12.6-volt line to other parts of the system — notably the exciter and VFO. If unwanted rf energy was permitted to reach the exciter it could lead to instability in the exciter or the amplifier, or both, because of feedback voltage. Various values of capacitance are used in this part of the circuit to ensure effective bypassing from vhf down to audio frequencies.

To prevent TVI and interference to other services we must make certain that the amplifier output is clean (contains essentially the desired signal energy). The 7-element low-pass filter (FL1) does an excellent job of "laundering" or "sanitizing" the amplifier output. Spectral photographs are shown in Fig. 2. A separate filter is switched into the circuit for each band of operation by means of S1. For this filter (or any filter) to work as designed it must be terminated in its characteristic impedance. Therefore, our antenna must present a 50-ohm impedance to the amplifier. The SWR should always be lower than 2:1 (preferably 1:1) to prevent damage to Q1 and Q2 and to ensure proper filter action.

The MRF476 transistors were designed primarily for the CB market. Therefore, they work nicely from 160 meters through 10 meters. This amplifier will provide a 6 dB increase over your 2-watt signal — a real boon to being heard better when the going is rough or marginal. For a more thorough discussion of amplifier circuits, consult the appropriate chapters of *The 1981 Radio Amateur's Handbook* and *Solid State Design for the Radio Amateur* (available from ARRL postpaid for $10 and $7, respectively).

Singular Board

As this series developed, it soon became apparent that the Universal Breadboard was as popular as it was functional. In fact, it was so functional and so popular

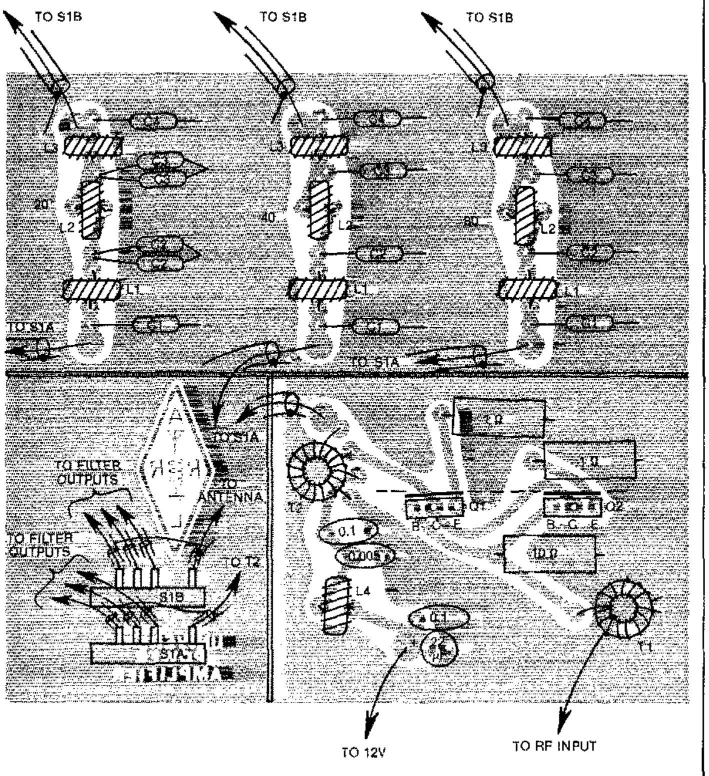
Table 1

Filter Component Values

Band	C1, C4	C2, C3	L1, L3	L2
80 M	560 pF	1200 pF	2.7 μH, 23 t. no. 22 T50-2	3.2 μH, 25 t. no. 22 T50-2
40 M	300 pF	680 pF	1.46 μH, 17 t. no. 22 T50-2	1.75 μH, 19 t. no. 22 T50-2
20 M	150 pF	360 pF	0.75 μH, 14 t. no. 20 T50-6	0.9 μH, 15 t. no. 20 T50-6

Note: Capacitors are polystyrene or silver mica.

[1]Notes appear on page 44.



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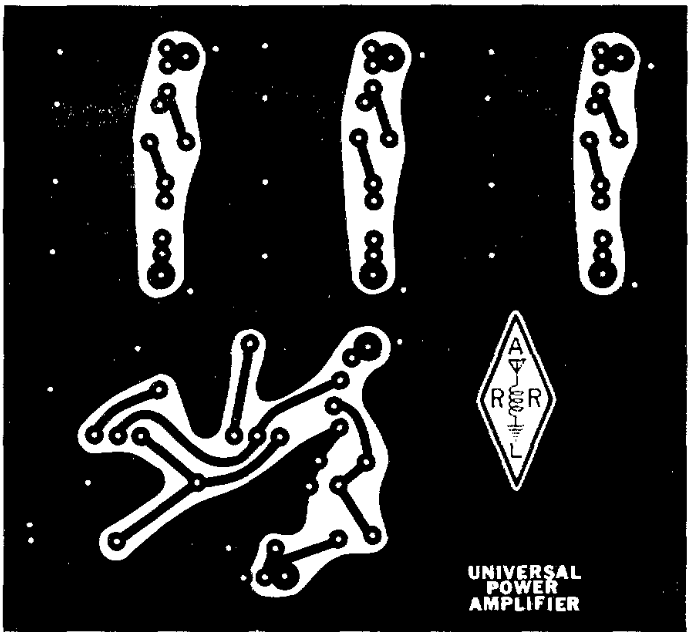


(B)

that it precipitated several bad jokes — the proposed projects ranged from the ridiculous to the bizarre, with one or two being physically impossible. Originally, we considered building this circuit on the Universal Breadboard. We did construct a version on one board, and it did work — sort of. Component spacing and isolation of input from the output were real problems. Those of you so choosing will be able to build this circuit on *two* of the breadboards with little difficulty. However, we decided that an etched circuit board designed specifically for this project — a singular board, if you will — would suit our purposes nicely and would be a worthy culmination to this series.[2] Fig. 3A provides a parts-placement guide for this circuit board.

Notice in the photograph of the amplifier that we have paid particular attention to shielding. The circuit has been divided into three compartments with vertical strips of double-sided pc-board material. Where it is necessary to pass leads from one compartment to another, holes have been drilled in the pc board "walls" and miniature shielded cable (RG-174/U or equivalent) has been used. Also, notice that in each filter section L2 is mounted perpendicular to L1 and L3. This is done to minimize stray coupling between the stages of the filters.

If you look closely, you will see that our foundation is a double-sided pc board. The top (component side) is only etched around those holes where leads pass through the board to be soldered. This is done to reduce the likelihood of a lead shorting to the top-side foil. The top foil, which is soldered to ground connections in several spots, serves as a ground plane and aids stability. The ground plane acts as a large capacitor and will bypass to ground any stray vhf or uhf currents that might develop. Connecting the ground plane to the etched-side ground in several spots reduces the potential for ground-

Fig. 3 — At A, parts-placement guide for amplifier components. Parts are placed on the top side of the board; the shaded area represents an X-ray view of the copper pattern on the bottom side. Resistances are in ohms. Capacitance values are in microfarads. Solid lines indicate compartment shields. The broken line indicates the heat sink for Q1 and Q2. Component values for the filter sections can be found in Table 1. A 27 pF and a 330 pF capacitor have been wired in parallel to provide approximately 360 pF at C2 and at C3 of the 20-meter section (it is often difficult to locate values of 360 pF). The four braids of the cables coming into S1A are soldered together as close to the switch as practical. A piece of fine bare wire may be used to lace the braids together to facilitate soldering. A similar procedure is used to solder the braids together at S1B. At B, circuit-board etching pattern for the amplifier. Black represents copper. The layout is shown at actual size from the pattern side of the circuit board. Leave the other side of the double-sided board intact during the etching. After drilling holes for leads, scrape 1/8 inch (3 mm) of the foil away from each hole.

loop currents to occur.

C1 through C4 should all be silver-mica or polystyrene capacitors. If polystyrene capacitors are chosen, be careful during installation. These capacitors simply will not withstand high heat. (Don't linger at the connection with the soldering iron.) The wire for winding the coils should be enameled. The 1 W resistor paralleled with T1 should be a noninductive carbon composition type. The band switch is a double-pole, three-position rotary type. At this power level, phenolic insulation is adequate for the switch; of course, if you have a small ceramic switch available, it will be ideal.

Although Q1 and Q2 are operated within their safe limits, it is a good idea to provide them with a heat sink. These transistors are packaged in the TO-220 style of case and have the collector connected directly to the mounting tab. A small heat sink is fashioned out of a strip of copper or pc-board material. The mounting tabs are then bolted to this strip. Because this is a direct electrical connection to the collectors of the transistors, make certain that the heat sink does not come in contact with the housing or any other component.

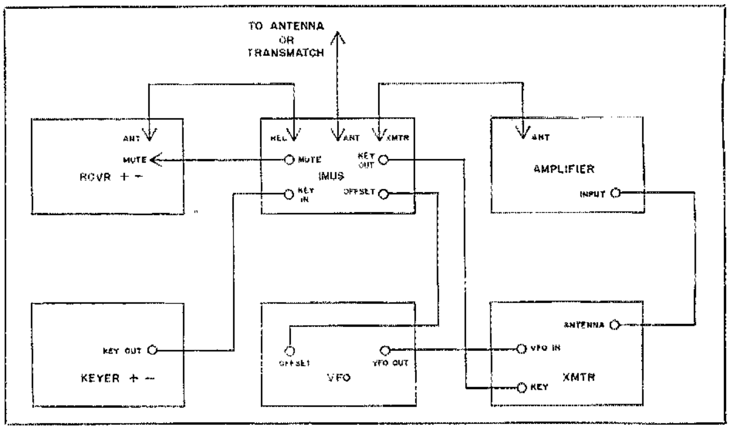


Fig. 4 — Pictorial of front panels and interconnection cables for the amplifier and the other units of this series. Power supply connections are indicated by + and −. Arrow heads indicate connections to be made on the rear of the unit.

Hookup

Simply put, the amplifier must go between the transmitter output and the antenna. Even though this seems simplistic, the logistics of installing the amplifier can be a little complex, depending upon your individual station and what accessories you may have. If you have built the other projects in this series, then the amplifier goes between the transmitter and the IMUS control (Fig. 4). If you will be driving the amplifier with an HW-8 or similar *transceiver*, then you will have to make arrangements to switch the amplifier out of the antenna line during reception. Additionally, we suggested at the beginning of this article that you should learn when to use the amplifier and when not to. How are you going to switch the amplifier in and out of the line conveniently? Two thoughts come to mind. You might consider adding an additional switch (double throw, double pole) which will allow you instantly to select between the amplifier and a *short* conductor. Remember to keep the input and output of the amplifier isolated. If you are using the projects from this series, then you might consider replacing J1 and J2 with short runs of coax with plugs on the ends. It would be a simple matter to unplug the amplifier and plug in the original jumper cable that runs from the transmitter to the IMUS control. Before you begin construction, sit down and carefully think through what you want in terms of options and convenience. Then custom-design this installation to fit your station.

If you have been operating your station from the variable power supply from this series,[3] you will need to make other arrangements for powering the amplifier. In fact you will be better off operating the amplifier from a different supply even if the supply that you are currently using will provide enough current for the amplifier and the other pieces of equipment that you are using. Separate power supplies lessen the possibility of rf from the amplifier getting into the low-level stages of the transmitter and causing problems. The 5 A supply from this series[4] would be ideal, or you could use one of the 2 A regulated supplies commonly sold for powering CB rigs.

The End? No, It's Just Starting

If you have followed these projects from the beginning and have assembled a complete station from this series, please drop us a note with your personal impressions of your equipment. If you can, please send along a good, high-contrast black-and-white photo of your station. We can't promise anything, but some of the material just might make it into "Strays." By the way, "instant" photos are almost never suitable for reproduction.

The whole idea behind this series is to provide you with simple (Universal, eh?) projects that would give you a basic station that is fun and convenient to operate. If it is not convenient, the fun wears off fast. Don't be like our friend with the hot peppers — if it is not fun, figure out why not and do something about it. Once you've perfected the device that will make it fun and convenient again, write us and ask for our author's guide. That is how we get a lot of our good outside articles. QST

Footnotes

[1]DeMaw and Shriner, "Transmitter Fundamentals," Basic Amateur Radio, *QST*, December 1979, p. 11.
[2]Circuit boards, negatives and complete parts kits for this project are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002.
[3]DeMaw and Shriner, "A Simple Utility Power Supply," Basic Amateur Radio, *QST*, November 1979, p. 22.
[4]O'Dell and Shriner, "5-A Loafer," Basic Amateur Radio, *QST*, November 1980, p. 43.

Strays

ATTENTION AFFILIATED CLUBS

☐ Annual Report forms are due for the 1981 calendar year. They were mailed with *Radio Club News* in January. If your records are up to date, your club has received a copy. Complete the forms now and remain on the active list. — *Sally O'Dell, AE8P, Club Program Manager*

HAM SAVES FIRE VICTIM

☐ When seconds meant the difference between life and death, Charlie Helmick, W8JZN, chief engineer at WTAP-TV, Parkersburg, West Virginia, rose to the occasion. Firefighters had just lowered the only victim of an apartment building fire from a second-story window when Charlie administered life-saving mouth-to-mouth resuscitation. The veterinarian who examined the victim said the golden retriever, named Fetch, would recover fully.

SWISS BEAR AWARD

☐ The New Bern ARC is sponsoring the "Swiss Bear Award," available to those who complete three two-way contacts with amateurs in the New Bern, North Carolina, area, between October 23, 1980 and October 23, 1981. Write to New Bern ARC, Inc., P. O. Box 2483, New Bern, NC 28560.

Technical Correspondence

Conducted by
Jerry Hall,* K1TD

The publishers of QST assume no responsibility for statements made herein by correspondents.

SMOKE DETECTOR INTERFERENCE — PART 2

□ I enjoyed the article on SDI[1] and as an amateur who has developed many custom-built, apartment-size, unobtrusive antennas, I sympathize with the guy who puts more rf into gadgetry than into the ether. Soon you begin to use the gadgetry as a replacement for your field-strength meter.

My concern is for those people who dismantle smoke detectors with ionization type detectors. Smoke detectors come in mainly two varieties, the optical refraction sensor, and the ionization sensor. The former is the one you described in your article in November 1980 *QST*. The principle of the ionization detector is the use of a capacitor with air dielectric and a radioactive ionization source. When smoke comes between the capacitor plates and is ionized by the radiation, the capacitance changes and trips the circuit. The danger in dismantling one of these detectors is the source of radioactivity. If the container is broken the radioactive chemical could be spread around or even ingested. Although the chemical comes in a small amount, "small" is not well defined when it comes to radiation poisoning. Therefore, as a safety precaution, I would recommend keeping one's fingers out of smoke detectors using ionization sensors. — *Andy Cwalina, WA4JJZ, 6 Duvall Ct., Arundel, Wilmington, DE 19808*

□ Since I have been a city fire fighter for more years than I like to admit, I read your smoke detector article in November 1980 *QST* with considerable interest. The fire-protection community is quite sensitive to comments on smoke detectors. The number of U.S. deaths from fire has dropped from an average of 12,000 to approximately 8500 in 1979, and many experts cite smoke detectors as a major factor.

Two organizations in the U.S. test smoke detectors for operation and efficiency. Underwriters Laboratories Inc. tests and "lists" smoke detectors, and Factory Mutual Research Corp. tests and approves detectors. If your smoke detector has an Underwriters Laboratories label on it, it is "listed" as an acceptable smoke detector, not just as a safe piece of electrical equipment. If it is also approved by Factory Mutual, the letters FM appear inside a diamond.

I am concerned not so much that some smoke detectors "false" in the presence of rf, but that they might not perform *as intended* in the presence of rf. This probably would not be a great problem for the average user, but boggles the mind at the possibility of a high-rise apartment building with several communications antennas on the roof. I suggest the ARRL correspond with Underwriters Laboratories and Factory Mutual Research Corporation about the results you've had. Their testing procedures may not be infallible, and perhaps you've discovered a significant sector. — *Don Norman, AF8B, Assistant Fire Chief, 41991 Emerson Ct., Elyria, OH 44035*

[Editor's Note: ARRL Hq. is following up on this suggestion.]

*Technical Editor, QST

[1]O'Dell, "SDI — Dangerous Crippler of Radio Amateurs," *QST*, November 1980, p. 34.

CHECK THAT CORD

□ Miserable winter weather and an upswing in amateur activities persuades me to make an annual power check then. We see if the generator will start in cold weather, change the dry-cell batteries and check the power cords. Not just the amateur equipment power cords, either!

Fig. 1 shows one of the culprits found this year. I had missed this plug for heaven-knows-how-many years behind the XYL's dresser, and I have no idea why we haven't had a fire. It doesn't take a fire in the ham gear to put a station off the air permanently!

Another good trick is to check the power cords for insulation life. Pull the plug from the wall receptacle and bend the cords on about a half-inch radius (around your finger) and watch for insulation cracks. Replace the cord if any are seen. Incidentally, do this at each end and the middle of the cord — often one part has brittle insulation while the other parts seem good. In some cases, this test has resulted in a shower of insulation flakes and two bare wires. P.S. It's also a good time to check your fire insurance policy. — *David T. Geiser, WA2ANU, RD 2, Box 787, Snowden Hill Rd., New Hartford, NY 13413*

Fig. 1 — Strong evidence that routine checks of power plugs and cords may prevent disaster!

MEASURING RESISTANCE OF ELECTRICAL CONNECTIONS

□ The very low resistance associated with an electrical connection is difficult to measure. Knowing its value, however, can be of great help to the amateur, particularly where joints are made mechanically and are subject to corrosion. The aluminum-to-aluminum connection in antenna systems is a good example, and is notorious for lowering the efficiency of antennas with low radiation resistance. Exposure to the elements can easily introduce resistance through the growth of aluminum oxide or other insulating compounds. Just a few tenths of an ohm will seriously degrade the performance of a shortened vertical or Yagi. The loss of high-Q traps will increase dramatically with small values of resistance.

Unfortunately, simply connecting a VOM across the suspicious joint and trying to measure resistance will prove futile because of the very limited ability of most meters to resolve fractions of an ohm. The solution lies in applying the "force" and "sense" principle known as the Kelvin contact. The Kelvin approach involves four measuring leads instead of the usual two (see Fig. 2). Two of the leads force a current through the suspected joint (in this example, a junction of aluminum tubing), and a second pair of leads senses the resulting voltage drop. Unavoidable voltage drops (V1 and V2) also occur where the forcing leads contact the tubing, but the sense leads are placed where they do not read this drop.

Although contact resistance is also present at the point where the sense leads contact the tubing, negligible current flows through the sense leads, resulting in virtually zero voltage error. The voltmeter sees only the drop V_X across the suspected joint. To find the resistance of that connection, divide the voltmeter reading in volts, V_X, by the current, 1A, to get ohms, R_X. This means that a VOM with 1 V full scale will read 1 Ω full scale and provide a very meaningful indication of joint quality. A good quality connection should be less than 10 milliohms.

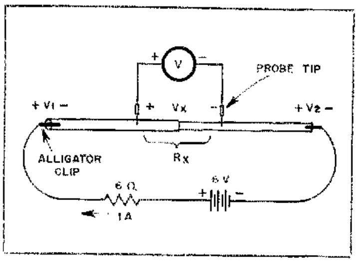


Fig. 2 — Setup for measuring resistance of electrical connections. Voltage drops V_1 and V_2, shown here with polarity marked, are unavoidable, but the measurement method excludes those drops. The resistance, R_X, equals the measured voltage divided by the current flowing through the connection. Resistances down to a few milliohms can be measured easily with this technique.

Using a 3-1/2 digit DVM will yield a resolution of 0.1 milliohms! This means that even the resistance of heavy, solid wire can be measured, or multiple soldered joints can be measured and compared for quality.

For portable work, a lantern battery (6 V or 12 V) works just fine as long as the forcing current is only allowed to flow long enough to make a reading. Even a single fresh "D" cell will work in a pinch. You need not limit yourself to working with only 1 A, either, as other values will give good results. Just remember that the lower the forcing current, the less will be your resolution.

We have used the Kelvin technique very effectively in troubleshooting a weathered vertical antenna. All joints, both mechanical and soldered, were checked in a short period of time and the culprits were readily identified. We feel the Kelvin technique can be a powerful tool for hams working on antennas. In addition to antenna work, you will find this technique useful in the shack to measure meter shunts, switch contacts, relay contacts, and so on. — *Dennis Monticelli, AE6C, and Jim Congdon, KA6CPJ, 48617 Tonopah Ct., Fremont, CA 94538*

ANSWERS TO LAST MONTH'S ANTENNA AND TRANSMISSION-LINE QUIZ

☐ Here are the answers to the 30-question quiz by Richard C. Fenwick, K4RR, in January 1981 *QST*. Our apologies for erroneously omitting one of the questions:

23) The gain of a horizontally polarized antenna at hf is significantly greater if the antenna foreground is sea water rather than ground.

A score of 20 puts you in the really knowledgeable class, while 15 is about average — provided, of course, that you were sure of the answers and not just guessing! If you missed on Questions 3, 4, 6, 11, 12 and 30, you're weak on fundamentals that every ham should know.

1) False. VSWR is lower at the input because of line losses.

2) True. VSWR depends on the impedance of the load, which is the receiver when receiving and the antenna when transmitting. These impedances are seldom identical.

3) True.

4) False. Reflected "power" is not actually power at all, but is a convenient fiction.

5) False. Feed-line radiation is usually negligible, unless the antenna is unsymmetrical with respect to the feed line or unless the conduction path along the outside of the coax from the antenna to ground is resonant.

6) False. Greater VSWR gives greater line loss.

7) True.

8) False. However, radiation is usually negligible below uhf.

9) False. However, some gamma-fed beams have exhibited a slight skewing of the pattern, which would seldom be of concern.

10) True.

11) False. Open wire can better handle the large voltages which may be encountered, has lower loss at high VSWR, and may be used as a quarter-wave impedance transformer — i.e., as a "tuned feeder."

12) False. The Transmatch affects only the impedance seen by the transmitter.

13) True. The gain of a dipole can be increased by as much as 7.2 dB by placing it in front of a flat screen reflector. Gains in excess of 6 dB are readily achieved in practice.

14) False. The difference is about 2 dB if both are tuned for maximum gain.

15) False. The radial system gives greater efficiency, typically by 3 dB or more.

16) False. Longer radials improve the gain, from decreased ground-reflection losses on sky wave.

17) True. The horizontal dipole has greater gain in its most favored direction, even near the horizon where the vertical monopole is often thought to be superior.

18) True. Signal-to-noise ratio is usually determined by atmospheric or other external noise, and is not significantly altered unless antenna efficiency is very low.

19) True, when loss resistance of the loading coils is made sufficiently low. The main advantages of the half-wave dipole are simplicity and greater bandwidth.

20) False. The folded dipole normally has greater bandwidth depending on construction details.

21) True.

22) True — much better, because of lower ground-reflection losses.

23) False. Ground-reflection losses are small in either case.

24) True.

25) False. Arriving signals will be randomly polarized, and a horizontal antenna usually gives greater gain.

26) True, when all noise is arriving at elevation angles near the horizon. Thus, a longer Yagi is preferable to two stacked Yagis, since the larger Yagi reduces the azimuthal beamwidth.

27) True. Almost 5 dB is achieved at a spacing of 0.67 wavelength.

28) False. Up to about 6 dB is obtained, from doubling of the field strength by addition of the direct and ground-reflected waves. The ground reflection is more efficient with horizontal polarization than with vertical, which accounts for the superior performance of sufficiently elevated horizontally polarized antennas for DX work. Ground-reflection characteristics also depend on ground electrical properties as well as the smoothness of the terrain in the antenna foreground.

29) False. The gain varies with height within a ±1 dB range, and is maximum for a height of about 0.6 wavelength, at an elevation angle of 24.6° above the horizon.

30) False. They are essentially equivalent. The folded dipole simply provides an impedance transformation. QST

Feedback

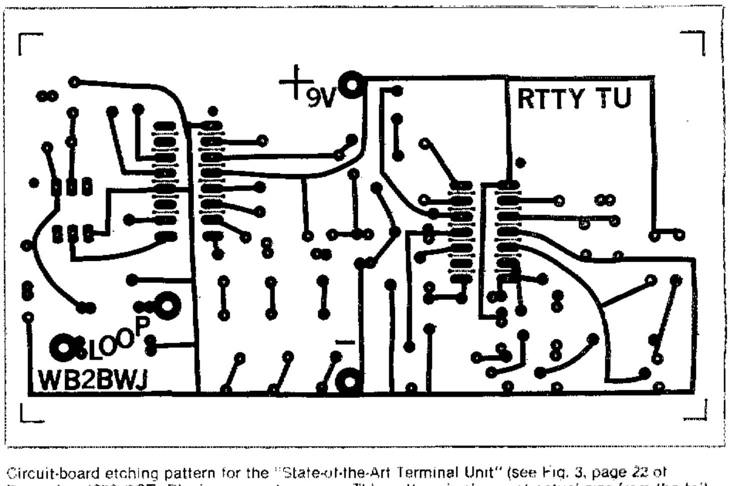
☐ Contrary to the statement in the caption, the etching pattern for Di Julio's "State-of-the-Art Terminal Unit for RTTY" appearing on page 55 of December 1980 *QST* is *not* at actual size. The pattern is reproduced here at the correct size.

☐ The list of abbreviations in December 1980 *QST*, page 66, includes the entry "THz." It stands for "terahertz," or 10^{12} Hz. — *Gene Preston, K5GP, Austin, Texas and Hans Schroeder, AE9G, Milwaukee, Wisconsin*

☐ In the article, "Broad-Band 80-Meter Antenna," by Harbach, December 1980 *QST*, page 36, the equation for *k* near the end of the article is missing a radical sign. The correct equation is

$$k = \sqrt{\frac{(R - Z_0)^2 + X^2}{(R + Z_0)^2 + X^2}}$$

☐ The Red Stick DX Association, Baton Rouge, Louisiana, is another "100 Percent" Club ("Club Corner," December 1980 *QST*, page 85).



Circuit-board etching pattern for the "State-of-the-Art Terminal Unit" (see Fig. 3, page 22 of December 1980 QST). Black represents copper. This pattern *is* shown at actual size from the foil side of the circuit board.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

A DUST COVER FOR THE BENCHER PADDLE

☐ A dust cover provides a lot of protection for a Bencher iambic paddle, especially for the average amateur who is likely to pile things and work on the radio operating bench as I do. I fabricated a cover from clear 1/8-inch (1.5 mm) Plexiglas in the manner shown in the accompanying diagram. The cover and sides are cemented together. Dimensions are shown in the drawing. The 1/64-inch (0.39 mm) dimension for the cut sizes is the tolerance needed to provide clearance for the base of the Bencher paddle. Be careful to hold to this measurement to obtain a proper fit. Item D in the drawing is the stop that allows you to position the cover 3/16 inch (4.8 mm) from the top of the Bencher. You may take some liberty with this measurement, but be sure that all four corners are made alike. — *C. L. (Chet) McClellan, K7HNM, Phoenix, Arizona*

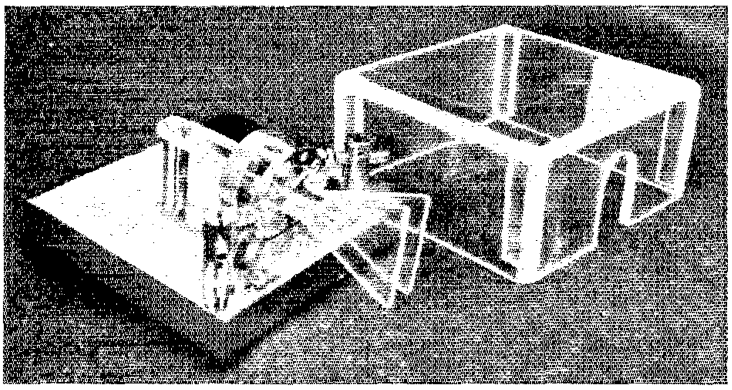


Fig. 1 — A practical, attractive dustcover for a Bencher paddle can be made with Plexiglas in the manner illustrated above. Chet McClellan, K7HNM, provided this idea for *QST*.

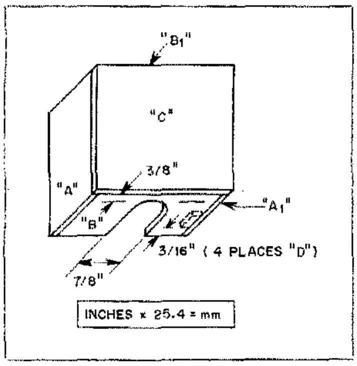


Fig. 2 — Details of the K7HNM Bencher paddle dust cover.

LOGIC PROBE MODIFICATION

☐ The Vest Pocket TTL Logic Probe (Rogers and Bartels, July 1979 *QST*) works fine, but reads zero on high-speed pulses. This can be overcome by adding a 1000-ohm resistor between pin 10 of U1 and the unused decimal point of the 7-segment readout. Actually, any value of resistor could be used as long as the decimal point is not dimmed to any great extent. A higher value does limit the current and thus the load on U1.

With this resistor in place, the decimal point will then light at all times *except* during a logic low (zero). If the decimal point is lit with a zero, then the circuit being tested is pulsed.

For packaging, a clear plastic tube (21/32-inch or 16.7 mm ID) can be used. I use a rain gauge. Plastic dust caps from SO-239 uhf connectors fit very snugly as end plugs. The probe tip can then be mounted directly on one of the caps rather than soldered to the board. For better visibility, the circuit board can be placed in the tube so that the readout is at the same end as the probe tip. A short wire is then used to connect the tip to the board. — *Dallas Williams, WA0MRG, Brush, Colorado*

MOSQUITO-LIKE WHINE IN OMNI-D

☐ An Omni-D (Series B) I was testing had a low-level but annoying mosquito-type whine in the receiver audio. I noted that not only could the whine be altered with the volume control but also with the digital display. I concluded that the source was probably the logic board, the result of the digital display enable-pulse scan frequency. In a telephone call to Ten Tec I was advised that the condition is not normal, but may occur in some units.

Ten Tec's Larry Worth and John McCoy suggested that perhaps the +12-V supply line to the logic board was radiating a signal that was being picked up by the i-f board. Before attempting anything else, I was advised to reroute the supply line if it was passing under the i-f board. This is a red wire connected to a feed-through insulator on the right side of the aluminum enclosure of the logic board.

To remove the supply line from a position under the i-f board, I first dismounted the i-f board and gently levered it upward with hemostats to release it from the socket. The supply line had been harnessed with tie-wraps which I cut to permit its extraction from the harness bundle. After removing it all the way to the shield at the rear of the i-f board, the harness was resecured with three new tie-wraps. The supply line was placed aside for remounting the i-f board. Once the board was secured, I rerouted the supply line above the board and against the shield. A single tie-wrap fed through a convenient hole in the shield keeps the line in place. After reconnecting the supply line to the logic-box feedthrough, the unit was tested and the annoying whine was completely gone. — *Bob Wheaton, W5XW, VP1XW/XE2XW, San Antonio, Texas*

MODIFYING THE HEATHKIT HW-101 FOR ZERO BEATING

☐ Being able to zero beat an incoming signal is as dear to the heart of a cw operator as full break-in and is sometimes more important. The lack of this ability is an inconvenience, to say the least. And it's a downright nuisance to operators on the other end, especially those who are trying to operate on a net frequency. I overcame this in my Heathkit HW-101.

The HW-101 has a separate crystal to accomplish offset tuning (to enable you to copy an incoming signal by the audio tone or beat frequency) 1 kHz away from the actual transmitting frequency. The audio oscillator, which supplies the sidetone and keys the transmitter circuits, is also 1 kHz in frequency and is supposed to provide on-frequency operation by comparing the pitch of the sidetone with the pitch of the incoming signal.

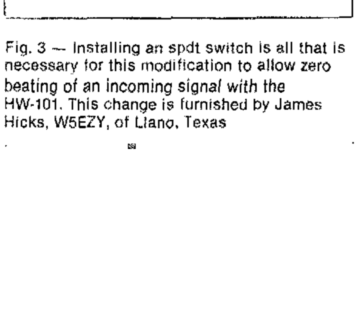


Fig. 3 — Installing an spdt switch is all that is necessary for this modification to allow zero beating of an incoming signal with the HW-101. This change is furnished by James Hicks, W5EZY, of Llano, Texas

*Assistant Technical Editor

Unfortunately, it doesn't work that way in practice. In the first place, the ear may not be that accurate. Second, the frequency separation of the receive and transmit crystals is not always exactly equal to the sidetone pitch because of the circuit variables involved.

Referring to the schematic diagram, we find that the receiving crystal (Y1) is 1 kHz higher in frequency than the cw transmit crystal (Y2). These crystals oscillate in the grid circuits of V16A and V16B respectively when voltage is appropriately applied. Voltage is applied to V16A when receiving and is switched via relay RL2 to V16B only when transmitting.

By installing an spdt toggle switch, the voltage can be manually switched to V16B while still in the receiving mode. This places the VFO dial on or very close to the zero beat of the incoming signal. A slight adjustment will put it right on frequency. Switching the voltage back to V16A restores the beat-frequency oscillator without disturbing the VFO setting and, presto, the transceiver is exactly on the frequency of the incoming signal.

I mounted my switch on the front panel midway between the dial escutcheon plate and the meter, placing it on a level with the other controls. This seemed to be the only location available, although I would have preferred having it elsewhere. Circuit changes are minor. Simply remove the blue-blue-white lead from lug 15 on the rear wafer of the mode switch (the wafer nearest the panel). I used three lengths of differently colored hookup wire, which I twisted together to make a neat installation. The blue-blue-white lead is soldered to either of the wires that connects to an outside terminal of the toggle switch. Connect the center wire from the toggle switch to lug 15 where the blue-blue-white lead has been removed. The lead from the remaining outside terminal of the toggle switch is wired to lug 17 of the rear wafer of the mode switch (it is right next to lug 15 and is identified by a yellow lead from terminal 5 of RL2).

No operating compromises result from this modification. One position of the toggle switch restores the circuit to normal. It has no effect on sideband operation or on transmitting. Because this modification requires drilling a hole in the panel of your HW-101 to install the toggle switch, consider first whether operating pleasure and efficiency mean more to you than the warranty on your rig or its trade-in value. Some companies will not accept trade-ins with irreversible modifications. If you eventually sell the rig yourself, however, the new owner will probably appreciate the improvement. As for myself, I plan to keep mine and enjoy it for a long time! — *James M. Hicks, W5EZY, Llano, Texas*

TRANSCEIVER CAUSES UNEXPECTED CAR BATTERY DRAIN

□ When I found the battery in my Chevy Monte Carlo completely dead one cold morning, I checked all electrical switches including that on my Kenwood TS-120S to be sure none had been left on. Finding each one turned off eliminated "cockpit trouble" as the cause. I proceeded then to charge the battery and be on my way.

The next morning brought on a repeat performance. The battery once more was dead. That meant off to the Chevrolet dealer for a further examination. They found no mechanical or electrical reason for the difficulty but they were suspicious of the battery. It was placed on their charger, brought up to full voltage and I returned home. The next morning, once again I was back at square one. . . the battery was dead. What to do?

Checking the electrical circuitry more carefully led me to the source of the problem. I found that there was a 1.25 A current drain on the + 12 V line to the TS-120S even though the ON-OFF switch on the equipment was in the OFF position. A bench test of the transceiver established that Q4 was leaking. Furthermore, a check of the diagram disclosed that the voltage feed for the collectors of the two final transistors does not go through the ON-OFF switch, but in fact is taken from the battery line prior to the switch. What to do?

My solution to the problem was to use a relay circuit as shown in the accompanying diagram. This will allow the + 12 V line to the transceiver to be disconnected except when the ignition key is on. I elected to use this method rather than make internal circuit changes that would affect the resale value of the TS-120S. Since then there has been no recurrence of battery failure. Other TS-120 owners who operate mobile may benefit from this information. — *Cary L. Townsend, W3BX, Bartlesville, Oklahoma*

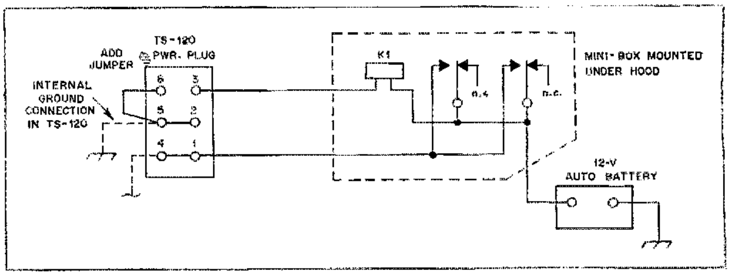


Fig. 4 — This relay circuit in the 12-V power supply line to the W3BX mobile transceiver ended a series of battery failures resulting from a leaking semiconductor in the TS-120 even though the power switch on the transceiver was off. The text explains. K1 should have a contact rating of 10 A for each section. A suitable relay is Radio Shack no. 275-208 or no. 275-218.

WEATHERPROOFING COMPOUNDS

□ In November 1978 *QST* "Hints and Kinks," a method of installing PL-259 connectors on hardline coaxial cable was explained. As an added measure to prevent oxidation between the aluminum-to-copper braid contact area, coat the aluminum hardline jacket with one of the commercial anti-oxidation compounds made for aluminum-to-aluminum and aluminum-to-copper electrical connections. Such products are available at most electrical supply houses under the name of No-Alox or Oxiban. Compounds like these are very useful when assembling antennas that have aluminum-to-aluminum contact areas. Beam and vertical antennas are in this category.

Another compound that is useful when assembling any fitting that must stand up to the weather is called Gaco Liquid Rubber. This is a brush-on liquid neoprene coating that will stick to most metals and plastics. It will not shrink or crack. Gaco is manufactured by Gaco Western, Inc., Seattle, Washington. — *Roger Linton, W2ZY, Vineland, New Jersey*

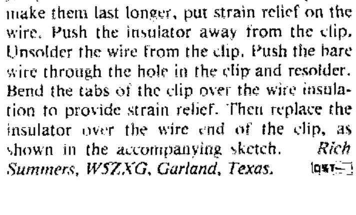
CB ANTENNA TO PC TOOL CONVERSION

□ Recently I acquired a 10-meter fm rig for the car. I purchased a CB stainless-steel whip (Radio Shack 21-903), which was installed on a bumper mount that I already owned. To tune the antenna for 10 meters, I removed about 1 foot from its length. (The easiest way to cut a stainless-steel whip is with a bench grinder.)

Because the whip is welded to the threaded ferrule, I cut the excess length from the top of the antenna. Being a bit on the cheap side, I used a bench grinder to turn the wasted top of the whip into a useful tool. First, I cut the rod about 5 inches from the static ball; with a heavy heart, I threw away the short piece that I had just removed. The newly cut end of the whip was turned down to a sharp point. This tool is quite useful for circuit-board work and general shop use. If I need to apply heavy pressure, the static ball saves a lot of wear and tear on my hands. If you aren't cutting a CB whip down for 10 meters, you might try stopping by your local two-way repair shop and asking if they have any defunct whips around that you can have. — *Pete O'Dell, AE8Q/1*

OLD TIMER'S NOTEBOOK: MAKE THOSE JUMPER WIRES LAST LONGER

□ Do you buy those inexpensive alligator-clip jumper wires that break off at the clip? To make them last longer, put strain relief on the wire. Push the insulator away from the clip. Unsolder the wire from the clip. Push the bare wire through the hole in the clip and resolder. Bend the tabs of the clip over the wire insulation to provide strain relief. Then replace the insulator over the wire end of the clip, as shown in the accompanying sketch. — *Rich Summers, W5ZXG, Garland, Texas.* QST

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THE COVER

If thoughts of spring have brought on the urge to do some direction-finding, this antenna/S-meter modification will get you going. See page 43.

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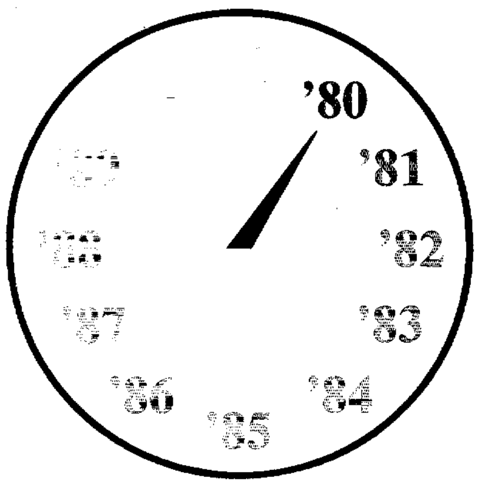


An independent survey provides a picture of Amateur Radio as we enter the Eighties: where we are, and where we are going.

By David Sumner,* K1ZZ

For almost two years, the ARRL Long-Range Planning Committee has been soliciting and studying comments from members on the future of the League and Amateur Radio.[1,2] For the committee members, analyzing the hundreds of thoughtful letters has been an enriching and educational experience.[3] However, from the start it was recognized that this process would yield only a part of the information needed by the LRPC. Input was needed from the amateur community as a whole, to supplement the thoughts, ideas and opinions of those who would take the trouble to put pen to paper. Some sort of survey was needed.

Although the League has conducted surveys of its own in the past, most recently in 1977,[4] this time it was decided to engage the services of an independent organization with professional experience in social research techniques. Proposals were requested and received from a number of such organizations, and after thorough investigation the Institute for Social Research of Florida State University was selected to conduct the survey.[5] Members of the LRPC collaborated with Florida State on the survey design.

Questionnaires were mailed to one amateur in every 44 in the U.S. and Canada selected on a random basis. The initial mailing was made in April 1980, with a follow-up mailing to non-respondents in late May and early June. The mailing was done by Florida State, with returns to be sent directly to Tallahassee; the identity of those surveyed has not been divulged to the League. The report of the survey results, delivered in October, contains a wealth of information on the problems, activities and interests of today's radio amateurs. The remainder of this article is a digest of the more than 500 pages of information contained in that report. Here we can just touch the high points; copies of the full report have been provided to all ARRL officers, directors, vice directors and LRPC members. The data presented here are from the Florida State report, but some of the conclusions are the result of further analysis by the ARRL staff.

*Assistant General Manager, ARRL

[1]Notes appear on page 18.

Survey Design

The sample consisted of 8895 amateurs in the U.S. and Canada drawn on a random basis from the computerized data base maintained by the Radio Amateur Callbook, Inc. These amateurs were sent four-page questionnaires containing 147 questions organized into 36 topics. The cover letter for the first mailing did not identify ARRL as the sponsor; interestingly, a number of members feared that the purpose of the survey was anti-ARRL and questioned League Headquarters about it. The second cover letter did identify the League as the sponsor. Each questionnaire bore a unique number to identify who had and had not responded to the first mailing, but absolute confidentiality of the respondents' identities has been maintained. The first mailing produced a usable return of 48.7% from the U.S. and 63.1% from Canada, the difference caused at least in part by the use of first class mail to Canada. The second mailing went by first class to both, and raised the return rate to 62.9% overall, and 71% for Canada. This is regarded as excellent for a mail survey. A follow-up telephone survey of 186 non-respondents was used to determine the extent of non-response bias.

The tabulation of results contained in the survey report included cross-tabulations of responses according to region of residence, status of membership in the League, level of Amateur Radio activity, year first licensed and class of license presently held. Later, a crosstabulation of female respondents was supplied. These crosstabulations permit a much more in-depth examination of the survey data than would otherwise be possible.

Because of the high rate of return, and because the original sample was a statistically valid random sample, the results are reasonably representative of the U.S. and Canadian amateur population. A comparison with known license figures shows that Novices, Technicians and Generals are slightly under-represented in the sample, and Advanced and Extra Class licensees are slightly over-represented. (See Table 1.) Similarly,

Table 1
Comparison of license class reported held by U.S. respondents with actual FCC figures (as of April 30, 1980, based on 370,015 licensees)

	Survey Respondents	*FCC Figures*
Novice	16%	18%
Technician	17	19
General	30	33
Advanced	28	23
Extra	9	7

League members are slightly over-represented, by about 7%. The telephone survey revealed that respondents tended to be more active in Amateur Radio than non-respondents, with respondents averaging 6.1 hours per week on Amateur Radio activities and non-respondents (those reached by telephone) averaging 4.2 hours. Respondents spent, on average, $308 in the past year on Amateur Radio while non-respondents spent $216. Respondents also had more money invested in their stations. However, there were no significant differences in the ages, year first licensed, income, education, etc., of the two groups. Nonrespondents were no more inclined to find fault with the League than were respondents. The survey shows that higher-class licensees and League members tend to have a greater investment of time and money in Amateur Radio, which is consistent with the above pattern of non-response. From this it can be inferred that the survey slightly overstates the level of activity of the amateur population, but is much more representative than past surveys.

The significance of the percentages given in this article varies somewhat, depending upon the size of the numerical base from which they are drawn. In general, according to Florida State, variations of less than 3 percent are not significant. Where the percentages are based on a crosstabulation, variations must be somewhat greater to be significant. For example, if the percentage of U.S. respondents with a particular characteristic is 50%, we can be quite confident that the actual number is somewhere in a range of ±3%, or between 47% and 53%. On the other hand, if the number of Extra Class licensees with the same characteristic is 60%, the actual number may be in a range of ±5%, or from 55% to 65%, because the sample size of Extras is smaller.

The Radio Amateur of 1980

If we could find one person who is the "average" or "typical" radio amateur of today, he would be a 46-year-old male living in a single-family home. He attended college and probably graduated. His annual family income is not quite $30,000, $308 of which is spent on Amateur Radio. He was first licensed in 1963, obtained his present class of license in 1968, and has found Amateur Radio to be useful in his career. He has $1668 invested in his station, has had no television or rf interference complaints in the past year, and does not feel limited by zoning or other antenna restrictions where he lives.

Our "typical" amateur spends 6.1 hours per week on Amateur Radio. His on-the-air time mostly is spent ragchewing, most likely on hf phone but followed closely by vhf fm and hf cw. However, he also spends a lot of time not actually transmitting: building and repairing equipment, experimenting, and monitoring repeaters. He probably has equipment that can be operated mobile in an emergency, though he may not have it actually installed in his car. If active, he is probably a member of ARRL; if not a member, it is most likely because he "just didn't bother" to join or rejoin. His attitude toward ARRL is generally favorable. He is likely not to see any amateur magazine except *QST*.

If an Amateur Radio issue comes up which he thinks is important he will express his opinions on the air, but probably not in any other way. He probably does not attend local club meetings regularly. He feels somewhat negative about the FCC if he is in the U.S., somewhat positive about the DOC if in Canada. He strongly supports the Morse code requirement for amateur licensing, especially for operation below 30 MHz. He is very concerned about malicious (deliberate) interference. He does not see phone patch or autopatch abuses as significant problems. Looking toward the future, he is interested in personal computers and amateur satellites, although he has made no plans to be active in either field.

So much for the "typical" amateur. The non-typical amateur is even more interesting, so let's take a closer look at the survey results. Where reference is made to a table or figure, study it carefully; you will see significant differences which are not discussed in the text.

Table 2 lists some selected demographics of our survey population: education, income and residence/station loca-

Table 2

Selected demographics of survey respondents

Highest level of education completed:	
Grade school or less	2%
Some high school	9
High school graduate	19
Some college	32
College graduate	18
Some graduate work	8
Graduate degree	14
Approximate total family income:	
Less than $10,000	10%
$10,000 to $19,999	27
$20,000 to $29,999	29
$30,000 to $39,999	18
$40,000 to 49,999	8
$50,000 or more	7
Station is located in (multiple answers permitted):	
Single-family residence on 1 acre or more	20%
Single family residence on less than 1 acre	63
Apartment, condominium, or other multi-family dwelling	6
College dormitory, military garrison or other group quarters	1
Mobile home	4
Automobile, truck or other vehicle	28
Have hand-held transceiver	17
Currently do not have a station	8

Table 3

Average investment in respondents' Amateur Radio stations and average annual expenditure on equipment, supplies, etc.

	Average investment	*Average annual expenditure*
U.S.	$1651	$308
Canada	$2073	$347
ARRL members	$2273	$456
Former members	$1382	$183
Never members	$882	$192
Old-timers	$2143	$316
Newcomers	$1221	$439

Table 4

Terms Used in this Article

Active — Reports some Amateur Radio activity in a typical week during the previous 12 months.
Inactive — Reports no Amateur Radio activity in a typical week during the previous 12 months.
Newcomer — First licensed in 1978 or later.
Old Timer — First licensed before 1946.
HF — Frequencies below 30 MHz.
VHF/UHF — Frequencies above 30 MHz.
DOC — Department of Communications, the Canadian equivalent of the Federal Communications Commission (FCC).
Ragchewing — Conversing with other amateurs on a wide variety of technical and non-technical subjects.

Table 5

Effect of Amateur Radio on career

	U.S.	*Canada*	*Old Timers*	*Newcomers*	*Novice*	*Technician*	*General*	*Advanced*	*Extra*	*Women*
	%	%	%	%	%	%	%	%	%	%
Am studying, do work, or did work in related field	43	45	66	29	25	41	39	53	65	14
In my career, Amateur Radio is or was:										
Very useful	26	34	57	8	8	19	24	36	42	13
Somewhat useful	27	24	24	17	15	27	27	31	31	16
Not particularly useful	41	38	19	54	53	48	49	31	24	63
Expect it to be useful	7	4	0	22	25	6	5	3	3	9

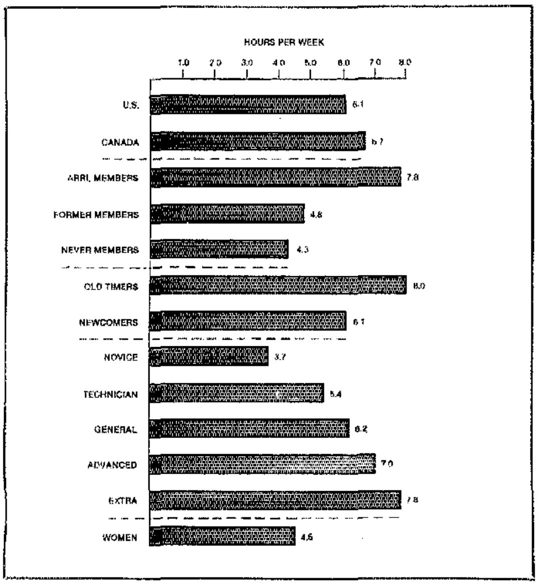


Fig. 1 — Average hours per week spent on Amateur Radio activities.

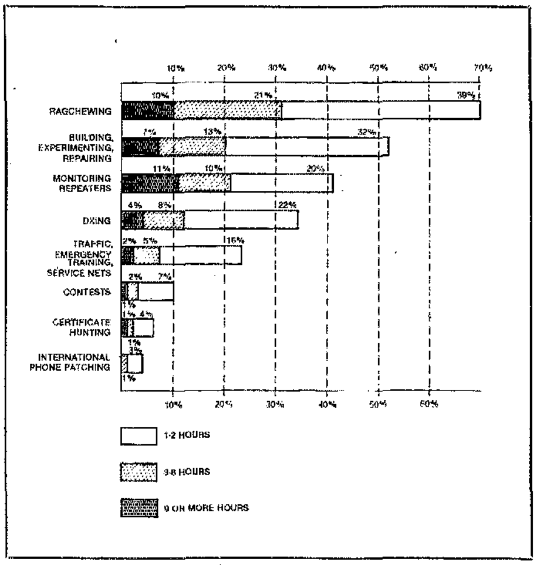


Fig. 2 — Activity by area of operating interest of active respondents. (Average number of *hours per week* during previous 12 months.)

tion. Table 3 shows the financial investment in their avocation of different groups of amateurs. Note that our definitions of "Newcomer" and "Old-timer" are somewhat arbitrary (see Table 4); the survey report broke respondents into five categories according to the year they were first licensed, but we show here only the two extremes because of space constraints. Table 5 analyzes the effect of Amateur Radio on one's career. Newcomers do not expect it to be as useful as old-timers have found it to be; whether this will change as they gain more experience, only time will tell.

Fig. 1 depicts how much time is spent on Amateur Radio activities, and Fig. 2 shows how that time is divided between various activities. Of course, some activities are not listed. Fig. 3 separates the on-the-air activity by band and mode. The results may surprise some who think that "cw is dead" or that "more people are active on 2-meter fm than all other bands combined." Neither statement is true. Predictions of future activity are also important, and are shown in Fig. 4 for some of the more esoteric communications modes. Interest in personal computers and amateur satellites is especially strong, but there is a healthy interest in a number of other new fields.

As a group, amateurs are very conscious of their responsibility to perform public service (Table 6). Emergency communications is seen as especially important, especially among newcomers and women. Table 7 shows that a majority of amateurs possess some capability for providing emergency communications, although only one in six participates in on-the-air training exercises. ARRL members are better prepared for emergencies than non-members. Again looking at Table 6, newcomers and women regard

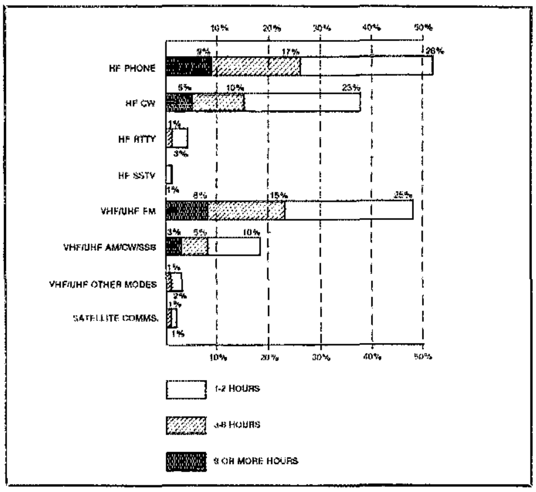


Fig. 3 — Activity by band and mode of active respondents. (Average number of *hours per week* during previous 12 months.)

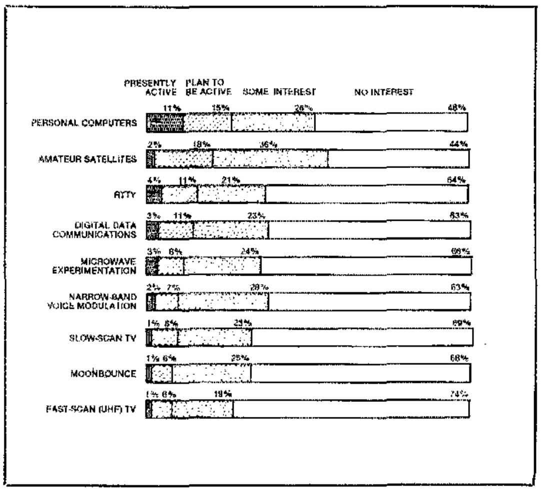


Fig. 4 — Answers to, "How interested are you in the following areas of Amateur Radio activity?"

Table 6

How amateurs rank the importance of the traditional justifications for the Amateur Radio Service

		U.S.	*Canada*	*Old Timers*	*Newcomers*	*Novice*	*Technician*	*General*	*Advanced*	*Extra*	*ARRL members*	*Non-members*	*Women*
		%	%	%	%	%	%	%	%	%	%	%	%
Preparation for, and provision of, emergency communications	very important	65	52	59	71	69	70	63	63	61	67	62	79
	important	33	45	39	27	30	28	34	35	36	32	35	20
	not important	2	3	2	2	2	2	3	2	3	2	3	1
Development of operating skills	very important	54	50	52	58	57	47	53	54	59	59	49	62
	important	44	48	46	40	42	51	45	44	39	40	48	38
	not important	2	2	2	2	2	2	2	3	2	1	3	1
Technical training and experimentation	very important	47	47	49	47	44	46	43	50	60	50	45	46
	important	49	49	49	49	49	50	53	47	38	48	50	49
	not important	4	4	3	5	6	4	4	3	2	2	5	5
Enhancement of international goodwill	very important	49	50	43	56	53	44	49	48	48	52	46	57
	important	43	43	47	38	40	45	43	43	45	42	44	39
	not important	8	7	11	6	7	11	8	9	6	6	10	4

Table 7

Level of emergency communications preparedness

(Multiple responses permitted)

	U.S.	*Canada*	*ARRL members*	*Non-members*
	%	%	%	%
Have one or more vhf/uhf mobile stations	50	62	61	42
Have vhf/uhf hand-held equipment	25	18	31	19
Have one or more hf mobile stations	20	23	26	15
Have emergency power for hf fixed station	20	21	25	16
Participate in traffic or emergency training nets	17	16	24	11
Member of ARES or RACES	12	6	18	6
None of the above	34	27	24	43

technical training and experimentation as "very important" less often than the other three traditional justifications for the Amateur Service: providing emergency communications, developing operating skills and enhancing international goodwill. (The four justifications are taken from the FCC Regulations, Section 97.1, which sets forth the "Basis and Purpose" of Amateur Radio in the U.S.)

Attitudes Toward ARRL

One of the most important survey objectives was to find out how amateurs feel about the League. We often hear criticism, constructive and otherwise, of how the organization functions. One of the purposes of the Long-Range Planning Committee is to recommend changes which will make the League more effective in the protection, promotion and advancement of Amateur Radio. To do that, we need to know how well people think the organization is doing now.

The key survey ingredient was a list of complaints a respondent might have about the ARRL. Respondents were asked to indicate which statements they agreed with, and were permitted to check as many as they wished. It was this part of the survey that caused some members to think it was "anti-ARRL," when in fact the objective was to get an accurate picture of amateurs' attitudes toward their national association.

The results are shown in Table 8. Among non-members, the reason for not belonging most often cited was, "Just didn't bother to join or rejoin." This was followed closely by, "Not active in Amateur Radio." Neither can be regarded as a complaint about the League. The only other important reasons given by more than a scattering of non-members had to do with the dues being too high, *QST* not being as good as some other magazine, and the ARRL position on U.S. amateur license restructuring — a throwback to a controversy almost two decades ago. However, the three of these *together* are the "most important reason" for less than one-fourth of the non-members, and are just as likely to be cited by members as by non-members.

While 77% of the members said they were basically satisfied with the League, the survey also showed the reasons for member dissatisfaction. The same three complaints were cited by members, along with three others: the need for the League to do more in public relations, in solving problems at the local level, and in representing Amateur Radio at the national level.

Having given people a chance to say where the League was not measuring up to expectations, the survey also gave them a chance to assess League performance in specific areas on a scale of "excellent" to "poor." Members particularly praised the *Handbook* and *QST* technical content, and in all cases a majority of members gave a rating of "excellent" or "good" (Fig. 5). In view of the results shown in Table 8, it is interesting to note that 28% of members thought the League's representation before Federal agencies was "excellent," 35% "good."

Table 9 shows who is, and who is not, a League member. Membership is highest among old-timers, Extra and Advanced Class licensees and active amateurs, and is lowest among inactive amateurs. A ma-

Table 8

Nonmember vs. member attitudes toward ARRL

	% of non-members agreeing with statement (multiple answers permitted)	*Single most important reason for not belonging*	*% of members agreeing with statement*	*Single most important reason for member dissatisfaction or lack of interest*
Just didn't bother to join or rejoin	41%	17%	0%	0%
Not active in amateur radio	28	14	3	2
Dues too high	24	11	15	9
QST not as good as some other magazine	23	6	16	6
Don't like ARRL position on U.S. amateur license restructuring	12	6	12	7
ARRL does not represent my point of view	10	3	5	2
ARRL not involved in problems at local level	10	3	12	6
ARRL not effectively representing national level	10	2	10	6
ARRL not responsive to needs/desires of amateurs	9	3	7	3
ARRL not doing enough for public relations	9	2	13	7
ARRL not interested in what I think	7	1	6	1
ARRL not effective representative internationally	7	2	5	2
Basically satisfied with ARRL	27		77	

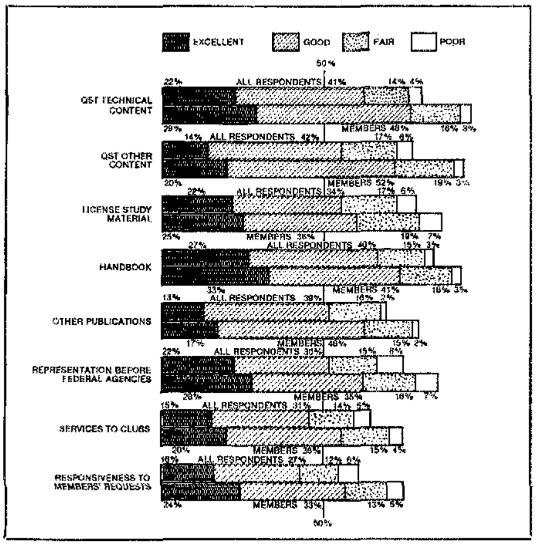


Fig. 5 — Assessment of ARRL performance in key areas. ("No opinion" answers not shown.)

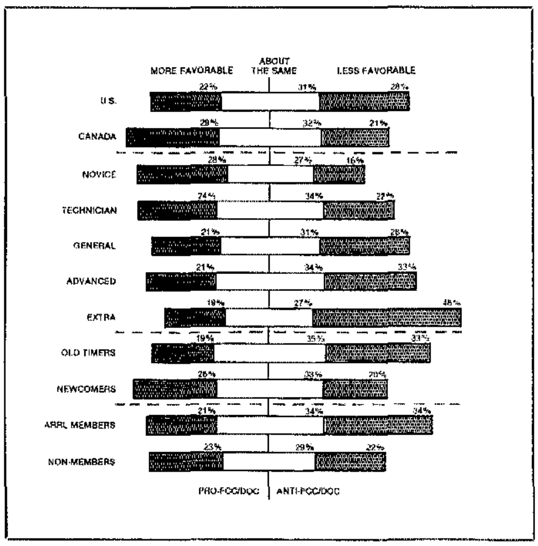


Fig. 6 — Assessment of the direction FCC/DOC are moving in actions affecting Amateur Radio. ("No opinion" answers not shown.)

jority of active amateurs are League members. Of those active three or more hours per week, 58% are League members; the more active the amateur, the more likely he or she is to be a League member.

Who Reads *QST*

Because *QST* is the most visible benefit of League membership, we were particularly curious to compare the readership of *QST* with that of the commercial publications. Table 10 compares the monthly magazines and newspapers serving the national Amateur Radio field in the U.S. and Canada. About 23% of the respondents did not answer this particular question, either because they did not regularly look at any of the listed publications or because they simply skipped the question; it is not possible to separate the two groups, so the percentages shown are calculated on the basis of the respondents who answered "yes" to one or more publications. As a result all of the percentages are slightly overstated in terms of the total amateur population, but the relative effect on all of the figures is the same.

Since the survey was taken, *Ham Radio Horizons* has ceased publication and has been combined with *Ham Radio*. Table 10 shows that one appealed primarily to newcomers and Novices while the other appealed primarily to old-timers and Advanced/Extra licensees, so there was relatively little overlap between the subscriber lists.

While not shown in the table, the survey revealed that the amateur magazine read most by non-members of the League is — you guessed it — *QST*.

How Did You Become a Ham?

When you meet other radio amateurs for the first time, a good conversation-starter is to ask how they happened to get involved in Amateur Radio in the first place. In planning our training efforts it is important to know where the new hams

Table 9

ARRL Membership

(Percentages shown are of those answering the question, "Are you now, or have you ever been, a member of ARRL?")

	U.S.	*Canada*	*Old-timers*	*Newcomers*	*Inactive*	*Active*	*Women*
Present member	46%	32%	64%	41%	22%	52%	32%
Former member	32	37	31	11	41	30	24
Never a member	22	31	5	48	37	18	45

	Novice	*Technician*	*General*	*Advanced*	*Extra*
Present member	29%	34%	41%	58%	76%
Former member	18	31	40	35	21
Never a member	53	35	19	8	3

Table 10

Response to the question, "Which of the following Amateur Radio magazines to you regularly look at?"

(Percentages shown are of those who said they regularly looked at one or more of the listed publications; see text.)

	U.S.	*Canada*	*Old-timers*	*Newcomers*	*Novices*	*Technicians*	*Generals*	*Advanced*	*Extra*	*Women*
CQ	21%	25%	20%	22%	24%	21%	21%	18%	24%	15%
73	37	25	27	36	30	43	35	39	37	32
Ham Radio	20	21	27	9	10	20	15	26	31	11
Ham Radio Horizons	23	12	16	36	35	24	23	18	15	28
Worldradio	7	2	10	7	5	5	5	9	13	9
QST	79	60	87	78	76	69	78	82	89	78
The Canadian Amateur	0	44	2	2	—	—	—	—	—	2

Table 11

Important influences in decision to become a radio amateur

(multiple answers permitted)

	Overall	*Newcomers*	*Canada*	*Women*
Relative	20%	28%	16%	66%
Friend or co-worker	49	47	39	26
CB	15	35	6	17
Shortwave listening	39	28	47	14
Listening to repeaters	5	11	3	13
Book, magazine, newspaper, etc.	26	22	28	8
Film, television, radio, etc.	2	2	2	0
Local or school radio club	16	17	16	15

Table 12

"How useful were each of the following in helping you to obtain your first operator's license?"

	Overall				*Old-timers*				*Newcomers*			
	Great help	*Some help*	*No help*	*Not used*	*Great help*	*Some help*	*No help*	*Not used*	*Great help*	*Some help*	*No help*	*Not used*
Class or formal instruction	31%	12%	3%	55%	18%	8%	3%	72%	47%	13%	2%	39%
Help from a friend	38	26	2	35	38	24	1	37	31	27	2	39
ARRL publications	37	31	3	30	34	26	2	39	32	35	3	31
Other publications	13	31	4	52	8	23	3	67	20	32	5	43
W1AW code practice	23	18	3	56	13	11	2	74	22	16	4	59
Other on-the-air code practice	19	22	3	55	27	22	1	50	13	22	3	62
Recorded code practice	38	22	2	38	17	10	1	71	57	22	1	19

	Canada				*Women*			
	Great help	*Some help*	*No help*	*Not used*	*Great help*	*Some help*	*No help*	*Not used*
Class or formal instruction	46	11	2	40	43	12	3	43
Help from a friend	30	28	4	38	56	18	1	25
ARRL publications	25	29	5	40	41	26	2	31
Other publications	15	34	4	46	20	26	4	50
W1AW code practice	36	11	5	48	27	16	3	53
Other on-the-air code practice	21	23	3	53	19	16	3	63
Recorded code practice	26	20	2	52	54	20	2	25

Table 13

Meeting Attendance

A) How many times have you attended the following types of meetings during the last 12 months?

	None	*1-2 times*	*3-8 times*	*9+ times*
Local (general interest) ham radio club	53%	18%	17%	13%
Specialty club (DX, RTTY, QCWA, etc.)	86	8	4	2
Hamfest	64	27	8	1
Convention	87	12	1	0
Swap meet/flea market	64	26	9	1

B) Those who have attended *at least one* meeting in the last 12 months.

	U.S.	*Canada*	*ARRL Members*	*Non-members*	*Old-timers*	*Newcomers*	*Novice*	*Technician*	*General*	*Advanced*	*Extra*
	%	%	%	%	%	%	%	%	%	%	%
Local (general interest) ham radio club	47	55	59	37	44	53	40	49	44	50	58
Specialty club (DX, RTTY, QCWA, etc.)	14	10	22	8	23	11	8	12	12	18	27
Hamfest	37	19	46	27	31	41	31	38	34	40	47
Convention	13	14	20	8	16	12	8	12	11	16	23
Swap meet/flea market	37	28	44	30	34	37	31	40	33	39	43

are coming from, so the survey set forth to find out. Respondents were asked to indicate which of a number of possible influences were important in their decision to become radio amateurs. The results are given in Table 11.

The table shows the importance of personal contact in the making of a ham. Just about half were influenced by a friend or coworker, and an increasing number (especially women) are influenced by relatives. CB is the next most important for those licensed in the past three years, although shortwave listening is still a significant source of new hams, especially in Canada. Somewhat disappointing is the apparent lack of impact of media such as films, television and radio. These media may be effective in building a favorable public image of Amateur Radio, but they are not attracting new blood into our ranks.

Once the decision to become a ham has been made, the studying begins. Table 12 shows the study aids used by new amateurs. Especially noteworthy is the sharp increase in the use of licensing classes or other formal instruction, and in the use of recorded code practice. It is also interesting that Canadians use W1AW more than their U.S. counterparts do!

Club and Meeting Attendance

We said that our typical amateur did not attend local radio club meetings regularly. This is borne out by Table 13. Canadians are more likely to attend local club meetings, but are less likely to go to other amateur gatherings. League members are far more likely to attend any kind of meeting than non-members. Newcomers go to local club meetings and hamfests more often than old-timers. (Clubs that sponsor licensing classes undoubtedly attract more newcomers than those that do not.) Compared with the ARRL membership percentages (Table 9), local general-interest clubs come out better among Canadians, newcomers, Novices, Technicians and (narrowly) Generals. Support for specialty clubs generally parallels membership in the League, though about one-third the level. Apparently, we need two complementary efforts at the local level: for local clubs to promote ARRL membership among their newer members, and for the League to encourage the more experienced amateurs to remain active in their local, general-interest amateur organizations.

Amateur's Opinions

To anyone who listens on the amateur bands, it should come as no surprise that amateurs say they express their views on the air more than any other way (Table 14). Local club meetings provide an outlet for about one-third of the amateurs, particularly Canadians. Canadians also are more likely to share their thoughts directly with the DOC than U.S. amateurs are with the FCC. Novices are particularly reticent.

We were somewhat disappointed to find that only one League member in seven said he would contact or write his ARRL Division Director to express his views on a matter of importance to Amateur Radio. Directors are elected by the members to make policy for the League, and if they are to represent the best interests of the members they must have some input. The corollary is that those who *do* take the time to write their Director may have a disproportionate influence.

The survey sought amateurs' opinions on several issues: the general direction being taken by FCC/DOC (Fig. 6), the importance of continuing the Morse code requirement for amateur licensing (Fig. 7 and 8), and the seriousness of malicious (deliberate) interference on the amateur bands. League members tended to feel the FCC was headed in the wrong direction on amateur matters, while non-members were evenly divided. Old-timers and Extras were the least likely to agree with the Commission's direction, with Novices the most likely to agree.

Amateurs overwhelmingly supported retention of the Morse code requirement, with those saying it was "absolutely essential" for operating privileges below 30 MHz outnumbering those who felt it should be dropped by about eight to one. The margin dropped to about two to one for operating privileges above 30 MHz, with many others feeling it was "important but not essential." In Canada, where a no-code vhf/uhf license with a rigid technical exam was introduced in 1978, amateurs were still opposed to dropping the requirement but were more likely to make a distinction between hf and vhf/uhf.

Malicious interference was seen as a "very serious" problem at hf by one-third of the respondents, and at vhf by one-fourth. However, as shown in Fig. 9, amateurs who are inactive are almost as likely to say it is a problem as those who are active. Here it may be worth quoting directly from the Florida State report:

Interestingly, this perception of the seriousness of the problem varies only slightly when controlling for hours per week on amateur activities. Even those who report no current activity have very similar opinions about interference. This suggests that attitudes about

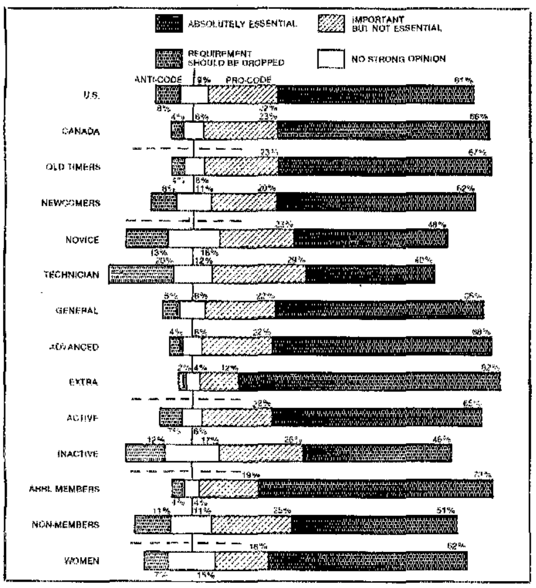


Fig. 7 — Attitudes toward Morse code requirement for hf (below 30 MHz) operating privileges.

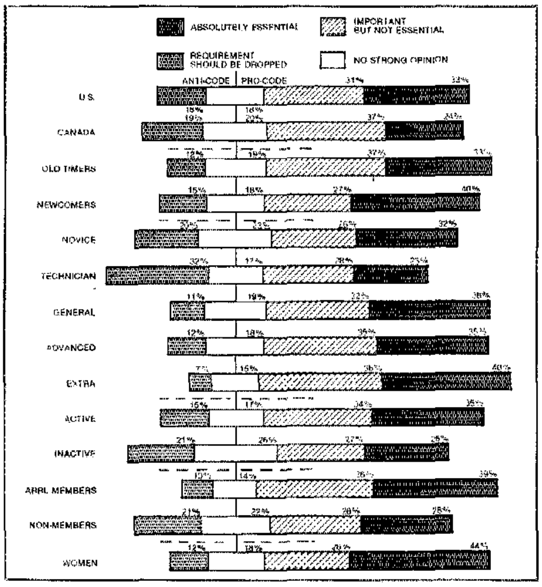


Fig. 8 — Attitudes toward Morse code requirement for vhf/uhf (above 30 MHz) operating privileges.

Table 14

In a matter of importance to Amateur Radio, how do you express your views?

(multiple answers permitted)

	U.S.	*Canada*	*ARRL member*	*Non-member*	*Old Timers*	*Newcomers*	*Novice*	*Technician*	*General*	*Advanced*	*Extra*	*Women*
	%	%	%	%	%	%	%	%	%	%	%	%
Talk about it on the air	58	59	65	53	65	42	23	60	62	69	66	45
Bring it up at local club meeting	34	46	42	27	30	33	24	37	31	37	40	40
Write to the FCC/DOC	12	21	15	10	14	10	8	12	11	14	18	11
Contact or write your ARRL division director	8	6	14	3	16	5	5	5	8	10	14	7
Contact or write your ARRL section communications manager	6	4	10	2	11	4	3	4	6	7	11	6
Contact or write ARRL Hq.	10	5	17	4	16	8	7	8	10	11	19	8
None of the above	27	21	17	35	19	38	55	26	26	18	16	35

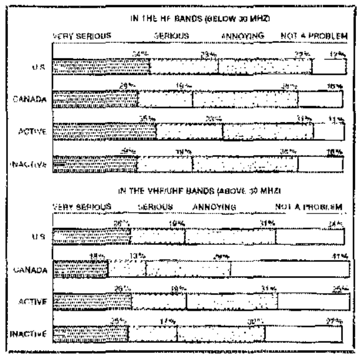


Fig. 9 — Opinions on the seriousness of malicious (deliberate) interference. Percentages are of those expressing an opinion.

interference are as much the result of group norms and beliefs as of experience. From this observation, we may conclude that these data tell us little about the actual number of persons who experience deliberate interference in their operating, only that there is a widespread perception of malicious interference as a serious problem.

This notwithstanding, Canadians are much less inclined to regard it as a serious problem, especially at vhf/uhf.

Women in Amateur Radio

Women always have been a small minority in the ranks of licensed amateurs. Even today, according to the survey, only 6% are women.

If we look more closely at that 6%, though, we see significant changes taking place. Among the newcomers, amateurs licensed since 1978, 14% are women (Table 15). Two-thirds of the female amateurs say relatives were important influences in their decision to obtain licenses (Table 11). Women are much more likely than men to cite "help from a friend" as being a great help in studying, and are more likely to have used ARRL publications and W1AW code practice (Table 12). Although women are less likely to be League members (Table 9), they claim to look at *QST* just as often as men (Table 10), which suggests that there are a lot of potential Family Members in their ranks. At least to now, Amateur Radio has had little effect on women's careers (Table 5).

Women are less active than men, averaging only 4.5 hours per week on Amateur Radio (Fig. 1). Though this information is not included in our tables, the survey also shows that women spend far less time on experimentation and on building and repairing equipment, but are more likely than men to spend a great deal of time (nine or more hours per week) monitoring repeaters and operating traffic/emergency nets. Another survey result not picked up in our tables is that women are more likely to be regular attendees at local, general-interest radio club meetings. This club orientation shows up in Table 14: In expressing their opinion on Amateur Radio matters, women are more likely than men to use the local club as the forum, and less likely to use the airwaves.

Table 15

Respondents' sex by year first licensed.

	Before 1946 %	*1946-60* %	*1961-70* %	*1971-77* %	*1978-80* %	*Overall* %
Male	100	96	96	92	86	94
Female	0	4	4	8	14	6

Women identify emergency communications, development of operating skills and the enhancement of international goodwill as "very important" to Amateur Radio more often than their male counterparts (Table 6). In a result which may be surprising to some, they support the Morse code requirement for licensing on vhf/uhf even more strongly than men (Fig. 8).

The image of the radio amateur as a reclusive chap, misunderstood and unappreciated even by his own family, is fading. Increasingly, Amateur Radio is a family affair, pursued ardently by wives and daughters as well as by husbands and sons.

Other Observations

In some cases the survey report is significant not for what it shows, but for what it *doesn't* show. For example, two of the problems facing amateurs that we hear about most often are antenna restrictions and TVI/RFI. However, 82% said antenna restrictions did not inhibit their Amateur Radio operating, and less than 10% reported receiving TVI/RFI complaints during the previous year, even from their own families. This is little consolation to those amateurs who *do* face these problems, of course.

We have not discussed the "region of residence" breakdown, other than for Canada, because in most cases the differences from region to region do not appear to be significant. However, it is worth noting that in the Western U.S. (W6 and W7 call areas) 24% of the respondents say they face antenna restrictions, as opposed to 17% for the rest of the U.S. and 15% for Canada. Amateurs in the West are less likely to use W1AW code practice, no doubt at least in part because of propagation. They are more likely to regard malicious interference on vhf/uhf as a "very serious" problem, by 37% vs. 23% for the rest of the country.

Conclusion

As the ARRL Long-Range Planning Committee prepares its recommendations for consideration by the Board of Directors, heavy reliance will be placed upon the results of the Florida State survey. In this article, lengthy as it is, it has been possible only to give a broad overview of the results; there is much more information available which will be of use to the LRPC. We wish to acknowledge the work of Dr. E. Walter Terrie, N4WA, and the staff of the Florida State University Institute for Social Research, in designing and executing the survey and in preparing a most comprehensive report. Thanks to their thoroughly professional efforts, we have an accurate benchmark for measuring Amateur Radio's progress in the 1980's and beyond. QST

Notes

[1] "It Seems to Us," *QST*, April 1979, p. 9.
[2] Clark, "Long-Range Planning," *QST*, December 1979, p. 65.
[3] Clark, "ARRL's Long-Range Planning Committee — A Progress Report," *QST*, June 1980, p. 54.
[4] Waters, "Not Just Bigger — But Better Than Ever," *QST*, April 1978, p. 52.
[5] "Moved and Seconded," Minute 25, *QST*, March 1980, p. 65.

Strays

SPACE SHUTTLE COMMEMORATIVE CERTIFICATE

☐ NASA's George C. Marshall Space Flight Center will hold a special-events operation during the first launch and orbital flight of the space shuttle. It is now scheduled for on or about April 7, 1981. Approximate frequencies will be 3810, 3910 (night), 7210 (day), 14,310, 14,240, 21,310 and 28,610 kHz. Listen for WA4NZD periodically beginning with launch time. A commemorative certificate and other information will be sent to stations who contact WA4NZD during the shuttle's maiden voyage. Send QSL along with time and frequency of QSO to MARC — WA4NZD, c/o NASA Exchange CM21X, Marshall Space Flight Center, AL 35812.

When kids spend Christmas in the hospital, what better way could there be to lift their spirits than to bring Santa Claus to them — via Amateur Radio? At the left, a patient at Mobile Infirmary Hospital chats with Santa via a radio provided by the Mobile (Alabama) ARC. At the right, a young fellow at Newington Children's Hospital asks Santa for a special favor — with the help of Miss Connecticut, Jeanne Caruso, and the Newington Amateur Radio League. *(Photos courtesy The Mobile Register via W9ARC and Newington Children's Hospital)*

T-R Switching With PIN Diodes†

Usable from hf to uhf, this state-of-the-art approach to T-R switching eliminates costly mechanical relays.

By Ian Ridpath,* ZL1BCG

PIN diodes are silicon junction diodes with specific characteristics that allow them to switch high levels of rf power while incurring very low losses. It is now possible to provide T-R switching at power levels in excess of 400 watts at temperatures up to 90° C (194° F) at SWR levels of 1:1 or at 100 watts up to 500 MHz under an infinite SWR condition for the same temperature range. In the past, this could have been done only with mechanical coaxial relays which are expensive and do wear out; solid state devices such as the PIN diodes do not wear out and are comparably less expensive.

The specially doped intrinsic or I layer of the diode allows the normal p-n junction capacitance to be reduced significantly and makes the ON resistance typically less than one ohm. A comparison of various diode types operated at vhf reveals how the properties of PIN diodes make them suitable for rf switching (see Table 1). When the diode is forward biased, it becomes a short circuit and when reverse biased, it is virtually an open circuit.

PIN diodes are available with dissipation ratings of up to 10 watts. Assuming maximum power dissipation and an ON (forward biased) resistance of 0.8 ohm, the diode current would be 3.53 A. This current would correspond to a power level of 625 watts in a 50-ohm impedance line. Naturally, the diode would require some form of heat sinking.

A Practical Application

One application of PIN diodes is shown in Fig. 1. In this example, the transmitter

Table 1
Diode Characteristics at VHF

Diode type	*Frequency (MHz)*	*On Resistance (ohms)*	*Off Resistance (ohms)*	*Capacitance (pF)*
Germanium (point contact)	150	20 to 200	10 k	10 to 20
Silicon (junction)	150	5 to 20	50 k	10
Silicon (high speed)	150	3 to 5	50 k	1 to 5
PIN	150	0.8	10 k	1
PIN	30	0.8	40 k	1 to 2

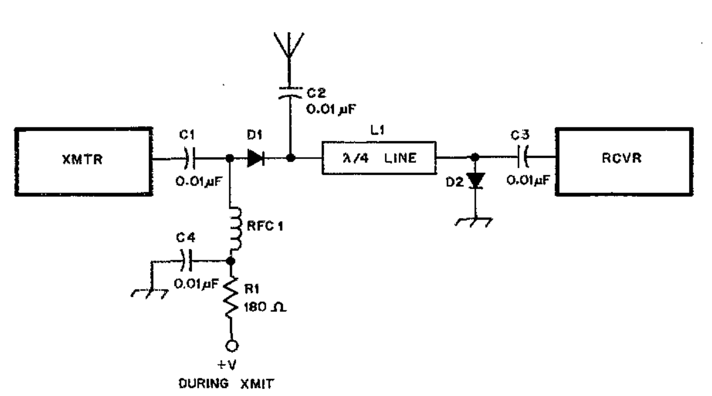


Fig. 1 — The basic PIN diode T-R circuit.
D1, D2 — PIN diode, 150 MHz, 1.5 W, Unitrode UM-9401 or equiv.
RFC1 — 0.035 µH, 5 turns no. 22 enam. wire, 1/4-in. (6.4 mm) dia., 1-in. (25.4 mm) long.

†Adapted from "Use PIN Diodes for T-R Switching and Throw Away Your Coax Relays" in *Break-In* (NZART), January-February 1980.

*50 David Ave., Manurewa, New Zealand

operates at a frequency of 430 MHz with a power output of 25 watts. The diode current is 55 mA and has an ON resistance of 0.75 ohm. R1 is approximately 180 ohms. A 50-ohm impedance system is used. The rf current present would be:

$$I = \sqrt{P/R} = \sqrt{25/50} = 0.7\ A$$

Thus, the power dissipated by the diode is $0.7^2 \times 0.75 = 367$ mW. A small, low-power PIN diode could be used such as the Unitrode UM-9401. This unit has a free-air power dissipation rating of 1.5 watts and is low in cost.

When the transmitter PTT line is enabled, both D1 and D2 are forward biased. The current path is through R1, RFC1, D1, the quarter-wave transmission line and D2 to ground. The ON resistance of D1 is about 0.75 ohm — nearly a direct short. This small resistance causes an approximate 0.2-dB loss of transmitter output power. The low impedance to ground at the D2 end of the transmission line is reflected to the D1 side as a very high impedance. For a 50-ohm line, the impedance would be:

$$Z = \frac{Z_o^2}{Z_L} = \frac{50^2}{0.75} = 3.333\ k\Omega$$

This impedance, compared to the 50-ohm impedance of the antenna line, is very high, so the line is essentially out of the circuit. In reality, a further loss of about 0.2 dB is incurred.

During receive, the voltage on the PTT line is disabled and both diodes are non-conducting. Thus, the effective high impedance of D1 isolates the transmitter from the antenna circuit. At the same time, the 50-ohm quarter-wave line reflects the 50-ohm antenna impedance to the receiver input. The total insertion losses contributed by the diodes and other components is approximately 0.4 dB for both the transmit and receive ports of the network. In theory, 55 dB of isolation is obtainable; in practice, transmitter-receiver isolation on the order of 30 to 40 dB is realized. The reason for the difference is that stray capacitances and the presence of the various components tend to feed some rf around the quarter-wave line and the diodes. At vhf, it is especially important to keep the leads of D2 as short as possible; a couple of extra millimeters of lead length can use a degradation of several dB in the isolation figure.

The theoretical transmitter-receiver isolation can be computed by comparing the rf power at the antenna to that at the receiver input when the transmitter is operated:

$$\text{Isolation (dB)} = 10 \log_{10} \frac{P_{ANT}}{P_{REC}}$$

The amount of power available at the antenna is 25 watts less the 0.4 dB loss or 23 watts. Calculation of the power reaching the receiver is done by using the equivalent circuit of the network when diode D2 is forward biased. It was shown the reflected resistance was 3.333 kΩ, so the rf current flowing in this branch is only:

$$50/3333 \times 23/50 = 7\ mA$$

This 7-mA current flows through diode D2 and the receiver input with most of the current passing through the low resistance path provided by the diode, 0.75 ohm. The power delivered to the receiver is approximately equal to $0.007^2 \times 0.75$ or 37 microwatts. Thus:

Theoretical isolation

$$= 10 \log \frac{23}{0.000037} = 58\ dB$$

To improve the practical isolation figure of 30 to 40 dB, a second quarter-wave line section and another diode can be added as shown in Fig. 2. This will tend to add another 10 dB or so of isolation and is sufficient to prevent burn-out of the rf input stage of the receiver.

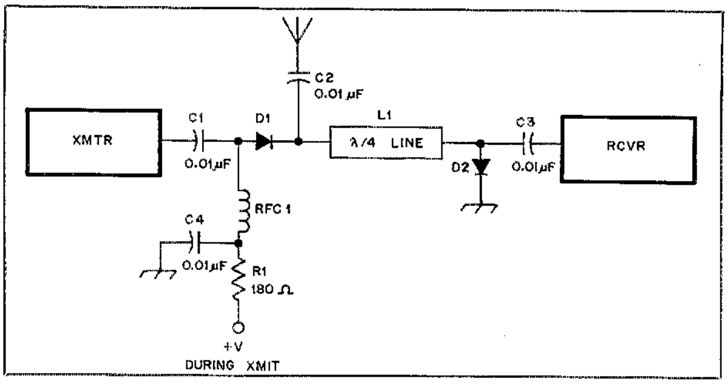


Fig. 2 — An additional quarter-wave line (L2) has been added to the basic circuit to increase the transmitter-receiver isolation by approximately 10 dB.

Bandwidth

Since any quarter-wave line section is a quarter wavelength at *one* frequency only, the antenna changeover circuits are frequency sensitive. However, typical curves show that sufficient isolation can be obtained over a frequency range of 10% of the center frequency. That is, isolation values of 30 dB or more and insertion losses of less than 0.5 dB occur over a minimum of ± 3% of the center frequency. At 430 MHz, a section cut for 435 MHz will work between 429 and 441 MHz. A system designed for 146 MHz would operate over the entire band from 144 to 148 MHz. At 14 MHz, a bandwidth of 500 kHz could be expected. However, it would be impractical to construct line sections for those frequencies. Lumped L-C networks can be used at hf as shown in Fig. 3. (The foregoing limitation does not apply to antenna switching since it is

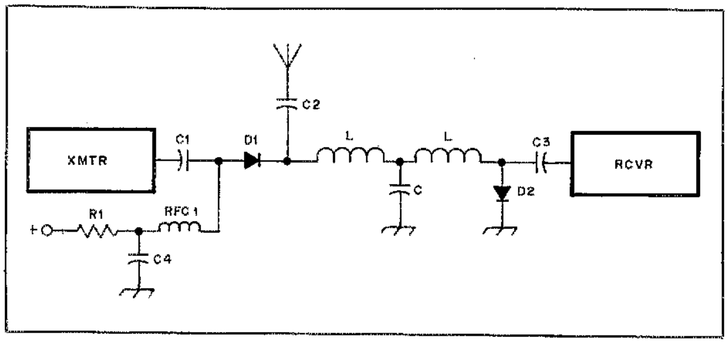
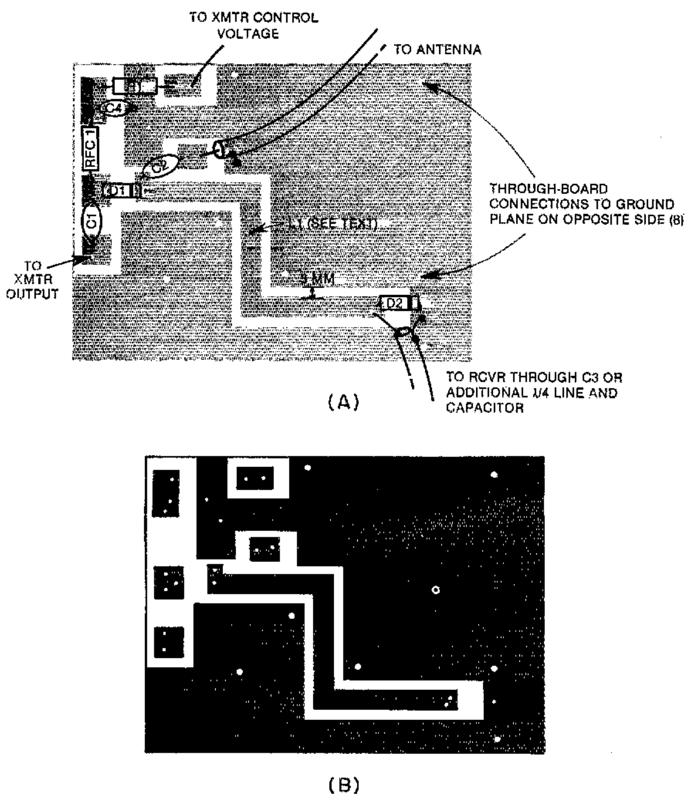


Fig. 3 — A PIN diode switch using lumped LC constants. This arrangement is suitable for use at hf. $L = Z_o/2\pi f$ and $C = 1/2\pi f Z_o$ where: Z_o is the characteristic impedance of the line.



INCHES (") x 25.4 = mm

Fig. 4 — At A, a layout for a 430 MHz PIN diode T-R switch using a strip line etched on double-sided pc board. The details of the strip line are given in the text. Eight through-board connections are made between the ground planes on both sides of the board. At B the pattern is reproduced full size with black representing copper.

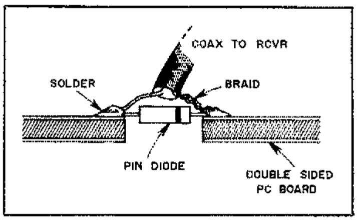


Fig. 5 — One method of attaching the PIN diodes to the double-sided pc board is shown here. Details are given in the text. The coaxial cable leads to the diode should be no longer than approximately 5 mm (0.2 in.).

quite practical to use quarter-wave coaxial cable line sections to perform matching and phase delay functions.)

PIN Diodes at UHF

An example of the use of PIN diodes for performing the T-R function for a uhf transceiver is shown in Fig. 4. In this case, the quarter-wave line section is a strip line etched on a double-sided pc board. It is vital that the diode leads be kept short to ensure good performance. The best way to achieve this is to cut out a small rectangle in the pc board and place the diode in this cutout so that the leads are flush with the plane of the board. The leads can then be soldered to the etched line and the ground plane. The coaxial cable connection to the receiver should be dressed so that very short leads are used at the point of connection to the diode. Fig. 5 shows how this is done.

When calculating the length of the quarter-wave line sections, the velocity factor of the transmission line must be taken into account. At 144 MHz, a quarter-wave section of RG-58/U (with a solid polyethylene dielectric) would be 1/4 × (300/144) × 0.66 m or 344 mm (13.5 in.) in length. At 430 MHz, the length would be 115 mm (4.5 in.).

For a pc board strip line quarter-wave section, other factors must also be considered. The dielectric constant of the board as well as the thickness of the copper affect the velocity factor. If glass-epoxy double-sided board with 1-oz copper is used, a 6 mm (0.24 in.) wide etched line will have a characteristic impedance of about 40 to 45 ohms. At 430 MHz, the length of a quarter-wave section would be found by:

$$L = \frac{1}{4}\left(\lambda\right)\left(\frac{K}{E_R}\right)$$

Where: λ is the free-air wavelength, K is the ratio of the line thickness to width, and E_R is the dielectric constant of the board material. Thus, our line would be:

$$\frac{1}{4}\left(\frac{300}{430}\right)\left(\frac{1.086}{1.58}\right) = 120 \text{ mm}$$

The dimensions of the strip line would then be 120 × 6 mm (4.72 × 0.24 in.). This line may be etched on the top side of the board with the ground plane surrounding it and spaced about 3 mm (0.12 in.) away; the bottom of the board should remain unetched.

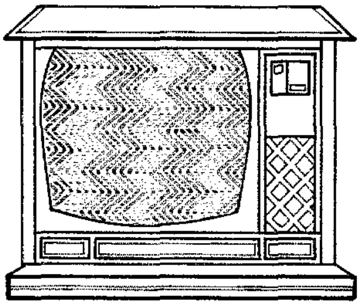
Remarks

For those who wish to experiment, the Unitrode diodes are available from larger distributors.[1] An existing relay type T-R system may be replaced by merely adding two PIN diodes, a resistor, rf choke, some coaxial cable and a few dc blocking capacitors. If you're a bit wary of "pumping" rf into the receiver and damaging it, the receiver port of the switch may be initially terminated with a 50-ohm resistor and the voltage across it measured to ensure that it is at a safe level.

Some of you may wish to try using PIN diodes at hf to switch or phase antennas by applying the dc control voltage to the center conductor of the coaxial cable. Experimenting will no doubt produce some interesting circuits, especially for vhf and uhf antenna switching. Such circuits are now being used commercially and there is no reason why amateurs should not make use of this relatively new technology. QST

[1] Unitrode Corporation, 580 Pleasant St., Watertown, MA 02172. An application note entitled, "PIN diodes for Two-Way Radio Antenna Switching" is available. Another source of information regarding PIN diodes is the Motorola Application note AN-548A, available from Motorola Semiconductor Products, Inc., P. O. Box 20912, Phoenix, AZ 85036.

Color TVI — A Solution



Got a tough color-TVI problem? Don't give up! A few feet of coax may turn out to be the coil of your dreams.

By Carl Eichenauer,* W2QIP

Suppose you have just put up a new two-band inverted V antenna for 80 and 40 meters. You find it works well — good signal reports, acceptably low VSWR, etc. — it makes you feel it was worth all the effort. Then suppose you took a look across the room at the TV set — what a revolting development! — vivid blue, red and green hash marks run across the screen every time you close the key! To make matters worse, the rig is running "barefoot" on 40 meters. A check on 80 meters reveals that the hash marks are of an even more ghastly nature. If you really want to see a hideous display you flip on the amplifier! How could this be? You *never* had TVI on 80 and 40 meters before!

Things That Didn't Work

You now consult a cadre of seasoned technical experts with whom you are acquainted. "Obviously," says the first expert, "you need a low-pass filter in the output transmission line of your rig." You assure him you have had one there for years and with this interference it makes no difference if the filter is in or out of the line.

A second expert now speaks: "It's apparent that you must not be aware that you should have a high-pass filter installed at the antenna input terminals of your TV set." You assure him that one has been implanted at that location for years. In fact, you connected *two* in tandem. Again, it made no difference.

"Well," says the third expert, "for a case like this you really ought to get rid of that cheap TV twin-lead feed line and use coaxial feed line — complete with balun matching transformers at both ends — between your TV antenna and your TV

*205 Lathrop Rd., Syracuse, NY 13219

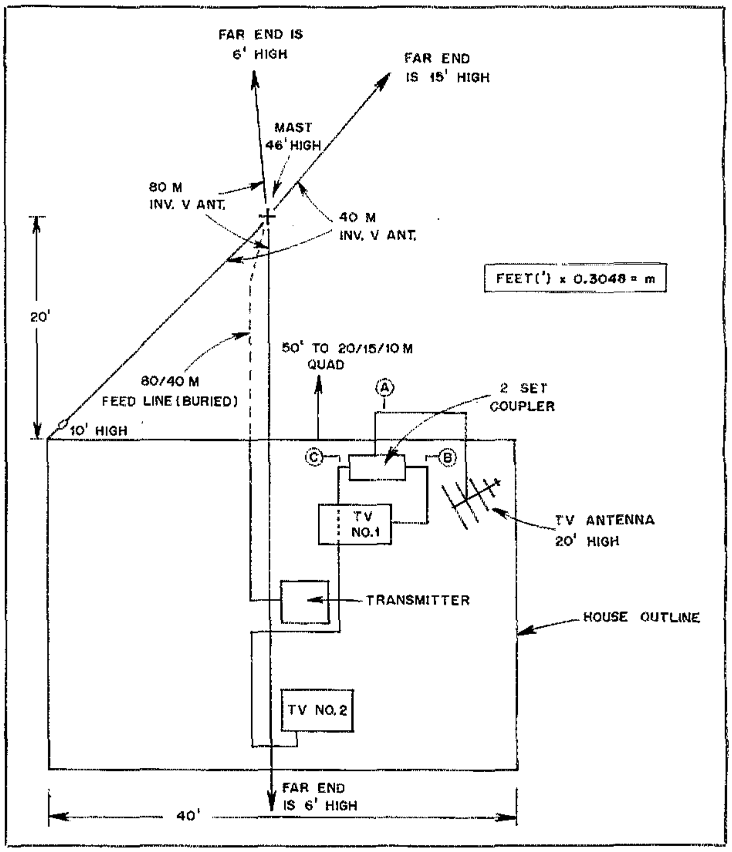


Fig. 1 — Plan view of the antenna, TV and transmitter layout. TV set no. 1, the two-set coupler and the transmitter are slightly below ground level. TV set no. 2 is slightly above ground level. The coaxial cable length from the TV antenna to the coupler is approximately 28 feet (8.5 m); from the coupler to TV set no. 1, 6 feet (1.8 m); and from the coupler to TV set no. 2, 35 feet (10.6 m). All antenna heights shown are relative to average ground level.

set." You assure him that is what you are using already.

"Now look here," says expert number four, "it's clear you have bad filters, a loose or corroded joint in your TV antenna or some other form of shoddy workmanship in your TV system." "Well," you ask, "how come there is no TVI when I aim my quad at the TV antenna on 20 and 10 meters and just a little bit on 15? And, after all, you have to expect some TVI on channel 3 — third harmonic, you know." No answer.

Two experts are left. "Look fella," says expert five, "haven't you ever heard of TVI coming back through your power line cord? You need a line filter!" This you hadn't tried. A trip to the local electronics outlet nets you a filter which "cuts most electrical appliance interference on color and black-and-white TVs. Instant installation." It did indeed install easily. Unfortunately, the TVI was the same with or without the line filter installed.

One expert is left. "Buddy," he declares, "the solution is simple — move out to the country where you have no neighbors, and convince your family that watching TV is bad for their eyes!" You are tempted . . .

Searching the Literature

The preceding tale of woe, while dramatized slightly, describes the problem I encountered and the steps I took to cure it — without success. A search of my *QST* file from the past 10 years yielded lots of TVI articles, but none with a solution to the problem at hand. The basic situation was mentioned obliquely in the ARRL *Handbook* as "color subcarrier interference."[1] The description didn't quite seem to fit my 40- and 80-meter problem, however. Another informative article, "Color TVI," described a situation similar to mine, except the problem occurred primarily on channel 4 and the interference band was 20-meter phone.[2] My problem was interference with channels 3, 5, 9 and 24, while operating 40 or 80 meters on either cw or phone. The Detroit, Michigan, group that was mentioned in the article hadn't found a good solution to their problem.

Then, in *QST*, I discovered an article — not on TVI — but on indoor antennas.[3] This is a subject near and dear to my heart because I've used so many indoor antennas at different locations. I started reading it, mostly to forget my TVI problem and reminisce about the good old days when no one even knew I had a ham station because it had an invisible antenna. Suddenly I got the idea which was responsible for solving my TVI problem.

Experimental Phase

Fig. 1 shows a bird's-eye view of the antenna farm on my 50-foot wide residential lot. Probably your first question is, "Why would anyone in their right mind run one leg of an 80-meter inverted V within 15 feet (4.6 m) of his TV antenna?" The location was dictated by the existing pole in the middle, the tree on one end and the lamp post on the other end. Besides, one doesn't have much leeway in placing a full-sized 80-meter antenna on a lot of such dimensions even under the best of circumstances.

In his article, Fred Brown states, "Inevitably, any conductor in your house, a quarter wavelength or longer, will be parasitically coupled to your antenna." Take a look at the coaxial feed lines going to the TV sets in Fig. 1. Don't they look like they fit the role of being coupled parasitic conductors? It looked that way to me.

Fred wisely counsels that before you spend a lot of time doing wrong things to improve the situation, you should make some initial measurements. He suggests the current-probe instrument shown in Fig. 2. The device is simple to construct, easy to use, and highly effective in measuring the presence of currents in parasitic conductors.

Armed with the current probe, measurements were made at various locations on the outer surface of the TV coaxial feed line with the rig operating at 3580 kHz. This is the frequency of the chroma oscillator in a color TV set and interference at this frequency seems to cause the most hideous TVI displays. There was no doubt left in my mind that substantial parasitic currents were flowing on the feed lines.

What next? Brown suggests the use of a "magic" figure-8 "breaker" loop for indoor antenna work when objectionable parasitic elements are encountered. My version of his breaker loop is shown in Fig. 3. It had to be somewhat larger than the original because Brown's was designed for 14 MHz and mine for 3.5 MHz. I used no. 12 house wire for the loops, tuned it with a 150-pF variable capacitor, and taped it to the TV coax line at location A in Fig. 1, just ahead of the two-set coupler. Placement selection was based on the assumption that "breaking" the feed line at this point would best isolate rf pickup from the vertical down lead of the TV antenna.

The moment of truth had now arrived.

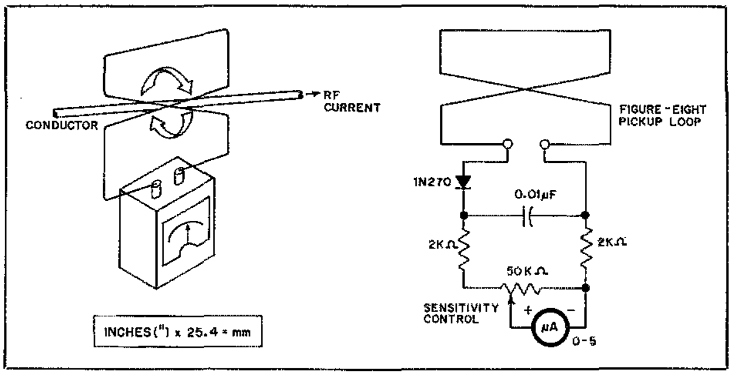


Fig. 2 — This current probe, constructed in a 3 × 4 × 5-inch (76 × 102 × 127-mm) enclosure, can be used to measure relative rf current in any conductor. The instrument may also serve as a field-strength meter or wavemeter. Arrows show how the magnetic field surrounding the conductor threads through the figure-eight loop. This model contains a 5-µA meter, but a less expensive meter movement, such as a 50-µA unit, may be employed. If a 0- to 1-mA meter is used, the sensitivity control should be changed to 10 kΩ.

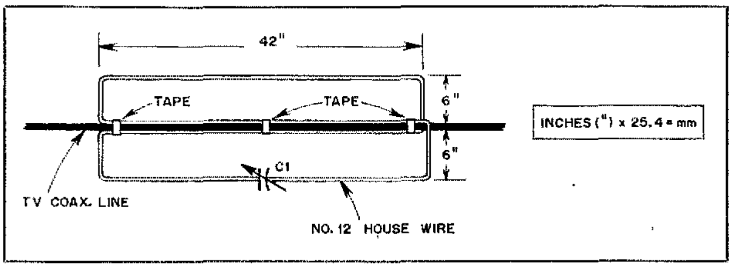


Fig. 3 — The breaker loop for 80 and 40 meters. The loops should be taped securely to the TV coaxial cable at several locations. Gaps between loops and the outer surface of the coax greatly lessen the coupling effectiveness of the assembly. C1 should be adjustable and have a maximum capacitance of 150 pF or more. Either air variables or compression capacitors are satisfactory.

[1]Notes appear on page 24.

The rig was placed in transmit. Slowly, the breaker loop variable capacitor was rotated. Eyeballs were fixed on the grizzly TV-set interference display. Suddenly — eureka! — the lines all but vanished! Who said TVI problems couldn't be licked?!

Wait a minute . . . what about 40 meters? When the SB-101 was keyed on 40 meters, the blue, green and red stripes were as gaudy as ever. Once again the variable capacitor on the breaker loop was slowly rotated to establish resonance on that band. Again success smiled on the experiment. The principle and hardware had passed its second test.

At this point, the third moment of truth arrived. The SB-220 amplifier was placed in action at full legal input power. The picture remained clear on the TV set for several seconds. Then, with an audible snap! the interference returned. The variable capacitor in the breaker loop had actually *arced over* between the plates! A check revealed that one of the plates of the vintage capacitor was bent, thereby reducing its voltage-handling capabilities, but the arc nevertheless indicated that the levels of power on the parasitic TV feed line were more than microwatts and probably more than milliwatts.

The bent capacitor plate was straightened and the breaker loop then kept the TV picture clean for sustained key-down periods. A subsequent test, using a hand-held 20-watt fluorescent light bulb positioned in contact with the two-set coupler outer surface showed that this highly *insensitive* indicator could be illuminated to full brilliance when the breaker loop was detuned from resonance! Small wonder that there was 40-meter TVI — the whole outer surface of the TV antenna system must have been near resonance on 40 meters before the breaker loop was introduced into the system.

Some Improvements

Once the source of a problem has been uncovered, one can sit back in his easy chair and conjure up better ways to lick the problem. In my case, there was insufficient room to install more than one of the large breaker loop assemblies in the vicinity of the two-set coupler. Because of the two-set installation, a single breaker loop could not completely eliminate the TVI when operating with full legal power on 80 meters. As a result, the more compact breaker loop design shown in Fig. 4 was devised. All the necessary parts were obtained at the local Radio Shack store.

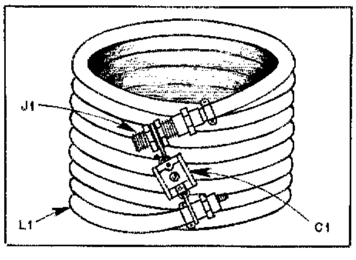


Fig. 4 — The compact breaker loop assembly. Construction of the assembly is discussed in the text.
C1 — 150-pF ceramic trimmer, Radio Shack 272-805.
J1 — F-81 bushing, Radio Shack 278-213.
L1 — 8 feet (2.4 m), 75-ohm coaxial cable with an F-59 connector on each end, Radio Shack 15-1530.

Simply coil the 8-foot (2.4-m) length of 75-ohm coaxial cable into an 8- or 9-turn assembly, and secure the coil with several strips of electrical tape. (The indicated assembly is supplied complete with end connectors.) Insert an F-81 bushing at one end and secure a copper wire of 5 or 6 inches (127 or 152 mm) in length to the bushing by means of the mounting nut that comes with it. Next, twist another 6-inch (152-mm) copper wire to the connector at the other end of the cable. Twist connections are suggested because these connectors do not take solder very well. Solder an appropriate tuning capacitor between the two copper wire ends using the shortest possible lead lengths.

The finished product you now hold in you hand is a resonant circuit comprised of the inductance of the outer surface of the coaxial cable coil tuned to resonance by means of the capacitor. When connected in tandem with your TV transmission line, it displays a high impedance on its outer surface, thereby vastly reducing the flow of any parasitically induced line currents on that surface. Of course, you have to tune the capacitor to make the circuit resonant at the interfering frequency. Resonance may be checked with a GDO or by tuning the capacitor for minimum TV interference. Installation of the breaker loop consists of opening the existing TV feed line connection, inserting the resonator and adjusting the capacitor for minimum interference.

In my particular installation, three breaker loops were used. Referring to Fig. 1 again, one assembly was installed at input port A of the two-set coupler and resonated at 40 meters. The other two units were installed at splitter ports B and C. They were resonated for 80 meters. For a single set installation, the resonator(s) should probably be installed at the coaxial connector closest to the TV set input, although checking of parasitic line currents may indicate a more effective location.

Conclusions

Every amateur/TV antenna installation is unique. Perhaps my system approaches a worst-case situation, but I suspect that a check with a detector such as shown in Fig. 2 will disclose TV feed line parasitic currents to a greater or lesser degree in most cases. One thing is certain: Hf currents on the TV feed line can bypass the front-end circuitry of a TV set and cause undesired displays on the picture tube. My guess is that the capacitance of the TV set components to actual ground provides a path through which the coaxial cable parasitic currents can flow. This idea was essentially borne out by my experience that the upstairs color set was much less severely affected than the downstairs set, which was in close proximity with earth ground.

While this study involved only a coaxially fed TV system, the problem may be as bad (or worse) with parallel-wire fed systems. Perhaps a breaker similar to the type recommended for amateur vhf work (as shown in the ARRL *Handbook*)[4] could be modified to tune to the lower frequency ham bands and produce the desired effect with such systems.

If you have a TVI problem that doesn't respond to the standard elimination measures, you may find the techniques described here (or variations thereof) will help solve your problem. Good luck!

Notes

[1] *The Radio Amateur's Handbook*, 1979 — 1981 editions, p. 15-13.
[2] Dage, "Color TVI," Technical Correspondence *QST*, September 1978, p. 32.
[3] Brown, "Better Results With Indoor Antennas," *QST*, October 1979, p. 18.
[4] *The Radio Amateur's Handbook*, 1966 edition, p. 581.

Strays

I would like to get in touch with . . .

☐ amateurs in Indonesia or Europe (especially The Netherlands) who collect Indonesian stamps. Don Griffith, NØRF, 603 Joyce Ann Dr., Manchester, MO 63011.

QST congratulates . . .

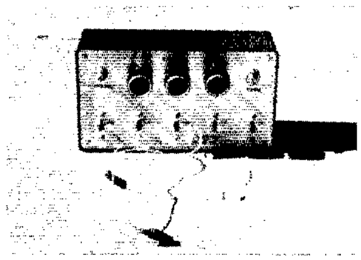
☐ L. Phil Wicker, W4ACY, for his 26 years of outstanding service to Amateur Radio in the Roanoke Division as assistant director, vice director and director. Phil received a special service award from John Kanode, N4MM, president of the National Capitol DX Association. John has since been elected vice director of the Roanoke Division.

☐ Kenneth M. Miller, K6IR/W9NQT, who has been elected a "Fellow" of The Radio Club of America, Inc.

☐ John Hunt, WB9VJZ, of Madison, Wisconsin, who has been awarded a $3000 American Cancer Society Institutional Research Grant at the University of Wisconsin, Madison.

• *Basic Amateur Radio*

A Cheap Resistance Box



Need a decade resistance substitution box? Let your junk box supplant your bank account. Build this replacement.

By Bill Davidson,* KW4J

Being the "cheap old codger" that I am, I didn't want to spend money to buy a decade resistance substitution box. That meant that I had to build one or do without, which would make experimenting difficult — particularly biasing transistor circuits.

A Logical Switch

Well, one look into a catalog showed me that if I bought the parts separately or as a kit, I would still be spending too much money! For example, a 10-position switch would cost about $2.75 — and I would need 10 of them. This had to be a junk box project.

Some reclaimed potentiometers seemed to be the most logical choice. But how to hook them together? A little reflection indicated that it would be necessary to wire the various values in series with some means of bypassing any particular value without breaking continuity. All that is required is an spdt switch and the chosen value potentiometer. A schematic diagram of my circuit is shown in Fig. 1.

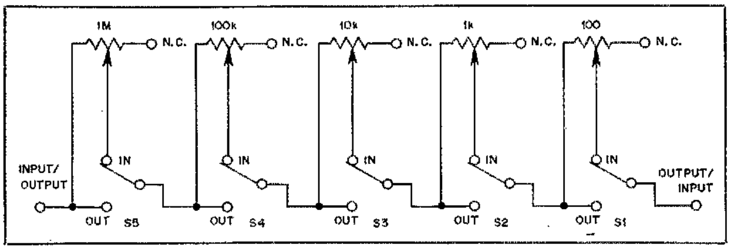


Fig. 1 — Schematic diagram of the cheap resistance box. Resistances are in ohms, k equals 1000, M equals 1000000. Component values, sizes and styles are noncritical. The switches can be any convenient (cheap) variety that provides at least one pole, double throw. The resistance settings of each potentiometer may be indicated by front-panel calibration marks.

I used three-position slide switches which I bought from a surplus dealer (S1-S5). The potentiometers came from various pieces of equipment that I had cannibalized over the years. The box is from Radio Shack (I had purchased it for another project, but it was too small). I had all the parts on hand to build the resistance box without having to buy anything.

The three-position slide switches did present one problem in that I had more positions than needed. By cutting the slot holes such that the switch lever will slide between two positions only, I made the front panel serve as a mechanical stop. I did cut one of the holes large enough for full movement of the slide lever; I can intentionally break the circuit if need be. If you want this feature and are planning to use spdt toggle switches, I would recommend that one of them be of the center-off variety.

My construction techniques may leave a lot to be desired, but they do get the job done. The switch slots were cut with a Dremel tool; a small file would also work. It took about three hours from start to finish, including adding dry transfer lettering. I was unable to put knobs on two of the potentiometers because the shafts were designed for screwdriver adjustment. As far as I am concerned, that is merely a matter of cosmetics and does not interfere with their operation.

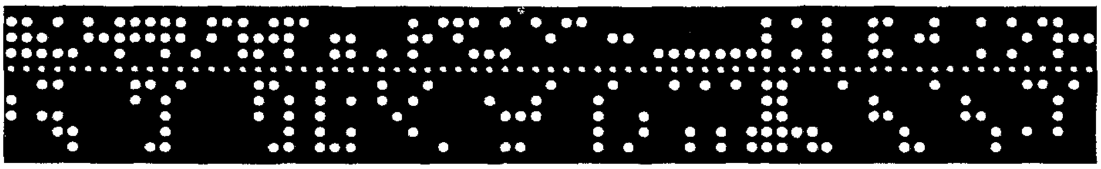
There is one obvious disadvantage to this design as compared with that of a decade resistance box. To adjust or measure a resistance accurately, the box must be disconnected from the circuit and measured with an ohmmeter. The box can be calibrated roughly with the position marked on the front panel. Of course, if multiple-turn potentiometers are used, it will be necessary to note the number of turns for a particular setting.

Another thing about this device is that any type and size of potentiometer can be used. Mine has 1 MΩ through 100-Ω potentiomenters because I had them and they were convenient. Virtually anything will work, even logarithmic taper (volume control) potentiometers.

I have used the box in several applications and found it adequate for my tasks. Perhaps you would be able to make use of a similar design at your work bench. After all, you don't have to be a "cheap old codger" to want to save money these days. QST

*2337 Regent La., Birmingham, AL 35226

But Do You Understand ASCII?



You may be familiar with the ASCII table. But putting this computer-age mode of RTTY to work depends on some important nitty-gritty technicalities, a few quirks and some fine points.

By Glenn L. Williams,* AF8C

"What is all the excitement about ASCII? I hear the FCC has added more rules to Part 97 by allowing ASCII on the amateur bands. And how will I ever learn what it is all about before I take that exam next month? Why do hams need ASCII anyway?" Perhaps these thoughts have brought concern to more than one amateur trying to upgrade or move into RTTY. The point is that ASCII has become the most important technical improvement in Amateur Radio since the arrival of single sideband. Many new and interesting developments are just in the offing and no one can say that all the implications are even known yet.

Informed amateurs are by now aware of the changes in the wording of Part 97.69 of the regulations as amended by the FCC in March 1980. At long last, the amateurs have a more modern RTTY mode, immediately compatible with their hobby computers and the more modern teleprinters.

Certain technical details of ASCII are not often spelled out in amateur publications. Quite often it is the computer hob-

*513 Kenilworth Rd., Bay Village, OH 44140

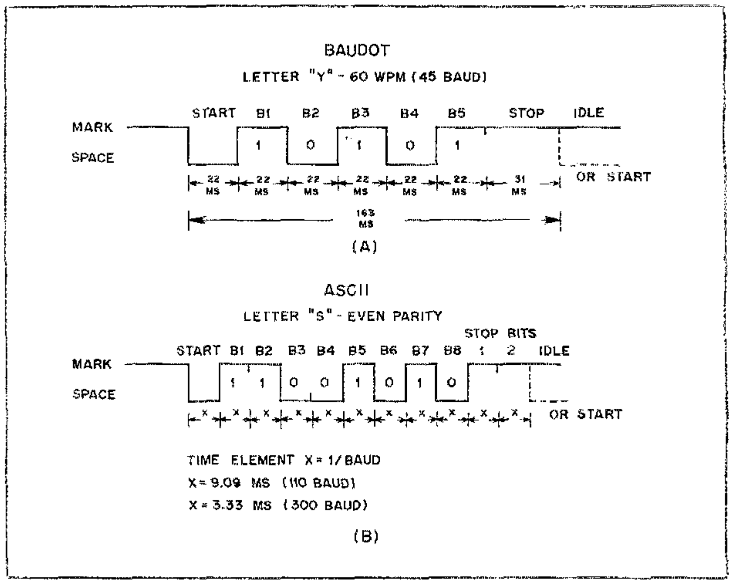


Fig. 1 — The time sequence for the Baudot letter Y is shown at A. B illustrates the time sequence for the ASCII letter S. The eighth ASCII bit is known as the parity bit (see text).

Table 1

Baudot Code

Code Bits							*Code Bits*						
B5	*B4*	*B3*	*B2*	*B1*	*Letters*	*Figures*	*B5*	*B4*	*B3*	*B2*	*B1*	*Letters*	*Figures*
0	0	0	0	0	blank	blank	1	0	0	0	0	T	5
0	0	0	0	1	E	3	1	0	0	0	1	Z	+
0	0	0	1	0	LF	LF	1	0	0	1	0	L	)
0	0	0	1	1	A	–	1	0	0	1	1	W	2
0	0	1	0	0	space	space	1	0	1	0	0	H	#
0	0	1	0	1	S	'	1	0	1	0	1	Y	6
0	0	1	1	0	I	8	1	0	1	1	0	P	Ø
0	0	1	1	1	U	7	1	0	1	1	1	Q	1
0	1	0	0	0	CR	CR	1	1	0	0	0	O	9
0	1	0	0	1	D	$	1	1	0	0	1	B	?
0	1	0	1	0	R	4	1	1	0	1	0	G	&
0	1	0	1	1	J	bell	1	1	0	1	1	FIGS	FIGS
0	1	1	0	0	N	,	1	1	1	0	0	M	.
0	1	1	0	1	F	!	1	1	1	0	1	X	/
0	1	1	1	0	C	:	1	1	1	1	0	V	=
0	1	1	1	1	K	(	1	1	1	1	1	LTRS	LTRS

LF = line feed
CR = carriage return

This is a typical Bit Map or Code Map showing the cross-correlation to Baudot code. Punctuation in Figures column may vary slightly depending on original use of the machine.

byist or professional who acquires his knowledge of ASCII by other means and who joins the knowledgeable few on the air to the bewilderment of the non-ASCII hams. These new users of the RTTY frequencies will bring a range of information and skills into the ranks of the old timers. So we will all need to comprehend the rules as set forth in Part 97.

This article explains the ASCII code and some common terminology and potential misunderstandings associated with ASCII and Baudot serial communications. It explains how the FCC rules open up the bands for the new mode but leave certain details unanswered. We will see that when the enthusiast has acquired hardware and invested his time in RTTY already, the adaptation to ASCII becomes as simple as minor speed and shift adjustments[1] and the addition of a new teleprinter.

Bits and Characters

RTTY communications prior to March 1980 used only equipment and methods compatible with International Telegraphic Alphabet No. 2 (commonly called the Baudot code). In that mode, a single character is sent with the well-known *start* bit, then five information bits and finally a *stop* interval about 1-1/2 bits long, as shown in Fig. 1A. The 5-level Baudot code is comprised of five elements of information, each one called a *bit* (from *bi*nary digi*t*) by the computer people.

The *start* bit, by dropping to the *space* current level, initiates movement of the mechanism in a teleprinter to perform printing or punching in the receiving equipment. Then the five bits of information sequentially pull in the selector magnet to set up the mechanism for a character which is completed by the *stop* bits at the *mark* current level.

By amateur regulations in Part 97.69, the length of the bit sequence, bit timing and words-per-minute rate were constrained to be certain standard rates and timing[2] so that amateurs and the FCC both could copy QSOs with commonly available equipment.

Bit sequencing, code and modulation rate were all predefined for the amateur in a mode that is becoming more and more outdated. The Baudot code, shown on a bit-level basis in Table 1,[3] predates ASCII by a number of years. The standard bit sequence of any character from Table 1 is that the *least significant bit* (LSB) is sent immediately after the *start* bit, followed by the other bits in ascending order until the *most significant bit* (MSB) is reached just before the *stop* interval. This is the way the serial code and the teleprinters have always operated, even though the bits could have been sent in reverse or some scrambled order. But to shy away from the standard was, and is, a way to invite incompatibility and confusion. (It is interesting to note that the bit sequencing, as this is called, is not specified in Part 97.69 explicitly. Nor is ASCII, as defined in the cited ANSI standard, defined with the bit sequencing. That definition is a different ANSI standard not mentioned in Part 97.69.)

Now, with bits of code, only 2^5 or 32 different unique codes exist if the code contains only five bits. Since there are 26 letters, 10 numerals (0 through 9) and many special characters (!@#$%¢& for example) obviously, there are more than 32 total characters to be printed. The 5-level code as a result reserves two special codes for FIGS and LTRS to actuate carriage shifting to permit an alternate set of printing characters to accommodate the left-over character requirements (Table 1). The RTTY enthusiast knows only too well what happens when a carriage shift character is lost during a noise "hit" in reception! The following printout is all garbled until order is restored, often too late, with another carriage shift character. A code with more bits would alleviate this problem, one would surmise. Imagine the problem for the computer programmers when the same code could mean one of two characters! The industry avoided this problem by adopting other codes, with ASCII becoming prevalent in the 1960s.

Baud Rate

But first, let us ponder "bauds" for a minute. By technical dictionary definition, loosely paraphrased, baud rate is *modulation rate* and not necessarily bits per second as is often presumed. Obviously, in order to pass information through the communications medium (wire or radio) the bits must be modulated onto some carrier at some keying rate. The simple 20-mA, 60-mA polar or nonpolar current loops are examples of modulation of current flow with bits of information, usually on a one-for-one basis. In this case, "baud per second" or baud rate is equivalent to bits-per-second (bps).[4] The next more complex method is to modulate an rf carrier on and off (A1), change its frequency (F1), change its phase (similar to F1) or do likewise with an audio tone which is then modulated by ordinary means onto an rf carrier (A2 or F2). The result so far still gives one modulation change per bit and is all we are allowed to do by Part 97.69. Here again baud rate and bps are the same.

But to satisfy the requirements for operation in noisy environments or with reduced bandwidths, the bits can also be modulated onto a medium where each bit is converted into a group of pulses (as in floppy disc recording) where some of the pulses provide clocking information, or the bits broken down into pairs which are used to phase-shift key several different audio tones at the same time (QPSK modems). In these circumstances, several changes of signal characteristics in combination result in the transfer of one or more bits at a time. That is, there may be *m* modulation changes per *n* bits transferred (*m* not equal to *n*). This lack of a one-for-one match of modulation changes and bits sent means that the baud rate may be different from the resultant bps rate.[5] Hence, there is some reluctance in the industry to use the term "baud rate" in order to avoid confusion as well as grammatical redundancy. We hams tend to refer to baud rate as meaning bits-per-second without worrying about being precise. Wisely, the rules of Part 97.69

[1]Notes appear on page 30.

limit our maximum baud-per-second rate because it is the modulation rate, not the effective bit rate, that causes rf sidebands.

The effective bit rate in the serial mode of character transmission accounts for less than maximum utilization of the bandwidth. In the case of the serial Baudot character, those *start* and *stop* bit intervals (Fig. 1A) do not convey information; rather they assist the receiving equipment in character synchronization. In particular, during the 163 millisecond (ms) period of one character time at one of the popular speeds, only five bits are transferred. Since five bits make one letter to be printed, there are 1/0.163 = 6.13 letters per second transferred. Presuming that an average word takes five letters and a space, the effective word rate is nearly one per second or about 60 words per minute (wpm). Yet, each bit time was 22 ms (1/0.022 = 45.45, rounded to 45 baud) which, if converted to bps without the lost time of start and stop times, would generate 90 wpm. Similarly, one can derive the relationship between the wpm and baud figures given in Part 97.69 for the Baudot alphabet at speeds other than 60 wpm.

The wording for ASCII section of Part 97.69 merely gives the sending speed in baud, with no correlation to wpm. Note from Fig. 1B that 110 baud is accomplished with 11 bit times per character and that 110/11 = 10 characters per second (cps). In wpm the speed is easily calculated to be 100 wpm at 110 baud. At 300 baud, using 11 elements per character, the calculations give 272 wpm.

In fact, the industry often uses just 10 bits per character at 300 baud (and above), which gives an even 300 wpm. Note that Part 97.69 does not specify the number of stop bits, and amateurs could send only one stop bit and attain that 300 wpm rate. The rub is that use of one stop bit with ASCII works well only on quiet circuits. Keeping the extra stop bit permits additional noise rejection by allowing the receiving equipment to "phase" on the two stop bits before being ready to begin another character.

ASCII

The computer industry long ago adopted forms of character representation other than Baudot. For instance, the Hollerith code was and is used for punched card data entry. IBM adopted a code called EBCDIC for data communications. Eventually, as computers and data terminals proliferated, the industry realized that a common communication code would be advantageous. A joint industry committee of the American National Standards Institute (ANSI) developed the new code, which during the 1960s became ASCII.

ASCII stands for American Standard Code for Information Interchange. Although there was an earlier version of the code, and even in the late 1970s the industry committee was looking at revising it again, the most widely used version of the code has been that adopted in the ANSI standard no. X3.4-1968. In that standard is a code table with explanatory items that break down the usages of the different characters, especially the control characters. The entire table is shown in Fig. 2.[6]

Implications in Use of ASCII

The ASCII standard has certain implications to the user, and certain aspects of the code are *not* standardized by ANSI STD X3.4-1968. For instance, ASCII does not imply serial only or parallel only, and it does not imply serial baud rate, bit sequencing, current or voltage levels. ASCII is only a code, a correlation of *ones* and *zeros* to particular alphanumeric control symbols.

Certain features are common between serial ASCII and serial Baudot. The start bit and one or two stop bits are used. By another standard, ANSI STD X3.15-1966, the bit sequencing on a serial circuit is defined as LSB first, MSB last, as in the old scheme. (Note: It is interesting that the FCC has stipulated ASCII per X3.4-1968 without including any reference to bit sequencing as in X3.15-1966.)

				b7 →	0	0	0	0	1	1	1	1
				b6 →	0	0	1	1	0	0	1	1
				b5 →	0	1	0	1	0	1	0	1
Bits b4	b3	b2	b1	Column → / Row ↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	¦
1	1	0	1	13	CR	GS	-	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

(A)

NUL Null
SOH Start of Heading (CC)
STX Start of Text (CC)
ETX End of Text (CC)
EOT End of Transmission (CC)
ENQ Enquiry (CC)
ACK Acknowledge (CC)
BEL Bell (audible or attention signal)
BS Backspace (FE)
HT Horizontal Tabulation (punched card skip) (FE)
LF Line Feed (FE)
VT Vertical Tabulation (FE)
FF Form Feed (FE)
CR Carriage Return (FE)
SO Shift Out
SI Shift In
DLE Data Link Escape (CC)
DC1 Device Control 1
DC2 Device Control 2
DC3 Device Control 3
DC4 Device Control 4 (Stop)
NAK Negative Acknowledge (CC)
SYN Synchronous Idle (CC)
ETB End of Transmission Block (CC)
CAN Cancel
EM End of Medium
SUB Substitute
ESC Escape
FS File Separator (IS)
GS Group Separator (IS)
RS Record Separator (IS)
US Unit Separator (IS)
DEL Delete

Related Information

Note: (CC) Communication Control
(FE) Format Effector
(IS) Information Separator

Variations in Names:

DC1	"X-ON"
DC2	"TAPE"
DC3	"X-OFF"
DC4	"TAPE"
DEL	"Rubout"

Machine Variations: Slight differences may appear on keytop legends and print wheel fonts.

(B)

Fig. 2 — The standard ASCII code map at A. This information is taken from the ANSI Standard no. X3.4-1968. Pocket cards with the ASCII code are produced by the Teletype Corporation, 5555 Touhy Ave., Skokie, IL 60076. Definitions of mnemonics appear at B.

It is not obvious whether the amateur shall have to transmit the codes in the normal bit sequence. With fixed teleprinters, the code has always been sent that way. But now, with computers, and the lack of a bit sequence specification, it becomes questionable whether or not the amateur could legally change the order of bits on an agreed-upon basis with another amateur and still call it ASCII.

With seven bits in the ASCII code (Fig. 2), up to 128 different characters can be formed. No longer is the code not long enough to accommodate the number of printing characters commonly used. There are also the control characters (line feed, carriage return, reader on, reader off, punch on, punch off and others) besides lower case (non-capitalized) characters. A character with all ones called DEL (delete) "rubout" may be used to correct errors in punched tape and both DEL and NUL (all zeros) are two non-printing, nonspacing characters that may be used for transmission "fill" characters. Users of ASCII serial links will often send eight bits of code with the eighth bit, the MSB, being used for a parity bit. The basic purpose of the parity bit is to assist in error detection when characters are received through a noisy or distorting medium. An explanation of parity follows later in this article.

With ASCII, a received character, mutilated by noise, is relatively independent of all other characters, with the exclusion of a few control characters that would actuate automatic functions in some teleprinters. But there are often ways to defeat, by operator intervention, the worst of these calamities. At least there is no longer any interaction between figures and letters as there always can be in Baudot when a FIGS or LTRS character is lost.

Control Characters Provide Desirable Features

If the serious reader studies Fig. 2, he or she will note that a large number of desirable features is available with the control characters in columns 0 and 1. These are obtained by typing a normal printing key character on a keyboard while simultaneously holding down a CTRL key, a SHIFT key or both. Thus, the layout of a keyboard keyset is often done with the ASCII table in mind (the so-called ASCII keyboard pattern) so that a normal letter typed with CTRL or SHIFT on will result in the same character as that letter gives when shifted sideways in the ASCII table from its normal column to a control column. However, not all keyboard manufacturers agree on the layout of the ASCII keyboard and one can even find some with essential keys (such as carriage return) missing. More on this later.

Parity

The 1968 version of ASCII may eventually be superceded by even more modern ASCII in which all eight bits of the byte are used. In the 1968 version of ASCII, shown in Fig. 2, the reader will notice that only seven information bits are specified. Most ASCII data transmission is byte oriented; that is, eight bits are transmitted. The user sometimes has the option of transmitting only seven information bits by use of a solid-state encoder, but the modern hard-copy teleprinters are eight-bit machines (including the paper-tape punch and reader) and somehow the eighth bit must be included. The last bit position before the stop bits (MSB) is reserved for this bit if convention is followed.

There are four ways this bit may be used if present, as some form of parity. The first way is to leave the bit always at the *mark* (one) level. The second way is for the bit to always be at the *space* (zero) level. But the essence of parity is to use the bit actively as an error-detecting device. Under "even parity" the bit is made one or zero so that when all eight bits are examined for the total count of the number of one bits, the total is an *even* number (0,2,4,6,8). Under "odd parity" the sum of all the ones must be *odd*, including the parity bit in the sum (for a 1,3,5 or 7 answer).

Those owners of hard-copy ASCII terminals or ASCII paper tape punches can check their parity by punching some random letters or numbers, then adding up the number of ones (holes) in a vertical (crosswise) column punched for a single character. Some machines will be found to always punch (*mark* parity) or never punch (*space* parity) the eighth bit. If the eighth bit varies, then counting a set of bits vertically for a single character will reveal the parity of the machine. For this reason the parity bit is sometimes referred to as the vertical redundancy check (VRC) bit. (Owners of model 33 teleprinters will note that the tape must be punched in "local" to reflect the parity of the keyboard.)

Parity Bit — Something Baudot Did Not Have

The parity bit, while not part of the ASCII code itself, according to ANSI STD X3.4-1968, is something new that Baudot did not have. With ASCII and parity bits on serial RTTY circuits, amateurs can use the parity bit to single out received characters with single (or odd numbers of) errors as a result of noise hits or fading or distortion. Characters with parity errors, on computers or "smart" terminals, can be rejected or at least "flagged" as having errors. Unfortunately, two (or an even number of) errors in a single character cannot be detected with parity checking on an isolated character-by-character basis. Statistically, far fewer errors occur where two bits are wrong than where only one bit is wrong.

However, that is about as fancy as one can go with error checking on the typical RTTY circuit where the characters are received as isolated units of eight bits. Furthermore, after a character is received wrong, for any reason, the rest is history. Only the more enterprising amateurs with more elaborate computers will be able to add up whole blocks of characters, test for other forms of checksums and automatically request retransmission of bad blocks. This protocol procedure of course has been followed in the telecommunications industry for years and is where the amateur begins to be involved in "packet" data transmission.[8]

Stop Bits

At one of the most common Baudot speeds the duration of a single bit is 22 ms (Fig. 1A). The stop interval at this speed is 31 ms, about 1.42 bit times.

In ASCII serial transmission, in the asynchronous mode, the stop interval lasts either one or two bit times which may be called *stop* bits. Model 33 style teleprinters will require two stop bits at 110 baud, whereas solid-state equipment (computers, thermal printers, etc.) running at 300 baud or more may use only one stop bit. The use of ASCII with two stop bits for RTTY may become standard, but the amateur is not restricted from receiving and decoding only one stop bit. The timer interval for the second stop bit can then be used in solid-state equipment to perform other functions (in programs) or used to check that the start bit is not coming too soon (wrong baud rate). Skipping the second stop bit is not a decision to be made lightly as noise tolerance is reduced at the same time.

UARTs

Frequently the amateur will find that acquisition of a hard-copy ASCII teleprinter (model 33 or similar) is more difficult or expensive than building up a video display device (glass teletype) or CRT terminal. Often new video terminals will cost less than new teleprinters and there are numerous kits and construction articles available.

The computers often use program software to decode the ASCII characters (and obviously can then be programmed to interpret 5-level code as well). Both computers and video terminals may use a hardware device instead of software to decode serial characters. These devices are integrated circuits with names like UART (universal asynchronous receiver-transmitter) or USART (universal synchronous-asynchronous receiver-transmitter) or other microprocessor family related names. These MOS devices, when driven by a stable TTL logic-level clock, can receive and send characters "like a teleprinter" and can also check for illegal parity such as wrong number of stop bits, missed characters, or wrong baud rate.

Therefore, they are very useful in computers and video terminals and hard-copy high-speed printers. Some can even handle 5-level code when suitably selected and controlled. *Voilà*! Instant mode and baud-rate switching is available without gears or jammed carriages. Unfortunately, UARTs do not provide hard copy printout by themselves and must be used inside more-involved equipment. Neither do video terminals usually provide hard copy output and many times the amateur must have that final result. The difficult decision of what to use to build up an ASCII terminal will be left to the individual amateur. The following information is provided to help in locating resources.

Source Material and Hardware

It is not the purpose of this article to suggest particular equipment, hardware or integrated circuits for purchase or vendors of the same. The decision of what to purchase to implement ASCII in the shack is left up to the reader and possibly other authors. Table 2 is offered as an aid. The categories of parts there must, however, indirectly infer the vendor or manufacturer sources; but no preference is implied or expressed. The lists of Table 2 are also not intended to be all-inclusive or discriminatory.

Table 2

Source Material and Hardware

ASCII Standards
- Code — American National Standards Institute
  - X3.4-1968
- Bit Sequencing — American National Standards Institute
  - X3.15-1966
- Parity — American National Standards Institute
  - X3.16-1966

Software, Computers
- TRS-80®
- Apple-II®
- North Star®

Books, Magazines, Manuals
- *BYTE*
- *Interface Age*
- Manuals (User's)
  - 6502
  - 6800
  - 8080
  - Z80
- *Specialized Communications Techniques*, ARRL, 1975 (no longer available from ARRL). See the 1981 *Handbook*.
- *TV Typewriter Cookbook* by Don Lancaster, Howard W. Sams and Co., 1976.

Integrated Circuits (UARTs)
- TR1602A
- AY-5-1013
- S1883
- MC 6850
- I8251A

Hard-Copy Printers
- Model 33 Teletype®
- Silent-700®

Application Hints

When looking for a model 33 Teletype, the amateur should seek out used, preferably rebuilt and tested units from used-equipment houses, possibly computer stores, even from classified advertisements. Some used equipment that has not been reconditioned is available from telecommunications industry outlets. Be sure to obtain manuals (three for the ASR 33) and learn how to connect to the input/output connector. Ask for help from a knowledgeable friend, amateur or computer hobbyist if any uncertainties appear.

There are several variations of the ASR (automatic send receive) and KSR (keyboard send receive) models of the model 33 series. These variations have relative advantages and disadvantages depending on the application. These variations or options are:

1) Keyboard parity: Even or mark (popular).

2) Current loop: 20 mA or 60 mA (internal strap).

3) Automatic form feed: On reception of CTRL-L or none (not installed).

4) Paper: Roll or fanfold.

5) Paper feed: Friction or sprocket feed.

6) Print wheel: Many variations (consult manual).

7) Tape reader: Automatic start/stop with character control (DC1, called X-ON; DC3, called X-OFF), *or* reader relay driven by extra pair of wires in input/output connector, *or* manual start/stop.

8) Tape punch: Automatic start/stop with character control (DC2, DC4), *or* automatic start/stop with lock-on feature controlled by operator, *or* manual start/stop.

9) Printer stand: Extra.

10) KSR-33: No paper-tape equipment attached.

11) No option items: 110 baud, oil punch tape (1 inch or 25.4 mm wide).

The serious enthusiast who is looking for a solid-state ASCII keyboard is usually in the market for an assembly or kit with an ASCII keyboard keyset, a printed-circuit board, a keyboard encoder integrated circuit and miscellaneous parts. The finished assembly will give a parallel output byte with strobe (upon key depression) to external smart logic or, in the case of video terminals, perhaps to character generator logic. The external logic will reformat the parallel information into serial output to an RTTY modulator. The external logic can be relatively simple and include a UART or it may be a whole computer system.

It is important for the reader to understand that such solid-state keyboards do have variations from manufacturer to manufacturer, as mentioned above. Some keyboards (such as the author's) do not, for some reason, contain all the desired keys or even necessary ones (in this case the carriage return key). If the reader is "stuck" with one of the these, he should note that the flexibility of the ASCII code, with CTRL and SHIFT variations, may often be used to work around the problem. For instance, CTRL J is really an LF (line feed) character; and CTRL M is in reality a CR (carriage return). Some keyboards may have something like a "new line key" which the user will test and find is actually CR.

In short, to make full use of ASCII, the user will find that keeping an ASCII table around is as vital as having his other handbooks and operating guides. The serious experimenter should plan on studying the ASCII table until he or she understands it fully. ASCII, the language of the computer and the heart of data communications, is now becoming the focal point of amateur RTTY.

APPENDIX

Although there are other ways of defining information elements besides binary, the binary mode is most perfectly suited for the switching actions of teleprinters and computer equipment. "Binary" stands for a number system based on powers of two, similar to our decimal number system which is based on powers of 10. In number systems, the base or radix (2 for binary, 10 for decimal) is not one of the allowed digits. There is no special symbol for 10 in the decimal number system. The allowed symbols are 0 through 9 for a total count of 10 symbols, with the number 10 being formed from combining 0 and 1. Likewise, in the binary number system there are just two symbols, neither of which is 2. They are 0 and 1. To make 2 in this system (this is the same as binary 10), the construction used is $1 \times 2^1 + 0 \times 2^0 = 10_2$. You can say "binary 10" or "decimal two" and mean the same thing. There is even "octal 10" (decimal 8) in base 8 and "hexidecimal 10" (decimal 16) in base 16, but that is outside the scope of this article. [QST]

Notes

[1]Former demodulators may have to be retuned for increased baud rate and/or wider carrier shift if 200-Hz shift becomes standard.

[2]Henry, "ASCII, Baudot and the Radio Amateur," *QST*, September 1980, pp. 11-16.

[3]See note 2.

[4]As explained in the Henry article, baud rate = 1/time of unit pulse.

[5]See "The New Baud Game," Technical Correspondence, *QST*, August 1980, p. 39.

[6]See Table 2 in the Henry article or *The Radio Amateur's Handbook* (1981), p. 14-26.

[7]But, as Henry points out, they cannot be corrected. (See note 2.)

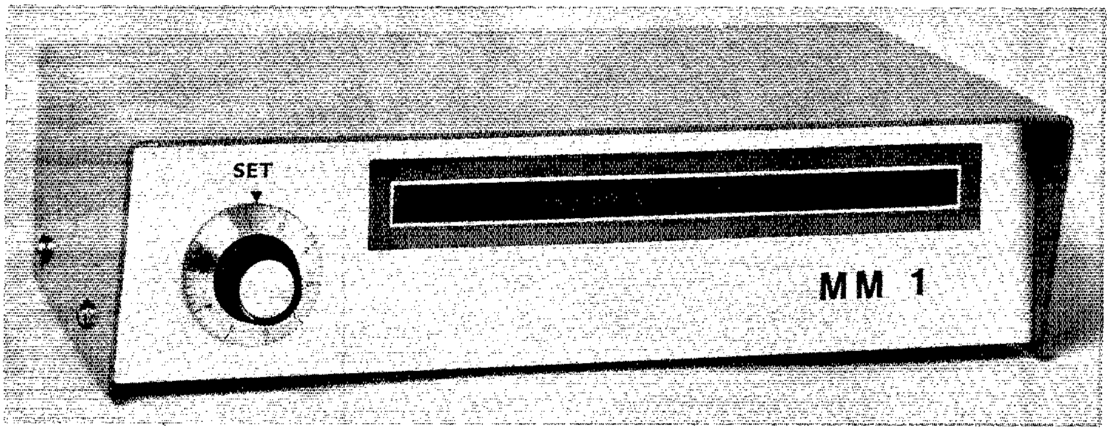
[8]See "An Introduction to Packet Radio," by Jan Hodgson, VE2BEW, *Ham Radio*, June 1979, p. 64.

[Editor's Note: Other information on ASCII may be found in the following material: *The Radio Amateur's Handbook* (1981), Chapter 14; "FM/RPT," *QST*, Feb. 1980, p. 83 and *QST*, April 1980, p. 70; "Happenings," *QST*, April 1980, p. 74.]

A Peak-Reading Bar-Graph Meter for SSB Transmitters

Step up to the bar! Put a little light on the subject of metering with this eye-catching and functional unit.

By Eric Kirchner,* VE3CTP



There's very little that's more annoying than having a DX 'phone contact ruined by an improperly adjusted transmitter operating on a neighboring frequency. In recent years, there has been an increase of such occurrences, possibly caused through the misuse of speech processors. Usually, this kind of QRM is quite unintentional and stems from the fact that many amateurs have no means of knowing when the transmitter final stage has reached the maximum point of linear operation. When this plateau is exceeded, the final amplifier becomes a clipper, which generates square waves (flat-topping). These square waves produce undesirable modulation distortion products (splatter) on either side of the main signal. Splatter can be traced to other sources, but in most cases it is caused by overmodulation.

But My Meter Says . . .

Because of their mass, ordinary moving-coil meters cannot follow the fast amplitude changes of the human voice. The amateur who does not realize this fact is surprised to see that after he has loaded the final amplifier stage of his transmitter to, say, 250 mA of plate current in the cw mode, the meter reads only 125 mA on ssb voice peaks. So the operator increases the mike gain until the meter again reads 250 mA on voice peaks. Without an oscilloscope connected to the transmitter output, he will not be able to see that his signal is now severely "flat-topping."

A rule of thumb was once established saying that the final amplifier plate current meter (or collector current meter) should display half the indicated steady carrier value on voice peaks. However, meters differ from one another in response time. Also, some have shunts connected in parallel with the movement, which further tends to dampen the meter action.

One way out of this dilemma is to eliminate reliance on the conventional milliammeter and use a peak-reading electronic bar-graph indicator such as the one described here. The recent appearance of two semiconductor devices simplifies the construction of such an indicator. One of these devices is the National Semiconductor LM3914,[1] and the other is a single dual-in-line package of 10 LEDs, the RBG-1000, which is manufactured by Litronix.

The LM3914 contains a series of 10 comparators, a ladder resistor network, a reference voltage regulator, 10 current sources to directly drive 10 LEDs, and an input buffer with a fairly high input impedance. Several LM3914s can be connected in series to drive up to 100 LEDs. For more detailed information on this device, consult the National Semiconductor Data Book.

The Circuit

The unit described here was designed for use in 50- or 75-ohm systems with an SWR of 3:1 or less. It is useful within a power range of 50 to 2000 watts, but the range can be changed to lower power

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[1]Notes appear on page 33.

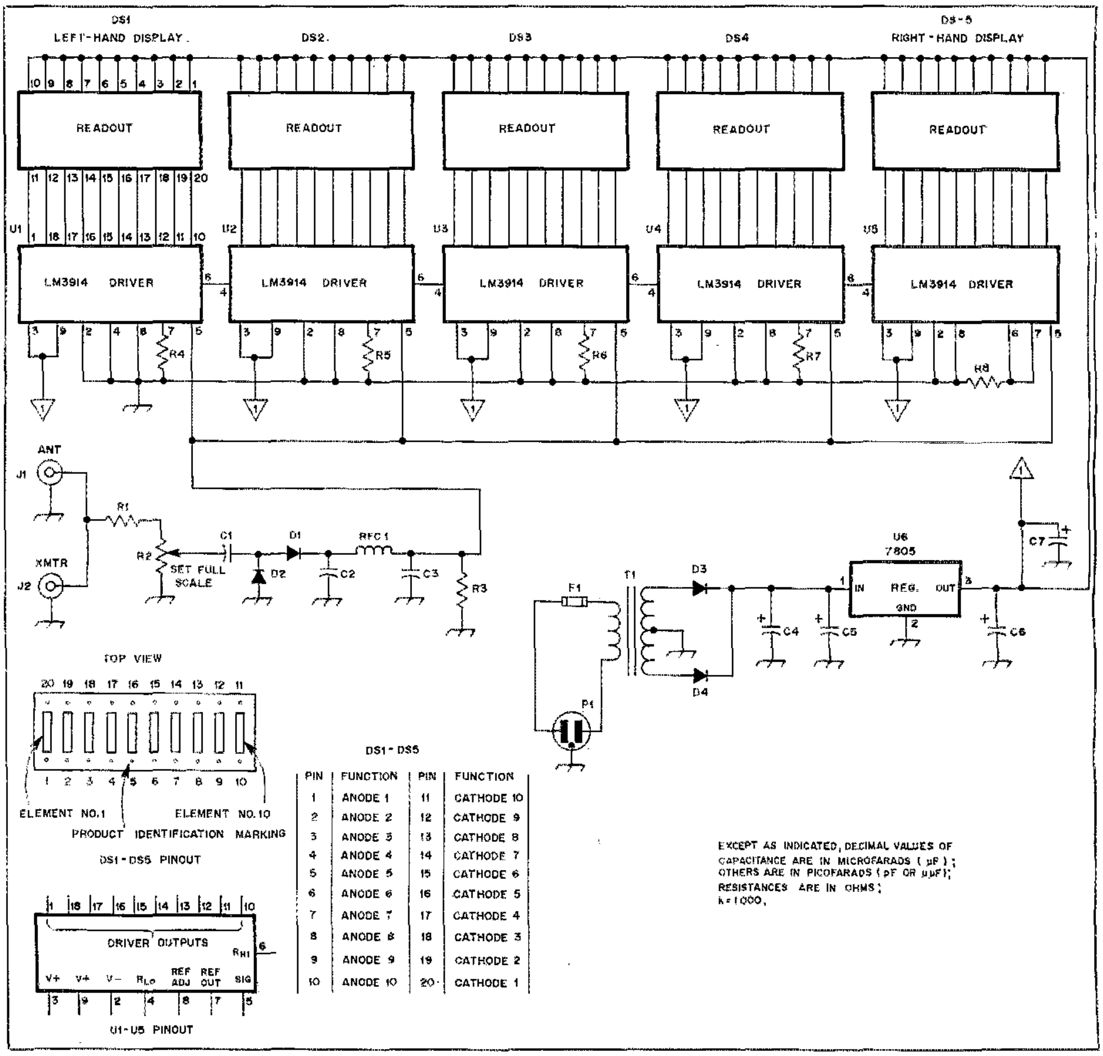
operation by decreasing the value of R1 (see Fig. 1).

The connectors J1 and J2 shown in Fig. 1 are connected to the coaxial feed line from the antenna and to the station transmitter or transceiver. The rf voltage present at the center conductor of the connectors is stepped down by a resistive divider R1-R2.

R2 is a carbon or conductive plastic potentiometer. It permits full-scale adjustment of the bar graph indicator. The stepped-down rf is coupled through C1 to the voltage doubler rectifiers, D1-D2 and the resulting dc is filtered by C2, RFC1 and C3. C3, in combination with R3, determines the decay time of the indicator. From this point, the dc voltage is fed to the buffered inputs of the LM3914s (U1 through U5). Without any rf at the input, the first LED of DS1 (connected to pin 1 of U1), will light when the unit is switched on. This serves as a POWER ON indicator.

Construction

The accompanying photographs show the layout and construction of the unit. Except for the connection between the center pins of J1 and J2 (which should be

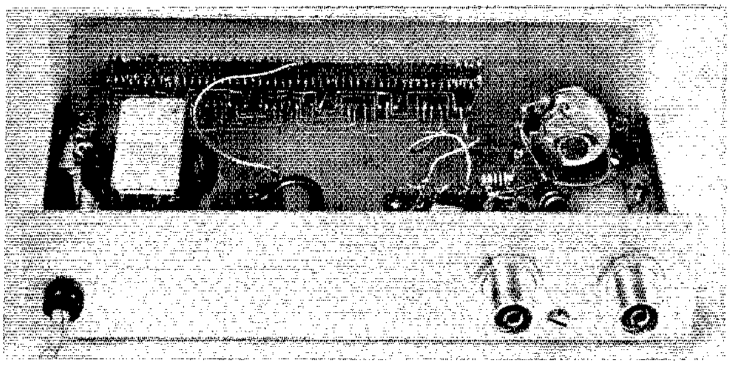


DS1 - DS5

PIN	FUNCTION	PIN	FUNCTION
1	ANODE 1	11	CATHODE 10
2	ANODE 2	12	CATHODE 9
3	ANODE 3	13	CATHODE 8
4	ANODE 4	14	CATHODE 7
5	ANODE 5	15	CATHODE 6
6	ANODE 6	16	CATHODE 5
7	ANODE 7	17	CATHODE 4
8	ANODE 8	18	CATHODE 3
9	ANODE 9	19	CATHODE 2
10	ANODE 10	20	CATHODE 1

Fig. 1 — Diagram of the peak-reading bar-graph meter. Rf appearing at J1-J2 is sampled, rectified and used as the input voltage for the LM3914s. Pin connections for each driver-readout combination are the same as for U1-DS1.

C1 — 0.01 µF, 500-V disc ceramic.
C2 — 0.033 µF, 50-V disc ceramic.
C3 — 0.1 µF, 50-V disc ceramic.
C4 — 1500 µF, 16-V electrolytic.
C5, C6 — 1 µF, 35-V Tantalum.
C7 — 22 µF, 16-V Tantalum.
D1, D2 — Silicon, fast-switching, 100 PIV, 1N4148 or equiv.
D3, D4 — Silicon, 1 A, 300 PIV, 1N4003 or equiv.
DS1-DS5, incl. — Litronix RBG-1000 LED readouts.
F1 — MDL 1/8-A fuse.
J1, J2 — SO-239 coaxial receptacle.
P1 — Three-conductor ac plug.
R1 — 47-kΩ, 1/2 watt.
R2 — 5-kΩ, 1/2 watt carbon potentiometer, linear taper.
R3 — 220-kΩ, 1/2 watt.
R4-R8, incl. — 1-kΩ, 1/2 watt.
RFC1 — 1 mH, low-current type suitable.
S1 — Spst toggle switch.
T1 — 117-V ac primary, 16-V ct at 0.5-A secondary (Hammond 166G16 or equivalent).
U1-U5, incl. — National LM3914N dot/bar display driver.
U6 — 5-V, 1-A, three terminal positive regulator, 7805 or equiv.



The two jacks at the rear of the unit are used for connection to the transmitter and antenna, and are interchangeable. Although the author used unclad circuit board in this unit, a drilled pc board which provides mounting holes for the rf rectifiers, filters and R2 is available, with instructions, from the author for $12.50; a money order is preferred. The ARRL and *QST* in no way warrant this offer.

as short as possible), the placement of parts is not critical.

The circuit board was first laid out on 0.1 inch (2.54 mm) graph paper using a lead pencil. Then the paper was taped to a piece of unclad circuit board material and used as a template. All hole locations were punched with a center punch, after which the graph paper was removed and the punch marks drilled with a number 60 bit. IC sockets were then installed and the socket pins interconnected using small-diameter wire (one strand of no. 22 stranded wire). With careful layout, no wire crossings are necessary. Only DS1 through DS5, U1 through U5, and resistors R4 through R8 are mounted on the board. The rf rectifier and filter components are soldered to a teminal strip which is fastened to the chassis. C5 and C6 should be soldered directly to the pins of U6. It is important that the housing and shaft of R2 are at ground potential.

Operation

Connect the unit between the antenna feed line and transmitter. Turn the meter on and set R2 to the full counterclockwise position. With the transmitter operating at maximum power in the cw or tune mode, adjust R2 so that the last LED (the one at the extreme right side) just barely lights up. Now set the transmitter mode switch to either usb or lsb and adjust the mike gain control so that the last LED *never* lights up, even on voice peaks. This will ensure that the final amplifier will never flat-top. Should the indicator remain at full scale or part way up the scale, it is an indication that the carrier suppression of the transmitter may be insufficient or a parasitic oscillation may be present. With this bar-graph meter operating at your station, you can be sure *you* won't be an annoying neighbor to those on nearby frequencies.

Notes

[1][Editor's Note: An in-depth look at the LM3914 may be found in *CQ*, May 1980, pp. 85-86.]

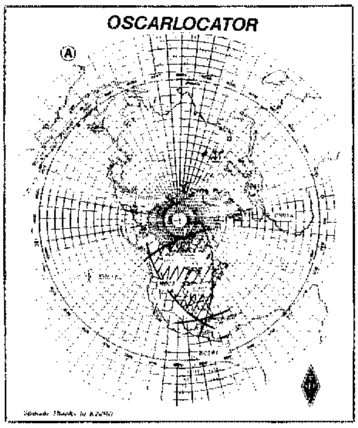
Strays

FIRST WAC VIA SATELLITE

All Nick Laub, WØCA, needed for a challenge was someone to say, "You can't work all continents via satellite." For a veteran like Nick, who has been licensed for over 50 years, it didn't take long to plot a satellite track of the six continents to Backus, Minnesota. Once it was determined that it *could* be done, Nick completed the feat in 13 months using only 10 watts of power.

When the last QSL card was received, Nick called ARRL headquarters with the news. Nick said he was sending the cards and wanted them checked to see if he qualified for the IARU WAC award. When the records and cards were checked, it was found that no one had ever worked all continents via satellite; in fact, no one thought it could be done.

Immediately after plotting the track on an OSCARLOCATOR, it was found that a long narrow area did exist from about 25° to 75° north latitude (see polar map). This was found by drawing an arc of 4900 miles, maximum range for AMSAT-OSCAR 7, from each of the six station locations that Nick contacted.



Drawing a 4900-mile arc (3-1/4-inch radius on OSCARLOCATOR) from each of the distant continent boundaries will determine if you are in the satellite WAC zone for AMSAT-OSCAR 7 operation. For AMSAT-OSCAR 8 the range would be approximately 4000 miles (2-3/4-inch radius on OSCARLOCATOR).

The next thing discovered was that there were no endorsement provisions for satellite WAC. ARRL General Manager/IARU Secretary Dick Baldwin, W1RU, and Hal Steinman, K1FHN, Manager of the Membership Services Department, which administers the IARU award, both agreed that a special first WAC "Via Satellite" award should be made, with provision that all future awards be restricted to satellites orbiting no greater than 1500 miles in altitude.

Nick Laub, WØCA, has earned the first "WAC Via Satellite" award. Congratulations, Nick!

Nick received his award at the recent AMSAT annual meeting. IARU/ARRL hq. is planning to issue special plaque awards, like Nick's, to the first 10 amateurs qualifying for the IARU WAC via satellite endorsement. *It can be done!* Who will be number two? — *Bernie Glassmeyer, W9KDR*

A Variable Frequency Crystal Oscillator

What can be done about the trade-off between the frequency range and stability of oscillators? The W3MT VXO, designed to generate a rock-steady signal, offers a practical solution to that exchange.

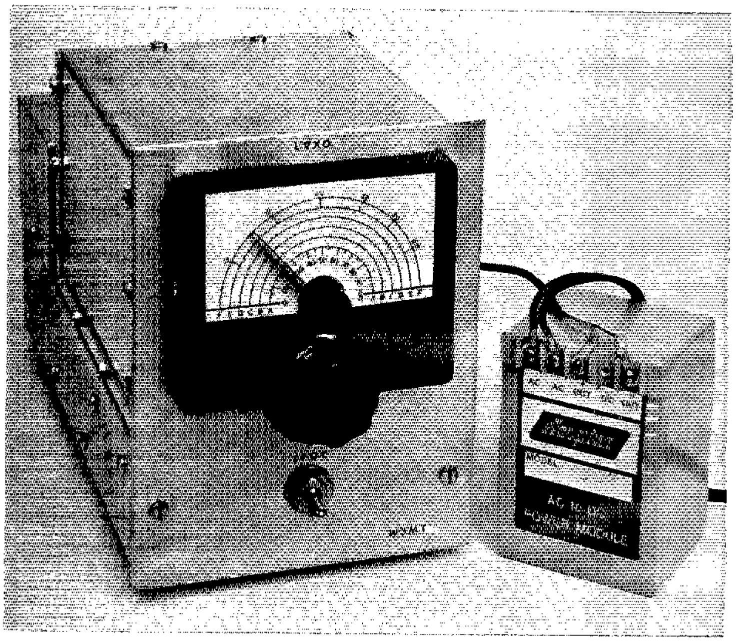
By Frank Noble, MEE,* W3MT

Variable-frequency crystal oscillators (VXOs) are found today not only in Amateur Radio equipment but also in commercial and military communications devices. The stability and resetability of VXOs justify application to equipment designed specifically for these services. For the radio amateur, a VXO solves the crystal/VFO problem at once. Additionally, the use of the VXO provides instantaneous frequency change to any part of a band.

The "rubber crystal" of the 1930s set the stage for the modern VXO. That device of a bygone era enabled the operator to move the crystal frequency a few "kc" by means of a variable pressure control mounted on the crystal holder. Contemporary VXOs, with more sophisticated circuitry, represent an appreciable improvement over the rather simple variable unit of the 1930s.

As the radio amateur approaches the task of designing a VXO, the project should be considered in its entirety. The objective in VXO planning is to design a variable crystal oscillator that not only can be adjusted to the exact frequency, but also to wind up with a unit in which the overall effectiveness is maximized, including a high degree of stability. An accepted manufacturing tolerance is of the order of 20 Hz per MHz. Such a tolerance is not likely to be obtained without careful design and good construction. A significant factor in developing a stable VXO is the coil design. This component is a major element in the determination of the operating frequency.

Although the frequency of a quartz-crystal oscillator can be varied over an appreciable range by connecting variable reactances in series with a crystal, generally this results in a compromise between frequency range and stability. The purpose of this article is to impart an understanding of that compromise. Pertinent equations and results in graphical form are aimed toward this end.



The W3MT variable crystal oscillator with power supply. Contained in the large Minibox directly behind the dial is the shielded frequency-determining circuit. A small shielded box at the rear, protecting Q3 and the output filter, keeps heat away from critical circuits. The spot switch, S1, is located below the dial.

A Thousand Times Better Stability

An amateur is not likely to go to the trouble of designing and building a VXO without being convinced that such an oscillator is far more stable than an induc-

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tively controlled oscillator (LCO). As will be shown graphically later in this article, the CVXO (capacitively tuned variable crystal oscillator) has a minimum stability rating that is 1000 times that of an LCO.

As a means of ensuring a greater amount of stability, the amateur who chooses to capacitively tune a variable crystal oscillator will not go wrong. The reason is that the stability advantage is mathematically at least 1000. On the other hand, an inductively tuned crystal oscillator (LVXO) leaves something to be desired from the standpoint of stability. Under some circumstances, an LCO may prove far more stable than an LVXO.

Crystal Behavior

A quartz crystal is an electromechanical unit that vibrates. It behaves much like a resonant L-C circuit similar to that shown in Fig. 1. More properly, an oscillating crystal may be thought of as a tuned circuit consisting of inductance, capacitance and resistance in series. As in the illustration, there will also be some shunt capacitance. The resistance R is that offered mainly by the crystal through electro-mechanical action. This R value is small in comparison to the inductive reactance at the operating frequency.

Another concern in the design of a crystal oscillator is the impedance of the oscillator. At frequencies lower than resonance, the oscillator network displays a high impedance and is essentially capacitive. As the oscillator is adjusted above resonance, the net reactance of the inductive part of the circuit is determined by calculating the difference between the reactance of L and that of C.

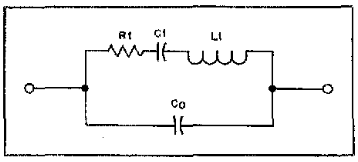


Fig. 1 — A resonant circuit equivalent to that of a quartz crystal resonator.

Whenever power is taken from an oscillator, there is bound to be some effect upon the stability of the circuit. In regard to circuit stability, consideration must be given to the load impedance which significantly affects crystal oscillator performance.

Stability Defined

Inasmuch as we are concerned here with stability, providing a definition of this term seems appropriate. Simply stated, the degree of stability is the percentage change in the load reactance required to produce a given percentage change in frequency. In an academic sense, this is a fair measure yielding useful comparisons.

This definition is unfair to the CVXO, nevertheless. In the real world, capacitors are much more stable than coils. Therefore, the CVXO will, in reality, perform even better than may be predicted in

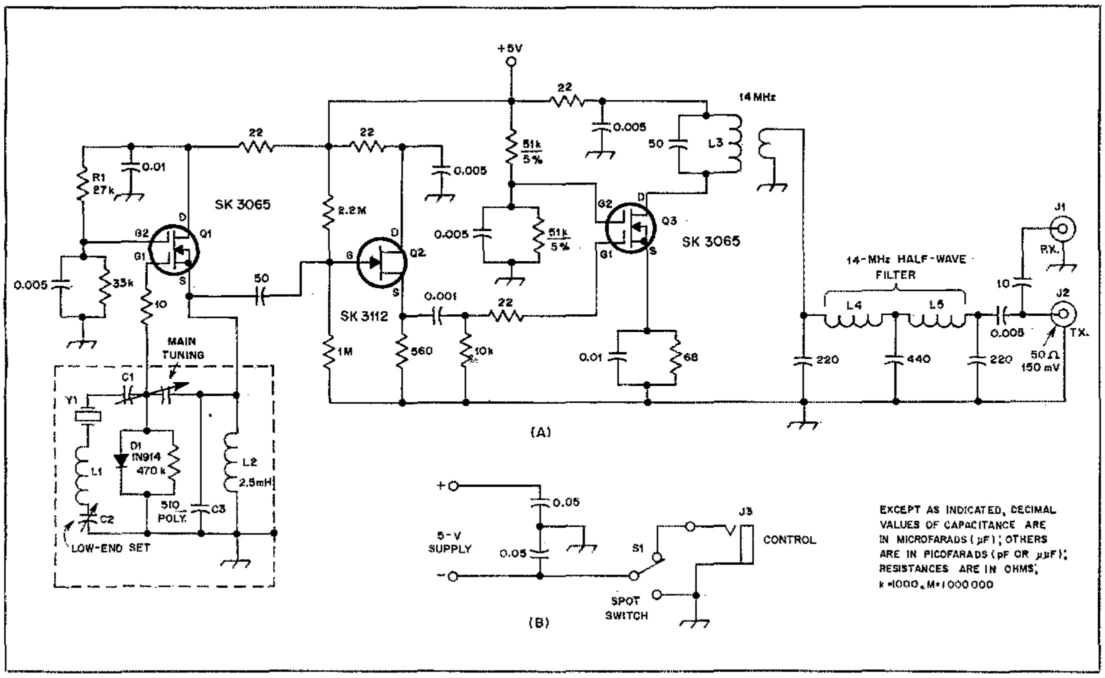
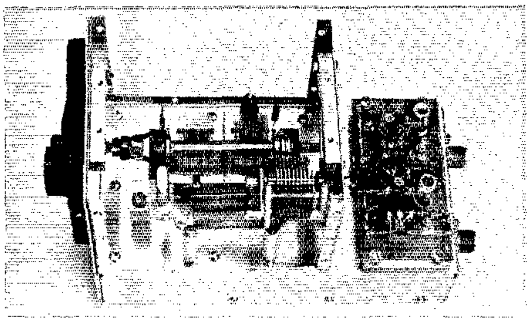
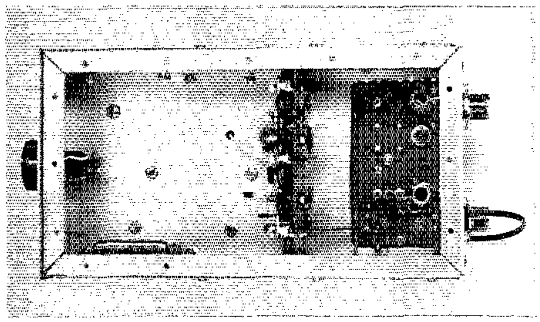


Fig. 2 — The W3MT variable-frequency crystal oscillator. This circuit is designed to provide a high degree of stability. A spotting-switch arrangement is shown at B. Power is provided by an external regulated supply. The control jack, J3, allows the oscillator to be energized from the station T-R switch by completing the connection from the negative lead to ground when transmitting. The spotting switch is for setting the oscillator on frequency when the transmitter is turned off.

C1 — Main tuning capacitor, dual 140 pF with midline plates, Hammarlund no. MCD-140-M or equiv.
C2 — Air-variable capacitor, 140 pF.
C3 — 510 pF, polystyrene.
D1 — Silicon planar diode, general purpose, 1N914.
J1, J2 — SO-239 coaxial connector.
J3 — Open-circuit phone jack.
L1 — Barker and Williamson Miniductor no. 3004, 1/2 inch dia, 32 tpi, 2 inches long, no. 24 wire, 12 μH.
L2 — Rf choke, 2.5 mH.
L3 — Slug-tuned ceramic coil, 3/8 inch, Miller no. 4404, 1.6-3.1 μH range set for 2.6 μH. Link 2 turns of hookup wire wound over cold end of tuned coil.
L4, L5 — 6 turns of hookup wire wound on the same type form as L3, 0.57 μH. See text for adjustment information.
Q1, Q3 — Silicon n-channel depletion dual-gate MOSFET rf amplifier, RCA SK3065 or equiv.
Q2 — Silicon n-channel depletion mode small-signal low-noise af amplifier junction transistor, RCA SK3112 or equiv.
Y1 — Quartz crystal, partially plated AT-cut, fundamental mode, type HC6/U, 14,030 kHz, 32 pF. Available from JAN Crystals, 2400 Crystal Dr., Fort Myers, FL 33907.



A view of the topside of the W3MT VXO chassis. The shaft of C2 projects through the rear of the shield box. Viewed from the front, the circuit board contains (left to right) Q3 and jacks J1 and J2. The control jack, J3, is below J2.



The bottom side of the W3MT VXO. Viewed from the front (left to right), Q1 and Q2 are mounted on a vertical circuit board placed below the rear edge of the large shield box, keeping the oscillator leads short but providing good thermal isolation.

theory. We can safely say that the CVXO is the arrangement of choice for situations where the crystal cost is not an object.

The W3MT Variable Crystal Oscillator

Although this article is mainly intended to be tutorial in nature, the circuit of the complete W3MT VXO is included for the benefit of those *QST* readers who may be interested in the design and construction. (The remaining theory related to VXO design follows in appendix form.)

As you may see by observing the circuit diagram (Fig. 2) the complete circuit is more than just a basic variable oscillator. In order to isolate the oscillator from the transmitter, as a means of avoiding the effect of load changes, buffers are provided.

A dual-gate, n-channel MOSFET (Q1), an SK3065, serves as the signal generator. C1, the main tuning capacitor, is adjustable over the frequency range of 14.000 MHz to 14.025 MHz. It may be rotated over a mechanical range of 15 to 85 percent of the full travel. The gain, adjustable upward by decreasing R1, should be just sufficient for reliable starting. The purpose of C2 is to adjust the low-frequency extreme to exactly 14.000 MHz. In the event of low crystal activity or low transconductance in Q1, the oscillator may be encouraged to start by decreasing C3 to not less than 300 pF or by increasing the drain voltage. Components in the shielded enclosure should be mounted rigidly, with special care given to the lead from gate 1. A ceramic feedthrough insulator is highly recommended for this purpose.

Q2, a source-follower buffer, is very effective in isolating the oscillator from the load changes which may occur in the circuitry that follows.[1] Q3, a tuned voltage amplifier, has a gain of 50. It is the tuned circuit that enables Q3 to produce a large amount of gain in addition to ensuring a good waveform at the output. A link winding on L3 matches Q3 to 50 ohms. Following the link is a dual pi-section, half-wave filter for harmonic attenuation. (Coils L3 through L5 should be separated at least 1-1/2 inches (38 mm) to minimize mutual coupling effects).

L4 and L5 are adjusted initially by connecting a 220-pF capacitor across the isolated coil and dipping the resulting parallel circuit at 14 MHz. The slugs in these coils are locked into position. Tuning of the output circuit is performed with the slug in L3.

Frequency spotting has not been overlooked in the circuit design. S1 and an external control via J3 provide the means for this.

You might ask, "May this circuit be keyed?" The answer is yes, but it is not recommended. As oscillator keying goes, this oscillator keys well, but there is a detectable chirp. In the writer's opinion, a heterodyne system with mixer keying is *the* satisfactory way to work break-in.

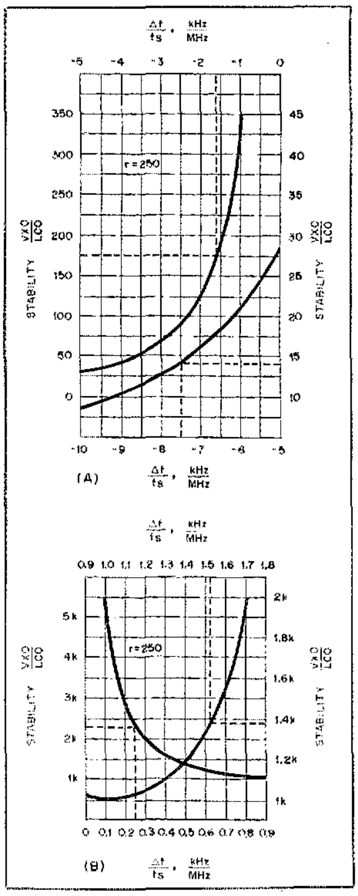


Fig. 3 — The graph at A represents the stability ratio of an inductance-loaded crystal oscillator to the common L-C oscillator vs. scaled frequency deviation below series resonance. At B the stability ratio of the capacitance-loaded crystal oscillator to the common L-C oscillator vs. scaled frequency deviation above series resonance is shown.

Power Supply and Enclosures

A 5-volt regulated power supply furnishes the operating voltage for the W3MT VXO. I mount this Acopian no. 5EB250 unit externally to the main chassis as you might gather from the accompanying photograph. The VXO demands only 15 mA, a modest amount easily supplied by the power unit.

For the chassis, a Bud no. AC-403 enclosure is well suited for accommodating the VXO. This Bud product has dimensions of 5 × 9-1/2 × 2 inches (127 × 241 × 51 mm). The oscillator shield box, also a Bud product, is model CU-3007-A which measures 6 × 5 × 4 inches (152 × 127 × 102 mm). A piece of 1/16-inch (1.6-mm) aluminum with dimensions of 5-1/8 × 6-1/2 inches (130 × 165 mm) serves as the front panel. A

[1] Notes appear on page 37.

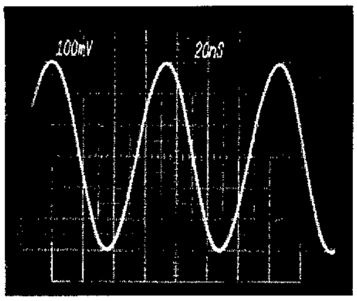


Fig. 4 — A smooth sine wave pattern is observed when an oscilloscope is connected to the VXO output. Filtering provided in the VXO circuit suppresses harmonic output and maintains spurious responses at an acceptable level.

small shield at the rear is homemade, being constructed also from aluminum. Measurements for the shield are 2-1/4 × 3 × 5 inches (57 × 76 × 127 mm). A Minibox is available that is a suitable substitute. For the dial, a Millen no. 10039 was chosen.

Performance

As is the case with any oscillator, the stability will improve with the quality of components and the mechanical construction. For a given amount of care in this regard, this oscillator should out-perform an LCO by a factor of at least 100. See Fig. 3. A sample of the sine-wave output as observed on an oscilloscope appears in Fig. 4.

The model presented here was tested against a tube-type frequency standard having a 7000-kHz FT-243 crystal without temperature control but with Zener regulation. Since the low-frequency extreme of the LVXO is its least stable setting, this is a severe test. The beat at 14.000 MHz remained within 10 Hz for a half hour. It is unclear, however, which oscillator was drifting. We conclude that this particular LVXO, in its worst situation, is approximately as stable as a run-of-the-mill crystal oscillator.[2] QST

Notes

[1]The load isolation provided by Q2 and Q3 is sufficient to prevent *any* frequency change when the 50-ohm output is keyed from open circuit to short circuit.

[2]A detailed mathematical analysis of the VXO has been prepared and copyrighted by the author, Library of Congress card no. TX 243-015.

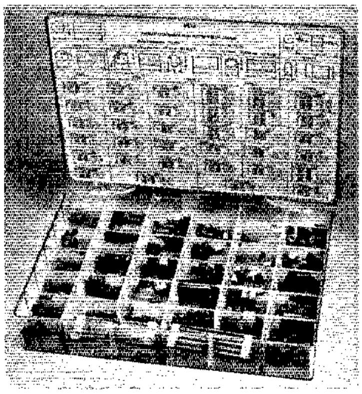
Bibliography

DeMaw, "Some Practical Aspects of VXO Design," *QST*, May 1972, p. 11.
"A J FET Crystal Oscillator," *QST*, February 1974, p. 34.
Lisle, "The Tunable Crystal Oscillator," *QST*, October 1973, p. 30.
Shall, "VXO — A Variable Crystal Oscillator," *QST*, January 1958, p. 11. Also see "VXO — II," *QST*, July 1959, p. 37.

New Products

FAIR-RITE JOULE BOX

☐ In case you've forgotten the definition of "joule," it's the energy expended in 1 second when a current of 1 ampere is flowing through 1 ohm of resistance. So you're perhaps wondering, "What's a Joule Box?" In our opinion, it's an experimenter's dream, if he or she likes to work with magnetic-core materials. Fair-Rite Products Corp. has put together a broad variety of ferrite core devices that today's amateur should find ideal for workshop and laboratory exercises in rf design.



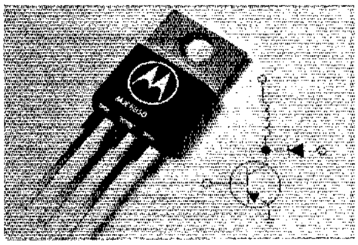
The plastic box is divided into 34 compartments, and each contains a collection of different ferrite cores. There are toroids, sleeves, balun cores, choke forms with pigtails and beads. The inner lid of the Joule Box contains detailed information that describes the contents of each compartment. This includes the part number, dimensions and type of ferrite material. The outer cover of the box lists the initial permeability, gauss, maximum permeability, Curie temperature, volume resistivity and H_C in oersteds.

Amateurs and professionals who like to design and build their own solid-state rf equipment should find the Joule Box as useful as their VOMs and other essential workbench accessories. Additional information on the core material, plus application notes, can be obtained from Fair-Rite's 92-page catalog, *Fair-Rite Ferrite Cores and Assemblies for the Electronics Industry*. Single-lot factory-direct price for the Joule Box is $20, postpaid. It is available also from Fair-Rite distributors for the same price, plus shipping charges. The company address is Fair-Rite Products Corp., Wallkill, NY 12589. — *Doug DeMaw, W1FB*

MOTOROLA PNP HIGH-VOLTAGE POWER TRANSISTORS

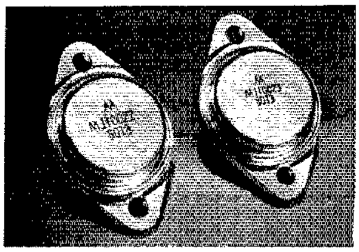
☐ The MJE5850, MJE5851 and MJE5852 are three new high-voltage pnp power transistors introduced by Motorola. These TO-220 plastic-packaged devices have a continuous current rating of 8 A and can handle peak currents of 16 A with $V_{CEO\,(sus)}$ ratings of 300, 350 and 400 volts, respectively, with a power dissipation rating of 80 watts. These units are designed of inductive switching circuits where fall time is critical. Some applications include use as switching regulators, inverters, solenoid and relay drivers, motor controls and in deflection circuits.

This MJE5850 series features fast turn-off times, with 100 ns inductive fall time at 25° C (typ) and 125 ns inductive crossover time at 25° C (typ). The operating temperature range is −65 to +150° C. These devices are complementary to the MJE13006 and MJE13007 npn transistors. — *Paul K. Pagel, N1FB*

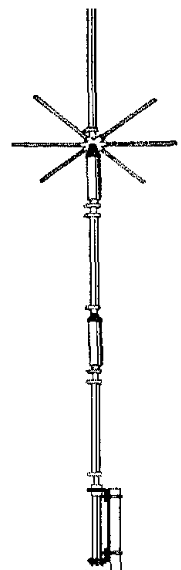


MOTOROLA POWER DARLINGTONS

☐ The MJ10022 and MJ10023 are two new Motorola npn power Darlington transistors. They are designed, according to the manufacturer, to handle a 40 A continuous current and 80 A peak current at potentials of 350 and 400 volts, respectively. These units have a minimum gain of 50 at 10 A and 8 at 40 A. Switching times are a maximum storage of 2.5 μs and fall time of 0.9 μs at 20 A. Copper construction and heavy-duty pins are featured with the TO-3 style metal packaging. These units are available from stock. — *Paul K. Pagel, N1FB* QST

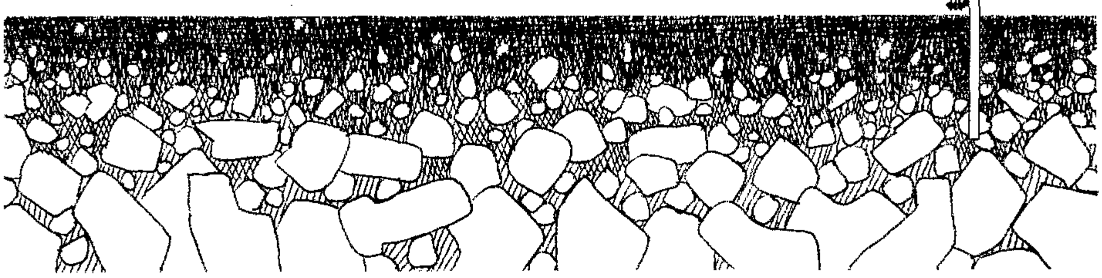


Measuring Soil Conductivity†



Two parameters have the most effect on the efficiency of a vertical monopole — the size of the radial system, and soil conductivity in the vicinity of the antenna. This simple test setup can be used to measure soil conductivity.

By Jerry Sevick,* W2FMI



An important parameter for vertical antennas is soil conductivity. The conductivity of the soil under and in the near vicinity of the antenna is most important in determining the extent of the radial system required and the overall performance. Short verticals with very small radial systems can be surprisingly effective.

Soil Conductivity

Most soils are nonconductors of electricity when completely dry. Conduction through the soil results from conduction through the water held in the soil. Thus, conduction is electrolytic. Dc techniques for measuring conductivity are impractical because they tend to deplete the carriers of electricity in the vicinity of the electrodes. The main factors contributing to the conductivity of soil are

1) Type of soil.
2) Type of salts contained in the water.
3) Concentration of salts dissolved in the contained water.
4) Moisture content.
5) Grain size and distribution of material.
6) Temperature.
7) Packing density and pressure.

Although the type of soil is an important factor in determining its conductivity, rather large variations can take place between locations because of the other factors involved. Generally, loams and garden soils have the highest conductivities. These are followed in order by clays, sand and gravel. Soils have been classified according to conductivity, as shown in Table 1. Although some differences are noted in the reporting of this mode of classification because of the many variables involved, the classification generally follows the values shown in the table.[1,2]

Table 1
General Classification of Conductivity

Material	*Conductivity (millimhos per meter)*
Poor Soil	1-5
Average Soil	10-15
Very Good Soil	100
Salt Water	5000
Fresh Water	10-15

Making Conductivity Measurements

Since conduction through the soil is almost entirely electrolytic, ac measurement techniques are preferable. Many commercial instruments employing ac techniques are available and described in the literature.[3] But rather simple ac measurement techniques can be used which provide accuracies on the order of 25% and are quite adequate for the radio amateur. Such a setup was developed by a colleague and neighbor, M. C. Waltz, W2FNQ, and is shown schematically in Fig. 1.

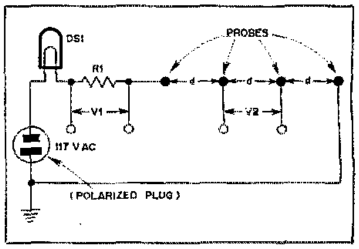


Fig. 1 — Schematic diagram, four-point probe method for measuring earth conductivity.
DS1 — 100-W electric light bulb.
R1 — 14.6 ohms, 5 W. A suitable resistance can be made by paralleling five 1-W resistors, three of 68 Ω and two of 82 Ω. (The dissipation rating of this combination will be 4.7 W.)
Probes — See text.

†Condensed and reprinted from Sevick's article, "Short Ground-Radial Systems for Short Verticals," which appeared in April 1978 *QST*, page 30.

*Bell Laboratories, Murray Hill, NJ 07974

Notes appear on page 39.

Four probes are used. Each is 5/8 inch (16 mm) in diameter, and may be made of either iron or copper. The probes are inserted in a straight line at a spacing of 18 inches or 460 mm (dimension d in Fig. 1). The penetration depth is 12 inches (305 mm). *Caution:* Do not insert the probes with power applied! A shock hazard exists! After applying power, measure the voltage drops V1 and V2, as shown in the diagram. Earth conductivity, c, may be determined from Eq. 1:

$$c = 21 \times \frac{V1}{V2} \text{ millimhos per meter} \quad \text{(Eq. 1)}$$

Soil conditions may not be uniform in different parts of your yard. A few quick measurements will reveal whether this is the case or not.

Fig. 2 shows the conductivity readings taken in my yard over the last three months in 1976. It is interesting to note the general drop in conductivity over the three months, as well as the short-term changes from periods of rain.

Antenna Efficiency Considerations

Vertical antenna efficiencies are based upon the losses that appear in series with the radiation resistance of resonant verticals. Although this approach to determining efficiency does not give a comparison between the very low angles of radiation (i.e., less than 15 degrees) of various radial systems, it does allow for comparisons in the 15- to 30-degree range, which is important for skywave transmission on the 40-, 80- and 160-meter bands. Mathematically this definition for antenna efficiency can be written as:

$$\text{Antenna efficiency} = \frac{R_{rad}}{R_{rad} + R_g + R_A} \quad \text{(Eq. 2)}$$

where

R_{rad} = radiation resistance
R_g = ground loss
R_A = ohmic losses caused by loading and in the antenna itself

With high-Q loading coils and practically any size aluminum tubing for the antenna, R_A can be minimized and therefore eliminated from the relationship of Eq. 2. The denominator of the relationship then becomes simply the measured input or feed-point resistance of the radiator.

Experiments show that the efficiency of a vertical antenna system employing small numbers of radials is quite dependent on the moisture content of the soil. The measured input resistance of a resonant 20-meter quarter-wavelength vertical is plotted in Fig. 3 vs. the number of quarter-wavelength radials, from one to eight. The radiation resistance is 35 ohms for the thickness of the verticals used in this experiment.

Consider the case with four radials. The input resistance was measured as 75 ohms under dry soil conditions and 64 ohms under wet conditions. It can be seen from Eq. 2 that the efficiency under dry conditions is therefore 47%, and improves slightly to 55% under wet conditions. This poor efficiency exists for a location with soil conditions that can be considered average. As can also be seen, the difference in efficiency between wet and dry conditions becomes less pronounced as the number of radials is increased. The antenna system also becomes more independent of soil conductivity as the number of radials is increased.

The simple soil conductivity measurement scheme described also gives one a tool for comparing a given location with others, as well as predicting the performance of a vertical antenna system. [QST]

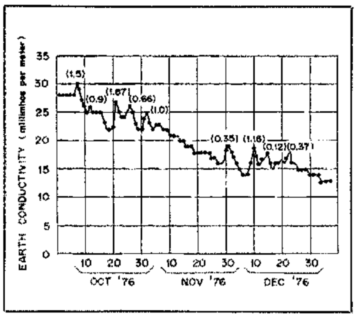


Fig. 2 — Earth conductivity at the author's location during the last three months of 1976. Numbers in parentheses indicate inches of rainfall (multiply by 25.4 for mm).

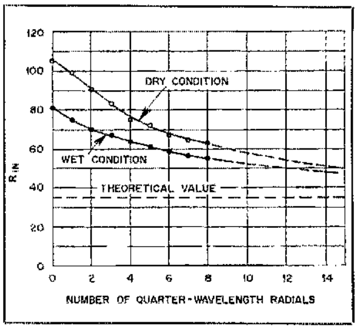


Fig. 3 — Input resistance of a 20-meter resonant quarter-wavelength vertical as a function of the number of radials and the condition of the soil. Under dry conditions the soil conductivity was measured at 10 to 15 millimhos per meter, and 25 to 30 millimhos per meter for wet conditions.

Notes

[1] Card, "Earth Resistivity and Geological Structure," *Electrical Engineering*, November 1935, pp. 1153-1161.
[2] *Reference Data for Radio Engineers*, fifth edition, Howard W. Sams and Co., Inc., ITT, pp. 26-3 to 26-5.
[3] Lagg, *Earth Resistances*, Pitman Publishing Corp., 1964, pp. 206-229.

LEO C. YOUNG, W3WV

☐ On January 16, 1981, the Amateur Radio fraternity lost one of its pioneers with the passing of Leo C. Young, W3WV, whose earliest ventures into the wireless art took place in 1905 when he was a boy of 14. He was one of the first employees of the Naval Research Laboratory in Washington, DC, when it was officially opened in 1923, and continued with the laboratory as a scientist until his retirement in 1967. In 1922 W3WV was credited with the development of radio equipment used in the detection of ships moving on the Potomac River, making the first use of what is now known as cw radar. In 1930 he supervised research experiments that produced the first detection of aircraft by reflection of radio signals, and in 1934 was responsible for the research that led to the development of the first system using radio pulses for range determination of stationary and moving objects, thus providing the groundwork for radar developments that profoundly affected the outcome of World War II.

W3WV, in his work at NRL, also made significant pioneering contributions in radio communications, electronic identification systems and radio control of missiles that influenced U.S. advance in these fields. He received the Presidential Certificate of Merit from President Truman in 1946, the Stuart Ballantine Medal of the Franklin Institute in 1957, and the Distinguished Civilian Service Award (the Navy's highest civilian award) in 1958.

Leo participated in the exploration by radio amateurs of the high frequencies for worldwide communications in the early '20s, continuing as an active amateur until declining health curtailed on-the-air operations during the past two years. He was a highly proficient cw operator and enjoyed contests. A charter member of the Naval Research Laboratory Amateur Radio Club, Leo was also a member of the Potomac Valley Radio Club for many years.

He is survived by his wife, Mabel, and two sons, Leo Jr., K3MZY, and Richard, W3PZW.
— *Vic Clark, W4KFC*

A Kite-Supported 160- (or 80-) Meter Antenna

"The Parafoil® is a ram-air wing type aerial device that has no rigid parts. If it is shaped like a wing, and looks like a wing, then it must be a wing. A Parafoil rises against NOT WITH the wind." — Domina Jalbert, a pioneer of tethered flight.

By John S. Belrose,* VE2CV

Kite flying is a sport that from early times has been a national pastime of Asian peoples. Kites have also been put to practical use. In 1751, Benjamin Franklin hung a metal key from a kite line and, by attracting electricity during a storm, demonstrated the electrical nature of lightning. In 1901, Guglielmo Marconi[1] flew a kite-supported antenna from Signal Hill, St. John's, Newfoundland and succeeded in receiving radio transmissions from the Poldhu Wireless Station in Cornwall, England. Kites were long used for weather observation, with instruments being carried aloft to record data.

There are about five basic types of kites: the 3-sticker (hexagonal), the Malay (modified diamond), the box kite, the tetrahedral and the parafoil, an aerofoil kite. The shape of the kite can be designed so that the kite will be self-correcting by incorporating a diehedral (two-sided) angle in the surface, or by bowing the main cross-stick to a depth of about 10% of its length. This latter type is the kind of tailless kite that Marconi flew. If not self-correcting, the kite will require a tail for stabilization.

The box kite,[2] the invention of an Australian named Lawrence Hargrave in the 1890s, is identified by its rectangular shape. The frame is twice as long as its width, the ends are left open, and one-third of its length is covered around each end. The bridle consists of two lines, one to each end of one of the vertical sticks, meeting a little above the lower edge of the top panel. The kite flies on one edge and needs no tail.

The tetrahedral kite[3] was invented by Alexander Graham Bell in about 1903. This structure, of triangular construction in every direction (longitudinal as well as transverse), was developed in his Nova Scotia laboratory. It is formed by six equal rods, and has great strength and lightness. Two of the sides of the tetrahedron are covered, and this constitutes the "sail" of the kite. A toy Tetrakite® manufactured by Synestructics, Inc.[4] has four such cells, hence four sails. Their Super Tetrakite has 16 sails.

Marconi launches a kite-supported antenna from Signal Hill, St. John's, Newfoundland, and succeeds in receiving radio transmissions from Poldhu, Cornwall, England (1901).

*3 Tadoussac Dr., Aylmer (Lucerne), Quebec J9J 1G1

[1]Notes appear on page 42.

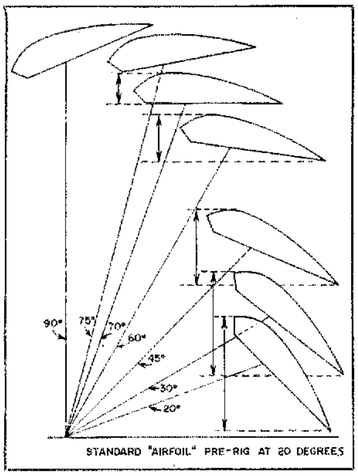


Fig. 1 — Sketch illustrating how stable flight is achieved with a Jalbert Parafoil. If the kite overflies, it stalls; if it underflies, it gains lift. It is a self-correcting device.

The tetrahedron shape is such that in every direction the cross-section is the same, which is the reason that the kite is so steady in flight. The kite flies on one edge of the sail(s) and needs no tail.

For the application considered here, viz. a kite-supported antenna for portable use, the Jalbert Parafoil kite[5,6] is perhaps the best of the various types of kites. The Parafoil is a ram-air wing type aerial device that has no rigid parts. It requires no sticks to carry and assemble. It combines in a marked degree the qualities of strength, lightness, lift and steadiness of flight. The Jalbert aerofoil kite achieves its lift and stability through its excellent aerodynamics, because its shape is that of an aerofoil. The bridal, which resembles the shrouds of a parachute, is prerigged at 20° so the kite flies stably when its kite line makes an angle 70° from the horizontal. If the kite overflies, it stalls; if it underflies, it gains lift. Hence it is always trying to fly at the design angle (Fig. 1).

The leading edge of the kite is open to wind, and it is launched by holding this edge into the wind. The kite fills with air, and becomes "rigid" because of the ram-jet action of the wind. A small amount of the air that enters the kite is bled out at the rear edge of the kite, and these jets blow onto the webbed "tail" flap, providing additional stability. The fins also act like stabilizers, similar to the rudder of an airplane.

Kites as antenna supports can be very successfully employed in the Arctic, on the land above the tree line, at the ocean beach, or anywhere that the wind can be depended upon. The kite flies best in a steady wind between 15 and 30 km/h (9 and 18 mi/h). In the higher winds, a tail is recommended to increase the stability of the Parafoil. The best tails are made of plastic strips, 50 mm wide and 3 to 4 m long (2 inches wide and 10 to 12 feet long). Use 5 to 6 multicolored strips to form a tail. A swivel snap attached to one end of each strip should be put on the loop at the center of the trailing edge of the parafoil. The swivel snaps keep the strips from becoming tangled. At all times a winch should be used to facilitate bringing the kite down. Also, never fly a kite carrying a wire antenna near power lines, or during an electrical thunderstorm. And don't fly the kite too high where aircraft are flying.

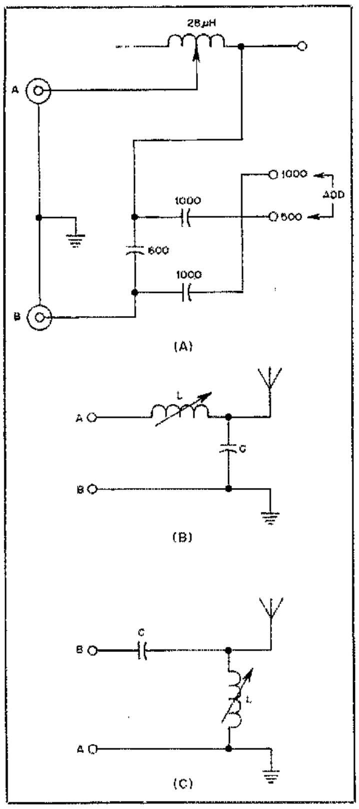


Fig. 2 — L-section matching network. Capacitances are in picofarads. The circuit at A is the schematic diagram of the antenna coupler used by the author. At B it has been configured to match a 1/2-λ antenna to 50 Ω. At C, the circuit will match a 5/8-λ antenna to 50 Ω.

The Antenna

Two types of antennas have been employed: a simple wire antenna which was end-fed by an L-section matching unit, and a J antenna. The J is an end-fed half-wave radiator, fed and matched by means of a tapped quarter-wavelength shorted transmission line, and constructed from 300-ohm twin-lead.[7]

If the kite-supported antenna is operated from an ocean beach, a 5/8-wavelength wire antenna could be employed and the ocean used as a ground plane. In this situation, the antenna will exhibit some directivity with maximum gain in the direction of the open sea. If an ocean is not available for a "ground plane," a half-wave radiator should be employed, since this antenna works well with no physical connection to the ground.

My wire antennas used braided, bronze fishing line (diameter of the wire is about 0.18 mm or 0.032 inch) and a test strength of 27 kg (60 lbs). Do not kink or solder to this wire; otherwise, it will break at these points. Braided monel and solid monel fishing lines are also available,[8] and in fact either of these lines might have better mechanical properties.

Since the length-to-radius ratio (h/a) is large, an end-fed half-wave radiator for 75 meters has a very high impedance (4000 ohms); the resistance and reactance values for a 5/8-λ antenna are estimated to be 135 − j912 ohms; that is, R_a = 135 ohms and X_a (capacitive) = 912 ohms.[9]

Matching End-Fed Wire Antennas

An L-network impedance-matching device is the simplest type that can provide a perfect match between the transmitter and the antenna. The one I used was the "Wide Range Wire Tuner" manufactured by the Unique Products Company, West Covina, California. This device allows for two configurations for the L-match network, and both are needed for 1/2- and 5/8-λ antennas (Fig. 2).

If the antenna is a resonant 1/2-λ radiator, the values for the inductance and capacitance can be readily calculated using

$$\begin{aligned} 2\pi fL &= j\sqrt{R1(R2 - R1)} \\ &= j\sqrt{50(4000 - 50)} \\ &= j444 \text{ ohms } (18.6\ \mu H) \\ \frac{1}{2\pi fC} &= -\,j\,R2\sqrt{\frac{R1}{R2 - R1}} \\ &= -\,j450 \text{ ohms } (93\ pF) \end{aligned}$$

where

R1 = desired transmitter impedance = 50 ohms

R2 = antenna impedance (estimated to be 4000 ohms)

The parenthetical values are inductance and capacitance for an operating frequency of 3.8 MHz.

When the antenna impedance is reactive, the L-network parameters can only be calculated by iteration; several settings provide zero reactance, but only one of these settings provides a match to 50 ohms. Also, the "tuning" will be more critical than for resistance matching. An initial dial setting calibration, in our case using a vector impedance meter and "equivalent" lumped-circuit antenna parameters, facilitated tuning in the field.

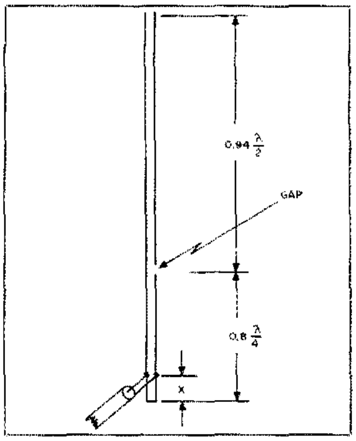


Fig. 3 — Schematic diagram of a J antenna which can be constructed from 300-Ω twin-lead. See text regarding dimension X.

These results are given in Table 1.

J Antenna for 75 Meters

A J antenna constructed from 300-ohm transmission line is sketched in Fig. 3. The lengths of the 1/4-λ matching stub and the 1/2-λ radiator are calculated from the conventional wavelength formula

$$\lambda = \frac{300}{f\ \text{MHz}}\ \text{meters}$$

Appropriate factors must be used, which for a 300-ohm twin-lead stub is 0.8 times a free-space quarter-wave (velocity factor for polyethylene is 0.8). For the radiator, the antenna length is about 0.94 times a free-space half-wave. The correct tap point, which must be determined by experiment, is about 0.0134 λ (distance X measured from the shorted end). Thus, for 75 meters (3.8 MHz), the length of the 1/4-λ section is 15.8 meters (51.8 ft) and the length of the 1/2-λ radiator is 37.1 meters (121.7 ft) for an overall length of 52.9 meters (173.5 ft). The tap point is about 1.03 meters (40-1/2 inches) from the shorted end. While any kind of 300-ohm twin-lead will work, that made by Belden (type 8230) was used, since, according to the manufacturer, it is stronger and has more flex-life than equivalent twin-lead. Hence, it should have superior resistance to the pulling, whipping and twisting that it is subjected to as a kite-supported antenna.

I have used kite-supported antennas on trips to Koartak, in an Inuit community on the northwest tip of Ungava Bay in Arctic Quebec. The braided bronze fishing-line antenna was wound on a fishing reel. Sixty to ninety meters (295 ft) of kite line was used above the wire antenna, so the kite flew in stable air.

Lighter-than-air balloons and Kytoons[10] (combining the advantages of a balloon and a kite) can also be used to hoist antennas aloft (see November 1975 *QST*, page 57). Regular meteorological-type balloons are close to useless as antenna supports unless there is no wind, because they tend to "heel over." There are two solutions. Either use a balloon with a very strong lift or use a Kytoon that is designed to fly in the wind. The ILC Dover Company[11] markets an inexpensive 1 cubic meter balloon with a lifting capacity of about 500 grams (1.1 pounds). Both ILC Dover and Jalbert Aerological Laboratories market Kytoons.

A Parafoil upside down on ground. The bridal resembles the shrouds of a parachute.

Table 1

L-Network Match for Various Antennas

Antenna Type	*Estimated Impedance $R_a \pm jX_a$ (ohms)*	*L-Section L (μH)*	*C (pF)*
Half-wave	4000	20.2	115.4
5/8-λ wire	130-j974 (43 pF)	15	105
5/8-λ whip	100-j600 (70 pF)	10.9	136

Concluding Remarks

Jalbert Parafoil kites are available in three sizes.[12] The kite most suitable for use in the present application is the model J-15. The model J-35 is a much larger kite which *must not* be flown without a winch. This larger kite is suitable for carrying a lightweight battery-operated repeater, or for supporting a vertical antenna for the higher hf or vhf bands where height is desired, and where the kite must support the coaxial feed cable.

In considering the application of a kite-supported repeater, it should be noted that the record height reached by a kite, according to the Encyclopaedia Britannica, was 7265 meters (23,835 ft). This height was reached on May 5, 1910, at Mount Weather, Virginia, using a train of 10 kites on piano wire from a ground winch. A more modest height would be quite satisfactory for a vhf repeater for emergency or experimental use.

The author holds the kite line immediately after launching. As can be seen from the faces of the children, kites are fun whether you have an interest in antennas or not.

Nylon flying line for the above-mentioned kites is available from the manufacturer in 914 m (3000 foot) lengths having 90 and 159 kg (200 and 350 lb) test.

All of us have dreamed of a skyhook for supporting a vertical antenna. If this article encourages you to fly kites in connection with your hobby of Amateur Radio, good luck, have fun, and may favorable winds be at your back when flying your Parafoil. QST

Notes

[1]McNicol, *Radio's Conquest of Space*, Arno Press, New York, 1974, pp. 132-143.
[2]*Encyclopaedia Britannica*, William Benton, publisher, 1964, pp. 421-422.
[3]Bell, "The Tetrahedral Principle in Kite Structure," *The National Geographic Magazine*, Vol. XIV, June 1903.
[4]Synestructics, Inc., 9559 Irondale Ave., Chatsworth, CA 91311.
[5]Jalbert Aerology Laboratories, Inc., 170 NW 20th St., Boca Raton, FL 33432.
[6]Jalbert, "The Jalbert Airfoil," *Annals of the New York Academy of Sciences*, 1969, pp. 163-271.
[7]Belrose, "The Vertical-J for 2-Meters — A Roll-up and Put in Your Pocket Type," *TCA* (The Canadian Amateur), Aug./Sept. 1979.
[8]In Canada, such fishing line is manufactured by the Schindler Co. of Canada, No. 1 Audley St., Toronto, ON M8Y 2X3.
[9]Jordan, *Electromagnetic Waves and Radiating Systems*, Prentice-Hall, New York, 1950, pp. 482-483 and 508.
[10]Ferrier and Baird, "A New Kind of Skyhook," *QST*, October 1946, p. 24.
[11]For more information contact Frank Mathews, ILC Dover, P. O. Box 266 Frederica, DE 19946, tel. 302-335-3911.
[12]See note 5.

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Bonadio, "The Balloon Antenna Rides Again," *QST*, March 1947, p. 60.
Griffin, "Tri-County Takes a Holiday or Benjamin Franklin in Reverse," *QST*, June 1939, p. 30.
Walker and Goodman, "Balloon-Supported Antennas," *QST*, April 1940, p. 40.

• *Basic Amateur Radio*

Simple Antenna and S-Meter Modification for 2-Meter FM Direction Finding

Enjoy hunting? Want to go after a tame little bunny or a wild turkey? Here are some tools that may help you.

By Peter O'Dell,* KB1N

"Did you see that silly man and woman driving around with the TV antenna on their car? They must have been down to the dump and picked it up. She was driving and he was holding onto the antenna with his arms stuck out the window. You'd think they would freeze to death in this weather. Funny thing is that they just kept driving back and forth. Some people are just plain crazy!" said the clerk to our friend Danny. Danny just smiled and nodded because he knew that the crazy man and woman were actually two rather inept bunny (hidden transmitter) hunters. They had managed to get close to the bunny, but couldn't locate him once they were in his immediate proximity. Of course Danny waited until a large crowd had gathered on the local repeater before telling us what the clerk had said *about my wife and me*. It sure is nice to have friends.

A Source of Vexation

Bunny hunts or fox hunts are organized events in which one member of the group retires to some out-of-the-way place and periodically transmits a signal. The objective of the other members of the group is to find the bunny as quickly as possible. There are a number of variations on this theme. On the other hand, a wild turkey hunt (well, at least, that's what I call it) occurs when an unknown operator begins transmitting an unidentified signal, intentionally or unintentionally, that causes disruption of service. The objective of the whole group is to find him/her and convince him/her to stop transmitting in such a manner. The generic term for these endeavors is direction finding (DF).

Direction finding is easy for a vhf fm signal; all you need is a map, a compass, a receiver and a directional antenna. If you are a couple of miles from a signal, you should have no trouble getting the general direction of its origin. Move to another location and take a second reading; draw the corresponding lines on your map and, *presto*, you know exactly where the transmitter is located — well, almost.

Most newcomers to DF make the same mistakes that we did. They try to use the same kind of antenna for DF that they use for making distant contacts. The trouble is that the objectives and needs of the two situations are quite different. Typically, a Yagi beam with parasitic reflector and directors will have one main signal lobe, several minor lobes and numerous nulls between the lobes. Hall has recently discussed the interpretation of patterns as presented in *QST*, so that information will not be repeated here.[1] Also, for more detailed information on antenna patterns, consult *The ARRL Antenna Book* (available from ARRL for $5). A pattern with one narrow major lobe is what is needed for making long-distance contacts.

But that is not the most useful pattern for DF operations. Usually, as an operator moves toward the location of the hidden transmitter, the signal strength will increase. Do you know what happens with an antenna/receiver system that determines direction based on the main lobe? Sooner or later the S meter will be fully

*Basic Radio Editor

[1]Notes appear on page 47.

deflected on some or all of the minor lobes as well as the major one. At that point the searchers will probably go back and forth or in circles because the signal will seem to be coming from several different directions at the same time! I speak from experience.

Fig. 1 shows the pattern of an antenna that can be much more useful for DF operations. The antenna has only one lobe in its pattern. Notice that there is only 3 dB difference 90 degrees either side of a bearing of zero degrees. This lobe is virtually useless for direction finding. But take a look at the null. The computer program used to generate plot points for this pattern indicated that the signal level at 180 degrees would be − 120 dB. [This is a somewhat nebulous number arising from rounding in the computer's math operations. The theoretical response is $-\infty$ dB. — Ed.] Ten degrees either side, the signal level rises to −40 dB — a difference of many, many dB! The point is, when the null is pointed at a signal, the operator should notice a *sharp* decrease in the received signal strength. This is a significant advantage for DF. Why? Because the antenna pinpoints a direction based on a *minimum* reading, it will be useful when close to the source. Cardioid is the general name applied to patterns with one very broad lobe and one very sharp null.

The Antenna

What kind of antenna produces a cardioid? Although there may be any number of different antennas that will produce this type of pattern, the simplest design is depicted in Fig. 2. Two quarter-wavelength vertical elements are spaced one quarter-wavelength apart and are fed 90 degrees out of phase. Each radiator is shown with two radials approximately 5 percent shorter than the radiators.

During the design phase of this project we used the TRS-80 computer to predict the impact on the antenna pattern of "slight" alterations in its size, spacing and phasing of the elements.[2] The results suggest that this system is a little touchy and that the most significant change comes at the null. Very slight alterations in the dimensions caused the notch to become much more shallow and, hence, less useable for DF. Early difficulties in building a working model bore this out.

This means that if you decide to build this antenna, you will find it advantageous to spend a few minutes to "tune it" for the deepest null. If it is built using the techniques I used, then this should prove to be a small task which is well worth the extra effort. Tuning is accomplished by adjusting the length of the vertical radiators, the spacing between them, and if necessary, the lengths of the phasing harness that connects them. Tune for the deepest null on your S-meter using a signal source such as a moderately strong

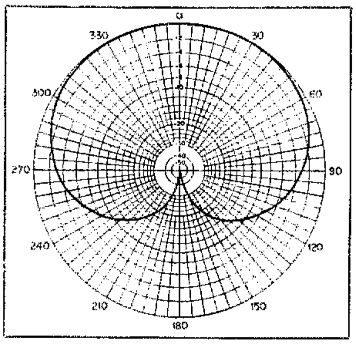


Fig. 1 — This is a cardioid antenna pattern. As the antenna is rotated, an operator would notice little change in the S-meter indication of an incoming signal until the notch was pointed at the signal. Then the S-meter reading should drop dramatically.

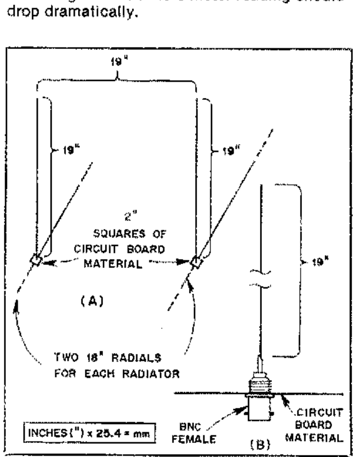


Fig. 2 — At A is a simple configuration that can produce a cardioid pattern. At B is a convenient way of fabricating a sturdy mount for the radiator using BNC connectors.

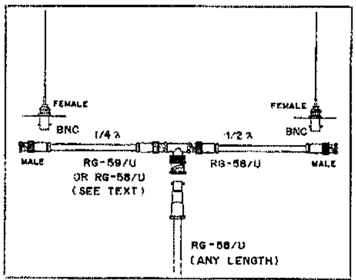


Fig. 3 — The phasing harness for the two verticals that produce a cardioid pattern. The phasing sections must be measured from the center of the T connector to the point that the vertical radiator emerges from shield portion of the upside-down BNC female; i.e., don't forget to take the length of the connectors into account when constructing the harness. If care is taken and coax with polyethelene dielectric is used, you should not have to prune the phasing line. With this phasing system, the null will be in a direction that runs along the boom toward the quarter-wavelength section.

repeater. This should be done outside, away from buildings and large metal objects — I tried tuning in our kitchen and found that reflections off our appliances were producing spurious readings. Beware too of distant water towers, radio towers, and large office or apartment buildings. They can reflect the signal and give false indications.

Construction is simple and straightforward. Fig. 2B shows a female BNC connector (Radio Shack 278-105) that has been mounted to a small piece of pc-board material. The BNC connector is held "upside down" and the vertical radiator is soldered to the center solder lug. A 12 in. (300 mm) piece of brass tubing provides a snug fit over the solder lug. A second piece of tubing, slightly smaller in diameter, is telescoped inside the first. The outer tubing is crimped slightly at the top after the inner tubing is installed. This provides positive contact between the two tubes. For 146 MHz the length of the radiators calculates to about 19 in. (480 mm). You should be able to find small brass tubing at a hobby store. If none is available in your area, you might consider brazing rods. I have noticed some available in the hardware sections of discount stores. It will probably be necessary to solder a short piece to the top of these since they come in 18 in. (460 mm) sections. Also, tuning will not be quite as convenient. Two 18 inch (460 mm) radials are added to each element by soldering them to the board. I happened to have two 36 in (920 mm) pieces of heavy brazing rod available so I used them.

The Phasing Harness

One of the requirements to produce a cardioid pattern is that the two elements be fed 90 degrees out of phase. Why not put a 19-in. (480 mm) quarter-wave section of coax between the two elements? Radio waves travel slower in transmission lines than they do in free space. Each type of transmission line has a characteristic known as the velocity factor. This is a fractional figure that will convert the electrical wavelength in free space to the electrical wavelength in the transmission line. Since it is a fractional value, the equivalent length of transmission line will always be shorter than the free space distance. In other words, an electrical quarter wavelength of transmission line will be shorter than the distance between the two radiators.

There are any number of ways of getting around this problem. One simple solution would be to separate the elements by a quarter wavelength and connect them with a piece of transmission line that is electrically three quarter-wavelengths long (or any other odd multiple of a quarter wavelength). Lewallen has noted that some care must be taken to avoid having unequal currents flowing in the two radiators.[3] He suggests the use of a T connector to split the phasing line as shown in Fig. 3. Unequal currents tend to reduce the depth of the null in the pattern, all other factors being equal.

With no radials or with two radials perpendicular to the vertical element, I found that a quarter-wavelength section made of RG-59/U 75-Ω coax produced a deeper notch than a quarter-wavelength section made of RG-58/U 50-Ω coax. However, with the two radials bent downward somewhat, the RG-58/U section seemed to outperform the RG-59/U. There will probably be enough variation from one antenna to the next that it will be worth your time and effort to try both sections and determine which works best for your antenna. The half-wavelength section can be made from either RG-58 or RG-59 because it should act as a 1-to-1 transformer. The most important thing about the coax is that it be of the highest quality (well shielded and with a polyethelene dielectric). The reason for avoiding foam dielectric is that the velocity factor varies from one roll to the next — some say that it varies from one foot to the next. Of course, it can be used if you have test equipment available that will allow you to determine its electrical length. Assuming that you do not want to or cannot go to that trouble, stay with polyethelene-dielectric coax. In short, stay away from coax that is designed for the CB market or do-it-yourself cable-TV market. (A good choice would be Belden 8240 for the RG-58/U or Belden 8241 for the RG-59/U.)

Both RG-58 and RG-59 with polyethelene dielectric have a velocity factor of 0.66. Therefore, for 146 MHz a quarter wavelength of transmission line will be 19 in. (480 mm) × 0.66 = 12.5 in. (320 mm).

A half-wavelength section will be twice this length of 25 in. (640 mm). One thing that you must take into account is that the transmission line is the total length of the cable *and the connectors*. Depending on the type of construction and the type of connectors that you choose, the actual length of the coax by itself will vary somewhat. You will have to determine that empirically.

In my earliest efforts I used a Y connector that mated with RCA phono plugs because it is widely available and the phono plugs are easy to work with. The results with this system were not satisfactory. The performance seemed to change from day to day and the notch was never as deep as it should have been. Although they are more difficult to find, BNC T connectors will provide superior performance and are well worth the extra effort. If you must make substitutions, I would suggest that you go with the UHF type connectors (mate with PL-259s).

Fig. 4 shows a simple support for the antenna. PVC tubing is used throughout. I bought the cheapest (smallest diameter) that I could find. Additionally, you will need a T fitting, two end caps, and possibly some cement. (I didn't cement mine together because I wanted to have the option of disassembly for transportation.) Cut the PVC for the dimensions shown. You can use a saw or a tubing cutter to cut the PVC. I prefer the tubing cutter because it produces smooth, straight edges and is a lot less messy. Drill a small hole through the pc board near the female BNC of each element assembly. Measure 19 in. (480 mm) along the boom (horizontal) and mark the two end points. Drill a small hole vertically through the boom at each mark. Use a small nut and bolt to attach each element assembly to the boom.

Tuning

The dimensions given throughout this article are those for approximately 146 MHz. If the signal that you will be hunting will be above that frequency, then the measurements will probably need to be a bit shorter. If you are to operate below that frequency, then they will need to be a little longer. Once you have built the antenna to the rough size, the fun begins. You will need a signal source near the frequency that you will be using for your bunny hunts (turkey hunts). Adjust the length of the radiators and the spacing between them for the deepest null on your S meter. I would make changes in increments of 1/4 in. (6 mm) or less. If you must adjust the phasing line, make sure that the quarter-wavelength section is exactly one-half the length of the half-wavelength section. Keep tuning until you have a satisfactorily deep null on your S meter.

Adding an S-Meter

You just realized your radio does not have an S meter built into it! What can you do? Adding an S meter is a lot easier and simpler than you might imagine. It seems that most of the hand-held units on the market today do not offer this particular "bell and whistle." I personally think this is unfortunate for the user and rather short-sighted on the part of the manufacturers. Fortunately for you there is only one difficult problem associated with adding an S meter — where to put it. Many of the smaller hand-helds simply do not have enough open space inside to install a meter. The obvious solution is to "outboard" the meter and connect it to the internal circuitry with a pair of wires.

Egads! Wires dangling from my new $300 hand-held! Yich! You can install a jack in the case of your hand-held and use the matching plug to connect the meter when you want it. Such a modification will not harm the appearance or resale value. The components are easy to find (Radio Shack sells a variety of matching plugs and jacks). The meter can be housed in a leatherette film carrier used by photographers to carry extra rolls of 35 mm film. The carriers are available from photography stores and discount stores

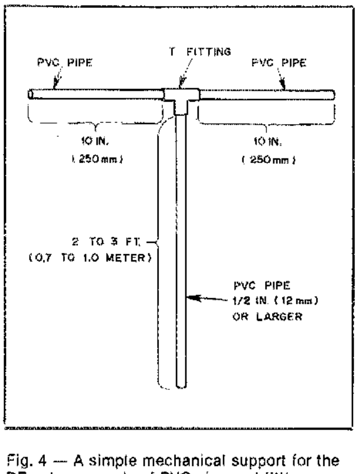
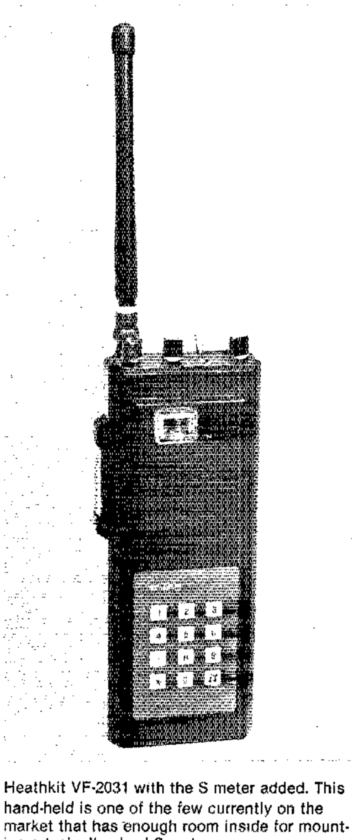


Fig. 4 — A simple mechanical support for the DF antenna made of PVC pipe and fittings.



Heathkit VF-2031 with the S meter added. This hand-held is one of the few currently on the market that has enough room inside for mounting a typically sized S meter.

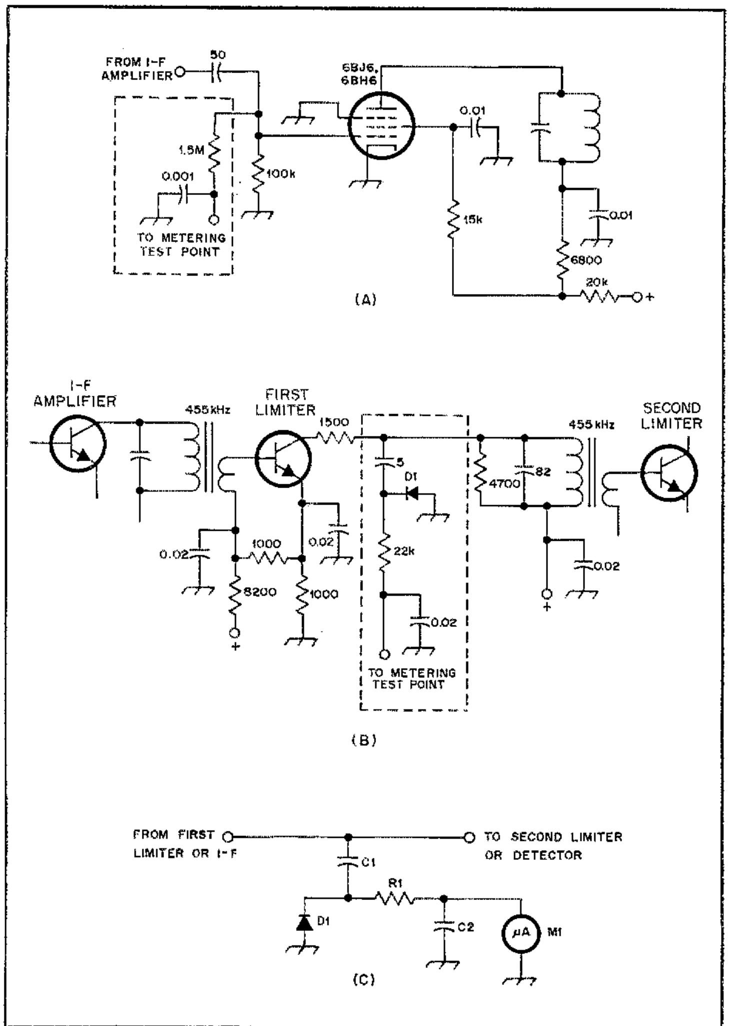


Fig. 5 — At A and B are portions of schematic diagrams of the limiter stages of tube and solid-state receivers, respectively. Many receivers have a test point at this stage for use during front-end alignment. The components associated with the test point are inside the broken lines. If your receiver does not have such a point, you can add the components shown in C. (See text for parts information.)

for less than \$2 each. They can be attached to the leather carrying case of your hand-held either with pop rivets or epoxy cement. This very functional modification for your hand-held will not detract from its appearance or resale value (in fact, it will probably boost the resale value slightly).

The detector of an fm receiver detects (decodes) the intelligence from the received signal by demodulating the deviation from the carrier frequency and the rate of change of this deviation. Any amplitude (strength) variations reaching the detector would be detected as noise or distortion of the intelligence in the fm signal. Depending on the design of the receiver, one or usually more stages of high-gain amplification precede the detector. There is an upper limit to the output level from any amplifier, regardless of the level of the input. This characteristic is used by the fm receiver to bring all signals or portions thereof up to the same signal level to minimize noise and distortion in the detected audio. Because these high-gain amplifiers bring the signal up to the upper *limit* of their ability, they are collectively known as the limiter stage(s).

By understanding the above action, you can see it becomes almost trivial to add an S meter to indicate relative signal strength. Fig. 5 (A and B) shows the limiter stages from typical tube and solid-state receivers. Notice that both diagrams have a terminal marked "to metering test point." Typically, a 200-microampere meter will be connected from this point to ground and used to align the front end of the receiver. The stronger the signal reaching the first limiter, the more the meter will be deflected. This is the very action that we are looking for in an S meter! If the schematic diagram of your receiver has such a "test point" indicated, then simply connect your meter here. If not, locate the corresponding point in your receiver and add the circuit that is shown in Fig. 5C. Component values are not critical for the capacitors and diode. Virtually any small-signal diode will be okay for the circuit. C1 and C2 can be any convenient value from 0.001 to 0.05 μF. Determine the value of R1 by substituting a small potentiometer (25 kΩ to 50 kΩ) for the resistor. With the strongest signal available, set the meter for full-scale deflection by adjusting the potentiometer. Once the proper value for full-scale deflection has been determined, remove the potentiometer from the circuit and use an ohmmeter to measure its value. Obtain a quarter-watt fixed value resistor that is close to this resistance and use this resistor for R1. M1 is a surplus S meter that requires up to 350 microamperes for full-scale deflection.

An Example

Some modern fm receivers have abandoned the use of discrete transistors in favor of monolithic ICs with the limiter stages and the detector all on one chip. One example of this approach is the Heathkit VF-2031 which uses the CA3089 chip. Fig. 6 shows a block diagram of the chip circuitry. Notice that pin 13 (bottom, center) is the output for a tuning-meter circuit. Attached to pin 13 is a resistor and a meter. Like most of the other chips in service, the CA3089 was designed primarily for use in fm broadcast receivers. However, a tuning meter will serve the same function as our S meter. A close look at the service manual of your receiver or the IC manufacturer's specification sheet will probably disclose similar possibilities.

Fig. 7 is a portion of the diagram of the VF-2031, showing the circuitry associated with the CA3089. Notice that pin 13 is already being used to trigger the squelch circuit. But notice also that pin 13 is tied to test point 1 (TP1). Guess what TP1 is used for. That's right — aligning the front end! One unexpected problem cropped up when I discovered that pin 13 never had less than 1.25 V dc on it. Three diodes, D1 through D3, serve the function of providing a constant voltage drop of about

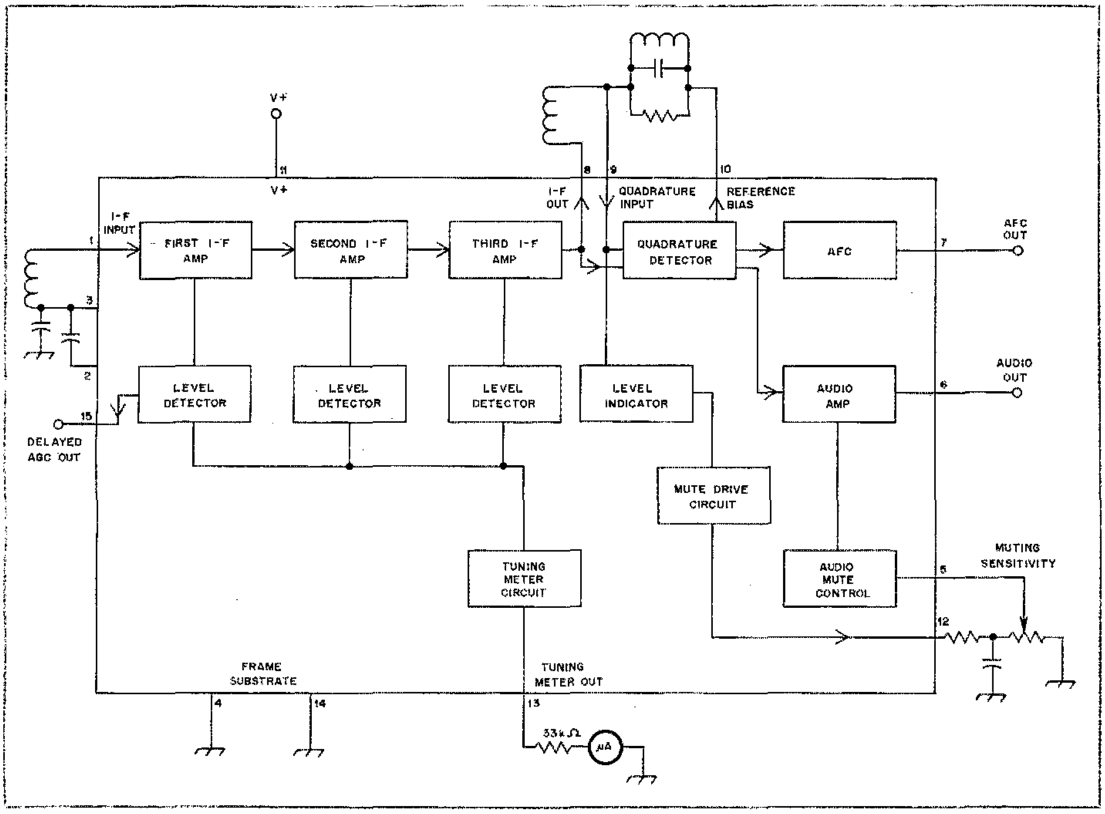


Fig. 6 — Internal block diagram of an RCA CA3089 monolithic limiter/detector IC. Notice that the chip has the circuitry built in for a tuning meter (S meter).

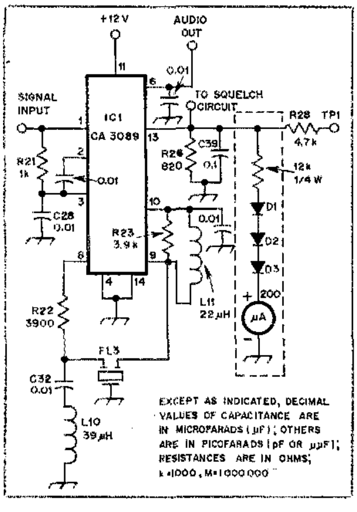


Fig. 7 — Portion of the schematic diagram of the Heathkit VF-2031. The components inside the dotted line were added to provide an S meter.

1.3 V. Without them in the circuit, the meter "idled" at about 1/3 scale when no signal was present. I used the method described earlier to determine the proper value of resistance to produce a full scale meter reading with the maximum voltage present at pin 13. The meter is a surplus unit that was obtained from Poly-Paks.[4]

One of the nicest things about the VF-2031 is the unused space inside which provides ample room for the tinkerer to add any number of options. I drilled a small hole in the front of the case and used a file to enlarge it to the size of the meter housing. I used a small dab of cement to hold the meter in place once I had determined the proper position. The diodes and resistor are encased in heat-shrink tubing and suspended between the meter and the circuit board. It has proved to be a most welcome addition to the transceiver. I suspect that many amateurs would find an S meter a welcome feature on a hand-held.

Go Get the Bunnies

The best offense is a solid defense! If you have the right tools, bunny hunts are one of the most enjoyable things to do with Amateur Radio on a balmy spring afternoon. And now you have the proper antenna and have added an S meter to your receiver (if it didn't already have one). But more important than just having a good time, you will be preparing a large number of the members of your club to track down the next turkey that takes roost on your repeater. If it is public knowledge that your club can pinpoint a turkey in a matter of minutes, he will probably go gobble somewhere else — turkeys are like that. QST

[Note: Next month we will conclude with some useful accessories. In the meantime, go ahead and try the antenna and S-meter combination — you'll like what you find.]

Notes

[1]Hall, "New Look for QST's Antenna Patterns," *QST*, July 1980, p. 26.
[2]See May, "Antenna Modeling Program for the TRS-80," *QST*, February 1981, p. 15.
[3]Lewallen, "Notes on Phased Verticals," *QST*, August 1979, p. 42.
[4]Poly-Paks part number 92CU5786. This meter or similar available from Poly-Paks, P. O. Box 942, South Lynfield, MA 01940, tel. 617-245-3828.

Product Review

Conducted By Paul K. Pagel,* N1FB

HEATH HX-1681 CW TRANSCEIVER

In both styling and circuit design, the HX-1681 QSK cw transceiver is ideally suited to mate with the HR-1680 ssb/cw receiver.[1] Frequency coverage of the '1681 is 500 kHz on each of four bands from 80 through 15 meters and one 500 kHz segment of the 10-meter band (28.0 to 28.5 MHz). There is virtually no extra coverage above or below these 500-kHz segments and WARC band provisions are not included. The analog dial has 5-kHz incremental markings with frequency resolution to approximately 2.5 kHz. Rated power output for the '1681 is 100 watts on 80 through 15 meters and 80 watts on 10 meters. It has provisions for full break-in operation as well as delayed switching output for keying and external power amplifier.

A straightforward heterodyne design is used in the transmitter. The 5.5- to 5-MHz VFO signal is mixed with the crystal-controlled HFO signal in a doubly balanced diode ring mixer. The output products of the mixer are fed to a switched band-pass filter that passes only the difference frequency. By using the difference frequency the dial will tune in the same direction on each band. The on-frequency signal is amplified by a two-stage, transistorized broadband amplifier, which supplies power to the driver stage. A 12BY7 is used as the power-amplifier driver, with its associated tank inductor switched by one water of the band switch. The driver-stage tuning capacitor is adjusted from the front panel. A pair of 6146s, operating Class AB1, is used in the final amplifier stage. The tubes are operated in a parallel, grounded-cathode configuration. Two band-switch wafers are used in the output network. One wafer switches in various capacitors to resonate the final tank circuit, and the other wafer inserts fixed low-pass filters for each band. These filters are designed for a 50-ohm terminating impedance. A built-in T-R switch is used to provide break-in (QSK) operation. When the key is closed, a diode in the receive antenna circuit is reverse biased and none of the transmitter output power will reach the receiver input.

The original keying waveform of the HX-1681 is shown in Fig. 3. Informed that this waveshape produced key clicks, Heath responded by supplying some modifications, which were applied to the review unit. The initial modifications were only partially successful; the waveform was softened, but transients appeared that created loud pops in the receiver audio during QSK operation with the HR-1680 receiver. This problem was eliminated using a circuit developed by staff member George Woodward, W1RN, and the writer. It is shown in Fig. 4 at A and B. This circuit keys the mute-sidetone circuitry independently and has a fast-attack/slow-decay action, which is advantageous during QSK operation. All the additional components are mounted on a terminal strip that is attached to the chassis by means of one of the power-supply circuit-board mounting screws. The waveform that resulted after the changes were made is shown in Fig. 5.

These changes were passed on the Heath. The official Heath modification that is being made to all existing stock and is available to '1681 owners at no cost is shown in Fig. 4C; the resultant waveform appears in Fig. 6. Although the rise time is less than 5 ms, no key clicks could be heard in a nearby receiver.

A unique feature of the '1681 is the extensive use of diode switching. By diode switching the HFO oscillators and band-pass filters, many physical construction restrictions are removed and only a 4-section band switch is required.

Four pc boards contain the bulk of the transmitter. Construction of the unit took a total of three weekends. No problems were encountered during construction, except when trying to follow directions in the wee hours of the morning!

Operational Results

On-the-air operation with the HR-1680/HX-1681 combination was superb. The QSK action is very smooth, with no popping evident

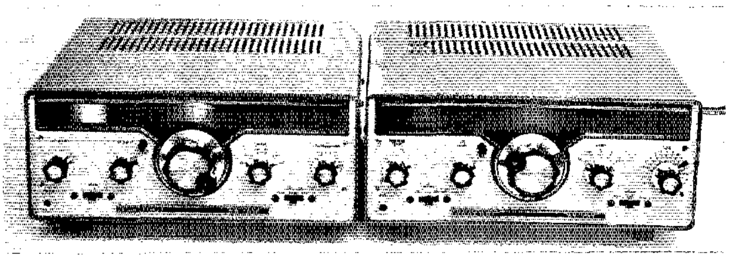


Fig. 1 — The HR-1680 and HX-1681 are compatible in both styling and circuitry. They make an attractive cw-only station.

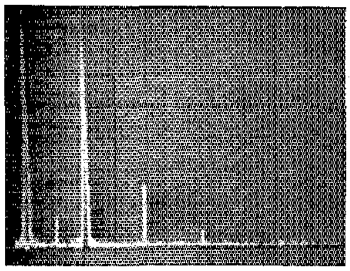


Fig. 2 — A spectrum analyzer photo of the worst-cast output of the HX-1681 transmitter on 80 meters. Vertical divisions are each 10 dB. Horizontal divisions are each 2 MHz. The large pip on the far left is generated by the spectrum analyzer, while the next large pip is the fundamental signal. Worst-case harmonic output is 54 dB down and the worst spurious output is 64 dB down. The HX-1681 complies with present FCC specifications for spectral purity. All measurements were taken in the ARRL lab.

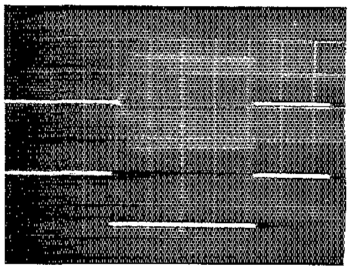


Fig. 3 — The original cw keying envelope of the HX-1681. Each division of the horizontal axis is 5 ms. The lower trace shows the actual key-down time. The wave starts to decay almost instantaneously after key up. The sharp trailing edge will produce key clicks.

Table 1
Heath HX-1681 CW Transmitter, Serial No. 908

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Power output: 100 watts on 80 to 15 meters; 80 watts on 10 meters.	>100 watts on 80 to 15 meters, and >80 watts on 10 meters.
Frequency stability: <100 Hz drift in a 30 min. period after 60 min. warm-up.	500-Hz drift during the first 30 min., <100 Hz per 30 min. period thereafter.
Harmonic radiation: 50 dB down at 100-watts output.	Worst case, 54 dB down.
Spurious radiation: 60 dB down at 100-watts output.	Worst case, 64 dB down.
Tuning rate: 15 kHz/turn.	15 kHz/turn
Tuning backlash: 50 Hz or less.	43 Hz.

*Assistant Technical Editor

[1] The Heathkit HR-1680 Receiver, Product Review, *QST*, January 1977.

in the receiver. If the band noise is objectionable or "semi-break-in" operation is desired, the LINEAR mode can be selected on the transmitter. Such operation is designed for use with an external amplifier; under these conditions, the receiver is muted continuously during transmit with a selectable amount of delay being chosen by the operator. Sidetone injection level is adjustable from the front panel. Received signal reports indicated good signal stability, but hard keying and key clicks were evident until the modifications were performed.

While I'm basically pleased with the unit, I'm puzzled by one design feature. There are two tuning controls on the '1681, one for final-amplifier plate tuning and the other for driver plate tuning. If there have to be two controls, why not gang the plate and driver tuning together and have a variable capacitor on the output network to match various load impedances? The fixed 50-ohm output is somewhat of a restriction and a Transmatch must be used with the transmitter to match other than 50-ohm loads.

If you're a Novice or just have a flair for cw, the HX-1681 will provide you with a solid signal on the 80- through 10-meter bands. The transmitter measures 6-3/4 × 12-3/4 × 12 inches (170 × 320 × 300 mm) HWD. It requires a power supply that will deliver approximately 800 V dc at 250 mA, 250 V dc at 50 mA, −130 V at 10 mA, and 12.6 V ac/dc at 2.5 A. A Heath PS-23 was used with the review transmitter. Price class of the HX-1681 is $240. It is available from the Heath Company, Benton Harbor, MI 49022. — *Gerry Hull, AK4L*

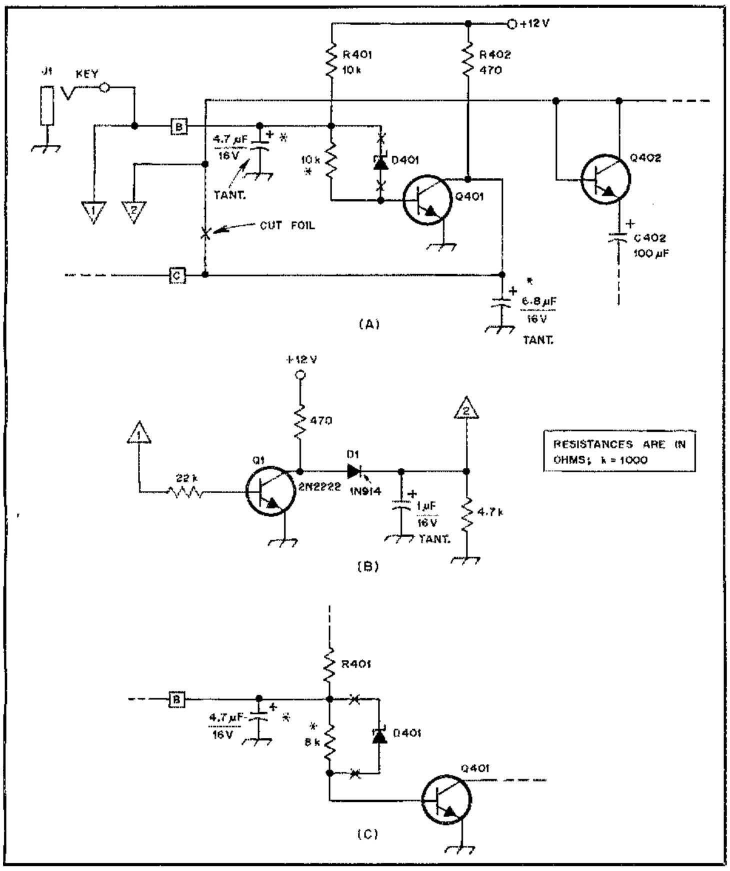


Fig. 4 — The modified circuitry of the HX-1681. At A and B, the circuit as modified in the ARRL lab. One foil cut is required. Added components are denoted by an asterisk; all components at B are added and mounted as described in the text. The circuitry at C uses two added components and does not require the additional components noted at B.
Q1 — Silicon npn 500 mW switching transistor, 2N2222 or equiv.
D1 — Silicon high-speed switching diode, 1N914 or equiv.

C-PROBE II

A nifty product of International Instrumentation, Inc. is the C-Probe II. This lightweight, palm-sized device, when connected to a frequency counter, enables the counter to furnish direct readout of capacitance values from 0.1 pF to over 10,000 µF. An optional circuit provision extends the high-capacitance range to 30,000 µF. The high µF option was not included with the unit tested in the ARRL laboratory.

Features of the C-Probe II include a crystal-controlled time base, 10-turn potentiometers for pF and µF calibration and a 10-turn zero-control potentiometer to compensate for stray capacitance up to 50 pF. Gate times are user selectable. Direct use of the C-Probe II with any frequency counter that has gate times equal to those used by the C-Probe II (0.1, 1 or 10 seconds) is another feature. It will work directly with BK, CSC, Data Precision, Davis, Fluke, Formula Int., Heathkit, HP Leader, Monsanto, NLS, Optoelectronics, Phillips, Poly-Pak, Quest, Radio Shack, Ramsey, Sabtronics, Sencore, Simpson, Systron-Donner and Tektronix counters. The C-Probe II emits frequency bursts containing a number of pulses per output gate time. These are effectively equivalent to the value of the capacitor under test.

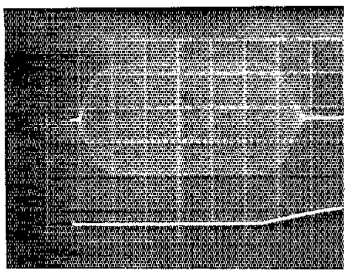


Fig. 5 — The cw waveform shown here, which results after installing the modification of Fig. 4 (A and B), produces no key clicks. At key up, the wave begins an approximate 7-ms decay cycle.

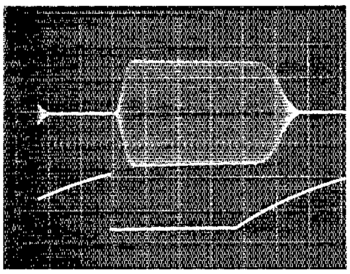


Fig. 6 — This waveshape, with the circuit of Fig. 4C installed, has an approximate 5 ms delay between key up and the start of the wave decay time. This delay may be disadvantageous at higher keying speeds.

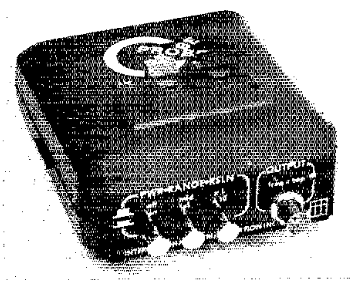


Fig. 7 — The C-Probe II. This accessory for frequency counters enables capacitance measurements to be read with the counter. The device is classified as a precision test instrument.

Table 2
C-Probe II Resolution

Range Switch	*pF*		*μF*	
Resolution Switch	× 1	× 10	× 1	× 10
Measurement Range	$1 - 10^7$ pF	$0.1 - 10^6$ pF	$0.001 - 10^4$ μF	$0.0001\text{-}10^3$ μF
Accuracy	0.25%	0.25%	0.5%	0.5%
Resolution	1 pF	0.1 pF	0.001 μF	0.0001 μF

Operating power for the C-Probe II is furnished by either an internally mounted 9-V battery or by an optional ac adapter unit. The unit tested had this convenient ac accessory. Other optional items may be ordered at the time of purchase. For instance, the Variable-Output-Attenuation Option is particularly useful with highly sensitive counters. Its purpose is to provide adjustment of the output amplitude of the C-Probe II from 10 mV to 5 V. If the option is ordered with the basic C-Probe II, it is factory installed. When ordered separately, this option is shipped in the form of a kit that is to be installed by the user.

The Hi-Mfd Option, mentioned above, provides a third range for the C-Probe II. This third range extends the upper measurement limit of the C-Probe II to 30,000 μF. If the Hi-Mfd Option is ordered at the same time as the basic unit, it too will be installed and calibrated. It is also available in kit form.

Some limitations in the use of the C-Probe II may be offered by counters with an insufficient number of digits in the readout. A seven-digit counter is sufficient for all measurements made by the probe. A six-digit counter is sufficient for measurements made in the × 1 resolution setting. This device, furthermore, is not intended to be used with counters that exhibit nonrepetitive gate and display times.

Table 2, prepared by the manufacturer, gives the range and resolution for the various settings of the range and resolution push buttons located on the panel of the C-Probe II. Verification of the degree of accuracy would have required precision equipment that was unavailable in the Hq. laboratory.

Dimensions for the C-Probe II are 2.5 × 4 × 5 inches (64 × 102 × 127 mm). Weight, including the battery, is 6.5 oz (184 gm). The enclosure is a molded plastic. Price class: $80. Orders may be sent to International Instrumentation, Inc., Box 3751, Thousand Oaks, CA 91359 — *Stu Leland, W1JEC*

HEATHKIT EE-104 PHASE-LOCKED-LOOP COURSE AND ET-3300 BREADBOARD

If somebody tells me something, I will remember about 10% of it. If they show me something, I will remember about 15% of it. But if they involve me in it, I probably will remember 90% of it. I cut my electronics "teeth" on Heathkits. Over the years, I have had a fondness for their products — partially because they have been very successful in giving me a sense of involvement with the equipment I have built.

It is easy for a programmed text to fall into a trap of merely showing the reader information without eliciting any involvement. Being a bit of a cynic, I wondered how well Heath had avoided this potential pitfall in their phase-locked-loop course. I was pleased to find that the text was authored by Howard Berlin, W3HB, [author of numerous articles in *QST* and other amateur publications. — Ed.]. Usually there are more people involved in the production of a programmed text than just the author; having a good writer didn't ensure that the course would be good, but it certainly didn't hurt either.

Before actually starting the course, I constructed the ET-3300 laboratory breadboard. Either this breadboard or something similar to it is required for full participation in the course. The ET-3300 consists of a chassis with four large breadboarding sockets installed on the top surface. Three dual-wire bus sockets are mounted between the four breadboarding sockets. These bus sockets are particularly useful for connecting various ICs and components to the appropriate power sources or ground. The ET-3300 has three power supplies built in: + 5 V at 1.5 A, + 12 V at 0.1 A and − 12 V at 0.1 A. The supplies are voltage-regulated, current-limiting sources that can save a lot of headaches if a circuit is inadvertently wired improperly.

Each chapter of the program (total of six chapters) begins with an overview and lists the objectives of the unit. Then follows a detailed discussion of the theory of operation of the particular components under study. From the theory, the course moves into the "hands on, build-it-and-see-what-it-does" laboratory section where the student sets up experiments that demonstrate the theories presented earlier. Each chapter concludes with an examination of the most important aspects of the unit. On the page following the examination, Heath has provided answers to the questions. If the student has not answered the questions to his own satisfaction, he is encouraged to go back over the material and work with it until he has mastered it.

Topics covered include phase detectors, VCOs, loop filters, digital synthesizers using divide-by-N counters, and monolithic IC PLLs. Devices that are covered in some detail include the 560 series, the 4046 and the HCTR 0320. In addition to the theoretical discussion and experiments with these devices, there is an appendix that contains extensive manufacturer's data sheets for each chip.

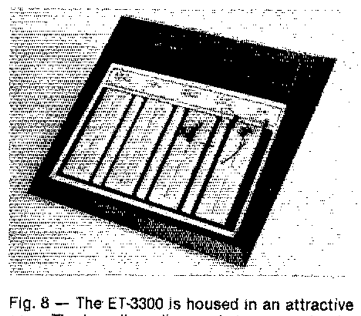


Fig. 8 — The ET-3300 is housed in an attractive case. The breadboarding sockets are made of a high quality plastic. The replaceable, silver-plated contacts also add to the durability and longevity of the unit. It compares very favorably with factory-built models costing up to twice as much.

If I have a criticism of the course, it is that some of the theory could have been backed up with more examples. It is logical and well thought out, but some of the concepts are difficult; some additional elaboration would have helped ease the way past these concepts. (That just means that some of us have to work a little harder.) Heath points out in their catalog that a dc voltmeter and a single-channel oscilloscope are needed to complete the experiments. They recommend a dual-channel scope and an audio signal generator if available. I would concur that some kind of scope and voltmeter are absolutely necessary, but I would add a frequency counter to the list of suggested additional test equipment. A frequency counter won't replace a scope, though. At times it may be advisable to double check the readings of a frequency counter against the scope; the low-percentage duty cycle of some of the wave shapes caused the frequency counter I used to give a false reading.

If the student scores at least 70% on the optional final exam, he'll earn a Certificate of Achievement plus three Continuing Education Units (CEUs).

Recently I enrolled in a college course. Tuition was $360 and the text book was $27.95. The text is full of ambiguities and sometimes about as clear as mud. The professor seems to be struggling to present the author's ideas in some coherent fashion. Also, I am out of the house away from my family two nights a week. Compare that with the Heathkit course — it costs only about $50 and it hasn't kept me away from my family any evening. The text is clear and well written. I've had hands-on experience which I might not get in a college course. Too bad the local college doesn't have the same money-back guarantee that Heath has! If you want to get a quick, inexpensive look at phase-locked-loops, then you may want to consider this course. Price class: course, $50; breadboard, $90; purchased together, $130. — *Peter O'Dell, KB1N*

B&W MODEL 370-15 ANTENNA

Dubbed a broadband folded dipole, this antenna is designed for operation within the frequency range of 3.5 to 30 MHz. The manufacturer claims a power-handling capability of 5000 watts PEP. The 370-15 requires no measuring or cutting; it is fully assembled and pretuned. The radiating elements are made of no. 14 stranded copperweld wire separated by lengths of PVC tubing 17/16 inch (21 mm) in diameter and 17 inches (432 mm) long. A 12:1 balun is supplied, to which is attached a 50-foot (15-m) length of RG-8/U coaxial cable. This balun contains a ferrite core made up of six 1/8 inch (3 mm) thick flat ferrite sticks approximately 4 inches (102 m) long and 7/8 inch (22 m) wide. At the midpoint of the opposite radiator is a balancing network. Investigation showed this network consists of six 3600-ohm noninductive resistors connected in parallel. Each resistor appears to be capable of dissipating approximately 50 watts. Therefore, the network would present a 600-ohm impedance with an approximate 300-watt dissipation factor.

Installation

B&W recommends the 370-15 be installed as a flat-top or sloper with the low end of the antenna as close as 6 feet (1.8 m) to the ground. The only items necessary for the erection of the antenna are some lengths of rope and a couple of supports. Suggested antenna heights are a minimum of 15 feet (5 m) or an average height of 25 to 40 feet (8 to 12 m). The user is cautioned to uncoil only half of the antenna at a time and not to do so until ready for the actual installation. This is a precaution worth observing since you will more than likely wind up with a "bird's nest" of tangled wires, insulators, coax and homo sapiens if you don't!

When the antenna arrived at Hq., its construction stirred some memories. A bit of investigation revealed a close resemblance between the 370-15 and an antenna described some years ago both in *QST* and *CQ.*[1,2,3] Some of the OTs in the crowd might remember that antenna as the "T2FD." The basic design of the T2FD antenna suggests a feed-point impedance of 600 ohms, which would require a 12:1 balun to match to 50-ohm coaxial cable. Physically, though, the dimensions suggested by Countryman and those used for the B&W antenna differ somewhat. The latter, designed for 80-meter coverage, uses a combination of the 40-meter radiator spacing and 80-meter radiator length used by Countryman.

In Use

Comparisons were made between the 370-15 and a 40-meter dipole, both configured as slopers. Both antennas were hung in the same plane with one end of each antenna at a height of about 28 feet (8.5 m) and the other ends 6 feet (1.8 m) above the ground; feed-line lengths each approximated 50 feet (15 m). Reports received on 40 meters consistently showed the 40-meter sloping dipole to be between one to two S units better than the 370-15. Results on 20 and 15 meters (the apparent resonant frequency of the B&W antenna) still favored the 40-meter sloper, while on 10 meters the 370-15 took the lead. Results of SWR measurements taken at the band edges are shown in Table 3. A Bird model 43 Thruline wattmeter with a 100-watt element was used to make these measurements. All measurements were made at the transmitter end of the length of coaxial cable supplied with the antenna.

The model 370-15 is available from Barker and Williamson, Inc., 10 Canal St., Bristol, PA 19007. Price class: $150. — *Paul K. Pagel, N1FB*

[1]Countryman, "An Experimental All-Band Non-directional Transmitting Antenna," *QST*, June 1949.
[2]Countryman, "Performance Of The Terminated Folded Dipole," *CQ*, November 1951.
[3]Countryman, "More On The T2FD," *CQ*, February 1953.

Table 3
B&W 370-15 Antenna

Sloping Dipole Frequency	*SWR*
3.5 MHz	5:1
3.9	4.5:1
7.0	5:1
7.3	4:1
14.0	2.5:1
14.350	2.25:1
21.0	1.8:1
21.450	1.5:1
28.0	2.5:1

New Books

☐ *A DXer's Technical Guide,* published by the International Radio Club of America, P. O. Box 21074, Seattle, WA 98111. Softbound, 8-1/2 × 5-1/4 inches, 98 pages, $5 postpaid.

One branch of the radio hobby is broadcast-band DXing. It dates back to the 1920s and still attracts its share of radio enthusiasts. Perhaps the oldest of the DXer's associations is the Newark News Radio Club, started by the Newark (New Jersey) *Evening News* back in the '20s; running a close second is the National Radio Club. Coming into existence more recently is the International Radio Club of America with home bases in both Victoria, British Columbia, and Seattle, Washington. I recently came across one of the IRCA publications, *A DXer's Technical Guide,* a 98-page volume that contains useful background information that should appeal to the DX fan.

Contained in *A DXer's Technical Guide* are reviews of some of the popular receivers used by many DX fans. Included are portables, table sets and communication types. Ten pages are devoted to audio filters, tape recording of DX stations and frequency measurement. Even receiver modification is not overlooked.

Readers will find the section on antennas of particular interest, for without an appropriate receiving aerial, DX-chasing can be a lost cause. There are practical suggestions on random-length wires, phased antennas, loops and the Beverage antenna. The book also provides information on getting the best transfer of signal energy from the antenna to the receiver by means of matching networks.

For the DXer who is not adverse to construction, this DXer's guidebook provides useful hints along with a list of parts suppliers. A handy display of schematic symbols is also provided. In addition, the editors have thoughtfully furnished a tabulation of reference books that can be of assistance to the DXer.

Other IRCA publications include *Principles of Broadcast Band DXing, The IRCA Foreign Logs* and *The IRCA Almanac.* Best known of the IRCA publications is *The DX Monitor,* which serves as the official club news bulletin. It is published 34 times per year. For information about these and membership in the IRCA, write to the IRCA, Box 21074, Seattle, WA 98111. — *Stu Leland, W1JEC*

☐ *The Radio Amateur's Conversation Guide,* by Jukka (OH1BR) and Miika (OH2BAD) Heikenheimo. Published by Transelectro Oy, Samsantie 46, SF-00610, Helsinki 61, Finland. Available in the U.S. from: Wayne Gingerich, W6EUF, 2301 Canehill Ave., Long Beach, CA 90815. Soft cover, spiral bound, 6 × 8-1/2-in., 92 pp., $10.

The Radio Amateur's Conversation Guide fills a long-empty gap in amateur literature. Its pages contain a wealth of information in eight different languages: English, German, French, Italian, Spanish, Portuguese, Russian (and Russian phonetics) and Japanese. Supplements are available in Finnish, Serbo-Croatian and Swedish. In addition, cassette tapes prepared by speakers using their native language may be purchased; they're an aid to learning correct pronunciation.

The book is divided into three sections. The first part lists the phonetic alphabet in each language (except Japanese, for some reason), along with cardinal (1, 2, 5, 100, etc.) and ordinal (1st, 3rd, 10th, etc.) numbers. The major portion of the book contains 147 variations of commonly used phrases grouped into several basic subject areas: ending the QSO, contests, regulations and so on, making it a useful tool for anyone involved in international QSOs. The last section of the book is a 450-word dictionary of Amateur Radio and electronic terms generally not given in the phrase section.

Using the book effectively may require a few tries, as most of us are in the habit of using short sentences or abbreviations and the phrases provided often contain more words than you might need ("Please repeat your QTH" instead of, simply, "QTH?"). There is no attempt to guide the reader on pronunciation — that's the job of the cassette tapes. "Espana" looks easy to pronounce, but would you have guessed ESS-PAHN-YA? Or, how about: "mnje" or "fsjo" in Russian? The cassette tapes would be a necessity if you've had no previous experience with the particular language. For use on cw or for adding to the back of a QSL card, however, the phrases work very well; just be ready for the reply!

English is probably the most widely used language in Amateur Radio, but how many foreign stations know much more English than that necessary to be able to give the standard signal report, operator name and QTH? This guide will be a big first step toward better communication. — *Tom Frenaye, K1KI*

Feedback

☐ Author Sherwood has some additional information for his article, "Improved RTTY Reception with the Yaesu FT-101," *QST,* November 1980. There should be no connection between S2A-5 and the accessory socket. If there is a wire at that point, move it to S2A-4. The blue coaxial cable lead should not be connected to S2E-5; disconnect, insulate and tie it back. Some FT-101E models require a diode instead of a direct connection between S2C-1 and S2B-5. The cathode is attached to S2B-5. Another diode, with the anode connected to S2B-1,2 and the cathode to S2B-5, is also required. The circuit modifications render the cw VOX feature inoperative and MOX or PTT must be used.

☐ The following corrections should be made for Di Julio's article, "A State of the Art Terminal Unit for RTTY," December 1980 *QST.* In Fig. 1, C8 is 0.005 μF; R15 only is connected between the collector of Q3 and the base of Q4. R14 is wired between the collector of Q3 and the +9-V line. Mark the audio level control connected to U2 as R4. On the parts layout, Fig. 3, change Q5 to read Q3. Rearrange the 1N4003 diode markings so that D4 becomes D6, D5 becomes D4 and D6 becomes D5, to agree with the schematic diagram.

☐ Frank Jaeger, WA9SQN, author of "The ARES Standard-Tone Alert System" (January 1981 *QST*, pp. 24-27), wishes to make clear that the lead marked K2 (near Q1) in the parts diagram should be connected to the K2 lead near Q2 *only* if the decoder is to latch a single relay on receipt of either tone. If a separate relay is used for 1050 Hz, the terminal near Q1 is unused. Pin connections 1 and 2 of U2 (NE567) should be interchanged on the schematic diagram to agree with the parts diagram.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

INSTANT BREAK-IN FOR THE HEATH SB-200

☐ The recent article by Clements[1] and two earlier articles[2,3] presented similar schemes for adding electronic bias switching to the Heath SB-220. In each case the SB-220 cathode-bias circuit was modified by using a Darlington pair as a series switch to control the bias applied to the 3-500Z final tubes. This bias scheme is readily adapted to the SB-200 even though the SB-200 uses a grid-bias arrangement.

The circuit is shown in Fig. 1. Instead of modifying the Heath bias circuit, a positive voltage is applied to the normally grounded filament winding center tap through the Darlington pair. When excitation is applied to the SB-200, the two transistors turn on, the center tap is grounded and the amplifier operates normally. With no rf applied, the transistors are off, the center tap is at +125 V and the 572B tubes are cut off. The 7500-pF capacitor ensures that the center tap stays at rf ground.

The component values are not critical. I started with Clement's circuit and ended up where my junk box took me. All components were mounted on a small piece of perf board supported by the two spacers which hold terminal strip S (the terminal strip which allows selection of 110- or 220-V operation). The filament-transformer center tap comes through the grommet near the terminal strip.

Installation of the circuit in Fig. 1 can be made in cookbook fashion but much can be gained by a careful reading of the three referenced articles. They are well written and provide insights into how and why the scheme works.

The approach presented here, leaving an existing grid-bias circuit intact and applying cut-off bias to the filaments and cathodes, can be used with many commercial and homemade amplifiers. The scheme is extremely simple and has the added advantage that existing alc circuitry does not have to be changed. I am particularly indebted to Fred Jensen, K6DGW, for technical advice freely given. — *Hank Garretson, K2SSX/W6SX, Loomis, California*

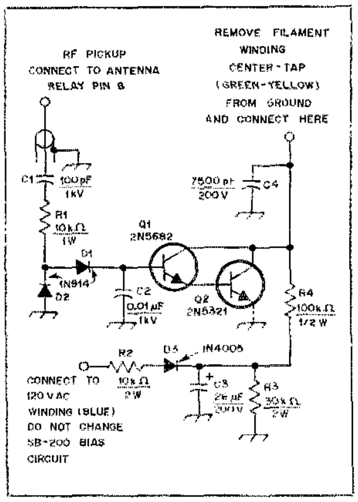


Fig. 1 — Electronic bias switching for the SB-200.

References

[1]Clements, "All Solid-State QSK for the Heath SB-220," *QST*, January 1980.

[2]Frey, "How to Modify Linear Amplifiers for Full Break-In Operation," *Ham Radio*, April 1978.

[3]Bryant, "Electronic Bias Switching for RF Power Amplifiers," *QST*, May 1974.

POSITIVE MUTING OF DRAKE TR-4C

☐ This modification provides positive muting of the TR-4C when used in conjunction with an external receiver. PTO dial-lamp switching for the R-4C external receiver is also provided as an operational status indicator. Fig. 2 illustrates the circuit modifications.

C-217 is removed from the TR-4C as are the switch jumpers (dashed lines). Add the phono connector J, as shown in the diagram. If the line to J from the receiver side of the transceiver/receiver switch is made very short, it need not be shielded.

Install a cable from J to the PTO lamp jack on the R-4C. The PTO dial lamp on the R-4C is illuminated only when that unit is the active receiver. After modification, you will find that the audio gain on the TR-4C does not have to be turned off when the external receiver is in operation. — *William F. Cade, K5HU, Tupelo, Mississippi*

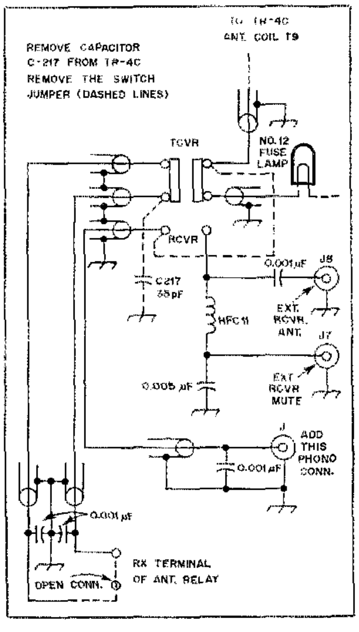


Fig. 2 — These simple changes in the Drake TR-4C provide positive muting when using the set in conjunction with an external receiver. J is an added jack. If feedthrough capacitors are used to bring the switch leads through the under chassis rf cage wall, the shielded leads may be replaced by unshielded wire. Likewise, the two 0.001 µF capacitors from these leads to ground may be omitted. The 0.001 µF capacitor in shunt with J is needed for proper operation.

TEMPO S-1 TRANSMISSION-LINE ADAPTER

☐ I recently purchased a Tempo S-1 transceiver, a fine piece of equipment except for the 1/8-inch (3-mm) phone jack used for connecting the antenna transmission line. In addition to being a nonstandard antenna connector, the jack seems to lack the durability to withstand the leverage exerted by RG-58/U coax. To avoid damage to the connector, I made an adapter consisting of a short length of RG-174/U with the appropriate connecting hardware obtained from Radio Shack.

At one end of the 4-foot (1.2-m) piece of RG-174/U, I soldered a 1/8-inch (3-mm) shielded miniature phone plug (RS no. 274-288). A small length of 1/4-inch (6-mm) dia heat-shrink tubing is slipped over the other end of the RG-174/U and that end prepared as shown in Fig 3. The coaxial cable is laid aside momentarily. After tinning the center conductor, prepare a solderless PL-259 (RS no. 278-196) by filing 1/4 inch (6 mm) of the plating from the neck of the plug. This area of the plug is then coated thinly with solder.

The next step is to push the braid back, insert the center conductor in the neck and pin of the PL-259 where the conductor is soldered in place. To complete the adapter, the braid is pulled down over the neck of the PL-259 and soldered to the tinned area. After sliding the shrink tubing over the neck of the plug, it is shrunk by heating.

Finally, attach a PL-258 double female connector (RS no. 278-1369) to the PL-259. You now have an adapter that accepts a PL-259 but does not threaten to damage the rig. To ease the minds of the "worry-warts" among us, the insertion loss for such a short piece of RG-174/U is less than 1/2 dB. — *Hal Steinman, K1ET/K1FHN*

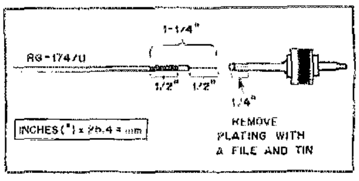


Fig. 3 — The antenna jack on the Tempo S-1 can be protected from possible damage by use of the simple adapter illustrated above. It consists of a short length of RG-174/U and connectors for each end.

ECONOMICAL SIGNAL GENERATOR FOR SSB RIGS

☐ I felt the need for a signal generator that would have high output peaks but low average voltage. It seemed such a device would be useful in tuning up my ssb transmitter and linear amplifier without unduly overpowering the dummy antenna.

*Assistant Technical Editor

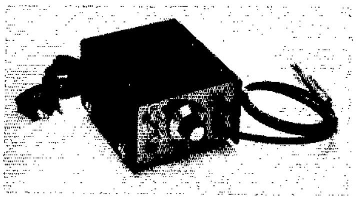


Fig. 4 — This miniature signal generator, which can be held in the palm of your hand, is a reliable ssb tune-up aid at W1ATC. It simplifies transmitter and amplifier adjustments.

The circuit is simple and has proved very useful, not only for transmitter tuning but also for setting the alc control on the linear amplifier. When my Dentron MLA-2500 is driven to the point where the alc starts to clip the peaks, the rf output to the dummy load is 50 watts.

Most of the components for the generator are available at Radio Shack stores. The 1000-ohm potentiometer shown in Fig. 5 is the

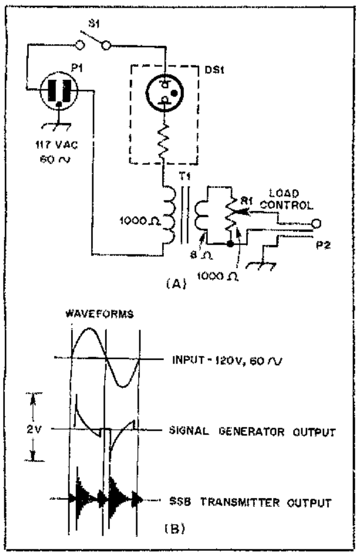


Fig. 5 — This circuit is for a very simple signal generator that can serve as an aid for adjusting ssb transmitters and linear amplifiers. T1 should be lightly loaded. Also shown is a representation of typical waveforms produced by the device and the resulting ssb transmitter output.
DS1 — Neon panel light with built in resistor, RS-272-704.
P1 — Ac plug.
P2 — Three-conductor microphone plug, RS-274-285.
R1 — Centralab potentiometer, 1000 ohms, no. F1-1000 or equiv.
S1 — Spst switch, RS-255-602.
T1 — Audio output transformer, 1000:8 ohms, RS-273-1380.
Misc. — Communications type knob, 0-10, RS-274-413; strain-relief plug; grommet.
Utility Cabinet — 3-1/4 × 2-3/16 × 4 inches, RS-270-251.

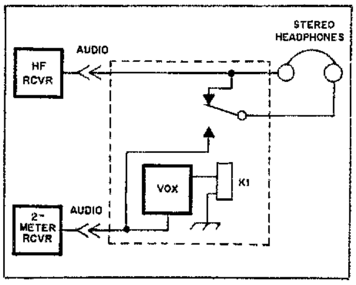


Fig. 6 — Contest operators who wear headsets sometimes miss contest related announcements on 2 meters. This simple arrangement of a VOX-operated relay and stereo phones enables the operator to hear the announcements while continuing contest activity.

level control. This control should also lightly load the transformer. — *Henry J. McCarthy, W1ATC, Grantham, New Hampshire.*

CONTEST SPOTTER

☐ A contest operator frequently misses announcements of new multipliers on 2 meters because he is wearing headphones. This idea provides a remedy and can be implemented easily or modified to suit the operator's desire.

My version uses the VOX circuit described on page 404 of the 1977 *Handbook*, minus the antivox audio amplifier and detector. Vcc can be 5 to 12 volts, depending on the relay you have. Under normal conditions, both sides of the stereo phones are connected to the hf receiver. When the spotting net is activated, the VOX circuit, through K1, connects one side of the stereo headphones to the 2-meter receiver. If desired, the operator can mount an override switch near the key so that the 2-meter signal can be killed if 100% concentration on hf is necessary.

For ease of hookup, use the miniature phone plug provided with most 2-meter rigs and the headphone jack on the hf receiver (with matching transformer if needed). Some other variations of the circuit might include replacing K1 with an analog switch (such as a CD14016B). The VOX circuit could also activate a tape to record all spotting announcements for review. — *Ed Goss, N3CW, Beltsville, Maryland*

PREVENTING ROPE FROM UNRAVELLING

☐ To prevent the ends of a length of rope from unravelling, I use "Dip-A-Whip," a white vinyl liquid that hardens when dry. The ends are simply dipped in the substance, removed and allowed to dry. I also find this product is useful as brush-on insulation for places that are not easily insulated in more customary ways such as 4-connector microphone plugs. Since Dip-A-Whip is water resistant, it is useful on soldered connections that are exposed to weather.

Because it is a solvent-based product, usual care should be taken to avoid breathing the vapor or having it contact eyes or skin. Dip-A-Whip is available from the Brookstone Company, Peterborough, NH 03458, and from any marine supply store, in white or red. — *Mark Schlageter, WA2WOV, Sussex, New Jersey*

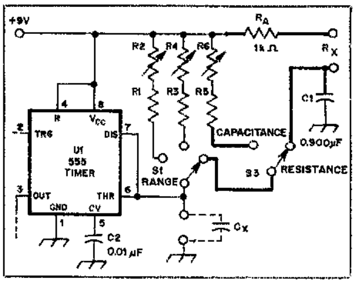


Fig. 7 — The capacitance meter described in August 1977 *QST* may be adapted to measure resistances from 100 to 999,999 ohms with this simple modification furnished by William Huffman, N5CC. R_A is a 1 kΩ precision resistor inserted in the circuit for extra current safety. It is necessary to subtract 1000 from the readings, but this allows resistances below 100 Ω to be measured.

DIGITAL OHMMETER

☐ Kramer's capacitance meter described in August 1977 *QST*, "Using a Frequency Counter as a Capacitance Meter," can easily be made to measure resistance with the modification shown in Fig. 7. All that is involved is an additional switch and a capacitor. The counter will indicate resistances directly with a range from 100 to 999,999 ohms. The accuracy will be close to 1%.

A high-stability type of 0.900 µF capacitor is recommended. The equivalent capacitance may be obtained by a combination of capacitors. To check the value, use the capacitance meter. Alternatively, place a midrange precision resistor across the ohmmeter terminals and trim the capacitor until the correct value of resistance is indicated.

Measurement of resistances below 100 ohms, or shorts on the ohmmeter leads, should be avoided because the circuit draws high current on very low resistances, which will affect battery life. With mid- and high-range resistances, battery drain can be ignored. — *William Huffman, N5CC, Oklahoma City, Oklahoma*

HINTS FOR THE WORKSHOP

☐ The simple receiver (March 1980 *QST*) is an almost perfect fit for a Radio Shack no. 270-253 utility cabinet. — *Jonathan T. Morey, W2HXF, Princeton, New Jersey*

☐ Need a cheap, durable method of recessing switches and connectors? Save the end bells from defunct transformers. Mounted as shown in Fig. 8, the components are protected and slight irregularities in the cabinet hole are concealed. — *Ken Thomson, W5IFH, Pasadena, Texas*

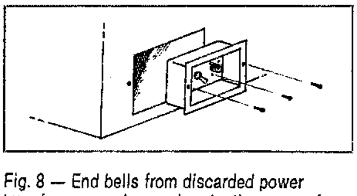
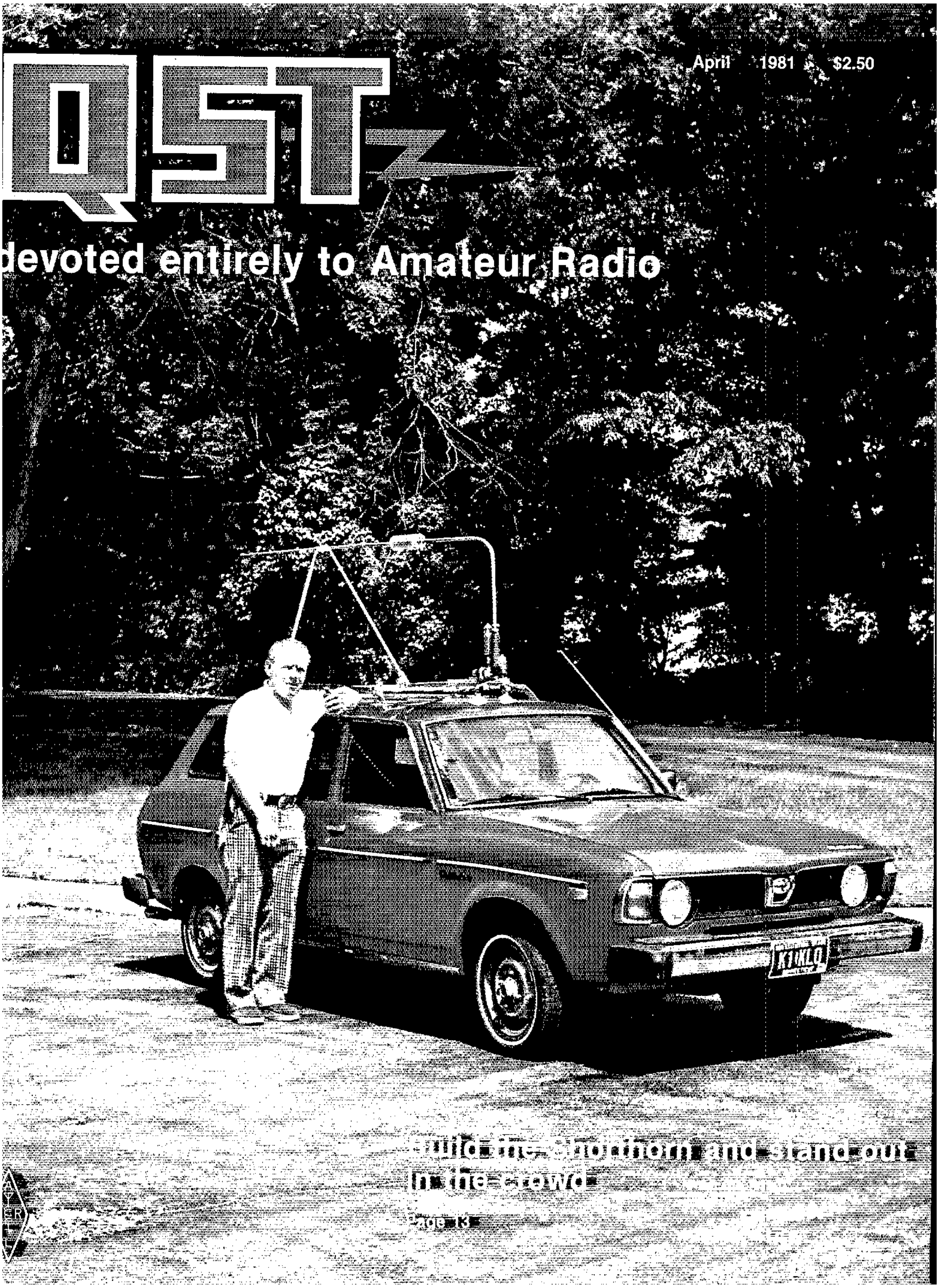


Fig. 8 — End bells from discarded power transformers make good protective covers for switches and connectors.



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K1KLO
Build the Shorthorn and stand out in the crowd
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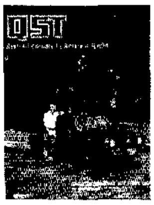
THE COVER



If you're the type who prefers to blend into the crowd, you won't want any part of this multiband mobile antenna. On the other hand . . . See page 16.

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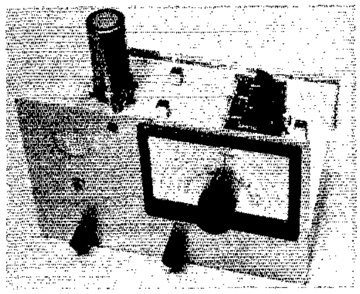


Four ICs and three bipolar transistors make possible this simple 75/80-meter receiver with high dynamic range. A subsystem chip is the heart of this circuit.

By Peter Chadwick,* G3RZP and Doug DeMaw,** W1FB

Have you worked with a subsystem IC? If not, the circuit approach discussed here should stimulate your interest in doing some design work with these multifunction chips. This is not a construction article, and for the present there is no pc-board pattern available. Our purpose is to illustrate a circuit and describe the performance characteristics it offers.[1]

Experienced builders should have no difficulty in developing a pc-board layout for the prototype discussed in this article.

*Applications engineer, Plessey Semiconductors, England
**Senior Technical Editor, ARRL

[1]Notes appear on page 15.

Others may wish to build their own version in a more compact format, and with circuit modifications of their choice. Some of the components are of British origin, while others are available from Radio Shack stores. We will specify inductance and turns-ratio values for the inductors and transformers for those who wish to construct equivalents to the British parts.

What is a Subsystem IC?

For the most part a subsystem is a type of LSI (large-scale integration) IC. That is, it has a large collection of individual circuits or stages formed on a single substrate (foundation). A number of semiconductor manufacturers offer subsystem chips, including RCA and National Semiconductor. Plessey has been in the subsystem business for quite some time, but their components were difficult, if not impossible, to obtain by small-quantity buyers in the USA. Thanks to the help of U.S. National Sales Manager Paul Cooper, K6PY, the situation has improved somewhat.[2] Information on securing Plessey semiconductors is available from the U.S. eastern office of Plessey.[3]

Fig. 1 shows the functional aspects of the Plessey SL6700 subsystem in block form. The actual circuit has thus far been unavailable from the manufacturer. The IC contains two i-f amplifiers, a doubly balanced modulator (or product detector), noise blanker, a-m detector and agc generator. The general lineup suggests a number of interesting amateur applica-

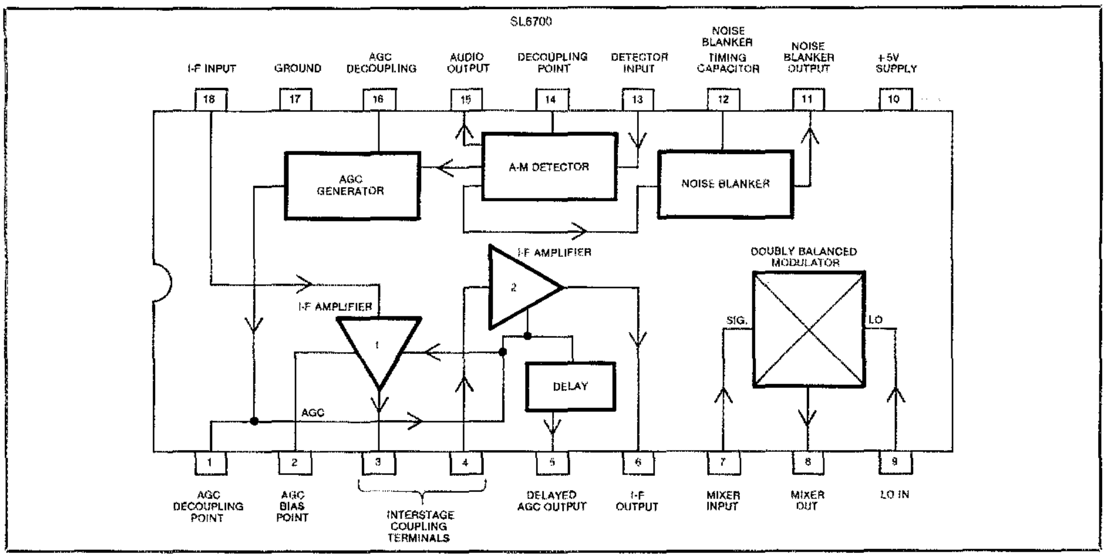


Fig. 1 — Block diagram of the inner workings of the SL6700 subsystem IC.

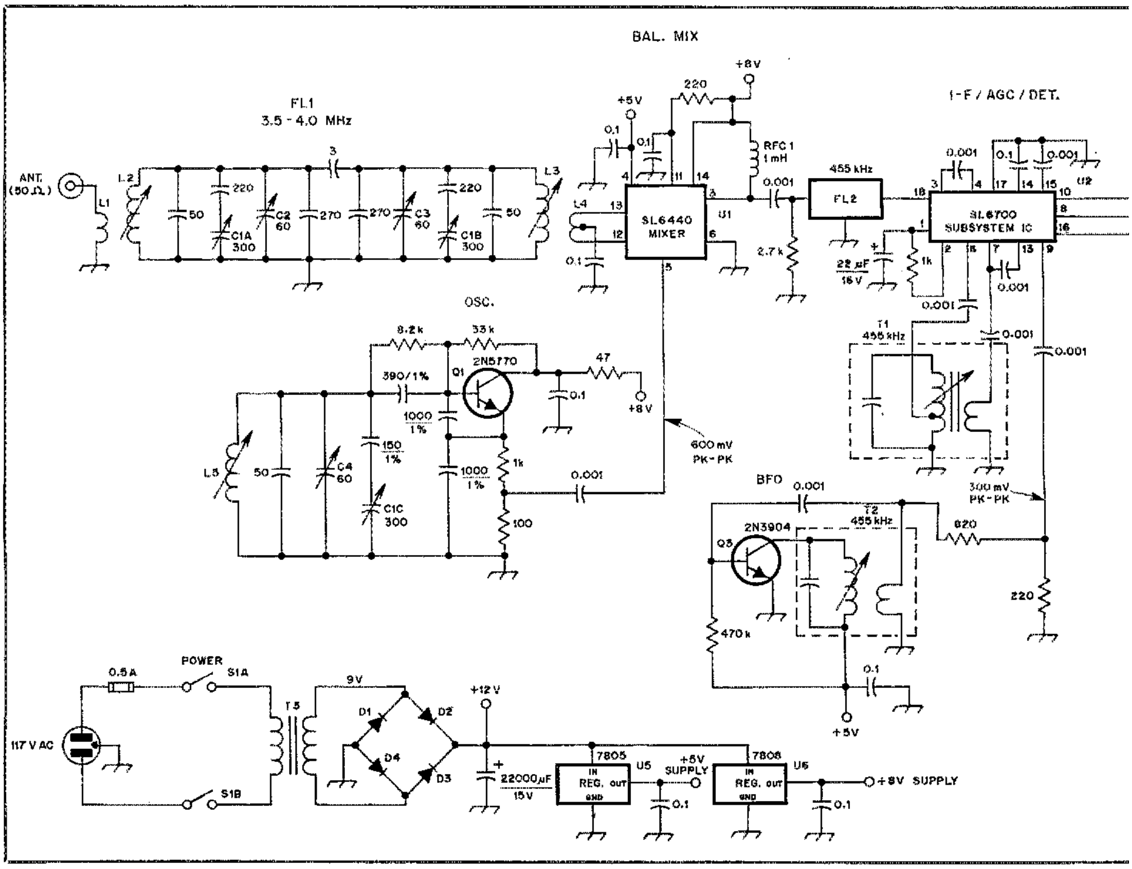


Fig. 2 — Schematic diagram of the G3RZP 80-meter receiver. Fixed-value capacitors are disc ceramic unless otherwise indicated, except for those in FL1, which are polystyrene. Fixed-value resistors are 1/4- and 1/2-watt composition types. Polarized capacitors are electrolytic.

C1 — Three-section variable, 300 pF per section (Jackson Bros., Ltd.).
C2, C3, C4 — Polystyrene trimmer, 60 pF max.
D1-D4, incl. — Silicon rectifier diode, 1 A, 50 PRV.
FL2 — Ceramic i-f filter, 2-kHz BW (Murata CFS-455J).
L1, L2 — Magnetic-core transformer.
L2 = 4.3 µH, L1/L2 impedance ratio = 15:1.
L3, L4 — Magnetic-core transformer.
L3 = 4.3 µH. L3/L4 impedance ratio = 10:1 + 1 (center-tapped L4 winding).
L5 — Variable inductor, 4.3 µH.
R1 — Linear-taper composition control, 10 kΩ.
R2 — Same as R1, but 250 kΩ.

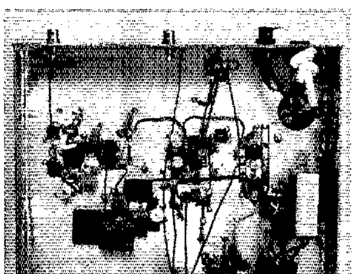


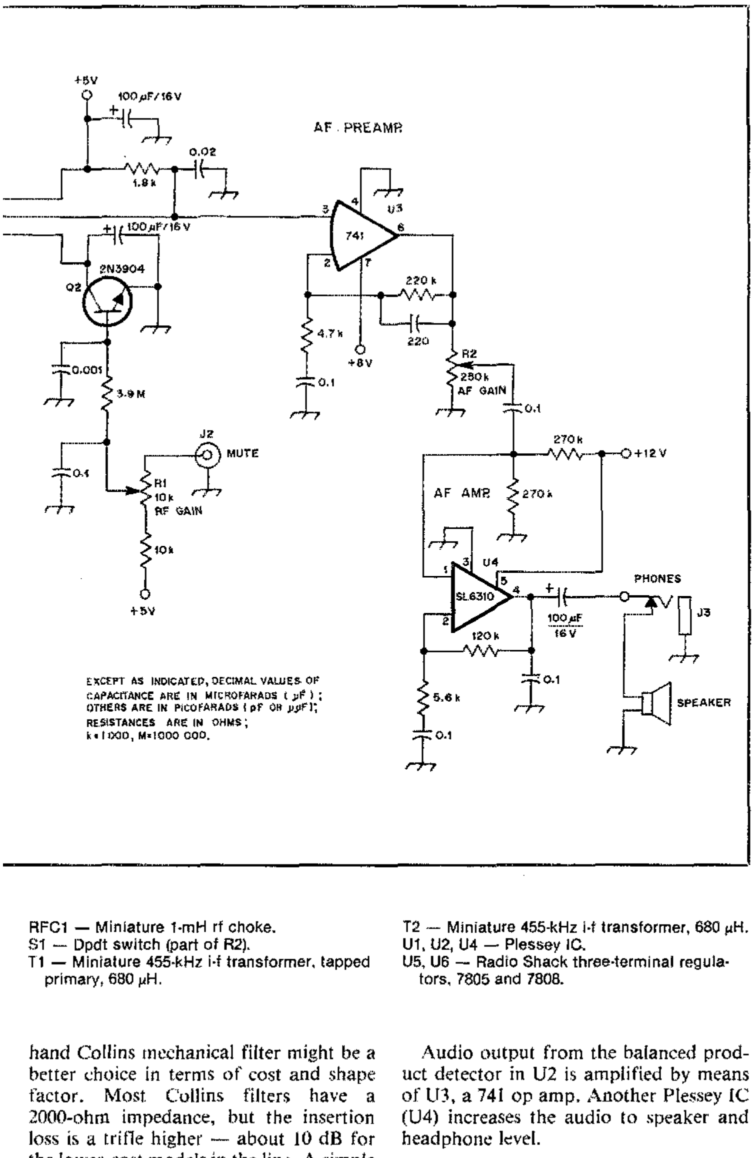
Fig. 3 — Bottom view of the receiver. Stick-on circuit strips were used to contain the ICs and other components. The chassis and panel are made from sections of double-sided pc board. The large rectangular capacitors on the lower left are Radio Shack 1% units that are used in the local oscillator.

tions for this chip. It is intended primarily for use with an i-f of 455 kHz. However, the manufacturer states that the IC is useful up to an i-f of approximately 12 MHz if careful layout is used.

The Composite Circuit

Fig. 2 contains the complete circuit of the 80-meter receiver, as designed by author Chadwick. The high-performance SL6440 doubly balanced mixer (U1) is supplied with signal energy from the antenna via tunable filter FL1. This filter is tracked with the local oscillator (Q1) by means of a three-section variable capacitor (C1). Optimum operating parameters for the SL6440 were given in an earlier *QST* paper.[4] Best dynamic range will occur when the LO injection level is approximately 0 dBm and with the conversion gain set for 0 dB or slightly less. U1 is a programmable mixer, in that the standing current can be varied by changing the voltage at pin 11. With the circuit shown in Fig. 2 the receiver MDS (minimum discernible signal) is −119 dBm. The IMD is 89 dB and the blocking level (excellent) is in excess of the ARRL measurement-equipment capability. These numbers equate to a receiver noise figure of approximately 20 dB, which, although high, is satisfactory for 80-meter operation most of the time. It appears that FL1 is fairly lossy, so the noise figure could be improved by decreasing the insertion loss of this front-end filter. An rf amplifier should not be necessary, and it would degrade the dynamic range if one were used.

FL2 is a Murata ceramic filter with a 2-kHz bandwidth. The characteristic impedance of the filter is 2000 ohms and the center frequency is 455 kHz. Insertion loss is between 6 and 8 dB. Unit cost in the USA is $35, according to three Murata distributors on the East Coast. A second-



RFC1 — Miniature 1-mH rf choke.
S1 — Dpdt switch (part of R2).
T1 — Miniature 455-kHz i-f transformer, tapped primary, 680 μH.
T2 — Miniature 455-kHz i-f transformer, 680 μH.
U1, U2, U4 — Plessey IC.
U5, U6 — Radio Shack three-terminal regulators, 7805 and 7808.

hand Collins mechanical filter might be a better choice in terms of cost and shape factor. Most Collins filters have a 2000-ohm impedance, but the insertion loss is a trifle higher — about 10 dB for the lower-cost models in the line. A simple post-mixer bipolar or FET amplifier could be used to compensate for the additional loss of a mechanical filter.

U2 contains the i-f (2 stages), agc and product detector portion of the circuit. T2 comprises the tuned circuit for the LC BFO. A miniature 455-kHz i-f transistor is suitable for use at T2. T1 is used as a 455-kHz coupling transformer between the two i-f amplifier stages in U2. It can be one of the tapped miniature 455-kHz i-f transistors found in pocket-size transistor radios.

Q2 is a dc amplifier that is used to control the i-f gain in combination with R1. Receiver muting is accomplished by shorting across J2.

Audio output from the balanced product detector in U2 is amplified by means of U3, a 741 op amp. Another Plessey IC (U4) increases the audio to speaker and headphone level.

Power Supply

Three operating voltages are required for this receiver (5, 8 and 12 volts dc). T3 supplies 9 volts ac to the bridge rectifier, and by virtue of a capacitor-input filter the dc voltage increases to 12. Regulators U5 and U6 drop the 12-volt bus to 5 and 8 volts, respectively.

The 12-volt branch of the dc is not well filtered. Because of this there will be a fairly strong 120-Hz hum in the headphones. The tiny speaker does not pass the 120-Hz component, and therefore is not heard. This can be resolved by using an 18-volt transformer at T3 and employing a 12-volt regulator after the rectifier diodes. U5 and U6 would remain attached to the 12-volt bus, as shown in Fig. 2, immediately after the 12-volt regulator.

Summary Remarks

Apart from the 120-Hz hum problem just mentioned, one minor anomaly was noted. The agc tends to lock up in the presence of very strong signals. This can be remedied easily by reducing the i-f gain slightly (R1). No attempt was made by author DeMaw to modify the circuit for the purpose of improving the agc action.

Real-life performance of the receiver is outstanding, based on evaluations by AK4L and N1FB of the ARRL technical staff. Both operated the receiver from their home stations and reported it to be "very strong" and "really clean." In terms of two-tone dynamic range it compares favorably with some $1000+ commercial receivers evaluated in the ARRL lab.

No doubt this circuit could be expanded to make it do a number of things that the basic circuit rules out. For example, a crystal-controlled BFO could be added to provide reception of upper as well as lower sideband. Also, a BFO crystal could be added to allow a 700-Hz note for cw reception. Down-converters can be added ahead of FL1 to permit reception of the 40-, 20-, 15- and 10-meter bands, as well as the three WARC-sanctioned amateur bands (10, 18 and 24 MHz).

The proof of the much-heralded "pudding" came when W1FB subjected the receiver to the relentless onslaught of W1AW's kilowatt signal on 80 meters (two city blocks away). When used in combination with a quarter-wave vertical, there was no aural evidence of receiver overloading. In fact, an RST 569 cw signal was copied perfectly only 5 kHz away from the W1AW operating frequency! Addition of an Autek QF1-A RC active audio filter made the receiver a stellar performer on cw. A 400-Hz cw filter at FL2 of Fig. 2 would do wonders during cw reception, and is an option worth considering.

Perhaps only portions of this circuit will be of interest to you, but in any event the Plessey ICs are interesting and useful. A wealth of IC-circuit information is contained in the Plessey book, *Radio Communications Handbook*, by Mr. James Bryant, Applications Manager of Plessey semiconductors. It is available from the U.S. offices at 1641 Kaiser Ave., Irvine, CA 92714.

Notes

[1]At the time this was being written, Circuit Board Specialists indicated that a kit version of the receiver, inclusive of a pc board, would be available at a future date.

[2]The Plessey ICs for this circuit are available from Circuit Board Specialists, Box 969, Pueblo, CO 81002.

[3]Mr. Patrick Redko, Eastern Sales Mgr., Plessey, 89 Marcus Blvd., Hauppauge, NY 11787.

[4]DeMaw and Collins, "Modern Receiver Mixers for High Dynamic Range," *QST*, Jan. 1981, p. 19. Also, see *Session 15 Preprint*, IEEE SOUTHCON/81, Atlanta, Georgia.

The Connecticut Shorthorn

Here's a mobile multiband antenna that will deliver a signal — it'll also help you locate your car in a parking lot!

By Andrew Pfeiffer,* K1KLO

If you've read the August 1967 issue of *QST*, it might be said you've now seen the long and the short of it. [Sorry! — Ed.] That particular issue described the Connecticut Longhorn, a horizontal, monoband mobile antenna which sprawled across the rather impressive rooftop of my 1964 Ford Country Squire. Unlike its predecessor, the multiband Connecticut Shorthorn is confined to the diminutive rooftop of my 1979 Subaru station wagon. Diminutive, too, is the size of the presently used Kenwood TS-120S transceiver when compared to that of the Heath HW-12A which was carried in the Ford. That's not where the differences end, either. The TS-120S has five bands of potential rf firepower to that of the HW-12A's single 3.5-MHz gun.

Design Concept

The difficulties encountered in designing and building a multiband mobile antenna (as opposed to a monobander) increase as the square of the bands involved; or, according to Murphy's Law no. 10: "The probability of an occurrence is in inverse ratio to its desirability." This presentation is meant to serve as a guide and stimulus for further experimentation by others and not necessarily for exact duplication.

As shown in Fig. 1, the basic antenna circuitry follows that of the original Connecticut Longhorn. Changes include a reduction in total radiator length (because of the obvious difference in car sizes); a shunt-feed inductance, L1, which is provided by three separate plug-in inductors (Fig. 2A) using a common adjustable ferrite slug; and the use of plug-in coils at L2 (Fig. 2B). Three separate inductors are used at L2 and, in conjunction with the remotely controlled ferrite slug (see Fig. 3), perform the function of a fine-tuning control. They cover the full frequency range of the transceiver along with L3 (Fig. 4), which is used only on the two lower bands. Fig. 5 shows the complete antenna assembly.

The control box for the Longhorn contained an SWR indicator and a dpdt switch with a neutral OFF position. This switch controlled the 12-volt dc motor which positioned the ferrite slug up or down inside L2 for obtaining exact operating frequency resonance.

The Connecticut Shorthorn control center shown in Fig. 6 is a bit more sophisticated. In addition to the original control complement, there's a digital up/down counter. A switch (S2) that is operated twice for each revolution of the motor shaft activates the counter. Rota-

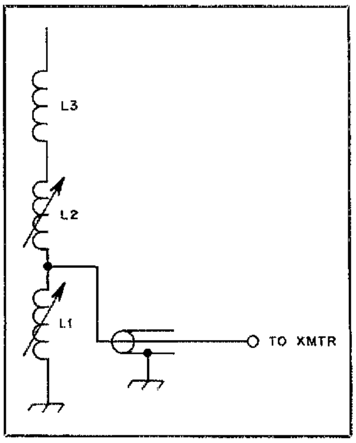
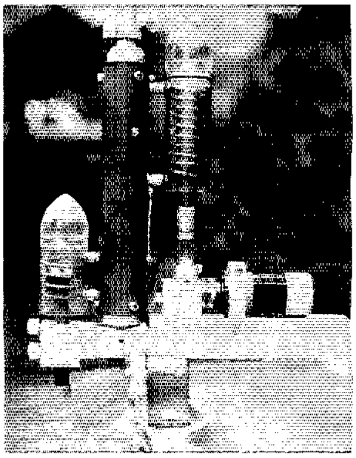
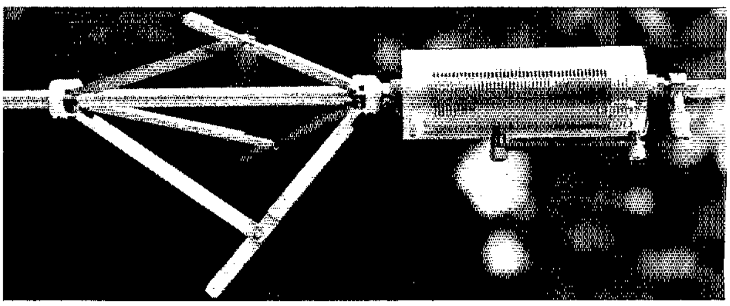


Fig. 1 — A schematic diagram of the Connecticut Shorthorn. L1 is the shunt-feed inductance and is used for impedance matching; L2 is employed for resonance adjustments; L3 is a loading coil used for 3.5 and 7 MHz operation.

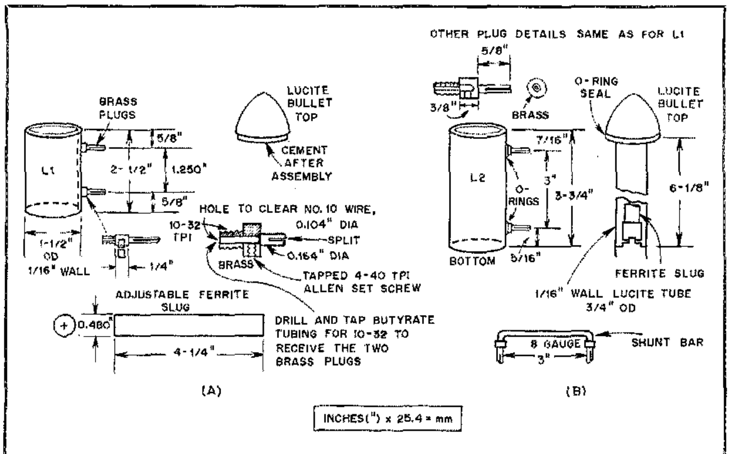


A close-up view of the plug-in coil assemblies; L1 is at the left and L2 at the right of the antenna base. The tuning motor is horizontally mounted to the right of L2.



The capacitive hat and loading coil L3, used on 80 and 40 meters, are shown here.

*132 Whippoorwill Rd., Old Lyme, CT 06371



L1 Inductances

Band (MHz)	No. of turns	Wire size	Turns' spacing
3.5	7	10	wire diameter
7.0	4	10	0.25 in. (6.4 mm)
14, 21, 28	3	10	0.375 in. (9.5 mm)

L2 Inductances

Band (MHz)	No. of turns	Wire size	Turns' spacing
3.5	24	12	0.040 in. (1 mm)
7	10	10	0.190 in. (4.8 mm)
14	10	10	0.190 in. (4.8 mm)
21	3	10	0.50 in. (12.7 mm)
28	shunt bar used		

Fig. 2 — At A, the mechanical assembly of L1 and table of coil winding information are shown. Construction of L2 and its coil data are shown at B. All inductors are wound on 1 inch (25.4 mm) diameter forms. The individual L1/L2 coils are enclosed in 1-1/2 in. (38 mm) diameter, 1/16 in. (1.6 mm) wall sections of Butyrate tubing to protect them from weathering. The O-ring seal and Lucite tube attached to the bullet top were added to weatherproof L2. Note that the slug must be lowered before L2 is unplugged or else breakage will occur.

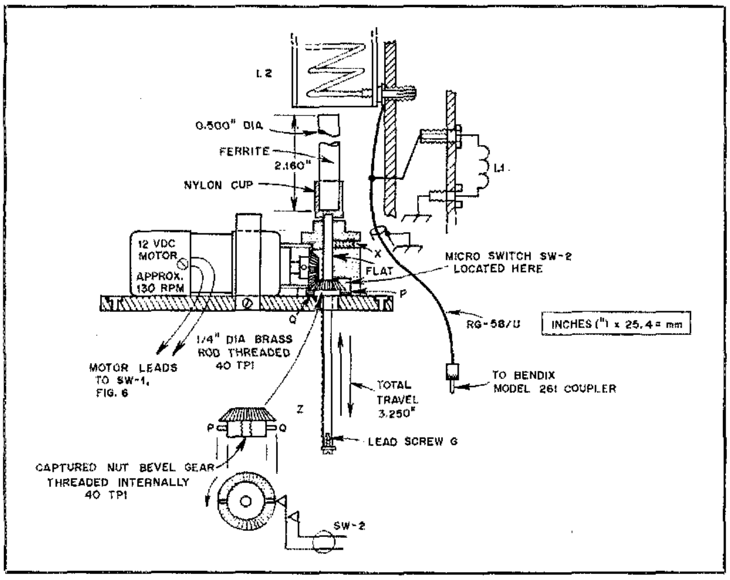


Fig. 3 — The remote variable-inductor drive assembly. Threaded drive rod G has a milled flat over its whole length; the rod is prevented from rotating by means of a set screw positioned against this flat at X. The hole in bevel gear Z is tapped for 1/4-40 threads per inch and mates with drive rod G. The motor-driven bevel gear drives the "captured nut" bevel gear Z, raising or lowering the ferrite rod inside L2. Projections P and Q on bevel gear Z activate switch S2 (see Fig. 6) twice per revolution. S2 will be activated for each 0.0125 in. (0.3 mm) of up or down travel of lead screw G. Two-conductor shielded cable is routed from S2 to the control center (see Fig. 6).

tion of the motor shaft is translated to a vertical travel of the ferrite slug in L2. The up/down counter display, visible to the operator at a glance, shows a relative number which is used to determine the position of the tuning slug in L2. Output from a free-running variable oscillator (U1) is controlled by S3 and programs the digital counter to any desired display independent of the action of S2. When a frequency change is made with the transceiver, it is important to know where the slug in L2 is located so that you can tell whether to move the resonance adjustment switch (S1) up or down in frequency.

Here's how the counter and its associated oscillator are used. The rig is set to operate at a particular frequency, say, of 7.200 MHz. The transmitter is keyed to produce a carrier and the resonance switch (S1) is activated until the resonance-indicating meter of the SWR bridge reads zero. The oscillator is then activated by S3 to display a readout of 7200. From then on, a comparison may be made between the transceiver frequency readout and that of the display counter to determine the correct direction, up or down, to move S1. The actual numbers can be logged for future reference.

Some Advice

A number of amateurs who are eager and willing to experiment with mobile, portable or fixed-station antenna systems find that, for whatever reason, the erection of a full-sized conventional dipole or vertical antenna is not feasible. Therefore, they turn to short radiators which must employ a loading coil. The following information is offered as an aid; hopefully, you can profit by my mistakes and not repeat them!

The wide-range pi-section output cir-

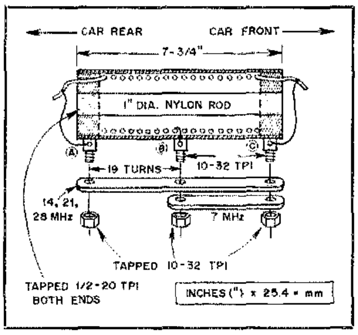


Fig. 4 — The main loading coil (L3) assembly. This coil is used on 3.5 and 7 MHz only. L3 consists of a total of 55 turns of no. 14 gauge wire wound on a 2-1/2-in. (63.5 mm) diameter form at 8 tpi. The inductor is enclosed in a 3 in. (76 mm) diameter, 1/8 in. (3 mm) wall Lucite tube. End discs are made of 1 in. (25.4 mm) thick Lucite. The brass shunt bar is placed across threaded studs at B and C, leaving a total of 19 turns of wire for 7 MHz operation; the entire coil is used on 3.5 MHz. Another bar, connected from A to C, shorts out all of L3 for 20-, 15- and 10-meter operation.

cuitry of the rigs of the past made it possible to correct for some antenna system mismatches. With modern broadbanded, no-tune rigs, we are obliged to correct any mismatch at the antenna itself. This is where corrective measures should be made in the first place — the broadbanded rigs keep us honest!

Many mobile hams I've contacted use so-called "antenna couplers" between the rig and the antenna coaxial feed line. The "coupler" will satisfy only the output impedance requirements of the transmitter and will do nothing to make the antenna resonant at the chosen operating frequency. This antenna resonance is a must if you are to realize maximum antenna efficiency.

In any and all antenna systems, two important conditions must be satisfied if we are to obtain the maximum potential output of any given transmitter. Simply, the output of the transmitter must like what it is looking into and, secondly, the antenna must be tuned to the operating frequency. In a physically shortened, loaded, quarter-wave antenna such as the Shorthorn, the Q is very high. Transmitter frequency excursions 10 kHz above or below the exact resonant frequency presented by the coil-loaded radiator adversely affect the rf output of the transmitter and attenuate the signal at the receiving point. I ran many tests that proved this. One 40-meter test, with Ole (N4ABM) in Reston, Virginia, indicated a six S-unit difference in signal strength between exact antenna resonance and frequencies 10 kHz above and below resonance during key-down cw conditions. S meters being what they are, the difference is relative, but significant. Results of similar tests at different times, bands and distances were much the same.

Shunt-feed inductance L1 and the adjustable ferrite slug used with the Shorthorn satisfy the first condition: The TS-120S is very pleased with what it is looking into. L2 and its remote-driven ferrite slug fulfill the second condition. Certainly there are other methods of accomplishing the same things — this is but one of them.

All the necessary specifications and dimensions for the construction of the Connecticut Shorthorn are given in the accompanying diagrams. Remember, however, that there are many variables. Slight changes in antenna height above the car roof (the counterpoise), physical placement of the various inductances in relation to each other and their relative position along the straight sections of the antenna system will change the resonance of the whole unit. The closer L3 is to the feed point, the lower the total inductance need be; the converse is also true.

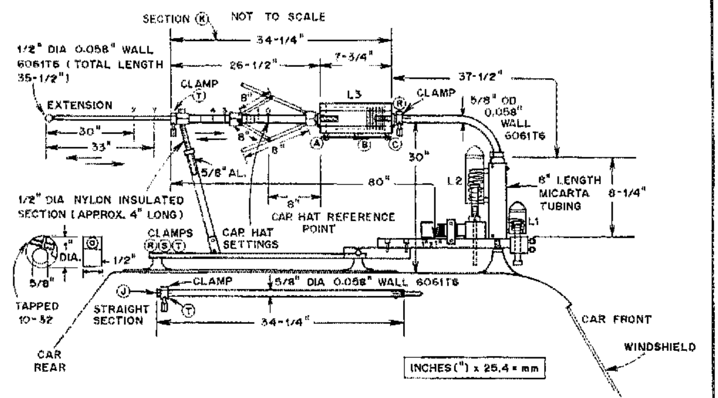
The various inductances may be calculated, but somewhere along the line you will definitely need to use a GDO. Be sure to loosely couple the GDO to the feed line; a one-turn coil of wire is sufficient. A word about GDOs: They will see and indicate everything within their tuning range — each and every resonant response along the particular length of coaxial cable used. Be ready (particularly on the higher frequencies of 14, 21 and 28 MHz) for more than one dip!

Winding the various inductances may require experimentation. Use the largest practical wire size. Coils, with the exception of L3 and L2 for 3.5 MHz, are wound with no. 10 copper wire; L3 is wound with no. 14 wire; and L2 for 3.5 MHz is wound with no. 12 wire.

Good grounding is a must! Inadequate grounding — particularly on 14, 21 and 28 MHz — may introduce you to a new experience, rf burns. Before I'd grounded the "beast" efficiently, the car's indicator lamps flashed on and off during operation on the higher frequencies!

On-the-air tests run with stateside and European stations have indicated that the system is omnidirectional. A half-hour test run with Jim, G4JPM, during which I drove the car in a large figure-eight pattern, showed there was little or no effect upon the signal level as received abroad. Similar tests with stateside stations had more or less the same results. I've more than "held my own" in local and other stateside contacts on all bands and in DX pile-ups. During one 21-MHz DX contest contact with a station in Germany (where nothing more than the usual 5/9s were given out), I received my final pat on the back. In a "semi-pile-up," the response to my call was: "K1KLO, your signal is exceptional — 20 over 9! Good luck in the contest!"

The 3-1/2 months invested in the construction of the Connecticut Shorthorn have been rewarded. It's finished, road-tested and ready to add to the QRM!



Freq. (MHz)	L1	L2	L3	Cap. Hat	Extension	Total Radiator Length
28	3 turns	shunt bar	J section replaces K section	0	1 in. high end 4 in. low end	84 in.
21	3 turns	3 turns	J section replaces K section	0	30 in. – X	110 in.
14	3 turns	10 turns	J section replaces K section	0	30 in. – X	110 in.
7	4 turns	10 turns	19 turns of L3*	3-3/4 in.	30 in. – X	110 in.
3.5	7 turns	24 turns	55 turns*	2-1/2 in.	30 in. – X	110 in.

*Section K with the adjustable capacitive hat and L3 are used on 3.5 and 7 MHz only.

Fig. 5 — The main antenna assembly. Details of the necessary antenna adjustments for each band are given in the table. Note: Section K with the adjustable capacitive hat and L3 are used on 3.5 and 7 MHz only.

Acknowledgments

I would like to recognize the following people who have helped with many aspects of this long and sometimes confusing project. My thanks to Ole, N4ABM, and Jim, G4JPM, for their time and patience in conducting the performance tests; to Chet, W1PE, Peter, N1AUT, and Mike Urban of the Veeder-Root Company, for their interest and help regarding the digital display counter and associated circuitry. And special thanks to my wife, Marianne. For three months she gave encouragement to an absent-minded husband who talked of nothing other than the inherent problems, goofs and glitches of this project. Marianne put up with all this, and with pride christened the finished product "The Connecticut Shorthorn"!

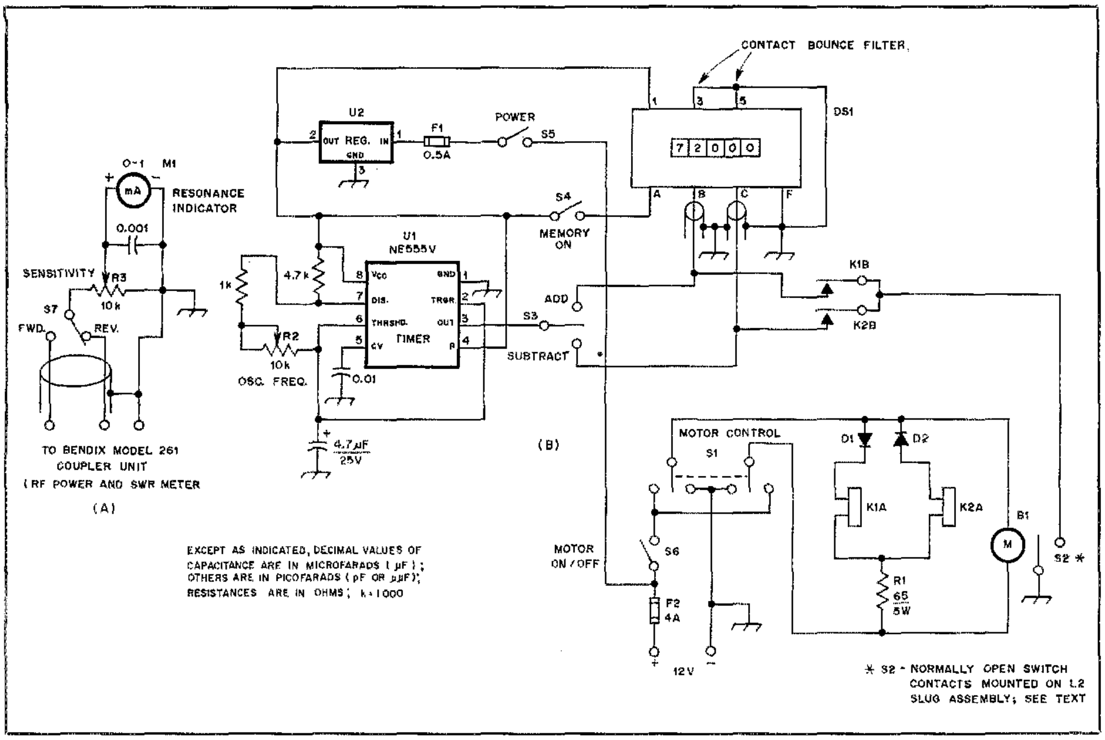


Fig. 6 — The control center diagram. Aluminum foil is used to enclose and shield the counter; the foil should be grounded to prevent receiver interference.

B1 — 12-volt dc motor, 130 rpm (surplus).
DS1 — Counter, Veeder-Root series 7996 mini-counter totalizer. (Veeder-Root, Digital Systems Division, Hartford, Connecticut 06102. Tel. 203-527-7201).
K1, K2 — Dpdt dip relay, 5-volt dc coil (Radio Shack 275-215 or equivalent).
S1 — Dpdt, center off, momentary-contact switch.
S2 — Normally open switch contacts mounted on L2 ferrite slug screw assembly.
S3 — Spdt, center off, momentary-contact switch.
U1 — NE-555 timer IC.
U2 — 12-volt regulator, LM-340-12 or equivalent.

Strays

GET IN ON THE FUN

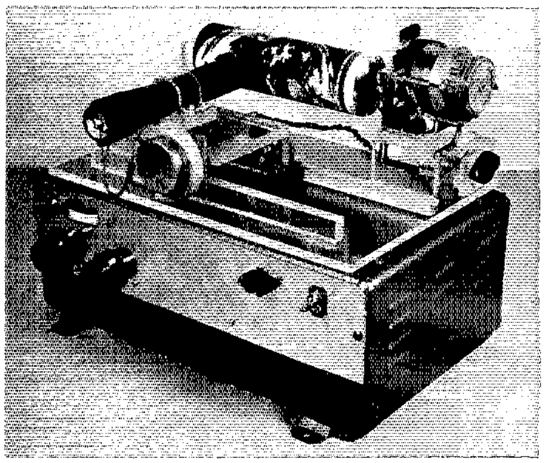
☐ All unlicensed members: have you ever considered obtaining an Amateur Radio license? As an ARRL member, you must have. Some of the 1980's on-the-air events included special operations from the Lake Placid Winter Olympics, Voyager I Flyby of Saturn and even the special QSL from Davy Crockett's birthplace in Morristown, Tennessee. If you missed out during 1980, be sure you're in on the fun in 1981. Be prepared for future activities of this kind by getting into Amateur Radio. Write to the Club and Training Department for additional information. We'll be happy to put you in touch with a club in your area. — *Maureen Thompson, KA1DYZ, Training Assistant*

QRP MOVEMENT GROWS

☐ Low-power fans may be interested to know that the G-QRP Club has just signed up its 1000th member. He is a former RSGB president (G3HCT). John still serves RSGB as a member of its various committees. The G-QRP Club has members from 32 countries and all continents. *Sprat*, the quarterly QRP journal, is sent to all members. The club offers awards and trophies to winners of its contests, and also operates an internal QSL bureau. Club membership is open to any amateur or SWL in the world with an interest in QRP (very low power). Membership/subscription to this RSGB affiliate club is 3.5 pounds or $9 U.S. Applications should be sent to Secretary George Dobbs, G3RJV, 17 Aspen Dr., Chelmsley Wood, Birmingham, B37 7QX England.

A U.S.-based QRP organization, QRP Amateur Radio Club International, Inc., has recently changed its rules for QRP awards to a specified maximum of 5 watts output. Previously, the term "QRP" was defined by the club as 100 watts, which was rather absurd in the eyes of many QRP enthusiasts. Members must agree to run no more than 50 watts on cw and 100 watts PEP for ssb work, except in time of public service and emergency. Membership is for the life of the applicant. Information concerning membership and club activities can be obtained from President Tom Davis, K8IF, 11729 Merriman, Livonia, MI 48150. Most cw QRP activity takes place on 1810, 3560, 7040, 7060, 14,060 21,060 and 28,060 kHz. The 7030 frequency has become loaded with QRM from the "speed merchants" with their keyboard keyers in the past two years, so for U.S. operations it is better to use the 7040- or 7060-kHz frequency for low-power QSOs. In Europe use 7030 kHz. — *Doug DeMaw, W1FB*

Printing Pictures from "Your" Weather Geostationary Satellite



Wherever on earth you're located, a rotating-drum facsimile unit like this will provide remarkably good weather pictures. Plan now to make one for your station!

By Guido Emiliani,* I4GU and Marciano Righini,** I4MY

In our previous article, "An S-Band Receiving System for Weather Satellites," (August 1980 *QST*, page 28[1]) we explained how to construct equipment for receiving weather pictures from satellites in space. As a sequel to that article, we now propose the use of a rotating-drum facsimile display including the related electronics for printing APT-WEFAX images on photographic paper.

Because the International Coordination Group of Geostationary Meteorological Satellites has standardized all aspects of the satellite communication system, the reproducing unit we shall describe can be operated readily by APT users all over the world. It takes advantage of the fact that all five spacecraft include a common downlink frequency of 1691.0 MHz. The format of the WEFAX data is identical for all satellites.

Video Modulation and WEFAX Image Format

From the characteristics of the APT modulation in Table 1, you can see that the 2400-Hz audio signal (subcarrier) is amplitude modulated by the video information. White corresponds to the maximum signal level, black to the minimum. The intermediate levels furnish the shades of gray. Notice that, even at minimum level, a small percentage (5%) of the subcarrier persists.

The line rate (horizontal scan) is 4 lines per second. As the picture is divided into 800 lines, vertical scan time is 200 seconds (image data only). The frame format is shown in Fig. 1. The scan is subdivided in the following manner:

1) Start signal for 3 seconds (12 lines) consisting of rectangular waves at 300 Hz.

2) Line synchronization code for 5 seconds (20 lines). Each of these lines begins with a black level of 12.5 ms (5% of the line); the rest of the line is at white level and has a duration of 237.5 ms (95% of the line). The 20 black levels print a black rectangle at the upper left of the frame.

3) A useful image consists of 800 lines (200 seconds). Each line begins with a white level of 11.9 ms corresponding to

Table 1

Modulation Characteristics of the APT-WEFAX Unit

Subcarrier frequency	2400 Hz
Subcarrier modulation	a-m
White level	maximum (80%)
Black level	minimum (5%)
Base-band video	1600 Hz
Line rate	4 Hz (240 lines/min)
Lines-per-image	800
Image time	200 seconds
Aspect ratio	1:1 (square)
Direction of horizontal scan	left to right
Direction of vertical scan	top to bottom
Index of cooperation	267.36

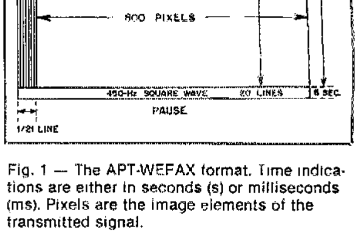


Fig. 1 — The APT-WEFAX format. Time indications are either in seconds (s) or milliseconds (ms). Pixels are the image elements of the transmitted signal.

*Via Fratelli Bandiera 18, 48018 Faenza, Italy
**Via Colombo Lolli 8, 48100 Ravenna, Italy

[1]This material was published in the Italian magazine *Radio Rivista*, March 1980.

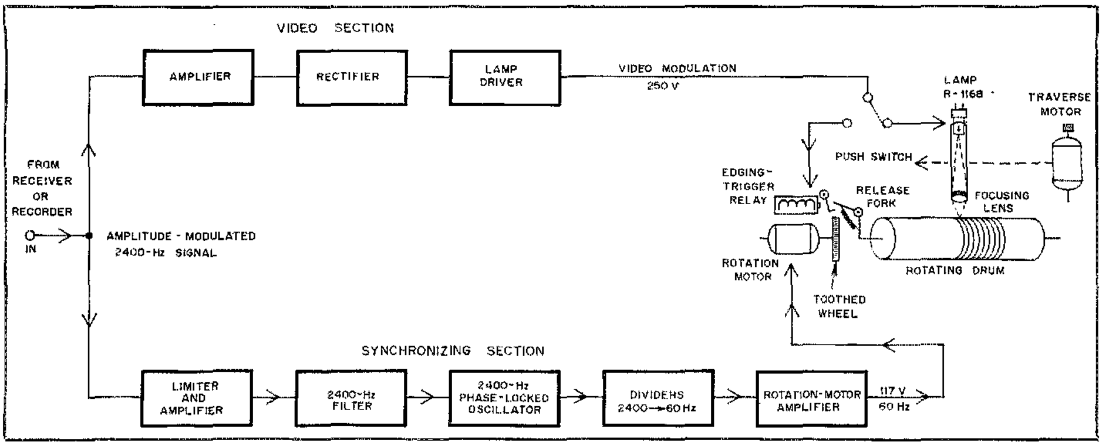


Fig. 2 — Block diagram of the facsimile reproducing unit.

1/21 of the line. This line start signal may contain a pattern of 2 white pixels followed by 2 black pixels modulated in a sequence of 7 cycles which simulates a frequency of 840 Hz in a rectangular waveform. The rest of the line containing the image data lasts 238.1 ms. The image is square.

4) Stop signal for 5 seconds (20 lines) consisting of rectangular waves at 450 Hz.

Picture Display

APT is a slow-scan TV system in which the image has to be fixed line after line on some support (photographic paper, for instance) so that, when the scan is over, one can get the cumulative view of the whole raster. This can be done in various ways. We will consider the two systems most widely used by radio amateurs — the *oscilloscope system* and the *rotating drum system.*

With the oscilloscope method, the raster (line structure into which the image is divided) takes shape on the face of a cathode ray tube and is fixed on the film of a camera situated in front of the CRT. This system is certainly the easiest of all because it does not involve moving parts. It is rather slow because of the double negative/positive passage and does not appear to be suitable for the APT frames of geostationary satellites. These frames must be set together to form a mosaic and therefore must be perfectly square.

The principle of the rotating drum system is that a spot of modulated light is focused on a sheet of photographic paper wrapped on a drum that rotates at the line rate of the video information, and, at the same time, traverses at the vertical scan speed. When the whole frame is exposed, the paper can be developed and the image seen in almost-real-time. This system, used by many commercial displays, gives geometrically perfect, high-definition, low-cost pictures. Moving parts are necessary, and the less mechanically talented amateur may require assistance to construct them.

Block Diagram

The system we use has a rotating drum

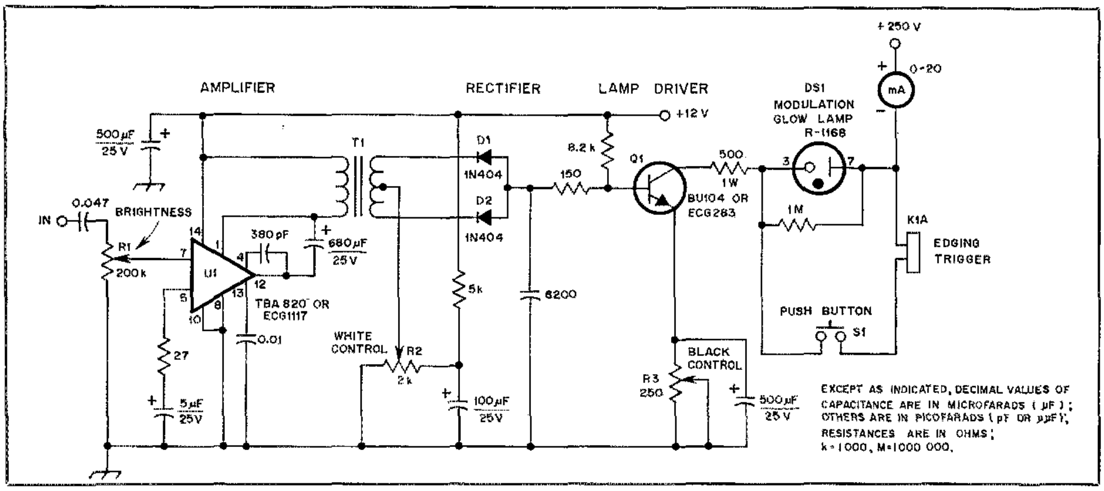


Fig. 3 — Video section of the reproducing unit. Resistors are 1/4 watt except as indicated.

D1, D2 — Silicon rectifier, 600 PRV, 1 A, 1N404.
DS1 — Sylvania modulation glow lamp R-1168 or equiv.
K1 — Modified relay, 3000 ohms, 15 mA. (See Fig. 9.)
S1 — Push-button spst.
T1 — Transistor type output transformer, 1 W, 8 Ω/200 Ω ct.
Q1 — Npn silicon HV high-current switcher, BU104, Sylvania ECG283 or equiv.
U1 — Audio amplifier, 2 W, TBA820, Sylvania ECG1117 or equiv.

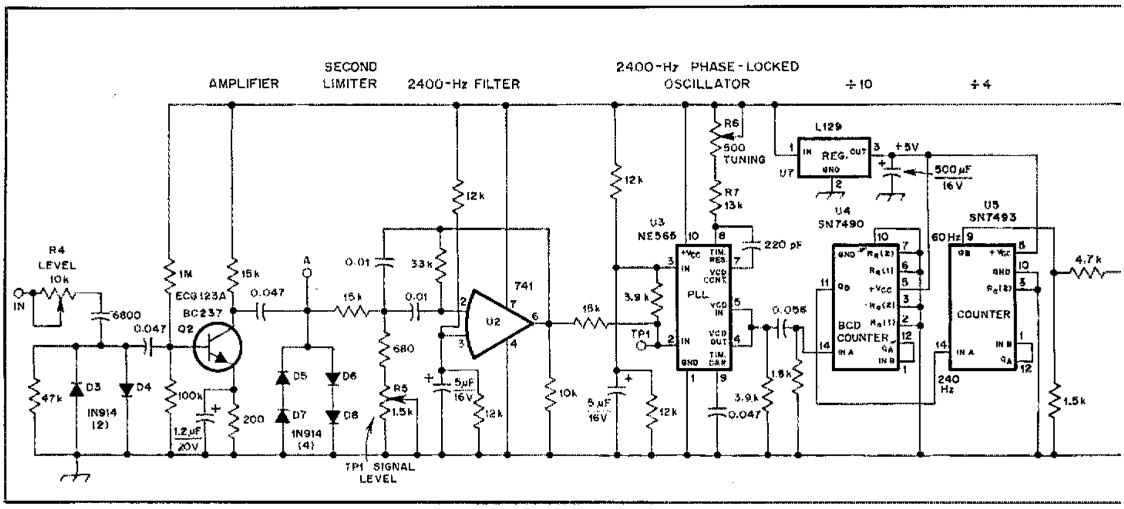


Fig. 4 — This is the circuit for the synchronization section of the facsimile reproducing unit. The subcarrier signal from the satellite is processed in this section for driving the rotation motor. Resistors are 1/4 watt except as noted.

C1-C3, incl. — See text.
D3-D8, incl. — Fast-switching silicon rectifier, 1N914.
Q2, Q3 — General-purpose silicon high-gain, low-power transistor, BC237, Sylvania ECG 123A or equiv.
Q4, Q5 — Npn silicon high-power, high-current

and prints the image on photographic paper. Fig. 2 shows the block diagram of the entire reproducing unit.

Incoming signals from the receiver are simultaneously applied to both the video and the synchronizing sections. Recording the signal and reproducing the picture later may be convenient and at times indispensable. In that case, you need a monaural (or stereophonic using one track) audio recorder.

In the video section, the modulated signal is rectified and amplified to drive the lamp, R-1168. This lamp provides the modulated light for printing the paper. The purpose of the synchronizing section is to divide the 2400-Hz signal down to 60 Hz in order to drive the rotation motor. A rotation rate of 4 turns per second must be maintained by the drum on which the photographic paper is wrapped. The function of the light gun is to carry the modulation glow lamp (R-1168) and the focusing lens. The light gun traverses parallel to the drum during the whole frame time. The edging relay aligns the image with the edge of the paper. Now, let's examine the various sections in detail.

Video Section

The strength of the modulated 2400-Hz signal is controlled by R1 (Fig. 3), which serves as a brightness control and should be accommodated on the front panel. It should be regulated to get the right light intensity. Developing time for the photographic paper should be two minutes at 20° C (68° F).

After the amplifying stage, U1, the signal is full-wave rectified by D1 and D2. These diodes are biased (1.5 V on their cathodes) by R2 which is the WHITE control. When the signal level is maximum, the lamp should be off and Q1 should not conduct. R2 and R3 should be accessible from the front panel. R3 is the BLACK control. It should be regulated for the maximum brightness of the lamp (therefore, maximum flow of current through lamp driver Q1) when the signal level is minimum.

The modulation glow lamp, R-1168, supplies the photographic paper with the proper amount of light. Characteristics of the lamp are shown in Table 2. It gives a peak of energy at 370 millimicrons, the frequency of violet. Also observe that the operating voltage should not exceed 150 V and that the average current may vary from 5 to 15 mA. To measure this current, a 20-mA (full-scale) meter has been put in series with the lamp. The average current value is to be found experimentally by regulating the strength of the signal with R1. The right amount of light depends on the kind of focusing lens used, on the distance between lamp and lens and on the grade of paper that is to be used. An average current of 7 mA should be sufficient for proper exposure. Too much current will shorten the life of the lamp.

The glow lamp with the smallest aperture (0.015 inches or 0.38 mm) is the R-1168. It is particularly suitable because a spot of light of the right size can be obtained with low demagnification. However, there are other glow lamps with larger openings. These are less expensive and give equally good results. Besides the R-1168, Sylvania makes the following: R-1130B (0.056 inches or 1.42 mm), R-1131C (0.095 inches or 2.41 mm) and R-1169 (0.075 inches or 1.91 mm). Other types we have used are the 1B59 and XL601. The edging relay and the push button functions will be dealt with later.

Table 2

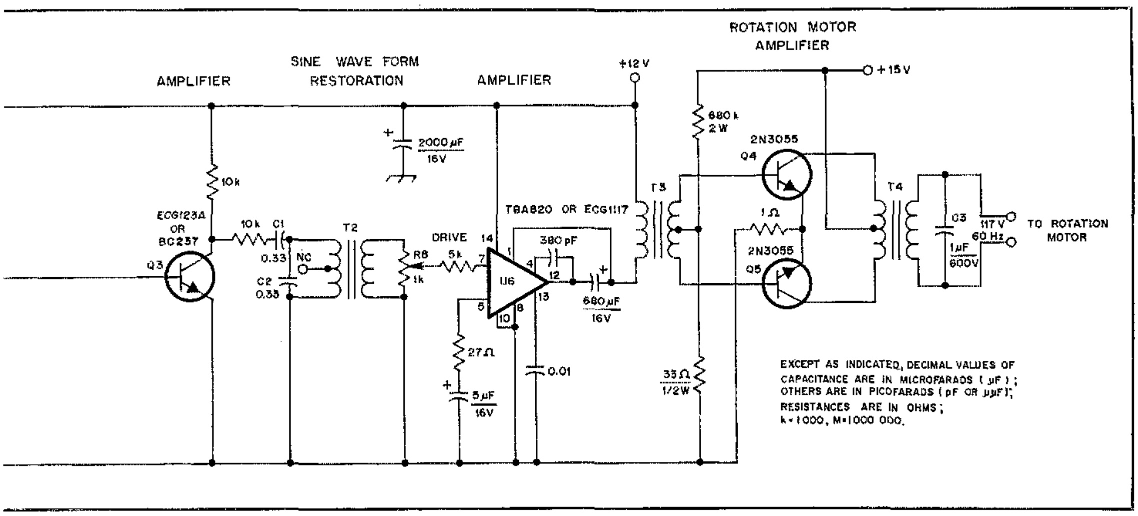
Modulation Glow Lamp R-1168 Characteristics

Operating voltage	150 V max.
Starting voltage	225 V min.
Current (avg.)	5 to 15 mA
Current (peak)	30 mA
Brightness	132 candles/sq. in. (0.2 candles/sq. mm)
Color of discharge	blue-violet
Glow aperture dia	0.015 inches (0.38 mm)
Rated avg. life	150 hours
Base type	intermediate shell octal
Lamp style	T9

Synchronizing Section

Rotation of the drum must be at the same rate as the image (4 lines per second). To obtain this rate, we drive the rotation motor with the reference signal (subcarrier) transmitted by the satellite. In Table 1, you can notice that the 2400-Hz subcarrier is always present. In fact, even at black level, a small percentage (5%) of the audio signal persists. So you can use the 2400-Hz frequency as a synchronizing reference and drive the rotation motor with a submultiple of that frequency.

The signal applied to the synchronizing section (Fig. 4) is amplitude limited by D3 and D4, amplified by Q2, limited again by D5, D6, D7 and D8 and filtered by U2, a 2400-Hz band-pass filter. For the right



audio amplifier, 2N3055.
T2, T3 — Transistor output transformer, 1 W, 8 Ω/200 Ω ct.
T4 — Filament transformer, 24 V ct/117 V ac, 20 W.
U2 — General-purpose operational amplifier, 741 or equiv.
U3 — Linear PLL, NE565.
U4 — Decade counter, SN7490 or equiv.
U5 — Four-bit binary counter, SN7493 or equiv.
U6 — Audio amplifier, 2 W TBA820, Sylvania ECG1117 or equiv.

setting of the filter, apply a 2400-Hz signal to terminal A. R5 should be adjusted to get the maximum signal amplitude at TP1.

U3 is a 2400-Hz oscillator which is frequency and phase driven by the incoming signal. It should oscillate at 2400 Hz even when the incoming signal is not present. Its frequency is given by R6 and R7. The value of R7 may differ, but not very much, from the one indicated. R6 is the oscillator fine tuning and should be adjusted only once.

The signal from U3 is divided by 10 at U4 and by 4 at U5. A 60-Hz signal at pin 9 of U5 is amplified by Q3, and the waveform is made sinusoidal by the LC network consisting of T2, C1 and C2. The exact values of C1 and C2 are to be found experimentally in relation to the transformer (T2) that is installed. R8 should be adjusted so that the amplifier U6 drives the push-pull final amplifier (Q4 and Q5) properly.

At the secondary of T4, you will have 117 V, 60 Hz to feed the synchronous rotation motor. The value of C3 is to be determined experimentally in relation to the motor used.

Synchronous Rotation Motor

We have already said that the drum must rotate at 240 turns per minute. With a 60-Hz driving signal, this speed can be obtained directly at the shaft of a 30-pole synchronous motor. If the motor has a smaller number of poles, its speed will be higher and a reduction gear will be necessary.

The relationship between frequency, number of poles and the number of turns is shown by the following formula:

$$\text{turns per minute} = \frac{120 \times \text{frequency}}{\text{number of poles}}$$

In practice you should get a 10-W synchronous motor with a rotation speed, at the shaft of the reduction gear, of 240 turns per minute. With the arrangement of Fig. 7 the shaft should rotate clockwise.

The drum is made of expanded polystyrene foam of the type used for making containers. Therefore it is extremely light, ready to follow the possible speed fluctuations and quick to reach the full rotation speed. It turns on small ball bearings or self-lubricating bushings.

The circumference of the drum establishes the size of the picture. Experience has shown that the optimum size of the image is 7 × 7 inches (180 × 180

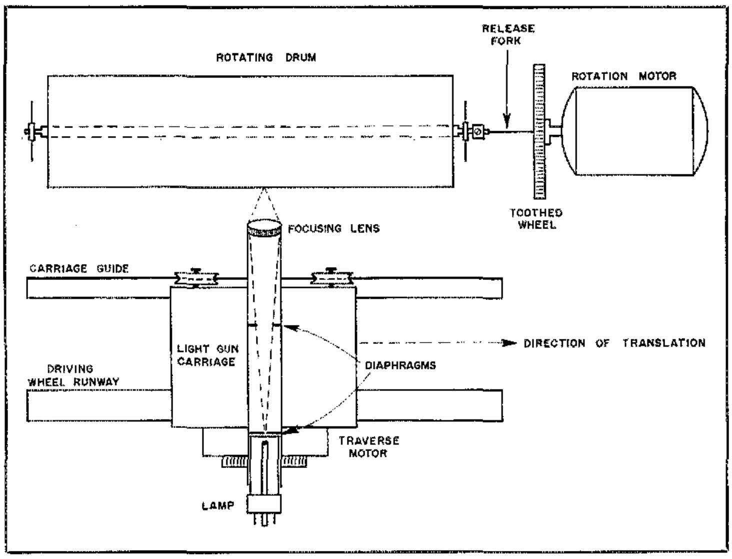


Fig. 5 — This drawing shows the physical arrangement of the facsimile display as seen from above.

mm). Photographic paper that is 7 × 9-1/2 inches (180 × 240 mm) is commercially available. If you choose this dimension, the diameter of the drum must be 2.2 inches (57 mm). The minimum length of the drum should be 7.9 inches (200 mm).

Edging Trigger

As may be seen in Figs. 8 and 9, the rotation motor and the drum are coaxial, but they are not integral. They become integral (rotate together) only when the release fork engages one of the teeth in the wheel that is fastened to the rotation motor shaft. If the motor and the drum were integral all the time, we could not set the exact point where the scan line begins, and the image would be cut haphazardly. To align the image with the edge of the paper, we have taken advantage of the black level that is present at the beginning of the 20 lines of the synchronization code preceding the image (see Fig. 1).

In practice, we wrap the paper around the drum, then insert the tip of the release fork in the relay keeper so that the motor and drum are not integral. The 300-Hz note warns us that the frame is going to begin. Then the rotation motor is started while the drum remains still. After 3 seconds of the 300-Hz note, there are 20 lines (5 seconds) which are at black level for the first 12.5 ms each. These impulses get the maximum current to flow through the lamp.

During the five seconds when the 20 lines are transmitted, we press the push button shown in Fig. 3. In doing so, the relay coil and the lamp are paralleled. A current of 15 mA (the maximum for black) will activate the relay. The first black impulse, no matter which one of the 20 after the push button has been depressed, activates the relay. In turn, the relay keeper is attracted and the release fork (returned by a spring) engages a tooth of the cogwheel. This coupling makes the motor and the drum integral and, because the drum is light, it reaches full speed immediately. The cogwheel should not be too heavy. Neither the diameter nor the number of cogs on the wheel is important.

An essential step in the preparations is finding the place where all lines start. A longitudinal line should be drawn on the drum. The edges of the paper are to be aligned with it when the sheet is wrapped around the drum.

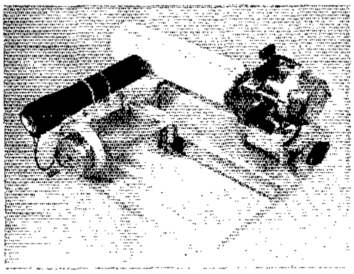


Fig. 6 — The carrying structure of the display is made of Plexiglas. Any other material from wood to metal is equally good. The alignment line and the two-faced adhesive tape can be seen on the drum, which is made from expanded polystyrene.

Translation

The light beam must traverse the paper while the drum rotates. These two combined motions result in the light beam developing a spiral on the paper consisting of the sequence of all the lines, one after another. There is a relationship between the two motions of rotation and translation. This relationship is given by the *Index of Cooperation*. The index number represents the product of the drum diameter and the number of lines scanned in the unit of measurement used.

Index = Dia in mm × number of lines scanned in one mm (in. = mm ÷ 25.4)

The Index of Cooperation of APT-WEFAX images is 267.36 and the diameter of our drum is 57 mm. Applying the above formula, we find that 4.69 lines should be scanned in 1 mm. As the line has a duration of 1/4 second, the spot will have to traverse 1 mm in 1.17 seconds, which means 171 mm in 200 seconds. The image will come out perfectly square, for it occupies only 20/21 of the line or 171 mm (see Fig. 1).

There are many ways to make the light beam traverse. The important point to keep in mind is that its movement must be extremely accurate so that the lines are separated by the same distance. The easiest way to obtain this condition is to put the light gun on a self-carrying carriage drawn by a synchronous motor (Figs. 5, 7 and 10). The carriage is guided parallel to the drum by a rail on which two grooved wheels roll. The driving wheel, located on the back of the carriage, is run by a small synchronous motor connected to the ac lines. It is a rubber wheel that operates on a runway.

As the carriage must traverse 171 mm in 200 seconds, we can calculate the circumference of the driving wheel. If we use a synchronous motor with 1 turn per minute at the reduction gear shaft, the circumference of the driving wheel will be 51.2 mm and the diameter will be 16.3

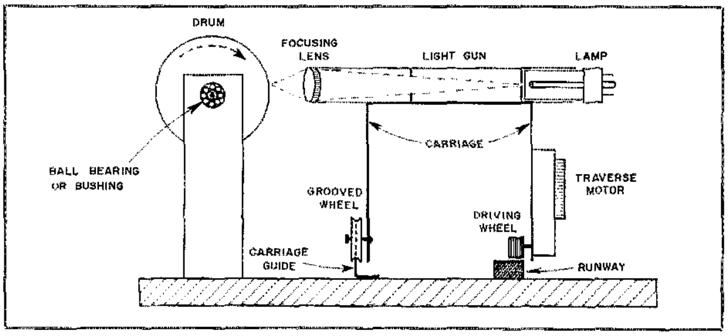


Fig. 7 — The facsimile display as seen from the left.

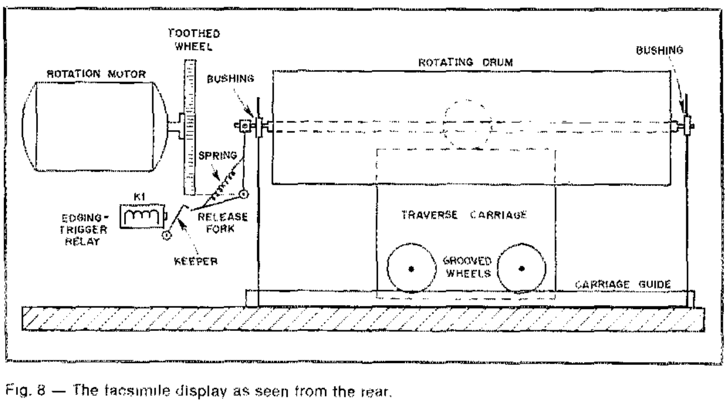


Fig. 8 — The facsimile display as seen from the rear.

mm. With the arrangement of Figs. 5 and 7, it should rotate counterclockwise.

Light Gun

The barrel holding the lamp and the focusing lens is shown in Figs 5 and 7. You should get a 10× eyepiece with a focal length of 15 or 20 mm (0.59 or 0.79 in.) and set it at one end of the light gun. Equip the eyepiece with a micrometer screw for fine-focus adjustment of the spot on the paper wrapped around the drum.

Set the lamp at the other end of the barrel at a distance from the lens that tentatively provides the best results as far as quantity of light, spot dimension and lack of halo are concerned. To reduce the halo, some diaphragms must be placed between the lamp and the lens. The first, with a 2 mm (0.78 in.) hole, is to be placed close to the flat head of the lamp — the other(s), at the distance that experience suggests. A black interior of the barrel is essential.

As the spot is projected on the paper, it may look very large, but you will notice that the outer regions of the spot are reddish, while the inner part is white. It is this bright small spot of actinic light which exposes the paper and which should be focused very carefully.

The dimension of the spot of light depends on the eyepiece and the lamp utilized in addition to the distance from the lamp to the lens. The spot should be neither too large (the lines would mix), nor too small (the lines would be too far apart). With patient attempts you will find the right size.

Photographic Paper

To apply the paper around the drum, use a strip of double-faced adhesive tape. This strip must be positioned on the longitudinal line drawn on the drum that serves to set the right edging of the image (Fig. 6). The edges of the paper are to be placed along this line and are to be pushed against the adhesive tape so that they adhere to it along the whole length.

As we said, the suggested size of the paper should be cut down to the appropriate size before wrapping it. We suggest glossy grade 3 paper. However, try other grades to find the one which makes the greatest possible number of details stand out. Development and fixing are carried out in the traditional way. If the exposure is proper, the paper should develop thoroughly in two minutes at 20° C. The whole process of printing and development must be carried out in red or yellow-green light.

Power Supply and Test Equipment

The reproducing unit requires four different voltages. For the video section (excluding the lamp) and the synchronizing section (excluding the final power amplifier), 12 V at 1 A regulated, must be furnished. The rotation-motor power amplifier (Q4 and Q5) requires 15 V at 1.5 A. Other voltages are 250 V at 30 mA for the glow modulation lamp and 117 V at 60 Hz ac for the translation motor.

When the main switch S1 is ON, the 12 V is always applied to the circuit. Only when the display is in operation are the 15 and 250 V applied. S2 serves as the standby switch.

A possible layout of the power supply is shown in Fig. 11. Any other arrangement providing the above voltages and currents would be equally suited.

For the proper setup of the reproducing unit, an audio frequency generator and an oscilloscope are needed. A frequency counter may be useful but is not essential. QST

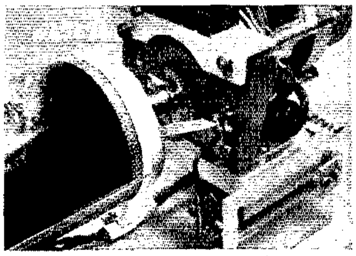


Fig. 9 — Detail of the alignment device. The release fork is inserted in the edging relay keeper. When the relay is activated, the release fork (returned by the spring) fits into a groove of the cogwheel fastened to the rotation motor shaft. In the display shown here, the drum shaft is inserted in a bushing connected to the motor shaft. The two shafts are independent of each other. Support for both the cogwheel and the drum shaft is provided by the motor shaft.

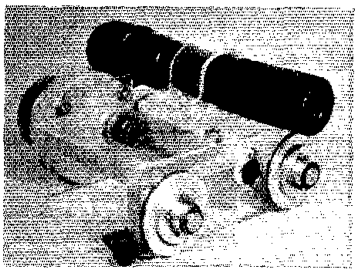


Fig. 10 — This photograph shows the traverse carriage with the light gun. You can see the two grooved wheels, a DIN socket for the voltages needed and a small wheel (bottom left) which, pressing against the guide rail, makes the traverse movement very smooth. On the back of the carriage you can see the traverse motor with the reduction gear and the small rubber driving wheel.

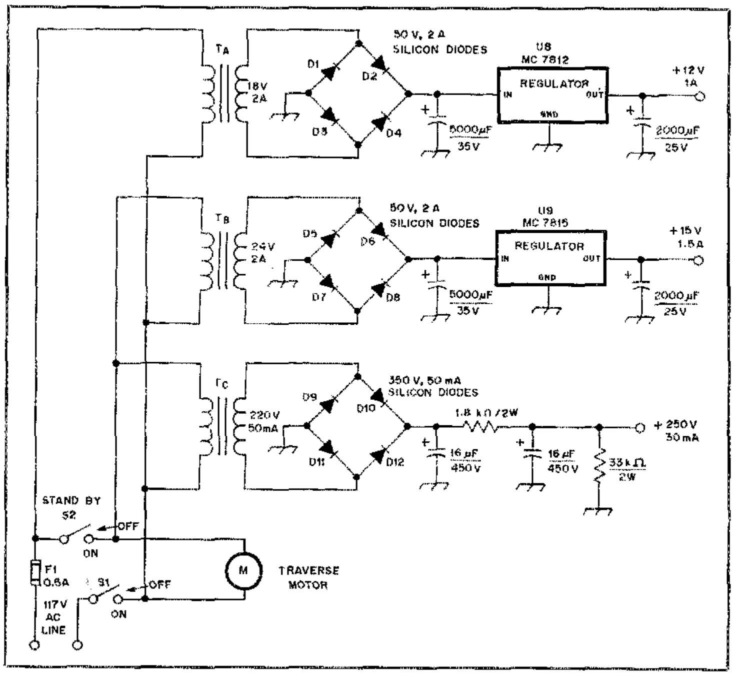
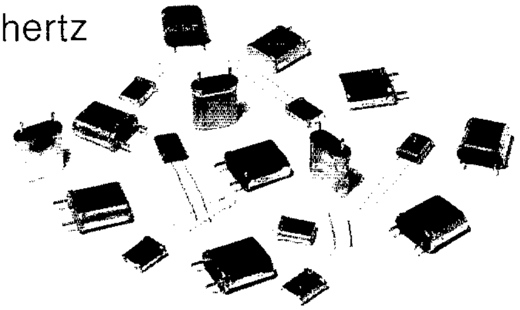


Fig. 11 — Power supply for the reproducing unit.
D1-D8, incl. — Silicon diodes, 50 V, 2 A.
D9-D12, incl. — Silicon diodes, 350 V, 50 mA.
F1 — 0.5 A fuse.
M — One-turn-per-minute synchronous motor, 5 W.
S1, S2 — Spst switch.
T_A — 117 V pri/18 V, 2 A sec.
T_B — 117 V pri/24 V, 2 A sec.
T_C — 117 V pri/220 V, 50 mA sec.

Do You Know Where Your Crystals Are?

Variations of only a few hundred hertz in the operating frequency of some of the crystals in your ssb rig can mean a big difference in the quality and intelligibility of your signal. Why?



By Joe Pettengill,* N2BC

Today's method of producing ssb signals involves an audio amplifier, an rf oscillator, a balanced modulator and a band-pass filter. Once the ssb signal is generated, the remaining processing is mostly heterodyning (adding or subtracting other frequencies to obtain the operating frequency) and amplifying the signal before coupling it to the antenna.

When the audio signal drives the balanced modulator, it modulates a crystal-controlled rf carrier and produces two sidebands — an upper and a lower sideband. During the modulation process, the carrier is almost balanced out and is present at a very low level at the output of the balanced modulator. This signal is then coupled to a band-pass filter, usually of the four-pole crystal type, which passes only one of the two sidebands and which provides further attenuation of the carrier.

Now, let's get back to that silly-sounding question. The operating frequency of the carrier oscillator crystal with respect to the filter will determine which sideband will be passed. Also, the exact relationship of the crystal frequency to the filter frequency will determine the quality of the signal that your ssb transmitter puts on the air.

*386 Montross Ave., Rutherford, NJ 07070

What happens to the filtered output signal with small changes in the crystal oscillator frequency? To answer this let's examine the output of the filter before it is heterodyned. We will look at the upper sideband only. (The processing of the lower sideband will be a mirror image of the upper.)

Where It Should Be

Fig. 1A shows a graph of the passband of a typical crystal filter, with the oscillator set for optimum operation of the circuit. The crystal oscillator frequency is close to 200 Hz below the 6-dB-down point of the lower frequency edge of the passband. This setting is optimum for two reasons. First, the carrier is attenuated by the filter. Second, and perhaps more important, the filter will pass the frequencies required for understandable human speech, 500 to 2500 Hz. Frequencies higher and lower will be rejected by the filter.

A number of studies have shown that loss of voice frequencies below 500 Hz and above 2500 Hz does not seriously affect understandability of speech in a communication medium. However, a loss of low-end frequencies above 500 Hz or a loss of high-end frequencies below 2500 Hz seriously affects the understandability of words spoken.

If the crystal frequency is only 1/100 of 1% low, it will be 500 Hz low and the resultant modulation products that should be passed by the filter will be 4999.8 kHz to 5003.5 kHz. Because the filter is fixed with a passband of 5000.3 kHz to 5003.0 kHz, the low-end speech frequencies corresponding to about 800 Hz audio will be rejected. Additional high-end frequencies will be allowed to pass causing interference to adjacent channels on the upper side of the signal (Fig. 1B). These factors combine to make understandability at the receiving end poor.

If we vary the frequency of the crystal oscillator upward from optimum by the same percentage factor, things again become bad. Not only do we affect the upper frequencies that will be passed by the filter, but we allow some of the lower sideband frequencies to be passed (Fig. 1C). Products corresponding from 0 Hz to 2200 Hz fall within the passband, which means that some of the significant high frequencies will be missing in the recovered audio at the receiving end. There is little appreciable attenuation of the vestigial carrier. The presence of lower-sideband frequencies will cause serious interference to other stations operating on the lower-side channels.

It's 11 P.M. Do you know where your crystals are?

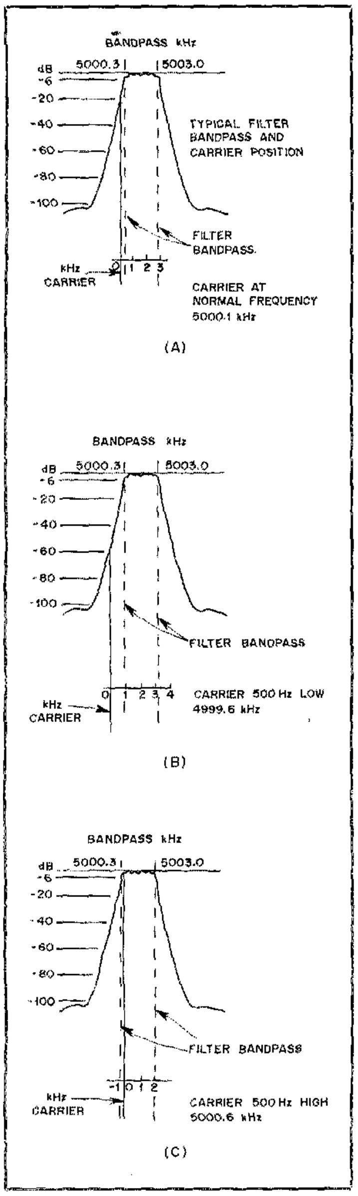


Fig. 1 — At A, the relative position of the carrier and the corresponding audio with respect to the passband of the filter. In addition to passing the desired audio products, the filter provides approximately 20 dB of attenuation of the vestigial carrier. If the carrier frequency is shifted 500 Hz low, the system has the characteristics depicted at B. The carrier is attenuated even more, but the products corresponding to low frequency audio are also greatly attenuated making it difficult for the receiving station to understand what is being said. At C, conditions that occur when the carrier frequency is shifted 500 Hz high are shown. The carrier is not attenuated by the filter and important audio products are lost. Additionally, portions of the lower sideband are passed through the filter. Again, the result is a poor signal.

First Packet Repeater Operational in U.S.

KA6M/R in San Francisco is the first U.S. all-digital, simplex packet radio repeater for use in the Amateur Radio Service. The repeater went into operation on December 10, 1980, and has been running both as a packet repeater and a beacon since. KA6M indicates that it has created a flurry of inquiries and that several amateurs are working on equipment that will bring them on line.

The primary function of a packet repeater is the same as that of the conventional repeater — to extend the geographic coverage of fixed or mobile stations. In terms of secondary functions, packet repeaters have the potential to far outstrip conventional repeaters with respect to flexibility and creative uses. A packet repeater or digital repeater ("digipeater" as the Canadians call it) is a machine which receives a message or block of data and, after verification, retransmits that message on the same frequency channel. Except for possible modifications of some address or control bytes, the message transmitted is the same as the message received. However, only a single simplex channel is required for operation. A conventional voice repeater requires two separate frequency channels.

KA6M/R is currently operating on 146.58 MHz, a simplex channel assigned in the San Francisco area for non-voice use. It transmits data at a speed of 1200 baud. The machine consists of a Z-80 microprocessor, a Bell 202 compatible modem and a solid-state transceiver (FT-202) utilizing PIN diode switching. Currently, the repeater is located in Menlo Park.

The framing format used for the packets is high-level data link control (HDLC), which is a new and internationally recognized standard in the communications industry. A frame consists of an opening flag byte, an address byte, a control byte, an information field, two bytes of CRC checking and a closing flag. The use of HDLC framing and control procedures guarantees highly reliable and nearly error-free communications. The Vancouver Digital Communications Group was the first amateur group to use HDLC framing.

As a beacon the machine transmits three packets every five minutes, immediately following its cw i-d. Each packet contains about 70 ASCII characters. Functioning as a repeater, it will retransmit any packet received which has the correct address and CRC checksum. The information field is currently limited to 256 bytes.

This repeater is one of the first steps in what is proposed to be a nationwide if not international network of interconnected computer systems. Several other groups, including the Amateur Radio Research and Development Corporation (AMRAD), are currently working on similar systems. Others are busily working on a slightly different approach that has been pioneered by a group from Ottawa, Ontario. Packet radio is a new frontier of Amateur Radio. The trailblazers and scouts are moving ahead. Can the swarm of immigrants be far behind? — *Hank Magnuski, KA6M, and Pete O'Dell, KB1N*

Strays

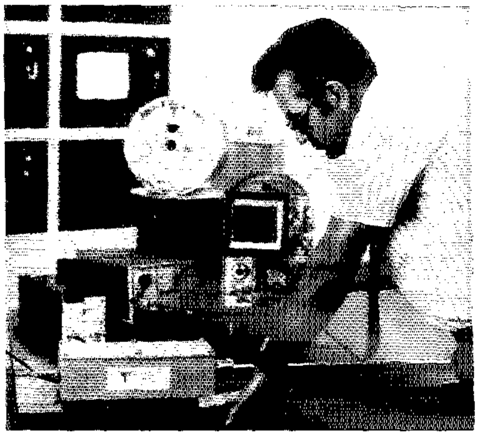
POSSIBLE ALUMINUM WIRING HAZARD?

□ Do you have a 15- or 20-ampere aluminum wiring system in your home? If so, you may want to read, "Was Your Home Built After 1964? Do You Have An Electrical System With Aluminum Wiring?" This booklet may be obtained by calling the following toll-free numbers: in the continental United States call 800-638-8326; in Maryland call 800-492-8363; in Alaska, Hawaii, Puerto Rico or the Virgin Islands call 800-638-8333. — *"Fire Investigation Handbook" issued by the U.S. Department of Commerce, August 1980.*

CALL FOR PAPERS

□ Papers are invited for the 1981 Annual VHF Conference sponsored by the Electrical Engineering Department of Western Michigan University at Kalamazoo. Principal emphasis will be on engineering developments applied to radio communication, design and construction on the frequencies of 30 to 1200 MHz. This conference will provide an opportunity for beginning or mature researchers to report their findings to their peers. We especially encourage the inexperienced inquirers to participate. Authors wishing to present papers should send by June 30, 1981, a synopsis describing the paper to: Dr. Glade Wilcox, W9UHF/9, Program Chairman, VHF Conference, Department of Electrical Engineering, Western Michigan University, Kalamazoo, MI 49008. — *Glade Wilcox, W9UHF/8*

Coaxial Cable — The Neglected Link



Is a better grade of coaxial cable worth the price difference? This analysis of the importance of shielding in coaxial lines explains why the answer is "Yes!"

By Charles Brainard, WA1ZRS, and Ken Smith**

When energy is transmitted through a coaxial cable, some of this energy may escape. Conversely, the cable may be in a field of energy and some of that energy can penetrate into the cable. The transformation of the energy out of, or into, the cable is called radiation, and the associated transducer is termed an antenna. The cable is a transmitting antenna when the energy escapes (egressive signals) and a receiving antenna when energy penetrates into the cable (ingressive signals). This phenomenon has many names associated with it such as leakage, radiation, isolation, shielding, shielding effectiveness, screening and screening efficiency.

Energy must pass through the cable shield for either egressive or ingressive signals. Obviously, for the most common use of coaxial cable, high attenuation of the energy passing through the shield is essential. There are cables that are designed for controlled leakage, and they are used when a highly controlled radiation of signals is desired. The following discussion, however, will be directed toward shields that are designed to prevent this leakage.

In 1960, a development program was established to investigate methods of construction of flexible coaxial cable to reduce cost, decrease attenuation and to improve rf shielding. It was found that test methods used to measure the radiated energy were quite difficult and were not sufficiently repeatable to evaluate different cables. This method measured the energy external to the cable resulting from a known energy level within the cable. Hence, a new test method was developed which gave relative ratings for cables in decibels. This method was found to be useful for evaluation of different cables even though these ratings could not be directly interpreted in radiation. The repeatability of the test was in the neighborhood of 3 to 5 dB, and it was found that relative ratings varied from 20 to 100 dB for various cables.

The theoretical development of electromagnetic field coupling through the shields of coaxial cable began many years ago and the general theory was presented in an article by Schelkunoff in 1934.[1] He represented the coupling by a transfer impedance and developed formulas for calculating the characteristics of solid shields. He also analyzed multiple-layer shields. Since 1934, numerous people have analyzed the coupling mechanisms and methods of measuring coupling. In the photograph, coauthor Ken Smith stands beside the Radiometer, an instrument that uses the triaxial test method[2,3,4] for measurement of the electromagnetic field coupling through the shield. He developed this instrument for the Times Wire and Cable Co. in 1978.

The purpose of this article is to show the transfer impedance and capacitive coupling impedance and, therefore, shielding effectiveness of different types of coaxial cables. The theory of electromagnetic field coupling and method of measurement will be reviewed, as will the measurement data of different types of cables.

Measurement

The Radiometer measures the absolute value of the transfer impedance and capacitive coupling impedance of the coaxial shield. An artist's sketch of the test setup is given in Fig. 1 showing that the cable is coaxially supported by a dielectric in the test chamber, creating a triaxial transmission system. The inner coaxial-transmission system is inside the test specimen and the outer coaxial-transmission system center conductor is the shield of the specimen. Its outer conductor is the test chamber. The specimen is terminated in its characteristic impedance by load A and the combination of the sweep oscillator and preamplifier. Load B and the detector are connected to the outer system by coaxial terminals. The rectangular termination on the ends of the chamber have ferrite toroids surrounding the test sample. These toroids minimize current flow along the shield of the test

*Times Wire and Cable Co., 358 Hall Ave., Wallingford, CT 06492

[1]References appear on page 31.

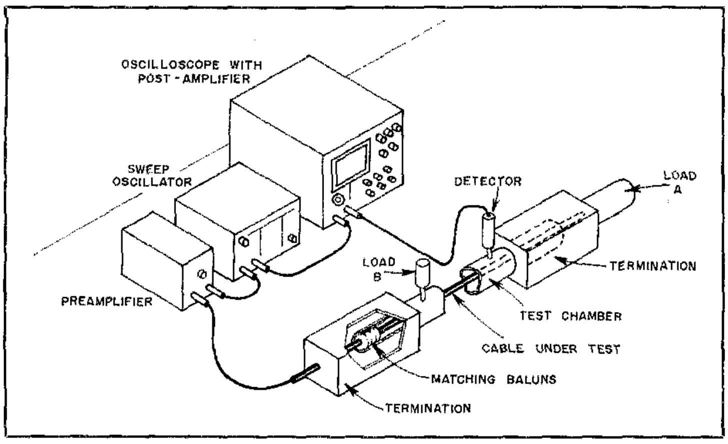


Fig. 1 — A setup for using a triaxial-test method for measuring the electromagnetic-field coupling through the shield.

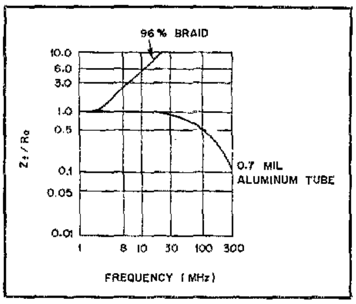


Fig. 2 — Coaxial-cable transfer impedances (Z_t) divided by the dc resistance of the shield (R_o) vs. frequency.

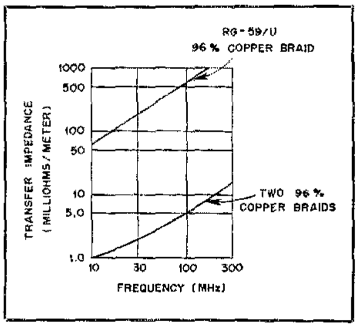


Fig. 3 — The relationship of transfer impedance vs. frequency for braided shields is shown by this graph.

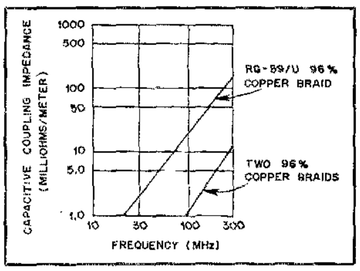


Fig. 4 — A graph representing capacitive coupling impedance vs. frequency for braided shields.

specimen to the end of the rectangular termination where the shield of the specimen is grounded. These rectangular terminations form baluns creating a high impedance allowing load B and the detector to match the impedance of the chamber. Errors are not introduced by leaky conductors; the shield of the specimen is unbroken through the entire length of the fixture. The connectors on the sample are connected to the ends of the rectangular terminations and are not critical since the baluns isolate the connector leakage from the signal in the test chamber.

When the equipment is set up as shown in Fig. 1, an analysis (neglecting attenuation and assuming the cable shield is uniform) shows that the magnitude of the output voltage in the triaxial transmission system is:

$$\left|V_f\right| = \left|\frac{(Z_t - Z_f)\, V_i \,\mathrm{Sin}\,[(B_s - B_c)\, L/2]}{Z_s\,(B_s - B_c)}\right| \qquad \text{(Eq. 1)}$$

where

V_f = the detector voltage with set up of Fig. 1.

V_i = the specimen input voltage.

Z_t = the transfer impedance in ohms per meter.

Z_f = the capacitive-coupling impedance in ohms per meter.

L = the distance between the coaxial terminals of the test chamber in meters.

Z_s = the specimen characteristic impedance in ohms.

B_s = the specimen phase constant in radians per meter.

B_c = the test-chamber phase constant in radians per meter.

An analysis of the output voltage with load B and detector exchanged shows:

$$VR = \left|\frac{(Z_t + Z_f)\, V_i \,\mathrm{Sin}\,[(B_s + B_c)\, L/2]}{Z_s\,(B_s + B_c)}\right| \qquad \text{(Eq. 2)}$$

where

VR = The detector voltage with load B and detector swapped.

Z_t and Z_f may be calculated since ratios V_f/V_i, VR/V_i, B_s, B_c, L and Z_s can be measured. The test procedure provided with the Radiometer includes tables which can be used to convert the voltage ratios measured in dB to transfer impedance and capacitive-coupling impedance. The minimal specimen attenuation is neglected but the chamber attenuation is accounted for. The tables were obtained from the following equations:

$$Z_t = \frac{1}{L}\sqrt{Z_s Z_c}\left(\left|\frac{\phi}{\sin\phi}\right| e^{x} + \left|\frac{\theta}{\sin\theta}\right| e^{y}\right) \qquad \text{(Eq.3)}$$

$$Z_f = \frac{1}{L}\sqrt{Z_s Z_c}\left(\left|\frac{\phi}{\sin\phi}\right| e^{x} - \left|\frac{\theta}{\sin\theta}\right| e^{y}\right) \qquad \text{(Eq. 4)}$$

where

Z_t = the transfer impedance in ohms per meter.

Z_f = capacitive coupling impedance in ohms per meter.

Z_s = the specimen characteristic impedance in ohms.

L = chamber length in meters.

$\phi = (B_s + B_c)\, L/2$ in radians.

$\theta = (B_s - B_c)\, L/2$ in radians.

Z_c = the chamber characteristic impedance in ohms.

B_s = specimen phase constant in radians per meter.

B_c = chamber phase constant in radians per meter.

$$x = \frac{DBR - \alpha_{c/2}}{8.68} = \mathrm{Ln}\ VR/Vi \qquad \text{(Eq. 5)}$$

$$y = \frac{DBF - \alpha_{c/2}}{8.68} = \mathrm{Ln}\ VF/Vi \qquad \text{(Eq. 6)}$$

α_c = chamber attenuation

Note: X, Y, DBR, DBF and α_c are negative quantities.

Discussion and Analysis of Transfer-Impedance Test Results

Transfer impedance in an elementary length of coaxial cable is defined as the ratio of the potential gradient (voltage) in the disturbed circuit to the current flowing in the interfering circuit. When the cable is acting as a transmitting antenna (egressive signals) the disturbed circuit is the environment around the cable. When the cable is acting as a receiving antenna (ingressive signals) the disturbed circuit is within the cable and the interfering circuit is the environment around the cable. A lower transfer impedance reduces the electromagnetic coupling (radiation).

The transfer impedance of a braided shield has two components — a diffusion component caused by current diffusing through the metal and a mutual-coupling component caused by penetration of the magnetic field through the openings in the braid. The mutual-coupling component can be represented by a mutual inductance. (Figs. 2, 3 and 4 are related to this discussion.)

The transfer impedance is the vector sum of these two complex quantities, and its magnitude is:

$$|Z_t| = \sqrt{(|Z_d|\cos\phi)^2 + (|Z_d|\sin\phi + |Zm|)^2} \quad \text{(Eq. 7)}$$

where

$\phi = 0.785 - \tan^{-1}(\cot d/\delta \tan d/\delta)$

Zd = the diffusion component of Z_t in ohms per meter.

Zm = the mutual-coupling component of Z_t in ohms per meter.

d = the diameter of braid wire in *meters.*

δ = the skin depth in meters.

The approximate diffusion component and mutual-coupling component for braided cable is obtained from an extension of Vance's equation[5] and Schelkunoff's.[1]

The diffusion component is:

$$|Z_d| = R_{dc}\frac{(\sqrt{2}\ )\,d/\delta}{\sqrt{\sinh^2(d/\delta) + \sin^2(d/\delta)}} \quad \textit{(Eq. 8)}$$

$$\delta = \sqrt{\frac{\rho}{\pi f \mu'}} \quad \text{(Eq. 9)}$$

The mutual-coupling is:

$$|Z_m| = \frac{\omega v\,\mu m}{\pi^2 D^2} \quad \text{(Eq. 10)}$$

where

ρ = the resistivity of the shield in ohms per meter.

f = the frequency in hertz.

μ' = the absolute magnetic permeability of the shield in henrys per meter.

d = the diameter of braid wire in meters.

R_{dc} = the dc resistance of the shield in ohms per meter.

ω = the angular frequency in radians per second = $2\pi f$.

v = the number of holes per meter in the braided shield.

μ = the absolute magnetic permeability of the insulation between the conductors in henrys per meter.

D = the mean inside diameter of the shield in meters.

m = the magnetic polarizability of the holes in the braid.[5]

Z_m = the mutual-coupling component in ohms per meter.

Z_d = diffusion component in ohms per meter.

δ = skin depth in meters.

Analysis of Capacitive-Coupling Impedance Test Results

The openings in the shield also allow the electric field to penetrate, creating electric coupling. This coupling can be represented by a capacitive coupling between the center conductor of the coaxial cable and the return path external to the cable.

The capacitive-coupling impedance is derived for the definition accepted by the International Electrotechnical Commission Working Group 1 (Screening Efficiency)[7] and Vance's equation for transfer admittance.[5]

$$Z_f = \frac{p}{m} Z_m \sqrt{\varepsilon r_e / \varepsilon r_i} \quad \text{(Eq. 11)}$$

where

Z_f = the capacitive coupling impedance in ohms per meter.

p = the electric polarizability of the holes in the braid.[5]

m = the magnetic polarizability of the holes in the braid.[5]

Z_m = the mutual-coupling component of Z_t in ohms per meter.

εr_e = the relative dielectric constant of the insulation in the external circuit.

εr_i = the relative dielectric constant of the insulation within the cable.

The capacitive-coupling impedance will be zero if there are no openings in the shield. If openings exist, then the capacitive-coupling impedance should vary directly with frequency. The test data plotted in Fig. 4 follows this characteristic reasonably well.

Conclusions

Measurements of the transfer impedance and capacitive-coupling impedance of coaxial shields can be made. Results agree with theoretical equations. Since the theory of transfer of energy through shields is known, an engineer can analyze and design coaxial cable theoretically. Because of the different types of coaxial cables in use today, the design engineer should be aware of the large variation in the coupling of electromagnetic fields through the shields.

The information in Table 1 gives an idea of the relative isolation of coaxial cable in accordance with percent and type of shielding. We have also indicated the losses in dB per 100 feet at 15 and 150 MHz (near two very popular Amateur-Radio bands) for each construction in the table. While Table 1 deals with RG-59/U cable, the isolation characteristics are applicable to any solid-dielectric cable while the losses in dB per 100 feet can be interpolated to other coaxial lines.

Down-line attenuation of cables is controlled by (1) the type and material of the center conductor; (2) the velocity of propagation and type of material of the center dielectric; and (3) the type and material of the outer conductor. An examination of the loss curves of Fig. 5 shows that RG-58 A/U exhibits loss characteristics from 11% to 12% more than that of RG-58/U. The only difference between these two cables is the nature of the center conductor. RG-58 A/U has a 19-strand tinned-copper center conductor. Both the stranding and tinning increase attenuation. Tinned copper is very popular with antenna manufacturers because it simplifies soldering. But, considering attenuation tinned-copper shields

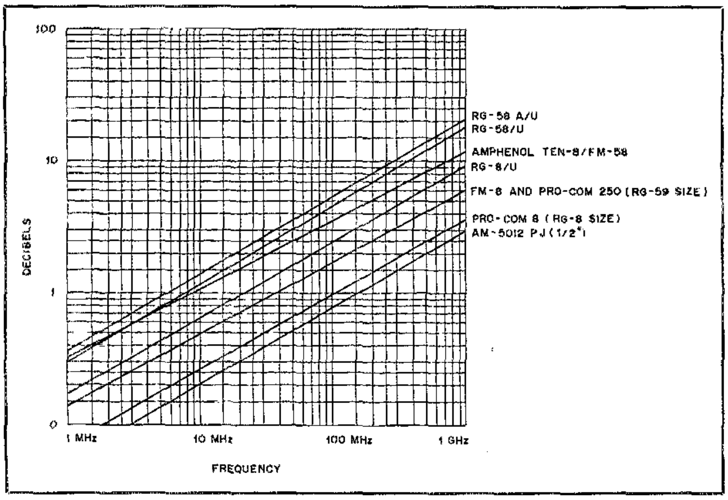


Fig. 5 — Nominal loss characteristics per 100 ft (30.48 m).

generate seriously detrimental effects above 500 MHz.

Another example that can be drawn from Fig. 5 is loss differentials (approximately 33%) between RG-8/U and FM-8 (Flexifoam by Times Wire). RG-8/U utilizes a 7-strand bare-copper center conductor and a 66% velocity core dielectric as opposed to a solid bare-copper center conductor and 79% velocity center core. It should be noted that in order for the FM-8 to possess a 50-ohm characteristic, the center conductor must be enlarged to 0.102 inches (2.59 mm) or no. 10 gauge vs. 0.0808 inches (2.05 mm) or no. 12 gauge for the center conductor on RG-8/U. As the velocity of propagation of a coaxial cable is increased while maintaining the same inside diameter of the shield, the center conductor must be increased in size in order to maintain the same cable impedance.

Braided-shield coaxial cables are, to varying degrees, impacted by their environment. That is, mounting a poorly shielded cable directly to a tower leg, as is so common, can drastically alter the attenuation characteristics of the cable. This change in characteristics is often in excess of 10 times. Degradation increases with frequency.

Placing poor cables in any conducting environment such as when attached to a tower leg or even buried in the ground can cause adverse results.

From the formulas in this article, transfer impedance and capacitive-coupling impedances can be calculated. As these impedance values rise, the outer conductor (shield) has larger openings. Consequently, higher-impedance cable is more affected by environment.

There is much more to coaxial cable than meets the eye. Since the cost of coaxial transmission line is usually relatively small in proportion to other station costs, it's difficult to reason the use of poor grade cable. A properly shielded line should be a must for all installations. BE

Table 1

Relative isolation characteristics of RG-59/U coaxial cable vs. percentage and type of braid coverage/shielding.

Shield	*Relative Isolation (dB)*	*Ratio of Power Radiated from Cable*	*Losses in dB per 100 ft. (30.48 m) 15 MHz*	*150 MHz*
40% bare copper	17	1:50	1.72	5.55
51% bare copper	18	1:63	1.72	5.55
59% bare copper	26	1:398	1.39	4.51
79% bare copper	34	1:2500	1.13	3.67
98% bare copper	52	1:160,000	0.98	3.20
96%/96% bare copper	83	1:2 × 10^8	1.01	3.31
Solid sheath (alum.)	282	1:17 × 10^{28}	0.89	2.91

Note: Isolation capabilities of coaxial cable at 20 meters is roughly 10 times as good as at 2 meters.

Table 2

Formulas Common to All Coaxial Cable

Capacitance (C) = $\frac{7.36E}{\text{Log}(D/d)}$ picofarads/ft

Inductance (L) = 0.140 Log (D/d) microhenrys/ft

Impedance (Z_o) = $10^3\sqrt{\frac{L}{C}} = \frac{138}{\sqrt{E}}$ Log (D/d) ohms

Velocity of propagation as % of speed of light = $\frac{100}{\sqrt{E}}$.

Time delay = 1.016 $\sqrt{E}$ nanoseconds/ft

Cutoff frequency = $\frac{7.50}{\sqrt{E}(D+d)} = F_{co}$ (GHz)

Magnitude of Reflection Coefficient =

$$(\Gamma) = \left[\frac{Z_r - Z_o}{Z_r + Z_o}\right] = \frac{VSWR - 1}{VSWR + 1}$$

$$VSWR = \frac{1 + \Gamma}{1 - \Gamma}$$

Peak voltage = $\frac{1.15Sxd\,(\log D/d)}{K}$

$$\alpha = \frac{0.435}{Z_o\,(D)}\left[\frac{D}{d}K_1 + K_2\right]\sqrt{F} + 2.78\sqrt{E}(P.F.)(F)$$

where
- α = attenuation in db/100 ft
- d = outside diameter of inner conductor in inches
- D = inside diameter of outer conductor in inches
- S = maximum voltage gradient of the cable insulation in volts per mil
- E = relative dielectric constant of the insulation of cable
- Log = Logarithm to base 10
- K = safety factor
- K_1 = strand factor and material
- K_2 = braid factor and material
- F = frequency in MHz
- P.F. = power factor

Feet × 0.3048 = meters

Properties of Wire and Cable Insulating Materials

Material	*Dielectric Constant*	*Power Factor*	*Volume Resistivity (ohms-cm)*	*Normal Operating Temperature Limits (°C)*
TFE	2.1	0.0003	10^{19}	−75 + 250
Polyethylene	2.3	0.0003	10^{16}	−75 + 80
Cellular polyethylene	1.40-2.10	0.0003	10^{12}	−75 + 80
Polyvinylchloride	3.00-8.00	0.0700-0.1600	2×10^{12}	−55 + 105
Nylon	4.60-3.50	0.040-0.030	4×10^{14}	−60 + 120
Kel-F	2.37	0.0270-0.0053	1.2×10^{18}	−40 + 150
Silicone rubber	2.08-3.50	0.007-0.016	10^{13}	−70 + 250
Ethylene propylene	2.24	0.00046	10^{17}	−40 + 105
FEP	2.10	0.0003	10^{18}	−75 + 200
Perforated TFE	1.50	0.0002	10^{19}	−75 + 250
Cellular TFE	1.40	0.0002	10^{19}	−75 + 250
Cellular FEP	1.50	0.0002*	18^{18}	−75 + 200
Polyimide	3.00-3.50	0.002-0.003	10^{13}	−75 + 300

*Varies with frequency

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[3]Bourseau and Sanjivy, "Mesure de L'impedance de Couplage et Application à L'étude des Écrans," *Cables et Transmission*, 10 (1), January 1956, p. 11.

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The ZS6U Minishack Special†

Like to experiment with simple antennas? Here are ideas for everyone from the antenna farmer to the apartment dweller.

By Colin Dickman,* ZS6U

The original article on the Minishack Special antenna appeared in *Radio ZS*, January 1973, and was reprinted there in metricated form in August 1977, entitled "The ZS6U Minishack Special — A Multiband End-fed Inverted-V Antenna System." The aim of this article is twofold: to provide a summary for the benefit of those who do not have access to the original article, and to expand on some of the original details.

Summary of the Original Article

1) By using a wire two wavelengths long at 10 meters, a very simple bandswitched L-network matching unit can be used to preselect 10, 15, 20, 40 and 80 meters quickly and reliably.

2) The system is preadjusted to provide a purely resistive load to the transmitter. Unlike other multiband systems, there is no reactance present to cause loading difficulties accompanied by rf in the shack and possible RFI.

3) There are no transmission-line losses. Consequently all of the rf from the transmitter is radiated by the antenna.

4) By using lobe alignment, the antenna yields useful directivity and gain over a dipole or vertical, especially at the higher frequencies.

5) On reception the antenna has a greater effective aperture at the higher frequencies than a dipole or vertical. In addition, the L network provides a degree of selectivity. The two together result in a stronger, cleaner signal.

6) The 2-wavelength version requires less than 14 meters (46 feet) of ground space. The length of the wire is obtained from the formula

$$L\text{ (feet)} = \frac{984\,(N - 0.0125)}{f\text{ (in MHz)}}$$

where N is the number of wavelengths at the highest frequency. (To convert from feet to meters multiply by 0.3048.) For example, for two wavelengths at 28.6 MHz, L = 68.4 feet (20.8 m). This is the overall length of the wire right up to the antenna terminal of the L network.

The circuit diagrams for L networks for 2- and 4-wavelength antennas are shown in Figs. 1 and 2, respectively. The adjustment procedure is to insert an SWR bridge

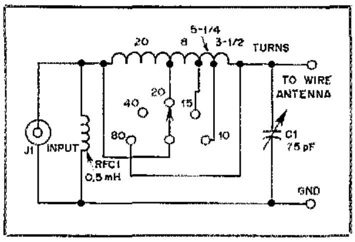


Fig. 1 — This simple, bandswitched L network is for use with the two-wavelength antennas of Figs. 3 and 5. Coil information is given in the text and Table 1.

Table 1

Coil Information for the Network of Fig. 1

Coil diameter (inches)	*Coil length (inches)*	*Largest usable AWG wire size*
1-3/8	1-1/2	18
1-1/2	1-7/8	17
1-5/8	2-3/16	15
1-3/4	2-5/8	14
1-7/8	3	13
2	3-1/2	11

Inches × 25.4 = mm

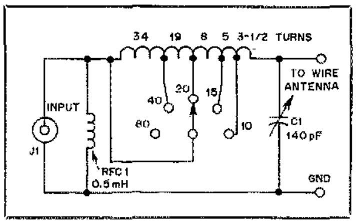


Fig. 2 — This L network is for use with the four-wavelength antenna of Fig. 4. See the text and Table 2 for coil information.

Table 2

Coil Information for the Network of Fig. 2

Coil diameter (inches)	*Coil length (inches)*	*Largest usable AWG wire size*
1-3/8	2-9/16	18
1-1/2	3-1/16	17
1-5/8	3-11/16	15
1-3/4	4-5/16	14
1-7/8	5	13
2	5-11/16	12

Inches × 25.4 = mm

*P. O. Box 46007, Orange Grove, Johannesburg, South Africa

†Adapted from an article in *Radio ZS*, January 1978, p. 8.

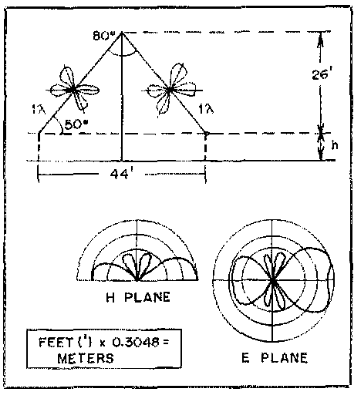


Fig. 3 — The standard ZS6U Minishack Special. H-plane and E-plane radiation patterns showing angle of radiation and directivity, respectively, are also shown.

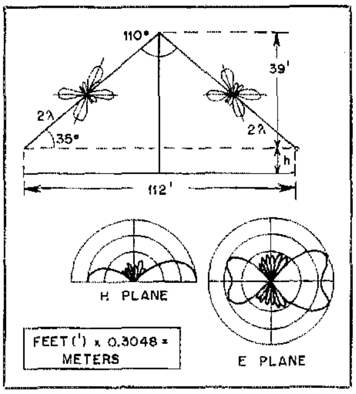


Fig. 4 — The full-size ZS6U Special has more gain than the standard version, especially on 80 meters.

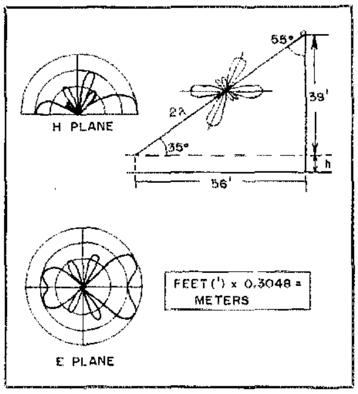


Fig. 5 — This version of the ZS6U special, which is two wavelengths long on 10 meters, may be just the solution to the antenna dilemma for many apartment dwellers.

between the rig and the L network, switch it to the reflected-power position and using sufficient carrier power on 40, 20, 15 and 10 meters in turn, adjust C1 for the lowest dip in the meter reading. With the two-wavelength system there is no tuning on 80 meters and C1 is merely set to minimum capacity. With the four-wavelength system the adjustment procedure for 80 is the same as for the other bands. Mark each band setting of C1 on its dial so that band changing merely involves switching the bandswitch and turning C1 to the calibrated mark for that band before tuning the rig.

The Wire Configurations

Having stretched and cut your measured piece of wire you will be looking for some way to string it up. The simplest way may be to use an L shape or you may need to take the wire in various directions to get it in the clear. Random shapes, however, do not do justice to the fine performance potential of this antenna. There are certain preferred configurations which will put the signal where it will do the most good. Be assured that the extra effort will be well worthwhile.

The principle of lobe alignment has been used in the three recommended configurations shown in geometric form in Figs. 3, 4 and 5 to achieve useful gain at low radiation angles. Using the formula and example given earlier, 2 wavelengths = 68.4 feet (20.8 m) and 4 wavelengths = 137 feet (41.8 m).

Fig. 3 depicts the standard ZS6U Minishack Special, which is 2 wavelengths long on 10 meters and 1/4 wavelength on 80. In this configuration, the change in direction of the wire at the apex splits the antenna into two 1-wavelength sections. Starting with the 50° lobe angle of a one-wavelength antenna in free space, the wire tilt, apex angle and height can be derived. The two pairs of horizontal lobes tend to reinforce each other to produce low-angle, bidirectional radiation along the plane of the wire. As with all end-fed antennas, the lobe amplitude in the free-end direction exceeds the reverse lobe because of progressive radiation loss along the wire. The gain of the 2-wavelength wire (about 2 dB) is added to the gain from lobe reinforcement (about 3 dB) to provide a total gain of about 4.5 dB. This gain is in a wide beam at a vertical angle of less than 10° in the direction of the open end of the wire. The theoretical patterns are shown in the accompanying vertical- and horizontal-plane diagrams for 10 meters. On the lower frequency bands the lobes become progressively misaligned, resulting in higher angles of radiation with less directivity and gain.

Fig. 4 is the full-size ZS6U Special. It is four wavelengths long on 10 meters and a half wavelength on 80. Here the tilt angle is 35°, resulting in a triangle having a height of 39 feet (12 m). If the dimension h, which represents the height at which the wire is connected to the L network, is taken to be 5 feet (1.5 m), then the pole height would be 39 + 5 = 44 feet (13.5 m), compared with 31 feet (9.5 m) in Fig. 3.

Because of the larger dimensions, the gain of the configuration in Fig. 4 is about 6 dB on 10 meters. It has a somewhat narrower beamwidth than the antenna of Fig. 3. As long as the full height is used, the performance on the five bands is better than the mini version by about 1.5 dB on each band. If the best possible performance is desired on 80 meters, this is the version to use. It requires the L network shown in Fig. 2.

The lobe-alignment principle for low radiation angles is also employed in the antenna of Fig. 5, which is half of the inverted V of Fig. 4. It has the same tilt angle and height but uses only two wavelengths of wire. As the polar diagrams indicate, this version is less desirable than the antennas of Figs. 3 and 4, but is preferable to a straight wire or a random shape. Apartment dwellers please note that this version may be used sloping downwards at the angle shown with good results. You will need to be on the fourth floor or higher.

Metal Obstructions

The near side of the wire is at high impedance on all bands and should therefore be insulated and kept as far as possible from metal window frames, gutters and cables. For example, it is not a good idea to close a metal-framed window with the wire clamped between the metal parts. Ideally, the near side of the wire should be secured to an anchor insulator and then should enter through a glass or plastic pane or a wooden window frame.

The support of the apex of the antenna should be a wooden pole guyed with nylon rope or metal wire broken by egg insulators. In certain cases where there are two suitable high points on either side of the antenna plane, they can be joined horizontally by nylon rope and the antenna wire can be thrown over the rope to form the apex.

If a metal pole is used it is best to shift it 7 to 10 feet (2 to 3 m) to one side so that it does not lie precisely in the vertical plane of the antenna. The resulting slight tilt in the plane will have little effect on performance.

All three configurations described show

decided gain in the direction of the free end of the wire and should therefore be erected pointing in the desired direction. If space allows, two antennas may be erected at right angles and switched to the L-network antenna terminal by means of a porcelain-insulated knife switch. Little is to be gained by joining two such antennas together, as the power in each would be halved. The impedance at the feed point would also be halved, upsetting the matching of the L network.

More About the L Network

Fig. 1 shows the network for two-wavelength antennas of the sort in Figs. 3 and 5. Fig. 2 shows the network that must be used with the antenna in Fig. 4. This network can also be used with lengths of 8, 12, 16 or 20 wavelengths.

One of the original problems facing builders of the original L network was that I used a piece of 1.4-inch (35-mm) OD polyethelene for the coil form and based my coil data on that. Here is a way for you to use the same number of turns and the same taps with a different diameter coil form. I derived the following formula, where L_1 and d_1 represent the given length of winding and diameter of coil, and L_2 and d_2 represent the new length and diameter:

$$L_2 = L_1 \left(\frac{d_2}{d_1}\right)^2 + \frac{d_2 - d_1}{2}$$

The formula is accurate over a 1.5:1 range. Tables 1 and 2 contain sets of values for each network. For example, if you use a coil diameter of 1.5 inches (38 mm) for the network of Fig. 1, you must spread the 20 turns evenly to occupy a winding length of 1.9 inches (47 mm). The maximum usable wire diameter given in the tables is derived from a spacing between turns equal to the wire diameter. An air-wound coil has the lowest losses, but if you use a coil form make sure it has a reasonably low power factor at 30 MHz. The switch is of the ordinary single-pole, five-position wafer variety, and the capacitor should have a spacing of at least 0.02 inch (0.5 mm) between the plates — otherwise arcing may occur. Enclose the unit in a plastic box. If a metal box is used, the coil should clear the metal by at least 1 inch (25 mm) on all sides.

I must emphasize that the L network must be looked upon as the equivalent of a quarter-wave transmission line and that resonance on each band (and therefore pure resistive load) is indicated by a dip in reflected power reading. If you leave your SWR bridge permanently in the line, here are a few words of advice. As hams are inveterate experimenters, it will not take you long to discover that if you fiddle with the L-network capacitor while tuning (contrary to instructions) you may find a setting other than the marked point on the dial which gives a higher reading on the "forward power" scale of the SWR bridge. You are about to fall into the trap of believing that you have discovered a way to radiate more power. But, alas, in reality the higher reading is caused by undesired reactive voltage being added to the desired resistive voltage. The moral is to interpret SWR-meter forward readings with caution.[1]

More About the Two-Wavelength Antenna on 80 Meters

Some constructors have had difficulty tuning the network on 80 meters. On this band the antenna is a quarter wave long — an earth ground is essential for its operation. As with any quarter-wave antenna, every foot of ground lead adds to the overall length of the antenna system.

If your ground system is so unsuitable that the antenna will not take power on 80 meters, there are three ways to handle the problem:

1) If the ground lead is about 15 feet (5 m) long or less, use a variable capacitor of about 300 pF in series with your antenna wire to cancel out the inductive reactance and electrically shorten the antenna. Set the capacitor for a minimum reflected power reading on the SWR bridge. This capacitor should be shorted out during operation on the other bands.

2) Use can be made of the property of a half wavelength of wire to repeat at its near end the conditions that exist at its far end. Choose a ground point sufficiently far away to accommodate a half-wavelength of ground wire at 80 meters. Use insulated wire because the middle of the wire will be at rf potential above ground. By varying the length of this wire, the antenna can be brought into exact resonance.

3) Use can be made of the property of a quarter wavelength of wire to act as an inverting transformer. Connect one end to the ground terminal of the L network and leave the far ehd free. The excess wire can be stapled around the skirting of the shack, hung out of the window or trailed along the ground, but must not be grounded. As in par. 2 above, its length can be trimmed to provide exact resonance. It should be noted that with this method an additional electrical ground must be provided to the rig for lightning and shock protection. If this protective ground upsets the antenna resonance, connect an rf choke in series with it consisting of a close-wound single layer of wire on a 1/2-inch (13 mm) OD ferrite rod. In any case, it is a good idea to use such a choke, especially when the ac-line ground is used, to reduce RFI with your neighbors.

Here's wishing you an outstanding signal. QST

[1]See "What Your Wattmeter Really Reads," by J. T. Kroenert, in February 1981 *QST*.

Strays

TA PROFILES

☐ Where would we be today without the knowledge of professionals in the area of safety and health? Probably in deep trouble! We are grateful to have on our TA roster an expert in this field, ARRL Technical Advisor John J. Champa, K8OCL.

First licensed in 1959 as KN8OCL, John presently holds an Advanced class license. His primary interest in Amateur Radio is satellite communications. He is a life member of the ARRL and AMSAT, a member of the Columbus Amateur Radio Association, Central Ohio Amateur Radio Emergency Service, plus numerous other societies.

John received his BA degree in Sociology/Psychology from Ohio State University, his MA in Management and Supervision from Central Michigan University and his DBA in Organizational Behavior from Western Colorado University. He is employed at Cooper Energy Services as Manager, Safety and Workers' Compensation. He resides in Columbus, Ohio, and enjoys gardening, music, reading and weight lifting. — *Marian Anderson, WB1FSB*

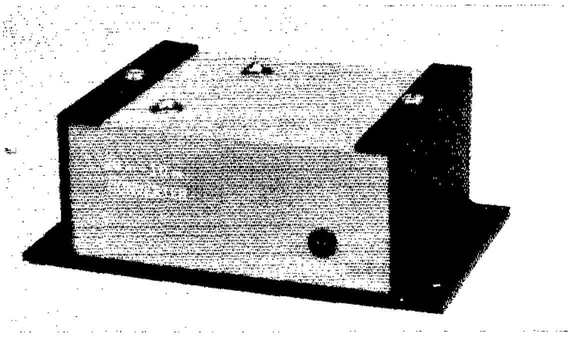
TA John J. Champa, K8OCL.

I would like to get in touch with . . .

☐ anyone interested in forming a scientist's net for radio amateurs. Ben Hawkins, KAØDVL, 6879 South Elizabeth Circle, Littleton, CO 80122.

☐ anyone building, flying or otherwise dealing with ultralight aircraft. Dominic A. Burlone, WD4IFY, Rte. 2, Stagecoach Dr., Anderson, SC 29621.

A QRP Transmitting Converter



Double up and have some fun as you chase 10-meter DX. Converting from 14 to 28 MHz is a simple technique that may be used at other frequencies as well.

By Jim Pitts,* KE4Y

Low atmospheric noise levels make the 10-meter band an excellent choice for QRP operation. Unfortunately, many QRP circuit designs cover only the 160- to 20-meter bands. This is primarily because of stability problems encountered when constructing simple VFOs for operation above 14 MHz. Also, it is difficult to build direct-conversion receivers with sufficient sensitivity and stability for use at higher frequencies. The 20- to 10-meter transmitting converter described here was designed for use with low-power transmitters or transceivers. At my station, the converter is used in conjunction with the Heath HW-8 transceiver and a separate ham-band receiver.

Circuit Description

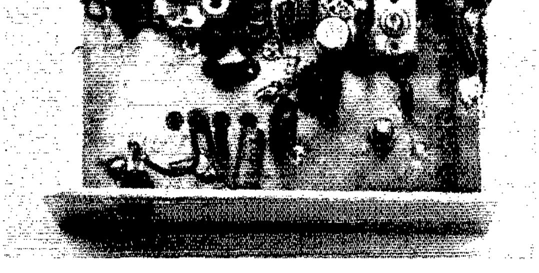
The design of the converter shown in Fig. 1 is based on principles outlined in *Solid State Design for the Radio Amateur.*[1] Many different circuits, some involving several stages, were tried before this simple circuit was chosen. It features simplicity, low cost and flexibility for adaptation to other bands.

The "heart" of the converter is the frequency-doubling stage. The 14-MHz input signal is transformed into a 28-MHz output signal by the action of D1, D2 and T1. You may recognize this configuration as being similar to that found in a full-wave power-supply rectifier circuit. R1 is used to compensate for differences in the characteristics of the diodes and secondary windings of T1. Asymmetry in these components would produce a nonsinusoidal waveform which would result in strong 14-MHz fundamental feedthrough. According to DeMaw and Hayward, diode doublers can suppress fundamental feedthrough by more than 40 dB.

C1 couples the 28-MHz signal to T2 and T3, which form a broadband impedance-matching network. The 16:1 matching network feeds the base of the transistor, Q1, through a ferrite bead. This bead and R2 help stabilize Q1, which is prone to oscillation because of its high f_T. The transistor is an easily obtainable 2N3866. This is an npn silicon vhf transistor with an f_T of 800 MHz and a maximum collector dissipation of 5 watts.

The output pi network provides some protection against the radiation of harmonics of the 28-MHz signal. However, ARRL lab tests showed that the addition of a low-pass filter was required to ensure spectral purity. Pads have been provided on the pc board for the installation of the required filter components. With the addition of these components, the second harmonic is suppressed approximately 64 dB below peak power output.

The simplicity of the QRP transmitting converter may be seen here. Low-pass filter components are grouped at one corner of the pc board beneath the binding post used as the dc input connector.



Construction

The prototype of the frequency doubler was constructed on single-sided pc board using a method similar to that of the ARRL breadboard described in *QST.*[2] This method is fine for construction of small, noncritical circuits and allows circuit changes to be made with a minimum of effort. A slightly more rugged and aesthetically pleasing version may be built using double-sided pc board, and this is the method used in the model shown here. (See Figs. 2 and 3.)

The board is mounted in a small enclosure that I purchased at a hamfest. A dull-black and fawn-gray paint job adds a professional appearance to the completed unit. J1 and J2 are phono jacks, but other types of connectors may be substituted.

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[1]Notes appear on page 37.

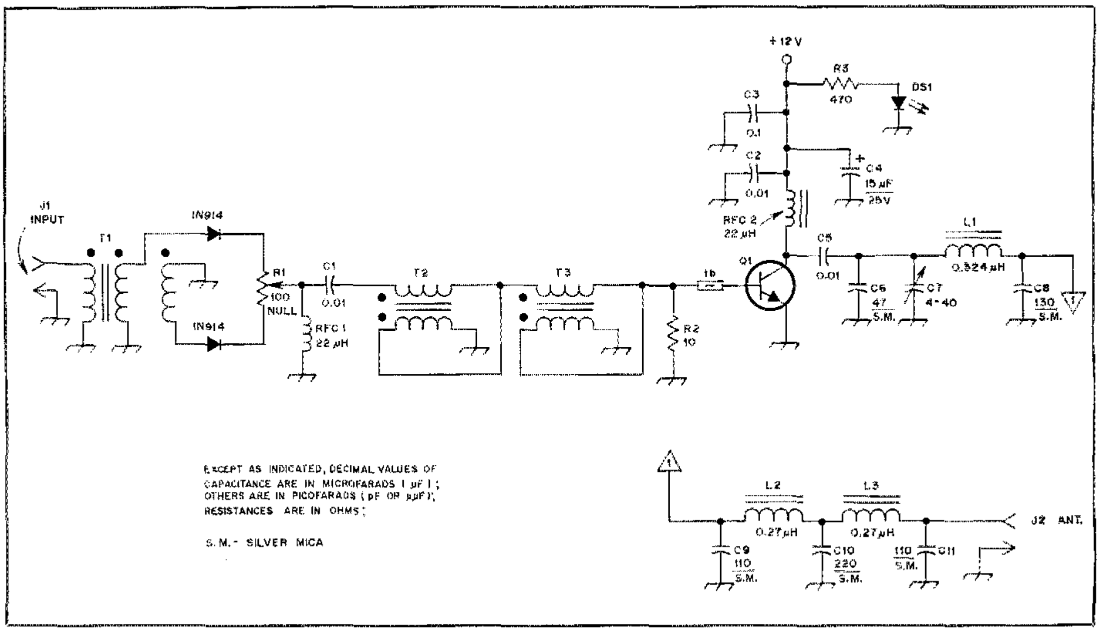


Fig. 1 — Schematic diagram of the transmitting converter. R1 is used to null the 14-MHz signal feedthrough. The low-pass filter consisting of C9, C10, C11, L2 and L3 is required to reduce the harmonic content in the output signal.

C1, C2, C5 — 0.01 µF, 100 V disc ceramic.
C3 — 0.1 µF, 100 V disc ceramic.
C6 — 47 pF silver mica or polystyrene, 100 V.
C7 — 4-40 pF trimmer (Arco 403 or equiv.).
C8 — 130 pF silver mica or polystyrene, 100 V.
C9, C11 — 100 pF silver mica or polystyrene, 100 V.
C10 — 220 pF silver mica or polystyrene, 100 V.
D1, D2 — Silicon, fast switching, 100 V; 1N914 or equiv.
DS1 — 3-V, 50-mA (max.). Radio Shack T1 mini LED (276-026) or equiv.
FB1 — Ferrite bead.
J1, J2 — Phono jacks.
L1 — 9 turns no. 23 enameled wire on T-50-6 core (0.324 µH).
L2, L3 — 5 turns no. 24 enameled wire on T-50-6 core (0.27 µH).
Q1 — Silicon npn vhf transistor (see text).
R1 — 100-Ω, pc-mount potentiometer.
R2 — 10 Ω, 1/2 watt.
R3 — 470 Ω, 1/2 watt.
RFC1, RFC2 — 20 turns no. 28 enameled wire on FT-37-61 core (0.324 µH).
T1 — 8 twisted trifilar turns no. 28 enameled wire on FT-37-61 core.

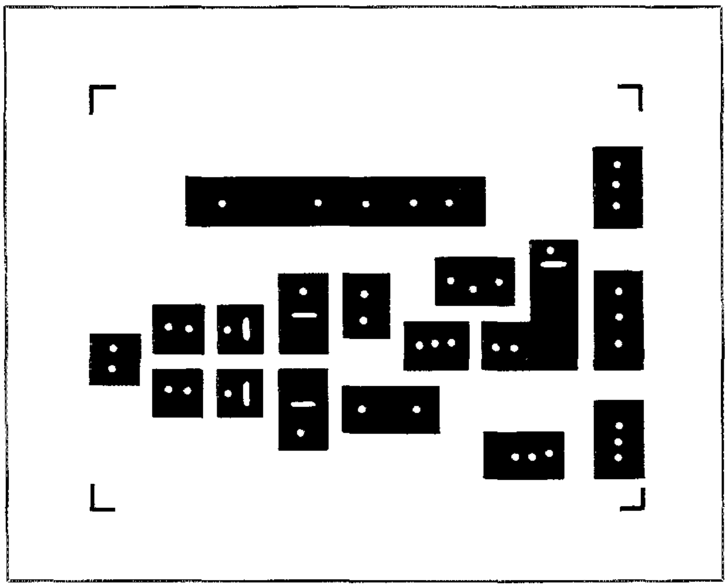


Fig. 2 — Actual size circuit-board etching pattern. Black areas represent copper. A double-sided board is used; only one side is etched. Clearance holes are drilled at the appropriate locations on the ground-plane side of the board to pass the component leads.

Connections from the board to the jacks are made with RG-174/U coaxial cable. An LED is used as a power-on indicator. A dpdt switch might be added to allow switching the doubler in and out of the line.

Alignment

The tune-up procedure is simple, but care must be taken to ensure stability. With no dc voltage applied to the converter, feed a 1-watt, 14-MHz signal into J1. While listening to the 14-MHz signal feedthrough with a receiver, carefully adjust R1 for a deep null in the signal strength. Next, attach a dummy load (a 52-ohm, 2-watt resistor will do) and power-indicating device such as a VSWR meter to J2. Apply 12 to 13.5 V dc to the converter and once again inject the 14-MHz signal at J1. Listen for the 28-MHz signal with the station receiver and adjust C7 for a peak in the signal strength; the SWR reading should be low. The converter may now be placed in the line and a careful check made for spurious emissions in the 10- and 20-meter bands. Hashy noise anywhere indicates parasitic oscillation problems. If such oscillations exist, try reducing the 14-MHz signal drive level and readjusting C7. Ensure you have the shortest possible emitter lead length on Q1. The output of the doubler should be approximately 1 watt. If more output is desired, you may try using higher values for R2, but stability is likely to be harder to achieve.

Additional Notes

The lack of tuned circuits in the doubler design is deliberate. As such, a simple change in the output-network component values makes it useful on other frequencies. Provisions could be made for switching the output networks as desired.

As with any similar multiplying scheme, VFO bandspread will be sacrificed. A 50-kHz transmitter frequency change results in a 100-kHz change at the doubler output. On the other hand, 500 kHz of the 10-meter band can be covered with a transmitter tuning range of only 250 kHz. Several 1000-mile (1600-km) contacts have been made using this transmitting doubler with a simple dipole antenna. Under proper ionospheric conditions, you too can expect similar results.

Notes

[1]Available from the ARRL, $7.
[2]Leslie, "Breadboard Revisited," February 1974 *QST*, p. 30.

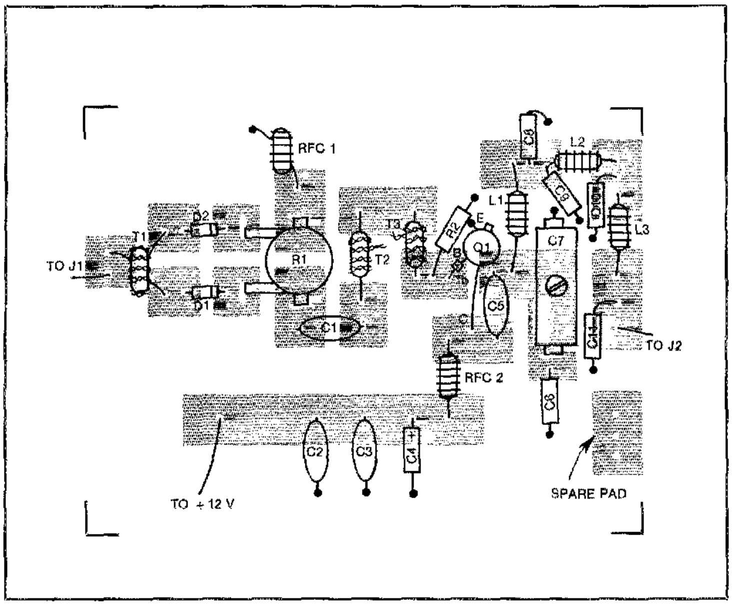


Fig. 3 — Parts-placement guide for the transmitting converter. A double-sided board is used with the components being placed on the ground-plane side of the board; the shaded areas represent an X-ray view of the etched side of the board.

Strays

John Walker, WD4HSF, and his wife, Lynn, stand before their yacht, *Gusto*, docked at Whangarie, New Zealand. The Walkers crossed the Pacific Ocean from the U.S. East Coast via the Panama Canal, and plan to resume their around-the-world voyage this spring. Look for John on 15 and 20 meters. *(photo courtesy of Paul M. Wilson, W4HHK)*

HIGH SPEED CLUB OF GERMANY

☐ The High Speed Club (HSC) is an international organization of cw operators, with headquarters in West Germany. HSC administers a number of awards and their club station is DLØHSC. For further information contact Edgar Schnell, DL6MK, or Kurt R. Schmeisser, W8LZV, 20114 Houghton Ave., Detroit, MI 48219, Tel. 313-534-4456.

WESTLINK TRUST FUND

☐ Rather than succumb to a less-frequent broadcast schedule, the weekly Westlink Amateur Radio News has set up a trust fund and is turning to the amateur community for support. If you would like to contribute, make your check payable to the Westlink Radio Network, c/o Dr. Norm Chalfin, K6PGX, P. O. Box 463, Pasadena, CA 91102.

QST congratulates . . .

☐ Gerry Wood, WB4ZQN, who was recently named Editor-in-Chief of the international music industry trade publication, *Billboard*.

ROANOKE DIVISION MEETING

☐ The Roanoke Division will hold a League Planning Meeting on May 9 and 10, 1981, at the Ramada Inn at Tyson's Corners, Falls Church, Virginia. All League members in the division are invited to attend, and each affiliated club in the division is urged to send at least one representative. All inquiries should be forwarded to: Northern Virginia Amateur Radio Council, P. O. Box 682, McLean, VA 22101. Reservations for rooms should be made directly with the Ramada Inn at 800-228-2828. Expressly request a reservation receipt. — *Gay Milius, W4UG*

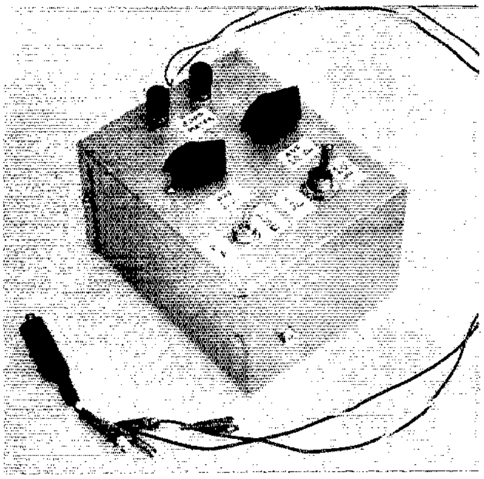
I would like to get in touch with . . .

☐ anyone knowing about the disposition of equipment of the late Dr. James Hard, XE1GE, deceased circa 1941. John Nagle, K4KJ, 12330 Lawyers Rd., Herndon, VA 22071.

☐ active members of Toastmasters International. Al Markwardt, W5PXH, 826 Sherbrook Dr., Richardson, TX 75080.

☐ those in need of KH6 contacts to meet daily on 15 meters. Contact Warren O. Smith, KH6AQ, 525 Pauka St., Kailua, Oahu, HI 96734.

Paying OHMage to Low Resistance — The Lohmeter



This project shouldn't be impeded by cost — it's low, too!

By Robert M. Forster,* W2DVG

Do you ever make meter shunts, check for ground connections, or estimate the copper losses in the secondary windings of a high-amperage transformer for that new regulated power supply you're building? If so, the low-ohms measuring meter described here is a simple and practical instrument that will make your job easy.

The Basics

This approach is by no means new, but it has had little attention in amateur publications. It's based on the principle of measuring voltage drops across a series chain of resistors carrying a uniform current. The instrument has the advantages that the readout scale is linear and that lead resistance from it to the unknown resistance is irrelevant.

Refer to Fig. 1. R1 is a current-adjustment resistor used to set the pointer of voltmeter M1 to full-scale deflection (FSD). R2 is the "standard" resistor — a resistor of known value. R3 and R4 represent the resistances of the leads from the instrument to the unknown resistance to be measured, RX. M1 and M2, identical voltmeters, measure the voltage drops across the standard resistance and at the *terminals* of RX. The absolute voltages across R2 and RX are of no importance. It is only necessary to know the *ratio* of V2 to V1. Since the current through the resistance chain is uniform, the voltages measured by M1 and M2 are proportional to the resistances of R2 and RX. Thus, if the FSD of M1 (as set by R1) is 100 and M2 registers 25, RX will have a resistance of 25/100ths of R2. For instance, with a 1-ohm standard, if M2 registers 87, RX is 0.87 ohms.

You can select a range to suit your needs: A 0.1-ohm standard provides a range from zero to 0.1 ohm, a 5-ohm standard sets the range from zero to 5 ohms, and so on. In a practical system, two separate voltmeters are neither necessary (a single unit can be switched) nor desirable (if they are not identical, the results will be erroneous). However, the single meter used should be a high-impedance type, 20 kΩ/volt or more.

A Practical Instrument

One example of this type of ohmmeter is shown in Fig. 2. The voltmeter is not built in. An instrument of this kind is not so frequently used that a good meter need be tied up permanently. Instead, a Simpson Model 260 VOM (or equivalent), using the 50-μA current-measuring position, is connected when making measurements. A 1-kΩ multiplier resistor (R1) is built into the case to permit it to be used as a voltmeter. Two resistors, R4 and R5, are used for the standard to provide ranges of measurement from 0 to 1 and 0 to 10 ohms.

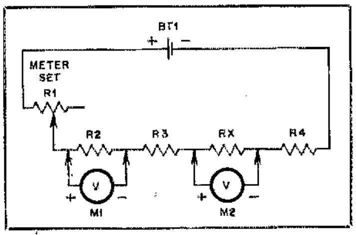
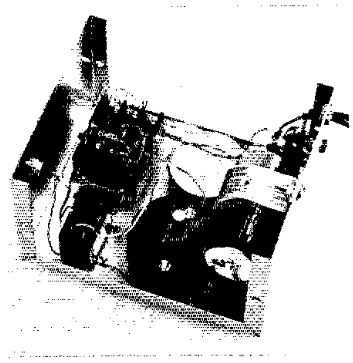


Fig. 1 — The basic circuit of the instrument. R1 is used to set the pointer of M1 at full-scale deflection.

Construction

Except for the 5 × 4 × 3-inch (127 × 102 × 76-mm) enclosure, all the parts used in my unit came from the ubiquitous "junk box." The 1-ohm standard was made using wire from a broken heater element; the 10-ohm unit is a combination of composition resistors. Access to a Leeds and Northrup bridge made accurate measurement of these resistors possible, but 5%-tolerance resistors will suffice.

S1 is a 3pdt heavy-duty switch. As may



The "standard" resistors are shown bridged across S1. An insulated standoff is used to support one end of R1. The binding posts are beneath the battery and not visible in this photo.

*130 Steelman Rd., Southern Pines, NC 28387

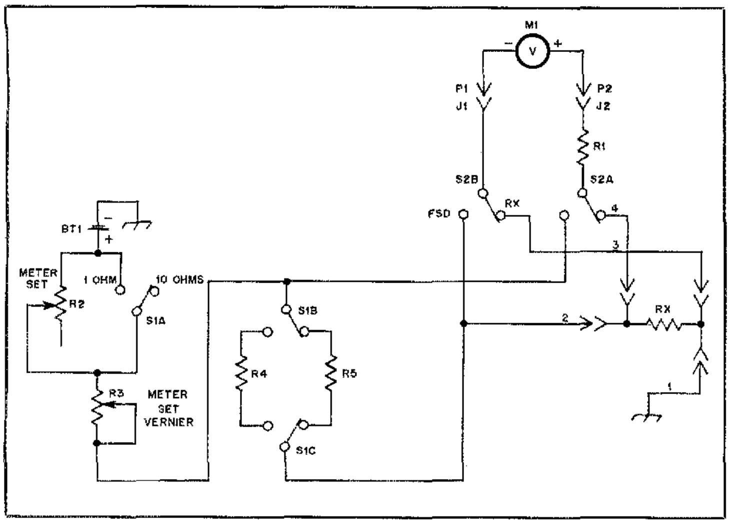


Fig. 2 — Schematic diagram of a practical instrument for measuring low ohmic values. A functional description is given in the text.

BT1 — 1.5-volt battery.
J1, J2 — Suitable connectors to mate with meter test leads.
M1 — 0-50 μA meter, may be part of a VOM (see text).
P1, P2 — Part of meter test leads.
R1 — 1-kΩ, 1/2 watt.
R2 — 50-Ω potentiometer, Mallory C50R or equivalent.
R3 — 6-Ω potentiometer, Mallory C6R or equivalent.
R4 — 1-Ω "standard," 5%, see text.
R5 — 10-Ω "standard," 5%, see text.
S1 — 3pdt switch, Cutler-Hammer 7615K2 or equivalent.
S2 — Dpdt switch.
Misc. — Alligator clips, enclosure.

be seen in the photograph, the outside lugs support the two standards. One switch section is used to short out R2 in the 1-ohm measuring position as shown in Fig. 2.

A word about the R2-R3-S1A network. A resistance range of 50 ohms is needed for FSD with all possible measurements. However, a vernier adjustment is desirable when setting the FSD for low values of RX. By combining R2 and R3, that vernier adjustment is available when needed.

The four leads to RX can be of any length required to suit the convenience of the constructor. Caution should be exercised when making the interconnections to prevent the possibility that the voltmeter pointer will be deflected in opposite directions when S2 is switched between FSD and RX. Leads 1 and 3 should be prepared using wire of one color, and leads 2 and 4 of another color. Then the matching colored wires are connected to each side of the RX terminals. An insulated boot should be placed over the alligator clip on lead 2 because when leads 1 and 2 are connected, current is drawn from the battery. If these leads accidentally touch while the unit is in storage, the battery will be under continuous discharge.

Setup

To prepare for use, leads 1 and 2 are connected across RX, the unknown resistance. The leads need not be very short. S2 is placed in the FSD position and R2 (or R3) adjusted until full-scale deflection is reached on the meter. Then leads 3 and 4 are connected across the unknown resistance with the clips directly applied to the terminals of RX. S2 is then switched to the RX position. The ratio of the RX voltage to the FSD voltage indicates the ratio of the ohmic value of RX to that of the "standard" resistor. It is convenient to use a meter scale on the VOM of 0-100 when a 1-ohm or 10-ohm standard is employed.

Application and Results

This meter has many uses: the making of meter shunts and current sensing resistors, distinguishing dead shorts from low-resistance paths, measuring resistances between "grounds," and determining the resistance of high-current power transformer windings. Many other possibilities exist, as well.

The accuracy of the measurements obtained will depend upon: the precision of the resistors used as standards, the ability to set the pointer of the meter to full-scale deflection, the linearity of the meter itself and how accurately the meter is read. With reasonable care, no difficulty should be encountered in achieving results commensurate with amateur practice.

Strays

ARRL PRESENTS ITS 13TH IEEE PROFESSIONAL PROGRAM

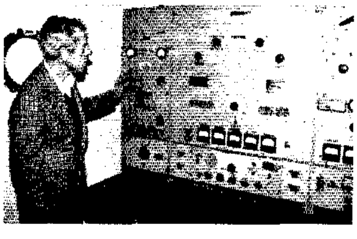
□ The League presented its 13th Technical Symposium for the IEEE (Institute of Electrical and Electronics Engineers) this year on January 14 at IEEE SOUTHCON in Atlanta, Georgia. The Symposium, Session 15, was entitled, "Modern Solid-State Devices, Techniques and Applications for High-Performance RF Communications Equipment."

Two of the committed speakers ARRL TA Rick Olsen, N6NR, and ARRL TA Ed Oxner, KB6QJ, had to cancel their appearances at the last minute. They were replaced by backup speakers Bill Allen of Lockheed (Georgia) and Tom Hayes of the Boston Siliconix office.

The session organizer was Doug DeMaw, W1FB. The organization of the program was aided by Marian Anderson, WB1FSB, who served also as session chairperson. A paper was presented by W1FB. The fourth speaker on the program was Dr. Ulrich Rohde, DJ2LR.

A show of hands indicated that approximately 75 percent of the attendees were radio amateurs as well as engineers. This has been typical during the eight years of ARRL involvement in IEEE technical sessions.

This was the first year for SOUTHCON. It will be held yearly and will alternate between Atlanta, Georgia, and Orlando, Florida. Amateurs are invited to attend the ARRL-organized sessions at IEEE ELECTRO, MIDCON and SOUTHCON Conventions. It's a good opportunity also to see the latest in components and test equipment. ELECTRO-81 will be held this year in New York City from April 7-9. The League's session is No. 30. It will be held at 12:30 p.m. on April 9, and the subject is antennas. See you there! — *Doug DeMaw, W1FB*



Thomas Stand, N6UG, inspects the autoalarm in the restored radio room of the *SS Jeremiah O'Brien*, the last unchanged World War II Liberty Ship. Members of the San Francisco Radio Club volunteered their time and efforts to complete this restoration. The ship is now permanently moored at Fort Mason in the Golden Gate National Recreation Area. *(Photo by John Wheaton, WA6MXS)*

From Cigar Lighter to 9.6 Volts

Mobiling with a hand-held transceiver? Here's a weekend project that won't drain your pocketbook or the transceiver batteries.

By Raymond Charland,* WA1IKJ

I own a Kenwood TR-2400 2-meter fm hand-held transceiver. A desire to eliminate using the internal batteries of the transceiver while mobiling led to the development of the circuit shown in Fig. 1.

Description

This adapter reduces the voltage available at the vehicle cigar-lighter socket to the 9.6 volts required by the transceiver. It maintains regulation over a current range of 30 mA during receive to approximately 600 mA during transmit and includes fail-safe protection by employing a 1-A fuse and a Triac "crowbar." R1 is used to adjust the output voltage to 9.6 volts and the combination of D3, Q1, R3 and R4 are part of the protection circuitry which will open the 1-A fuse should the regulator fail and more than 11.5 volts appears on the output line.

R5 and DS1 were late additions to the circuit and are used to indicate actual power availability. Their inclusion is the result of a few weeks of operating with the adapter in vehicles equipped with cigar-lighter receptacles having varying degrees of contact cleanliness. The TR-2400 memory contents would be erased unknowingly if an instantaneous loss of supply voltage occurred — most aggravating. Now, the LED will indicate any such loss of voltage.

Construction

The adapter I built is wired point-to-point in a 1-1/8 × 2-1/8 × 3-1/4-inch (28.6 × 54 × 82.6-mm) plastic box with an aluminum cover (Radio Shack 270-230). The voltage regulator, U1, is mounted on the aluminum cover. With a continuous current drain of 800 mA, the regulator and cover get warm, but not excessively. All parts attached to the box cover are in the 9.6-volt positive lead, but should the cover be grounded accidentally to the car, F1 will open.

Input and output leads are fed into the box from opposite ends through rubber grommets. The input lead is fitted with a cigar-lighter plug and includes an in-line fuse holder for F1. I fitted the output lead with a plug to mate with the charger input jack on the TR-2400.

In order to switch between the transceiver internal battery pack and the adapter, I installed a small, single-pole, two-position switch in the battery pack cover. The charger jack is used for the adapter input as well as its original purpose.

I'm sure you'll find the construction of this adapter well worth the small expenditure of time and effort. It's especially handy when you encounter extended operating periods in an environment which provides a readily available source of + 12 volts.

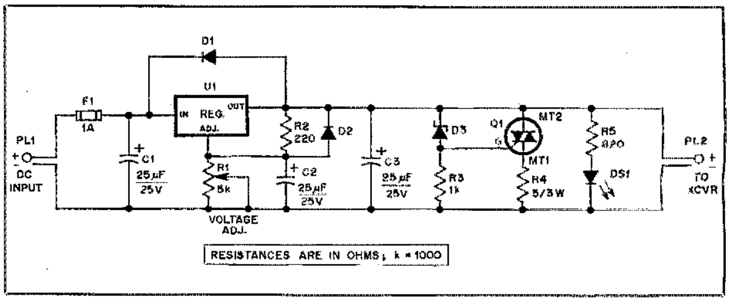


Fig. 1 — Schematic diagram of the adapter. Construction of the unit is described in the text. F1 is mounted in an in-line fuse holder. Resistors are 1/2-W types unless otherwise specified.

D1, D2 — Silicon, 1-A, 50-PIV, 1N4001 or equivalent.
D3 — 11.5-V, 1-W Zener.
DS1 — Miniature red LED.
F1 — 1-A fuse.
PL1 — Cigar-lighter plug.
PL2 — Miniature plug to mate with transceiver jack.
Q1 — 200-V, 6-A Triac (Radio Shack 276-1001 or equivalent).
R1 — 5-kΩ linear-taper potentiometer.
U1 — Adjustable 3-terminal 1.5 A positive voltage regulator, LM317K or equivalent.

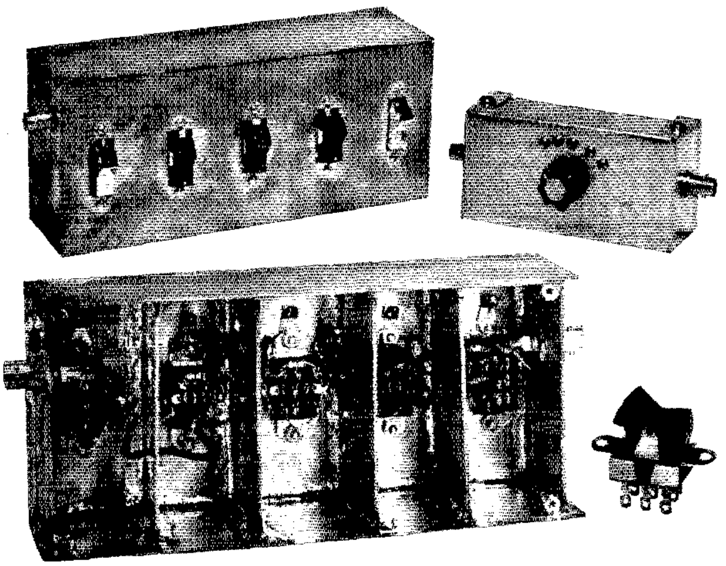
*Summit Rd., Prospect, CT 06712

• *Basic Amateur Radio*

Knock-It-Down and Lock-It-Out Boxes for DF

Direction finders know that the real trick is pinpointing the signal when you are within a few hundred feet of the source. Here are a couple of devices that will keep the nearby signal from "blowing away" your receiver front end.

By Peter O'Dell,* KB1N



Two approaches to building the attenuator. Rotary switch model (upper right) is smaller, lighter and less effective. Lower photo: inside view of rocker-arm switch version of the attenuator. During construction slight variations in the positioning of the resistors were tried for improved isolation between ports. Test data revealed no significant difference. RG-174/U routed through small holes in the walls connects one stage to the next. Copious amounts of solder are used to bond the walls to ensure minimal leakage from one compartment to another. Size of box (and compartments) is not critical.

A few years back I was in the ARRL lab when a manufacturer came in with a new transceiver. He proudly announced that this receiver had an "uncrunchable" front end. Doug DeMaw, Senior Technical Editor, looked at him, smiled and said, "Nothing has an uncrunchable front end when you are next door to W1AW. We've put an rf voltmeter between an antenna terminal and ground here when W1AW is on the air and measured in excess of 15 V rf." The manufacturer paled somewhat, but went ahead with his tests and demonstration. As I recall the receiver did have a good front end, but it didn't quite stand up to W1AW.

When you are in the presence of strong rf fields, it is necessary to alter your procedures when making measurements involving rf. One of the simpler devices for assisting in this problem is an attenuator. An attenuator does what its name implies; it attenuates or reduces the level of a signal. A good commercial attenuator will cost upwards of $100. Another device that can be useful in strong rf fields is a screen room. The ARRL lab, along with most major radio manufacturers, has a screen room available for testing equipment. A screen room is an enclosure usually big enough for at least one person and several pieces of equipment. The room is completely surrounded by a good conductor such as copper. Rf on the outside stays on the outside, and rf on the inside stays on the inside. A screen room will cost thousands of dollars and is usually not very portable. This month we have a couple of cheap imitations that will substitute very nicely for these "high-priced spreads."

Knock It Down

My initial investigations of the antenna described last month[1] (see Feedback in this issue for an update on phasing harness construction) indicated that, for my receiver to be able to discern a null in the signal level, it needed up to 60 dB of attenuation in front of it. In other words, the signal level at the output of the attenuator should be 1/1,000,000 of the power at the input. In fact the 60-dB figure seemed to be a bare minimum with 70 or 80 dB being even better. That is not as difficult as it may sound. I said earlier that a good commercial attenuator will cost upwards of $100, so you are probably sitting there mumbling that this turkey in Newington is going to tell me to go out and plop down $100 for something I will use once a month or less for bunny hunts. Well, for less than $10 in parts and three or four hours of your time, you can have an attenuator that will work very well up to 250 MHz. After you have it built and have learned to use it, you will probably find lots of other uses for it and will wonder how you ever got along without it.

Fig. 1 shows two different types of attenuator pads that consist of three

*Basic Radio Editor

[1]Notes appear on page 44.

resistors each. Resistors aren't that expensive, even 5% tolerance variety. The pad at A is a T network (if you straightened out the bends in the schematic diagram, the pad would look like a letter T). The pad at B is a pi circuit (you guessed it; it looks like the Greek letter pi). Notice that each circuit is symmetrical; i.e., its input looks just like its output. The input and the output of each can be used interchangeably. The circuits are designed to present a nominal impedance of 50 Ω and an attenuation of 12 dB, but notice the difference in resistance values. The choice of which circuit arrangement to use is normally a matter of which is the most convenient for mechanically arranging the resistors. More on this later. Also, one type of circuit for a given attenuation value may call for oddball values of resistors that are not commonly available, while the other network for the same attenuation may call for values near standard.

Thus, you see, one pad in and of itself is simple. The problem is to isolate the input from the output. This can be done by keeping the input physically separated from the output and by judicious use of shielding. If you wanted a 100-dB attenuator, you could build a box from circuit board material with five compartments in it and put in five 20-dB pads in series. This would be fine if the only value of attenuation you ever needed would be 100 dB. Such is not the case.

Fig. 2 shows a simple solution to this problem. We have added a double-pole double-throw switch to each of our compartments. With the switch in one position, the attenuator pad is in the circuit; in the other position, the pad is out of the circuit. Ah, much more versatile! Unfortunately, the fundamental rule of economics (and everything else in the

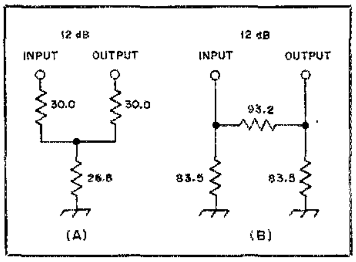


Fig. 1 — Schematic diagrams for two attenuator pads. At A, an attenuator in a T configuration; at B, a pi configuration. Both pads have nominal input and output impedances of 50 Ω. Both are symmetrical.

universe) is "there *ain't* no such thing as a free lunch." The price to be paid here is primarily that the sets of switch contacts will look somewhat like a capacitor. Depending on the style of switch, this "phantom" capacitor may bypass the signal around the pad and send it on to the next stage at almost the same level that it arrived. This is one of the reasons that commercial attenuators cost so much. They are constructed to avoid this problem.

We can avoid this pitfall by carefully choosing our switches. Ordinary toggle switches are probably the worst possible choice. Slide switches or rocker-arm switches are the best bet of the types commonly available. I used rocker-arm switches that I obtained from a surplus dealer for a very reasonable price. Fig. 2 shows each section having a 20-dB pi-network pad. The pi network is convenient for use with dpdt switches. You may find it useful to replace one of the 20-dB pads with a 12-dB pad. This will give your attenuator increased versatility with little effect on total attenuation.

An Alternative to Our Alternative

Fig. 3 shows a somewhat easier-to-build version of the attenuator. S1 is a single-pole, six-position rotary switch. The enclosure is an ordinary aluminum box. Five 12-dB pads are wired in series; S1 permits us to select up to 60 dB of attenuation (theoretically, anyway). An aluminum box is certainly easier to work with than one made of circuit-board material. It is much simpler to drill a hole for the shaft of one rotary switch than it is to use a nibbling tool or file to make five rectangular holes for switches. No individual compartments are used in this construction. I used the T-circuit arrangement to avoid long ground leads, thinking this would provide better isolation between attenuator sections.

But again we run into the "no free lunch" rule. The single-switch circuit is easier to build, but it has some minor differences in operation. First let me mention that the arrangement of five switches and five compartments provides a constant 50 Ω system impedance. No matter how much attenuation is switched in or out between the antenna and the hand-held receiver, the terminating impedance in either direction is 50 Ω. (This assumes the hand-held receiver has a 50 Ω antenna input, although it may be something entirely different.) Not true with the single-switch attenuator circuit. The receiver and the bank of resistors are combined as a load for the feed line coming from the antenna, and this load changes with different switch positions. Similarly the load seen by the receiver, looking back toward the antenna, changes with different attenuation levels. These drawbacks are insignificant if our sole intent is to knock down

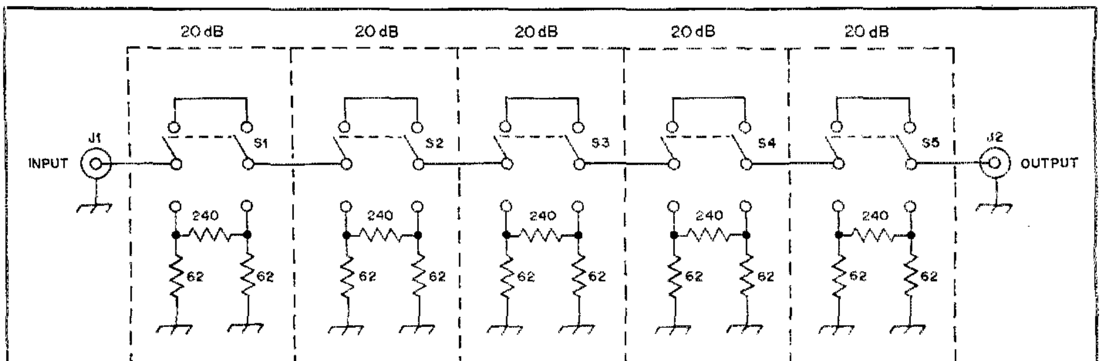


Fig. 2 — Schematic diagram of 100-dB attenuator. Resistance values are in ohms. Resistors are 1/4-watt, carbon-composition types, 5% tolerance. Broken lines indicate walls of circuit-board material enclosure. A small hole is drilled through each wall to route RG-174/U shielded hook-up cable. Leads are kept short. Enclosure dimensions are 7-1/2 × 3-1/2 × 2-1/4 in. (190 × 90 × 57 mm). See photo.

J1, J2 — Female BNC connectors.
S1-S5, incl. — Dpdt rocker-arm switches. Suggested source: Diamondback Electronics Company, P. O. Box 12095, Sarasota, FL 33578, Tel. 813-953-2829.

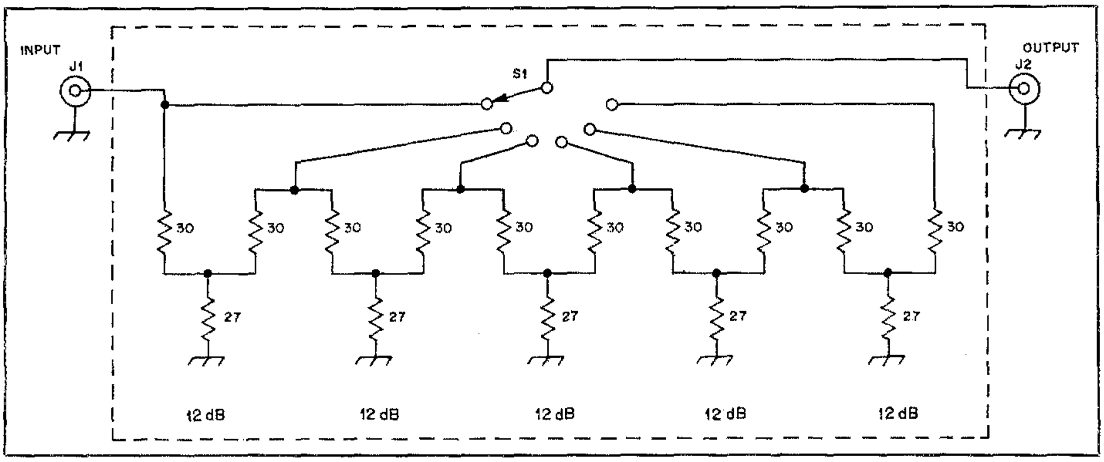


Fig. 3 — Schematic diagram for alternative-style construction. Resistances are in ohms. Resistors are 1/4-watt, carbon composition types, 5% tolerance. Broken lines indicate aluminum box housing. S1 is connected to the jacks with RG-174/U cable. Five solder lugs are mounted to the box around the switch to provide ground connections.
J1, J2 — Female BNC connectors. S1 — Single pole or double-pole, six-position rotary switch (Radio Shack 275-1386).

the level of an incoming signal. But for more precise work with attenuators you may want to devote some extra effort and use the five-switch arrangement.

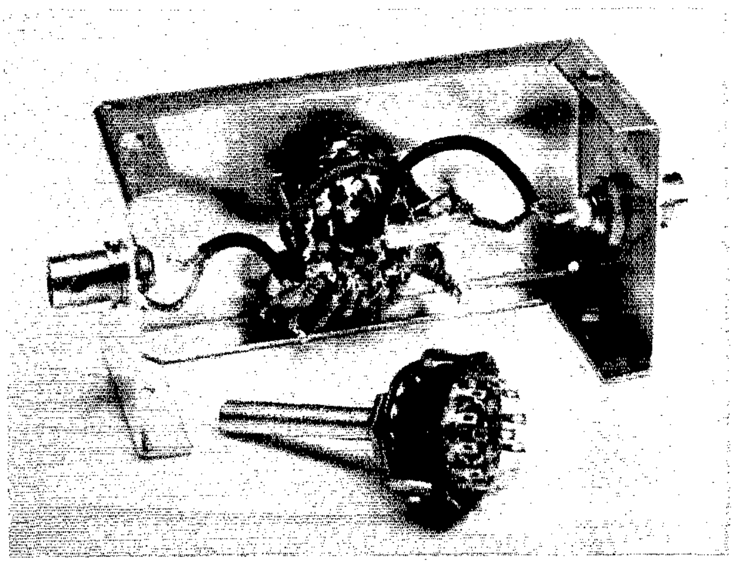
Is the extra effort worth it? For proof, we turn to the spectrum analyzer. An earlier article in *QST* gave a detailed description of the use of the spectrum analyzer.[2] Suffice it here to say that the spectral display shows a range of frequencies along the horizontal axis of a CRT. The vertical position indicates the amplitude (strength) of the signal at the corresponding frequency. Fig. 4 shows two traces on the CRT. The top trace depicts a sweep generator fed directly into the spectrum analyzer. The lower trace shows the rocker-arm switch attenuator added to the circuit and set to pass the signal straight through. The vertical divisions are 2 dB per major division, so the attenuator has an insertion loss of about 0.8 dB.

Fig. 5 shows four traces on the spectral display. The top trace was made with the attenuator connected and all switches in the "out" (pass through) position. The three traces below the top one display the results when switching in three of the 20-dB pads, one at a time. Hence, the attenuation actually obtained is very near the design value at these frequencies (150-MHz center frequency, 5 MHz per horizontal division and 10 dB per vertical division). Ultimate attenuation for the five sections of 20-dB pads was found to be 95 dB — just 5 dB short of the design value!

Fig. 6 depicts the results of the rotary-switch version of the attenuator. In this case the sweep generator was set to 0 dB (top of the CRT display). The attenuator was then added to the circuit and the top trace was made. Here we have an insertion loss of about 5 dB as a result of the impedance mismatches mentioned earlier. The second trace down is with the first section switched in. It is a nominal 12-dB pad and does produce approximately that amount of attenuation. Adding a 20-dB pad gives us another 16 dB. Now things start to get interesting! Add one more 20-dB pad and get a whopping 9 dB. The fourth section is a 12-dB pad and in reality nets us about 4 dB. What appears to be a thick trace at the bottom is actually two traces. That's right — the final 20-dB pad results in only 2 or 3 dB of actual attenuation, because the signal leaks around the networks!

From this analysis, we can conclude that taking the time to build a circuit-board box and using rocker-arm switches is worth it. If you don't want to take the time to do it right, then a rotary switch in an aluminum box will probably produce around 45 dB of attenuation. You might as well use 12-dB T pads throughout this one since they are easier to build in this

Rotary switch version. Although considerably easier to construct, this model does not perform as well as the rocker-arm switch type.



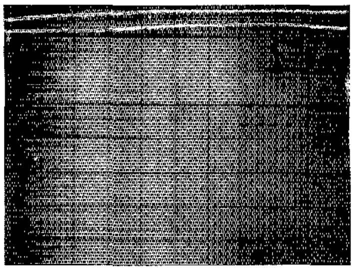


Fig. 4 — Spectral display depicting the insertion loss of the rocker-arm switch attenuator. (See text). Reticle graduations are 2 dB per vertical division, 5 MHz per horizontal division, 150-MHz center frequency.

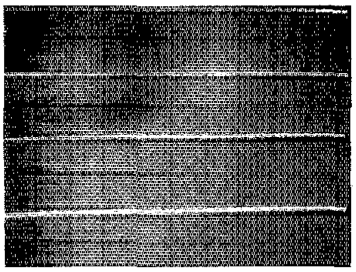


Fig. 5 — Spectral display showing the cumulative effect of adding 20-dB attenuator sections to the circuit. 10 dB per vertical division, 5 MHz per horizontal division, 150-MHz center frequency. See text for discussion.

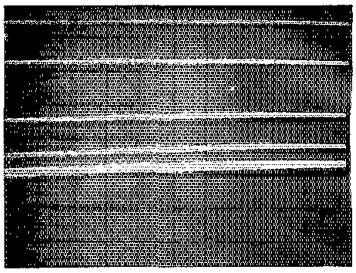


Fig. 6 — Spectral display depicting insertion loss and cumulative attenuation of rotary switch attenuator; 10 dB per vertical division, 5 MHz per horizontal division, 150-MHz center frequency. See text for discussion.

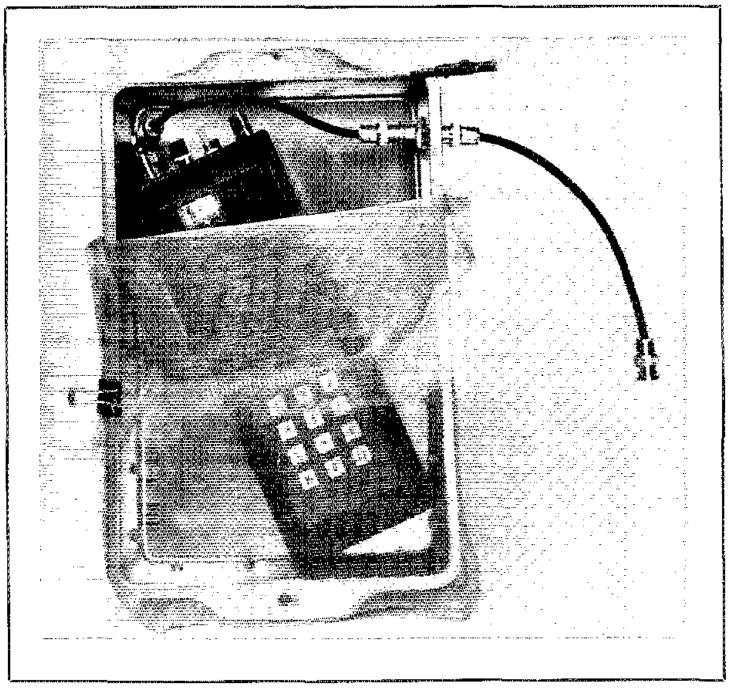
format than the pi sections of any value. You can probably get over 70 dB of attenuation by bolting two aluminum boxes together and building two identical attenuators in series. Other values of attenuator pads can be constructed from common resistors. If you would like to know more about these circuits, consult the *ARRL Electronics Data Book* or Chapter 16 in the *1981 Radio Amateur's Handbook*.

The Portable RF Coffin

Most modern, portable 2-meter fm rigs have plastic cases which are durable and help keep the cost of the equipment down. Unfortunately, rf passes right through the plastic. When you get within a few hundred feet of a 1-watt signal source you will probably find that more rf is going through the case than is coming through your antenna and attenuator. So what do you do? Put your radio in a screen room!

It would be foolish to suggest that you construct a full-fledged screen room and tote it about. You can, however, put the radio inside the equivalent and provide some means for being able to observe the meter movement from outside the enclosure. Because my radio already had the S meter mounted in its case, I chose to use screen wire for part of my enclosure. Thus, I could see the meter through it. The rest of this "portable rf coffin," as my co-workers dubbed it, consists of a breadpan that I paid $1.29 for in a local discount store. I used a BNC double-female bulkhead connector to route the rf into the enclosure. The screen is bolted to the pan for about 2/3 of the length of the pan. Once the radio is installed inside, large alligator clips or spring paper clips are used to keep the screen tightly meshed around the lip of the pan. If you have performed the S-meter modification presented in last month's article, you might consider mounting the meter to the lid of an aluminum box instead of using the breadpan and the screen wire.

The "rf coffin" or portable screen room. The screen wire is bolted to the lower 2/3 of the pan. The radio is connected to the external antenna through the coaxial cables and the double-female bulkhead connector. Several large spring paper clips or alligator clips are used to secure the screen flap once the radio is installed and adjusted.



I conducted some experiments in my backyard with the attenuators, rf coffin and cardioid antenna. I was able to get enough of a null to pinpoint a 1-1/2 watt transmitter from about 50 ft (16 m). Once I was closer than that, enough rf got inside the coffin to pin the S meter regardless of the direction of the antenna. Without the coffin, the S meter was pinned from a considerably greater distance. As DeMaw indicated, if you are close to a "big" signal, you will have to contend with front ends that go *crunch*.

These articles are intended to give you a few tips on the equipment that you will need for vhf fm direction finding. The projects are inexpensive, easy to duplicate with ordinary parts and easy to use. Your group can make up for a lack of sophisticated equipment with sheer numbers. Build the necessary equipment, get organized and go hunt a few tame little bunnies. That way you will be ready for the next wild turkey that comes along. QST

Notes

[1] O'Dell, "Simple Antenna and S-Meter Modification for 2-Meter FM Direction Finding," *QST*, March 1981, p. 43.

[2] Rusgrove, "Spectrum Analysis — One Picture's Worth a ..." *QST*, August 1979, p. 15.

Product Review

Conducted By Paul K. Pagel,* N1FB

Yaesu FT-107M HF Transceiver

The FT-107M is a full-featured, completely solid-state transceiver offering the radio amateur a high degree of versatility which is further enhanced by a variety of available options. Standard equipment includes all the features we have become accustomed to in an advanced transceiver; smooth VOX operation, an effective noise blanker, semi-break-in cw and a good rf speech processor, to name a few. Band coverage is complete, 160 through 10 meters, including the three new WARC bands.[1]

The all-solid-state PA is rated at 240 watts input on cw and ssb, and 80 watts input on a-m and fsk. Being solid-state, the PA is somewhat more sensitive to SWR than rigs using vacuum tube finals. Built-in protection circuitry automatically reduces input power in the event of high SWR, thus preventing damage to the output transistors. The power reduction is gradual, rather than the abrupt shut-off found on some rigs. Operating into a 2:1 SWR will result in approximately a 25% reduction in output power. The heat sink for the finals is fitted with a thermostatically controlled fan to cool the unit during long transmissions.

Other features of the FT-107M include a 20-dB attenuator, offset tuning on receive and/or transmit, and digital and analog frequency readout. Some of the more unusual features found on the '107 are an af peak/notch filter, SWR meter, 170-Hz fsk circuitry and variable i-f bandwidth. The af filter can be tuned from 300 Hz to 1.4 kHz in either the peak or the notch mode. Tuning in both modes is very sharp, and some care is required in adjusting the frequency for maximum effectiveness. The peak mode is useful on cw, even when the optional 600-Hz i-f filter is used. The variable bandwidth control is like that found on the FT-101ZD.[2] It allows the i-f bandwidth to be adjusted from 2.4 kHz to 300 Hz. This can be very helpful when operating ssb under crowded band conditions.

Power requirements for the FT-107M are 13.6 V at 20 A dc. For operation from the 117 V ac line, two power supply options are available. The FP-107E is an external supply with built-in speaker, while the FP-107 supply can be installed in the transceiver cabinet for compactness.

Digital Memory and DMS

Perhaps the most unusual option available for the '107M is its digital memory system. The DMS system provides a synthesized VFO (the main VFO is a conventional LC tuned oscillator) and 12 memories, each of which can be used to control transmit or receive frequency, or both. In addition, memory fine tuning and the normal offset tuning can be applied to the memory frequency. This allows considerable flexibility in frequency control. But wait — there's more! The DMS (Digital memory Shift) control enables the operator to shift a memory channel, in 100-Hz steps, to either the upper or lower band limit. This is done by means of an optically encoded, detented control. When combined with the optional YM-35 hand-held scanning microphone, the operator can tune to any frequency in the band with just one hand. Three buttons, on top of the mike, control the direction and speed of scanning. As pointed out in the owners manual, a slight chirp may be heard when using the DMS. The chirp is very brief and not objectionable. It is caused by the relatively long

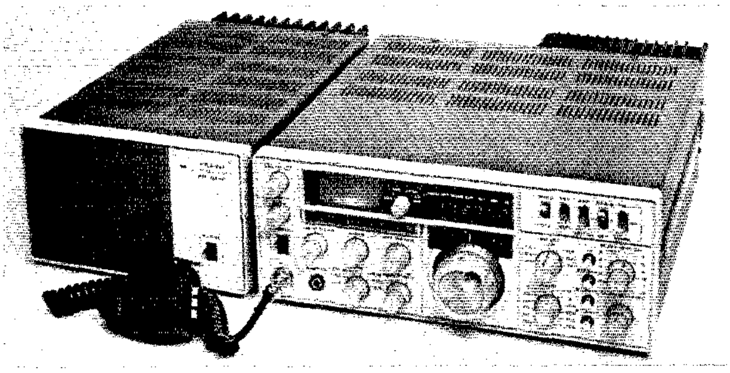


Fig. 1 — Yaesu's FT-107M and matching external ac-operated supply. The optional YM-35 microphone shown may be used for frequency control of the transceiver.

Yaesu FT-107M Serial No. 9N030626

Manufacturer's Claimed Specifications	*ARRL Lab Measurements*
Frequency coverage, (MHz) 1.8 - 2.0 3.5 - 4.0 7.0 - 7.5 10.0 - 10.5 14.0 - 14.5 18.0 - 18.5 21.0 - 21.5 24.5 - 25.0 28.0 - 29.9	As specified plus 40 kHz beyond each band edge.
Power input (dc): 240 watts (ssb, cw), 80 watts (a-m, fsk).	
Output power: Not specified.	Greater than 125 watts on 160, 80, 40 and 20. Greater than 110 watts on 15 and 10 meters.
Carrier suppression: Better than 40 dB, (at 14 MHz).	51 dB (at 14 MHz)
Unwanted sideband suppression: Better than 50 dB, (at 14 MHz, 1 kHz tone).	Better than 60 dB (at 14 MHz, 1 kHz tone).
Spurious output: Better than 50 dB down.	47 dB down from carrier (1.8 MHz)
Transmitter third-order IMD: Better than 31 dB down.	32 dB down from PEP.
Receiver sensitivity: 0.25 μV for 10 dB S/N.	0.16 μV for 10 dB S/N (at 14 MHz).
Rf attenuator: 20 dB ± 3 dB.	21 dB.
APF, notch frequency range: 300 Hz to 1.4 kHz.	260 Hz to 1.7 kHz.
Notch filter depth: Not specified.	35 dB.
Audio output power: 3 watts at 10% THD (into 4 ohm load).	Greater than 3 watts at less than 10% THD.
Receiver MDS: Not specified.	−133 dBm on 80 meters, −133 dBm on 20 meters.
Receiver two-tone, third-order IMD dynamic range: Not specified.	82 dB on 80 meters, 90 dB on 20 meters.
Receiver blocking dynamic range: Not specified.	Could not be measured because of receiver noise.

*Assistant Technical Editor

[1]The 10-, 18-, and 24-MHz bands are not yet open to U.S. amateur occupancy. See Baldwin and Sumner, "The Geneva Story," *QST*, February 1980, p. 53.

[2]Product Review, *QST*, December 1979, p. 52.

lock-up time of the synthesizer, which also ensures that the LO signal is clean, thus not compromising the receiver performance. ARRL laboratory tests confirm this; receiver measurements made using both the synthesized and the conventional VFO produced the same results.

Circuit Highlights

Each major functional unit of the transceiver is contained on a separate, plug-in circuit board. Extensive use of diode switching permits band and mode changes to be made by switching only dc control voltages to the various boards. The only point at which diodes are not used for rf switching is at the output of the PA; each of the output low-pass filters has a relay at each end.

During receive, the incoming signal is preselected by a single-tuned circuit and applied to a dual-gate MOSFET (a 3SK51-03) amplifier. The amplified signal passes through a two-pole band-pass filter before being fed to the doubly balanced diode ring mixer. Following the first mixer, the signal is band-pass filtered, buffered and then applied to the crystal filter. The i-f amplifier uses two dual-gate MOSFETs, while a doubly balanced diode ring is used as the product detector. The overall performance of the receiver is very satisfactory with the exception of poor cw filter performance. The skirt selectivity of the 600-Hz filter, while adequate for most operating, was far from outstanding. Also, the two-tone, third-order IMD dynamic range measured on 80 meters was less than expected, 82 dB compared to 90 dB measured on 20 meters. To determine if the unit received for review had a problem, a second FT-107M was solicited and the measurements were repeated. Nearly the same results were obtained with the second unit.

The transmitter section of the '107M is of conventional design. The local oscillator is a premix type using a 5-MHz VFO frequency which is mixed with the output of a crystal oscillator. A separate crystal oscillator is used for each band, and the crystal frequencies are such that the LO signal is always above the signal frequency.

Low-power a-m operation is provided by modulating the 8988.3 kHz carrier signal. Fsk is generated in a similar manner: the carrier oscillator frequency is shifted the required 170 Hz. During a-m and fsk operation, the rated input power of 80 watts produces an output power of 10 watts.

Figs. 2 through 4 show cw keying waveforms obtained when operating the FT-107M under differing conditions. Fig. 2 shows the waveform when the DRIVE control is adjusted for maximum input power. It was noted during testing that the first dot transmitted has a different waveform, as shown in Fig. 3. This photo was taken by closing the manual transmit switch and then keying a single dot. This waveform variation is likely caused by the time constant of the alc circuit. The waveform shown in Fig. 4 was produced by adjusting the DRIVE control to the point at which the alc meter just begins to show an indication; the output power at this point was 100 watts. While the keying waveforms shown in Figs. 3 and 4 depart from the ideal 5 ms rise and fall times, on the air tests showed only the slightest "click" to the signal.

The spectral photograph in Fig. 5 shows the transmitter two-tone, third-order IMD performance to be reasonably good. Suppression of spurious emissions easily meets current FCC requirements (see Fig. 6). The maximum output power obtainable from the '107M tested was typically 126 watts, dropping to 112 watts on some bands. Other pertinent specifications and test results are listed in the table.

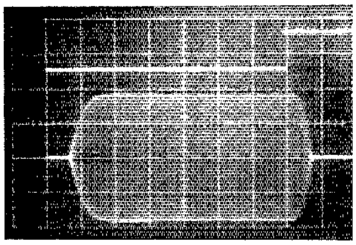


Fig. 2 — Cw keying waveform of the FT-107M with DRIVE control adjusted for maximum input power. Upper trace is the actual key closure; lower trace is the rf envelope. Each horizontal division is 5 ms.

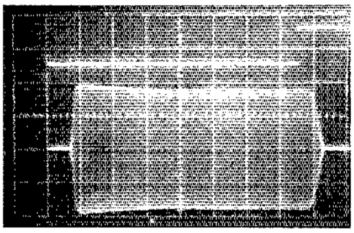


Fig. 3 — Cw keying waveform of the first dot in string. All operating conditions are the same as those used for Fig. 2.

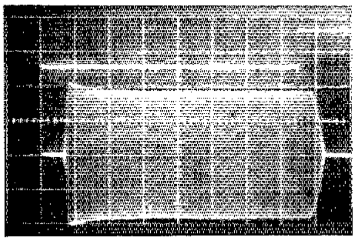


Fig. 4 — Cw keying waveform with the DRIVE control adjusted to the point at which the alc indication just begins. All other operating conditions are the same as those used for Fig. 2. Note that under these conditions the rise time is reduced to about 1 ms and fall time to about 2 ms.

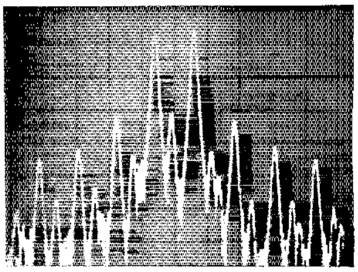


Fig. 5 — Spectral display of the FT-107M output during two-tone IMD test. Third-order products are 32 dB below PEP and fifth-order products are 41 dB down. Vertical divisions are 10 dB; horizontal divisions are 1 kHz. Transceiver was being operated at rated input power on the 20-meter band.

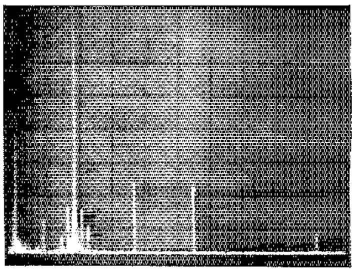


Fig. 6 — Spectral display of the FT-107M output operated at rated input power on the 160-meter band. Output power is approximately 125 watts. All spurious emissions are better than 40 dB below the carrier. Vertical divisions are 10 dB; horizontal divisions are 1 MHz. The FT-107M complies with current FCC specifications for spectral purity.

On-the-Air Operation

Using the FT-107M on the air was, for the most part, a pleasure. The broadband design allows quick, no-tune-up band changes — provided the antenna system used shows a reasonably low SWR on all bands. Both received and transmitted audio quality is excellent and the cw keying drew no unfavorable comments. Receiver sensitivity was more than adequate even when using small antennas.

A minor problem with the S-meter calibration was noted during on-the-air tests: The S-meter readings seemed rather high compared to those obtained with the station receiver normally used. Tests with a calibrated signal generator showed that an S-9 meter reading required only a 1.5 μV signal! Following the S-meter calibration procedure given in the owner's manual resulted in a 52 μV signal producing an S-9 reading. The number of decibels per S unit averaged 3.5 across the meter scale, which is somewhat less than the 5 or 6 dB per unit normally found.

Station accessories available include the FC-107 antenna tuner, FTV-107R vhf/uhf transverter, FV-107 external VFO and the SP-107P speaker/phone patch. All of the above accessories match the FT-107M in color and styling. Price class: FT-107M with DMS, $1170; FP-107E, $145. Manufacturer: Yaesu Electronics Corp., 6851 Walthall Way, Paramount, CA 90723. — *George Collins, AD0W*

KENWOOD TR-2400 2-METER FM TRANSCEIVER

□ Need a durable, convenient-to-use rig that should handle just about any 2-meter I'm situation you're likely to encounter? Kenwood's Model TR-2400 synthesized hand-held is that kind of rig.

The TR-2400 is built around a sturdy aluminum frame, partially encased front and back with dark-gray high-impact plastic covers. The physical layout is well planned, with the VOLUME, SQUELCH, TRANSMIT OFFSET, special purpose (OPEN/BUSY, SUBTONE, REVERSE/NORMAL) switches and a quick-disconnect BNC antenna jack on the top surface. The LCD readout, multifunction 16-key pad and special (FREQUENCY LOCK, TRANSMIT LOCKOUT, LAMP) switches are located on the lower front panel, with jacks for the earphone, battery charger and microphone on the right-hand side. The PTT thumb switch is well placed on the left-hand side and the 8-ohm internal speaker and condenser microphone are located at the top of the front panel.

Power is supplied by a 9.6-volt NiCad battery pack which drops into a bottom rear compartment accessible through a slide-out panel removable with a coin. Accessories supplied with the standard unit include the rubber stub antenna, NiCad battery pack, ac wall charger, earphone, plugs for microphone and standby inputs and instruction manual. (The manual contains thorough operating instructions, a block diagram and schematic, but no maintenance information.)

Frequency Synthesis

Synthesized hand-helds are becoming more the rule than the exception today, thanks to comparatively recent developments in electronic technology. The convenience and versatility of the "800 channel" rigs are hard to dispute. The Kenwood approach was "digital control of a phase-locked voltage controlled oscillator," or placing the frequency output of a VCO under microprocessor control. At its simplest, you tell the microprocessor by means of the keypad and function switches what you want, and it controls the electronics within. Thus, when you want to operate a 146.28 MHz/146.88 MHz repeater, for example, you enter the exact receive frequency using the keypad: punch the four digits 6,8,8 and Ø (the 1 and 4 are assumed and the decimal point automatically "set" by definition). Assuming all the other controls are set properly (−600 kHz offset, etc.), you'll be operating right where you want!

Operating frequency range is controlled by the microprocessor according to the "operational rulebook" preprogrammed at manufacture. Under microprocessor control, the TR-2400 covers the entire 2-meter amateur band plus those frequencies down to 143.900 MHz and up to 148.495 MHz. You cannot *directly* enter any frequencies above 147.995 MHz or below 144.000 MHz, but you can scan manually beyond these limits. By pressing continuously the up or down "arrow" keys, corresponding to the keypad's "#" and "*" respectively, you'll reach the upper and lower extreme limits mentioned above. When you reach 148.495 MHz scanning up in frequency, the synthesizer "jumps down" to 143.900 MHz and continues scanning up from there in 5-kHz steps. The reverse is true when scanning down beyond 143.900 MHz. To change frequency by 5 kHz only, depress the appropriate arrow only momentarily. To change from one frequency (within the 2-meter band) to another, enter the last four digits of the desired new frequency as described above: the last digit to the left of the decimal point (MHz units-place) and the three digits to the right of the decimal point. The last digit will always be a Ø or a 5, as the synthesizer generates frequencies in minimum 5-kHz increments. If you enter a 5, 6, 7, 8 or 9, the last digit will be a 5; if you enter a Ø, 1, 2, 3 or 4, the last digit will be Ø. The last four digits of the frequency currently being generated may be viewed in the LCD readout.

Fig. 7 — The Kenwood TR-2400 2-meter fm transceiver. The BNC antenna connector is a thoughtful feature.

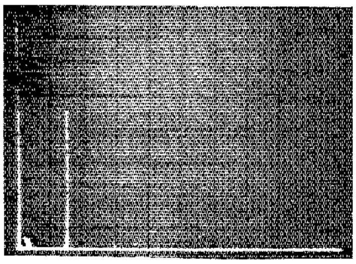


Fig. 8 — Spectral display of the TR-2400. Vertical divisions are 10 dB; horizontal divisions 100 MHz. The fundamental has been reduced in amplitude approximately 34 dB by means of notch cavities; this prevents analyzer overload. Power output is 2 watts at a frequency of 147.88 MHz. The second harmonic is just barely visible approximately 74 dB below peak fundamental output. Tests were performed in the ARRL lab. The TR-2400 complies with current FCC specifications for spectral purity.

Memory

The TR-2400 incorporates 10 memory channels to program with your most-used local frequencies. With several of the channels programmed, changing frequency becomes a simple matter. Pressing the key labeled MR (memory recall), followed by the number of the memory channel holding the frequency you want, will do it.

With your local repeaters' frequencies programmed into the memory channels, you'll also be able to scan all ten of them automatically. Pressing the MS (memory scan) key will return the rig to the frequency stored in M1 where it will pause for one second, change to the frequency stored in M2, pause, and so on. From MØ it recycles back to M1 and continues scanning. Though this scan rate seems fairly slow, if you care to monitor only two repeaters, for example, you can speed up the apparent scanning rate (see "Hints and Kinks," December 1980, p. 53). The same can be done with three repeaters or more, or you can set up a "priority channel" by programming a priority frequency in every odd-numbered memory channel with five other frequencies entered in the even-numbered memories.

When scanning, you have the option to pause on either open channels or busy channels using the OPEN/BUSY push-button switch on the top panel. Scanning will resume when the status again changes. To stop the rig manually from scanning, press the keypad button labeled STOP. This button serves double duty as the C or CLEAR key when you've made entry errors using the keypad. As the keys are exposed and susceptible to unintentional entries during everyday use, provision has been made to prevent errors by locking in the displayed frequency. When you slide the F.LOCK switch on, you will not be able to change the frequency manually. If the radio is scanning *before* this switch is activated, it will continue to scan the 10 memories and will not stop until you've turned the F.LOCK off and hit STOP.

Receiver/Transmitter

The receiver performs well and exhibits no overloading problems unless operated immediately next to another 2-meter rig. The internal speaker provides surprisingly good audio, though in a noisy environment, such as the inside of an automobile, you'll need to turn the volume up near its limit. The transmitter yields a minimum of 1.5 watts with the batteries charged. At full charge, you'll typically get over 2 watts out from the rig. A spectral display of the output is shown in Fig. 8.

One quirk that we noticed is the way the transmitter "sweeps hot" from the receive frequency to the transmit frequency. Whatever the split, whether the standard ±600 kHz or the broadest possible split (143.900 MHz to 148.495 MHz using the nonstandard split capability), when you key the PTT switch the TR-2400 begins transmitting instantaneously at the receive frequency; very quickly (less than a second) the transmitted carrier sweeps up or down to the appropriate transmit frequency. As the thought of an rf pulse traversing the entire band raised a few questions in our minds (hmmm . . . wonder if we'd key up all the repeaters for miles around?), we took a long, hard look. The fact is that at any given frequency, the transmitted pulse "looks" like a very low power transient that does not break squelch. It certainly did not key up any of the local repeaters, many of which are near ARRL Hq., and the pulse could barely be detected above the noise as a very low audio "bip" in a second receiver a few feet away. Though quick, it *was* present as a full-powered pip racing up the display of the spectrum analyzer.

Early models of the TR-2400 (those characterized by a spring-return (no-click) REV/NORM push button on the top panel — later models have a locked-detent button that remains halfway "down" when in REV position) were electronically gated to prevent transmitting. Though the synthesizer did sweep from the receive to the transmit frequency, the transmitter was disabled for a few hundred milliseconds and nothing was transmitted until after the transmit frequency was reached. Several owners of earlier models have commented about the delay on transmit, wondering why their first syllable was often "chopped" off. This is the answer. Later models, those with a detent or "cocked" position in REV operation are not gated: When you key the transmitter, you are transmitting immediately, but the listener may still miss the first syllable.

Within the amateur allocations, this really poses little problem, as we demonstrated with our test. When considering MARS or CAP operation, however, where reception is often below 144 MHz and transmission above 148 MHz, the newer TR-2400s *do* transmit while sweeping across frequencies that are not authorized for use. The operator should be aware of this feature.

Transmitted audio quality is excellent. The tiny internal condenser microphone seems to do the job quite well, as reports were good whether through repeaters or operating simplex. Though most listeners could tell that the rig was a hand-held, the tonal qualities of the operator's voice were reproduced well enough that he was easily recognized.

Power Consumption

The 9.6-volt battery pack consists of eight standard 1.2-volt AA NiCad cells wired in series and held together in a shrink-wrap sleeve. With the wall charger, Kenwood states that full recharge (from complete discharge) should take about 15 hours; this seemed to be a pretty fair estimate under a variety of operating conditions over the test period of several months. The normal claimed operating time of the TR-2400 is 2-1/2 hours at a 1:3 transmit/receive ratio. I found this estimate to be a good rule of thumb, though I did not sit down for a 2-1/2 hour stint with a stopwatch! Good 2-meter fm operators normally do much more listening than talking (the proverbial elephants — all ears and little mouth), and will find their operating time greatly extended beyond the 2-1/2 hours claimed. On the other hand, our alligator friends (all mouth and no ears) should carry an extra battery pack, as their operating time will be less per charge (poetic justice!). An informative chart of battery voltage versus operating time is included in the operating manual.

With the power switch turned off, the memory backup circuitry that keeps the 10 memories "loaded" draws about 0.8 mA. Though this is normally insignificant during active periods, Kenwood has included the option of eliminating even this drain over long periods of non-use: Turn the TX OFFSET to BU.OFF (back up off). I found that putting the TR-2400 aside for over a week with the memories saved would reduce later operating time before a charge was needed; reprogramming the memories is so simple a task that turning this off for extended "down times" should be standard procedure!

Another way Kenwood chose to prolong the usefulness of a full charge was to use a liquid crystal display (LCD). The TR-2400 display is non-defeatable and must be left on whenever the power is turned on; but the power consumed is truly insignificant. One complaint often heard about LCDs is that they are difficult to read. Though the TR-2400's LCD digits don't "jump out" at you like their bright-red LED counterparts, they posed no problem whatsoever even in dim lighting conditions. And, for viewing the display in total darkness, you need only throw the LAMP switch and a small bulb illuminates the entire display. As the bulb does consume a good deal of power, it should not be left on indiscriminately — but there are a few instances where you'd need more than several seconds to check your frequency.

While we're looking at the display, it would be a good time to note four LCD "pointers" that convey additional information to the operator. One, the MR indicator, tells you that the operating frequency in the display has been "called" from one of the 10 memories. The LAMP indicator lets you know that the lamp has been left on; in bright light the lamp is not noticeable and this warns you to turn it off before the batteries have unnecessarily been drawn down. A third indicator, labeled BATT, warns that your batteries are close to full discharge. When this comes on you have only enough power left for one or two *short* transmissions. The fourth indicator, ON AIR, tells you that the radio is presently transmitting; that is, it is keyed. These latter three indicators proved indispensable in saving the battery charge on several occasions.

Kenwood recommends recharging the battery pack for about 10 hours after unpacking the rig, even though the batteries are fully charged at the factory. We did this but still experienced a bit of a problem for the first few weeks of operating as the batteries would not hold a full charge for very long. Leaving the rig off for as little as two days after a full charge would leave the battery pack on the verge of "going south." After a few weeks, however, the problem seemed to cure itself, though I suspect several cycles of deep discharge and complete recharge — "exercising" the batteries — may have helped. Kenwood cautions against operating while recharging the batteries with the wall charger and recommends not leaving the rig plugged into the charger after the 15 hours required for full charge. When both cautions were inadvertently violated, the rig suffered no apparent damage, though I suspect that the potential for doing harm does exist.

Other Features

Several other features are worth mentioning. With the TX OFFSET switch you can select ± 600 kHz offsets or simplex operation as with most new rigs, but one can also program so-called "oddball" splits directly. Enter the last four digits of the repeater input frequency into memory 0 (MO), enter the repeater output frequency into the display and turn the TX OFFSET switch to the M position. With this setup, you will listen on the displayed frequency and transmit on the frequency stored in MO, regardless of the size of the split. The receive frequency is displayed during receive and the transmit frequency displayed during transmit.

The remaining two push-button switches on the top of the radio control two equally useful functions. The button marked S.TONE enables a subaudible tone generator (not supplied with radio and not available from Kenwood). The instruction manual describes clearly how to install one of these generators, which are readily available from several sources for those needing tone-access capability. The NORM/REV switch allows you to "flip" your transmit and receive frequencies and "play repeater." With the button depressed, you'll receive on the repeater input and transmit on the repeater output: a quick way to check if you're close enough to someone to work them simplex, freeing the repeater for others, or for working others should the repeater be down unexpectedly for a short time.

The BNC "quick disconnect" antenna jack is one of the more useful features of the TR-2400, though few people think of it in those terms. It readily accommodates the supplied stub antenna and most any other 2-meter antenna that can be adapted to BNC. Many TR-2400 users use magnetically mounted 5/8 λ whip antennas on their cars, inserting an easy-to-find SO-239 to male BNC adaptor between the commercial antenna's PL-259 plug and the rig. A quick twist and the radio is ready to go.

The TX-PTT/STOP or transmit lockout prevents transmission when in the STOP position. This is handy when swapping between antennas or when the radio is sitting on the car seat beside you, situations where transmitting accidentally could cause you or others problems.

And for the autopatch user, the multifunction keypad does more than just "talk to the microprocessor." Twelve of the 16 keys function as a Touch-Tone generator during transmit (digits 0-9, * and #). Operation is standard, though the radio must be keyed with the PTT switch; because of the other keypad functions, the rig cannot be automatically keyed when a button is depressed.

Its multiple features, versatility and ease of operation make Kenwood's newest entry in 2-meter fm hand-helds a joy to operate.

Kenwood TR-2400 2-Meter FM Transceiver Serial No. 0121277

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 144.000 to 147.999 MHz with direct programming	143.900 to 148.495 MHz manual scan
Rf output power (50 Ω load): 1.5 W	2 W
Spurious emissions: 60 dB below fundamental	>60 dB below fundamental
Power requirements: 9.6-volt dc battery pack.	
Dc current drain:	
Approx. 28 mA receive/no input signal.	
Approx. 500 mA transmit.	
Approx. 0.8 mA memory backup.	
Receiver type: Double conversion;	
first i-f — 10.7 MHz;	
second i-f — 455 kHz.	
Sensitivity: <1 μV for 30 dB S/N.	0.31 μV for 20 dB quieting.
Audio power output, 8-ohm load: >200 mW (10% distortion).	180 mW (undistorted).
Size (HWD): 7-9/16 × 2-13/16 × 1-7/8 in. (192 × 71 × 47 mm).	
Weight: 1.62 lbs (0.74 kg)	
Color: Brushed aluminum, charcoal gray and black.	
Price class: $400.	
Manufacturer: Trio-Kenwood Communications, Inc., 1111 West Walnut, Compton, CA 90220.	

Whatever the application, autopatching, monitoring a number of local 2-meter repeaters, searching for accessible machines in unfamiliar territory or joining in a friendly roundtable, the TR-2400 will find a place in many active 2-meter fm shacks. — *Steve Place, WB1EYI*

GARGLER, INC. MICROPHONES

☐ At last! A phone operator's microphone that has all the features required by the amateur or CBer! Gargler, Inc. has developed a group of space-age microphones that will satisfy the needs of contesters, DXers and ragchewers. The manufacturer offers vanity accessories for those who wish to be "big frogs in little ponds," plus some assorted functional accessories.

The problem with past and present microphones has been a lack of variation in design. That is, most mikes have not been designed for the application, at least with respect to hams and CB operators. Furthermore, existing microphones dictate the voice reproduction quality by virtue of the bandpass constrictions of the microphone element. It dates back to the days of "burnt-lip" modulation (loop modulation), wherein one was inclined to shout into a megaphone to avoid rf burns that could result from coming into physical contact with the mike. We've progressed well beyond that primitive stage of voice operation, graduating to carbon mikes, condenser mikes, ribbon mikes, dynamic mikes, crystal mikes, electret mikes and — finally — ceramic mikes. But, all suffer the same shortcomings: no significant "bells and whistles," to use the vernacular. Transceivers have become endowed with countless unnecessary frills and goodies. Why not the same for microphones? After all, the cw operator's needs have been addressed nicely with electronic keyers, keyboard keyers, CMOS keyers and memory keyers. Why has the phone operator been ignored? We may never know the answer, but we can rejoice in the knowledge that *finally* the shy or "leather-lunged" voice enthusiast can stand proudly with his or her cw counterparts. Gargler, Inc. has answered the ssb/a-m/fm person's need!

Microphone Features

The basic microphone mainframe is their model Profundo 10X, illustrated in Fig. 9. It becomes apparent that panoramic speech was a fundamental design objective when we observe the width of the microphone head (1 ft./305 mm). The height of the head is 3 in. (76 mm). This portion of the mike is available in a plane format or with a 180-degree curvature. The latter is for those operators who move their heads and wave their arms during the heat of phone-contest operating. The curved format permits a uniform dyne level on the mike element over a 180-degree range. This prevents "voice QSB" within a 1-dB level range, which can be vital during weak-signal work.

Perhaps of equal value is the luster-chrome back shield (splatter plate). It serves three important functions: (1) It prevents saliva droplets from reaching the station equipment beyond the mike, thereby eliminating the need to periodically clean and polish the panels of the transceiver and linear amplifier. (2) It provides 30 to 35 dB of background noise (blower fans, etc.) suppression. (3) It allows the operator to see his or her own image clearly during operating periods (important to some

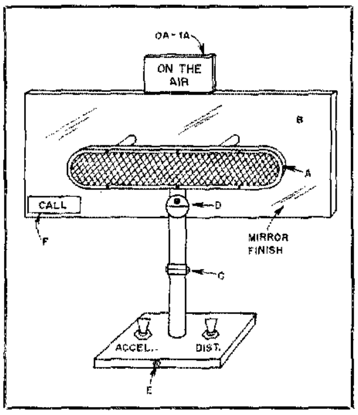


Fig. 9 — Line drawing of the Profundo 10X Magnum with connection points indicated for accessories. The mike element is 12 in. (305 mm) long and 3 in. (76 mm) high. A splatter shield is situated behind the microphone (see text).

on-the-air personalities). The reviewer wants to caution the buyer that this part of the 10X must be cleaned and polished frequently, especially if the operator is in the habit of snacking while operating.

Areas C and D in Fig. 9 are jointed. Section C permits forward and reverse tilting, while point D contains a ball joint. This makes the mike adaptable to persons of assorted heights. It also accommodates operating tables of various heights. Those with large paunches may find it convenient to lean back and place the Profundo 10X directly on the flat part of the stomach. This technique has been proved desirable for ragchewing sessions.

Other Features

Let's now discuss those space-age features of the 10X. This brings us to the Contester Model 4X Magnum. It contains battery-operated CMOS circuitry in the base of the mainframe. One circuit is called a "speech accelerator." It contains a memory and word processor that permits transmitting the human voice at four times the spoken rate. This can be equated generally to the function of a keyboard keyer with a buffer circuit. We may ask, "Of what value is this feature?" Well, if you've ever listened to the phone bands during a contest, you've no doubt heard many operators trying to talk so fast that they nearly choked! This is because some humans lack the necessary speech articulation to talk clearly while speaking rapidly. Slow talkers, and those with regional accents, will be able to match operating advantages with the best of them when using the model 4X! This circuit is invaluable in DX pile-ups for "tailending" on voice. You can almost always beat the other guy when dropping in your call at accelerated rate. *Caution:* The reviewer has learned that this feature is unacceptable for certain operators who normally are regarded as "fast talkers." The transmitted voice energy may be too fast for intelligibility, especially when QSOing with foreign amateurs who aren't adept at the English language.

For those who do not own speech processors or can't afford to buy one, take heart! The Contester 4X has a built-in circuit that can introduce just enough distortion to make one's voice sound like it has been routed through a speech processor. By actuating the DISTORTION switch on the mike base you can sound like most of those who use processing regularly, but Gargler's circuit has a "distortion limiter" that prevents excessive signal bandwidth. This enables the operator to identify with his or her peers, while not causing splatter on the phone bands, such as is commonly heard with misused conventional processors. The manufacturer plans to introduce a model Contester 10^8X in a few months. It will have "limitless distortion," which will be controlled by means of a 10-turn Helipot.

Fig. 9 shows a jack at point E. This is for use with the Gargler TI-10A outboard 10-minute automatic timer. If the operator forgets to identify his or her station each 10 minutes, the TI-10A disables the output from the mike element and inserts a voice-simulator i-d, such as, "This is KN1FE." Then the mike is reinstated for continued communications. The operator is never aware that the i-d is being sent, so the function does not interfere with the flow of speech or thought. The i-d is inserted in the buffered speech so no information is lost. Neat, we say!

Some operators insist on having an on-the-air indicator in the shack. Well, Gargler has thought of that feature too. The OA-1A plug-in display attaches to the top of the splatter shield of the Profundo, as shown in Fig. 9. This display is voice-actuated, and has an audio agc circuit that prevents the light from flashing on and off in sync with the spoken words. The original model (LQ-1) used a liquid-crystal readout. Owners complained because visitors to the shack were unable to see the on-the-air sign light up. So, Gargler now uses bright red 1/2-in. (13 mm) LED blocks.

Finally, owners can have the microphone personalized at no extra cost. The call letters are embossed at the lower left of the splatter plate in 1-in. (25 mm) high gothic letters. Some of the newer U.S. calls are too long to fit on the left. In this situation half of the call is embossed on the left, and the remainder (suffix) is impressed at the lower right of the splatter shield.

We feel that this line of microphones is ideal for today's dedicated voice operator. Those seeking Ragchewers Certificates will be delighted with this apparatus. You may want to try one of the Gargler products during the phone Sweepstakes contest, or just for bursting DX pile-ups on 20 meters. Whatever your operating preference, Gargler offers you the modern approach to voice communications. Dealer inquiries are invited. — *Lypp Survis, YØWL* QST

Gargler Profundo 10X Microphone

Manufacturer's Specifications

Height: 2 ft (610 mm).
Weight: 5 lb (2.2 kg).
Color: Gold or chrome (buyer's choice).
Power requirements: 9-volt transistor-radio battery.
Frequency response: dc to 50 kHz.
Output voltage: 10 volts (50,000 ohms).
Price class: $495 (Contester 4X).
Manufacturer: Gargler, Inc., 70 Braeburn Rd., Bristol, CT 06010.

Technical Correspondence

Conducted by
Jerry Hall,* K1TD

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AVERAGE OR RMS POWER?

☐ Articles about power amplifiers, whether audio or radio frequency, often contain statements about power ratings. Many times these ratings are confusing, with terms such as *peak music power, average power, rms power* and others appearing with no clear explanation of what the terms mean. In particular, *rms power* and *average power* are seen most frequently.

Instantaneous power to or from a device is the product of the voltage across the device times the current into or out of it at a particular instant. If conventional current is flowing into the positive terminal of the device, then the device is accepting power. Otherwise it is giving up power.

The time average of the instantaneous power is what a wattmeter would indicate, and is known as the average power. For a purely resistive circuit with a fixed ac or dc voltage, this is equal to the effective (rms) voltage times the effective (rms) current. If these values remain unchanged, the average power remains constant at $V_{rms} \times I_{rms}$. Note that this should be referred to as average power or just plain power. It is not proper to refer to this as rms power.

The rms value of anything, whether it be voltage, current or some other quantity, is defined as the square root of the mean of the squares of the quantity — hence the name root-mean-square. In mathematical form this is given for voltage in the equation

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2\,dt}$$

As examples, the rms value of a sine wave of voltage is 0.707 times its peak value, while the rms value of a triangular wave is 0.577 times its peak value. The rms value of a dc (constant) voltage is equal to its dc value. Therefore the rms value of a constant and unvarying power reading is the same as its average value, but the rms value of a power that varies with time in some fashion is *not* the same as its average value. Actually, for any nonconstant value of a quantity, the rms value is always greater than the average value.

If a sine wave of voltage is applied to a resistance, the average power is $(V_{rms})^2/R$. The power fluctuates, however, from $(V_{max})^2/R$ to zero. This is shown in Fig. 1. In this instance the rms power, using the strict and correct definition of rms, is *not* the same as the average power. Note that the average power is half the peak power, but the rms power is (by calculation) 1.225 P_{av}. A wattmeter would indicate P_{av} and not P_{rms}. The true heating power and the power useful in producing sound or rf output for the above case is P_{av}, and *not* P_{rms}.

Of course, in more complicated situations the relationship between P_{av} and P_{rms} must be

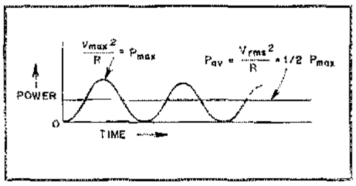


Fig. 1 — The instantaneous power for a voltage sine wave varies from zero to P_{max}. As may be seen here, the average power is 1/2 P_{max}. This is not the same as P_{rms}.

determined for each case, but P_{av} is less than P_{rms} in every instance except when the power does not vary with time.

In many instances the term *rms power* is used loosely to mean average power. This practice should be discouraged, since the two terms are clearly not the same in most cases. — *James N. Thurston, W4PPB, 322 Woodland Way, Clemson, SC 29631*

I-F CAN MYSTERY SOLVED

☐ I think I can enlighten your readers about the nature of the long i-f cans which you describe as possibly being fm discriminators in your article on chokes and coils in the Radio Shack $1.98 bargain assortment.[1] I, too, bought one of these packs, sorted through the obvious stuff, then came upon The Mystery Item.

After some diligent efforts with my crude homemade test equipment and some pliers, I was able to determine that the item is really two i-f coils separated by a ceramic filter. By wiring it as shown in Fig. 2, I was able to get the following bandwidth characteristics: 454.4-452.4 kHz at − 6 dB and 449.6-457.9 kHz at − 24 dB. So these little items should make up a nice i-f strip. I've wired strips using transistors and 3028 ICs, per the *Handbook* receiver section. — *James G. Ruggiero, 208 Graves Ave., Blacksburg, VA 24060*

[1]DeMaw, "A Radio Parts Eldorado!" August 1980 *QST*, p. 20.

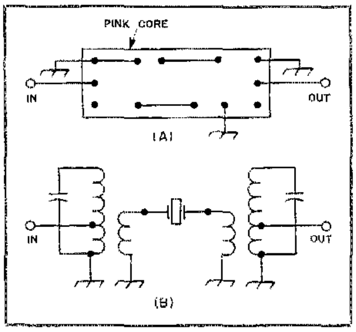


Fig. 2 — Mystery i-f can unveiled. The connections shown at A result in the circuit shown at B. See text for bandwidth characteristics.

TIPS FOR SOLAR CELL USERS

☐ After reading those two interesting articles on solar power in August 1980 *QST*,[2,3] I thought I would pass along a few things I've learned since going solar in August 1979. First of all I'm using a Gel Cell-type storage battery instead of a lead-acid car battery. The Gel Cell has two main advantages. First of all it is completely sealed and could be permanently installed upside down. Second, it can withstand over 400 complete charge-discharge cycles. Under normal operation it is unlikely you would completely discharge it even one time, which means it should provide you with reliable power for many years. Its disadvantage is the dollar cost per ampere hour of storage capacity. The unit I'm using is the Globe Union model U-128, which is rated at 28 ampere hours. This forces you into the QRP category unless you want to spend a lot of money on batteries. My equipment consists of three transceivers at 5, 15 and 25 watts.

The next item is the blocking diode which is used to prevent the battery from discharging back into the solar panel when the sun goes down. This diode should be the Schottky type which has a 0.3 volt drop across it. This is compared to the silicon type which has a 0.8 volt drop. However, Schottky diodes with a higher current rating also have higher leakage current in the reverse-bias direction. The one I'm using was hand picked and the leakage current is less than 10 μA at 14 V.

Last is the question of whether or not you

[2]Halliday, "Solar Powering a Ham Station," August 1980 *QST*, p. 11.
[3]Blakeslee, "An Electronic Switch for a Solar Panel," August 1980 *QST*, p. 12.

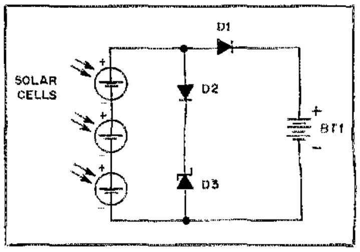


Fig. 3 — The shunt regulator used with solar cells at W8AC. See text for information on the solar cells and battery. D1 and D2 are Schottky diodes rated to handle the maximum current the solar panels will deliver. D3 is a 14-V, 50-W Zener diode.

*Technical Editor, *QST*

need a voltage regulator. The problem arises because Gel Cell and car batteries require a charging voltage around 14 volts, but solar panels designed for a 12-volt system can supply more than 17 volts with direct sunlight. I operated my system for over 10 months without any regulator. If you use the system enough the battery will always be in some state of discharge, and it in turn will load down the solar panel below 14 volts. If you let the battery completely charge, however, the terminal voltage could increase as high as 17 volts and reduce the life of the battery.

At the present time I am using a simple shunt regulator, Fig. 3. D1 and D2 are both Schottky diodes. The type you would use will depend on the maximum current your panel could generate. The only purpose of D2 is to compensate for the 0.3 volt which is dropped across D1, the blocking diode. D3 is a 14-volt Zener diode rated at 50 watts, more than enough to handle the 1-1/2 ampere panel I'm using.

Shunt regulators have never been very popular because of their high power consumption. In this case, however, where the source of energy is as free as sunshine, that is no longer a factor. One additional advantage to this type of regulator is that it requires no power from the battery for operation. — *Jim Martin, W8AC, 24455 Lakeshore no. 1804, Euclid, OH 44123*

USING BALUNS IN TRANSMATCHES WITH HIGH-IMPEDANCE LINES

☐ The article by DeMaw, W1FB, "Ultimate Transmatch Improved" (July 1980 *QST*, page 39), contained comments on the use of baluns in Transmatches and the disastrous results that can be suffered when attempting to use high power and feed high-impedance balanced loads. The high voltages that are developed cause arcing between turns of the balun, upsetting its function and likely destroying it.

The Ultimate Transmatch is such an exceptionally broad-range matching device it seemed a shame it was limited to only low-impedance *balanced* loads when using high power. I had been working on the problem and had solved it shortly before Doug's article appeared. After reading his suggestion that the user limit high-power operation to impedances of 300 Ω or less, I realized I had the solution to one of the few remaining limitations of this most effective device.

While trying to find a solution, I wound several varieties of baluns, including an air-wound version. All conventional baluns failed by arcing between turns whenever the load was more than a few hundred ohms, as DeMaw predicted. Ultimately the solution was found in the method of winding the balun. It was wound on two T-200 Amidon cores according to instructions in *The Radio Amateur's Handbook*, but with three major differences. First, the coil was wound with the turns well separated and equally spaced (Fig. 4A) instead of with the turns close together (Fig. 4B). Second, 10 bifilar turns were used (instead of the 15 indicated in the *Handbook*) to limit the amount of wire on the form and to permit maximum spacing of the turns. (Amidon instructions indicate 10 turns is adequate for 3.5- to 30-MHz operation.) And third, additional insulation was obtained by dipping the assembly in polyurethane varnish.

The photos show the completed balun. Construction is as follows:

1) Use two Amidon T-200 cores. (The *Handbook* suggests three cores for 2 kW, but two proved adequate for my particular 2-kW final.)

2) Insulate each core by winding with two layers of no. 27 glass-cloth insulating tape.

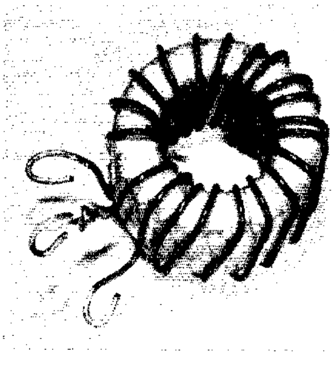
3) Stack the two cores and wind another layer of tape around the two.

4) Wind 10 bifilar turns of no. 14 Teflon covered wire spaced equally one wire from the other, as shown. Be careful to keep all turns separated as far as possible. *Do not let any turns touch each other.*

5) Dip the assembled balun in clear polyurethane varnish (I used Behr no. 603 clear gloss) while holding the balun by one of the wires. Keep the wire ends clear of the varnish, or be sure they are scraped clean before making connections. Suspend the assembly and let it dry for 24 hours.

6) Wind a final layer of tape around the turns to be sure they are held in place.

7) When mounting the balun, be sure to keep it as far away from the housing and other components as possible to avoid rf flashover.



The upper photo shows the balun wound and ready for immersion in polyurethane varnish. After drying, the balun is wrapped with a final layer of glass-cloth insulating tape and installed away from other components, lower photo.

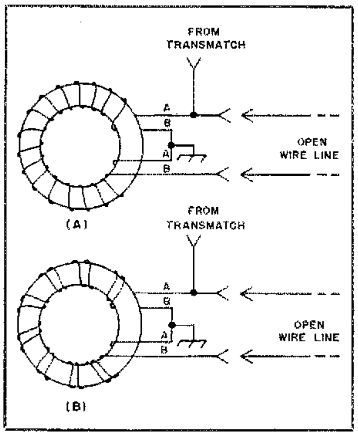


Fig. 4 — Fanckboner recommends winding toroidal baluns with the bifilar turns equally spaced, as shown at A, rather than in the conventional method shown at B. This helps to avoid arcing between turns at high power when lines with high input impedances are being fed.

Performance is highly satisfactory. When put into operation, the balun functioned perfectly with no problems. Voltage between legs of the open-wire transmission line appeared to be well balanced, as indicated by a neon lamp. Core saturation did not occur even when running 2 kW ssb. With the key down for one minute at 1 kW input (on an unused frequency, of course) there was only a slight rise in balun temperature. This test was made on 40 meters with a transmission line length that presented a high impedance at the feed point.

It is now possible to run the full legal input to my 4-1000A final with all lengths of transmission line I have tried, 10 through 80 meters, without breakdown using my 80-meter open-wire center-fed antenna and homemade Transmatch. This modification has made it a more truly universal matching device and has enhanced its versatility considerably. — *William E. Fanckboner, W9INN, 811 Cathy Ln., Mount Prospect, IL 60056*

SOMETIMES BALUNS ARE BALONEY

☐ A *QST* article by Bruce Eggers, WA9NEW, presents several interesting and, I believe, valid conclusions about when baluns are or are not needed.[4] However, it is somewhat misleading to draw conclusions about 80-meter dipoles from the results obtained from the 1.6-GHz half-wave dipole used in the author's tests. From the photographs it appears that his test dipoles were fed with RG-8/U coax. Scaled to 80 meters, this would represent a coax feeder having a diameter of 14 feet or 4.3 meters — clearly *not* a typical 80-meter dipole! Unfortunately it is impossible to construct a true scale model of an 80-meter antenna at 1.6 GHz — to accurately scale RG-8/U would require a feed line of less than 0.001 inch (0.03 mm) diameter.

Fortunately for those of us who operate on the lower frequencies with dipoles and wonder about the need for baluns, a report by the Stanford Research Institute contains the answers.[5] The radiation patterns of full-size hf antennas, including dipoles with and without baluns,

[4]Eggers, "An Analysis of the Balun," April 1980 *QST*, p. 19.

[5]Ray, "Full-Scale Pattern Measurements of Simple HF Field Antennas," *Special Technical Report 10*, Stanford Research Institute, Menlo Park, CA. Available from National Technical Information Service, Springfield, VA 22161, as number AD487494.

were measured. The patterns were obtained by flying a fully instrumented helicopter around the antennas. The conclusions are in basic agreement with Eggers, and can be restated quite simply. A wire dipole being operated at or near resonance does not require a balun in order to have a symmetrical pattern. (Of course, as Eggers points out, metallic objects in the vicinity of the antenna may distort the pattern, but this would be the case with or without a balun.) Also, as has often been stated, the coax should be brought straight down at right angles to the antenna for at least a quarter wavelength if possible.[6]

The Stanford report also reveals that when a wire dipole without a balun is operated at a frequency far off resonance, the pattern will be severely distorted. An example might be operating a coax-fed 80-meter dipole on 40 meters. Even though the pattern may be distorted, however, I would advise *not* using a balun. The reason is simply that the termination that the dipole feed point presents to a 1:1 or a 1:4 ferrite-core balun is highly mismatched when the dipole is far off resonance. In such a case, the amount of power transferred through the balun is highly problematical. One might well conclude that not only is there no real need for a balun when feeding hf wire dipoles, but that a balun may in some cases introduce more problems than it supposedly cures. — *Jacob Z. Schanker, W2STM, 65 Crandon Way, Rochester, NY 14618*

[6] *The ARRL Antenna Book*, any edition.

TVI FROM SWR INDICATORS AND POWER METERS

☐ I wish to bring your attention to something you may or may not already know about. It concerns the Daiwa CN-720 and similar SWR indicators/power meters causing TVI on channel 2 when used on the hf bands, especially 10 meters. I discovered this almost by accident after battling a TVI problem for almost a year.

I use an ICOM 701. The transmitted signal passes through a low-pass filter mounted close to the output of the rig, through the CN-720, into a small tuner and out to a quad antenna which is up 35 feet (11 meters). I use RG-8X coax. Everything is installed properly, and bonded and soldered according to good installation techniques. There are grounding jumpers to all the above equipment, connected to a driven ground 8 feet (2.4 meters) deep and approximately 6 feet (1.8 meters) from the rig, using no. 4 stranded copper wire. During transmission my "hash" caused a completely negative picture on TV sets within a one-block radius of my QTH.

Using the techniques described in *The Radio Amateur's Handbook* and the ARRL *Radio Frequency Interference* booklet, I got nowhere until I removed the CN-720 completely from the circuit. No more TVI! I took the CN-720 to a test facility that had a spectrum analyzer and they confirmed it was the source of my problem. I tried a smaller version, the CN-520, and the same problem recurred.

I contacted J. W. Miller and returned my CN-720. Miller confirmed my suspicions that the problem was caused by the LEDs that indicate the power range being used. They disconnected the LEDs and returned my unit. With the LED bridge disconnected, my station is free of TVI. A look at the circuit shows the take-off point between a 3.9-kΩ and a 5.1-kΩ resistor through a 1N60 diode in parallel with a 0.01-μF capacitor to ground through LEDs with a switchable common ground. Wow, what a harmonic generator!

After reading the Product Review of the CN-720 (January 1979 *QST*, page 47), I agree 100%. No one usually tests an SWR/power meter for harmonics, but from now on maybe they should. I felt obligated to write so other hams might be made aware of a potentially serious TVI problem. — *Jack Tobias, N6BBR, 2345 Newport Blvd. no. 36, Costa Mesa, CA 92627*

[Editor's Note: In addition to the problem Tobias describes, we have also found switching diodes and diodes remaining in the signal path in power amplifiers when the amplifiers are *off* to sometimes be a source of TVI. The use of diodes (including LEDs), as well as other solid-state devices that may be behaving as rectifiers in the transmission line path, may require remedial measures when a TVI problem exists. Items received for advertising approval and Product Review are now being examined for this possibility in ARRL lab tests.]

HARMONIC RADIATION FROM A TRANSMITTER CHASSIS

☐ One transmitter TVI problem seems to occur quite often, namely harmonic interference on a TV channel despite the use of a low-pass filter at the output of the transmitter. Such a problem is described in Hints and Kinks, June 1979 *QST*, page 41. The writer of that information described a successful modification of a commercially designed transmitter which reduced the harmonic radiation from the transmitter by 17 or 18 dB. There is another approach to such a TVI problem which may complement transmitter modification, or in some cases may provide a solution when successful modification of the transmitter is not possible.

Use of a low-pass filter alone does not make any provision for *dissipation* of the unwanted harmonic energy produced by the transmitter. Since there is a high degree of impedance mismatch between the coax cable and the input of the low-pass filter at frequencies above the cutoff frequency, there is a high VSWR on the feed cable between the transmitter and the filter at harmonic frequencies. Also, since there is usually no provision for external dissipation of this energy and since harmonic energy is continually being produced, dissipation occurs only in the final amplifier stage and in the cable. Consequently there is a likelihood of harmonic energy radiation from the transmitter itself, as well as possible harmonic energy radiation from the cable because of leakage, faulty connectors and so forth.

An obvious solution is to use a high-pass filter having a 50-Ω resistive load connected in shunt with the feed cable, e.g. by means of a coaxial T connector. Such a high-pass filter should be designed to have the same cutoff frequency as the low-pass filter, to have a 50-Ω input and output impedance, and to have series M-derived end sections so that its input impedance at frequencies below cutoff will be high.

The result will be that harmonic energy is dissipated in the 50-Ω load connected to the output terminals of the high-pass filter. The shunt effect of the high-pass filter will be negligible at low frequencies because of the high input impedance of this filter below cutoff. There will be no high currents and voltages at harmonic frequencies since the SWR at the harmonic frequencies will be close to unity. Harmonic energy will be dissipated outside of the transmitter chassis, and not all in the final amplifier, so the final stage will run a bit cooler. Of course, all this leads to less TVI. This concept of complementary filters has been used for many years in hi-fi installations for separation of high and low frequencies. — *Ken Miller, W2KF, 309 Cherry Hill Blvd., Cherry Hill, NJ 08002*

[Editor's Note: Information on the construction of a low-pass/high-pass absorptive filter is contained in *The Radio Amateur's Handbook*, 1979 through 1981 editions, page 15-8.]

ON REWINDING POWER TRANSFORMERS

☐ I was delighted to find the Basic Amateur Radio article by O'Dell and Shriner, "Rewinding Transformers," in the October 1980 issue of *QST*. Although transformers are readily available in my area, the prices have skyrocketed in the last few years so now they are a luxury item. However, I found an old filament transformer in my junk box with a 2.5-V, 5-A secondary which seemed ideal for rewinding.

The instructions were clear and I had no difficulty rewinding the secondary to get 18 volts. The only trouble was, when reassembled, the new secondary windings vibrated, causing the transformer to hum loudly. I assumed that this was occurring because the new secondary winding was not as secure as the original secondary.

The transformer was perfect except for the noise, so I wanted to find a way to fix it without taking it apart again (once was enough). I remembered that the original secondary winding had been secured with some kind of compound, possibly varnish. So I got a can of varnish and soaked the entire transformer in it for an hour. After letting the transformer drain off and dry out for a day, I tried it again and was delighted to find it completely quiet.

As a result of this experience, I would recommend that the rewound coil of the transformer be soaked in varnish before reassembly. This should avoid the problem of noisy windings which I experienced. — *Jack Botner, VE3LNY, 35 Wynford Hts. Cr. no. 1708, Toronto, ON M3C 1L1*

FEEDBACK ON DIRECTION-FINDING ANTENNA

☐ In the construction of the phasing harness for the direction-finding antenna in my article, "Simple Antenna and S-Meter Modification for 2-Meter FM Direction Finding," March 1981 *QST*, I inadvertently multiplied the velocity factor by the length of a real resonant antenna, as opposed to a theoretical (free space) antenna. Since the real antenna is shorter than the theoretical, the calculated length of the half-wave phasing harness is off slightly. The formula that should be used is

$$\text{length (in.)} = \frac{5902 \times \text{velocity factor}}{f\ (\text{MHz})}$$

The correct lengths for the phasing lines for operation at 146 MHz are 26.7 in. for the half wavelength, and 13.35 in. for the quarter wavelength (678 mm and 339 mm, respectively). When the error was discovered, a new set of phasing lines was constructed with the correct dimensions; as the computer program had predicted, the notch was deeper. If care is taken in disassembly, the same BNC connectors can be used for the new lines. It is probably worth the effort. — *Peter O'Dell, KB1N, ARRL Hq.*

Feedback

☐ In the article by May, "Antenna Modeling Program for the TRS-80," February 1981 *QST*, the program listing on page 16 has no known errors. There is an unnecessary statement in line 70, however. *A(N,4) = A(N,4)*: may be removed from the listing. For clarification, line 390 has no zeros except in 4ØØ. Following the 2 should be the word *OR*. If you're successfully using this program, K1TD at Hq. would like to hear from you.

☐ The correct identification of the Heath HX-1681 which appeared in the March 1981 *QST* Product Review column is *transmitter*, not transceiver.

☐ Fig. 2 in Ridpath's "T-R Switching With PIN Diodes," March 1981 *QST*, omitted the added quarter-wave line and diode. The correct figure is shown here. Further, the etching pattern is *not* actual size. A full-size pattern appears in Fig. 2.

In the third column on page 20 the numbers in the calculation of power reaching the receiver were slightly garbled. It was shown that the reflected resistance was 3.333 kΩ. The amount of rf current flowing in this branch is only 50/3333 times the antenna current:

$$50/3333 \times \sqrt{23/50} = 10 \text{ mA}.$$

The power delivered to the receiver is thus

$$0.01^2 \times 0.75 \text{ or } 75\ \mu\text{W},$$ and the isolation is

$$10 \log \frac{23}{0.000075} = 55 \text{ dB}$$

☐ Dexter R. Wheeler, W1TUM, points out that the "Considerate Operator's Frequency Guide," January 1981 *QST*, page 47, should list the satellite downlink frequencies as 29.30-29.50 MHz.

☐ In addition to the plaques listed in February 1981 *QST*, page 73, the Long Island DX Association is sponsoring a DXpedition (phone) plaque in memory of Howard Geberth, W2NUT/1, for the 1981 ARRL International DX Contest.

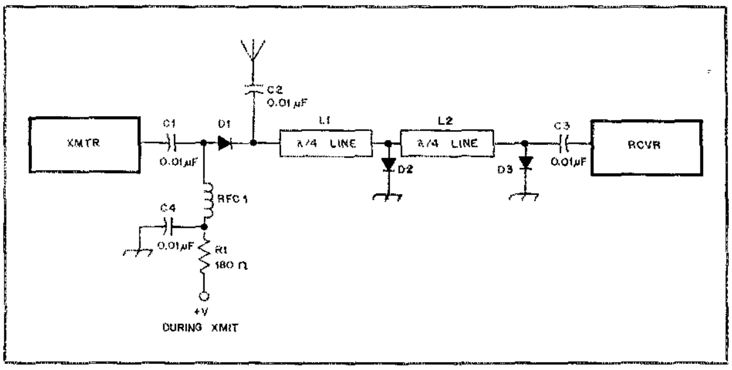


Fig. 1 — The correct Fig. 2 diagram for "T-R Switching With PIN Diodes," March 1981 *QST*, page 20.

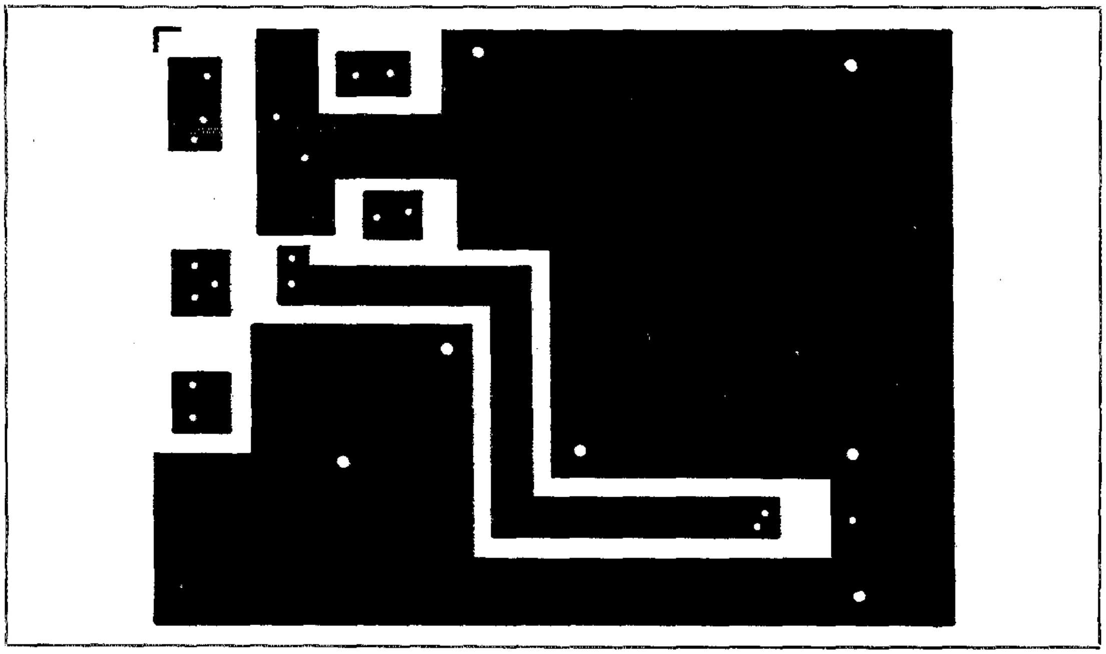


Fig. 2 — The etching pattern for Ridpath's "T-R Switching With PIN Diodes." Black represents copper.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

DEMAW'S ANTENNA SOLVES 2-METER COVERAGE PROBLEM

☐ My liaison work between the Macomb County Amateur Radio Emergency Service 2-meter net and the National Traffic System required a more effective antenna at my station than the quarter-wave radiator I had been using. Doug DeMaw's article, "Build Your Own 5/8-Wave Antenna for 146 MHz" (June 1979 *QST*), induced me to construct such an antenna. By operating this antenna as a ground plane, mounted on my chimney, the signal coverage from my station became county-wide with considerable gain over the quarter-wave unit.

Construction of the antenna is shown in Fig. 1. The mounting base is cut from flat-plate aluminum and formed over a 3/8 inch (10 mm) drill held in a vise. All 45° bends in the ground-plane radials can be formed in the same vise after the holes are drilled. I mounted the whole thing on a 12 foot (3.6 m) length of 1-1/2 inch (38 mm) tubing. It is secured to the tubing by two stainless-steel hose clamps. The coaxial cable is extended through the tubing for a neater appearance. A plastic pill bottle, having been drilled for a 3/16 inch (4.5 mm) hole in the bottom, is slipped over the antenna to protect the coil from the weather.

So far the antenna has given satisfactory performance with my Tempo S-1. I guess this letter is my way of saying thanks for an article that solved a problem that arose when our repeater was taken off the air during net operations. It saved me money, the cost being around one-tenth of a commercial antenna. The project gave me the pleasure and satisfaction of making something that worked. — *Harry G. Bellows, KB8MX, ex-KA8EZM, Mt. Clemens, Michigan*

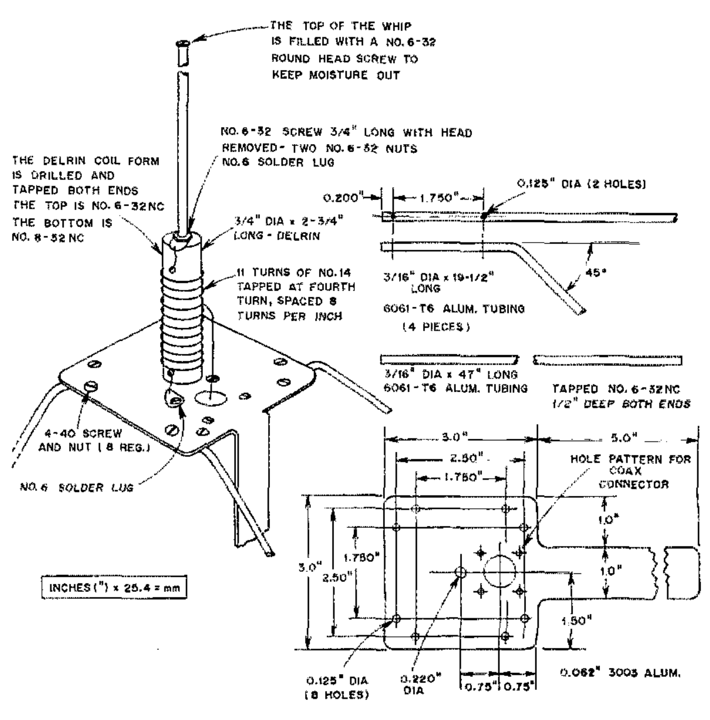


Fig. 1 — Details of the KB8MX version of Doug DeMaw's 5/8-wave 2-meter antenna. Signals from KB8MX now cover Michigan's Macomb County for the Macomb County Amateur Radio Emergency Service 2-meter network. This antenna did the trick.

THE COAXIAL-CABLE BALUN

☐ The two main advantages of coreless baluns over the ferrite-core type is that they are not subject to core saturation and possible power loss known to affect ferrite-core baluns under some conditions. Furthermore, coreless baluns present low SWR readings over a broad band of frequencies. I have a Collins-type coaxial-cable balun (Figs. 2 and 3) in my antenna system, put there originally because I did not wish to string up a footwarmer for the birds nor did I wish to waste costly energy.

A coaxial-cable balun is easy to build and inexpensive, and does not require the help of an rf lab, computer or calculator. To form the coil, the cable may be wrapped around a plastic bottle in the manner shown in Fig. 2. For mechanical stability the turns are closely spaced. An odd number of turns allows the center feed point and the output leads to appear on opposite sides of the coil.

Some liberty can be taken in the amount of cable used for the balun since it is a broadband device. "Cut and try" construction works well. The approach, therefore, is to have the balun become self resonant for the band to be used (or the *middle band* where a triband antenna is to be installed). Since my tribander covers 10, 15 and 20 meters, I made the balun resonate in the 15-meter band. Keep in mind that a balun is not a matching device like the L-match, pi-network or Transmatch. It is simply a transformer that, in this case, has a 1:1 ratio and connects an unbalanced line to a balanced

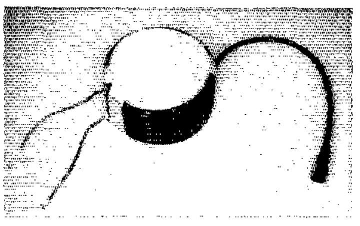


Fig. 2 — A coreless balun formed around a section of a plastic bottle. It contains an odd number of closely spaced turns of coaxial cable so that the terminating ends and the feed point are on opposite sides of the coil, offering an advantage for installation.

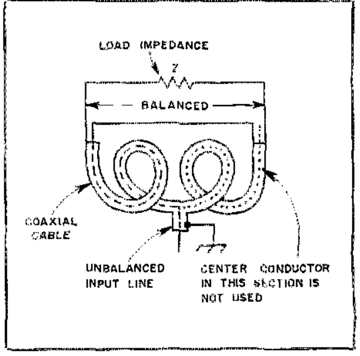


Fig. 3 — This illustrates the general configuration of the Collins type coreless balun as explained in the publication *Fundamentals of Single Side Band*, published by the Collins Radio Co., in 1959. In the accompanying text, Wayne Cooper, AG4R, explains the construction of a balun suitable for use with a 10-, 15- and 20-meter tribander antenna.

*Assistant Technical Editor

load. The resonant frequency of a coreless balun is easily checked with a dip oscillator (see page 21-3 of the 1981 *Handbook* for related information). Obtaining resonance is mainly a matter of adjusting the turns or varying the coil diameter.

A practical way to eliminate cable fittings or splices would be to cut the coil at the center tap point. Then use one of the half lengths to measure down the transmission line from the antenna. Connect the outer shields together at this point and rewind the balun coil as part of the transmission line. All exposed connections should be made weatherproof.

My balun is constructed with RG-8/U. A predetermined 5 foot, 5 inch (1.65 m) length of cable provided with an additional 6 inches (152 mm) for connecting leads, is soldered to the shield as explained above. The two ends are wound into a 7-turn coil having a 5-1/2 inch (140 mm) ID. Before I connected the output ends, I rechecked the coil at 21 MHz with my dip meter. An SWR bridge at the transmitter end of the line showed that the completed balun had a 1:1 ratio at 28 MHz and 1:1.3 at 3.5 MHz. I placed a 50-ohm dummy load across the balun output for this test. Total loss was 1 dB, an increase of 0.2 dB from the original line measurement.

An experimental balun I constructed consists of a 10 foot, 1 inch (3 m) length of RG-8/X cable plus connecting leads. This is wound into a coil of 9 turns having a 4-3/8 inch (111 mm) ID with a resonant frequency in the 21-MHz band. Checking it with an rf bridge and a 50-ohm load, I found that the balun displayed these impedance readings at the frequencies indicated: 3.5 MHz — 65 ohms; 7 MHz — 60 ohms; 14 MHz — 55 ohms; 21 MHz — 55 ohms and 28 MHz — 50 ohms. It can be seen that this balun configuration will also give a low SWR as a transformer connected to a 50-ohm antenna load. — *Wayne Cooper, AG4R, Miami Shores, Florida*

[Editor's Note: Attention is called to the following *Ham Radio* articles: Badger, "A New Class of Coaxial-Line Transformers," February 1980, pp. 12-18, and Nagle, "The Half-Wave Balun: Theory and Application," September 1980, pp. 32-35.]

HALF-SLOPER HARDWARE

☐ The quarter-wave or "half-sloper" wire antenna is being used by a great many amateurs on 40, 80 and 160 meters. This interesting and sometimes perplexing antenna generally gives a fairly good account of itself for local and DX QSOs, but many have written to Hq. and asked, "How do I attach the half-sloper to my tower?" Certainly, there are many practical ways to make the attachment point, but each has its weaknesses. I have found the method illustrated in Fig. 4 to be satisfactory for my needs. Perhaps it could be used as successfully at other locations.

Dimension "A" of Fig. 4A should be slightly smaller than the diameter of the legs of your tower. This will permit effecting a tight compression of the homemade clamp when the two no. 8 bolts are screwed into the mating nuts. My clamp/bracket is made of no. 16-gauge aluminum stock. It was formed around a piece of tubing that was slightly smaller in diameter than the legs of my Rohn 25 tower. The lips of the clamp were compressed in a vise until the aluminum sheeting was drawn to the approximate shape of the tubing.

The shortcoming of this attachment method is oxidation and electrolysis between the dissimilar metals. A good electrical contact is needed between the tower and the bracket to ensure that the shield braid of the 50-ohm coax is making a finite-resistance contact to the tower leg. I've found that a coating of silicone grease inside the clamp and on that part of the tower leg helps to slow down oxidation. Cleaning the mating surfaces and applying fresh grease every six months (in salt-air environments), or once a year (inland locations) should prevent problems.

Once the antenna wire is soldered to the coax connector, I suggest that a generous application of noncorrosive sealant be applied to the rear of the coax connector and around the heads of the mounting bolts.

A ceramic standoff insulator is mounted on the bracket just below the coax fitting. A long solder lug is affixed to the top of the insulator. This permits clamping the antenna lead to the insulator, as shown in Fig. 4B, for the purpose of reducing stress at the coax connector. Earlier installations of mine lacked this feature, and the lead wire eventually broke loose at the connector.

The main antenna insulator is supported from the lower part of the clamp bracket by means of a short loop of no. 14 solid-copper wire, as shown in Fig. 4B. This short guy section will remain durable even though the sloper moves about in the wind. Make sure that the loop of antenna wire from the standoff insulator to the lower part of the main insulator is large enough to permit ample play as the sloper wire is blown to and fro in the wind. — *Doug DeMaw, W1FB*

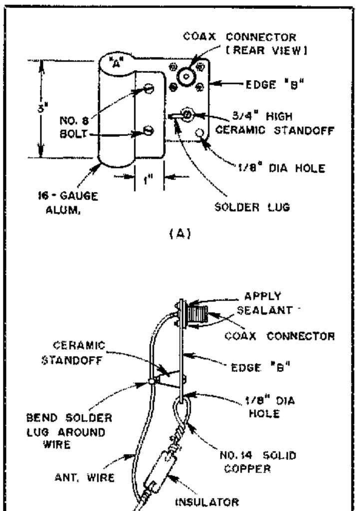


Fig. 4 — Details of the homemade clamp/bracket used for the W1FB half-sloper antenna (A). An edgewise view of the assembly is shown at B to illustrate how the standoff insulator is mounted. The coax connector should be coated with sealant to prevent oxidation between it and the aluminum bracket. Inches × 25.4 = mm.

ANTITORQUE DEVICE FOR WHIPLASHED BEAM ANTENNAS

☐ How many of you have had the gears torn out of your rotator motor as a result of high winds or sudden braking stops of your antenna? Recent QSOs led me to believe that the problem is a common one.

When I decided to invest in a tower and multiband beam antenna, the problem was uppermost in my mind. My good friend Gerald Smith, W9JGB, offered a suggestion on how to avoid such damage.

The simple device consists of a heavy spiral spring welded to two pieces of pipe, one inside the other (Fig. 5). The top of the spring is welded to the top pipe and the bottom is welded to the lower pipe. Any size pipe can be used but the two pipes must be capable of telescoping. Furthermore, the spring must fit fairly snugly over the larger of the two. In my case, I have a 1-1/2 inch (38 mm) upper pipe and a 2 inch (51 mm) lower pipe. The spring is just 2 inches in diameter and 10 inches (254 mm) long. It is formed from 1/4 inch (6 mm) spring steel. The heavier and stronger the spring, the better it is, for it takes up only the greatest of shock to your rotator gears. It should not be so weak that every little breeze will swing your antenna one way or the other.

Construction is not difficult. I simply telescoped the two pipes to the desired length, slipped the spring over the pipes and made sure to center the spring at the point where the smaller pipe extends from the larger pipe. A welding bead was then placed around the top spiral of the spring, firmly attaching it to the smaller pipe. A similar bead was then placed around the bottom spiral of the spring to hold it firmly to the larger pipe.

Before telescoping the two pipes, I smeared heavy lubricating grease on the smaller pipe. When the assembly was completed, I smeared additional grease on the coils of the spring.

Obtaining the proper spring may present a problem for amateurs living in some areas. Fortunately for me, the good people at the Superior Spring Manufacturing Co. in Kokomo furnished me with a one having the correct size.

Since I installed this device, my Mosley TA-33 on top of a 40-foot tower has withstood some very heavy winds, and the gears in my CDE rotator remain intact. I think this is an excellent investment. — *Russ Rennaker, W9CRC, Kokomo, Indiana*

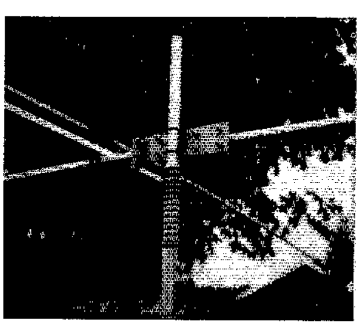


Fig. 5 — A shock absorber type spring and telescoping pieces of pipe prevent heavy winds from wrenching the beam antenna atop W9CRC's tower. This safety measure avoids possible damage to the rotator gears.

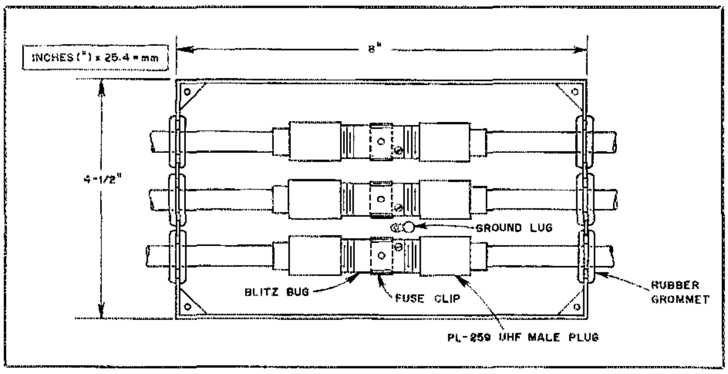


Fig. 6 — An enclosure for coaxial feed line lightning protectors. The housing is a Bud P/N AC-1407 aluminum chassis with bottom plate P/N BPA-1507. Buss P/N 5592-33 fuse clips hold the arrestors. Grommets at each end of the enclosure provide snug protection against weather.

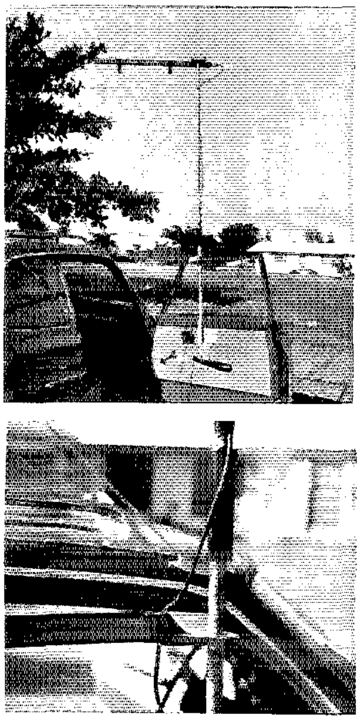


Fig. 7 — This rotatable mobile antenna, used for transmitter hunting, is the work of Bob White, WB4TNV. The 5 foot (1.5 m) electrical conduit mast slips into a piece of pipe bolted to a wooden tee that fits in the door handle. The lower photo shows the aluminum bracket that supports the mast. A handlebar grip, shown above the bracket, facilitates turning the antenna. It takes Bob only three minutes to put the antenna in operation.

ANTENNA FEED-LINE ENCLOSURE FOR COAXIAL LIGHTNING PROTECTORS

□ Permanent yet inexpensive in-line lightning protection for antenna transmission lines is provided through the use of the Blitz Bug, manufactured by Cushcraft. Each of my three coaxial lines now has this protection.

To ensure weatherproofing, ease of maintenance and component accessibility, and to provide a static drain to ground, I designed the enclosure shown in Fig. 6. The housing is a 4-1/2 × 8 × 1-1/2 in. (114 × 203 × 38 mm) chassis equipped with three fuse clips suitable for mounting 9/16 in. (14.3 mm) OD fuses. These clips firmly hold the Blitz Bugs. The protectors are model LAC-2 (uhf female ends). If necessary, the lightning protectors can be snapped out easily.

In order to pass the coaxial feed lines in and out of the enclosure, three holes are made on each side of the chassis. Each of these 13/16 in. (20.6 mm) holes is fitted with a 3/4 in. (19 mm) grommet. These grommets have an ID wide enough for RG-213/U or RG-8/U transmission line while providing a snug fit. When the grommet is pushed out of the mounting hold, there is sufficient clearance for the PL-259 coaxial male plug to pass through.

A ground post may be installed at a convenient point on the enclosure and a ground clamp placed on the outside of the box. Heavy wire (no. 8) should connect the static drain screws on the lightning protector to the ground post.

Once the cables are connected (the grommets should be placed on the cable ends before installing the PL-259 connectors) and the Blitz Bugs are snapped into the clips, the enclosure is ready for mounting. I mounted mine under the house eave near my tower. Added weather protection is afforded by the use of a chassis cover plate. The ground lead from the exterior of the box to an adjacent ground rod consists of heavy braided wire. [Editor's Note: Copperweld electrician's ground rods are well suited for grounding antenna systems.]

The arrangement of Fig. 6 can be adapted to other antenna system requirements. In any case be sure to ground your tower! — *Edward A. Whitman, K2MFY, Plainview, New York*

LIGHTNING PROTECTION FOR THE HAM-M CONTROL BOX

□ After the destruction of one meter movement and several diodes in my Ham-M control box because of lightning surges within the vicinity of my tower, I decided that it would be advantageous to isolate the box whenever serious weather threatened. At first this seemed an easy task, but it involved disconnecting eight control wires from the terminal strip located on the rear panel of the box. To get around this time-consuming method, I installed Molex male and female connectors directly in the control line. Readily available and reasonably priced, they are easy to disengage and save me from the feeling of anxiety during the thunderstorm season. — *James E. Mackey, K3FN, West Chester, Pennsylvania*

A 2-METER FOX-HUNT ANTENNA

□ To be successful at hunting a transmitter or tracking down a jammer, you need a directional antenna that will enable you to take bearings quickly without getting out of your car. An inexpensive stowable mast, mounted on a car door as shown in the accompanying photographs (Fig. 7), provides a simple way of supporting a rotatable mobile antenna. Each car model, of course, will require some variation from this particular arrangement.

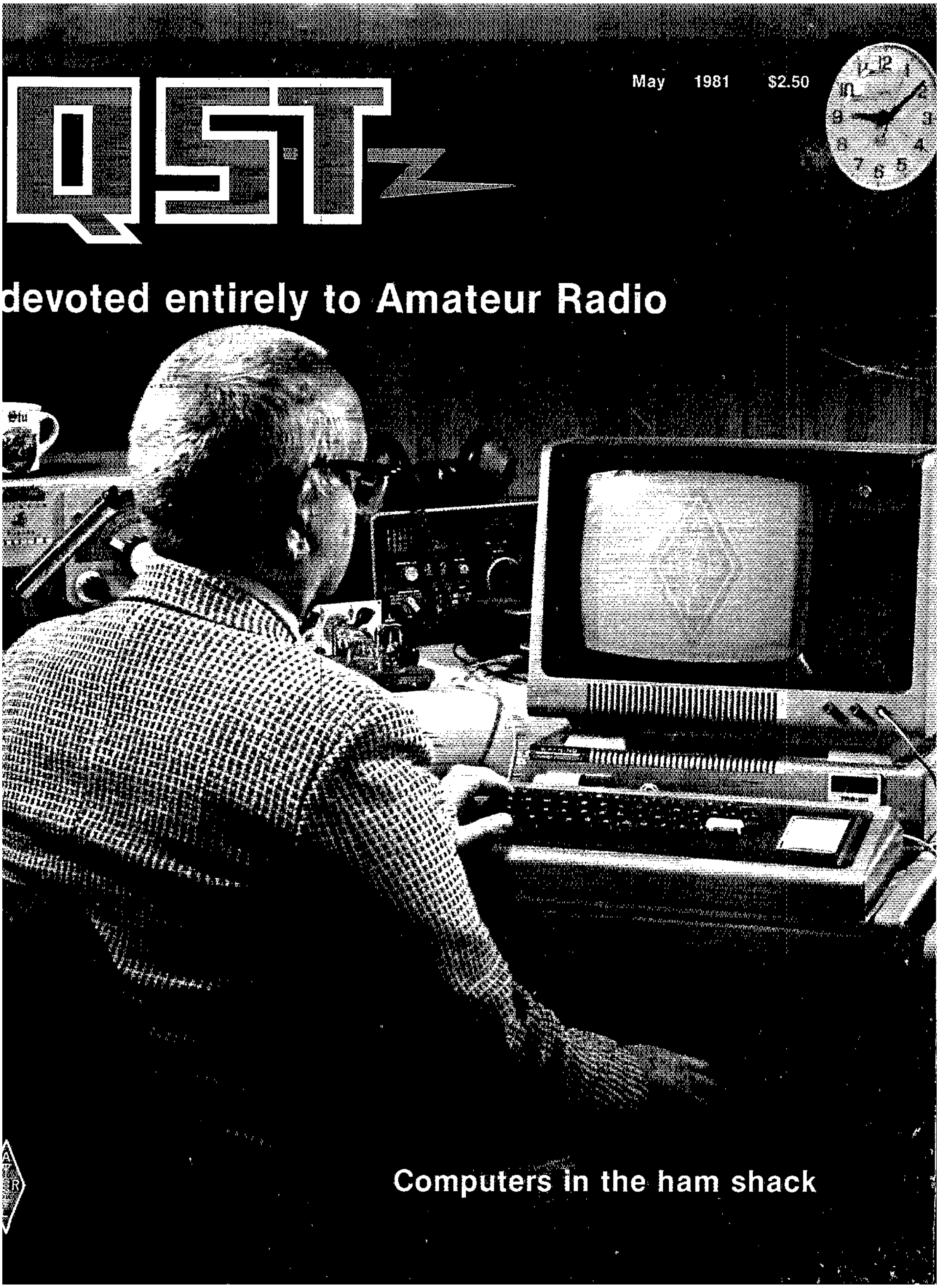
The mast is made from a 5 foot (1.5 m) length of 1/2 inch (13 mm) electrical conduit. Other materials required include a 1 foot (305 mm) length of pipe with an inner diameter large enough to accept the 1/2 inch conduit. You will also need a 12 × 3 inch (305 × 76 mm) piece of aluminum to make a bracket, 12 inches (305 mm) of rubber from an old tire inner tube and a scrap of wood to be fastened to the bottom of the 12 inch length of pipe as shown in the photograph. Two bolts from your junk box will be adequate for fastening the wood to the pipe. A sheet metal screw is the only other item on the materials list.

Wrap the rubber around the top of the door at a point adjacent to where the mast will project upward past the window frame. Bend the aluminum around the rubber so that the piece of aluminum can serve as a bracket for the mast. See the photos. Drill a 5/8 inch (16 mm) hole through the bracket to accommodate the mast. To avoid getting cut or scratched by the bracket, the edges of the aluminum should be filed. Make a small hole for the sheet metal screw which serves to draw the ends of the bracket together once it is placed on the door.

Cut the piece of wood to fit in the hole of your door handle (arm rest). The wood should extend 6 inches (152 mm) above the handle. Bolt the 12 inch length of pipe to the wood, being sure to countersink the bolts on the back of the wood to prevent scratching the car.

Once you slide the mast through the bracket and into the larger pipe attached to the wood, your installation is finished. To make storage easier, you may wish to cut the mast into two sections that can be joined with a fitting. To prevent the mast from turning while driving, drill a hole through the 12 inch pipe and the mast. Then insert a nail. Use of a handlebar grip facilitates turning the antenna.

The folding log-periodic antenna I have used contributed to winning a share of the fox hunts and led to the QTH of a jammer who was caught. I can furnish information on this antenna for anyone who wishes to send me an s.a.s.e. — *Bob White, WB4TNV, Coral Springs, Florida* QST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THE COVER

Computers in the hamshack can make mundane tasks fun, and complex ones possible! For two practical examples, see pages 18 and 30.

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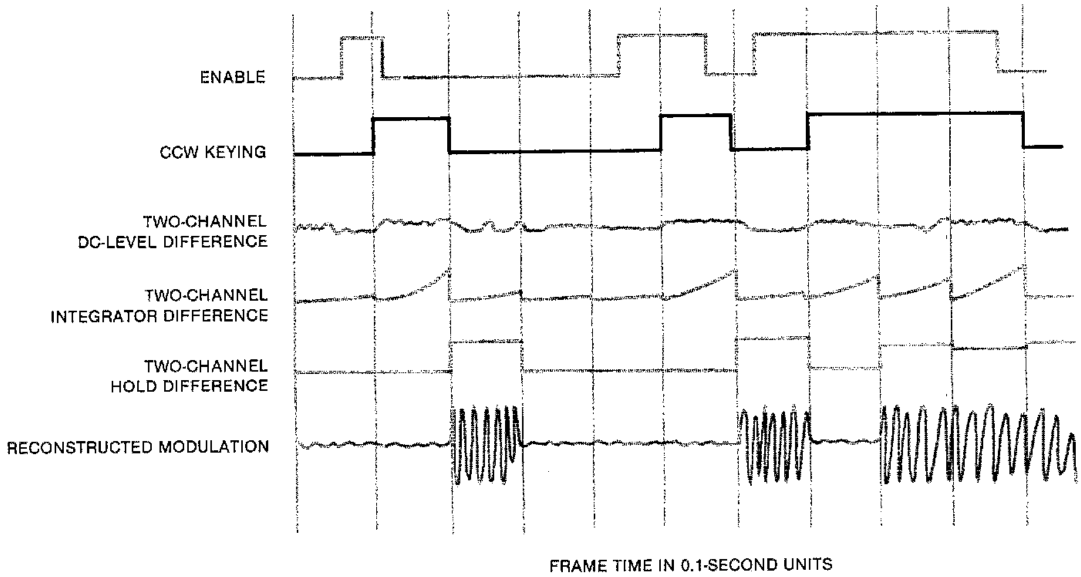
Coherent CW — The Concept

Part 1: Would you think that you could ***decrease*** your transmitter output power by a factor of 10 and ***increase*** signal readability by the same amount — simultaneously? It's being done now.

By Charles Woodson,* W6NEY



The more we know about something we seek, the easier it is to find. This principle applied to Morse cw communications is called coherent cw or ccw. On-the-air trials of this technique have shown it will provide an improvement of more than 20 dB in communications effectiveness over ordinary cw methods. This same principle can be used with RTTY, ASCII and fsk signals, but this discussion will focus on cw keying.

Cw signals may be analyzed as a series of digital units, all of which have (at least approximately) a unit of time in common. For convenience, I'll call this time unit a "frame." Each frame contains either a "mark" (key down) or a "space" (key up). Fig. 1 illustrates this concept.

Ordinary cw dots, dashes and spaces begin at somewhat arbitrary times, depending on when the operator happens to press the key. Thus, the frame length varies to a considerable degree, and you can't predict when each frame starts and ends. With ccw, all dots, dashes and spaces are exact multiples of the basic time unit and occur within predictable time frames. This includes any pauses during transmission. When received, ccw signals sound like any other cw signal except that they are being sent very precisely, as with

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Fig. 1 — The elements of ccw communication. Frames, in 0.1-second units, are shown on the horizontal axis. The enable (top waveform) shows the closure of a manual key by the operator. When referenced to the precise frame times, it can be seen that the dots, dashes and spaces of the enable are not accurate in length. Note that with the ccw-keyer waveform a mark or space is begun only at the beginning of the frame period and continues for the full period(s). As received, the signal is mixed with QRM and QRN. The difference between the dc voltages from the switching mixers of the two channels (third waveform) is a function of the desired, but weak, signal. An integrator sums the power (voltage) received over the frame period. This sum is sampled at the end of the period and held until the beginning of the next period. The recovered modulation is used to key an audio signal for detection by ear

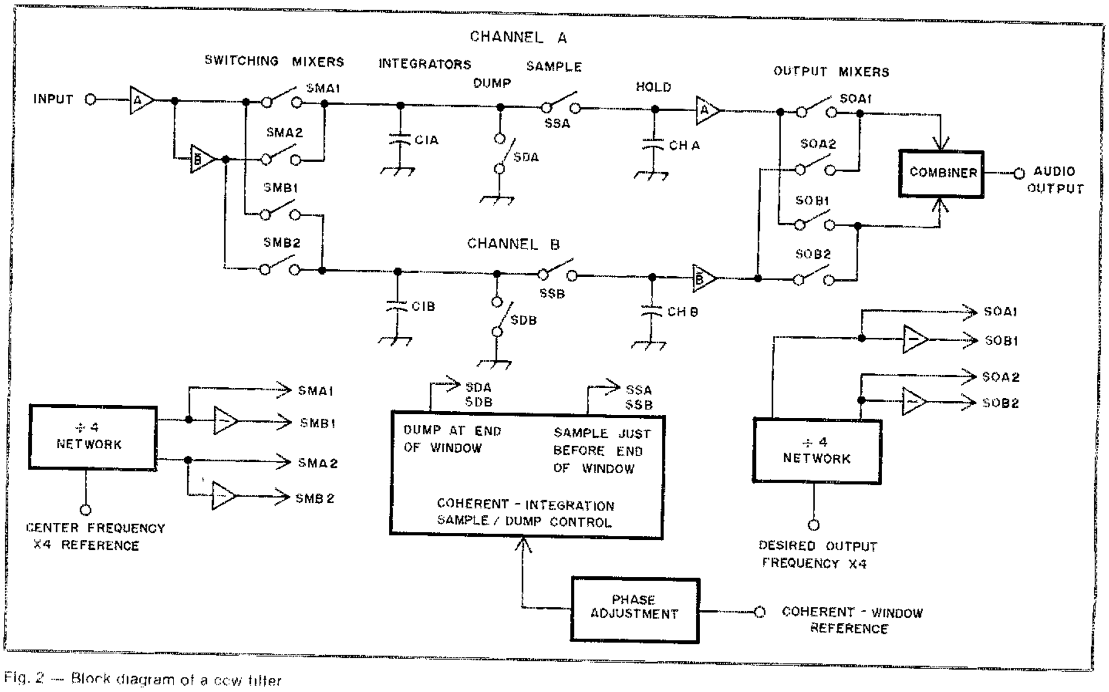

Fig. 2 — Block diagram of a ccw filter

a perfect "fist." This characteristic is utilized to permit the use of very narrow bandwidth filters.

CW Filters

In general, receiver filters with bandwidths much wider than that of the desired signal are less effective because they allow reception of additional noise and undesired signals. At 12 wpm a cw signal occupies about 10 Hz of the spectrum, yet 500- or 2300-Hz-wide filters are frequently used for cw reception. With a 500-Hz filter, one hears the 10-Hz-wide desired signal and 490 Hz of noise and QRM! By analogy, an ssb operator using a similar approach would listen to 100 kHz of the band at one time!

High-Q analog cw filters are not useful at the narrow bandwidths approaching the bandwidth of a 12-wpm cw signal. Such filters, with bandwidths less than 500 Hz, tend to "ring" or produce an output after the signal ceases. The human ear is confused by such ringing. Also, the receiver stability and resetability required in conjunction with the filter, on the order of a few hertz, is difficult to achieve.

Phase-locked loop (PLL) filters with time constants long enough to produce bandwidths of only a few hertz unfortunately take tens of seconds to achieve lock. PLLs also tend to lock on the strongest signal in the passband and are, therefore, sensitive to QRM. PLL filters have their place of importance, but not with the bandwidths required here.

The filter we need will provide a bandwidth of only a few hertz without ringing and without a tendency to lock on the QRM. Such a filter improves the signal-to-noise ratio dramatically. A 1-W signal copied through a 10-Hz bandwidth filter is comparable to a 50-W signal heard through a 500-Hz filter or a 230-W signal heard through a 2300-Hz filter.

The CCW Station

Typically, ccw stations agree on an operating frequency (e.g., 14,049,000 Hz ± 2 Hz) and a frame length (usually 0.1 second, the speed of 12 wpm), and acquire the "framing" — when each frame starts and ends — as part of the signal-tuning process. Thus, the frequency, frame length and frame phase are all known at the receiving end and are used to advantage in the detection process.

To achieve the necessary frame-length accuracy and to get on the operating frequency within the narrow tolerance of the filter, all frequency-determining oscillators in both the transmitter and receiver of the ccw station must be highly stable and accurate. The stability and accuracy requirements are obtainable by using carefully built crystal oscillators which are compared to a reference frequency such as WWV. Time discipline for the transmitted signal is determined by a reference oscillator which is divided to provide a 10-Hz synchronizing signal for the transmitter keyer. The ccw filter at the receiving station uses timing signals derived from the station reference oscillator. These timing signals tell the receiver filter when to expect a frame to begin and end.

The Coherent Integrating Filter

Fig. 2 shows a block diagram of the filter which makes possible the efficient reception of a ccw signal. The major blocks of each of the two filter chains are: input mixers, integrators, sample-and-hold circuits, output mixers and the timing and control circuitry. The reason for the two chains will be examined later; for now, we'll follow the signal through one chain.

The Mixer: The first part of each filter chain is a switching mixer where the desired signal (along with adjacent QRN and QRM) is mixed with a reference signal of the same frequency as the desired signal. (Solid-state switching is performed in the actual circuit, but for simplicity, mechanical contacts are shown in Fig. 2.) The reference signal is obtained from a stable source such as the timing and control circuitry, and it determines the center point of the ccw filter. A signal at the desired frequency comes out of the mixer as a dc voltage — the stronger the signal, the larger the voltage. An off-frequency signal, however, comes out of the mixer as a low-frequency ac voltage. We mix the incoming signal right down to zero beat. Undesired signals will be distinguished from the desired signal because they are not exactly zero beat.

The Integrator: An op-amp integrator comprises the second part of each filter chain. We use the integrator to distinguish the desired signal (the zero-beat dc voltage) from the undesired signals (low-frequency ac voltages) coming from the mixer. The integrator may be thought of as a moderately large capacitor. A synchronizing "dump" signal from the timing and control circuitry shorts out this capacitor at the start of each time frame. Any desired signal (dc voltage) during the time frame causes the capacitor to charge. The resulting voltage at the end of the time frame is a function of the strength of the desired signal received during that frame.

QRM and QRN, being off frequency, appear as ac signals to the integrator capacitor. These charge the capacitor for part of the time frame, but discharge it for other parts of the same period. Consequently, signals off frequency do not have as great an effect on the integrator output as do signals exactly on the desired frequency. That is how the ccw filter achieves its selectivity.

As an example, consider an interfering carrier which is 10 Hz above or below the desired signal. Following the switching mixer, this QRM appears as a 10-Hz ac voltage. If the filter is set to the ccw standard frame length of 0.1 second, then the 10-Hz interfering signal goes through one complete cycle during the integrating period. At the end of the time frame, the QRM-produced voltage at the integrator output is zero. Thus, the ccw filter has a null just 10 Hz above and below its center frequency. There are also similar nulls at other 10-Hz multiples.

Sample-and-Hold and Integrator Reset: At the end of each time frame, a "sample" signal from the timing and control circuit transfers the voltage at the integrator output to the sample-and-hold circuit. That circuit "remembers" that voltage for the following interval. Once the sample-and-hold has acquired the integrator output voltage, a dump signal from the timing and control circuitry shorts out the integrator capacitor. It does this by means of a CMOS analog switch connected across the capacitor. This allows the integrator to start over again with zero voltage at the start of the next time frame.

Resetting the integrator at the end of each time frame lets the ccw filter avoid the ringing (or intersymbol interference) common to other narrow-bandwidth filters. Note that this is possible only because the ccw filter "knows" when each time frame begins and ends. It is here that the time discipline of the transmitted signal is used to advantage in the detection process.

Output Mixer: This last block of the filter chain is much like the input mixer; it functions as an amplitude modulator, using the sample-and-hold output voltage to control the amplitude of a sidetone. The purpose of this mixer is to construct a sidetone for the human operator to hear.

Why Two Channels?

If the incoming signal is in phase with the center reference, then the mixer output is always positive. The integrator which follows will see a positive dc voltage. If the signal is out of phase with the reference, then the mixer output is always negative. The integrator will see a negative dc voltage. The positive or negative dc voltage charges the integrator capacitor, the sample-and-hold "remembers" that charge during the next time frame, and the output mixer generates a sidetone whose amplitude is proportional to the voltage on the sample-and-hold capacitor. But if the signal is 90° out of phase with the reference frames, then the mixer output will at times be positive and at other times be negative during a given input cycle. This output will be averaged to zero by the integrator. The result is no filter output from this channel.

The situation is different for each channel because the A channel input mixer is operated by a reference which is 90° out of phase with the B channel reference. Thus, if a signal is 90° out of phase with the A channel, it will be in phase (or 180° out of phase) with the B channel. At all phase differences between the two channels, the product of the two channels is always the desired signal despite the phase relationship between the center frequency reference and the incoming signal.

If the desired signal is graphed as a phasor (as in Fig. 3) one might say that the B channel picks up the X component of that phasor, and the A channel picks up the Y component of the phasor. The two-channel output mixers are also driven with signals 90° out of phase. That way, the output tones combine vectorially. The result is that the combined output is a tone whose amplitude reflects the amplitude of the desired signal, regardless of the signal phase. The phase of the output tone also reflects the phase of the desired signal.

The theoretical response curve of the filter may be developed. We won't go into the mathematical details except to say that the amplitude response is a sin X/X curve, like that in Fig. 4. For a 0.1-second frame length, the nulls in the filter response occur every 10 Hz either side of the center frequency. The 3-dB points on this curve are 9 Hz apart; the 6-dB points are 12 Hz apart.

Fig. 5 compares the ccw filter (0.1 second frames) with an ordinary 500-Hz cw filter and a 2700-Hz ssb filter. On this scale it is impractical to show the numerous nulls in the ccw-filter response; shown instead is the envelope of the primary response.

How Much Improvement?

One way of comparing ccw with the ordinary cw method is to consider the filter noise bandwidth. This is the bandwidth of

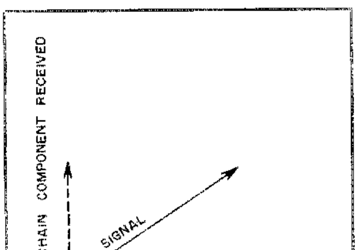

Fig. 3 — The desired signal considered as a phasor.

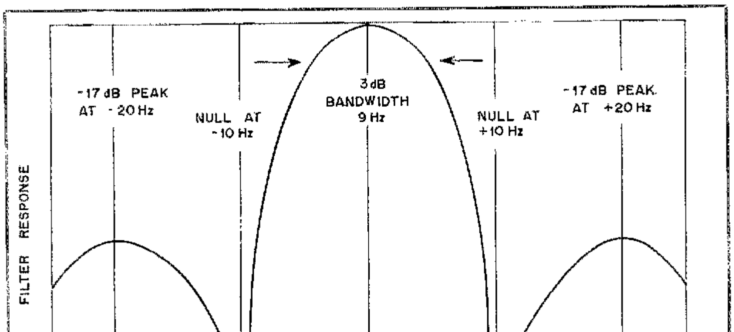

Fig. 4 — Filter-response curve for a 10-Hz bandwidth ccw filter.

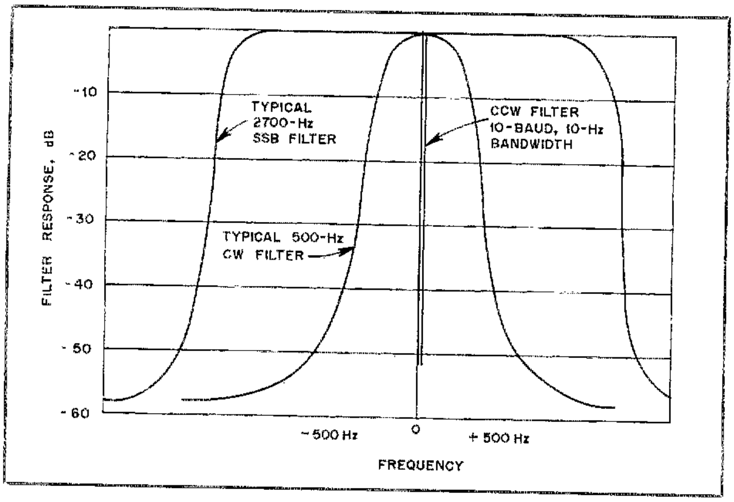

Fig. 5 — A comparison of three filter-response curves.

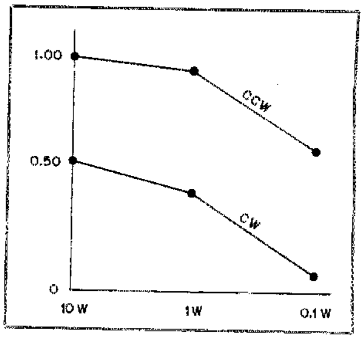

Fig. 6 — A graph of the average proportion of copy made by four operators of simultaneously sent cw and ccw signals. Three different power levels were used. See text.

an ideal steep-sided filter which would pass the same amount of random noise as the filter being considered. For 0.1-second frame length ccw, the filter noise bandwidth is 10 Hz. This equates to an approximate superiority of 17 dB over a 500-Hz cw filter and about 24 dB over a 2300-Hz filter. Such estimates should be reasonably accurate with respect to noise, but when QRM is present, the ccw filter probably does even better. Using a ccw system of 0.1-second frames with ground wave in the presence of natural noise, and adjusting power for matching readability, I have measured an approximate 16-dB improvement over a 470-Hz crystal filter; this is close to the theoretically expected value.

Narrowing the ccw bandwidth by using longer frame times provides an additional signal-to-noise advantage at the price of slower information transmission rates. A 0.1-second integration period gives about 24 dB improvement over a 2300-Hz crystal filter: a 1-second integration period (1.2 wpm), 34 dB; a 10-second period, (0.12 wpm), about 44 dB. These speeds are slow, but the improvement in effective communication with lower power is quite fascinating.

The improvement gained by long-frame ccw is limited by phase modulation introduced by the propagation path. For 14-MHz signals, motion in the F layer typically produces 2 or 3 Hz of phase (or frequency) modulation for a JA to W6 path.[1] (We have also observed what appears to be propagation time delays under poor band conditions.) When the filter passband becomes so narrow that this modulation exceeds the filter bandwidth, further improvement in signal-to-noise ratio cannot be obtained by narrowing the filter passband.

In evaluating filter effectiveness, noise bandwidth does not tell the whole story; there are psychological considerations, too. The human ear is frequency sensitive, and the human brain can focus on particular cw signal frequencies amid the noise and QRM. Skillful cw operators use this capability well. My observations have led me to conclude that this skill is worth at least a 6-dB margin when using a 2300-Hz filter. QRM, however, is often a confusion factor and therefore causes more degradation of copy than an equivalent amount of random noise. These psychological factors are difficult to quantify, but probably reduce the advantage of ccw over ordinary cw.

Fig. 6 shows graphically the results of on-the-air comparisons between cw and ccw made in 1975. Transmissions were made on 14,049,000 Hz from JR1ZZR at power levels of 10 watts, 1 watt and 0.1 watt using ccw and a vertical ground-plane antenna on a four-story building. A three-element beam was used for reception at W6BB. The ccw signals were received simultaneously as cw and ccw signals, and were recorded on separate channels of a stereo cassette recorder. We selected sample periods from the cassette recording and played back the signals to four moderately experienced cw operators. The average proportion of copy shown on the graphs is based upon words considered copied. The copy content was taken from radio journals. Extrapolation of these data indicate an estimated 13-W cw signal as equivalent to a 0.1-W ccw signal in communications effectiveness, or a 24-dB superiority for ccw.

[1][Editor's Note: The amount of "signal spreading" is determined in large measure by the earth's geomagnetic activity (A-index), which is more severe under disturbed conditions.]

Concluding Remarks

The ccw technique appears to be most promising, especially where signals are weak compared to the noise and QRM. Under high absorption and QRN conditions (as often experienced on 80 and 160 meters) the additional selectivity of ccw would be helpful; we don't have data on that yet however.

Ccw might be used for EME communication, but the problem is complicated because of lunar-motion Doppler effects. One might need a computer to calculate the frequency at which the signal is expected to return. Also, achieving the necessary frequency stability of 1 or 2 Hz is more difficult at the higher frequencies used for EME.

Some of the simplest rigs are the easiest to convert for ccw operation. To obtain the full advantage of the ccw mode, however, receiver quality should be high. In Part 2, I will describe the equipment and methods used for communicating by ccw. [QST]

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Coaxial Cable Antenna Traps

These traps are neat, compact, cheap and easy to assemble. If you're a ham, that's got to sound interesting!

By Robert H. Johns,* W3JIP

Both the coil and capacitor of a parallel-resonant antenna trap can be made from the same length of coaxial cable. This type of trap construction offers several electrical advantages and is easy for the home builder to construct.

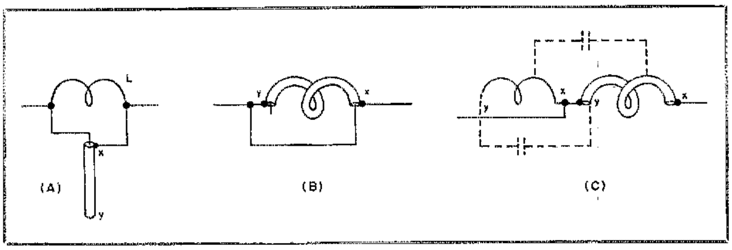

Fig. 1 — The simple trap at A uses a length of coaxial cable for the network capacitor. At B, a single piece of coaxial cable serves as both the coil and capacitor. The presentation at C is explained in the text.

The Concept

Parallel-tuned circuits, such as shown in Fig. 1A, are common. An inductance, L, is tuned to resonance by means of a capacitor made from a piece of coaxial cable. The capacitor is formed by the capacitance existing between the inner and outer conductors of the cable. By proceeding one step further, both the inductor and capacitor of the resonant circuit may be made from the same length of coaxial cable. This is shown in Fig. 1B where the cable is formed into a coil. The upper end of the braid (X) has become the right side of the inductor and the lower end (Y) has looped around and joined the antenna wire and inner conductor from the other side of the coil to become the left end of the inductor. Note that the inner conductor is cross-connected to the outer braid at the opposite end of the coil; this is essential. Were it joined to the braid at X, there would be no capacitor formed, since there would be no voltage difference between the conductors at X and by transformer action, all points along the cable would be at the same potential.

To help visualize the inductors and capacitors formed by this connection, the inner conductor and outer braid coils are separated as shown in Fig. 1C and placed end to end. The cross connection is joining the two in series, X to Y, in the middle. The capacitors indicated by the dashed lines are representative of the distributed capacitance between corresponding points of the two coils and the capacitance between the inner and outer conductors of the cable. Antenna traps made this way have excellent Q. High Q is desired for a trap in a multiband antenna because at frequencies lower than the one to which it is tuned, it becomes a loading coil.

Coaxial cable capacitors have good high-voltage ratings and don't change capacitance with temperature. Assuming the impedance at the end of a dipole to be as high as 8000 ohms, a kilowatt of power in the antenna would develop 3000 volts rms at the end of the dipole to drive the resonant current in a trap located there.[1] While it is difficult to estimate the actual coaxial cable trap ratings, I have tested traps made with RG-58/U at a 1-kW input power level and they held up nicely. High Q, conservatively rated traps could be made from RG-8/U cable with some increase in construction difficulty and weight. The weakest point (at which the cable might arc over if not insulated properly) is at the free end of the inner conductor, point Y, in Fig. 1. Any sharp points exposed to the air at that location require attention.

Traps for Wire Antennas

Figs. 2 and 3 show a trap made for use

[1]Notes appear on page 17.

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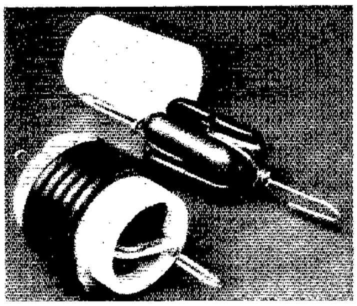


Fig. 2 — The construction of a coaxial-cable trap. Copperweld wire loops are first attached to the egg insulator. Holes are drilled in the polyethylene form to pass the cable leads as described in the text. The form is a snug fit around the insulator.

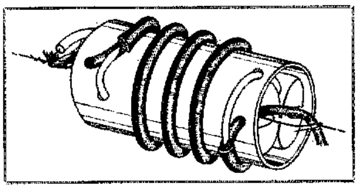


Fig. 3 — The braid of the coaxial cable is used to form the trap coil; it is soldered to the no. 14 Copperweld wire which is looped through the insulator and used for attachment to the antenna wire. At the right-hand side of the trap, the inner conductor is separated from the braid and passed through the inside of the trap. At the left end of the trap it is soldered to the braid and antenna wire, forming the cross connection. The inner conductor emerging from the coax at the left of the trap is held in place merely by means of a hole drilled through the coil form; no solder connection is made.

with a dipole, inverted V or other wire antenna. The coaxial cable, RG-58/U, is wound on a 1/8-in. (3.2 mm) wall polyethylene tube coil form 1-1/2 in. (38 mm) in diameter that is force fit over a plastic egg insulator. This assembly is lightweight, strong and inexpensive, and also helps in making the necessary cross connections. The thick-walled tubing aids in insulating the free end of the coaxial cable inner conductor.

To make a trap, several inches of the cable jacket are removed, the braid loosened, and the inner conductor and dielectric fed through a hole in the loosened braid. Two pieces of Copperweld wire should be attached to the egg insulator (Fig. 2); they furnish tie points for the antenna wire and traps, and the capacitance between them will be part of the completed trap. As shown in Fig. 3, the cable braid is passed through a hole in the polyethylene tubing at the right-hand side of the coil and is soldered to one piece of the Copperweld wire on the insulator. The center conductor passes through another hole in the coil form 90 degrees beyond the first hole and is routed through the egg insulator beside the other piece of Copperweld wire and soldered to it at the opposite end. (This is the cross connection shown in Fig. 1B.) The required number of turns of cable may be determined from Table 1. Wind them tightly onto the coil form. Once again, separate the braid and center conductor. Pass the braid through a hole in the form and solder it to the Copperweld wire (as shown in Fig. 3) at the left of the coil. A diagonal hole is drilled into the wall of the coil form and the free end of the inner conductor of the cable placed into it to provide some degree of mechanical stability and electrical isolation; this end is left unattached.

When constructing a trap, one should keep in mind that both a coil and capacitor are being formed. The cable should be handled carefully, especially the dielectric between the inner and outer conductors. The mechanical arrangement does not require soldering close to the dielectric, which shouldn't be harmed if unnecessary heating from a soldering iron is avoided. It's better to heat a joint quickly with a large iron than cook the work for a long time with a small iron.

The coaxial cable is available with either a stranded or solid-center conductor. Stranded conductor cable is more flexible and is preferred. If solid-center conductor cable is used, it will require more care and patience in separating the braid from the dielectric and center conductor because of the stiffness of the cable. The lengths of cable given in Table 1 are measured between the holes in the tubing through which the braid passes. These lengths are about 0.4 in. (10 mm) longer than that required by a close-wound coil of the same number of turns. The coils can be tuned to the proper frequency with the aid of a GDO by spacing the coil turns on the form. An adjustment range of 5 to 10% is possible.

Once the traps are tuned to the desired frequency, they should be secured in position. Tape could be used, but I suggest covering the entire trap with a weatherproofing and insulating layer such as the silicone rubber coating produced by Dow Corning. This compound is brushed on and will set overnight. It is intended as a roof-mending product, but has excellent insulating properties as well. It is available in quart (0.95 liter) sizes at most discount stores. The trap shown in Fig. 4 has been coated with this material. Silicone rubber caulking material that is widely available in tubes may also be used.

Fig. 5 contains the dimensions of a five-band trap dipole for 75 through 10 meters. It may prove to be a bit short on 75 meters since the antenna with which the measurements were made was only about 20 ft (6 m) high at the center and drooped to about 8 ft (2.4 m) at the ends. Notice that the antenna is not as short or as heavily loaded by the traps as some trap dipoles. The coaxial traps are relatively small and do not offer much loading inductance on the lower-frequency bands. This provides an advantage in antenna bandwidth, each dipole exhibiting a low SWR over almost as broad a range as a normal half-wave dipole. Trap antennas which are heavily loaded by the trap coils display a narrow bandwidth.

The reason for this loading coil behavior can be seen in Fig. 6, where the sum of all the distributed capacitance is shown as C. The inductance of the circuit is comprised of the inner and outer conductors of the coil in series. The antenna connections are "tapped down" on the outer braid half of this coil. At resonance, the trap still presents a high impedance. Below the resonant frequency of the trap, the loading coil inductance is much less (perhaps 25%) of the total inductance, producing a very small loading coil at below-resonant frequencies.

Traps for Verticals and Beams

The coaxial cable trap can be incorporated into antennas made from tubing by wrapping the cable on an insulating

Table 1

Construction Data for the Traps

Band of Resonance (meters)	On 1-1/2 in. (38 mm) form: Number of turns RG-58/U	Coil length (mm)	On 7/8-in. (22 mm) form: Number of turns RG-58/U	Coil length (mm)
10	3-3/4	30	6-1/2	50
12	4-1/2	30	7 1/2	55
15	5	35	8-1/4	55
17	5-3/4	35	9-1/2	60
20	6-3/4	45	12	80
30	9-3/4	60	17	100
40	12-3/4	75		

In. × 25.4 = mm

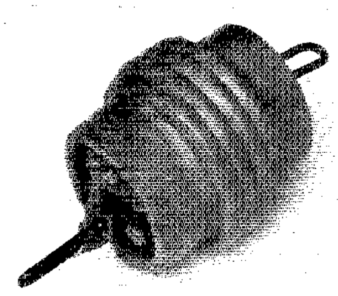


Fig. 4 — A coaxial cable trap with a silicone rubber coating.

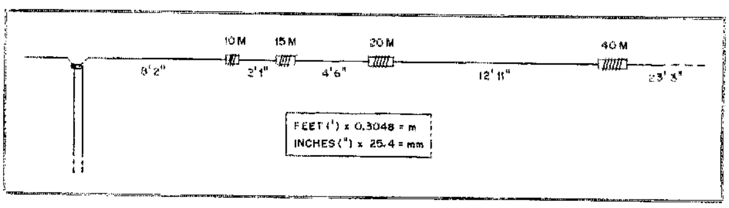


Fig. 5 — A 75- to 10-meter dipole using the coaxial-cable traps. One half of the antenna is shown.

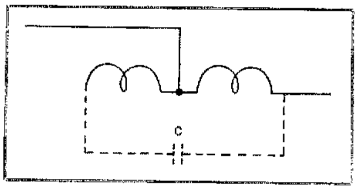


Fig. 6 — The entire coil formed by the inner and outer conductors in series is contributing to the trap inductance at resonance. Below resonance, when the trap is acting as a loading coil, only the outer braid is active, producing a much smaller effective loading inductance than that normally encountered with other types of traps.

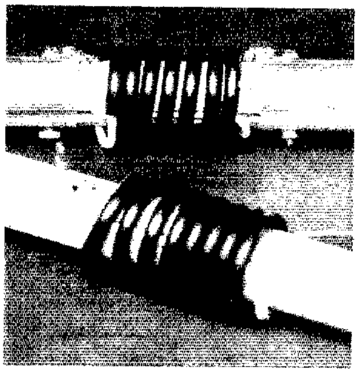


Fig. 7 — These coaxial-cable traps are wrapped on wooden dowels. The inner conductor of the cable at the right-hand side completes the cross connection at the left end by passing beneath the turns of the coil through a slot made in the dowel. The free end of the inner conductor at the left-hand end is tucked into a hole in the dowel.

Fig. 8 — This trap has been reinforced by a fiberglass sleeve, as described in the text.

section between the tubes. A wooden insulating section may be made from rock maple dowels, which are sold in most hardware stores. Wood is a perfectly good insulating and support medium for antennas when it is protected from moisture. With modern materials like potting plastics or silicone rubber to coat the dowels, we don't have to boil them in paraffin like grandpa did.

Fig. 7 shows a trap mounted on a 7/8-in. (22 mm) dia dowel placed between two lengths of 1-in. (25.4 mm) dia aluminum tubing. Dowels that are 1/8-inch (3.2 mm) smaller in diameter than the tubing will telescope nicely, provided the tubing wall thickness is 0.058-inch (1.5 mm). Dowels can also be used to join sections of 3/4-inch (19 mm) diameter aluminum tubing and 1-1/4-inch (32 mm) diameter TV masts.

A lengthwise slot is sawed in the dowel to pass the inner conductor of the cable beneath the coil turns to make the cross connection. The braid of the cable trap is soldered to a lug that is held to the tubing by means of a bolt passed through the tubing and the dowel. Tuning of the trap is done by spacing the cable turns on the form. This should be done before attaching the tubing, as the presence of the tubing will lower the apparent trap frequency, and resonances in long lengths of tubing can be coupled to the GDO, producing confusing results.

While a hardwood insulating section secured between lengths of tubing is strong enough for beams and most verticals, it might not be strong enough to use when a 10-meter trap is mounted near the base of a large, unguyed vertical antenna. In such a case, additional strength may be obtained by building up a fiberglass sleeve around the trap and ends of the tubing, as shown in Fig. 8. Fiberglass repair kits for automobile bodies are available in auto parts stores. If you aren't familiar with the use of these materials, make a practice trap first. Since the resin is messy and has an obnoxious odor, the work should be done outdoors.

Approximate lengths for a vertical antenna can be taken from Fig. 5. Lengths for triband beam elements proved to be almost the same as those of a half-wave dipole. Start with those lengths and make the elements shorter as required. A simple 40-, 15- and 10-meter vertical using a single (10-meter) trap has been described.[2]

Amateurs are encouraged to build these traps for their own use. Manufacturers are cautioned that a patent application has been filed for these traps and all rights under the patent code will be enforced. Kits are also available from the author to aid in assembling the traps described in this article.[3] QST

[1] *The ARRL Antenna Handbook*, thirteenth edition, p. 109.

[2] Johns, "Three Band Trap Vertical," *Ham Radio Horizons*, December 1980.

[3] R. H. Johns — Scientific Instruments, 3379 Papermill Rd., Huntingdon Valley, PA 19006. Parts and coaxial cable to construct two traps for wire antennas: W10, W15, W20 — $4.90; W40 — $5.40. Parts and cable for one trap for antennas made with tubing: T10, T15 — $3; T20, $3.50. Please add $1 for postage. The ARRL and *QST* in no way warrant this offer.

Strays

TA PROFILES

☐ The talents of ARRL Technical Advisor Paul M. Wilson, W4HHK, of Collierville, Tennessee, are sincerely appreciated. He is our specialist for vhf/uhf meteor scatter, EME and related modes of communication.

Licensed as W4HHK since 1941, Paul now holds an Extra Class license, plus Radiotelephone First and Radiotelegraph First Class licenses with a Radar endorsement. His primary interests in Amateur Radio are vhf/uhf and cw. He received an ARRL Technical Merit Award jointly with W2UK in 1955 for 144-MHz meteor-scatter work, and jointly with W3GKP in 1969 for 2300-MHz EME work. Several "firsts" can be added to Paul's achievements in Amateur Radio: first 144-MHz meteor-scatter contact, first 2300-MHz EME contact, and first confirmed amateur reception of NASA's Apollo Missions on "S" Band (2.2 GHz) as Apollo X spacecraft orbited the moon (see "The World Above 50 MHz," January 1954, December 1970 and August 1969 *QST*).

Paul has written technical articles for *QST* and has been a member of ARRL since 1940. He is also a member of Army MARS, Society of Wireless Pioneers, Mid-South Amateur Radio Association and Central States VHF Society.

Retired from his position as a studio engineer with WMC-TV, Paul now has more time for Amateur Radio, photography, camping and traveling with W4UDQ, his wife, "D.B." — *Marian Anderson, WB1FSB*

TA Paul Wilson, W4HHK, stands before his towering 18-ft dish antenna.

Crystal Filter Design with Small Computers

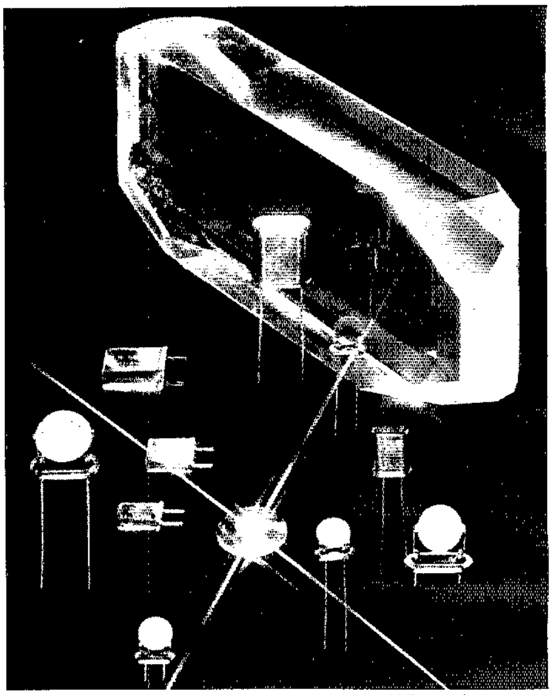


photo courtesy M-Tron Industries, Inc.

Thinking of making a crystal filter? This computer program will provide excellent results. It even allows calculations for filters that provide large bandwidths.

By Dr. Ulrich L. Rohde,* DJ2LR

Crystal filters are being used where superior selectivity is required and the specific bandwidth may be anywhere from a few hundred hertz up to 100 kHz. Crystal filters, as generally offered, are of the Chebyshev design. These filters, however, frequently exhibit bad ringing and group-delay distortion. A natural question at this point would be, "Is there an alternative and, if so, what is it? In answer, this article provides information on the use of a small BASIC computer to aid in building more suitable crystal filters. The actual program is shown, along with computer results. In addition, attenuation graphs are provided to illustrate the effects of additional filter poles. The program is written in such a way that it allows the calculations of large-bandwidth crystal filters. Such information has not been available previously.

Standard Filter Design

A half-lattice crystal filter with one crystal appears in Fig. 1. Filters of this type have been designed into receiver circuits, but with rather poor results. By tuning the neutralizing capacitor, C1, a pole can be moved in order to influence the bandwidth and the notch depth.

Fig. 2A presents the attenuation performance of a single-crystal 300-kHz filter. The notch at the right is set by the neutralizing capacitor. Attenuation in excess of 100 dB is possible.

The close-in performance of the single-crystal filter can be seen in Fig. 2B while Fig. 2C is a graph of the overall performance. If the pole is removed far enough, as in Fig. 2C, the selectivity improves greatly on the left side and the filter action becomes symmetrical. In reality, though, such filters do not offer outstanding performance. Consequently, they are seldom used today.

A typical ssb filter has a total of six crystals. How a filter of this type behaves is indicated by Fig. 2D. In practice, the ultimate rejection would be limited to 120 dB.

Crystal filters are found frequently in up-conversion receivers like the DJ2LR HF-1030. Fig. 2E shows the performance of a typical circuit of this nature. If the filter is improperly tuned, a performance similar to that in Fig. 2F can be expected. At times, such an adjustment may be useful to suppress a mixing product or an image if a 60-dB attenuation on the other side is sufficient.

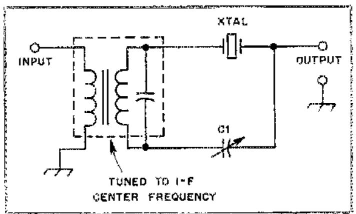


Fig. 1 — A half-lattice crystal filter circuit.

In practice, we should evaluate those performances when we are working with a crystal filter design and then calculate the parameters of the particular crystal filter in which we are interested. This can be done with the aid of the program.

Table 1 contains a list of program information covering a wide variety of possible bandwidths for a universal crystal filter. The basic configuration for such a crystal filter appears in Fig. 3. It consists of three tuned transformers constructed with small pot cores suitable for high-frequency application. A pot core recommended for this application is Siemens' type 4.6 × 4.1 (mm), no. B65495-K0005-A017 for lower-frequency use. For the region around 10 MHz, the core material K65495-K00016-A001 is satisfactory.[1]

Computer-Aided Design of a Crystal Filter

Lines 1 through 20 in the program of

*52 Hillcrest Dr., Upper Saddle River, NJ 07458

[1]Details on Siemens' pot cores are found in the Siemens book, *Ferrites Soft-Magnetic Material Data Book 1979/80*, p. 98. This book is available from the Siemens Corporation, 186 Wood Ave. S., Iselin, NJ 08830, tel. 201-494-1000.

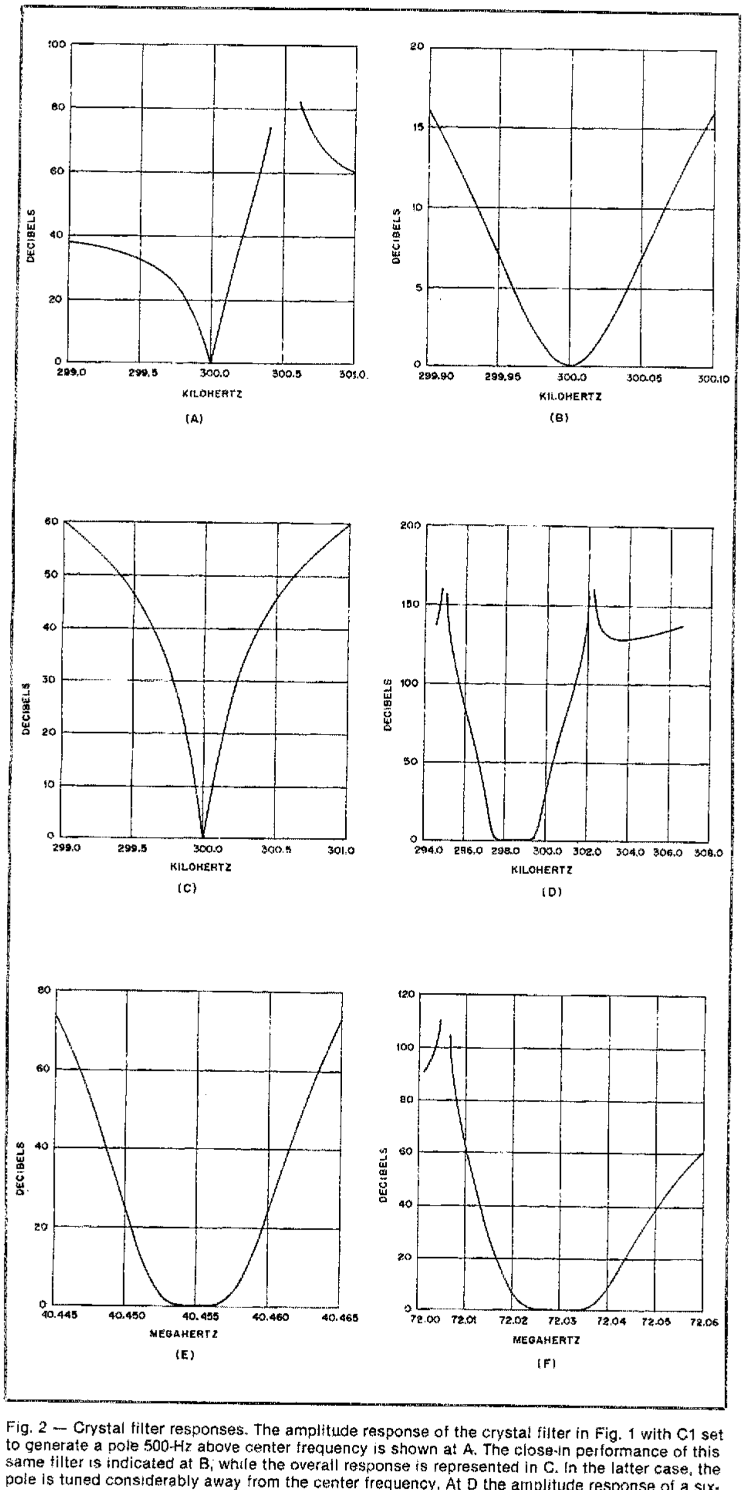


Fig. 2 — Crystal filter responses. The amplitude response of the crystal filter in Fig. 1 with C1 set to generate a pole 500-Hz above center frequency is shown at A. The close-in performance of this same filter is indicated at B, while the overall response is represented in C. In the latter case, the pole is tuned considerably away from the center frequency. At D the amplitude response of a six-crystal single-sideband filter at 300 kHz. A Chebyshev six-crystal filter at 40.455 MHz is represented by the curve at E. The curve at F is for the amplitude response of a 72.03-MHz crystal filter with an attenuation pole on the left side.

Table 1 activate the user-definable keys available on the Tektronix 4051/52 computers. After initiation of the program, it will start on line 100 and ask whether the results should be displayed on the screen or on the printer. Most of the hobby computers on which this program will run have printer-definable ports that have to be addressed. The address to which the information is routed is V5.

In line 200, the computer will ask the center frequency. In line 230, it will ask the bandwidth while in line 250 it will request the crystal inductance.

Fig. 4 shows the inductance in relation to a function of frequency for a crystal that can be manufactured. The highest possible inductance for L1 should always be selected without sacrificing performance in a manner that would lead to spurious response. A minimum Q of 80,000 (100,000 is better) for the crystal is desired for narrow bandwidths. If you start building a crystal filter and order the crystal from a company like Bliley, a firm experienced in crystal and filter manufacturing, you will do well to have them verify these two parameters.

At line 260, the computer will ask you for the capacitance of the holder. You can generally presume that the HC-18/U holder is rated at 1.5 pF, with the larger HC-6/U unit having a capacitance of 6 pF.

On line 280, you will finally be asked what filter response you desire. Various types of responses are available. If selectivity is the prime object, a Chebyshev filter should be chosen. Where constant group delay and therefore low fm distortion are required, a flat delay is important. For perfect pulse response, either the linear phase filter or the Gaussian response should be chosen.

Amateurs who desire additional general information on filter theory will find Zeverev's *Handbook of Filter Synthesis,* published by John Wiley and Sons, particularly useful. The "look-up" tables I refer to in this computer program are taken from his book. In this publication, Zeverev briefly elaborates on the difficulties in building crystal filters that have a large bandwidth in comparison to the center frequency. A typical problem, for instance, is one concerning a 10- to 20-kHz-bandwidth filter designed for 10 MHz. Because Zeverev seems to avoid giving clear design rules for such filter circuitry, additional guidelines are needed. This is where the computer program fills in, for it incorporates the necessary "spreading inductance" which will cure the problem.

Another good source of general filter information is the ITT book *Reference Data for Engineers,* fifth edition, chapters 7, 8 and 9. Inasmuch as many readers may be less interested in precise theory, preferring just to build some filters, none of the mathematics is repeated. Fig. 5 is a graph with the different response curves shown in comparison with each other.

Computerized Tuned-Circuit Information

After you have responded to the query in the filter program concerning the type of filter you wish to have, the computer will use the "look-up" table as provided by line 890 and 1290. The aim of this part of the program is to calculate the component values of lines 380 through 580. You can delete lines 140 and 590, a screen-erase command for the Tektronix computer. Lines 600 through 840 transfer the characteristic values to the printer or the screen. Lines 600 to 650 print, respectively, the header, the center frequency, the bandwidth, the inductance, the internal impedance and the external reference capacitance. Other information includes the input impedance that is printed in line 660 with the required inductance, the capacitance in line 700, and the output values in line 670 together with line 710.

Lines 680 and 690 determine the tuned circuit for the middle of the range. In order to obtain the right crystal from the manufacturer, the four frequencies required are printed on lines 720 through 750. A six-digit accuracy is desirable when these crystals are ordered. Line 800 gives the reference input voltage for a second computer program to determine the actual band-pass characteristic. Lines 820 through line 840 verify that all tuned circuits are on the center frequency.

When aligning the filters, do realize that any mistuning of the input stages will result in poles as shown in Figs. 2A, 2D and 2F. In order to get sharper skirts at times, it is desirable to use poles like these. They can always be determined experimentally. The procedure is to set all three tuned circuits precisely on the center frequency with the crystals inserted.

For those amateurs who do not have a computer, some calculations of interest also are shown in the tables. Table 2 shows the Butterworth, Chebyshev, flat-delay crystal filter, linear-phase crystal filter and Gaussian response filter for a 250-Hz bandwidth. The Chebyshev response should really be avoided because of ringing. The optimum choice probably is the flat-delay or linear-phase approach.

As we take a look at the filters of Table 2, we see that 9 MHz has been selected for the center frequency with a 250-Hz bandwidth. The present inductance is 200 mH. All other values are self-explanatory.

My calculations for single-sideband filters for both upper and lower sidebands are shown in Table 3. For perfect low distortion, the flat-delay versions should be preferred.

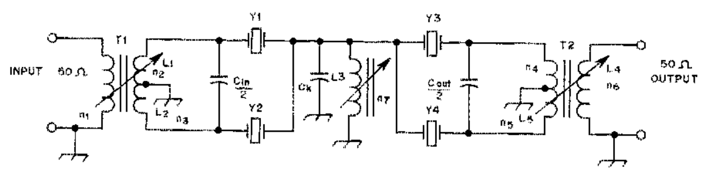
In cases where further selectivity is required, two of those crystal filters can be cascaded either directly with a 1-dB resistive matching pad in between or a transistor stage with 3 to 4 dB gain and heavy feedback. Finally, for those in-

Table 1

Wide Bandwidth Filter Design Program

```
1 GO TO 100
4 RUN 280
8 PAGE
9 GO TO 200
20 LIST 1290, 2000
100 INIT
110 SET KEY
120 DIM C(13)
130 C$=""
140 PAGE
150 PRINT "*** CRYSTAL FILTER PROGRAM *** J__J__"
160 REM COPY-RIGHT RESERVED
170 REM ULRICH L. ROHDE, PH.D., SC.D.
180 PRINT "DO YOU WANT OUTPUT AT SCREEN (32) OR PRINTER (41)?"
190 INPUT V5
200 PRINT "WHICH CENTER FREQUENCY DO YOU WANT?"
210 INPUT F0
220 PRINT "WHICH BANDWIDTH DO YOU WANT?"
230 INPUT B0
240 PRINT "WHICH INDUCTANCE DO YOU HAVE?"
250 INPUT L
260 PRINT "WHAT HOLDER CAPACITANCE DO YOU HAVE"
270 INPUT C(9)
280 PRINT "WHICH FILTER TYPE DO YOU WANT, BUTTERWORTH,"
290 PRINT "CHEBYSHEV, FLAT DELAY, LIN. PHASE, GAUSS RESP. (B,C,F,L,G)?"
300 INPUT A$
310 IF A$="" THEN 1290
320 IF A$="B" THEN 890
330 IF A$="C" THEN 970
340 IF A$="F" THEN 1050
350 IF A$="L" THEN 1130
360 IF A$="G" THEN 1210
370 RETURN
380 R0=PI*L*B0
390 C0=1/(2*B0*PI↑2*F0*L)
400 Q0=150000*B0/F0
410 R1=R0*(K2↑2+(1/Q1-1/Q0)↑2)/(1/Q1-1/Q0)
420 R2=R0*(K2↑2+(1/Q4-1/Q0)↑2)/(1/Q4-1/Q0)
430 C(1)=C0*K2/(K2↑2+(1/Q1-1/Q0)↑2)-2*C(9)
440 C(8)=C(1)+2*C(9)
450 GO TO 1300
460 C(2)=C0*K2/(K2↑2+(1/Q4-1/Q0)↑2)-2*C(9)
470 C(10)=C(2)+2*C(9)
480 GO TO 1340
490 C(11)=C0/K2-4*C(9)
500 C(3)=1/((2*PI*F0)↑2*L1)+C(11)
510 F1=F0-B0/2*(K2+K1)
520 F2=F0-B0/2*(K2-K1)
530 F3=F0-B0/2*(K2+K3)
540 F4=F0-B0/2*(K2-K3)
550 C(4)=1/(4*PI↑2*F1↑2*L)
560 C(5)=1/(4*PI↑2*F2↑2*L)
570 C(6)=1/(4*PI↑2*F3↑2*L)
580 C(7)=1/(4*PI↑2*F4↑2*L)
590 PAGE
600 PRINT @V5:F$;"J__"
610 PRINT @V5:"F0= ";F0
620 PRINT @V5:"B0= ";B0
630 PRINT @V5:"L= ";L
640 PRINT @V5:"R0= ";R0
650 PRINT @V5:"C0= ";C0
660 PRINT @V5:"RIN= ";R1
670 PRINT @V5:"ROUT= ";R2
680 PRINT @V5:"CK= ";C(3)
690 PRINT @V5:"LK= ";L1
700 PRINT @V5:C$;L1,"CIN= ";C(12)
710 PRINT @V5:D$;L2,"COUT= ";C(13)
720 PRINT @V5:"F1= ";F1
730 PRINT @V5:"F2= ";F2
740 PRINT @V5:"F3= ";F3
750 PRINT @V5:"F4= ";F4
760 PRINT @V5:"CS1= ";C(4)
770 PRINT @V5:"CS2= ";C(5)
780 PRINT @V5:"CS3= ";C(6)
790 PRINT @V5:"CS4= ";C(7)
800 V0=(R1+R2)/R1
810 PRINT @V5:"V0= ";V0
820 W0=1/(2*PI*SQR(L1*(C(12)+C(1))))
830 W1=1/(2*PI*SQR(L2*(C(13)+C(2))))
840 PRINT @V5:"POLE FREQUENCIES ARE ";W0;" ";W1
```

```
850 CALL "WAIT",1
860 PRINT @V5:"J _J__J__"
870 GO TO 280
880 END
890 Q0 = 100
900 F$ = "BUTTERWORTH RESPONSE 4TH ORDER CRYSTAL FILTERJ__"
910 Q1 = 1.0457
920 Q4 = 1.0457
930 K1 = 0.7369
940 K2 = 0.5413
950 K3 = 0.7369
960 GO TO 380
970 Q0 = 1000
980 F$ = "CHEBYSHEV RESPONSE 4TH ORDER CRYSTAL FILTER 0.01DB RIPPLEI__J__'
990 Q1 = 1.8258
1000 Q4 = 1.8258
1010 K1 = 0.6482
1020 K2 = 0.5446
1030 K3 = 0.6482
1040 GO TO 380
1050 Q0 = 1000
1060 F$ = "MAXIMALLY FLAT DELAY 4TH ORDER CRYSTAL FILTERJ__"
1070 Q1 = 0.2334
1080 Q4 = 2.2404
1090 K1 = 2.5239
1100 K2 = 1.1725
1110 K3 = 0.6424
1120 GO TO 380
1130 Q = 1000
1140 F$ = "LINEAR PHASE 4TH ORDER CRYSTAL FILTER 0.05DEG PHASE ERRORJ..."
1150 Q1 = 0.4934
1160 Q4 = 0.7182
1170 K1 = 1.632
1180 K2 = 0.7181
1190 K3 = 0.7391
1200 GO TO 380
1210 Q0 = 1000
1220 F$ = "GAUSSIAN RESPONSE 4TH ORDER CRYSTAL FILTERJ__"
1230 Q1 = 0.2747
1240 Q4 = 0.4083
1250 K1 = 2.2792
1260 K2 = 0.7553
1270 K3 = 0.9896
1280 GO TO 380
1290 END
1300 C$ = "TUNED INPUT L1 = "
1310 C(12) = 1. 0E - 11*1. 0E + 8/F0
1320 L1 = 1/((2*PI*F0)^2*(C(12) + C(1)))
1330 GO TO 460
1340 D$ = "TUNED INPUT L2 = "
1350 C(13) = 1. 0E - 11*1. 0E + 8/F0
1360 L2 = 1/((2*PI*F0)^2*(C(13) + C(2)))
1370 GO TO 490
```



$n_2 = n_3$

n_2 is determined from L1 or L2
To obtain the required value for n_2 let

$$n_1 = \sqrt{\frac{R_{in}}{50\ \Omega}} \cdot n_2$$

$n_4 = n_5$

n_4 is determined from L4 or L5.
To obtain the value n_6 let

$$n_6 = \sqrt{\frac{R_{out}}{50\ \Omega}} \cdot n_4$$

For different impedance, n_2 and n_4 may be changed or the source on board changed from 50 ohms.

Fig. 3 — A four-crystal filter circuit. The input and output impedances are determined by the turns ratio of the input and output transformers. Also shown are the calculations for this filter.

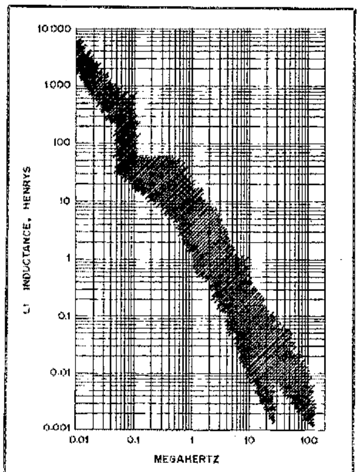


Fig. 4 — This graph shows the relationship of inductance and frequency for a particular crystal selected as a test example.

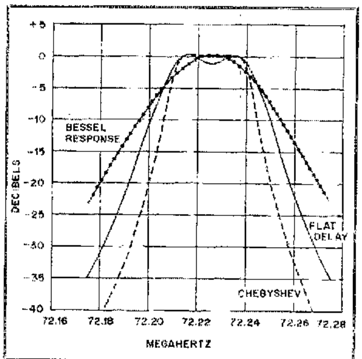


Fig. 5 — The Bessel, flat-delay and Chebyshev responses are represented by this composite graph. The Chebyshev response provides the steepest skirts, while the Bessel response has the poorest amplitude curve.

terested in constructing a double-conversion receiver, the parameters for a 41-MHz crystal filter are provided in Table 4. Table 5 is a Gaussian response filter designed for use in a radar receiver.

In Summary

This short presentation on how to design and build crystal filters with the aid of a small computer should encourage experimentation with various types of filters. In the past, wideband filters like the 72.225-MHz, 31-kHz bandwidth filter of Table 5 required special computer programs. Now this unique program can solve the design problem for an extremely wide bandwidth range.

Table 2

Calculations for Some Large-Bandwidth Filters

	BUTTERWORTH RESPONSE FOURTH ORDER CRYSTAL FILTER	*CHEBYSHEV-RESPONSE FOURTH ORDER CRYSTAL FILTER (Ø.Ø1dB RIPPLE)*	*MAXIMALLY FLAT DELAY FOURTH-ORDER FILTER*	*LINEAR PHASE FOURTH ORDER ORDER CRYSTAL (0.05° PHASE ERROR)*	*GAUSSIAN RESPONSE FOURTH ORDER CRYSTAL FILTER*
FØ =	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ
BØ =	25Ø	25Ø	25Ø	25Ø	25Ø
L =	0.2	0.2	0.2	0.2	0.2
RØ =	157.Ø79632679	157.Ø79632679	157.079632679	157.079632679	157.079632679
CØ =	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø
RIN =	176.77ØØ73394	199.7392822Ø7	688.699716Ø17	325.996645717	560.476789ØØ7
ROUT =	176.77ØØ73394	199.7392822Ø7	1078.92346935	251.3Ø4525198	387.579899958
CK =	3.856888Ø33E-1Ø	4.655256668E-1Ø	2.0557123Ø9E-1Ø	2.8Ø686Ø945E-1Ø	2.581716487E-1Ø
LK =	1.7Ø2249344E-6	1.18Ø9353Ø2E-6	2.7Ø6242448E-6	2.4Ø7155723E-6	2.716479143E-6
TUNED INPUT					
L1 =	1.7Ø2249344E-6	1.18Ø9353Ø2E-6	2.7Ø6242448E-6	2.4Ø7155723E-6	2.716479143E-6
CIN =	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø
L2 =	1.7Ø2249344E-6	1.18Ø9353Ø2E-6	1.553941872E-6	2.Ø57891921E-6	2.527836771E-6
COUT =	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø
F1 =	899984Ø 225	899985Ø.9	8999537.95	89997Ø6.2375	899962Ø.6875
F2 =	9ØØØØ24.45	9ØØØØ12.95	9ØØØ168.925	9ØØØ114.2375	9ØØØ19Ø.4875
F3 =	8999840.225	8999850.9	8999773.1375	8999817.85	8999781.8875
F4 =	9ØØØØ24.45	9ØØØØ12.95	8999933.7375	9ØØØØØ2.625	9ØØØØ29 2875
CS1 =	1.563654Ø31E-15	1.563650322E-15	1.563759Ø72E-15	1.56370Ø591E-15	1.56373Ø32E-15
CS2 =	1.56359ØØ17E-15	1.563594Ø13E-15	1.563539819E-15	1.56355882E-15	1.563532327E-15
CS3 =	1.563654Ø31E-15	1.56365Ø322E-15	1.563677343E-15	1.5636618Ø6E-15	1.5636743Ø3E-15
CS4 =	1 56359ØØ17E-15	1.563594Ø13E-15	1.563621537E-15	1.5635976Ø1E-15	1.563588337E-15
VØ =	2	2	2.5666Ø94297	1.77Ø88Ø7Ø844	1.69151819943
POLE					
FREQUENCIES	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ
	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ

Table 3

Single-Sideband Filter Calculations

	UPPER SIDEBAND CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE	*UPPER SIDEBAND MAXIMALLY FLAT DELAY FOURTH ORDER CRYSTAL FILTER*	*LOWER SIDEBAND CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE*	*LOWER SIDEBAND MAXIMALLY FLAT DELAY FOURTH ORDER CRYSTAL FILTER*
FØ =	9ØØ21.ØØ	9ØØ21ØØ	89979ØØ	89979ØØ
BØ =	21ØØ	21ØØ	21ØØ	21ØØ
L =	Ø.Ø3	Ø.Ø3	Ø.Ø3	Ø.Ø3
RØ =	197.92Ø337176	197.92Ø337176	197.92Ø337176	197 920337176
CØ =	8.932764334E-11	8.932764334E-11	8.93693393E-11	8.93693393E-11
RIN =	215.822217917	906.264311969	215.821952659	906.266750613
ROUT =	215.822217917	733.98Ø82547	215.821952659	733.962678696
CK =	3.52Ø472927E-1Ø	1.836453586E-1Ø	3.522137182E-1Ø	1.837352494E-1Ø
LK =	1.611Ø14457E-6	2.754931668E-6	1.611772269E-6	2.756184362E-6
TUNED INPUT				
L1 =	1.611014457E-6	2.754931668E-6	1.611772269E-6	2.756184362E-6
CIN =	1.11Ø851912E-1Ø	1.11Ø851912E-1Ø	1 11137Ø431E-1Ø	1.11137Ø431E-1Ø
L2 =	1.611Ø14457E-6	1.779138943E-6	1.611772269E-6	1.77996Ø146E-6
COUT =	1 11Ø851912E-1Ø	1.11Ø851912E-1Ø	1.11137Ø431E-1Ø	1.11137Ø431E-1Ø
F1 =	9ØØØ847.56	8998218.78	8996647.56	8994Ø18.78
F2 =	9ØØ22Ø8.78	9ØØ3518.97	8998ØØ8.78	8999318.97
F3 =	9ØØØ847.56	9ØØØ194.355	8996647.56	8995994.355
F4 =	9ØØ22Ø8.78	9ØØ1543.395	8998ØØ8.78	8997343.395
CS1 =	1.Ø422Ø27Ø4E-14	1.Ø42811741E-14	1.Ø43176Ø16E-14	1.Ø437859Ø6E-14
CS2 =	1.Ø41887546E-14	1.Ø41584337E-14	1.Ø4286Ø416E-14	1.Ø42556783E-14
CS3 =	1.Ø422Ø27Ø4E-14	1.Ø42353989E-14	1.Ø43176Ø16E-14	1.Ø43327513E-14
CS4 =	1.Ø41887546E-14	1.Ø42Ø41582E-14	1.Ø4286Ø416E-14	1.Ø43Ø14668E-14
VØ =	2	1.8Ø9897Ø86Ø7	2	1.8Ø987488308
POLE				
FREQUENCIES	9ØØ21ØØ	9ØØ21ØØ	89979ØØ	89979ØØ
	9ØØ21ØØ	9ØØ21ØØ	89979ØØ	89979ØØ

Table 4

Calculations for a Double-Conversion Receiver 41-MHz Crystal Filter

	CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE	*CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE*	*CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE*
FØ =	4.Ø455E + 7	4.1E + 7	7.Ø455E + 7
BØ =	7ØØØ	7ØØØ	7ØØØ
L =	Ø.Ø1	Ø.Ø1	Ø.Ø1
RØ =	219.911485751	219.911485751	219.911485751
CØ =	1.78895746E-11	1.769177415E-11	1.Ø27212746E-11
RIN =	24Ø.Ø69542975	24Ø.Ø8611Ø77	241.4Ø15Ø5946
ROUT =	24Ø.Ø69542975	24Ø.Ø8611Ø77	241.4Ø15Ø5946
CK =	6.6Ø9534562E-11	6.511358Ø11E-11	3.465894436E-11
LK =	3.943635932E-7	3.893569691E-7	2.341Ø824Ø9E-7
TUNED INPUT			
L1 =	3.943635932E-7	3.893569691E-7	2.341Ø824Ø9E-7
CIN =	2.471882338E-11	2.439Ø2439E-11	1.419345682E-11
L2 =	3.943635932E-7	3.893569691E-7	2.341Ø824Ø9E-7
COUT =	2.471882338E-11	2.439Ø2439E-11	1.419345682E-11
F1 =	4.Ø45Ø8252E + 7	4.Ø9958252E + 7	7.Ø45Ø8252E + 7
F2 =	4.Ø4553626E + 7	4.1ØØØ3626E + 7	7.Ø4553626E + 7
F3 =	4.Ø45Ø8252E + 7	4.Ø9958252E + 7	7.Ø45Ø8252E + 7
F4 =	4.Ø4533626E + 7	4.1ØØØ3626E + 7	7 Ø4553626E + 7
CS1 =	1.548Ø51812E-15	1.5Ø7165686E-15	5.1Ø349971E-16
CS2 =	1.5477Ø4578E-15	1.5Ø6832117E-15	5.1Ø284239E-16
CS3 =	1.548Ø51812E-15	1.5Ø7165686E-15	5.1Ø349971E-16
CS4 =	1.5477Ø4578E-15	1.5Ø6832117E-15	5.1Ø284239E-16
VØ =	2	2	2
POLE FREQUENCIES	4.Ø455E + 7	4.1E + 7	7.Ø455E + 7
	4.Ø455E + 7	4.1E + 7	7.Ø455E + 7

Table 5

Calculations for a 31-kHz Bandwidth Filter

	GAUSSIAN RESPONSE FOURTH-ORDER CRYSTAL FILTER
FØ =	7.2225E + 7
BØ =	31ØØØ
L =	Ø.Ø13
RØ =	1266.Ø618394
CØ =	1.74Ø514567E-12
RIN =	4788.47944845
ROUT =	3377.929Ø4618
CK =	7.245912256E-12
LK =	4.438ØØ5914E-7
TUNED INPUT	
L1 =	4.438ØØ5914E-7
CIN =	1.384562132E-11
L2 =	4.39519567E-7
COUT =	1.384562132E-11
F1 =	7.217796525E + 7
F2 =	7.224862Ø45E + 7
F3 =	7.2197954Ø5E + 7
F4 =	7.222863165E + 7
CS1 =	3.74Ø138126E-16
CS2 =	3.7328264Ø2E-16
CS3 =	3.738Ø67416E-16
CS4 =	3.734892759E-16
VØ =	1.7Ø5428327
POLE FREQUENCIES	7.2225E + 7
	7.2225E + 7

Strays

John Schmale, K2IZ, N.Y.C./Long Island SCM, towers behind members of the Hall of Science Amateur Radio Club (Queens, New York) after presenting Public Service Commendations to many of them for their dedicated efforts during the recent Italian earthquake disaster. Club members received, relayed, answered or directed more than 1000 messages during the around-the-clock operation that lasted nearly two weeks. *(photo by Fred Kahn, WB2TBC)*

FIRE AT SEA

☐ Last October, the Dutch ship *Prinsendam* caught fire in the Gulf of Alaska, and 533 passengers and crew were forced to abandon ship. Through poor sea conditions, people were lifted by helicopter from their lifeboats to the rescue ships. Alaskan Amateur Radio operators monitoring the situation quickly realized that their services would be needed. Health-and-welfare nets were organized, and liaisons with the Red Cross, Alaska State Troopers and the Coast Guard were set up.

As the passengers and crew safely arrived on shore, the expected communications crunch developed. Shifting band conditions were a problem. Another obstacle was passing traffic to foreign countries with whom the U.S. had no third-party agreement. As a result of outstanding cooperation among amateurs and their good on-the-air conduct, over 300 pieces of traffic were successfully passed. Fortunately, there were no fatalities during the rescue; the ship, however, sank. — *Don Bush, KL7JFT*

From left to right stand Jack van der Zee, radio officer of the *Prinsendam*, Jim Pfister, N6CF, and David Ring, N1EA, radio officers aboard the *Williamsport*, one of the tankers involved in the rescue effort. Jack maintained vital communications in the smoke-filled radio room despite melting cables and dwindling emergency power. Providing an essential link in the communications, Jim and David relayed positions and estimated time of arrivals and kept the distress frequency clear. *(photo courtesy David J. Ring Sr.)*

The Vertical-V Antenna

"Rabbit ears for hf? Heresy!" you declare. Or is it? Let this article tempt you to find out what the "ears" can do for you!

By Dr. Lawrence B. Owen,* WB6HNQ

Most amateurs undoubtedly are familiar with the properties of inverted-V hf antennas. The inverted V is simple, is inexpensive to build, provides a good match to a 50-ohm coaxial line and produces a quasi-omnidirectional horizontally polarized radiation pattern when used at its fundamental frequency. It occurred to me recently that a vertical-V (an inverted V rotated 180 degrees in the vertical plane) might also have some interesting performance characteristics. In terms of appearance, the vertical-V is reminiscent of an indoor TV rabbit-ears antenna (Fig. 1).

A cursory literature review revealed that rigorous analysis of basic V-antenna performance had been completed by the late 1940s.[1,2] In fact, Wells[3] can probably be credited for the invention of the inverted V in 1944. Kraus, in the introductory chapter of *Antennas*,[4] points out in a generic sense that a cylindrical vertical-V can be expected to yield a broader usable bandwidth than the corresponding dipole. In considering the relative merits of vertical-V versus other common types of wire antennas, it seems clear that the vertical-V offers the potential for significantly improved performance. I am surprised, therefore, to find that in *QST*, at least, there has been no description of a practical vertical-V for amateur hf use.

The classical inverted V, while providing excellent performance, does suffer from several deficiencies. Ground effects undoubtedly degrade radiation efficiency and influence feed-point impedance. If the antenna is supported from a metallic structure, additional parasitic losses can occur. Since the antenna is center fed, unbalanced currents may be induced on the transmission line even if a balun transformer is used at the feed point. Finally, sloping the elements downward increases the likelihood of parasitic losses in nearby ground-mounted structures.

Vertical-Vs would be affected to a much lesser degree by the factors described above. In addition, vertical-Vs provide the additional advantages of increased effective antenna height, simpler construction (only one central support required when self-supporting aluminum elements are used) and a capability for rotating the antenna. My experiments indicated that a vertical-V exhibits a 6-dB

*Terra Tek, Inc., 420 Wakara Way, Salt Lake City, UT 84108

[1]Notes appear on page 25.

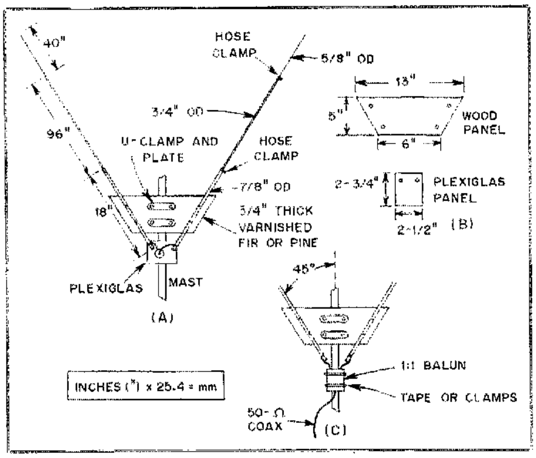


Fig. 1 — Construction details for the 15-meter vertical-V antenna. As indicated in section A, each element is bolted to the wood and Plexiglas panels. For the wooden panel use 1/4 × 2-1/4-inch bolts. For the Plexiglas panel use 1/4 × 1-1/2-inch bolts. Panel dimensions are shown at B. Part C shows the angle for the elements and the position for the balun. Both elements are individually adjusted to a length of 135.7 in (3.446 m) for resonance at 21.225 MHz.

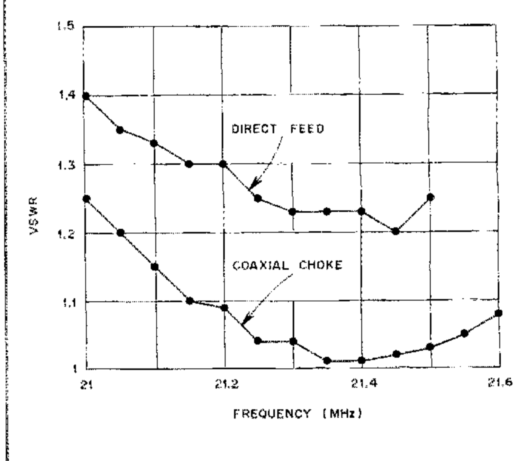


Fig. 2 — The VSWR performance of the 15-meter vertical-V antenna with and without the coaxial cable choke.

front-to-side ratio, suggesting that the ability to rotate the antenna might be advantageous under certain operating conditions.

Making a comparison of the mechanical properties of a vertical-V with those of an equivalent single-element delta loop or quad also proves to be instructive. A rather obvious point is that the vertical-V is lighter and offers lower wind loading than either a quad or delta loop cut for the same fundamental frequency. My experiments indicate that the length in feet of a resonant half-wave vertical-V constructed from aluminum tubing is approximated by 480/frequency (MHz). The length in meters is 146.3/frequency (MHz). A 1/4-wave vertical-V element is, therefore, about 28.5% and 4.5% shorter than single legs of corresponding equilateral delta loops and quads, respectively. You can conclude that the vertical-V offers the advantages of reduced construction cost, lower wind loading and weight. Besides being simpler to construct, it permits direct matching to a 50-ohm coaxial transmission line.

Construction

The basic design for a single-element 15-meter vertical-V is shown in Fig. 1A. Telescoping sections of aluminum tubing are used for the elements, which have outer diameters of 7/8 in. (22 mm), 3/4 in. (19 mm) and 5/8 in. (16 mm). One end of each of the two 7/8-in. and 3/4-in. element sections are slotted with a hacksaw to a depth of about 1 inch (25 mm). Since the elements must be insulated from each other and from the support bracket, the 7/8-in. dia element sections are mounted on a wood base. The wood (fir or pine) has several coats of varnish to ensure reasonable service life. The 3/4-in. OD elements are telescoped into the base section and secured with stainless steel hose clamps. The same procedure is used to secure the 5/8-in. OD sections to the 3/4-in. OD elements. A standard "coax" male connector is mounted in a piece of Plexiglas that is secured directly to the base-element sections.

The input impedance of the antenna is a function of the apex angle. My prototype employed an apex of 100°. As shown by the SWR curves in Fig. 2, excellent bandwidth and low SWR were attained. The data suggest, however, that an even better match to 50-ohm coaxial cable could be obtained by reducing the apex angle slightly to between 90° and 95°.

Initially, the antenna was fed directly by RG-8/U coaxial cable. With this arrangement the upper SWR curve shown in Fig. 2 was obtained. The SWR seemed too high and my Century 21 transceiver was bothered by severe distortion in the keying monitor. Rf feedback, traced to rf flowing along the shield of the transmission line, takes the blame for this condition. A coaxial choke installed at the antenna feed point solved the difficulty. This choke is constructed by simply forming a 5-in. (130-mm) dia coil consisting of four turns of transmission line that is taped to the mast.

Setting the resonant frequency of the antenna requires loosening the two base-element clamps and adjusting the telescoping elements as necessary for the lowest SWR. The initial 1/4-wave element length (11.3 feet or 3.45 meters for 21.225 MHz) was obtained from my empirically derived expression: length in feet for a quarter wavelength = 240/frequency in MHz. To determine the length in meters the equation is m = 73.2/frequency in MHz. The solder joints and the coaxial cable were subsequently sealed with a rubber repair compound obtained from a local hardware store. Any one of several commercial or homemade 1:1 baluns may be used to eliminate the need for separate Plexiglas coaxial connector mounts and coaxial chokes.

Performance of the 15-meter vertical-V was excellent during a six month period from October 1979 to March 1980 while I was using a Century 21 transceiver with 25 watts of rf output. All operations took place from a QTH located about 50 miles east of San Francisco. A total of 103 stations were worked. DX included contacts with Canada (6), Mexico (3), Hawaii (2), Japan (24), Australia (9) and New Zealand (1). The remaining 58 contacts included all contiguous U.S. call areas.

A second series of tests was carried out after the vertical-V elements had been shortened to 8.9 ft (2.7 m) for CB operation. CB tests, using a Radio Shack ssb rig, were conducted as a simple means of evaluating the major polarization mode of the antenna. Several local CB operators used quad antennas that featured instantaneous selection of either horizontal or vertical polarization. Tests indicated that the V was about 12 dB stronger when horizontal polarization was selected by the other operator. This suggests that a significant element of vertical polarization was produced by the V. Thus, the vertical-V offers a reasonably good compromise between quasi-omni-directional radiation and bipolarization performance.

There seems little doubt that the vertical-V is an excellent performer. Construction of single-element monoband versions for operation from 14 to 30 MHz (or higher) is certainly feasible. Multiband operation should be relatively easy to achieve by making use of various concepts developed over the years for conventional dipoles and verticals. A more intriguing thought, however, would involve appropriate modifications for producing a vertical-V beam antenna. As a starting point, I would suggest using conventional element spacing parameters developed for horizontal Yagi arrays. Input impedance, however, will probably be lower than for the equivalent Yagi. The advantages of increased effective height, shorter turning radius, reduction of adverse boom and tower interactions on beam performance, and the potential for increased bandwidth should be sufficient to justify further experimentation.

Notes

[1]Jasik, *Antenna Engineering Handbook*, McGraw-Hill, 1961.
[2]King, *The Theory of Linear Antennas*, Harvard University Press, 1956.
[3]Wells, *The Quadrant Aerial*, J. IEE (London), 1944, Part III, Vol. 91, p. 182.
[4]Kraus, *Antennas*, McGraw-Hill, 1950.

Strays

AMATEURS NEEDED TO ASSIST IN CONTAINING CALIFORNIA FIRES

☐ Amateurs in San Bernadino County have been asked to assist the California Department of Forestry during wildland fires. Two-meter communications will be provided for reconnaissance from the fire scene to central headquarters. Logistical support traffic will be passed from the fire camps to headquarters. Messages for the National Traffic System will be accepted for out-of-county and out-of-state firefighters. Interested volunteers please contact Thomas L. Markley, WA6IKH, 17400 Valley Blvd., No. 70, Fontana, CA 92335 or tel. 714-350-2194.

QST congratulates . . .

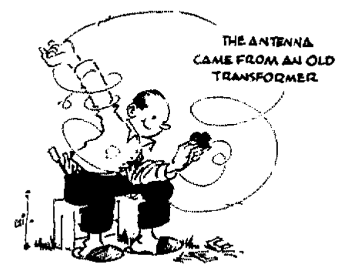
☐ Stuart Meyer, W2GHK, who was recently elected President of the Institute of Electrical and Electronic Engineers Vehicular Technology Society.

Some participants in the ARRL-sponsored IEEE SOUTHCON/81 professional program (Session 15) in Atlanta, Georgia, were, left to right, Dr. Ulrich Rhode, DJ2LR; Bill Allen; Marian Anderson, WB1FSB; Doug DeMaw, W1FB; and Tom Hayes. For further details see April 1981 *QST*, page 39. *(photo courtesy W1FB)*

• *Basic Amateur Radio*

Which Antenna to Use?

Many beginners ask the ARRL staff, "What's the best antenna I can put up?" Well, there is no "best" antenna, but here are some pointers for the newcomer.



By Doug DeMaw,* W1FB

"Your *Antenna Book* and the *Handbook* confuse me. They don't tell me which antenna works best." Statements like that are common in letters sent to ARRL Hq. by new amateurs, and understandably so. But, it's a question that has no specific answer because of the many factors that must be considered when making a choice. Generally, the criteria are based on usable property, economics, materials available, operating frequency, attitudes of neighbors, desired communications distance (local or DX) and restrictions and zoning ordinances. All of the foregoing must be considered when selecting an antenna for amateur use. In order to avoid being long-winded in this discussion, let's assume that the following conditions prevail: no restrictions, no problems with neighbors, the house is on a standard city lot, the materials are available locally and we want to work DX and close-in stations. This is a typical scenario for a new radio amateur, and we will key our discussion to this setting of the stage.

Some Basic Requirements

In order for any antenna to perform to the best of its capability it must be as high in the air as possible, and preferably 1/2 wavelength or greater above ground at the chosen operating frequency. Thus, for operation in the 40-meter Novice band (7.1 MHz), our antenna should be 69 feet (21 m) or more above ground. This can be approximated by dividing 492 by the frequency in MHz, or 492/f(MHz), which provides the height in feet. If our 40-meter dipole were only 30 feet (9 m) above ground, it would still work okay, but it would be less useful for DXing. This would be caused by the *angle of radiation* being higher at reduced antenna heights. We can understand this phenomenon by referring to Fig. 1. The outgoing wave from an antenna strikes the ionosphere obliquely and reflects back to earth. This might be compared to a pool shot, where the ball is banked. Therefore, the lower the radiation angle in degrees, the greater distance the ball or signal will travel.

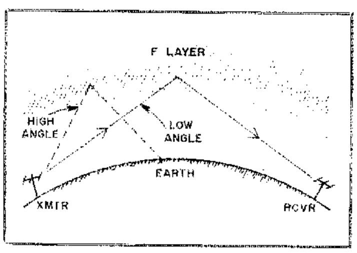


Fig. 1 — Illustration of how radio waves are reflected from the ionosphere. The low radiation angle is preferred for long-distance communications. If high-angle radiation (dashed lines) prevails, the skip distance will be much shorter.

Under some conditions of propagation the signal may take two hops (double-hop skip), and the distance covered will be even greater. The radiation angle will, however, still determine the actual distance of the communication. The angle of radiation is shown in simple form versus antenna height in Fig. 2 at B and C.

We can see from the foregoing discussion that an antenna which is relatively close to the ground can work in our favor for short-haul contacts. The higher radiation angles will return the signal to earth much closer to the transmitting station than in the case of DX work, and local contacts out to a few hundred miles will be enhanced by virtue of our stronger signals. When antennas are very high above ground (one wavelength or more) it is not uncommon to have "dead zones" a few hundred miles from the transmitter; but, at great distances the signal will be much louder than when the transmitting antenna is close to the ground. Some operators have identical antennas for a given band, with one close to the ground and the other quite high up. The antennas are then chosen for the desired communications distance versus band conditions at a given time. This discussion applies only to high-frequency communications. At vhf and higher the antennas should be as high above ground as possible for *line-of-sight* work. In other words, our discussion deals mainly with signals that are reflected from the ionosphere.

The height of an hf antenna has an effect also on the *radiation resistance*, par-

*Senior Technical Editor

ticularly with respect to horizontal dipoles. This effect is shown graphically in Fig. 3. For a typical amateur hf-band antenna installation, however, the mismatch will not pose a problem of great consequence unless the feed line is quite long (more than 100 feet or 30.5 m). The longer the feed line (especially coaxial cable), the greater the losses in the line. These losses increase as the operating frequency is made higher. For example, if the feeder caused a 3-dB loss of the rf energy and the transmitter was putting out 50 watts, there would be only 25 watts of power delivered to the antenna. There would be a similar loss during receive. A 3-dB loss is one half an S unit (if they are accurate). The smaller the diameter of the coaxial cable, the greater the losses per foot. For this reason we should try to use RG-8/U or RG-11/U rather than RG-58/U or RG-59/U types of cable at the higher frequencies. Surplus coaxial cable should be avoided, for aging causes contamination of the dielectric material and makes the cable very lossy. It is wise to start with new cable and replace it every few years.

We should strive to keep the radiating portions of our antenna well removed from trees, power lines, phone wires, downspouts or other conductive objects. Close proximity will cause distortion of the radiation pattern and absorption of the signal energy, which will make our antenna less effective than it might be otherwise. Metallic objects that are close to the antenna (a few feet or less) can detune the antenna and cause a mismatch at the feed point. From all of the foregoing we can extract a basic rule: *keep the antenna as high and as in the clear as possible.*

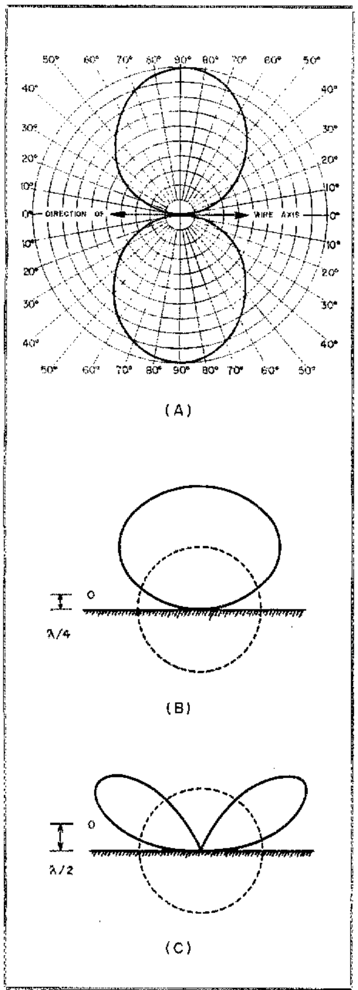


Fig. 2 — If we could rise above our dipole antenna and observe the radiation, we would see the figure-8 pattern at A. This would be seen if the horizontal dipole was 1/2 wavelength or greater above ground. The lobes are off the broadside of the dipole. At B we can see the effect of having the dipole only 1/4 wavelength above ground. There is no apparent directivity, and the radiation angle is very high. At a height of 1/2 wavelength (C), the dipole exhibits two major lobes and has a much lower radiation angle (desired for DX work).

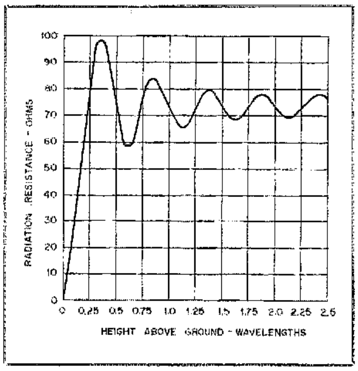


Fig. 3 — The radiation resistance of the antenna feed point varies with the effective height above ground. Here we see the effects of height for a dipole at various elevations above a theoretically perfect ground. At a height of 1/2 wavelength the antenna can be matched nicely with 72-ohm feed line.

Wire Antennas are Easy

Not many amateurs are willing to invest in towers, rotators and beam antennas at the beginning. We can apply the "crawl before walking" concept, and obtain good results with wire types of antennas. Plenty of DX has been worked with simple antennas, so let's see what options are open to us.

Random-Length Wires: A random length of wire can be used to explore the hf bands, but it represents the least effective of the wire antennas unless it is erected high and has considerable length [1/4 wavelength or greater, derived from 234/f(MHz), which yields the approximate length in feet]. Long spans of wire do not constitute a "long-wire antenna," although they are called that rather frequently. A classical long wire is 1 wavelength or more in electrical dimension.

The "random" antenna is one that is strung from a point near the ham station to some supporting structure a convenient distance away. It will exhibit a variety of feed impedances over the range of hf amateur bands. If it approaches a 1/4-wavelength condition (or odd multiple thereof), the impedance will be low — probably between 15 and 100 ohms, depending on a variety of factors. But, at other frequencies it may be close to 1/2 wavelength or multiple of that electrical length. This being the case, the feed impedance will be very high — 1000 ohms or more. If we are to provide an impedance match between our 50-ohm transmitter/receiver combination and the end of the antenna, it will be necessary to use an antenna-matching device (Transmatch, antenna coupler or antenna tuner, as they

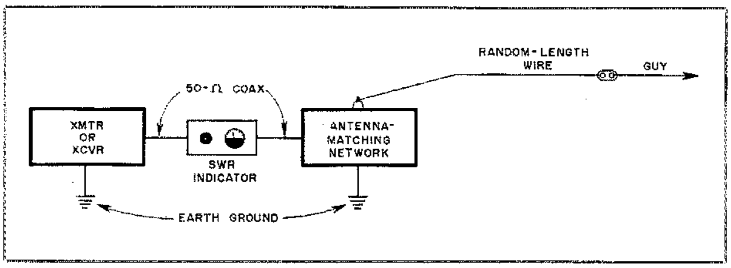


Fig. 4 — Method for using a random-length antenna for multiband operation. The wire is matched to the transmitter by means of a coil and capacitor network (Transmatch). Proper tuning of the network is determined by observing an SWR indicator and adjusting the network for minimum indicated SWR.

are called). This will enable us to change bands and maintain maximum power transfer to the antenna, which will happen when a matched condition exists. Our SWR indicator will show a ratio of 1:1 when the tuner is adjusted correctly. A setup of this kind is shown in Fig. 4.

The shortcoming of this type of antenna system is that rf energy can easily appear on the station equipment. A "hot" key, microphone or transceiver panel will be noted. Also, unwanted rf energy can get into the keyer or the rig and raise havoc. This is most apt to occur when the antenna operates close to a half wavelength or multiple thereof. When the feed impedance is low, rf will probably be absent on the station equipment. In either case, a *short* earth ground is necessary to minimize the hot-chassis problem. The shield braid from a discarded piece of coaxial cable will serve nicely as a ground conductor. It should be as short and direct as possible, running from the chassis of the rig and antenna matcher to a cold-water pipe and/or pipe driven into the ground just outside the shack. Ham shacks that are on the second or third floor of a dwelling are notorious for exhibiting the hot-chassis syndrome. This is because it is difficult to effect a good earth ground from so high up. Sometimes 1/4 wavelength of wire can be laid around the baseboards of the room to serve as a counterpoise ground, and often it will prevent rf from getting on the station equipment.

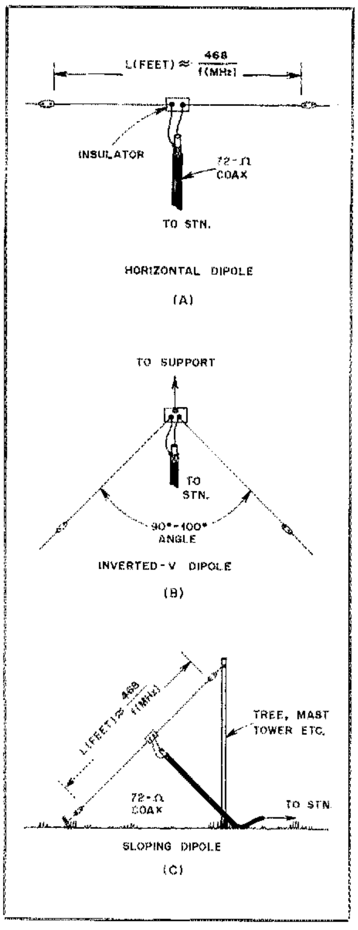


Fig. 5 — Examples of simple but effective wire antennas. A horizontal dipole is shown at A. The legs can be drooped to form an "inverted V," as seen at B. A sloping dipole (sloper) is illustrated at C. The feed line should come away from the sloper at 90° for best results. If the supporting mast is metal, there will be some directivity in the direction of the slope. The antennas at B and C provide vertical polarization and are predominantly omnidirectional if they are supported on a non-metallic mast.

End-fed Hertz antennas, and some end-fed Zepp antennas, create similar problems with stray rf energy, owing to their relatively high feed impedances (high rf-voltage point). When this problem can't be solved, it is wise to use a coaxial-cable feed system with an appropriate low-impedance antenna, such as a dipole or doublet.

Dipole Antennas: The most common of the beginner antennas is the standard half-wavelength dipole. It is fed at the center by means of low-impedance line, such as coaxial cable, TV Twinlead or open-wire feeders. Some amateurs have even used plastic zip cord (ac line cord) with considerable success! The dipole can be erected horizontally, as a "sloper" or as an "inverted V." The latter was derived from the Quadrant antenna which was used in the early days of radio. Fig. 5 illustrates the various formats for a dipole antenna.

Dipoles are bidirectional (figure-8 pattern) off the broad side of the antenna, but only when the dipole is 1/2 wavelength or more above ground. The closer the antenna is to the earth, the less directional it becomes and the higher the radiation angle will be (Fig. 2). The sloper and inverted-V configurations produce essentially vertical polarization, which is excellent for ground-wave and DX contacts. The sloper, if not mounted on a metallic support, will be omnidirectional in response, as will the inverted V. If either antenna is supported on a steel mast or tower, there will be some directivity (not gain) in the direction of the wire slope.

The advantage of the dipole antenna is its simplicity. The disadvantage is its single-band performance (unless tuned feeders and a Transmatch are used to provide multiband operation, as in Fig. 6). The length of a dipole in feet is determined from 468/f(MHz). Hence, a dipole for 3.7 MHz would be 126 feet, 6 inches (38.5 m) long. Some final adjustment of the leg lengths is usually done to bring the VSWR as close to 1:1 as possible. This can be achieved by inserting a VSWR indicator (sometimes called a "bridge") in the coaxial feed line at a convenient point, then cutting or adding wire in equal amounts to the ends of the dipole until the lowest reflected voltage is noted on the in-

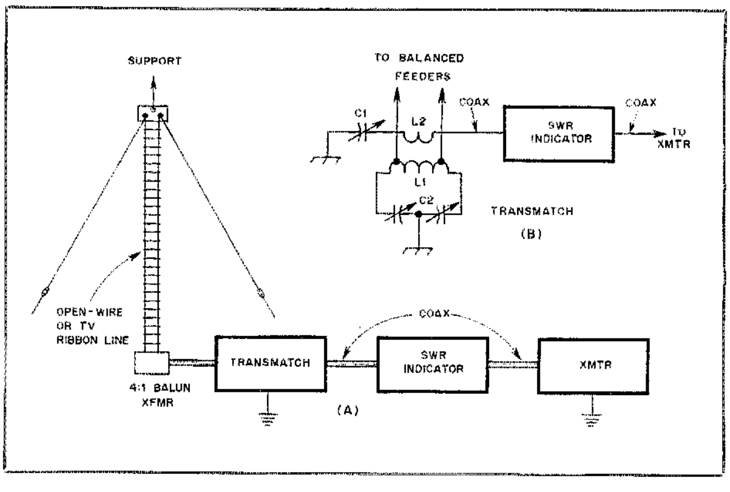


Fig. 6 — Fundamentals of a multiband inverted-V dipole. Balanced, low-loss feeders are recommended (see text). A Transmatch is used to maintain an SWR of 1:1 over the operating range of the antenna. At A we have a balun transformer (to convert from a balanced to unbalanced feed line), a Transmatch and an SWR indicator. Typically, these components are located near the operating position. At B we see the circuit of a Transmatch that is well suited to use with balanced feed lines. The balun at A can be eliminated when using the network at B, and generally the overall system will be more efficient with this style of Transmatch.

dicator. This will usually be a value less than 2:1, in terms of the forward/reflected voltage ratio respective to a half-wavelength dipole that is fed with coaxial cable.

All antennas have a specific useful bandwidth. Dipoles are no exception. The lower the operating frequency, the narrower the antenna bandwidth over a specified VSWR range. Therefore, the antenna should be optimized for the part of the band we use the most. Novices should tune the antenna for the center of the Novice band when using coaxial-cable feed line. At 80 and 40 meters the bandwidth will be especially narrow between the 2:1 VSWR points (Fig. 7), with 100 kHz being typical on 80 meters, and 200 kHz an average expectation on 40 meters. For this reason it is common to hear an amateur say, "I don't work 80-meter cw because my dipole is cut for the ssb portion of the band." In such cases the antenna won't load (accept power) because of the high VSWR in the opposite end of the band. A Transmatch could be utilized to *disguise* the SWR condition, and fair performance would result. But, the mismatched condition at the dipole feed point could not be remedied by that means. A Transmatch merely effects a match between the transmitter and the station end of the feed line — this is important to remember. If it were connected between the antenna feed point and the feed line, it *could* correct the mismatch, but this would be impractical.

Multiband Operation

In Fig. 6A we have what is called a multiband inverted-V antenna. It could just as well be a horizontal dipole if the builder preferred that format. Balanced open-wire or TV-ribbon feeders are specified. The open-wire line is preferable, because the losses will be lower than with TV ribbon. The overall length of the dipole is determined by 468/f(MHz) at the lowest intended operating frequency. If it is dimensioned for use on 80 meters, operation will be possible from 80 through 10 meters by using a balun (balanced to unbalanced) transformer and a Transmatch, as illustrated. Some Transmatches come equipped with a built-in balun, which is included for use with balanced feeders.

A more effective method for matching the transmitter to a balanced feeder system is shown in Fig. 6B. In this example the feeders are brought to the operating position and tapped on L1 of the matching network. The length of L1 (effective inductance) must be changed for each band of operation, and this is possible by means of a switch or clip leads. The feeder tap points on L1 must also be changed in accordance with the band of operation. The E. F. Johnson Matchboxes were based on this kind of matching network.

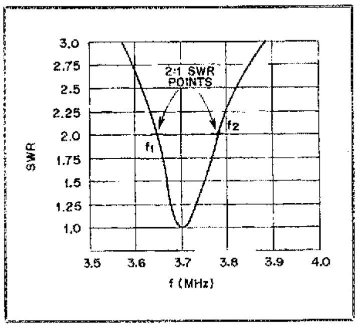


Fig. 7 — Typical SWR curve for an 80-meter dipole with coaxial-cable feed. The antenna should accept the transmitter power quite well when the SWR is less than 2:1 (3650 to 3750 kHz in this example). The bandwidth of an 80-meter dipole may be greater than that indicated here, depending on how it is built.

The shortcoming of a multiband dipole is its declining performance as the operating frequency is increased: an 80-meter antenna of this type will perform rather well on 80 and 40 meters. It will give fair results on 20 meters, and may yield mediocre performance on 15 and 10 meters in terms of DX work. However, the multiband inverted V is a very popular all-around antenna despite the compromises. Once erected, it need not be trimmed. The Transmatch will compensate for the SWR "seen" by the transmitter.

The tuned-feeder concept can be applied to the antennas in Fig. 5 as well. The classic name for a straight dipole with tuned feeders is the "Center-Fed Zepp." The inverted-V format is preferred by many because it requires only one support, is essentially omnidirectional and is vertically polarized. The center should be erected as high as possible above ground for best results.

What Kind of Wire is Best?

There is confusion among beginners about what kind of wire is suitable for the radiator of an antenna. Some have asked, "Can I use wire that has plastic insulation?" Others have wondered, "What size wire must I use?" In both cases there is no particular answer. Bare wire and insulated wire both work fine in the range from 1.8 to 30 MHz. The insulation will not degrade the radiation of the antenna. The wire size can be the largest you can acquire or afford. Generally, 12-, 14- or 16-gauge sizes are used. But, very fine wire, such as nos. 20 through 26, is satisfactory if there is not too much stress on the legs of the antenna. The smaller wire will break easily in wind and ice, and this must be considered when making a choice.

Hard-drawn copper or Copperweld wire is the most rugged, and is not subject to stretching with stress versus time. No. 12 or 14 plastic-coated house wiring is excellent for dipole antennas if it is available. Stranded copper works just as well as solid copper for amateur antennas. Some amateurs use insulated hookup wire and report good results. The primary consideration is that we use strong enough wire to ensure that the antenna stays aloft once it is erected.

The end insulators can be made from any good grade of material such as glass, plastic or phenolic. If you don't want to buy insulators, you can make them from pieces of glass-epoxy pc board (copper removed) or Plexiglas. Some amateurs have used the white, plastic six-pack retainers as strong insulators. Others report fine results with plastic clothespins and hair curlers. The center insulators for dipoles can be fashioned from Plexiglas or similar material. Always be sure to seal the open end of the coax cable with epoxy cement or Silastic compound to keep the dirt and moisture from entering the cable.

Homemade open-wire line can be built easily. The line spacing and wire size aren't important for a multiband dipole. A good compromise is to use no. 16 wire for the two conductors, spaced 3 to 4 inches apart. The spacers can be made from plastic clothespins, hair curlers or even a 1/4-inch (6-mm) diameter wooden dowel rod that has been boiled in paraffin wax. We must be innovative if we are to save money!

Trap Dipoles

"Can't I use a trap dipole?" Sure, if you don't mind buying a commercial product. But, a homemade trap dipole is hard to design and to tune if one is a beginner to radio, so the commercial product might be the best to consider.

A trap dipole permits multiband operation without a Transmatch. It uses a coaxial feed line which can be connected directly to the transmitter and receiver. It can be erected as shown in Fig. 5. The trade-off is in performance. The bandwidth will be narrower than with a full-size dipole, and there will be some losses in the traps. However, in an actual on-the-air situation it may be hard to tell the difference between a trap dipole and a single-band, full-size one. Nearly all multiband antennas represent a compromise between convenience and performance.

The best plan is to try various antennas and learn which one will work best for you. Identical antennas often yield different results at separate locations. This is because of the terrain, conductivity of the earth below the antenna and other factors. It won't take long to determine how effective your antenna is, once you start contacting stations near and far. If the performance is dismal, try another style of antenna. Experimenting is part of what Amateur Radio is all about! QST

Computer Control of the IC-255A

Ready for the computer age in Amateur Radio? It won't be long before many hams tie their computers to their radios. Here is an example of what we may all be doing one of these days.

By Curt Terwilliger,* KI6J

If you want unlimited scanning ability, or a chance to try spread spectrum techniques, or even an automated logger, build this simple interface and connect your ICOM IC-255A 2-meter fm transceiver to your computer. No modifications to the rig are required — just plug the interface into the accessory socket on the rear apron! The interface lets your computer set the frequency, check the squelch, read the frequency and activate the PTT line — all from one parallel input port and one parallel output port. And if you add a modem or TU, you have an automated ASCII station.

Inside the IC-255A

The secret of the IC-255A's versatility is its internal microcomputer. The tuning, offset and frequency memory of the radio are controlled by information that its internal central processing unit (CPU) gives the synthesizer. Normally, this information is read from the front panel knobs and switches, but ICOM also provided for a remote data input from the accessory socket. The CPU periodically scans the socket to see if a remote control device is active, and then reads or writes data as requested. The program that is stored in its CPU specifies the exact timing format for data exchanges. I obtained a timing sketch by writing to the factory; unfortunately, the explanatory notes were in Japanese! However, Mr. Don Specht of ICOM provided a most helpful translation. Anyway, computer signals are an international language.

The message format is shown in Fig. 1. The first character transmitted is the destination address. The possible destinations are 435 MHz, 144 MHz, 50 MHz hf and Idle. These are represented by numbers 11 through 15 (hexadecimal B through F). Because the destination in this case is the IC-255A, the address is 12 (C_{16}). The rig responds with its address as acknowledgment. Then four digits of data are transferred, most significant first. These are equivalent to the digits displayed in the LED readout on the front panel. The remote interface may read or write each digit as desired. For example, if the remote interface were to set the frequency to 147.360 MHz, it would write 7 3 6 0 after the address exchange. If it were to verify the frequency it would read the four digits after the address exchange.

Control Signals

The three signals that control data transfer are DATA BUS CONTROL (DBC), REMOTE (RT) and NOT DATA VALID ($\overline{DV}$). DBC controls the direction of data transfer; a high level signals data from remote to the rig. To send an address, the data bus is loaded, DBC is raised and then

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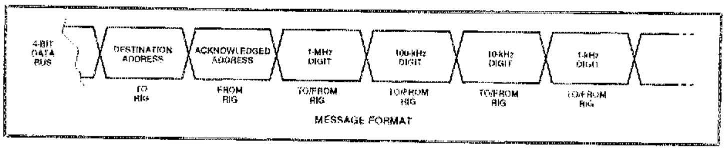


Fig. 1 — Message format required by the IC-255A internal CPU.

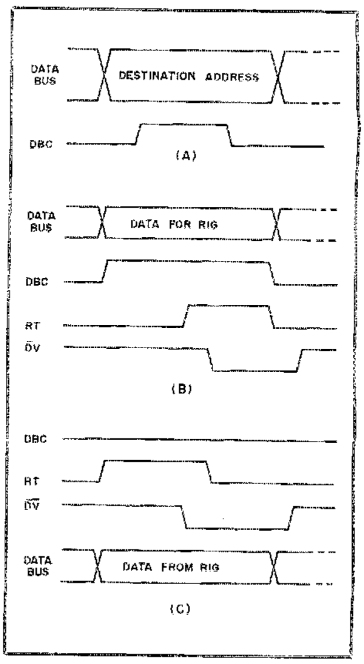


Fig. 2 — Timing diagrams for IC-255A/interface data exchange: at A, address transmission; at B, data sent from interface to IC-255A and at C, data sent from IC-255A to interface.

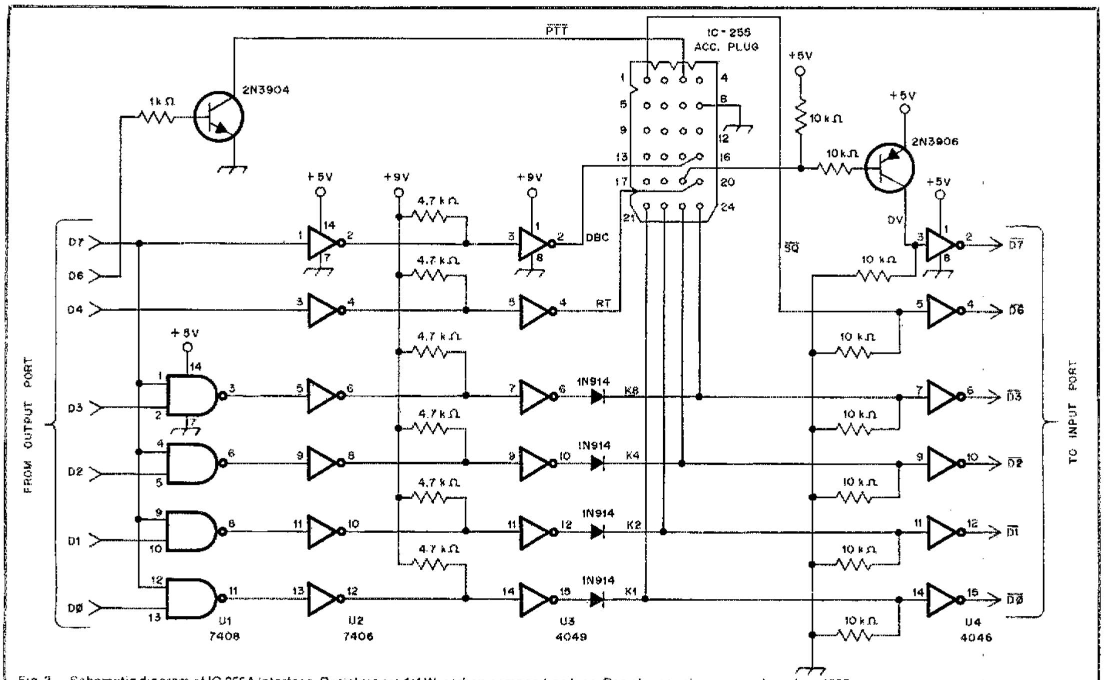


Fig. 3 — Schematic diagram of IC-255A interface. Resistors are 1/4 W, carbon-composition type. Resistance values are in ohms; k = 1000. Construction may be by any convenient technique. Lead lengths are not critical.

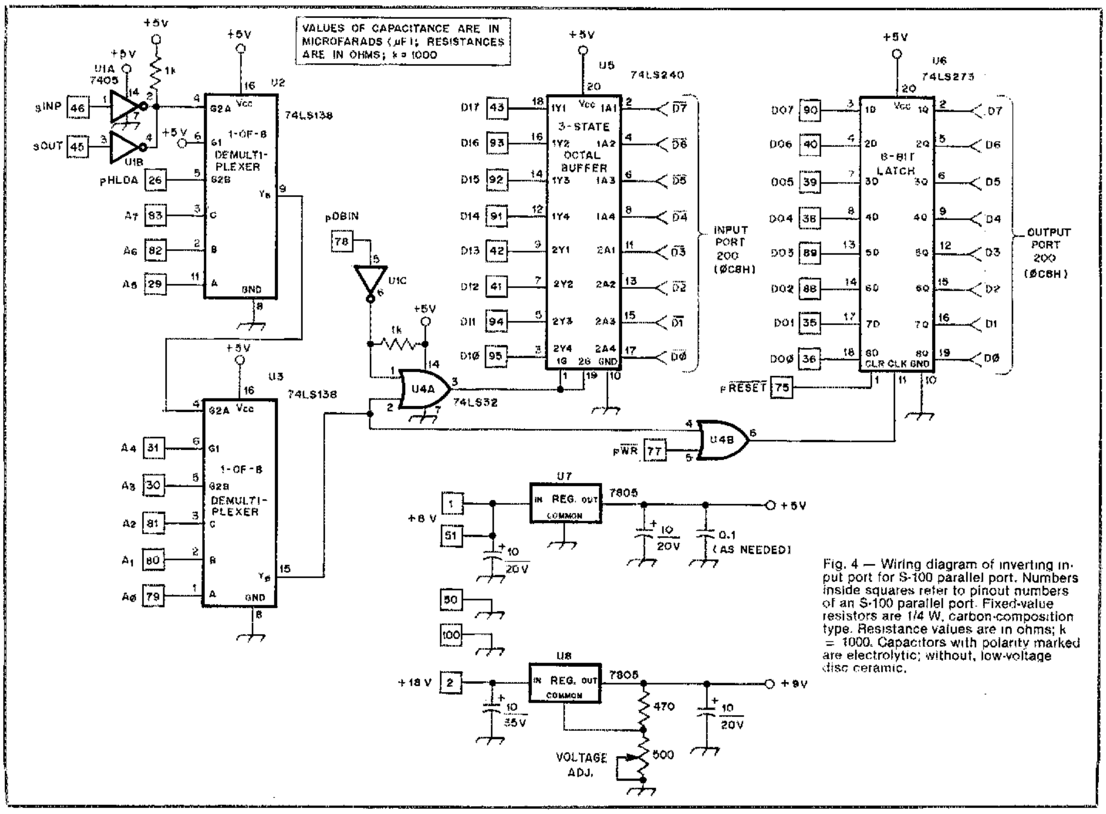


Fig. 4 — Wiring diagram of inverting input port for S-100 parallel port. Numbers inside squares refer to pinout numbers of an S-100 parallel port. Fixed-value resistors are 1/4 W, carbon-composition type. Resistance values are in ohms; k = 1000. Capacitors with polarity marked are electrolytic; without, low-voltage disc ceramic.

DBC is lowered. This procedure is shown in Fig. 2A.

The lines RT and $\overline{DV}$ regulate the transfer of subsequent data. The remote interface writes a digit by raising DBC and placing data on the bus. It then raises RT to signal data availability. The rig lowers $\overline{DV}$ to indicate it is reading the data. The remote interface lowers RT to signal the end of that digit, and the rig raises $\overline{DV}$ to indicate readiness for a new digit. This sequence is shown in Fig. 2B.

The remote interface reads a digit by lowering DBC and raising RT. The rig places the digit on the bus and then lowers $\overline{DV}$. The interface reads the digit and lowers RT. The rig then raises $\overline{DV}$. This sequence is shown in Fig. 2C. This type of "handshake" allows the slowest device to control the transfer, whether it is the rig or the remote interface. Thus we needn't worry about the type of computer used for remote control.

The Control Circuit

The control circuit basically shifts logic signals between CMOS levels (for the ICOM) and TTL (for the computer). The four data bus signals are fed to the input port through 4049 CMOS inverters. Output signals to the data bus are enabled by the DBC line. When DBC is high, the four AND gates pass output port data through two inverters and a series diode to the data bus. The series diode allows the inverter output to pull up but not to pull down. The resistors to ground (both on the interface and inside the rig) form a passive pulldown. A similar output stage is used inside the rig. It is set to a low state when DBC is high, allowing the interface to control the data bus without any interference.

When DBC is low, the interface data is set to all zeroes, and the data drivers in the rig are enabled. The rig can pull any line up if desired or let the lines sink low through the pull down resistors. The diodes in the output lines of the interface prevent its inverters from shorting the data bus to ground.

The $\overline{DV}$ output from the rig can only pull down. It is shunted by a pulldown resistor, which makes it inconvenient to

Table 1

Program Listing for IC-255A SCAN

```
   5  REM  THIS IS CROMEMCO 32K  STRUCTURED BASIC
  1Ø  PRINT"ICOM SUPER SCAN"
  2Ø  PRINT
  3Ø  I = 1
  4Ø  INPUT"ENTER SCAN FREQ. IN HERTZ (Ø TO TERMINATE) = ",F(I)
  5Ø  IF F(I) = Ø THEN GOTO SCAN1
  55  FLAG = Ø
  6Ø  IF(F(I)> = 1438ØØ.Ø) AND F(I)< = 148195.Ø THEN FLAG = 1
  7Ø  IF NOT FLAG THEN PRINT "OUT OF RANGE." : GOTO 4Ø
  8Ø  I = I + 1
  9Ø  GOTO 4Ø
 1ØØ *SCAN1
 11Ø   REM SCAN ROUTINE
 12Ø   LASTI = I - 1
 13Ø     FOR I = 1 TO LASTI
 14Ø     F = F(I) - 14ØØØØ.Ø
 145     NOESC
 15Ø     GOSUB SET'FREQ
 154     ESC
 155     COUNT = 125
 156     GOSUB DELAY
 16Ø     GOSUB LISTEN
 17Ø     IF NOT ACTIVE THEN GOTO SS2ØØ
 175     DCOUNT = Ø
 18Ø     GOSUB LISTEN
 19Ø     IF NOT ACTIVE THEN DCOUNT = DCOUNT + 1
 2ØØ     IF DCOUNT = 1ØØ THEN GOTO SS2ØØ : REM NEXT CHANNEL
 21Ø     IF ACTIVE THEN DCOUNT = Ø
 22Ø     GOTO 18Ø
 23Ø   *SS2ØØ
 24Ø     REM NEXT SCAN VALUE
 25Ø     NEXT I
 26Ø   GOTO 13Ø
 7ØØ   REM ICOM DRIVERS
 71Ø   REM
 72Ø   REM THIS IS AN SBASIC VERSION OF THE ICOM DRIVERS
 73Ø   REM WHICH CONSISTS OF READ AND WRITE ROUTINES
 74Ø   REM WHICH ARE CALLED FROM SBASIC BY GOSUBS.
 750 *READ'FREQ
 76Ø   REM READ'FREQ RETURNS THE FREQUENCY IN A BYTE
 77Ø   REM RANGING FROM 38ØØ TO 8ØØØ
 78Ø   GOSUB TXADR
 79Ø   GOSUB IRCV
 8ØØ   REM GET FIRST DIGIT
 81Ø   GOSUB IRCV : F = A*1ØØØ
 82Ø   REM SECOND DIGIT
 83Ø   GOSUB IRCV : F = F + A*1ØØ
 84Ø   REM GET THIRD DIGIT
 85Ø   GOSUB IRCV : F = F + A*1Ø
 86Ø   REM GET LAST DIGIT
 87Ø   GOSUB IRCV : F = F + A
 88Ø   REM FINISHED
 89Ø   RETURN
 9ØØ *SET'FREQ
 91Ø   REM SET FREQ SETS THE ICOM TO THE FREQ SPECIFIED
 92Ø   REM by 14ØØØØ kHz PLUS FREQ F
 93Ø   GOSUB TXADR
 94Ø   GOSUB IRCV
 95Ø   REM FIRST DIGIT
 96Ø   A = INT(F/1ØØØ) : GOSUB ISEND
 97Ø   F = F-A*1ØØØ
 98Ø   REM SECOND DIGIT
 99Ø   A = INT(F/1ØØ) : GOSUB ISEND
1ØØØ   F = F - A*1ØØ
1Ø1Ø   REM THIRD DIGIT
1Ø2Ø   A = INT(F/1Ø) : GOSUB ISEND
1Ø3Ø   F = F - A*1Ø
1Ø4Ø   REM LAST DIGIT
1Ø5Ø   A = INT(F) : GOSUB ISEND
1Ø6Ø   RETURN
1Ø7Ø *TXADR
1Ø8Ø   REM TXADR SEND THE 144 MHz ID TO THE ICOM
1Ø9Ø   OUT 2ØØ,128 + 12 : REM SET DBC AND SEND ØCH
11ØØ   COUNT = 32 : GOSUB DELAY
111Ø   OUT 2ØØ.12
112Ø   COUNT = 18 : GOSUB DELAY
113Ø   RETURN
114Ø *I RCV
115Ø   REM IRCV READS A BYTE FROM THE ICOM
116Ø   OUT 2ØØ,16 : REM BIT 4 IS RT
117Ø   J = INP(2ØØ)
118Ø   IF J<128 THEN GOTO 117Ø
119Ø   J = BINAND(J,15)
12ØØ   A = J
121Ø   OUT 2ØØ,Ø
122Ø   J = INP(2ØØ)
123Ø   IF J> = 128 THEN GOTO 122Ø
124Ø   RETURN
125Ø *I SEND
126Ø   REM ISEND TRANSMITS A BYTE TO THE ICOM
127Ø   OUT 2ØØ,128 + A : REM FIRST SIGNAL WITH DBC
128Ø   COUNT = 18 : GOSUB DELAY
129Ø   OUT 2ØØ,128 + 16 + A : REM ADD RT
13ØØ   J = INP(2ØØ)
131Ø   IF J<128 THEN GOTO 13ØØ : REM WAIT FOR DV
132Ø   OUT 2ØØ,A
133Ø   J = INP(2ØØ)
134Ø   IF J> = 128 THEN GOTO 133Ø
135Ø   RETURN
136Ø *DELAY
137Ø   REM ABOUT 2 MILLISECOND PER COUNT
138Ø     FOR C = 1 TO COUNT
139Ø     NEXT C
14ØØ   RETURN
141Ø *LISTEN
142Ø   REM RETURNS ACTIVE = 1 IF SQUELCH BROKEN
143Ø   MASK = BINAND(INP(2ØØ),64) : REM BIT 6 IS SQUELCH
144Ø   ACTIVE = NOT MASK
145Ø   RETURN
```

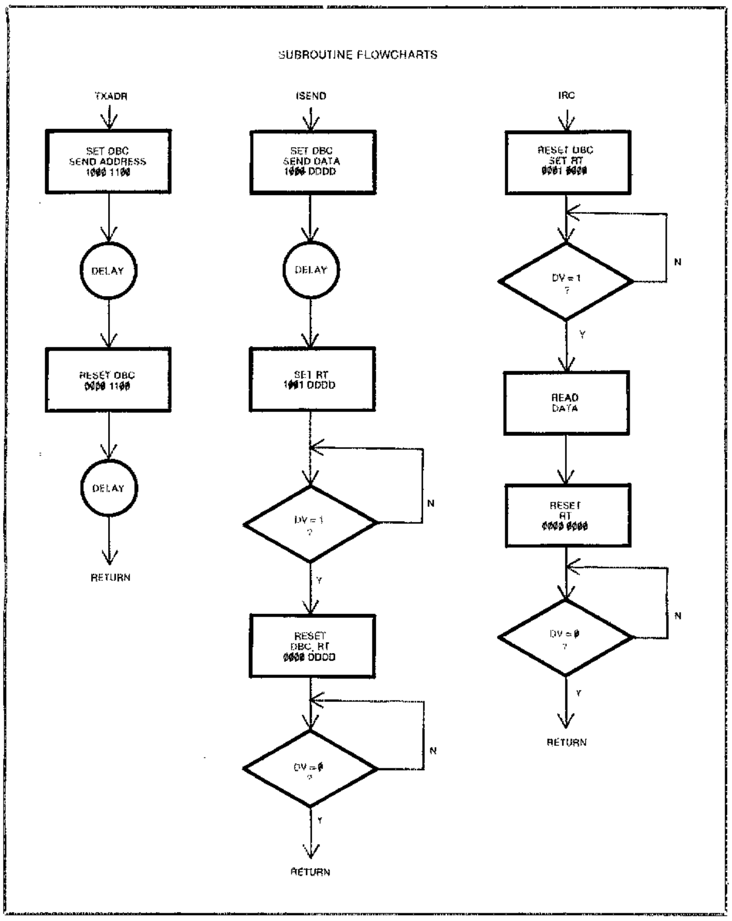


Fig. 5 — Flowcharts for subroutines used to make up various programs.

drive a CMOS input. Therefore, a discrete transistor is used; this extra inversion causes the input port to read DV (active high) rather than $\overline{DV}$ (active low).

The circuit in Fig. 3 can be connected to any parallel port with latched output data. Seven output bits and six input bits are required. The output bits are active high while the input bits are active low; the input bits may be complemented in software or by an inverting input port. A suggested circuit for an S-100 parallel port is shown in Fig. 4. This circuit was used in a Cromemco machine to develop the software to be described.

Some Software Examples

The BASIC program in Table 1 is a demonstration program of a 10-channel scan routine. The scan stops on an active channel and resumes about three seconds after activity stops. One advantage of having a large number of scan entries is weighting the scan sequence. For example, suppose you wanted to monitor the club repeater on frequency A, and you also wanted to check the simplex frequencies B and C occasionally. The scan sequence might then be AAAABAAAAC to monitor A 80% of the time and B and C 10% each.

This program is made up of three fundamental subroutines: transmit address, receive data and send data. Using these it is possible to then write elaborate programs. Flowcharts for these subroutines are shown in Fig. 5. With these few bytes of software, some very trivial outboard hardware and a little imagination, you will be bringing your shack into the computer age. A couple of more pieces of equipment and you have an automated ASCII station. Packet or spread spectrum, anyone? QST

Strays

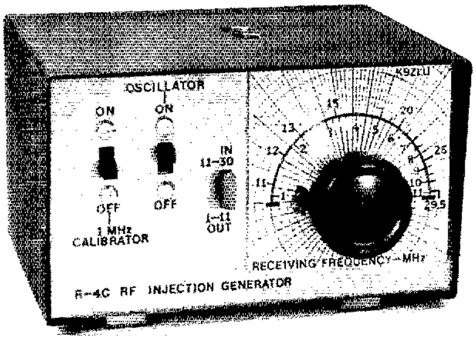
***QST* congratulates . . .**

☐ Graham MacLachlan, VE3HDU, of Willowdale, Ontario, who despite having suffered a stroke, was "determined not to let that stroke deprive me of a useful life." MacLachlan organized and maintains a stroke-unit fund for the Sunnybrook Medical Centre in Toronto, works dedicatedly for the Ontario Heart Foundation and still finds time for his hobby, Amateur Radio.

☐ Margaret (WB8CLG) and Sam (WB8FNR) Noblet of Middletown, Ohio, who recently were honored with a "Ham of the Year Award" by the Dial Radio Club for their services to Amateur Radio.

Members of the Livonia (Michigan) Amateur Radio Club prepare for a test run of their vertical DXpedition, Operation Skylark, to be held at 10,000 ft over Livonia on Sunday, May 24, on 146.58 MHz simplex. Deciding that the only unexplored regions left were *up*, the club christened this to be the first Aerpedition. All 2-meter hand-held operators are encouraged to participate in this QRP DX adventure. Contacts will be limited to those using 5 watts or less. Could this be amateurs' "A small step for man . . .?" *(photo courtesy Harry G. Wayne, W8RYH)*

General-Coverage Reception with the Drake R-4C Receiver



With this low-cost adapter, you now can enjoy the full capabilities of the R-4C. The basic idea is adaptable to other such receiver types as well.

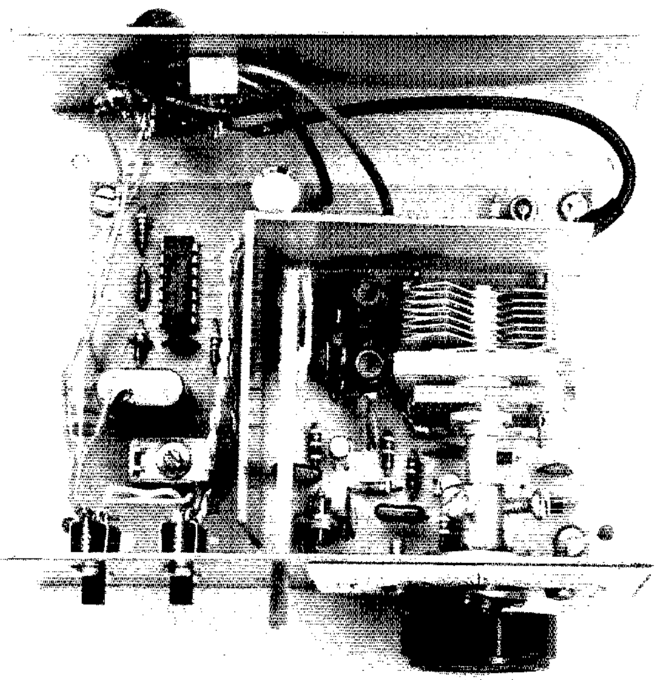
By Robert H. Luetzow,* K9ZLU

This rf injection generator is designed as a general coverage receiving adapter for use with the Drake R-4C receiver and may also be used with the R-4B series. The output of the generator is connected to an unused auxiliary crystal socket at the rear of the receiver chassis and provides the rf voltage required to permit reception on frequencies between 1.5 and 30 MHz. Operation between 5 and 6 MHz is *not* recommended because of the i-f arrangement of the receiver. If all new parts are used for construction of the unit, the total cost of this project should not exceed $40. The basic design may be altered as required to be used with other types of receivers.

The Circuit

An injection frequency between 12.6 and 40.6 MHz with an amplitude of approximately 1.3 volts is required at the auxiliary crystal socket. Injection frequencies needed for specific receiving frequencies are shown in Table 2-1 of the R-4C manual, and the preselector settings may be found in Fig. 3-2.

The generator circuitry is shown in Fig. 1. It consists of a band-switched, grounded-drain Colpitts oscillator coupled to a source follower to provide isolation from the R-4C. Band switch S1 selects coils L1 and L2 for oscillator fre-



The crystal calibrator may be seen at the left of the photo, with the power supply components arranged along the top of the pc board. Phono jacks, mounted on the rear panel, are used for the antenna input/output and rf output connections. The supply voltage lines and ground strap pass through a grommet and are secured by a cable clamp attached to the rear panel.

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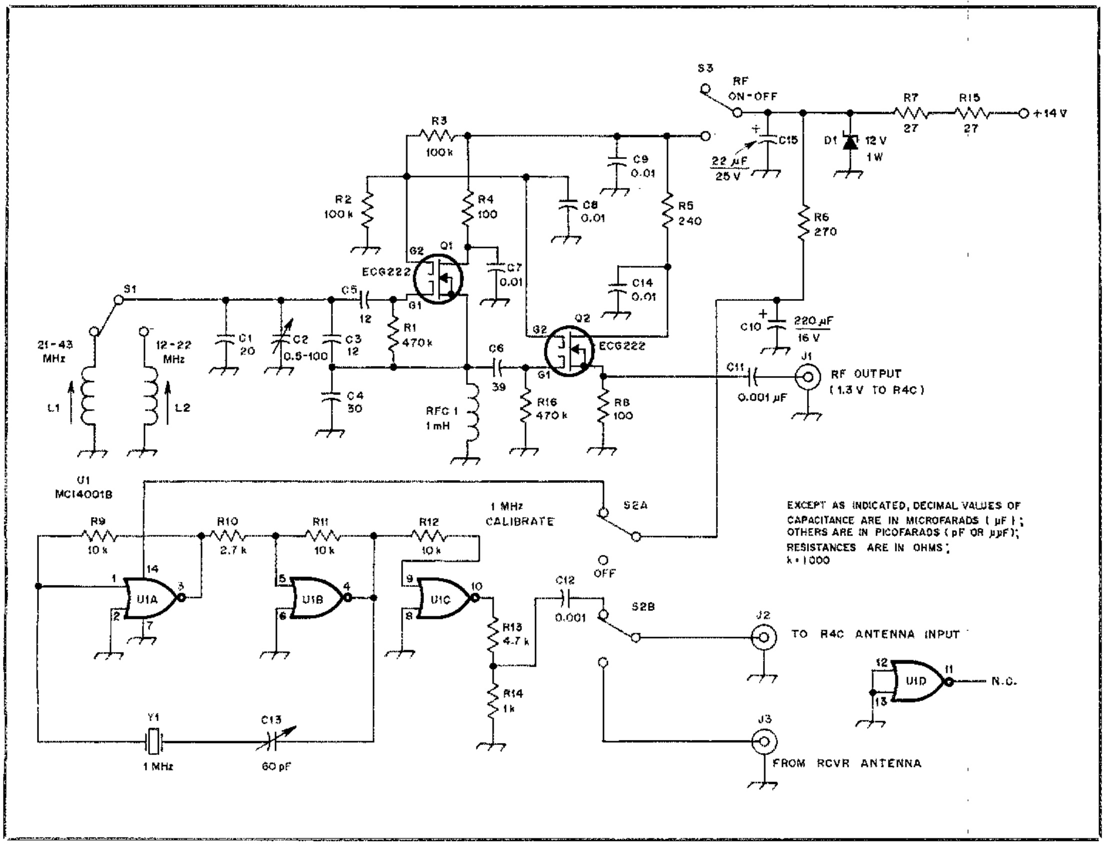


Fig. 1 — Schematic diagram of the rf injection generator. All resistors are 1/4-watt types, 10% tolerance.

C1 — 20 pF silver mica, 100 V.
C2 — 0.5-100 pF air variable.
C3, C5 — 12 pF silver mica, 100 V.
C4 — 30 pF silver mica, 100 V.
C6 — 39 pF silver mica, 100 V.
C7, C8, C9, C14 — 0.01 µF disc ceramic, 50 V.
C10 — 220 µF, 16-V electrolytic.
C11, C12 — 0.001 µF disc ceramic, 50 V.
C13 — 60 pF compression trimmer.
C15 — 22 µF, 25-V electrolytic.
D1 — 12-V, 1-W Zener diode.
J1-J3, incl. — Phono jacks.
L1 — Adjustable 0.5-0.7 µH, slug-tuned phenolic form, pc mount, 1/4-in. (6 mm) dia, 7 turns no. 24 enam. (see text).
L2 — Adjustable 1.5-2.6 µH, same form as L1, 12 turns no. 24 enam.
Q1, Q2 — N-channel, dual-gate MOSFET, 12,000 µmhos, ECG222 or equivalent.
S1 — Spdt slide switch (see text).
S2 — Dpdt slide switch.
S3 — Spdt slide switch.
U1 — Quad NOR gate, MC14001B or equivalent.
Y1 — 1-MHz crystal, HC-6/U holder.

quencies of 21 to 43 MHz or 12 to 22 MHz, respectively. Approximately 1.6 volts at 12.6 MHz and 1.3 volts at 40 MHz is available from the generator when it is connected to the receiver. A crystal calibrator (U1) uses a quad NOR gate CMOS IC to generate a good, clean calibration signal for use between 1 and 30 MHz. S2, the calibrator ON/OFF switch, is wired to supply the calibrating signal to the R-4C antenna circuit when the calibrator is turned on, and connect the receiving antenna to the circuit when the calibrator is off.

Generator Construction

The most stringent construction requirement of the generator is the mechanical rigidity required to secure oscillator stability. All components are mounted on a pc board; the overlay is shown in Fig. 2. An L shaped shield encloses the tunable generator circuitry. It is fashioned from pieces of single-sided pc board and connected to the main board by means of short lengths of bare wire. These wires (soldered to the copper foil of the shield pieces) are passed through small holes in the main pc board (not evident in the pc layout) and soldered to the ground foil of the main board.

C2, the tuning capacitor, is secured to the main pc board by means of an L shaped bracket made from sandwiched pieces of circuit board material. This bracket is mounted so it will align the tuning capacitor shaft with the vernier dial mechanism mounted on the front panel. The vernier mechanism was removed from a readily available 8:1 reduction drive dial assembly (Calectro E2-744).† A piece of clear plastic, salvaged from an electronic parts package, is used as dial pointer. If the construction described is followed closely, the dial layout shown in Fig. 3 can be used. Any change in parts values in the VFO circuitry will cause a corresponding change in the tuning dial layout. The markings are used only to locate the correct calibration signal. If you wish to make your own dial layout, do so only after the generator has been completed and installed in the cabinet *with the cover*

†[Editor's Note: *Various types of reduction* drives are available from Radiokit, Box 411, Greenville, NH 03048.]

in place. A shadow front 3 × 5 × 4-inch (76 × 127 × 102-mm) metal box (Calectro H4-746) was used for the unit shown in the photographs.

The band switch is made from a slide switch (mounted on the main pc board) that has a piece of unclad circuit board material notched to fit the switch actuator and epoxied to it. This arrangement results in a push-pull switch that is activated by the extension arm through an elongated slot in the front panel. The coil forms used for L1 and L2 are 1/4-inch (6.4 mm) slug-tuned pc-mount units from a Radio Shack assortment.

This receiving adapter is designed to use the + 14 V supply available at the R-4C ACCESSORY socket. It has been observed that some receivers have a high amount of ac ripple in the accessory supply, which causes ac modulation of the received signal. If an excessive amount of ac ripple is present in your receiver supply, the simple ripple filter shown in Fig. 4 may be constructed on a small piece of perf or pc board and attached to the rear of the oscillator compartment shield. Zener diode D1 and resistors R7 and R15 should be removed. The output of the ripple filter is then connected to the point on the circuit board that was formerly the junction of D1 and R7.

You should also check C166, C167 and C201 in the receiver accessory supply if it has a high ripple content. Note that the R-4C accessory supply is rated only for 50 mA and is not protected by a fuse. So make sure there are no wiring errors in the receiving adapter circuit!

Interconnection

A short piece of RG-174/U coaxial cable is used to interconnect the rf generator and the R-4C. One end of the cable is terminated with a plug made from the bottom section of an HC-6/U crystal holder. The center conductor of the cable is connected to one pin, the other pin is left empty and the braid of the cable is attached to the body of the crystal case which is then filled with epoxy. When connecting the generator to the receiver, the crystal holder plug is arranged so that the center conductor of the cable from the generator is connected to the *top* hole of an auxiliary crystal socket at the rear of the R-4C. *Nothing* is connected to the bottom pin of the socket. A partial diagram of the R-4C circuitry involved is shown in Fig. 5. A ground lead (made

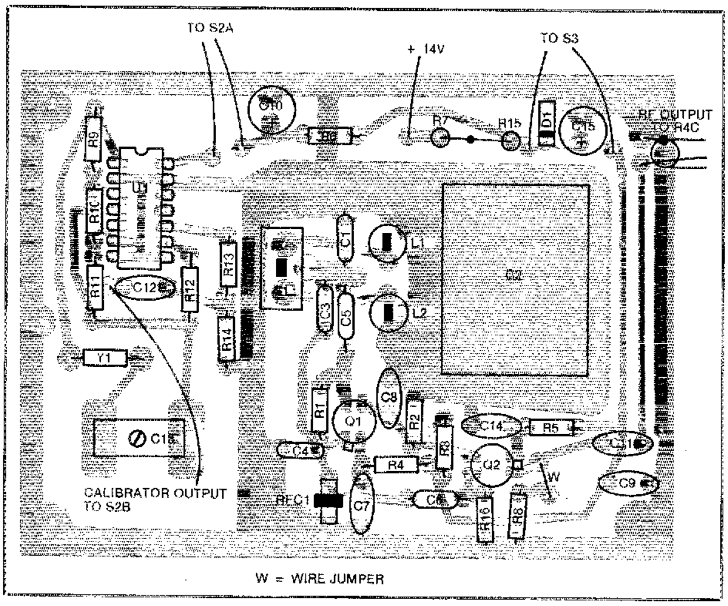


Fig. 2 — Parts-placement guide for the general-coverage receiving adapter. Parts are placed on the unclad side of the board; the shaded area represents an X-ray view of the copper pattern.

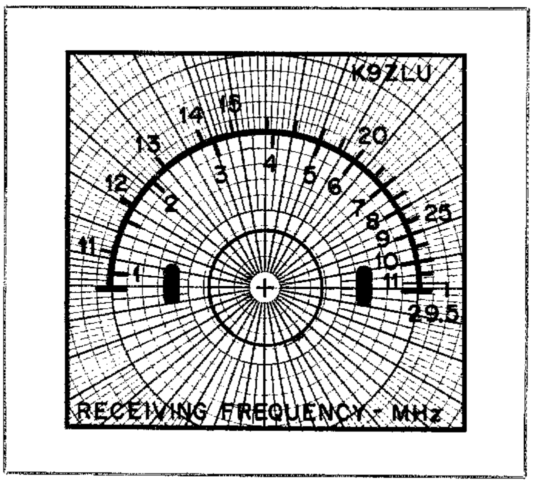


Fig. 3 — The dial layout for the general-coverage receiving adapter. If the VFO circuit parts values do not vary widely from those given in Fig. 1, this pattern may be used directly. Refer to the text for further information.

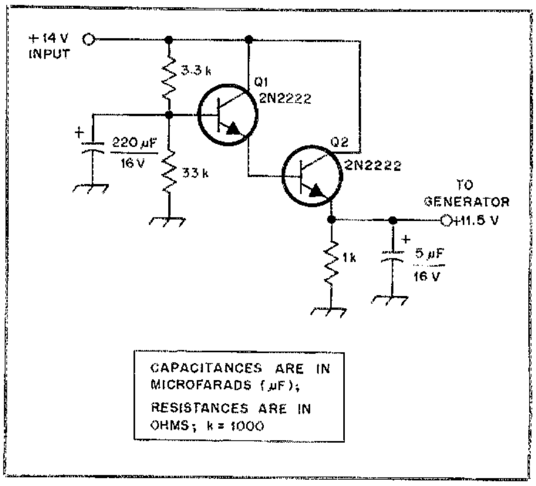


Fig. 4 — This optional ripple filter may be constructed on a piece of perf or pc board. Its use is discussed in the text.
Q1,Q2 — Npn silicon bipolar transistor, general purpose type, 500 mW, 2N2222 or equivalent.

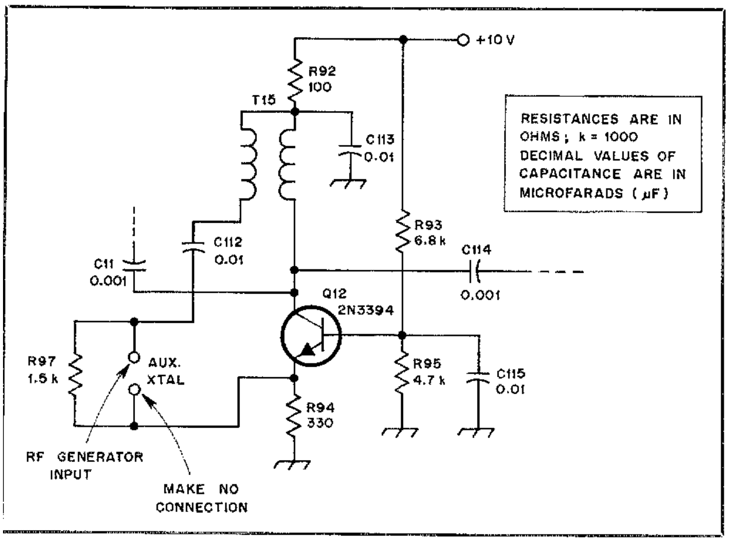


Fig. 5 — A partial diagram of the R-4C crystal oscillator circuitry. Component designations are those of the manufacturer.

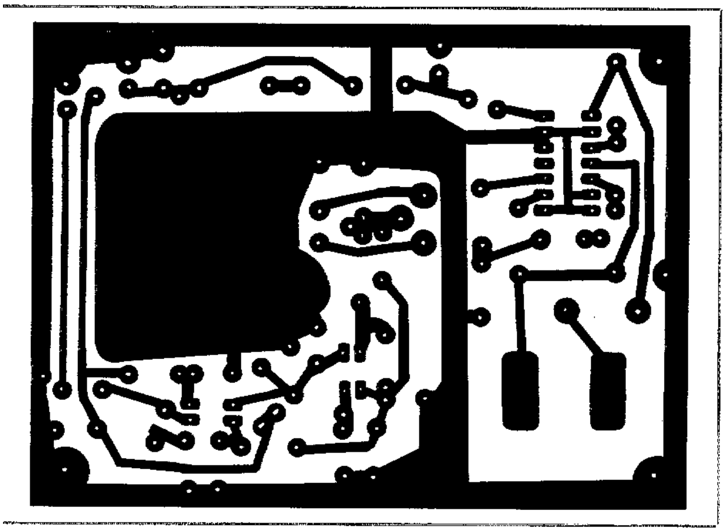


Fig. 6 — Circuit-board etching pattern for the general-coverage receiving adapter (see the parts layout of Fig. 2). Black represents copper. The pattern is shown at actual size from the foil side of the circuit board.

from a piece of coaxial cable braid) is connected between the ground foil of the generator circuit board and the receiver chassis. This additional ground lead helps reduce the detuning effects of hand capacitance. Keep all connecting leads as short as possible.

Preliminary Checks

After making the proper generator/receiver interconnections, turn on the receiver, generator and 1-MHz calibrator. Check for a calibrator signal at 4, 7, 14, 21 and 28 MHz. Once calibrator operation has been ensured, check to see if the rf generator is working properly. With the generator band switch in the 1 to 11 MHz position and the generator oscillator tuned to 14 MHz, a 14 MHz signal should be audible in the receiver (XTAL switch in NORMAL position.) Remember, with the generator band switch in the 1 to 11 MHz position, the generator produces an rf signal between 12.1 and 22.1 MHz. With S1 in the 11 to 30 MHz position, a 22.1 to 40.6 MHz signal is generated. A 28 MHz signal should be located with S1 in the 11 to 30 MHz position.

Calibration

The enclosure cover must be in place before calibration can be completed. Start by tuning the R-4C to a 7-MHz signal with the XTAL switch in the NORMAL position. Then tune the generator to 7 MHz and adjust L2 so the 7-MHz signal can be received. Next, locate a signal at 4 MHz. Adjust the generator dial pointer and coil L2 to locate the 4- and 7-MHz calibration points as accurately as possible. Set the R-4C to receive WWV at 10 MHz and adjust C13 in the calibrator circuit for zero beat. You may need to readjust coil L2 and the dial pointer to ensure the 4- and 10-MHz dial settings are accurate. The 11- to 30-MHz band is calibrated in a similar manner by adjusting coil L1 and using the 20-, 15- and 10-meter bands for alignment purposes.

While the R-4C was not designed for receiving signals below 1.5 MHz, I have been able to receive strong broadcast stations at frequencies as low as 1 MHz while using the rf injection generator. Three units have been built according to the information given here and all three have worked flawlessly. Have fun and many enjoyable hours of listening! QST

Strays

ANOTHER ATLANTIS?

☐ The Bowie (Maryland) Amateur Radio Club will be operating a mini-DXpedition from Tangier Island, Virginia, May 23 at 0000Z to May 25 at 1500Z. Each year, the club operates from a remote island on which no amateur activity has previously taken place; Tangier Island, it has been predicted, will eventually disappear from Chesapeake Bay because of erosion. To receive an Island Certificate, amateurs working the station, N3GR/4, should send a large s.a.s.e. and a QSL card to John Rouse, KA3DBN, P. O. Drawer M, Bowie, MD 20715. Cw — about 40 kHz up from the bottom of 80 through 10 meters; Novice — 7125, 3725, 21,125 and 28,125 kHz; ssb — 3895, 7245, 14,305, 21,380 and 28,590 kHz. — *John Rouse, KA3DBN, Bowie, Maryland*

Product Review

Conducted By Paul K. Pagel,* N1FB

Kenwood TS-830S HF Transceiver

Intense interest? That would be an understatement of the atmosphere created at Hq. by the announcement and subsequent arrival of the TS-830S. Why? Well, some of its more salient features are a double-conversion receiving system, a choice of a number of cw filter options at *both* intermediate frequencies, the inclusion of independent variable bandwidth tuning (VBT), and IF SHIFT with a tunable i-f NOTCH as well as receiver and transmitter incremental tuning (RIT, XIT). Fixed-frequency control (FIX), ssb off-the-air monitoring (MONI), a 20-dB receiver front-end attenuator, noise blanker and transmitter rf-type speech processor are all push button selectable. The display hold (DH) switch will maintain digital readout of a chosen frequency while the VFO is tuned to another frequency — like an electronic note pad. There's also a built-in 25-kHz marker generator, manually selectable agc functions (OFF, FAST, SLOW), and LEDs which indicate the operator's choice of RIT, XIT, RF ATTenuator, VFO, FIX and NOTCH.

Connections to and from a linear amplifier, monitor scope, and transverter are provided for on the rear panel by means of one 7-pin and two 8-pin DIN jacks. The 1/4-inch (6.4 mm) key jack, 1/8-inch (3.2 mm) external speaker jack, anti-VOX, bias, and rf output voltmeter controls, antenna and ground connectors, fuse, screen voltage on/off switch, and a very quiet PA cooling fan are also on the rear panel. The two-conductor (ungrounded) power cable is permanently wired into the unit; no multi-pin connector is used. Two predrilled holes are provided for additional phono jacks if required for some added function. All of the previously mentioned "goodies" are contained in a package smaller than that of the TS-820.[1] Unlike the '820, no provisions have been made for use with a 13.8-V dc supply or fsk.

Some Features

A PLL circuit and programmable divider are used in the TS-830S which eliminates the need for separate heterodyne oscillator crystals for each band. This circuit uses a single 10-MHz crystal and with the 5.5- to 6-MHz VFO provides all the injection frequencies required by the transceiver.

QRM may be fought by using the variable bandwidth tuning (VBT), IF SHIFT and i-f NOTCH controls of the '830. These features may be used independently or in conjunction with one another. VBT permits the operator to vary the i-f passband width within limits determined by i-f filters installed. With only the stock 2.4-kHz filter in the transceiver, an effective bandwidth of 500 Hz may be obtained at the narrowest setting of the control. The IF SHIFT moves the i-f passband frequencies higher or lower without upsetting the frequency to which the receiver is tuned, and it has an adjustment range of approximately ±1.2 kHz. An interfering carrier within the passband of the filter may be reduced or eliminated by the NOTCH filter in the receiver second i-f.

*Assistant Technical Editor

[1]"Product Review," *QST*, September 1976.

Agc is manually switched. Three switch positions are provided: FAST, SLOW or OFF. This is a welcome feature, especially for cw operators. Agc action is smooth with no evidence of popping.

One attraction of the '830 for many amateurs is the use of reliable 6146B tubes in the final amplifier stage. They're proven performers and are still preferred by many operators. The '830 provides a bit more output than was available from the '820, too.

Operational Notes

One word could be used to sum up the on-the-air behavior of the '830 — smooth. The review unit was put into service in several "shacks" over a period of months. Contest operators commented favorably about the control locations. Audio-level balance between the internal speaker and headphones is excellent; tweaking the audio gain during such a changeover is unnecessary. The audio quality of the internal 3-inch (76 mm) speaker is quite good, better than that of many units I have heard.

The digital frequency display will show the proper receive or transmit frequency, including the cw offset. It is fully operational beyond the 500-kHz frequency segments (unlike the TS-120),[2] and the analog dial is like that of the TS-120. Analog-dial linearity error never exceeded approximately 800 Hz.

VFO stability is excellent both electrically and mechanically. To test the mechanical stability, I used the gravitational-attraction and manual-persuasion methods — dropping the front of the transceiver about 3 inches (76 mm) to the desk top and pounding on the top of the cabinet with a clenched fist. A considerable amount of physical abuse was required to shift

[2]"Product Review," *QST*, February 1980.

Fig. 1 — Spectral display of the TS-830S on 160 meters (worst case). Vertical divisions are 10 dB each; horizontal divisions, 2 MHz. Second harmonic output is approximately 45 dB below the peak of the fundamental. The TS-830S complies with current FCC regulations regarding spectral purity.

Fig. 2 — Spectral display of noise about the carrier frequency of the TS-830S. The carrier is at the left. Output power is 100 watts at a frequency of 14.25 MHz. Vertical divisions are 10 dB each; horizontal divisions are 20 kHz each. The bottom line of the trace is the analyzer noise floor at 80 dB below peak output.

the VFO frequency even slightly.

Receiver "birdies" are at a bare minimum and very weak; in no instance did one cause the S meter to move. With an antenna connected to the transceiver, none was discernible. Only one response was noted to be in-band (1.843 MHz), two are out of band (7.343 and 7.464 MHz), and all others occur at frequency segment edges (0 or 500 kHz).

Many airborne pulse-type noises were effectively reduced or eliminated by the noise blanker. The effectiveness of the blanker is dependent on the frequency of operation and the noise source itself. In some instances, it was found to work well against the "woodpecker."[3] The blanker threshold is adjustable from the front panel. Care should be taken to avoid excessive blanker gain, especially with crowded band conditions, because distortion products will become evident within the receiver — you'll hear QRM you ordinarily wouldn't.

The receiver and transmitter incremental-tuning controls (RIT/XIT) are useful in avoiding interference and also in snagging that hard-to-get DX station in a pileup. The range is somewhat limited, approximately ±2 kHz, and I felt a range of ±5 kHz would be more suitable.

WARC, AUX and FIX

In the stock transceiver, the three WARC bands (10, 18 and 24.5 MHz)[4] are operational during receive only, but a simple modification outlined in the manual enables transmission. The bands may be added singly (by removing individual diodes) or simultaneously (by cutting a wire). The latter method is far easier because the diodes are somewhat inaccessible.

An auxiliary (AUX) position on the BAND switch permits the user to install components to provide for *receive only* operation on yet another frequency range of choice. The FIX button selects a single, user-supplied crystal for operation on a specific frequency (MARS or AUTOSTART, for instance). To gain access to the crystal socket, the bottom cover of the '830 must be removed, but the crystal trimmer can be reached by means of an access hole in the cabinet bottom.

[3]Editor's Note: The "woodpecker" is a pulse transmission frequently heard in the 20-meter amateur band, occasionally in others. The pulse duration and repetition rate create a woodpecker-like sound when the signal is tuned in a receiver.]

[4]Baldwin and Sumner, "The Geneva Story," *QST*, February 1980, p. 53.

Table 1

Kenwood TS-830S Transceiver, Serial No. 1020313

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: 160-10 meters, WARC bands included.	As specified plus approximately 70 kHz beyond upper and lower band edges.
Modes of operation: ssb/cw.	As specified.
Readout: analog and digital; 6-digit, fluorescent-blue digital display.	0.25-inch (6.4 mm) digits
Resolution: analog, 1 kHz; digital, 100 Hz.	As specified.
kHz/turn of knob: not specified.	25
Backlash: not specified.	Nil
RIT/XIT range: ± 2 kHz.	− 1.5, + 1.9 kHz
I-f notch depth: >40 dB.	30 dB
Receiver attenuator: 20 dB.	As specified.
S-meter sensitivity (μV/S9): not specified.	160 m, 56; 80 m, 56; 40 m, 56; 30 m, 100; 20 m, 56; 17 m, 48; 15 m, 75; 12 m, 54; 10 m, 67.
dB/S unit: not specified.	From S5 to S9, 5 dB; below S5, nonlinear and less than 5 dB/unit.
Receiver sensitivity: 0.25 μV for 10 dB S + N/N.	Receiver dynamics measured with optional YK-88C and YG-455C 500-Hz i-f filters installed. (see below)
Audio power output (8-ohm load): 1.5 W	As specified.
Power consumption: receive (heaters off), 32 W; transmit, 295 W.	Not measured.
Transmitter rf power output: not specified.	>100 W every band.
Spurious suppression: better than 60 dB.	− 62 dB
Harmonic suppression: better than 40 dB.	Approximately − 45 dB on 160 m (worst case).
Carrier suppression: better than 40 dB.	As specified.
Third-order IMD: better than − 36 dB.	− 32 dB (see spectral photos)
Key-down time limitation: cw — 1 minute.	
Frequency stability: within 1 kHz during the first hour after 1 minute of warmup; within 100 Hz during any 30-minute period after warmup.	<10-Hz drift from a cold start to 30 minutes later. (Measured with transmitter operating at 80-W input, key down.)
Size (HWD): 5.3 × 13.3 × 13.3 inches (133 × 333 × 333 mm).	
Weight: 29.8 lb (13.5 kg).	
Color: gold-brown gray.	

	80 m	*20 m*
Noise floor (MDS) dBm:	− 136	− 136
Blocking DR (dB):	129	noise limited
Two-tone 3rd order IMD DR (dB), high- and low-frequency products.	83 (h) 89 (l)	82 (h) 89 (l)
Third-order input intercept	− 13.5 (h) − 5 (l)	− 13 (h) − 5 (l)

SSB

DX-station reports repeatedly attested to the effectiveness of the speech processor; it is an rf type and utilizes the 8.83-MHz i-f filter to "scrub" the signal. Therefore, substitution of the narrower YK-88SN (1.8-kHz) optional filter is not advised in an attempt to narrow the receiver passband; the VBT (variable bandwidth tuning) function may be used instead. Some of the natural voice quality is lost when the processor is used, but this is characteristic of these devices. In addition to the use of the transceiver metering system, operation of the processor can be readily verified by observing the output waveform displayed on the station monitor scope (what do you mean, you don't have one?) and by using headphones (to avoid feedback) with the MONITORING feature of the '830. Some "talk-back" was noted during ssb operation while wearing headphones (MONI switched off), but it was not noticed when using a speaker.

The operator should ensure that the DRIVE control of the '830 is properly peaked. Otherwise the alc meter indications will be low. This might lead to improper adjustment of the MIC gain or PROCESSOR LEVEL controls and earn you a bad on-the-air reputation. When the controls are properly adjusted, the meter alc indications are sharp and reliable.

Both high- and low-impedance microphones may be used with the TS-830S. With low-impedance types, the MICrophone gain will simply be set at a higher level. A four-pin microphone connector is used.

CW

Early in the review period, cw operation was undertaken with only the 2.4-kHz ssb filter in the transceiver. By using the VBT, IF SHIFT, NOTCH and TONE controls to advantage, I was quite satisfied with the receiver performance. It

Fig. 3 — Two-tone, third-order transmitter IMD spectral display of the TS-830S. Operating frequency is 14.250 MHz; power input, 110 watts average; vertical divisions, 10 dB; horizontal divisions, 1 kHz. The third-order distortion products are approximately 32 dB below PEP output; individual tones are 6 dB below PEP output. All measurements were made in the ARRL lab.

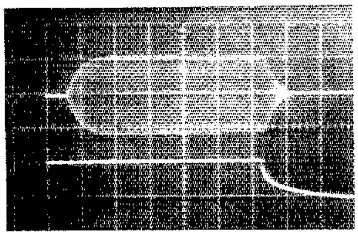


Fig. 4 — Keyed cw waveform of the TS-830S. The CAR control has been adjusted for no alc indication as described in the text. This waveform is essentially click free.

is conceivable that the occasional cw operator might never need to add the sharper cw filters; you can always install them at your leisure. But dyed-in-the-wool cw operators will rejoice at the choice of options afforded them. The review unit was later operated with 500-Hz filters in both i-fs and then with the 250-Hz filter in the second i-f. My opinion (and that of many other operators) is that the combination of the two 500-Hz filters provides sufficient selectivity for all but the most critical situations. There's even an optional 270-Hz filter for the first i-f, if you're not satisfied! Filter installation takes only about 10 minutes. I'm sure someone is bound to offer a filter-switching addition for the '830. Perhaps a post-filter amplifier stage will also be included since there is none supplied with the '830 to make up for the additional filter loss, although this created no great difficulty.

The cw-output waveform is well-shaped. Care must be taken to ensure that the CAR level control is adjusted to the point where no alc reading is indicated on the meter. This manner of adjustment is not pointed out in the operator's manual, but should be observed in order to prevent making the wavefront too sharp, which would result in the generation of key clicks.

When using VOX-keyed cw (so-called "semi break-in") the initial code element is shortened, and a steep wavefront is created that definitely will produce a click. This is characteristic of all transceivers which use similar VOX-keyed T-R systems for cw operation. Also, the VOX will drop out between words at slow cw speeds even with the DELAY control set at maximum. One way to avoid both these situations is to use the SEND REC switch or PTT operation; a foot switch may be connected by means of the ACCESSORY jack if desired. I modified the VOX delay circuitry for a longer delay time constant to suit my operating tastes. The procedure is outlined in the "Hints and Kinks" section of this issue.

In the CW positions of the MODE switch, a low-pass filter is switched into the audio chain to attenuate the higher audio frequencies and make copying a bit less tiring. Use of the TONE control will also help.

RTTY, SSTV and ASCII

To operate these modes, interconnections are made to the MIC and SPEAKER jacks. There is no RTTY position on the MODE switch, and operation takes place with the ssb filter in place on lsb. Here, the VBT and IF SHIFT functions will come in handy during reception. The manufacturer recommends that the final-amplifier input power be reduced to less than 100 watts during these modes of operation. However, the measured efficiency at that power-input level is poor — about 20%.

The instruction manual contains a number of errors of different types, and some information I felt would be helpful is lacking. The description of the location and means of access to the final-amplifier neutralizing capacitor is incorrect. This capacitor may be found mounted in an inverted position beneath the plate tuning capacitor with the shaft protruding near a notch in the final-amplifier tube-socket mounting board. Switches S19 and S21, which appear on the schematic, are not mentioned in the text, but are part of the XVTER and EXT VFO jacks, respectively. When the appropriate plug is inserted into the jack, the switches are automatically activated.

A 7-pin DIN plug is supplied for use with the REMOTE jack, but no 8-pin plug for the XVTER jack. These 8-pin plugs may be obtained directly from Kenwood.

Some TS-830S owners have reported an intermittent shift in display and operating frequency (no such problem was experienced with the review unit). The cause may be traced to a loose self-tapping screw on the AF-AVR unit (X49-1140-00). Kenwood service bulletin no. 840 recommends placing a toothed lock washer between the pc board and heat sink at two screw locations.

Conclusions

Did I like its performance? You bet! So did everyone else who had a chance to use it. The '830 is an ideal unit for fixed-station operation and small enough to grab by its built-in handle and take on vacation with you. Whether your operating style is casual or contest, the TS-830S has a lot to offer you.

Among the extra "goodies" available to accompany the '830 are two VFOs, the VFO-230 and VFO-120. The '230 is a 20-Hz-step digital VFO with five memories while the '120 is the analog unit which also mates with the TS-120 transceiver. The TS-830S is available from Trio-Kenwood Communications, Inc., 1111 W. Walnut St., Compton, CA 90220. Price class: TS-830S, $930; VFO-120, $160; VFO-230, $300. — *Paul K. Pagel, N1FB*

CUSHCRAFT A3 TRIBAND ANTENNA

The arrival of the A3 had been perfectly timed — just before the beginning of a spring holiday weekend — and the prospect of good weather was encouraging. Three hours (and a couple of big insect bites) after the box was opened, the A3 was ready to have the coaxial feed line attached. No parts were missing except the weatherproof connector boots which the enclosed literature stated were supplied for use with the PL-259 connectors. I was later informed by the manufacturer that no such boots are included in the A3 package and that the paperwork had been mistakenly packaged with some of the earlier A3s.

Mechanical Aspects

A 3/16 inch (4.8 mm) thick, 6 inch (152 mm) square plate is used for the boom-to-mast adaptor. Solid aluminum V blocks are used for the plate-to-mast clamping pieces, not a type of plastic as found on some antennas. The element ends are slotted to provide a good mechanical and electrical connection between the sections of telescoping tubing, but no conductive grease is supplied.

The 12 traps are rated for full-legal-power handling capability, separate traps being used for the 10- and 15-meter bands on each element. All parts are rugged and of good quality. I would have preferred stainless-steel worm-gear clamps at all the required positions; that type is used only at the boom splice and on the center section of the driven element. The other clamps are those which employ a machine screw for tightening the clamp.

If any newcomers may be contemplating the assembly of the A3, remember to check the trap labels, keep the arrows on the labels pointing toward the boom, and keep the drain holes in the traps pointing downward. Otherwise, you'll have the traps reversed, and in the second instance, you'll not allow for proper drainage of accumulated moisture from the traps.

Three sets of element-length measurements are suggested by the manufacturer for different portions of the bands: phone, cw and mid-band. A glance at the manufacturer's VSWR charts for the A3 and some thinking about which mode you most often use will help you make your choice. I used center-band lengths. Some touching up of element lengths may be required at any one particular installation. In my case, I elected to lengthen the element tips by 1/2 inch (13 mm) to move the 20-meter VSWR curve slightly to favor the cw portion of the band. This resulted in the curve being shifted approximately 50 kHz lower, still providing good coverage of the whole band without an excessively high VSWR. The SWR curves shown in Fig. 5 are the results obtained at these settings.

Fig. 6 shows a close-up of the driven element. The center section of the driven element is a piece of fiberglass tubing 1/8 inch (4 mm) thick, 10 inches (254 mm) long and 1 inch (25.4 mm) in diameter. This insulates the feed point from the boom. The coaxial feed line has the braid and center conductor separated for a length of 4 inches (102 mm) for attachment to the feed point. An 8-turn, 6 inch (152 mm) diameter feed-line choke is formed from part

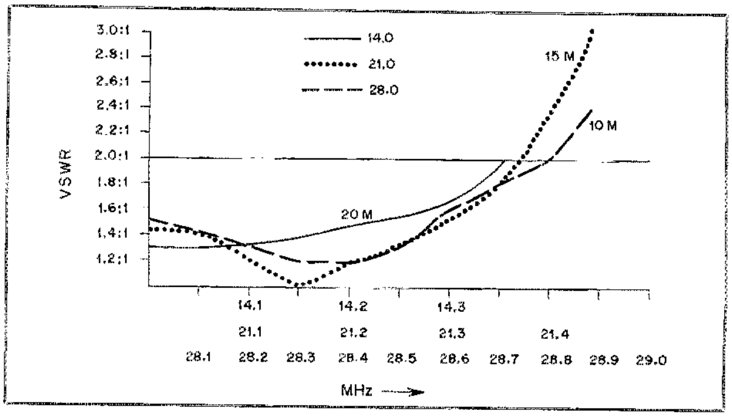


Fig. 5 — SWR curves for the Cushcraft A3 installed at N1FB. Midband settings were used and the beam installed at a height of 30 feet (10 m).

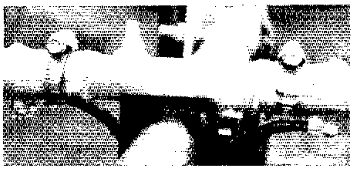


Fig. 6 — A piece of fiberglass tubing serves as a driven element insulator. The clamps, screws and bolts have been coated with a clear waterproof sealant for weatherproofing.

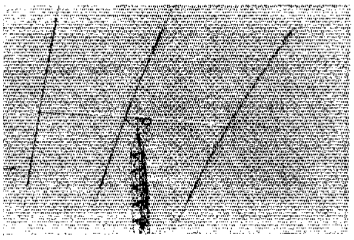


Fig. 7 — The Cushcraft A3 triband beam is shown here ready for action on 20, 15 or 10 meters. The feed-line choke is attached to the boom.

of the feed line.[1] I taped and clamped the choke to the boom with a stainless-steel hose clamp. This choke may be seen in Fig. 7.

The A3 has been a good performer during the many months it's been in service. Good front-to-back and front-to-side ratios have been observed on both DX and local signals on all three bands. No "cold" numbers are available for such ratios. The ARRL does not have an antenna testing range to accurately measure such parameters, and measurements performed at different station locations with the same antenna would likely produce varying results.[2] No structural failures have occurred since the antenna was installed despite some rough New England weather conditions.

The low values of SWR encountered have made operating with broadbanded transceivers a pleasure. Changing bands becomes a simple matter of flipping the band switch to the desired band of operation. It would be somewhat ridiculous to use a "no-tune" transceiver and have to use a Transmatch!

The Cushcraft A3 is available from: Cushcraft Corp., 48 Perimeter Rd., P. O. Box 4680, Manchester, NH 03108. Price class: $220. — *Paul K. Pagel, N1FB*

MIRAGE B-23 2-METER, 30-WATT, ALL-MODE AMPLIFIER

If a piece of equipment has a lot of knobs and switches, a reviewer can go on ad nauseam listing every detail of operation. But what do you say about something that has no switches or knobs to fiddle with? Well, it is certainly simple to operate. In fact the B-23 is so simple to use that one can easily install it out of sight (under the dash?) and forget about it.

The active device in the circuit is a Motorola MRF-240, which is a relatively new 40-W vhf device that is capable of being operated in a linear mode. The circuit is designed so that the amplifier is limited to about 30-W output when operated within specifications, thus contributing to the safety margin and longevity of the MRF-240. With about 1-1/2 W drive (fm carrier), the amplifier produces an output power of 25 W. Under these conditions, it draws about 3.5 A from a 13.8-V source. If the driving power is raised to 5 W, the output power increases to 30 W and current consumption to 3.8 A. The MRF-240 is designed to withstand high VSWR without self-destruction, but at reduced output. When operated into a load with a VSWR of 2:1, the B-23 output power was reduced by about 20%.

I used the amplifier strictly with a low-powered fm driver — it certainly seems to be ideal for that. But there is another side to the B-23; it can be used as a linear amplifier for low-level ssb signals. Spectral examination indicates that its linearity is as good as any other solid-state, 2-meter linear power amplifier that we have checked in the lab. It would appear that the B-23 is also a good choice for those having a low-powered, 2-meter ssb unit.

The B-23 has adequate output filtering to ensure that spurious signals outside the passband are attenuated more than enough to meet current FCC specifications. Part of this filter, including two harmonic traps, is always in the circuit whether the B-23 is powered or not. This is significant because the amplifier has a T-R relay that is actuated by an rf-sensing circuit. A small portion of the signal present at the input is diode rectified and triggers a transistor relay driver. A diode is a nonlinear device that does an excellent job of generating harmonics. Therefore, if all the filter sections were switched out of circuit when the amplifier was not powered, the resultant output could contain harmonics with amplitudes well above the maximum allowed. A number of amplifiers currently being sold suffer from this design problem — they are not advertised in *QST* because of this. Happily, the B-23 passed this check with flying colors.

With dc power applied and with no signal present at the input, the B-23 draws less than 4 mA. Theoretically, a typical automobile battery could be expected to last for several thousand hours under this current drain without need of recharging. However, my personal inclination is to turn everything off when I get out of my car (actually, a heavy-duty relay energized by the ignition switch does this for me). I would recommend that the user install a toggle switch of adequate rating so that he may turn the amplifier on and off at will. An LED and a current-limiting resistor could be added as a visual indicator of the status of the amplifier. In a mobile installation, the switch, LED and resistor could be placed conveniently near the operating position with the amplifier mounted safely out of sight.

A few words about the B-23 construction are in order. The circuit board is the usual glass epoxy, silver-plated stripline style that has become the vhf standard. The case and heat sink are made of heavy-duty, black anodized aluminum which contributes to durability and heat dissipation. It appears that quality components have been used throughout. A reverse-polarity protection diode is connected across the dc line after the fuse.

In short, I am pleased with the performance, construction and design of this amplifier. Anyone looking for an amplifier to go with his hand-held should give consideration to the B-23 — particularly if low-power ssb operation is contemplated. Further information may be obtained from Mirage Communications Equipment, Inc., Box 1393, Gilroy, CA 95020. Price class: $90. — *Peter O'Dell, KB1N*

Table 2
Mirage B-23 Serial No. 868-980

Manufacturers Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 144 to 148 MHz	144 to 148 MHz
Power input: 100 mW to 5 W maximum	100 mW to 5 W
Power output: 30 W for 2-W input	30 W for 5-W input, 25 W for 1.5-W input
Modes: fm, cw and ssb	
DC power input: 13.6 V dc at 5 A nominal	3.5 to 3.8 A at 13.8 V dc (varies with drive).
Size: 2.25 × 4.75 × 4 in. (57 × 120 × 102 mm)	
Weight: 1.25 lb (0.57 kg).	

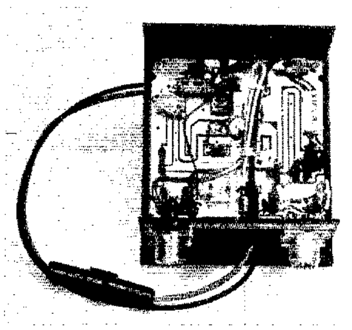


Fig. 8 — Neat, compact layout of the B-23 amplifier. This package can easily be tucked out of sight — even in today's compact cars.

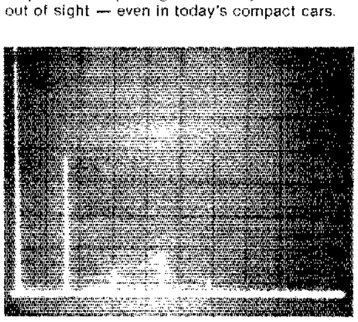


Fig. 9 — ARRL-lab spectral photograph of the output of the Mirage B-23 amplifier. Vertical divisions are 10 dB each; horizontal divisions, 100 MHz. The fundamental frequency at 144.05 MHz has been attenuated approximately 32 dB by means of a two-cavity notch filter in order to prevent overload distortion in the spectrum analyzer. The B-23 complies with current FCC specifications regarding spectral purity.

[1]*The ARRL Antenna Book*, thirteenth edition, pp. 115-116.
The ARRL Antenna Anthology, pp. 145-148.

Technical Correspondence

Conducted by
Jerry Hall,* K1TD

The publishers of QST assume no responsibility for statements made herein by correspondents.

5-A LOAFER FEEDBACK AND UPDATE

All voltage regulators are not created equal! After our article appeared last November[1] we received a letter from Virgil Leenerts, WØINK. He warned us that he had experienced difficulty with some 3-terminal, 1-A monolithic regulators when employed, as we suggested, with diodes in series with pin 3 (common). The circuit arrangement is depicted in Fig. 1. His experience was that the regulator would self-destruct if the output of the regulator were shorted to ground. He suggested that we experiment with the 5-A variety and determine if the same problem existed for the higher-current models.

First we connected the common and input of a Fairchild 78H12 regulator to a 20-V supply and shorted the output to ground (common). The chip became quite warm; as soon as the short was removed, the output returned to 12 V. We then installed the diodes between pin 3 (common) and ground as shown in Fig. 1. Again the output was shorted to ground (not to common). After a few seconds, the case became quite hot. We removed the short and checked the voltage at the output — now 20 V! The regulator had failed; had there been 12-V equipment connected to the output, chances are that it would have been damaged. We then duplicated the tests with a National Semiconductor LM-340-K; it did not fail.

We contacted Fairchild and were told that they were unaware of any such problem, but that they would check into the matter and get back to us. A few days later the engineer from Fairchild called back and told us their laboratory had confirmed that the regulator could fail in this manner. He said that not every chip failed, but that enough did to suggest avoiding this circuit. Apparently the constant voltage drop of the diodes can reverse-bias a transistor inside the regulator. This forces the internal pass transistor to turn on when it should be shut down.

Fairchild recommends a voltage divider approach for those circuits requiring a higher output voltage than the nominal voltage of the regulator chip (Fig. 2). Suppose that U1 is a 12-V regulator, and that we desire an output of 13.8 V. R1 is arbitrarily chosen to be 560 Ω. The value needed at R2 is calculated based on the formula

$$R2 = R1 \frac{V_x}{V_u}$$

where V_u is the nominal output voltage of the regulator chip and V_x is the difference between the desired output and V_u. From the formula, we determine that R2 should have a value of 560 × 1.8/12 or 84 Ω. A standard-value, 82-Ω resistor should work quite well. Because there is a constant potential of 12 V across R1, it will have a continuous current of 21 mA. This means that the resistor will have a constant power dissipation of about 260 mW. A 1/2-watt resistor should provide an adequate safety margin for R1. A 1/2 watt resistor for R2 will also be adequate.

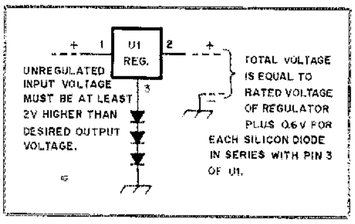


Fig. 1 — A common circuit for boosting the output voltage of a 3-terminal, voltage-regulator chip. Fairchild has determined that, under certain conditions, this circuit can cause failure of the regulator, resulting in the full input voltage appearing at the output terminal. If you use this circuit, the diodes should be removed for safety (see accompanying text).

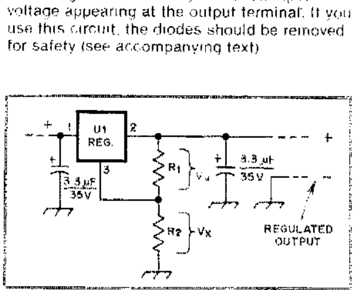


Fig. 2 — If you must raise the output voltage of a 3-terminal regulator, this is the circuit that Fairchild recommends. It would be wise to test the regulator by shorting the output to ground for a few seconds. If the output returns to normal after the short is removed, it should be safe to attach equipment.

The circuit in Fig. 2 should be immune to the shortcomings of Fig. 1. It is now our recommendation, however, that you use 3-terminal regulator chips at their nominal output voltage just to be on the safe side. If it is necessary to raise this voltage, then use the circuit in Fig. 2. Nevertheless, it would be advisable to test your particular regulator chip by shorting the output to ground for a few seconds and then by checking the output with a voltmeter. If the circuit is safe, the chip should not be damaged; if it is not safe, it is better to find out now instead of later when several hundred dollars' worth of equipment may be connected to the supply. *Peter O'Dell, KB1N, and Bob Shriner, WA0UZO*

COMPONENTS FOR MORSE READOUT DIGITAL DIAL

I would like to pass along to *QST* readers some information about obtaining components for the digital-dial Morse readout.[2] The 1981 Jameco catalog (Jameco Electronics, 1355 Shoreway Rd., Belmont, CA 94002) lists the 74C915 7-segment to BCD decoder IC that many builders have had trouble locating. In fact, this catalog lists *all* of the ICs used in the project. — *Bill Alliston, W3ICB, 4880 Greensburg Rd., Murrysville, PA 15668*

FINE POINTS ON MODULATION SYSTEMS

The article on modulation systems in August 1980 *QST* is most interesting and informative. I would suggest only one change in the article. Mr. Greaves uses the term *deviation ratio*, D, as the ratio of the peak carrier-frequency deviation to the corresponding maximum-frequency component of the message. Most modern textbooks on the subject call this ratio the *modulation index*, β, and use the term deviation ratio to mean the peak carrier-frequency shift divided by the carrier frequency. The modulation index is usually defined in the way indicated for purely sinusoidal audio. This may be a small point, but I feel that modern terminology should be used to keep confusion from occurring when other articles are read. — *James N. Thurston, W4PPB, 322 Woodland Way, Clemson, SC 29631*

I read the article by Wayne Greaves, WØZW, on modulation systems with great interest.[3] I have worked with and designed modulation systems professionally for many years, and would like to point out that the noise performance of different systems can be obtained only by assuming that the same peak transmitter power and the same type of message signal exist in all systems. If this is done, dsb is 6 dB better than a-m, and ssb is 9 dB better than a-m. It is this 9 dB, plus the availability of good, low-cost band-pass filters, that has killed a-m in Amateur Radio systems.

As far as fm is concerned, it all depends on the deviation ratio. If this ratio is unity, the system is about 5 dB better than a-m because of the triangular noise spectrum. One can, of course, get better noise performance by increasing the deviation ratio, as Greaves explains in the article. — *Leland E. Thompson, K6SR, 14851 Devonshire Ave., Tustin, CA 92680*

RADIOTELEPRINTER CODES

In the September 1980 issue of *QST*, the article "ASCII, Baudot and the Radio Amateur," by G. W. Henry, Jr., K9GWT, perpetuates the misuse of two terms which have caused confusion for a long time. The terms are Baudot in reference to the teleprinter code, and baud rate in reference to signaling or pulsing rate.

The code shown in Table 1 of Henry's article is in reality the CCITT alphabet no. 2 derived from Donald Murray's work at the turn of the

[1] O'Dell and Shriner, "5-A Loafer," November 1980 *QST*, p. 43.

*Technical Editor, *QST*

[2] Alliston, "A Morse Readout for Your Digital Dial," November 1979 *QST*, p. 33.

[3] Greaves, "Modulation Systems and Their Noise Performance," August 1980 *QST*, p. 23.
[4] See reference 3.

century to free the telegraph operator from requiring a knowledge of the code structure. Baudot's work some 15 to 20 years earlier on multiplexing telegraph signals produced a different code structure (the real Baudot code) which resulted in the CCITT alphabet no. 1. Alphabet nos. 1 and 2 are similar only in having five elements per character, but the codes are otherwise entirely different, since they were developed to serve different requirements. Even the idle condition is different, Murray's idling on continuous marking and Baudot's idling on continuous spacing.

Baudot's code has never been used commercially in North America. When Messrs. Krumm developed the start-stop teleprinter in the U.S. in the 1910s, they chose a slightly modified version of Murray's code, and this has been used for five-level machines, essentially unchanged, ever since. In short, there *is* a Baudot code, and it is *not* used in North America. A very good reference on these codes is chapter 2 of *Telegraphy* by J. W. Freebody (Sir Isaac Pitman and Sons, Ltd., London, England).

One often sees the term *baud rate* thrown about in current literature. Baud is, by definition, a rate. Therefore to talk of baud rate is to talk of the rate of a rate, which mathematically implies the rate of change of a rate. With care and attention, careless or uninformed use of terminology and the resulting confusion can be avoided. — *Ernest J. Moore, VE3CZZ, 37 Ashgrove Cres., Nepean, ON K2G OS1*

TUNING AND CONSTRUCTING BALANCED TRANSMISSION LINES

□ In the December 1980 issue of *QST*, O'Dell illustrates the popular T-match circuit for tuning unbalanced coaxial transmission lines, and he describes a more complicated circuit for tuning balanced lines.[1] If the T match is a good circuit for unbalanced lines, then a balanced version of the T match (see Fig. 3) could be used for tuning balanced lines. The balanced feeder itself could be made from equal lengths of coaxial cable suitably connected (see Fig. 4), thus forming a shielded balanced line to facilitate routing it between the antenna and the transceiver.

The balanced T match, Fig. 3, requires fewer elements to tune and is easier to construct and adjust than the circuit described by O'Dell. T1, the balun transformer, provides the required unbalanced (transceiver output) to balanced transformation. Since it is on the *input* or matched side rather than the output unmatched side typical of most Transmatch circuits, its losses are minimized. Harmonic generation by the balun, which could be a problem for high SWR and power, is also avoided. The balanced T match can be thought of as two unbalanced T sections symmetrical with respect to "virtual" ground (the dashed line in Fig. 3). The load impedance to be matched is divided and balanced with respect to this ground. Thus for the same impedance match, balanced with reference to unbalanced, the series capacitive reactance values and the shunt inductive reactance value each side of virtual ground will be halved. The total inductance is twice its halved value, or the same value. In the circuit shown, T1 is a 1:4 balun and the load is matched to 200 ohms balanced instead of 50 ohms unbalanced. Therefore the component values used for the coaxial T match should be satisfactory for its balanced cousin, except that dual-section capacitors are needed.

[1] O'Dell, "Antennas and Grounds for Apartments," December 1980 *QST*, page 40.

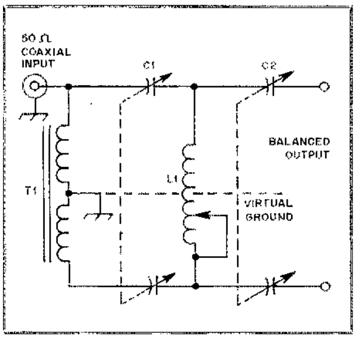


Fig. 3 — A balanced T match for antenna transmission lines. T1 is a standard 1:4 toroidal balun. See text for values of C1, C2 and L1.

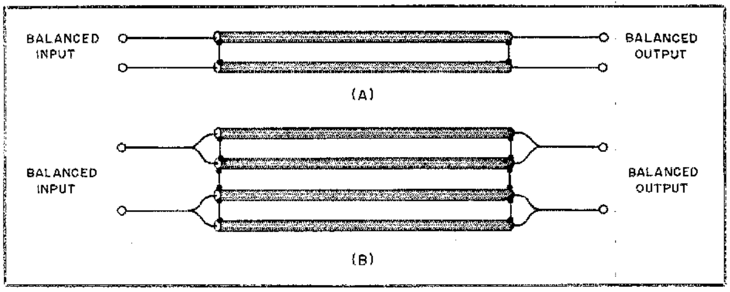


Fig. 4 — Shielded balanced transmission lines utilizing standard small-size coaxial cable, such as RG-58/U or RG-59/U. These balanced lines may be routed inside metal conduit or near large metal objects without adverse effects.

Shielded balanced lines are more useful than open-wire lines. Since there is no noise pickup on long lines they can be buried and they can be routed through metal buildings or inside metal piping. Shielded balanced lines having impedances of 140 ohms or 100 ohms can be constructed from two equal lengths of 70-Ω or 50-Ω cable (RG-59/U or RG-58/U would be satisfactory for amateur power levels). The shields are connected together (see Fig. 4A) and the two inner conductors are the balanced line. At the input, the coaxial shields should be connected to chassis ground; at the output (the antenna side), they are joined but left floating. A high power, low loss, low impedance 70-Ω (or 50-Ω) balanced line can be constructed from four coaxial cables. Again the shields are all connected together. The center conductors of the two sets of coaxial cables which are connected in parallel provide the balanced line. — *John S. Belrose, VE2CV, 3 Tadoussac Dr., Aylmer, PQ J9J 1G1*

HARDLINE CONNECTORS AND CORROSION

□ I read with interest the article in Hints and Kinks, September 1980 *QST*, "Connectors for CATV 'Hardline' and Heliax." The construction details for the 1/2-inch hardline were, to me, timely and very easy to follow.

I modified the adapter sleeve, however. Instead of the 1/2-inch ID aluminum sleeve to join the coaxial connector with the aluminum jacket, I used copper tubing, slotted and tinned on the inside. My reasoning was based on the compatibility of metals. The EMF (volts) for copper is −0.20, for tin-lead solder −0.50 and for aluminum −0.60. I felt there would be less corrosion between the tinned copper surface and the connector or the aluminum jacket than between the aluminum sleeve and the connector. I also felt the aluminum oxide on the aluminum sleeve and the aluminum jacket would increase contact resistance. Further, the stainless steel clamp (the EMF is −0.20 volt, the same as copper) is more compatible with the copper sleeve adapter. — *Dennis Pochmerski, WA2DHV, RD 1, Box 155, Freehold, NJ 07728* QST

Feedback

□ "Receiving with Plessey ICs," April 1981 *QST*, page 13, did not carry a credit line for J. M. Bryant, G4CLF. The authors wish to acknowledge his part in developing the 80-meter receiver; he built the test model.

□ In Wetherhold's "Modern Design of a CW Filter Using 88- and 44-MHz Surplus Inductors," December 1980 *QST*, Fig. 1B should show a connection across the top two terminals of the left-most inductor in the lower stack.

□ The correct address for author Jim Pitts, KE4Y, whose article, "A QRP Transmitting Converter," appears in April 1981 *QST*, is 4113 Dienes Way, Louisville, KY 40216.

□ In "Results — 1980 Simulated Emergency Test," April 1981 *QST*, local activity listings for Michigan and Ohio were accidentally interchanged. Cheboygan/Presque Isle is actually in Michigan, while Columbiana and Montgomery/Greene Counties are actually in Ohio. The correct totals for these two ARRL sections are Michigan — 4148, Ohio — 9406.

□ CARRC (Canadian NewsFronts, March 1981 *QST*) have advised that although it is hoped that a second balloon package will be carried as a passenger on a scientific flight during 1981, no firm commitment has yet been negotiated. Present or future club participation in the space shuttle project should not be assumed. — *James Barrie, VE4FK, Pinawa, Manitoba* QST

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

TS-830S VOX DELAY MODIFICATION

☐ A number of TS-830S owners have commented that they felt the maximum VOX delay time offered is a bit too short when operating cw; this becomes quite apparent at slower keying speeds. This VOX circuit differs a bit from the ordinary in that it has been designed to offer two different delay time constants: a longer one for ssb and a shorter one for cw.

As shown in Fig. 1A, two capacitors, C48 and C49, are involved. During ssb operation Q14 shorts out C49, placing C48 in the circuit alone. When operating cw, C48 and C49 are in series, reducing the total capacitance from 3.3 µF to half that value.

To negate Q14 action, I removed C48 and C49 and replaced them with a single capacitor as shown in Fig. 1B. The AF unit pc board (X49-1140-00) must be removed to accomplish this. Five screws hold the board and associated heat sink in place on the chassis (do not remove the screws holding the board to the heat sink). No wires or connectors need be undone. Using a low-wattage soldering iron and wicking material, remove the two capacitors. Replace them with a single capacitor which has its positive terminal inserted into the pc board hole formerly occupied by that of C48; the negative end of the capacitor is soldered to the pad which held the negative terminal of C49 (ground foil). This leaves Q14 isolated and without effect on the VOX circuit delay.

I personally preferred a longer time constant than that originally afforded by the circuit and used a 6.8 µF Tantalum capacitor as a replacement. With front panel control of the delay time constant, I find there is sufficient range to suit my operating requirements. — *Paul K. Pagel, N1FB, ARRL Hq.*

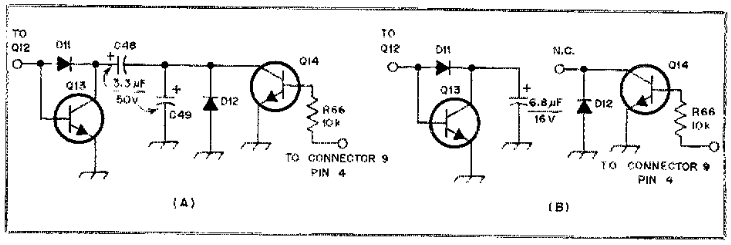


Fig. 1 — At A, a portion of the TS-830S VOX delay circuitry. The modified circuit is shown at B. Component designations are those of the manufacturer. Resistances are in ohms; k = 1000

SOLAR PANEL CHARGES BOAT BATTERY

☐ At trolling speeds the alternator on my boat does not rotate fast enough to charge the battery. As a result, the charge would become depleted over a period of five or six weeks. The sun's free energy provided an ideal solution to the problem.

I procured a 36-cell solar panel mounted on an aluminum T section that's about 4 feet (1.2 meters) long. The cells are so connected that they produce 0.5 A at 15 V. I bolted the panel to the stern of the boat in a position that is clear of the motor when the latter is in the tilt-up position. See Fig. 2. I wired the panel circuit in parallel with the alternator as indicated in Fig. 3. A diode protects the cells from fluctuating alternator voltage and from the battery voltage during noncharging hours. A 500-mA meter monitors the charging rate.

Results so far have been excellent. Over a year's time the battery did not run down nor was there any need to add water. The panel produces nearly 200 mA on a sunny day, while on dull days the output drops to 50 mA. If the battery is fully charged, the rate is automatically cut to a mere trickle.

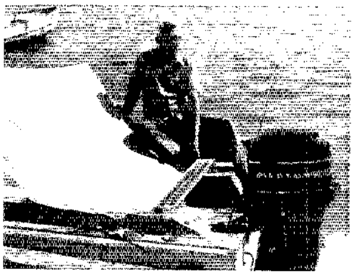


Fig. 2 — Walter Wright, WB5MQX, uses solar power to keep his boat battery fully charged. The 36-cell solar panel is positioned to clear the motor in its tilt-up position.

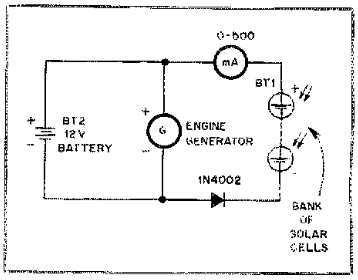


Fig. 3 — With this circuit, a storage battery can be kept fully charged with the help of sunlight. On a sunny day a 36-cell panel will provide a charging current of 200 mA.

A member of our radio club, Felix Campbell, K5DMU, simultaneously used the same idea for his boat. Neither of us was aware of the other's experiments. In view of our success, I am submitting my plan to *QST* in response to suggestions that I publicize it for the benefit of other amateurs. — *Walt Wright, WB5MQX, Santa Fe, New Mexico*

MAKING DOUBLE-SIDED CIRCUIT BOARDS

☐ Perhaps one of the most difficult tasks in constructing double-sided photosensitive pc boards in the home is the alignment of the negatives (or positives) before exposing the board. A very simple and inexpensive method is used in the ARRL lab. It requires a piece of sheet glass the same thickness as the pc board to be used. The size depends on how large the pc pattern happens to be.

A scrap of pc board is butted against the edge of the glass. One negative is then placed on the top of the glass and the edge of the negative is taped to the scrap pc board with masking tape. See Fig. 4. The glass is then flipped over so that the other negative can be mounted in a similar manner and aligned with the first negative. Look straight down on the negatives to avoid parallax. After alignment, the glass sheet is removed and replaced by the sensitized pc board. A piece of tape can be used to hold the negatives against the board while making the exposure. — *Gerry Hull, AK4L, ARRL Hq.*

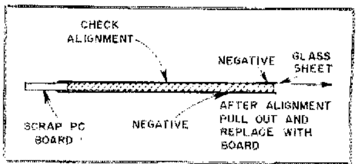


Fig. 4 — A method of checking negative alignment for double-sided circuit boards.

CONVERTING A VIBRO-KEY INTO A KEYER PADDLE

☐ Modifying a Vibroplex-type key into a paddle for use with an electronic keyer involves only a few changes. The first step is to make a new bar from steel, brass or copper. Having the bar chrome plated will give it a professional appearance. There are specialty shops in many areas where such plating is done.

Dimensions for the bar are shown in Fig. 5A. The bar should be drilled and tapped to accept a machine bolt for adjusting the paddle. I used a 4-mm (5/32-inch) dia bolt equipped with a 16-mm (5/8-inch) dia screw nut that locks the bolt in position.

*Assistant Technical Editor

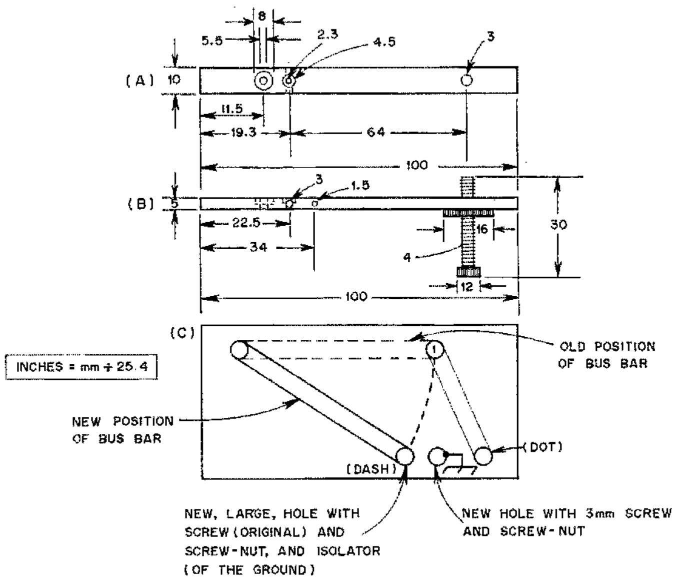


Fig. 5 — These simple modifications are for converting a Vibroplex-type key into a paddle for use with an electronic keyer. Dimensions for the new bar required for this modification are shown in A and B. On the bottom of the key the bus bar shown in heavy lines is moved to the position indicated. The output terminals are at the lower right in the drawing at C. Holes for the original terminals may have to be enlarged to accommodate insulating sleeves, which can be made from plastic tubing or other material. A new hole must be made for the ground connection. Measurements are in millimeters.

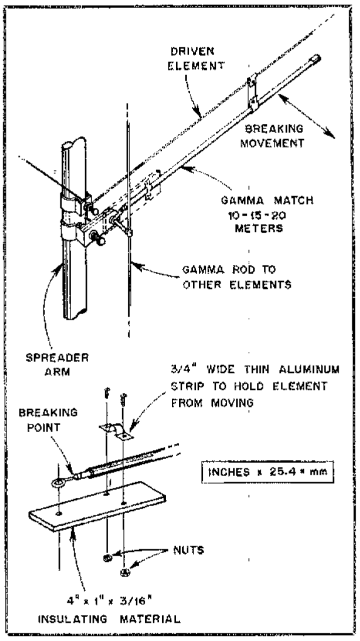


Fig. 6 — Addition of the insulating strip shown in this drawing is advised by Merell Hess, Sr., WØMLT, as a means of preventing wind damage to the stubs on a Hy-Gain quad antenna.

The terminals on the base are modified as needed so that the dot and dash circuits are insulated from the base. The original holes may be enlarged to accommodate sleeves for insulating the terminal bolts from the base. An additional hole, bolt and nut must be provided for a ground terminal. This hole may be placed midway between the two original holes. The ground connection on the key is to be connected to the ground on your electronic keyer.

As indicated by the drawing, the left-hand terminal on the key is for dashes while the right-hand terminal is for dots. Notice also that one of the bus bars (Fig. 5C) is moved to a new position so that it connects directly to the dash terminal.

After all the components have been installed as illustrated, simply adjust the setscrews for good operation. "But, how well does it work?" you may ask. To that question I'd say, "Hear me on 20 meters!" — *Fernando Cereja, CT1ZQ, Lousan, Portugal*

PREVENTING WIND DAMAGE TO MATCHING STUBS

☐ My Hy-Gain quad was constantly being subjected to breakage of the matching stubs as a result of strong winds. The force of the wind would move the stub in a front-to-back direction while the mounting lug was held rigidly. Replacements are expensive and quads are not always readily accessible at a nearby store. Three small insulating blocks solved the problem. Now the element cannot move as before. The detail in Fig. 6 illustrates the mechanical cure. I am sure many hams will appreciate the idea of this simple addition, which eliminates replacing the damaged parts. — *Merell Hess, Sr., WØMLT, Westminster, Colorado*

NUT STARTING WITH NEEDLE-NOSE PLIERS

☐ Needle-nose pliers can be converted into a useful gadget for starting nuts in those places that are difficult to reach with your fingers. See Fig. 7. The handle bearing against the knurled screw head is drilled for a loose fit while the opposite handle is tapped with a 6-32 thread. A bolt with a knurled screw head is inserted through both the drilled and tapped holes. Adjustment of the bolt permits the pliers to become a small vise that will hold a nut firmly at various angles, resulting in a less "profanogenic" situation. Clearly, the screw may be removed for normal use of the pliers. — *Frank Noble, W3MT, Bethesda, MD*

DIMENSIONS FOR THE K7HNM BENCHER DUST COVER

☐ Amateurs who wish to make a copy of Chet McClellan's dust cover for the Bencher key (see Hints and Kinks, *QST*, February 1981) will find the following dimensions helpful for preparing the clear plastic (Lucite) panels. For A and A1, cut two pieces (3/16 × 1-7/8 × 4-1/8* inches (4.76 × 47.63 × 104.78 mm). For B and B1, cut two pieces 3/16 × 1-7/8 × 4-1/64 inches (4.76 × 47.63 × 102 mm). For C, one piece is required with dimensions of 3/16 × 4-1/8* × 4-3/8* inches (4.76 × 104.78 × 111.13 mm). Four pieces are needed for D and these have dimensions of 3/16 × 3/8 × 1-5/8 inches (4.76 × 9.53 × 41.28 mm). Tolerances indicated by the asterisk (*) are + 1/64 inch and − 0 (0.397 mm and − 0). — *Stu Leland, W1JEC, ARRL Hq.*

A TOUCH-TONE IMPROVEMENT

☐ I am employed in commercial broadcasting as a chief engineer for WDUZ. For years I have

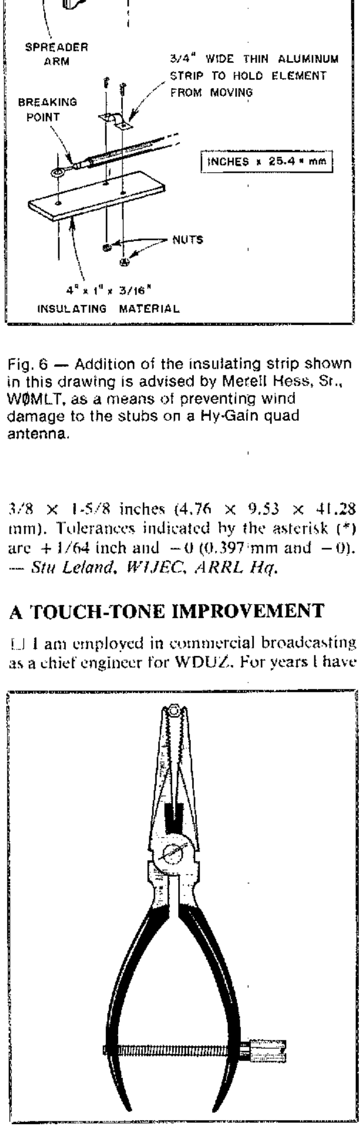


Fig. 7 — A pair of pliers may be converted into a vise-like gadget for nut starting by drilling a hole in each handle and tapping one hole. A 6-32 bolt with a knurled nut on one end serves to adjust the clamping action of the tool.

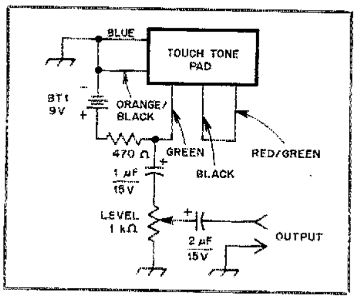


Fig. 8 — Stephen Konopka suggests this modification of the Touch-Tone pad circuit illustrated on page 439 of the 1977 *Handbook*. He indicates the change improves keying and frequency stability.

used the *Handbook* as a reference.

I would like to offer an improvement on a circuit described in the 1977 edition. Page 439 shows connections for making a standard Touch-Tone pad operable. While the unit does function as described, I find that oscillation starts somewhat slowly and the frequency tolerance is below that of the capability of the pad. My offering is the result of experimentation and studying a Bell System manual concerning the subject.

A simple connection change will result in proper operation. I am providing a revised diagram (Fig. 8). The change results in sharper keying and better frequency stability. — *Stephen A. Konopka, Green Bay, Wisconsin*

THE HW-8 AND THE ACCU-KEYER — A GOOD CW TEAM

☐ In the process of modifying my HW-8, I built and installed an Accu-Keyer inside this QRP rig. The circuit is taken from the *Handbook*. To begin this addition, take off the front panel of the transceiver. Remove the bandwidth switch and in its place insert the speed control potentiometer for the keyer. Mark the size of the potentiometer on the inside of the chassis. Then, remove the potentiometer. Just to the left of the band switch there is space for a toggle switch. Mark the location for the switch hole, replace the panel and carefully drill the hole. Then once again remove the panel. Mount the speed control and the switch on the chassis with nuts and lock washers. These provide the correct spacing between the chassis and front panel. Tighten them securely and replace the front panel. Use an additional nut on each new control. Connect the leads from the bandwidth switch to the new toggle switch, positioning the wires carefully. I use *up* for wide and *down* for narrow.

Drill a hole and mount a 1/4-inch (6 mm) 3-conductor phono jack on the rear panel. Make two small holes for mounting the keyer board. Leave ample room for clearance between the keyer board and the "ears" standing up on the main circuit board. Connect the dot, dash and ground input leads from the keyer to the 1/4 inch (6 mm) jack. Install the wires from the speed control potentiometer to the hand-key jack.

The +5 V needed for the keyer may be taken from the power switch in the HW-8. To regulate this voltage, I installed a 5 V, 1 A voltage regulator which I mounted on the rear wall of the HW-8. The wall serves as a heat sink and a chassis ground.

A 2500:8-ohm output transformer, inserted in the audio output of the HW-8, provides enough audio to drive a loudspeaker that can be heard even when operating mobile. This addition does not prevent the use of headphones.

My modification plans also include the RIT/QSK circuit changes described in July 1977 *QST*. By moving the preselector peaking capacitor to the rear panel, the mounting hole left vacant by the capacitor provides a suitable location for the RIT control. There is also room on the panel for a spotting switch. I prefer to use an spdt push-button type for this purpose.

If you wish to refinish the panel of an HW-8, paint can be prepared by a paint dealer so that it will closely match the light Heathkit green. New labels are easily made with dry transfers. When refinished, the set should look as good as new. — *Bill Inkrote, Jr., K2NJ, Flemington, New Jersey*

[Editor's Note: Carl Youngs, W3NWS, notes that a wrinkle-finish paint closely matching the Heath panel color is packaged in a spray can by the Illinois Bronze Powder and Paint Company, Lake Zurich, IL 60047. The color is Celestial Blue, No. 338. Many local hardware stores carry products from this firm. Attention is also called to the painting idea suggested by Carl Nebelsky, AA1U, in Hints and Kinks, *QST*, March 1979.]

OLD TIMER'S NOTEBOOK: A THREE-ELEMENT WONDER BAR FOR 10 METERS

☐ When the Wonder Bar antenna was reintroduced in Hints and Kinks (April 1980 *QST*) in response to reader inquiries, I recalled how I adapted the Wonder Bar design to a 3-element beam. Because this antenna performed so well on 10 meters, I thought some *QST* readers may wish to try my scheme. Essentially the antenna consists of three bow ties arranged and spaced as indicated in Fig. 9. Only the middle element is driven with the end elements parasitically operated.

Each element is constructed with aluminum tubing in a similar manner to that described in Hints and Kinks. The center insulator for each element is made from Plexiglas and is mounted to the boom by an aluminum angle. A two-turn link, connected to the transmission line, is placed at the center of the middle radiator coil.

Use of a dip oscillator will enable the builder to check the resonant frequency of the antenna. Element tuning is accomplished by spreading or compressing the coils to obtain resonance at the desired frequency.

Because this antenna is effective yet inexpensive, it should appeal to 10-meter enthusiasts. Connections and the terminating end of the transmission line should be weatherproofed. — *Frank Masho, W3CBM, Springfield, Pennsylvania*

NEUTRALIZING HINT

☐ An ordinary vacuum-tube voltmeter, coupled by means of an rf probe to the output circuit of a transmitter, serves well as a sensitive "feed-through" indicator while neutralization adjustments are being made. With excitation and filament voltage applied to the final amplifier tube (be sure to kill the plate and screen voltages), adjust the neutralizing capacitor for minimum reading on the VTVM.

If the transmitter is completely shielded and coupled to a coaxial output line, insert a coax T-coupler between the amplifier and the line to provide a tap point for rf probe. — *V. L. Clark, W6ZW, La Crescenta, California*, Hints and Kinks for the Radio Amateur, *1959*.

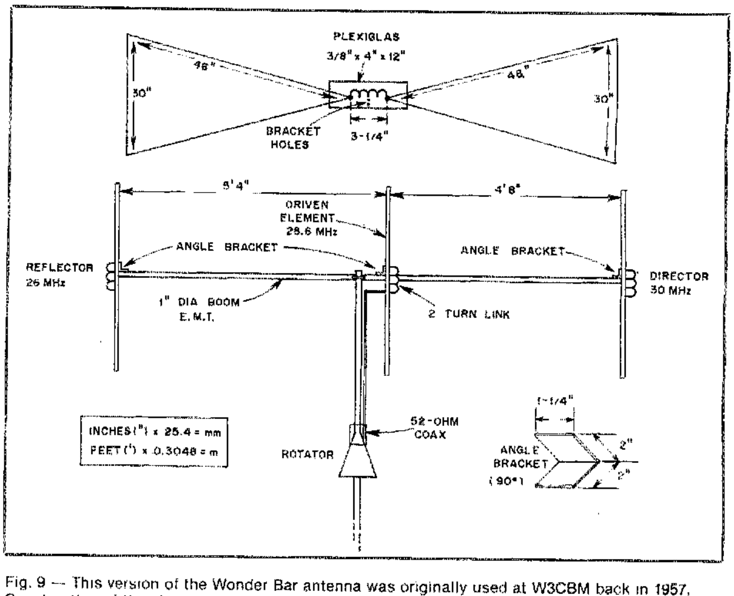
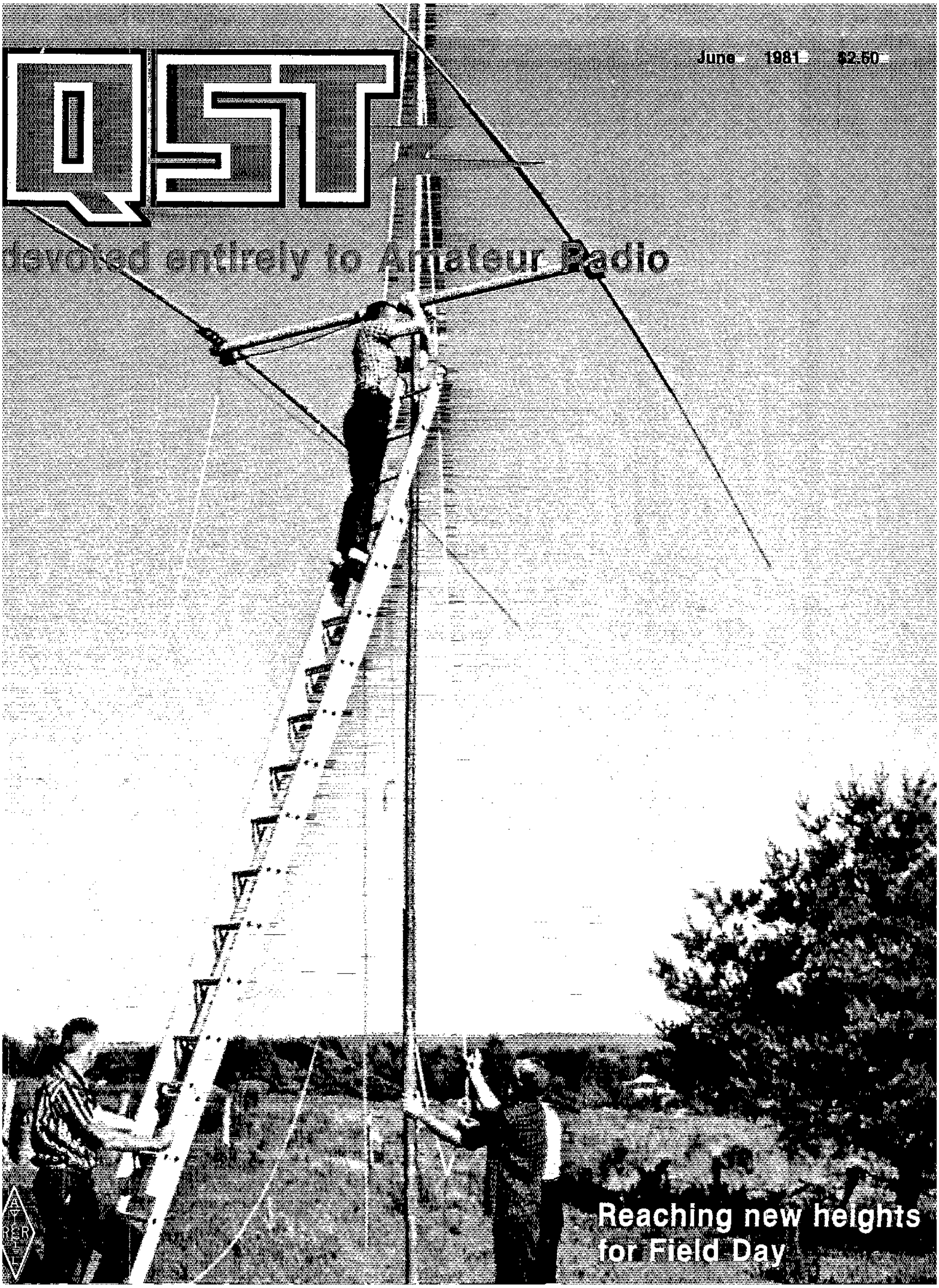


Fig. 9 — This version of the Wonder Bar antenna was originally used at W3CBM back in 1957. Construction of the elements is similar to the method described in Hints and Kinks, April 1980. The tuning coils are made with no. 12 aluminum wire. Coil dimensions are: Reflector — 14 turns, 1 inch (25 mm) dia. Driven element — 12 turns, 1 inch (25 mm) dia. Director — 10 turns, 1 inch (25 mm) dia. Coil length — 3-1/4 inches (83 mm). Angle Brackets — Three 1-1/4 in. long brackets are required and can be made from 2-inch aluminum angle stock.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for Field Day

QST

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THE COVER

Ah, Field Day! Complete rules appear in May *QST*, page 80; a ladder mast is described in this issue, page 24. *(Photo courtesy George Hart, W1NJM)*

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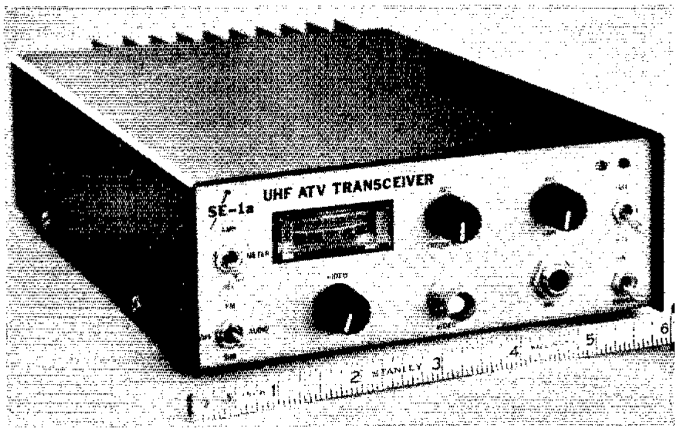
Or how I learned to see myself as others see me!

By Henry B. Ruh,* KB9FO



(Photo courtesy Science Workshop)

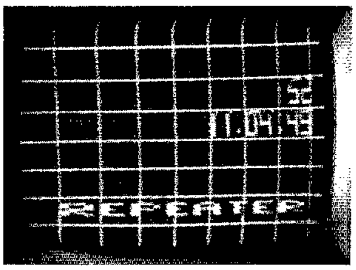
There has been an explosive increase in amateur television (ATV) activity in the past few years. Many hams who were involved in ATV years ago and a number of newcomers are discovering that ATV is inexpensive, fun and educational, allows for a more vivid expression of self, and provides a vital public service. ATV has come of age.

ATV is identical to the type of TV you are accustomed to watching in your living room. The technical standards are basically the same. Video is transmitted by amplitude modulation. The audio is transmitted in any one of a number of ways: on a 4.5 MHz subcarrier (as with commercial TV), by frequency modulating the video carrier (called on-carrier sound), or by using another amateur frequency (such as 2 meters) for separate sound transmission.

Fun With Repeaters

There are ATV repeaters similar in operation to the more familiar 2-meter fm repeaters. Three different types of ATV repeaters exist. Some (such as WR4AAG, Washington, DC), operate in-band. These receive a TV signal in the 450-MHz band and repeat the signal in the same band.

*7391 W. State Highway 46, Ellettsville, IN 47429



An example of the display presented by a computer-operated ATV repeater. The picture conveys time, signal report and test pattern information. *(Photo courtesy W6ORG/RPT)*

Self-explanatory — an ATV CQ!

The obvious advantage is that you need only *one* antenna for transmission and reception. As your station becomes more sophisticated, or if you live close to the repeater, you can also monitor your own transmitted signal (full duplex). Most operations are half duplex — you take turns transmitting and receiving.

Some ATV repeaters operate cross-band; you transmit to the repeater in the 450-MHz band and receive the repeater signal in the 1240-MHz band. This requires the use of two antennas and two transmission lines, but it allows you to become interactive with the repeater; you "talk" to the repeater and it "talks" back to you. Many of these repeaters are connected to computers, which you access with an ASCII keyboard while transmitting afsk. The repeater/computer digests your input and sends something back to you which is displayed on a video screen: games, signal reports, computer-remembered messages, the output of your own computer program, weather maps, weather radar pictures or videotaped replays of previous transmissions. Not only can you interact with the repeater, but your friends can join in the fun since everyone can watch and take turns transmitting to the repeater. A sophisticated system can accommodate more than one "player" by using different inputs and a common output. Play chess or bridge with the computer or your friends. Transmit computer to computer and watch the results on the screen. Your imagination is the key.

A third type of repeater system would incorporate different inputs/outputs or special TV modes such as narrow-band TV. This system is used in Europe where the signal bandwidth is more restricted than in the U.S. The usual technique is to restrict the video baseband to 1 or 0.5 MHz. Australian amateur systems have one freedom not permitted in the U.S.: They can have an output in the 35 cm band which is in the middle of the uhf TV band. This allows the public to watch as well! Of course, you could provide a receiver and modulator and put your signals on you local cable TV system.

ATV Past

In the early days (before 1960), it was common practice to use a commercially available uhf TV tuner or converter modified to operate on 420 to 450 MHz. These tuners proved to have a 14-dB or higher noise figure, and a severe lack of gain (sometimes no amplification at all), resulting in a 7- to 20-dB conversion loss. It's no wonder that uhf TV reception was then problematic! Such receivers would pick up a 500-watt TV signal 1 or 2 miles (1.6 or 3.2 km) distant, but anything beyond that was sheer luck. So if you tried the TV tuner approach earlier and lost interest because you couldn't see anything, that's the reason why! Modern receivers, converters and preamps have typical noise figures of 1.5 dB or better and often a gain of 20 dB or more. Today, there's no squinting through the "snow" even when viewing the output of a station using a 10-watt transmitter at a distance of 60 miles (100 km).

Before 1975, all ATV work was done with horizontally polarized antennas. Over the years, we have changed to vertical polarization. Why? Primarily because the *repeaters* are vertically polarized. DXers use horizontal polarization, but unless you live in the great midwest (anything between the east and west coast mountain ranges), you probably won't be DXing anyway. ATV repeaters use vertical polarization to achieve omnidirectionality. While commercial TV stations use antennas that have omnidirectional horizontal gain, ATVers haven't discovered the slot radiator, traveling wave or pylon type antennas and have resorted to using vertical gain antennas of the multi-dipole or Station Master types. This is probably because such antennas can be purchased off-the-shelf and the others would have to be built.

Getting Started

You can build your own equipment, or buy it, either in semi-kit form or right off-the-shelf for plug-and-play (appliance) operation. A typical ATV station can be put together for about half the price of an hf transceiver or the price of a 2-meter fm rig — about $250 to $350. If you're an "appliance" operator, you will spend more to get the same results as the ham who is able and willing to build or scrounge some of the equipment. A lot of ATVers got on the air for less than $50 by using cast off equipment and gear bartered for at hamfests. You already own the most essential item, a TV set. Other equipment you'll need includes the receiver and transmitter, a TV camera, some low-loss coaxial transmission line and an antenna. A list of suppliers and the equipment they offer is shown in Table 1. You are encouraged to write for their catalogs.

Receiving: A complete ATV receiving station may be yours by merely connecting the output of a 439-MHz converter to your TV set and an antenna to the converter input. Converters range in price from $10 for the simple Varactor tuner type to approximately $80 for the more deluxe units which include low-noise rf amplifier stages and doubly balanced mixers.

Transmitting: Modern ATV transmitters have provisions for both on-carrier and subcarrier audio. The on-carrier audio capability is needed if you're going to be using an ATV repeater. Most of the ATV repeaters use a separate receiver to recover the frequency-modulated on-carrier audio signal. This is because most ATVers started with a 450-MHz fm rig and added video provisions to it. Today, you can purchase units that fit in the palm of your hand and are powered from a 12-V dc source capable of supplying a few amperes of current. (The power supply should be no problem since you probably have one in your shack already. If not, a simple supply may be built or purchased.) Low-power transmitters cost about $80 and a power amplifier approximately the same; even complete transceivers are available.

Video Sources: The required video input for the transmitter can be obtained from a TV camera or other video source such as a video tape machine. Camera requirements are minimal. It should deliver a 1-V composite video signal, have either interlaced or random scanning, and horizontal and vertical sync pulses which need not conform exactly to any technical standard. A closed-circuit TV (CCTV), surplus commercial, home video, or home-built camera may be used. Prices can range from as little as $10 for a camera purchased at a hamfest to as much as $850 for a first-class color camera. A means of supporting the camera will be needed. Most cameras can be fitted to a standard photographic tripod or, in a pinch, be suspended from the ceiling with a length of wire.

If you own or have access to a video tape recorder (VTR) or a slow-scan TV (SSTV) setup, you can use that as a video source as well. With the VTR, you can make your own programs and record what you're receiving off the air. This is especially nice when friends ask you what you do with your ATV gear — show them the tape!

Your Studio

Probably the most often overlooked

Table 1
ATV Equipment Suppliers

Suppliers	*Equipment*
P.C. Electronics, 2522 Paxson, Arcadia, CA 91006	Transmitters, receivers, antennas, converters, cameras, semi-kits, ATV repeaters, amplifiers, accessories
Aptron Labs, 3623 Grandview Dr., Bloomington, IN 47401	Transmitters, receivers, antennas, converters, ATV repeaters, accessories (for 450 MHz only)
Science Workshop, P. O. Box 393 J, Bethpage, NY 11714	Transceivers, converters, accessories
Denson Electronics, P. O. Box 85, Rockville, CT 06066	Cameras, monitors, surplus TV equipment
Spectronics, Inc., 1009 Garfield, Oak Park, IL 60304	Antennas, some surplus equipment
Applied TV Research (ATV Research), 13th and Broadway, Dakota City, NE 68731	Cameras, monitors, accessories, kits

item in any ATV station is lighting. While our eyes do not easily recognize shadows and areas of relative darkness, the camera will tend to emphasize these differences and produce pictures that look different on the TV screen than they appear to our eyes. Areas of interest must be lighted evenly. The best way to do this is to use three lights: a general flood light to the left and right of the camera position, directed toward the area of interest, and a back light, shining from above and behind the subject. The back light helps to eliminate shadows and separates the subject from the background. A photographic light bar may be attached to the camera mount to allow the light source to follow camera movement.

The amount of light required will depend on the camera being used. Older cameras need anywhere from 600 to 1000 watts to light a given area, newer monochrome and early color cameras 300 to 600 watts, and the newest cameras 100 to 300 watts. The newer cameras also have much better automatic light compensation and are not blinded by "hot spots" (highlights or bright back-lighting). Cameras, lenses and studio lighting are covered in detail in the listed publications.[1,2,3]

You will undoubtedly want to show photos, slides and drawings to your "audience." An easel placed in a convenient area may be used to do this. A roll of RTTY paper placed behind a panel with a slot at the top through which to pull the paper becomes a quick and easy way to write messages. You can even use paper towels and crayons!

Antennas and Transmission Lines: You *must* use a good antenna and transmission line if you expect decent results at uhf. At these frequencies and in lengths exceeding 20 feet (6 m), you might regard RG-8/U as a dummy load. A *short* length of RG-8/U or other cable of good quality is okay for use as a "pigtail" up near the rotator, but that's about it. If you're contemplating the use of CATV cable, be careful. CATV trunk cable is checked only to 300 MHz. Even the Superbrand cable is swept only to 400 MHz. Also, CATV cable connectors are expensive and hard to get. Homemade connectors on CATV coax are generally poor at these frequencies. Heliax cable at a cost of approximately $1 per foot (0.3 m), less at hamfests, is to be desired. Since you'll buy the cable only once, you might consider using cable such as 1/2 inch (12.5 mm) Andrew Heliax. The best compromise between price and performance at 450 MHz is 7/8 in. (22 mm) air dielectric Andrew Heliax. It costs about $2 per foot (0.3 m). Purchase a sufficient length to allow for gradual bends; sharp bends in this type of transmission line must be avoided. The transmission line should be fastened to the tower to prevent wind flap and provide mechanical support.

Notes appear on page 14.

Ernie Williams, WB6BAP, operates the ATV camera for the Rose Parade coverage while an unidentified friend relays information.

Brass type UHF or N connectors should be used to ensure low loss and long life. Avoid using adapters as they introduce loss; every decibel at these frequencies makes quite a bit of difference in signal strength. The connectors should be attached securely to the transmission line and each connection weatherproofed using PVC tape or other methods.

A uhf antenna offering a gain of 15 dB or more should be used. The Cushcraft DX-420 is about the least expensive commercial unit available and it works well. The J-Beam model MBM-48, offers superb performance in a small package. It is a skeletal slot array that has about 5.5 dB of gain. KLM's 420-450-27 is a multiple-driven-element Yagi design with 27 elements. All three antennas have proved themselves in actual use. If you can afford to purchase more than one antenna, stack as many of them as you can. Don't worry about size. At uhf, you can mount a 200-element array in the space required by a 10-meter monobander with room to spare. You can even tell your neighbors that it's a new TV antenna. (Well, it is!)

Perhaps you would like to build your own antenna using one of the number of different designs that have appeared in various amateur publications over the years. Once a particular design is chosen, do not deviate from the given dimensions; measure them accurately. A 1/2-inch (13 mm) error at 450 MHz has more of an effect on antenna performance than it does at 20 meters! Measure twice, cut once, and you should be set.

Remember that treetops are your electrical ground at 450 MHz. "Earth" may be up 50 feet (15 m) or higher if you live in a wooded area. You must get the signal above the treetops if you expect a working range of more than a few miles. If this principle is put into practice, you'll find that your 450-MHz working range is nearly what you would expect on 2 meters.

On The Air

At this point, you can get on the air and have fun. What can you expect from your low-power unit? Well, the known record for a 1/4-watt ATV signal is a distance of 215 miles (346 km). Granted, this is unusual, but a 10-watt transmitter is reliable for communicating over distances of 20 to 30 miles (32 to 48 km), and often as much as 60 miles (100 km), depending on surrounding terrain and the antenna system used.

While on the subject of power, remember that the video is amplitude modulated except that it is *negative* modulation. During a-m phone operation, the carrier level increases when you modulate. With ATV video, the carrier level *decreases* with modulation. This is done to reduce the effects of noise on the stability and viewability of the picture. Since the modulation is subtracting from the carrier level, the output power (as indicated on a wattmeter) will indicate a lower level of power during modulation than with an unmodulated carrier.

If you desire a more technical explanation of the makeup of a TV signal, excellent texts are available.[4-8] *A5 Amateur Television Magazine*[9] is a bi-monthly compendium of all ATV activity and provides a continuing source of information.

Building Up

A couple of additional items will help "sharpen up" your ATV station operation. One of the more valuable aids is an rf monitor/demodulator. A TV set/converter combination will not permit accurate off-the-air monitoring because it will overload. The inexpensive (about $25) rf monitor/demodulator allows you to demodulate your transmitted signal and view it on an oscilloscope or video monitor. It is the only way you have of seeing what your signal really looks like without going to a friend's house a mile away and viewing it in his shack.

The second item is a video monitor. With it, you can observe video information *before* it is fed to the transmitter so that you can align your shots, watch VTR playback and so on. A simple selector switch will allow it to be used for all video sources. New monitors cost about $150 and are well worth it.

Outdoors with ATV

Sooner or later, you'll want to explore the great outdoors. There's no reason why your ATV station can't follow you. ATV has been used from Field Day sites, mountaintops, airplanes, hot-air balloons, ships, rooftops, cars, trucks, vans and motel rooms.

There have been numerous fly-bys at hamfests by TV-equipped planes. I was pleased to work with Tom, W6ORG, for the first airplane-to-airplane TV QSO while we both flew over Lake Mead near Las Vegas, Nevada. ATV has been used to transmit parades for shut-ins and allowed Santa to visit children in hospitals. It was responsible for the closing of a car theft and "chop shop" ring when an ATV fly-by revealed several stolen cars and travel trailers to interested police who happened to be viewing the ATV demonstration. During the Tournament of Roses Parade in Pasadena, ATV televised the traffic flow for the Los Angeles Police Department. ATV can create a real public image for Amateur Radio. The possibilities are endless! If nothing else, set up a camera and CCTV monitor and let the folks look at themselves looking at themselves!

I hope the information presented here has provided you with some ideas and will perk your interest in ATV. The next "BCNU" you transmit could mean just that! QST

Notes

[1]Ruh, "Amateur Television in a Nutshell, Vol. 2," Available from *ATV Magazine*, 7391 W. Highway 46, Ellettsville, IN 47429, $9.95 postpaid (available October 1, 1981).

[2]Zettl, "Television Production Handbook," third edition, Wadsworth Publishing Co., Belmont, California.

[3]*Teaching Health Professionals Interpersonal Skills: Using Television*, Vol. 5. Available from National Medical Radio Visual Center, Center for Communicable Disease Control, Atlanta, Georgia.

[4]Ernst, "Fernsehfernempand als Hobby." Available from W. Keller and Co., Stuttgart, West Germany.

[5]See note 1.

[6]See note 2.

[7]*Amateur TV Handbook*, RSGB. Available from Ham Radio Bookstore, Main St., Greenville, NH 03048.

[8]Presti, *ATV Handbook*. Available from Aptron Publications, P. O. Box 323, Bloomington, IN 47402, or Ham Radio Bookstore, Main St., Greenville, NH 03048.

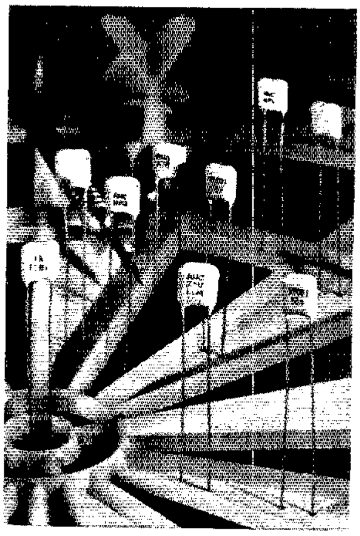
[9]*ATV Magazine*, 7391 W. Hwy. 46, Ellettsville, IN 47429. Subscription rates for this bi-monthly publication are $7.50 in the U.S. and $10 outside the U.S.

New Products

RMC-RADIO CERAMIC CAPACITORS

☐ The new type 5050L, 0.5 × 0.5 × 0.2 inch (13 × 13 × 5 mm), leaded and unleaded ceramic multilayer capacitors recently introduced by RMC-Radio Materials Corporation provide up to 5.6 μF capacitance in a compact, bond-metallized package. They are for use in filters, in delay lines, in thick-film technology, for high frequency bypassing and for direct insertion into pc boards. The capacitors are available in COG, X7R and Z5U EIA class codes and offer exceptional frequency stability and low leakage.

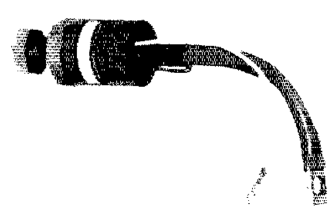
For further information, contact: RMC-Radio Materials Corporation, 4242 W. Bryn Mawr Ave., Chicago, IL 60646. — *Paul K. Pagel, N1FB*



MCG DC CROWBAR

☐ The Model LVC-1H is only one-fifth to one-third the size of conventional crowbars, making it ideally suited for applications where small size and low cost are important parameters. The unit has a trip voltage of 5 to 35 V dc (higher voltages available on request) at a current level of 55 A continuous. The LVC-1H has been designed to operate over a very wide temperature range.

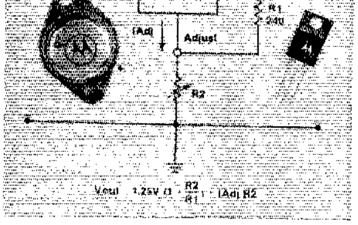
This crowbar is especially useful in applications where high dc transients may destroy ICs, microprocessors, microprocessor power supplies, etc. By shorting the dc bus in the event of power-supply failure, the crowbar prevents wholesale damage to expensive electronic components. Recovery is automatic when power is removed temporarily. Further information may be obtained from MCG Electronics Inc., 160 Brook Ave., Deer Park, NY 11729. — *Paul K. Pagel, N1FB*



MOTOROLA ADJUSTABLE 3-TERMINAL POSITIVE VOLTAGE REGULATORS

☐ Motorola has introduced a series of 3-terminal positive voltage regulators capable of supplying in excess of 3 A over an output voltage range adjustable from 1.2 V to 33 V. The LM150/250/350 are exceptionally easy to use and require only two external resistors to set the output voltage. Internal current limiting, thermal shutdown and safe area compensation are employed making these devices virtually failure proof.

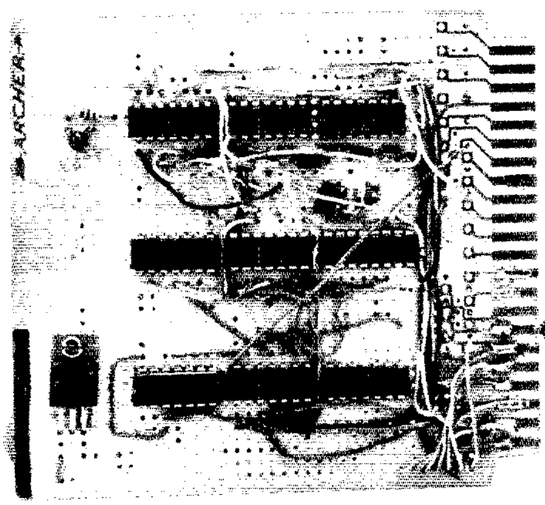
The LM150 series serves a wide variety of applications including local on-card regulation, adjustable switching regulation and a programmable output regulation. It also serves as a precision current regulator. These devices are available in a TO-3 metal case and in a low-cost, industry standard TO-220 plastic case. Further information may be obtained from Roger Janikowski, Motorola Semiconductor Products Inc., P. O. Box 20912, Phoenix, AZ 85036. — *Paul K. Pagel, N1FB* QST

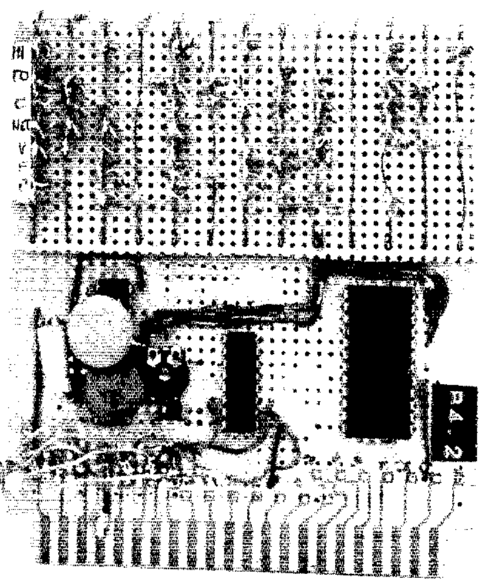


Mnemonic Encoder — Lets You Know What Your Repeater Is Up To

Wish you had an inexpensive device that would allow your repeater to talk back to you? This may be the board of your dreams!

By Robert DeMattia,* AK1J





Okay, so you've heard one of those microprocessor controlled repeaters crank out "beer" when someone "times-out." You wish your repeater could do that too, but you can't afford new logic. The circuit described in this article will solve your dilemma. It can make your repeater crank out seven short messages or mnemonics at a cost of about $25 and a few hours of your time.

Circuit Description

Fig. 1 shows the entire circuit. There are seven input lines which are normally high. When one goes low, its value is decoded into BCD format. This BCD value is then loaded into U3. U5A provides an enable pulse to U3 that is delayed by an amount of time approximately equivalent to the propagation delay of U3. Any value greater than zero at the input of U3 will also cause a strobe signal to be sent to the control logic (U6 and U7).

This logic is turned on by the strobe, which in turn starts the clock, ~~U9~~. U9 drives a binary counter, which feeds a 4-line to 16-line demultiplexer. Depending on the input of this demultiplexer, one of its 16 lines goes low from its normal high state. This provides the potential for a diode, connected across the input line of data selector U11, to bring the input line down from its normally high state. The data selector chooses one of the seven input lines, depending on the value stored in the 7475. The input line is normally high. However, the input line goes low when a diode is connected anode-to-input and cathode-to-demultiplexer-output and when that particular output is low. The inverted output of the 74151 changes to a high, enabling a code oscillator or such.

While this is happening, the PTT output goes high, enabling the repeater transmitter to turn on. When the counter reaches 1111_2, a clear pulse is sent to the 7475, to the control logic and to the counter itself. Notice that the 7475 is cleared by enabling it temporarily. You

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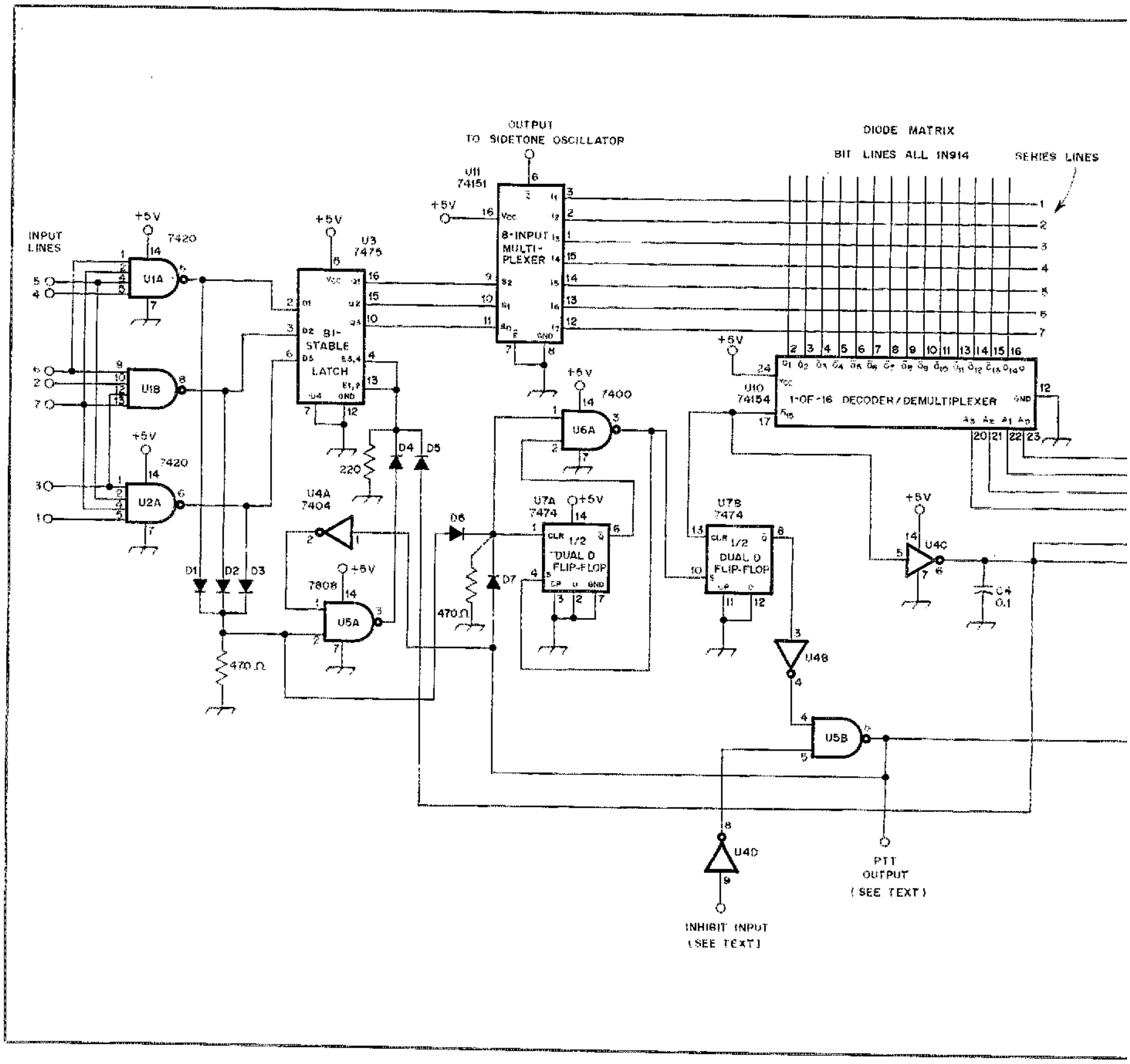


Fig. 1 — The Mnemonic Encoder circuit. Pins not shown on ICs are not used and not connected. Noise suppressor capacitor C1 should be as close as possible to U8.

C1, C2, C4 — 0.1 μF disc ceramic.
C3 — 22 μF, 16 V electrolytic.
D1-D6, incl. — Small-signal, general-purpose silicon, 1N914 or equiv.
Diode matrix diodes — Small-signal, general-purpose silicon, 1N914 or equiv.
R1 — 100-kΩ, thumbwheel potentiometer.
U1, U2 — TTL, dual 4-input NAND gate IC, 7420.
U3 — TTL, bistable latch IC, 7475.
U4 — TTL, hex inverter IC, 7404.
U5 — TTL, quad 2-input AND gate IC, 7408.
U6 — TTL, quad 2-input NAND gate IC, 7400.
U7 — TTL, dual D flip-flop IC, 7474.
U8 — TTL, divide-by-sixteen counter IC, 7493.

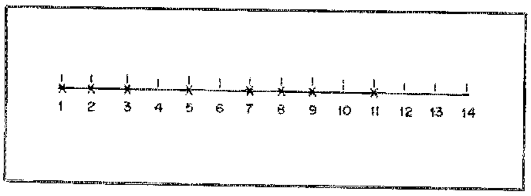


Fig. 2 — Example coding diagram for a diode matrix to send C. Numbered tick marks refer to output lines of demultiplexer. X indicates that a diode should be installed at this junction; no X indicates that the junction should be left open.

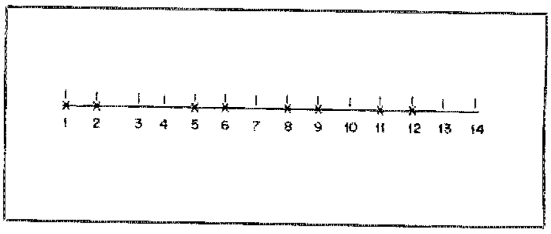
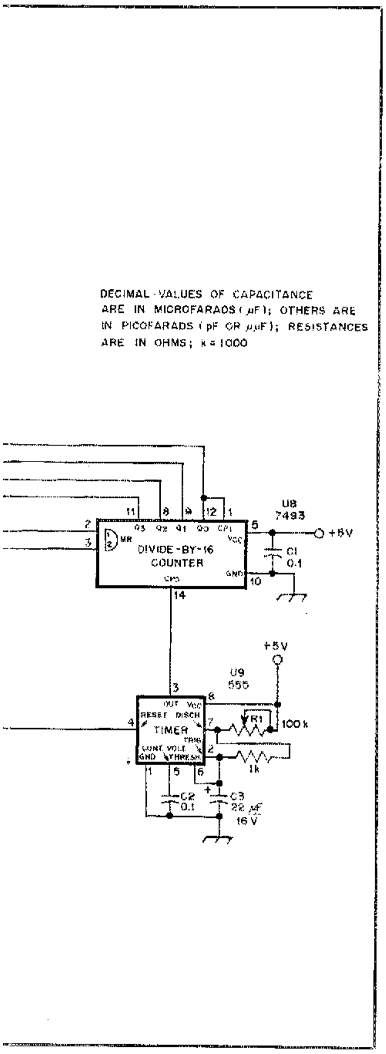


Fig. 3 — Coding diagram for "fudging" the message TO. The method and purpose are described in the text.



U9 — Timer IC, 555.
U10 — TTL, 1-of-16 decoder/demultiplexer IC, 74154.
U11 — TTL, 8-input multiplexer IC, 74151.

may be asking "What if a value is still present at the 7475 input? Won't that value load?" Yes. However, study the control logic more carefully, particularly U6A and U7A. It is designed not to react to a strobe pulse unless it first clears. Therefore, the circuit cannot recycle.

Programming the Diode Matrix

Programming the matrix is quite straightforward — no Karnaugh maps here! Start at bit 1 of the demultiplexer. Choose one of the data input lines. Now wire a diode with the anode to the input line and cathode to the demultiplexer when you want the sidetone on. To program a dot, you would wire one diode. A dash would be 3 consecutive diodes. Don't forget spacing! There should be one space between dots and dashes in the same letter and three spaces between different letters. The proper sequence for the letter "C" is illustrated in Fig. 2.

You may have to "fudge" a bit, since you have only 14 bits to work with. For instance, on the K1BA repeater in Boston, it was desired to have the machine say "TO" for timeout. It is obvious that TO just doesn't fit. Because all the elements are dashes, each dash was shortened 1 bit as was the letter space. The result is that TO sounds a little bit faster than the rest of the messages. Fig. 3 gives a diagram of how we "fudged" TO.

Input and Output

All the input lines should be controlled by something compatible with TTL. Either a device with a high impedance to low output or a TTL high to low output is recommended. The inhibit input is designed to freeze the circuit whenever the input is high. This works when the circuit is in the middle of a cycle as well as before the code has started. It should be used with care. Control device levels for it should be the same as described for the input lines.

Both the CODE and PTT outputs are TTL levels. The PTT output goes from its normal state of 0 V to +5 V when the circuit is activated. The CODE output goes high whenever the sidetone should be on. Again, care should be used not to allow these outputs to sink too much current. If you are not sure, use a simple npn transistor such as a 2N2222 in conjunction with the outputs. With the proper care, this circuit should work with almost any repeater control system.

What to Say

If you can't think of enough things to say, here is what was used in Boston. When the repeater is controlled off or on, it sends a C. When the phone patch rings, it sends a P. As mentioned above, if someone times out the repeater, it sends TO. If there has been a recent power failure, it sends PI. A V is sent in conjunction with a circuit that is used for testing Touch-Tone pads. When the repeater first comes up after not being used for a while, it sends HI following the repeater i-d. If a net is scheduled for the evening, the repeater sends NET during the day to remind everyone. Obviously, there are external controls that are needed for most of these functions. Many repeaters already have them and, therefore, the interfacing is left to you. What do you want your repeater to say? QST

Strays

AMATEURS AWEIGH!

☐ The crew of the *USS Samuel Eliot Morison (FFG-13)*, the Navy's newest guided missile frigate, would like an Amateur Radio station for recreational and educational purposes. Anyone wishing to donate a setup, including transceiver with phone patch capability and a vertical trap antenna, should contact CDR Larry J. Andrews, *USS Samuel Eliot Morison (FFG-13)*, FPO Miami, FL 34092.

TA PROFILES

☐ We extend our thanks to ARRL Technical Advisor Daniel N. Petersen, WA6OIL, for his services as our consultant on pc-board fabrication, circuit packaging and microwaves.

Dan is 29 years of age and has been licensed as WA6OIL for nine years. He now holds an Advanced class license. Employed as an engineering technician at Digital Development Corporation, Dan's job is creating a working prototype from an engineer's rough sketch. He says, "getting a gizmo to work from hieroglyphic symbols scratched on the back of an envelope certainly keeps one's brain sharp."

Dan enjoys electronics as a hobby, and has fun building his own test equipment and communications gear, sometimes from the box on up. Dan and his wife Patti, KA6DOZ, reside in San Diego, California. — *Marian Anderson, WB1FSB*

Meet TA Dan Petersen, WA6OIL.

I would like to get in touch with . . .

☐ Sinclair ZX-80 computer users interested in forming an ssb net or in exchanging programs and technical information via newsletter. Marty Irons, K2MI, 46 Magic Circle Dr., Goshen, NY 10924.

Coherent CW — The Practical Aspects

Part 2: In Part 1, the concept of ccw was described. You'll now see how you can put the concept into practice.

By Charles Woodson,* W6NEY

Coherent cw operation imposes two basic requirements at the transmitting end. First, the keying must be done within the time frames established by a stable frame reference. These frames must be sufficiently regular to enable the receiving station to determine accurately when they occur. Second, the carrier frequency must be stable within a hertz or so during the contact, including all keying periods. The time frames can be established by a frequency standard with the reference signal being divided by CMOS or TTL to produce pulses which define the frame. Many ccw stations use standards such as those described by Kelley,[1] although any comparable standard would do.

*2301 Oak St., Berkeley, CA 94708

[1]Notes appear on page 23.

To keep the frames accurate within 1/20 of a period for 10 "windows" per second · requires a stability factor of 1/720,000 Hz per hour of contact. Since the standard mentioned is accurate and stable to less than 1 part in 10^7 over the required period, it exceeds the required accuracy easily. A station standard suitable for supplying the 10-Hz keying reference and the ccw filter frame reference is shown in Fig. 7.

Keying

Fig. 8 shows a simple system that may be used for ccw keying. I have adapted both the Heath HD-10[2] and the Accu-Keyer[3] for ccw operation. The Accu-Keyer is superior because of its 1-bit memory. At present, I use an AKB-1 keyboard, which is available with a ccw option. I've also used a KIM-1 computer for generation of ccw and ASCII. The computer uses its internal timing clock to generate an interrupt at the beginning of each frame period. The clock frequency must be adjusted precisely for such use.

Hand sending of ccw is different from ordinary random-frame cw and takes a while to learn. This is because dots, dashes and spaces can only occur in pre-established frames and we are accustomed to initiating dots, dashes and spaces whenever we wish. With a bit of practice, the initial sending errors decrease to near that of the error rate of ordinary cw keying. You learn to hold the key down until you hear a dot or dash start and then

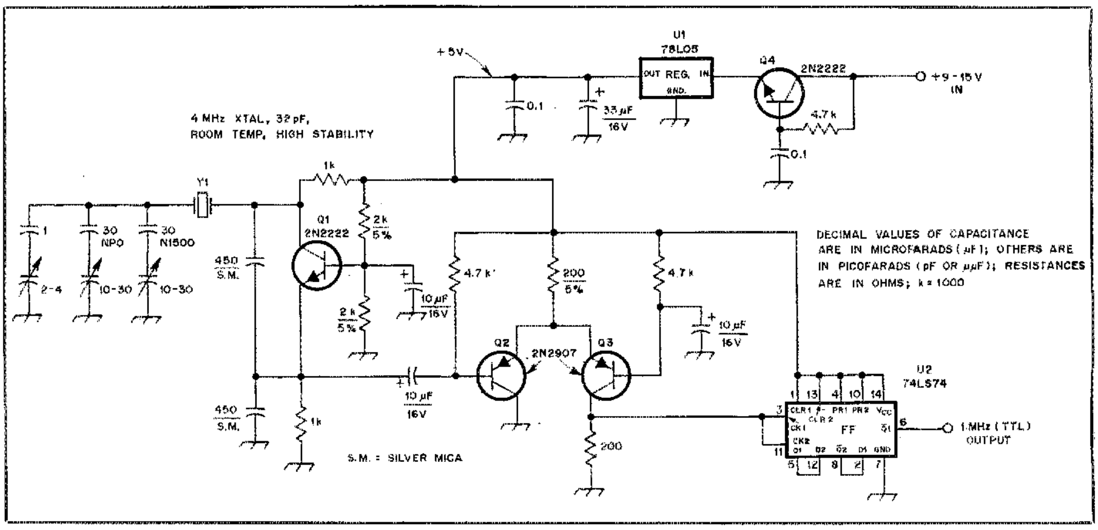


Fig. 7 — A 1-MHz frequency standard for ccw station use.

you're able to send in rhythm with the frames for a word or phrase. A keying monitor is a must!

Transmitter Stability

The receiving filter passband requires that the transmitted frequency be stable during the contact period. This is perhaps the most difficult parameter to be met for ccw operation. For a cw signal time frame of 0.1 second, a 14-MHz signal must be stable to within 1 or 2 Hz. High-quality crystal oscillators have such stability except when a varying load is placed upon them, as when a transmitter is keyed. During keying, the frequency of a typical transmitter crystal oscillator will shift approximately 50 Hz. Under ordinary circumstances this wouldn't be noticed, but for a ccw signal, this would mean loss of reception because the shift is more than five times the receiving filter passband and would equate to a 20-kHz shift of a regular cw signal. Such shifting produces an amusing situation. When copying with the ccw filter in the presence of strong interference, the interfering signals sometimes appear to swish up and down the band during keying. Even if they cross the ccw frequency, the time they are in the filter passband is small. The result is that they have relatively little effect on the ccw signal itself. However, these interfering signals — through cross-modulation, overloading early receiver stages, and their effect on agc — can (and often do) cause problems.

Transmitter stability has been achieved by using high-quality crystal oscillators which are not keyed and which are followed by several stages of amplifiers and buffers to nullify the loading effects of keying. A schematic diagram of such a transmitter-exciter is shown in Fig. 9. The power output of this exciter is about 0.1 watt and it has been used by itself (with an antenna matching network and keyer in

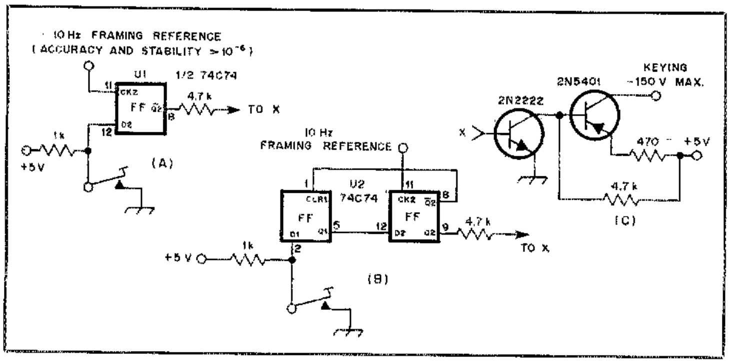


Fig. 8 — Two simple ccw hand keyers. The key must be kept closed until the beginning of a frame, determined by the framing reference signal. Once transmission is initiated, although the key may be opened, the transmitter will remain keyed until the end of the frame period is signaled by the framing reference. The keyer at B includes a one-bit memory which makes coherent keying by hand much more convenient. When the key is closed, the first flip-flop is set and remains set even if the key is opened. When the clock pulse arrives, the second flip-flop is set, which causes the first to be cleared unless the key is still closed. If your rig uses inverted TTL keying, use the $\bar{Q}$ output.

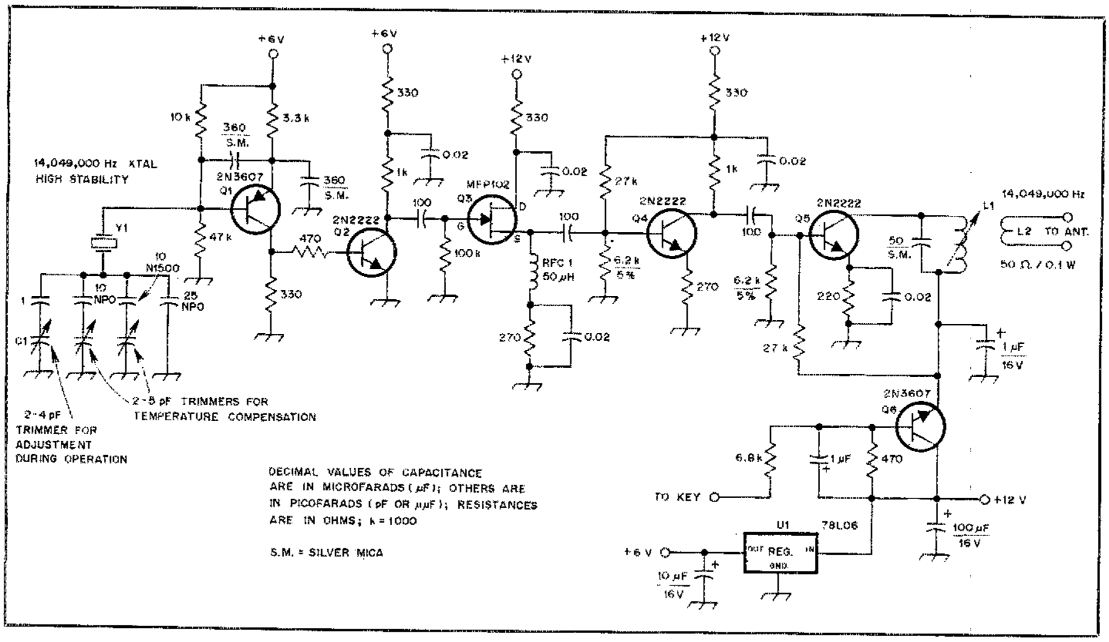


Fig. 9 — Schematic diagram of a low-power ccw exciter/transmitter. The capacitance from the crystal to ground should total about 32 pF. Fixed capacitors should be high quality ceramic or silver mica types. C1 is used to adjust the frequency of operation and affects the total capacitance by less than a picofarad once temperature compensation has been achieved with the other trimmers (see text).

L1 — Miller 4404, approximately 2.5 μH.
L2 — Two turns no. 18 enam. over "cold" end of L1.
Y1 — Fundamental mode crystal, 32 pF load capacitance, room temperature, high accuracy crystal. Available from ICM, 10 North Lee, Oklahoma City, OK 73102.

the final stage) and as a VFO replacement. Tests have shown that after a 30-minute warm-up period the oscillator is stable within a hertz during keying and remains so for over an hour. The crystal tuning allows VFO-type operation over a 20-Hz range. To facilitate stability, very little power is drawn from the oscillator and two stages of isolation are used to minimize the load on the oscillator by later stages. In most situations, particularly when the rig is left on all the time, the N1500 compensation capacitor and corresponding trimmer may be omitted and a fixed capacitance value added in parallel with the rest of the units. When the temperature compensation trimmers are used, they are adjusted while measuring the operating frequency at two different temperatures, say, 68 and 86° F (20 and 30° C). One trimmer is adjusted to decrease capacitance and the other to increase capacitance by a like amount. The frequency is measured at the two temperature extremes again and this process continued until the oscillator frequency is the same at both temperatures.

Another method of transmitter frequency stabilization is to use PLLs to control the frequency of oscillators and use a highly stable oscillator as a reference for the PLL. A direct-conversion receiver employing this technique was described by McCaskey.[4] Maynard used a 5.0- to 5.5-MHz synthesizer output and a 9-MHz frequency standard to control an HW-8.[5] I have used a method which mixes the HFO, BFO and VFO frequencies of a double-conversion transceiver (SB-303/SB-401 combination), locking the result by controlling the VFO frequency.[6] A simple scheme (shown in Fig. 10) is used for locking the VFO (LMO) of an SB-303 receiver by using the built-in variable capacitive diode circuit employed for fsk operation. A high-impedance voltmeter connected to point C can be used to monitor the lock condition. During operation, the VFO is tuned slowly across the frequency of the standard; frequency lock occurs about 250 Hz above and below the reference frequency. Once locked, the crystal oscillator controls the receiver frequency and it can be set more accurately than the VFO. The crystal oscillator can be replaced by a 5.0- to 5.5-MHz synthesizer which is controlled by a suitable reference frequency; Petit has designed such a synthesizer which operates in 100-Hz steps.[7]

A block diagram of the transmitter currently in use at my station is shown in Fig. 11. The 12.9-MHz crystal oscillator is designed for high stability. Similar oscillators are used for operation on 21 and 28 MHz. The synthesizer is controlled by a 1-MHz oscillator similar to that described in Fig. 7. The two oscillators run continuously and are connected to the doubly balanced mixer, but the 14-MHz stage following the mixer is keyed. This allows break-in operation on the same frequency.

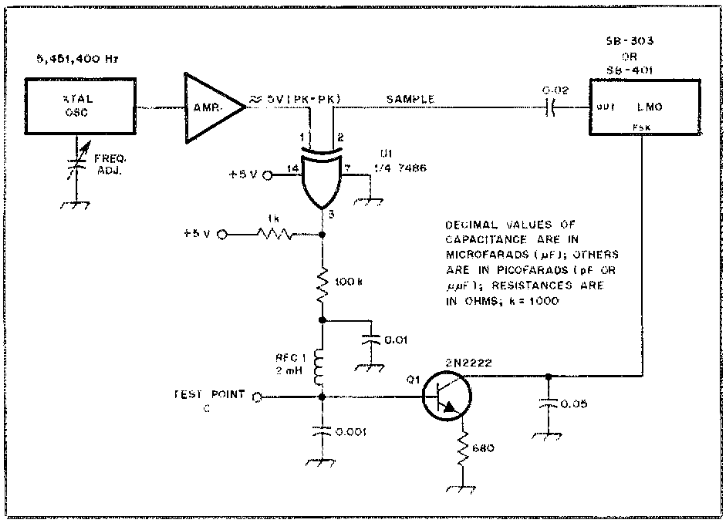


Fig. 10 — This method may be used to lock the LMO of the popular Heath SB series of equipment. Point C is a test point which is used to monitor the lock condition (see text.)

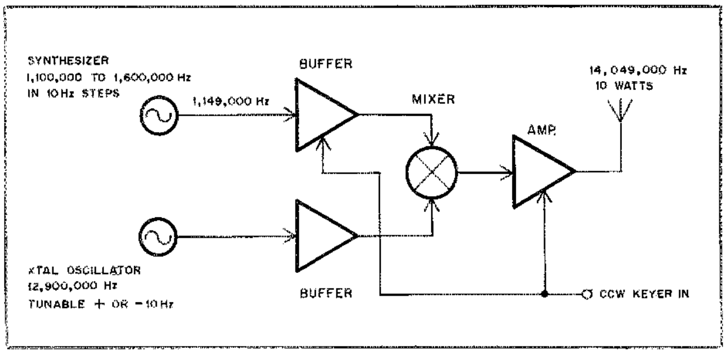


Fig. 11 — Block diagram of the transmitter used by the author. The two oscillators run continuously for improved stability.

Receiver Requirements

In addition to the ccw filter, the receiver must exhibit stability on the order of 1 Hz over the length of a contact and have a tuning resetability which is less than the bandwidth of the filter. Searching for a signal while using a filter bandwidth of only 10 Hz requires almost 200 times as long as it takes to tune a band using a filter with a bandwidth of 2.1 kHz. If the phase and frame size were also unknown, it would take over 1000 times as long to tune a band searching for a ccw signal as it takes to look for an ordinary cw signal. That is why current practice involves agreeing on a precise frequency and frame length in advance. Adequate stability is easy to obtain with good crystal oscillators in receivers when temperature has been stabilized by a long warm-up period and a stable environment exists.

Fig. 12 is a block diagram of the receiver currently in use at my station. Rough tuning is done by adjusting the hf crystal oscillator and the BFO, which have ranges of about 800 Hz, to the desired frequency. The VFO of the ccw filter center frequency reference (four times the center frequency) is used for fine tuning over a range of about 25 Hz. An i-f strip similar to one designed by Hayward[8] provides performance superior to others I have used. Best results are obtained when the agc is controlled by the agc output of the ccw filter.

Keitaro Sekine, JA1BLV, uses a crystal-controlled FT-901 and also has built a 2980- to 3080-Hz RC VFO for use as the reference for the center frequency of the ccw filter. Oscillators in the transceiver have been stabilized by using temperature compensation methods and high-stability crystals.

The Filter

A practical coherent digital filter may be seen in Figs. 13, 14 and 15. The first CD4060A6 is used as a switching mixer while the second controls the sample and dump functions. An audio signal output may be derived from a digital mixer (such as shown in Fig. 14) driven by the output from the two channels. The signal is the difference between the two and can be made single-ended by using an op amp, or both channels may be fed to A/D converters for computer input. A frame reference for the ccw filter is shown in Fig. 15.

A Microprocessor-Controlled Filter

The logic diagram of Fig. 16 is that of the computerized system which has been used at my station. The switching mixers are essentially the same as those used in the filter described previously. A computer program controls the A/D conversion and dump functions. Computer con-

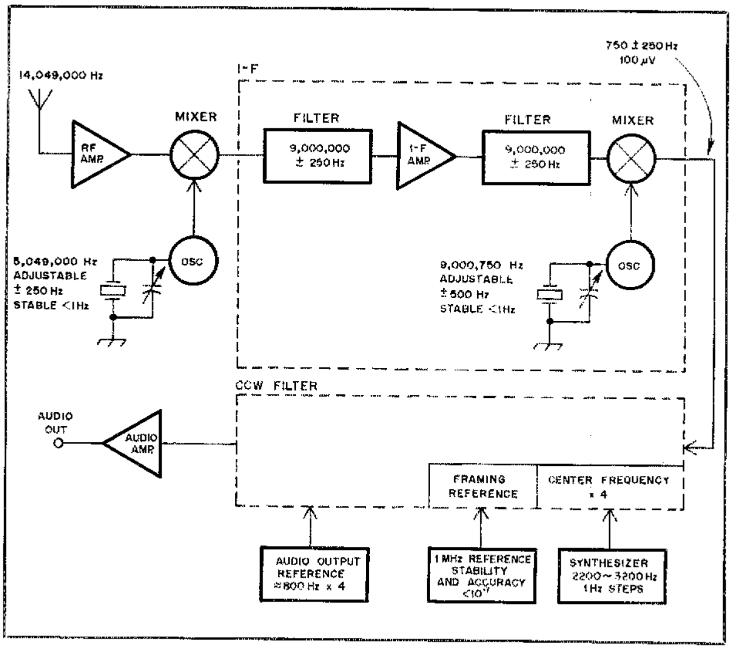


Fig. 12 — A block diagram of the receiver used by the author.

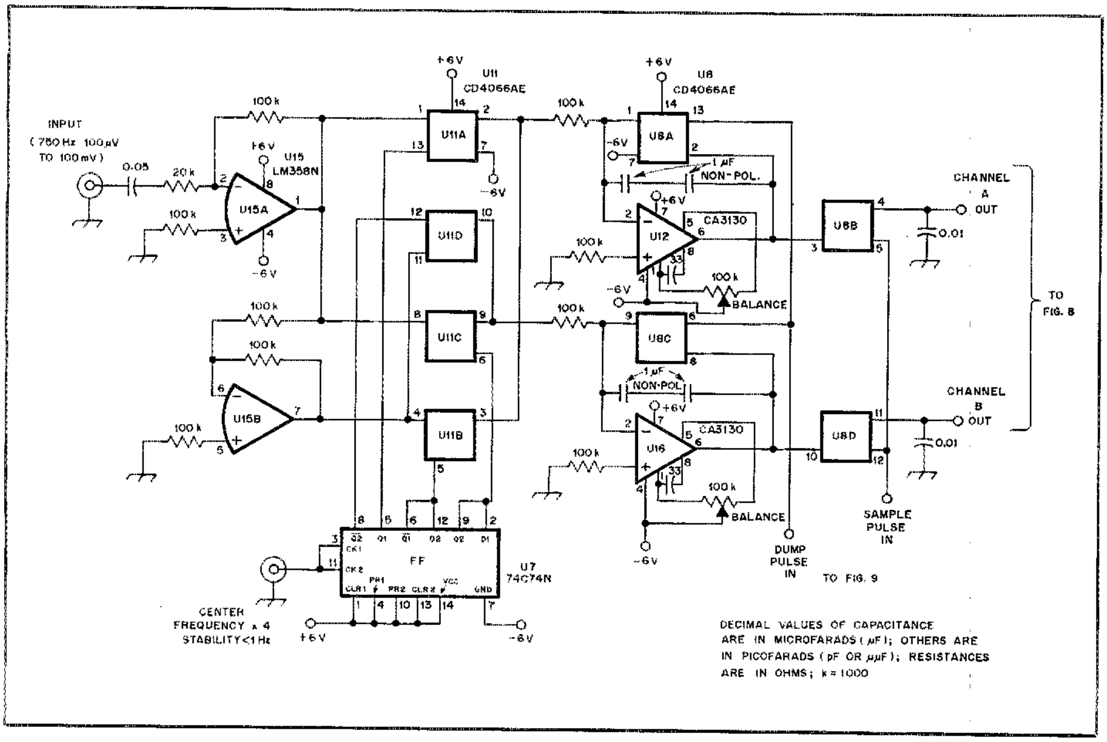


Fig. 13 — The front end of the coherent cw filter described in the text.

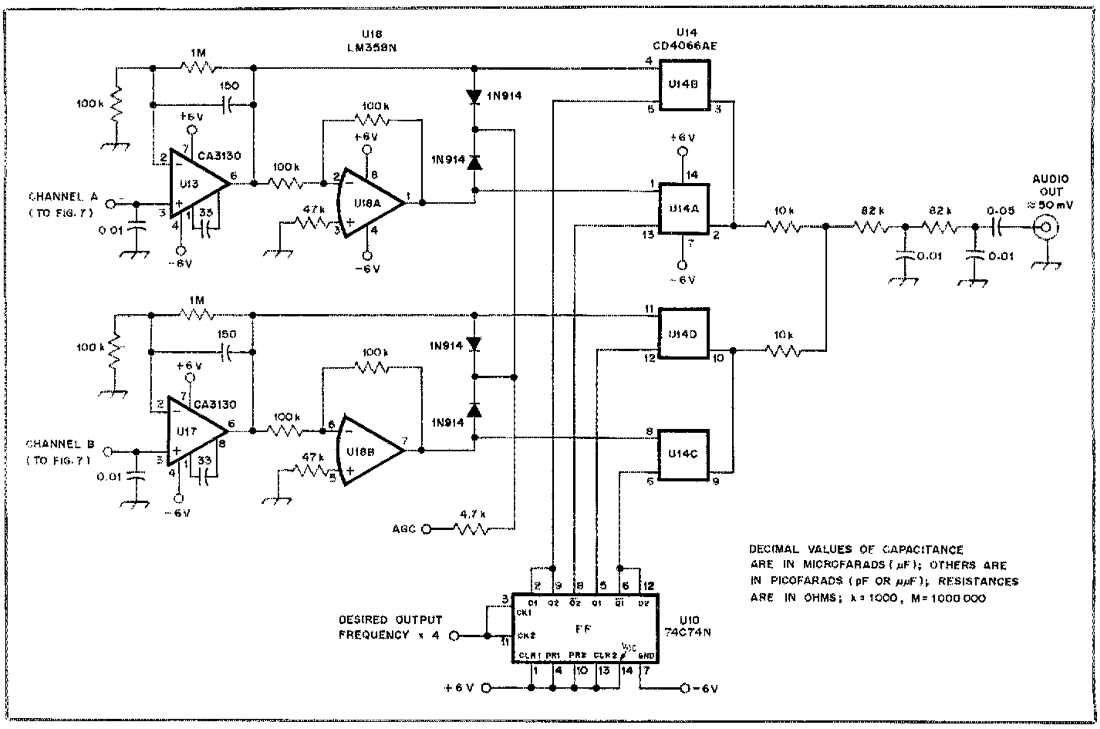


Fig. 14 — This portion of the ccw filter employs digital mixing to generate an audio output.

trol of the mixer has been employed, but use of an operator-controlled VFO is a convenience. The 1-MHz internal clock is stabilized and used to define the ccw frames. Phase is adjusted by the computer program. This is done by operator command. The operator indicates an advancement or retardation of the framing phase in 10 ms increments by pressing a computer key. I have experimented with a computer program to adjust framing phase automatically, but have not yet found a satisfactory way to maintain framing phase lock during breaks in the QSO caused by QRM or pauses. Between control of the sample and dump functions, the computer also converts the received Morse signals to ASCII code and transfers the ASCII code to a CRT character display terminal or printer.

Weak Signals and Noise

The reception of weak ccw signals is quite different from that of ordinary weak cw signals. Under standard conditions, as the cw signal gets weaker, QRN or QRM remain as "no signal" output and we eventually end up with a noise level dependent upon the bandwidth of the filter. With ccw, noise is a series of "dots" in frames and varies randomly in intensity. With the ccw filter, output is limited by design to one frequency and a weak signal is characterized by missing and extra dots randomly mixed with the desired signal.

Frame phase adjustment is important because if it is not accurate, a blurring of the dots and dashes into adjacent frames occurs. This makes the signal unreadable and it might go unnoticed if it is weak. When receiving a series of dots (a standard part of a ccw CQ), you can tune for maximum contrast between dots and spaces. With a strong signal, even a 10% phase error can be noticed. A slight lead error causes a weak mark just *before* each dot or dash while a lag error results in a weak mark just *after* the dot or dash.

Operating Practices

Under favorable conditions, it is often convenient to operate the ccw filter at shorter than optimal frame periods. With 0.01-second frames, the bandwidth is around 100 Hz and phase adjustment makes little difference. Although selectivity is reduced and signal level decreased by 10 dB, this method is used during initial signal detection. Once a signal is located, phase adjustment and longer frame periods may be used to optimize reception.

Phase tuning may be used instead of tuning a band of frequencies. This is accomplished by using an agreed-on frame length and frequency of operation and tuning for proper phase by adjusting the filter phase. Once phase adjustment is close, the frequency may be fine tuned as well. Present practice calls for sending a 15-second stream of dots to help in frame acquisition. A steady carrier of 10 seconds duration is an aid when fine tuning to frequency.

Time-reference signals from stations such as WWV may also be used to adjust the keying and reference frames of ccw receiving filters. Such adjustment must take into account the electromagnetic distance of the standards station to the receiving station as well as the electromagnetic distance between communicating stations. This procedure allows phase to be fixed and the operating to be the primary parameter which must be considered. Communication between stations located in Japan and California has been successfully accomplished using this technique. It is, however, a more difficult procedure to follow than phase tuning.

Conclusions

Ccw offers the possibility of employing some interesting operating techniques. Suppose Amateur Radio stations of the world agreed to operate at frequency multiples of 10 Hz. This would provide 20,000 channels at the bottom 200 kHz of

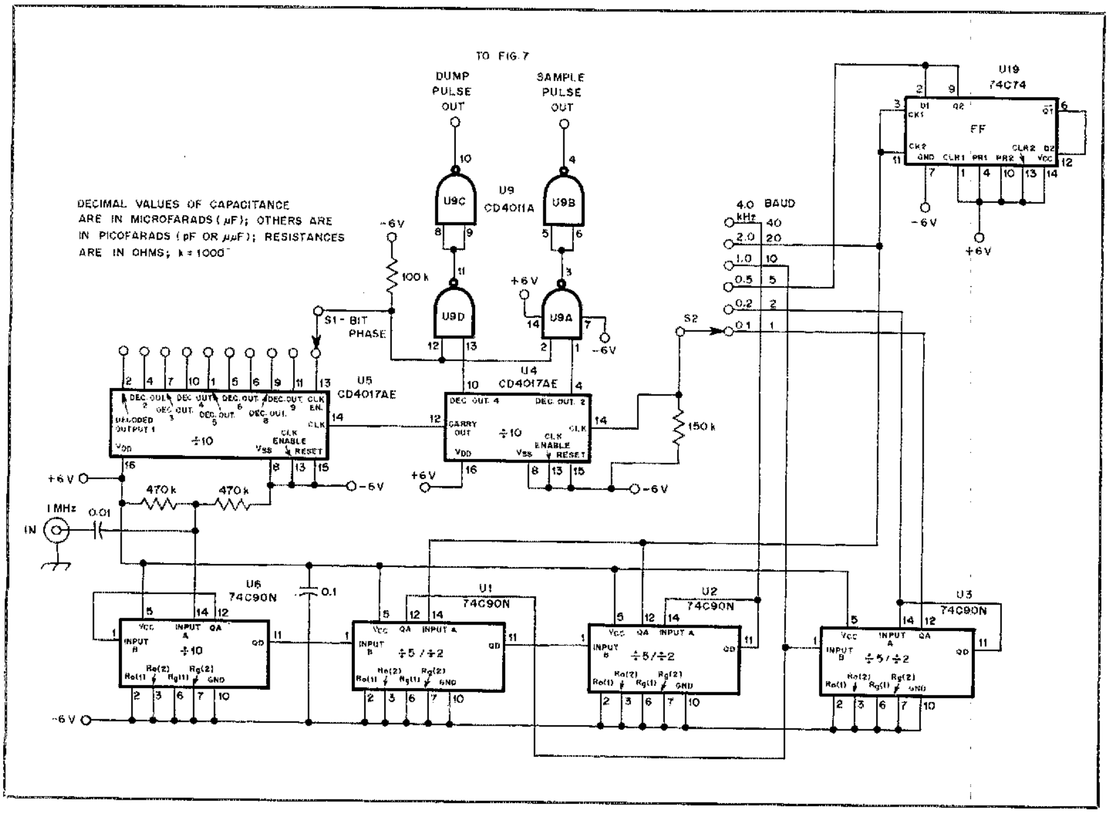


Fig. 15 — Frame reference circuitry of the ccw filter.

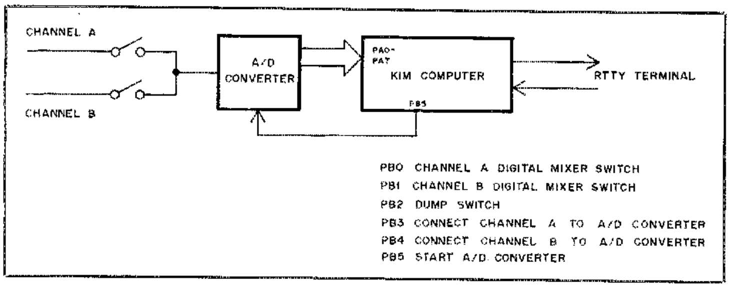


Fig. 16 — An experimental computerized ccw filter system used by the author. The filter used is similar to that of Figs. 13, 14 and 15, except that all switches are computer operated.

a band. If operators further agreed on sending in frames synchronized to 0.1-second UTC time pulses, you could set the framing (about a 0.03 second delay) to correspond to the distance of the stations you wish to contact, say 6200 mi (10,000 km). Once this is set, a check of the channels may be made for a station at the desired distance. Generally, you could detect signals at distances of 5000 to 7500 mi (8000 to 12,000 km) without further adjustment. Imagine microprocessor control over the entire procedure and the automatic detection of stations a particular distance away!

Coherent cw is a useful technique which improves communications effectiveness in excess of 20 dB. This factor can be used to offset poor propagation conditions, small or poorly located antennas, or low-power operation. It has the potential to be as revolutionary to cw as ssb has been to phone communication.

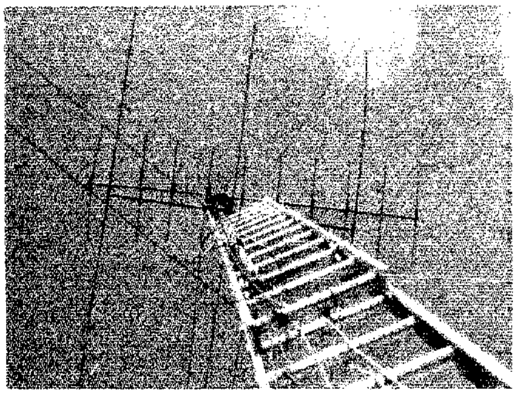
Acknowledgment

Many of the ideas presented here are based on ideas of Ray Petit, W7GHM. It is impossible to discuss ccw without mentioning him. This article has benefited considerably from critical comments and suggestions from Jim Maynard, K7KK, and Ray. QST

Notes

[1]Kelley, "Universal Frequency Standard," *Ham Radio*, February 1974.
[2]Woodson, "Conversion of the HD-10 Keyer to CCW," *CCWN* 1975:43.
[3]Tyrrell, "Modifying the Accu-Keyer for CCW," *CCWN* 1976:68.
[4]McCasky, "The Coherent Ten-Tec: A Practical CCW Station Assembly," *CCWN* 1975:24
[5]Maynard, "HW-8 for CCW," *CCWN* 1978:153-155.
[6]Woodson, "Stabilization of the SB-303 Receiver for CCW," *CCWN* 1975:60.
[7]Petit, "Synthesizer for 5 to 5.5 MHz," *CCWN* 1976:65.
[8]Hayward and DeMaw, *Solid State Design for the Radio Amateur*, ARRL, 1977, pp. 225-235.
[9]Double sided, drilled, glass epoxy printed circuit boards for the filter are available from the author at a cost of $40. The ARRL and *QST* in no way warrant this offer. Most component parts may be obtained from Jameco Electronics, 1021 Howard Ave., San Carlos, CA 94070.

A Ladder Mast



Step up to a new high in expedient antenna supports. An aluminum ladder will extend your Field Day signal.

By Keith D. Baker,* VE2XL

There are occasions when a temporary support is needed for an antenna system, e.g., antenna testing, site selection, emergency exercises and Field Day. Ordinary aluminum extension ladders are ideal candidates for this service. They are strong, light, extendable, weatherproof and easily transported. Additionally, they are readily available and can be returned to normal use once the tower project is concluded. A ladder tower will easily support a lightweight triband beam and rotator (see the cover of October 1979 *QST*).

The First Step

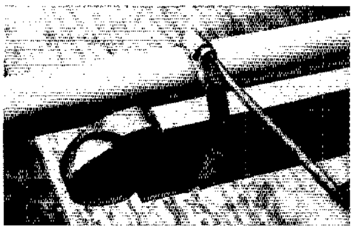
With patience and ingenuity one person can erect this assembly. One of the biggest problems is holding the base down while "walking" the ladder to a vertical position. Once it is up, I use 1/4 inch (7 mm) polypropylene rope to guy the tower; the rope guys are arranged in the standard fashion with three at each level. If you have help available, the ladder can be walked up in its retracted position and extended once the antenna and rotator are attached. The lightweight pulley system found on most extension ladders will not be strong enough to lift the ladder extension and survive. You will need to replace this with a heavy-duty pulley and rope. Make sure when attaching the guy ropes that they do not foul the operation of the sliding upper section of the ladder.

There is one hazard to avoid. Do not climb or stand on the ladder once it has been extended — even so much as one rung. If the locking mechanism should fail, you would likely lose a limb or two, if not your life. The risk simply isn't worth it. Never, ever, stand on the ladder and attempt to raise or lower the upper section. Do all the extending and retracting with the heavy-duty rope and pulley!

If you are going to raise the ladder by yourself, here are some pointers that may help. First of all, make sure that the rung latching mechanism is operating properly before you begin. The base must be hinged such that it does not slip along the ground during the erection activity. The guy ropes should be tied and positioned in such a way that they serve as safety constraints in the event that you lose control. You should have available a device, e.g., another ladder, for supporting the ladder during the rest periods. After the ladder is erect and the lower section guys tied and tightened, raise the upper portion one rung at a time. Do not raise the upper section higher than it is designed to go (you may pay a high price for the extra height).

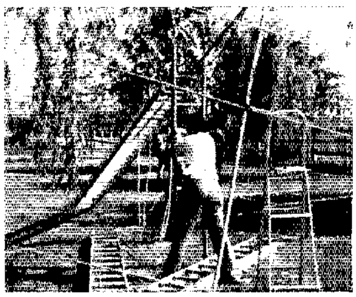
Finding suitable guy anchors can be an exercise in creativity. Fence posts, trees and heavy pipes are all possibilities. If nothing of sufficient strength is available, you can drive anchor posts or pipes into the soil. Sandy soil is the most difficult to work with because it does a very poor job of holding the anchor. I have driven a discarded back axle from a car into the ground to use as an anchor; it is substantial. When I am finished with it, I use a chain and car bumper jack to remove it.

Above all else, keep the tower and antenna away from power lines. Make sure that if you lose control, nothing can touch the lines. Disassemble by reversing the process. Ladder towers are one of the best bets for "quickie" antenna supports. See you on FD.



Hose clamps can be used to secure the mast to the ladder leg. *(All photos by VE2XL)*

U bolts are used to clamp the lower end of the mast to one of the upper rungs of the ladder.



Walking the ladder up to its vertical position. Keith, VE2AQU, supports the mast with a second ladder while Chris, VE2FRJ, checks the ropes.

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Amtor, an Improved Error-Free RTTY System†

Sitor, Spector, Microtor and now Amtor — what do they have in common? For one thing, the underlying principles are similar. More importantly, they just might usher in a new era for RTTY communication.

By J. P. Martinez,* G3PLX

Since getting a microprocessor-based home computer working at my station, I've spent some time using it to perform many of the functions of conventional RTTY equipment. The flexibility of the microprocessor (μP) also made possible the experimentation with techniques using other than the well-known start-stop RTTY code. In the UK, we are permitted to carry on experiments of this sort on 2 meters and above, so no time was lost in trying out synchronous systems where no start-and-stop bits are sent and the clocking of data is done by accurate frequency standards at both stations. Some forward-error correction codes were tried in which additional check-bits sent with the data enable the receiver to correctly reconstruct the original data in the event of the presence of some erroneous bits. This proved promising, being about 6 dB better than conventional RTTY.

Another area explored is the ARQ (Automatic ReQuest) whereby any errors at the receiving end are detected by the use of extra parity bits, and a request is made for the repeat of the bad character by the receiving station. One such system, requiring both stations to operate in the duplex mode, gave spectacular results via OSCAR satellites. Under this circumstance, there was complete immunity to fading, interference and errors associated with keeping the receiver on tune. Loss of signal merely caused temporary pauses in the traffic.

Adapting this system to everyday amateur operating practice proved difficult until the "discovery" of an ARQ system already in use in the maritime service for Telex traffic. This system can be used by two stations in simplex communication on the same frequency by working in a synchronized quick-break fashion. On-the-air results from this system were similar to those of the duplex technique. It became clear, therefore, that it would be very useful to amateurs, not only on vhf, but also on the hf bands.

Since this system is already an international standard (CCIR Recommendation 476) and is in worldwide use, we had no difficulty in gaining permission for its use on hf by UK amateurs. Commercially, this system is known by various trade names such as Sitor, Spector and Microtor. To avoid confusion with the commercial equipment, the name "Amtor" has been devised to refer to any amateur use of the system described in CCIR 476. What follows is a description of how Amtor works. I hope to show that this ingenious system could have a lot to offer and that it can be readily implemented by modern μP techniques using either a home computer or a dedicated unit.

*11 Marchwood Ct., Broadsands Dr., Fort Gomer, Gosport, Hants, England

†Translated and reprinted from OZ (Denmark), November 1980.

STA Granted for Experimental Error-Free Amateur RTTY

The Federal Communications Commission in 1980 granted Special Temporary Authority to four licensed radio amateurs for the purpose of conducting tests with an error-free mode of amateur teleprinter communication (Amtor). This authorization permits the use of digital teleprinter code as described in CCIR Recommendation 476 (Rev. 74). It expires November 30, 1981.

Participants in this STA are William C. Meyn, K4PA, of Reston, Virginia; Charles A. Roettcher, K3FLS, of Washington, DC; Melvin Leibowitz, W3KET, of Wilmington, Delaware; and Walter E. Kaelin, KB6BT, of Saratoga, California.

First Principles

Imagine two stations, A and B, in simplex communication on ssb with the operators desiring to exchange messages reliably under poor conditions. If A sends three words, for example, B replies with "Roger" or "Say again." A then goes on to the next three words or repeats the last three. If A cannot tell, however, whether B said "Roger or "Say again," then he will have to say instead of three words, something like "Please repeat." To make matters worse, if B cannot tell whether A gave three words or said "Please repeat," leading B to transmit "Say again," then A gets completely confused and doesn't know what to say. This may seem trivial, but if we are to automate this verbal ARQ system, a better method must be found.

In Amtor, A sends three characters in a burst of synchronous frequency-shift data. B, in response, sends the acknowledgement signals in the reverse direction as a single character. How, then, can Amtor provide a solution for the communication problem mentioned above? A practical approach is to encode the acknowledgement signals differentially using two control characters we may call C1 and C2. When B is copying correctly, he replies with C1 and C2 alternately after each block. If a bad block is received, he repeats the same control code as the last time. If A sends "Please repeat," then B repeats the same control code as the last time. Thus B's reply is the same for a "Please repeat" block as for an error. It doesn't matter, therefore, if the bad block was a "Please repeat" block.

In the ssb example, B knows when errors have occurred because he cannot recognize a word. This works because the number of recognizable words is much smaller than the number of different sounds. To put it another way, language contains redundancy. The only errors that will pass undetected are those which transform one word into another. This can be minimized by careful choice of words. There are 32 recognizable characters in the teleprinter system. These

Table 1

Conversion Between Amtor Code and Murray Code

The codes are transmitted left to right. The higher frequency of the fsk signal is represented by "1."

Murray Code	*Ltrs*	*Figs*	*Amtor Code*
11000	A	—	1110001
10011	B	?	0100111
01110	C	:	1011100
10010	D		1100101
10000	E	3	0110101
10110	F		1101100
01011	G		1010110
00101	H		1001011
01100	I	8	1011001
11010	J	bell	1110100
11110	K	(	0111100
01001	L	)	1010011
00111	M	.	1001110
00110	N	,	1001101
00011	O	9	1000111
01101	P	0	1011010
11101	Q	1	0111010
01010	R	4	1010101
10100	S	'	1101001
00001	T	5	0010111
11100	U	7	0111001
01111	V	=	0011110
11001	W	2	1110010
10111	X	/	0101110
10101	Y	6	1101010
10001	Z	+	1100011
00010	carriage return		0001111
01000	line feed		0011011
11111	letters		0101101
11011	figures		0110110
00100	space		0011101
00000			0101011
	RQ		0110011
	beta		1100110
	alpha		1111000
	control 1		1010011
	control 2		0101011
	control 3		1001101

normally are transmitted by 32 combinations of 5 data bits. If 5 data bits are used, any bit error will transform one character into another and the error will pass undetected. Amtor has the advantage of using 7 data bits giving 128 combinations of which only 32 are recognizable. Careful choice of which 32 are used minimizes the possibility of an undetected error. One would not, for example, have chosen two codes that only differed by one bit. In fact, only those codes with three zeros and four ones are used, making it easy to check for errors at the receiving end. There are 35 such codes, and so the three spares are available for control purposes. Among these is the RQ character used by the transmitting station to signal "Please repeat." There is also the idle character known as beta. A third character, alpha, is explained later in this article. The C1 and C2 codes and C3, to be explained shortly, are also 7-bit characters from the same set. Since these are always sent only in the reverse direction, they are never confused with the others. The conversion from Amtor code to standard teleprinter characters is shown in Table 1. Note that this code is designed to translate easily to and from the Murray code.

The changeover in direction of transmission is not left to the operators, for there could be a misunderstanding if the link fades out just before the expected end of an "over." There are two ways to signal for the changeover. The sending station may end an "over" with the two-character sequence +? or the receiving station operator may press the TRANSMIT button. By either method the receiving station stops replying with C1 or C2 and instead acknowledges with C3. Upon receiving this information, the sending station transmits the block "beta-alpha-beta." In response, the receiving station transmits an RQ character, whereupon the transmitting station goes to the receive mode. Bursts of data from each station are so timed that even if both are transmitting blocks momentarily, each one can still receive one character of the other's block in the position expected to be a control code. This seemingly complicated process does ensure that the changeover proceeds in an orderly manner and cannot go awry, no matter what.

Timing of the various signals is shown in Fig. 1, with some of the possibilities for errors. Note that the two stations do not behave identically in respect to timing. One is called the master station and the other the slave for reasons which will become apparent shortly.

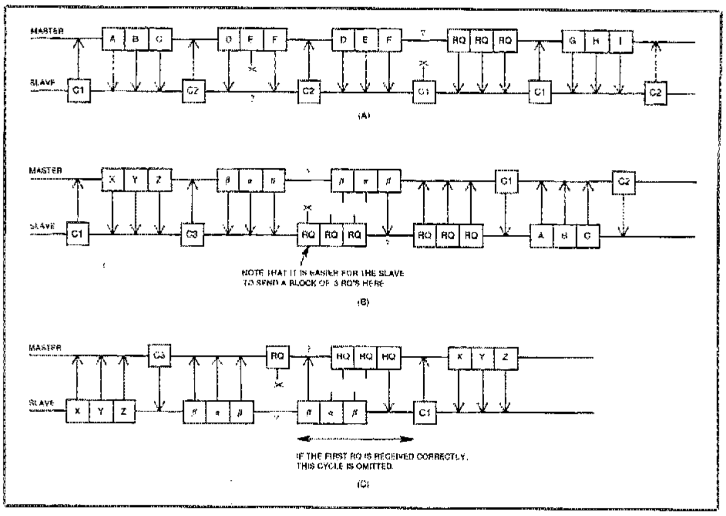


Fig. 1 — Timing of various Amtor signals. Included are some possibilities for errors. As you study this illustration, note that the two stations do not behave identically in respect to timing. One station is designated as the master, the other as the slave. Shown at A is a representation of the master sending to the slave, with errors. At B is a situation where there is a changeover from master to slave sending. The master is once again sending to the slave in the situation at C.

Performance

Although Amtor, in common with any ARQ system, eliminates virtually all errors resulting from the radio link, it is worthwhile pausing to see exactly how good it is. A simple analysis can be made by supposing that the radio link alternates between perfect copy and perfect random noise. With only noise in the receiver, all 128 7-bit patterns are likely to be received with 34 of these being acceptable (the RQ character is treated the same as an error). Thus the chances of a whole block of three being accepted by mistake is $(34/128)^3$ or about 1.9%. Therefore, with no signal, the receiving printer will be idle for 98.1% of the time while the system is asking for repeats and will be printing garble for 1.9% of the time. This compares with 100% correct copy when the signal is good.

By using the foregoing information, we can calculate the proportion of garble to good copy for various proportions of good signal to bad. A similar analysis for the reverse path shows that when there is no signal in this direction, 0.8% (1/128) of the message is unwittingly lost into thin air. The combined effect of these factors is shown in Table 2.

Synchronization

Since Amtor is a synchronous system with no start and stop bits, the timing at both ends must be stable. Some means must be found to get the two stations in step and to keep them that way over a period of time, even if the two clocks are only slightly different in speed. The synchronization procedure starts with the first station (the master) sending a special sync block repeatedly. The slave station continuously shifts in received bits until 21 consecutive bits correspond exactly with the expected sync pattern. The slave then starts to reply in the gaps, sending back

Table 2

Amtor Performance

The assumption is made that the signals in both directions alternate between perfectly good and perfectly bad.

Percentage of Time Signal is Usable	*Percentage of Transmitted Message Received Correctly*	*Number of Spurious Characters Printed, as Percentage of Transmitted Message Length*	*Time Taken as Multiple of 100% Signal Case*
100	100.0	0	1.00
90	99.9	0.2	1.11
80	99.8	0.5	1.25
70	99.7	0.8	1.42
60	99.5	1.2	1.66
50	99.2	1.9	2.00
40	98.8	2.8	2.50
30	98.2	4.4	3.30
20	96.8	7.5	5.00
10	93.0	16.9	10.00
5	85.2	35.6	20.00
2	61.7	91.8	50.00
1	22.7	185.5	100.00

one of the control codes. The master station, meanwhile, has been shifting in received data bits during the gaps in its transmissions. When it recognizes two consecutive control codes, it stops sending sync blocks and changes to sending traffic. In fact, to guard against the possibility of the slave getting the sync pattern right, just by chance, the master sends two different sync blocks alternately, and the slave must get them both in order correctly to lock in. The first of these blocks has an RQ in the second character, with two alphabetic characters in the other two positions. At the same time, the second block has two more alphabetic characters in the first two positions with an RQ in the third. The RQ characters prevent the four alphabetic characters from printing out at the slave station. These four characters can be chosen by the users, but must be agreed upon beforehand by the operators at the two stations concerned.

In commercial maritime service, these characters form a selective-calling code; but for amateur use, the four-character group suggested for all random QSOs is, perhaps not surprisingly, CQCQ, so that the two sync blocks are C,RQ,Q and C,Q,RQ. Alternatively for "sked" QSOs where a random reply might be unwelcome, the letters can be made up from the last four letters in the station call sign.

To accommodate any slow drift in timing between the two stations after initial contact, the slave station monitors the timing of the data transitions received from the master. If these tend to drift away from the optimum point, i.e., half way between the adjacent sampling instants, then the local clock is shifted to correct this. Thus, the slave timing follows exactly that of the master. The master uses the same technique to make sure it is sampling the signal from the slave at the optimum instants.

Resynchronization

The drift correction is very slow in action. As a result, it is not easily disturbed by short periods of interference. However, if contact is lost completely for some time, then both stations must reestablish the correct timing. This is done by operator intervention and restarting the contact as if commencing a new QSO. When both stations have been receiving errors or requests for repeat for 32 blocks, then they both will automatically drop back to the synchronization procedure, with the sending station retaining any unsent message in a buffer. A remarkable feature of the system is that it remembers which station was sending before the interruption, and when back in sync again, a change of direction is made automatically if required. The remainder of the interrupted message is then sent without gaps or errors.

Timing Considerations

CCIR Recommendation 476 specifies the block repetition rate at 2.222 per second and the data rate within bursts at 100 bits per second. Thus, a block of three characters takes 210 ms and a control code 70 ms, leaving 170 ms in which neither station is transmitting. At first it might seem like a good idea to allow the biggest margin of time for delays in antenna changeover relays, and to arrange the slave station to reply 85 ms after the end of the master's transmission. The effects of distance between the two stations, however, cannot be ignored. This is particularly so for intercontinental QSOs. The velocity of radio waves is 186.4 miles/ms (300 km/ms). As a result, the slave station will receive a delayed signal from the master, and the resultant reply will be received late at the master station by 2 ms for every 186.4 miles (300 km) separating the two stations. Thus, to make sure that this slave reply is not obliterated by the next master transmission on long-distance QSOs, the slave must reply as soon as possible after receiving the signals from the master. With practical equipment, and taking into account delays through various filters in the equipment, it looks as though 12,400 miles (20,000 km) is about the maximum range for Amtor to function successfully. In other words, it will just about cover the world on hf, at least by short path, but rules out some satellite possibilities and moonbounce.

Amtor in Practice

Is Amtor really practicable for radio amateurs? From our experience in the UK, the answer is a definite "yes." Many stations in the UK have Amtor in operation using a program written for 6800-based μP machines. A special-purpose unit has also been designed that is essentially a small μP system which will allow any station furnished with conventional RTTY equipment to extend operating capabilities to Amtor. No specialized μP know-how is needed to construct this unit. It is available in the UK in kit form for £76 (about $170). Most stations have found that their existing equipment will change over from transmit to receive and vice versa in less than 10 ms. Only minor modifications have been needed in other equipment. If anything, performance has been better than Table 2 suggests. In one recent QSO where a comparison was made between conventional RTTY and Amtor, with hard copy from both ends to check the errors, G3PLX and G3RSP/MM, working with 50 W erp over a 6200-mile (10,000-km) path on 20 meters, conventional RTTY was producing barely 20% copy while Amtor showed an impressive 99.3% copy, although slowed down by QRM to 25 wpm. Amtor has also been used on nonoptical vhf paths to send such sensitive data as μP machine-code instructions for updating the Amtor program itself as the project developed.

Conclusion

I believe that the Amtor system described in this article is ideally suited to Amateur Radio operation. My hope is that radio amateurs in other countries will join those of us in the UK who have been using this mode. In spite of its complexity, Amtor can be implemented using modern microprocessor techniques which have become available recently. Readers interested in further information on the μP program flow chart are directed to Ref. 1, while further information on the special-purpose unit mentioned will be made available in Ref. 2. Microprocessor enthusiasts with 6800-based machines are invited to contact the writer for further details of the software that is available. QST

References

[1]"Amtor, An Improved RTTY System Using a Microprocessor," *Radio Communication* (RSGB), August 1979.

[2]"Amtor, The Easy Way," *Radio Communication*, (to be published).

Easy 50-Ω Feed for a Helix

Looking for an easy way to match that helical antenna? Here's a new twist that will keep you from going in circles.

By Joe M. Cadwallader,* K6ZMW

Recent interest in circular polarization (cp) on the vhf and uhf bands is growing, perhaps partially because of AMSAT-OSCAR Phase III and other satellite work. One of the most popular cp antennas is the helix, first described in depth by J. D. Kraus.[1] The helix is easy to build and very forgiving of minor dimensional errors owing in part to its rather broad (70%) bandwidth. For this reason the actual performance of a helix closely matches the theoretical performance.

Problems and Cures

While working at 1296 MHz, where I've used both a quadhelix[2] and a helical feed for a dish, I found two deficiencies of the helix. First, terminating the helix at a connector in the center of the helix (Fig. 1) is mechanically awkward and electrically rather undefined. I chose to terminate the helix in an N connector mounted on the ground screen at the periphery of the helix (Fig. 2). Simply connect the helix conductor to the N connector as close to the ground screen as possible (Fig. 3). Then adjust the first turn of the helix to maintain uniform spacing of the turns.

This modification goes a long way toward curing the second deficiency of the helix — the 140 Ω nominal feed-point impedance. Troetschel's approach[3] solves the feed impedance problem nicely in multiple helix arrays, but matching 50 Ω coax to a single helix is still a problem. The traditional quarter-wavelength matching section has proved difficult to fabricate and maintain. But if the helix is fed at the periphery, the first half turn of the helix conductor (leaving the N connector) acts much like a transmission line — a single conductor over a perfectly conducting ground plane. The impedance of such a transmission line is:

$$Z_0 = 138 \log \frac{4h}{d}$$

where Z_0 is the impedance of the line, h is the height of the center of the conductor above the ground plane and d is the conductor diameter (both h and d must be in the same units of measure). The cross-sectional detail of Fig. 1 diagrams this. Clearly, the impedance of the helix is 140 Ω a turn or two away from the feed point. But as the helix conductor swoops down toward the feed connector (and the ground plane), h is getting smaller; therefore, the impedance is dropping. The 140 Ω nominal impedance of the helix is being transformed down to a lower value. For any particular conductor diameter, an optimum height can be found that will produce a feed-point impedance equal to 50 Ω. Preferably the height should be kept very small, and the diameter should be large. Apply power to the helix and measure the VSWR at the operating frequency; adjust the height for an optimum match.

¹Notes appear on page 29.
*23427 Clearpool Pl., Harbor City, CA 90710

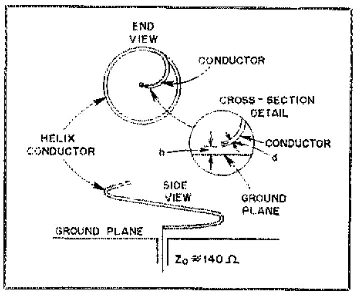


Fig. 1 — End view and side view of traditional helix configuration. Cross-sectional detail shows "standard" method for attaching feed line to the helix.

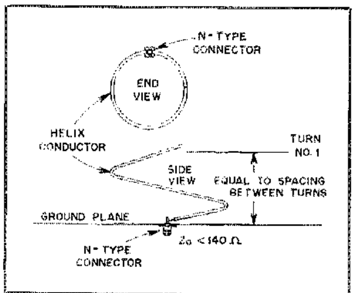


Fig. 2 — End view and side view of peripherally fed helix.

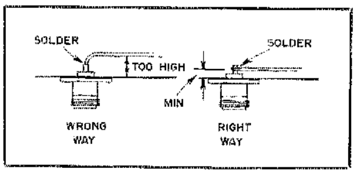


Fig. 3 — Wrong and right ways to attach helix to N connector.

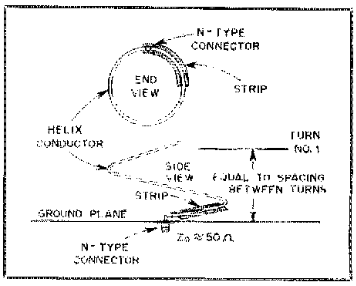


Fig. 4 — End view and side view of peripherally fed helix with metal strip added to improve transformer action.

Typically, the conductor diameter may not be large enough to result in a 50-Ω match at practical (small) values of h. In this case a strip of thin brass shim stock can be soldered to the first quarter turn of the helix conductor (Fig. 4), as described recently by Kraus.[4] This effectively produces a larger diameter conductor which causes the impedance to drop further. The edges of this strip can be slit every 1/2 in. (12 mm) or so, and bent up or down (toward or away from the ground plane) to tune the line for an optimum match.

This approach will yield a perfect match to nearly any coax. The usually wide bandwidth of the helix (70% for VSWR less than 2 to 1) will be reduced slightly to about 40% for the same conditions. This is not enough to be of any consequence for most amateur work. The improvements in assembly, adjustment and performance are well worth the effort to make the cp helix more practical to build and tune. QST

Notes

[1]Kraus, *Antennas*, McGraw-Hill Book Co., 1950, chapter 7.

[2]*The ARRL Antenna Book*, 13th edition, pp. 260-263.

[3]Troetschel, "A Quadhelix Antenna for the 1215-Mc. Band," *QST*, August 1963, p. 36.

[4]Kraus, "A 50-Ohm Input Impedance for Helical Beam Antennas," *IEEE Transactions on Antennas and Propagation*, Vol. AP-25, No. 6, November 1977, p. 913.

Strays

PRUDENT READING

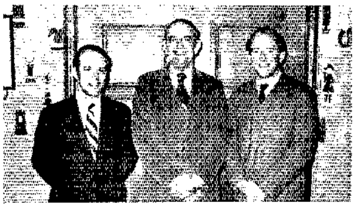
☐ The National Electrical Code, the purpose of which is ". . . practical safeguarding of persons and property from hazards arising from the use of electricity," has many headings (in Article 810) applicable to Amateur Radio. Among them are: Amateur transmitting and receiving stations — antenna systems, Material, Supports, Avoidance of contacts with conductors of other systems, Splices, Grounding, Grounding conductors — receiving stations, Size of antenna, Size of lead-in conductor, Clearance on building, Entrance to building, Protection against accidental contact, Antenna discharge units — transmitting stations, and Grounding conductors — amateur transmitting and receiving stations. If you would like specific details of these subjects, check your local library for the *1981 National Electrical Code Book*. It may also be obtained from the Construction Book Store, Inc., 1830 NE 2nd St., P. O. Box 717, Gainesville, FL 32602. — *John Reisenauer, KA7BKI*

I-D'ING FOR PROTECTION

☐ According to *Desert AIRE Waves*, you can help protect your gear from theft by engraving it with a number already accessible to the FBI's computer file listing of stolen property, the National Crime Information Center. You should use, for example, your driver's license number preceded by your state's two-letter code, thus automatically linking your name and address to your gear. Don't use your Social Security Number; it is meaningless to this computer. In the event of theft, chances of recovery of your gear are somewhat increased by using this system. — *Worldradio News*

I would like to get in touch with . . .

☐ anyone interested in forming a net of amateurs who are also lawyers. Peter B. Broida, K3SFP, 353 N. Edison St., Arlington, VA 22203.



Three of the four Associate Deans at Yale Law School also happen to be Amateur Radio enthusiasts. They are, from left to right, Edward Dauer, K1CBR, Arthur Charpentier, N1AQM, and James Zirkle, AG1X. N1AQM recently retired, and his gift was a 2-m, hand-held transceiver to keep in touch. *(photo by Sven Martson)*

MOVING? UPGRADING?

☐ When you change your address or call sign, be sure to notify the Circulation Department at ARRL Hq. Enclose a recent address label from a *QST* wrapper if at all possible. Address your letter to Circulation Department, ARRL, 225 Main St., Newington, CT 06111. Please allow six weeks for the change to take effect. Once we have the information, we'll make sure your records are kept up-to-date so you'll be sure to receive *QST* without interruption. If you're writing to Hq. about something else, please use a separate piece of paper for each request.

MOUNT ST. HELENS AWARD

☐ A full-color photographic award showing last year's spectacular eruption is now available by contacting, with no band or mode restrictions, eight or more stations in Clark, Cowlitz, Skamania or Lewis counties, Washington. Any contacts made after March 27, 1980, are valid. Send log information, station calls, dates, signal reports and $2 to: Awards Manager, CCARC, P. O. Box 1424, Vancouver, WA 98668. All proceeds will go to the Reid Blackburn Scholarship Fund. Reid, W7AIA, lost his life in the disaster. — *John Mollan, AE7P*

AMATEUR ANTICS

Strange Antennas

☐ A long time ago, a VE7 was on the air with a good signal. He said he was using his bedsprings as his antenna. His wife was still asleep, he added, and the rig loaded up better that way!

☐ Ted Wion, WA6OJE, reports having great success using his soldering iron for an antenna. One day, Ted was repairing a coax line that was still connected to the receiver. He touched the tip of the hot soldering gun to the inner conductor of the coax, and a few signals jumped out of the 75-meter noise. Thinking that if he could hear them maybe he could work them, he tried and succeeded — with the gun still plugged in the wall! This became a challenge, and Ted claims to have subsequently worked all 50 states and four countries with that unique antenna. He sends a special certificate with his QSL stating that he was using a soldering-iron antenna.

Big Antennas

☐ In the 1967 Sweepstakes contest, Thomas Taormina, WA5LES, and Charles Coleman, K5LZO, strung a V beam from a blimp floating at 185 ft. Each leg was half a mile long, and the array was so heavy that they had to use an automobile to pull the V legs out tight.

☐ During the 1974 Field Day, the operators at K5DUT/5 erected a full-sized, 2-element quad for 75 meters. The array was pulled up on four 60-ft poles, and the loops were spaced 40 ft apart. — *John G. Troster, W6ISQ, 82 Belbrook Way, Atherton, CA 94025*

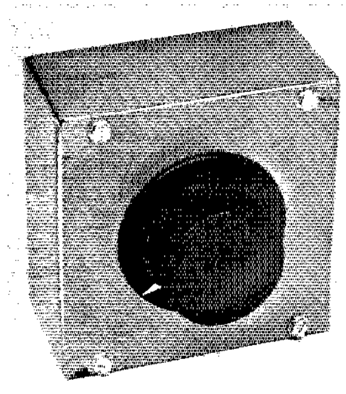
[Editor's Note: Please send all correspondence to the author at the above address.]

I would like to get in touch with . . .

☐ other amateurs who are pathologists. Philip Altman, MD, 1050 Linden Ave., Long Beach, CA 90801.

• *Basic Amateur Radio*

Julie's Custom Antenna Switch



Hear about the Novice who had to walk behind the bench to change the feed-line cable each time she wanted to switch bands? There must be an easier way.

By Peter O'Dell,* KB1N

Julie looked depressed as she slumped into the visitor's chair in the shack. I had just finished modifying a piece of equipment and really wanted to get on with testing it, but something told me that my star Novice needed a little cheering up and a few words of wisdom. "What's the matter, kid? Run into some misogynic old buzzard on 75?"

The Truth Untangles

"No, I don't pay attention to lids of any kind anymore. I just ignore them. Besides, I don't go for the General until next week, so you know I wouldn't be on 75." There was an edge of irritation in her voice, so I knew that something was really bothering her.

"Good grief! You're not worried about the exam, are you? You shouldn't have any trouble. In fact, my fearless forecast is that you will come home with the Advanced, at least." An icy glare told me that I was still wide of the mark. This one was going to be tough, particularly if she didn't start talking about her problem — I failed ESP-101 back in college.

After a few seconds of silence, I finally broke down and asked, "What is it, then, that has you looking like something that a mangy cat drug in?"

"Gee, thanks for the compliment, teach." Sarcasm oozed from her voice.

"I didn't mean it that way. Normally, you have a very cheery, optimistic attitude. Now you look frustrated and depressed, as if you've given up all hope. What is this insurmountable problem that has you down?" It was obvious by now that Julie was in no mood to respond to my usual string of wise cracks. Too bad.

"Larry brought one of his friends home from the office last night. I think you met him at our barbecue last summer. He was the fellow that everyone called 'tiny'."

Her expression hadn't changed any. Sure I remembered Tiny. As I thought of his massive physique, an overabundance of jokes and wise cracks welled up inside me. But I managed to merely nod to her, indicating that I remembered him.

She continued, "Well, it seems that Larry has been bragging to his fellow workers about how smart his wife is since I got my Novice. I think that they have all heard about every DX contact that I've made. He also told them about the transceiver I built — he didn't bother to mention that it was a kit, though. He's sweet."

Ahah! With that comment about her husband came the first glimmer of a smile. At this point I was wondering if Tiny had become so enthused with Julie's radio that he had eaten it. As I recalled, he had an appetite that matched his frame. Still, she wasn't ready for any wisecracks so I just nodded and waited for her to continue.

"After dinner and getting Danny to bed, the three of us went down to the basement so I could work magic while the two of them looked with awe. Forty was a mess with the foreign broadcasts so I flipped the rig up to 10. The band was wide open to VK-land. I unscrewed the 40-meter antenna and reached for the 10-meter vertical. Well, there it was. The cable was draped across the floor and Tiny was standing on the PL-259. Mashed that sucker flat. He was embarrassed and I was flustered."

"Is that all that's bothering you, Julie?" I asked.

Her eyes spoke long before the words came out: "Of course not. I had a spare PL-259 in the junk box that I quickly put on the cable using the pictorial diagram in the A-Double-R-L *Handbook*. That was a snap. I worked three VKs before the band closed, but I think Tiny was more impressed with my handling of the soldering iron." She had a cynical half-smile now.

I still didn't know what was troubling her, but I felt that I was about to find out. "I got up this morning and asked Larry if he minded watching Danny while I went downtown. So Larry and Danny spent the morning in his garden while I was off to Earl C's Discount House of CBs. What a weird place! I think he probably sells amplifiers to the CBers, but it's convenient to have him here in town.

"I looked around at the racks for a while, then I found what I was looking for: an antenna switch marketed as the Gargler 10-100-Super IV. The box said it was for CBs up to 5 kW. I knew that was preposterous, but I thought that it would handle my 100 watts."

"Oh, my. I'm beginning to get the picture. Tell me what happened." I tried to

*Basic Radio Editor

smile my best reassuring smile because I had this feeling that we would be replacing the solid-state finals in her rig very shortly.

"I mounted the switch to my desk top and attached the cables. I switched the various bands in and out and the receiver *sounded* like things were working. I tried transmitting and found that the rig was not playing quite right. So I put the SWR bridge in between the rig and the new switch. The SWR was higher than I remembered it being but it was especially bad on 10 meters — almost 2:1. I decided that I would worry about that later because the rig will operate with SWR up to about 2.5:1. Well, at least that's what the owner's manual says."

Crispy Cridders

Replacing solid-state finals can be a nightmare — particularly with some of the modern rigs that have such poor owner's manuals. I need a 20× magnifying glass just to see the tiny little schematic, and there is no theory of operation and no voltage readings and no resistance readings. Stumbling around in the dark gives me a headache. If I ever get my hands on the jerk who decided to leave all the essential information out of owner's manuals for Amateur Radio equipment, I'll . . . Julie was speaking again so I had to quit daydreaming and pay attention.

"I fired up on 10 meters and started calling CQ. A DL came back to me and after the preliminaries we got into a ragchew. I noticed a funny smell in the room. I even thought that I was hearing a hissing sound on the sidetone when I transmitted. Suddenly the rig started acting really strange with dial lamps flickering. The output meter showed almost no output. I looked at the switch and smoke was boiling out of it. Larry told me that I screamed loud enough to wake the dead."

"So you blew the finals out?" I tried to speak as gently as possible because I knew how she must feel. I can't say that I was enthused about the job that I was sure we would be doing in a few days.

"No, I don't think that the finals were damaged. I tried the transmitter into my dummy load and everything seemed okay. I even put it back on the air after taking the switch out of the line. It seems to have survived the ordeal in perfect shape."

I was both relieved and puzzled — relieved that her transceiver had not been damaged and puzzled at what had her so upset. "Huh? But if your rig wasn't damaged, what is it that is bothering you?"

For a minute it appeared that she was going to cry as she started talking about *it*. "It just frustrates me to no end. I thought that I was being so logical. Because of some past experience with CB accessories I knew that there was a good chance that the ratings were somewhat optimistic. Good grief, you'd think that something rated for 5 kW would handle at least 100 W. I guess the thing that has me the most upset is that I thought I had figured everything out for myself this time without having to ask you for advice. I certainly blew it this time."

"Take it easy on yourself. Your logic was absolutely right. Do you happen to have the switch with you?" I had noticed the brown bag when she came in. Come to think of it, I had noticed a slightly acrid odor just after she arrived. I'd even absentmindedly glanced around the room to see if I had trouble.

As she spoke, the pungent fumes permeated our house. I was surprised that my wife didn't call the fire department. Guess she is used to the odors of burning phenolic by now. "Gadzeus! That thing smells awful!" I wasn't joking. "Looks like the case is really some type of plastic. It sure looks like metal, but metal would not bubble like this."

Julie looked on as I removed the three screws that held the case together. Instantly, I spotted several things that were wrong inside. The layout suggested that it had been designed by a deranged gorilla. "Here is where your trouble started. This switch wafer — what's left of it anyway — is made of a phenolic material. It is okay for low level signals, maybe on the order of a few watts or so, but it would never take the rated 5 kW. Look at the layout. These leads must be six or eight inches long. Quiz time! How much is that in millimeters?" I asked.

She sat back and thought for a couple of seconds. "There's 25.4 mm per inch, so that should be 150 to 200 mm roughly." I told you she was my star Novice.

I used a pencil tip to point to one of the solder connections on the lug of an SO-239. "This looks like the culprit that actually did you in. Notice that now the wire is not even connected to the lump of solder on the lug. The black spot on the solder indicates that there has been some arcing. The dull coloring of the solder suggests that it was a cold solder joint to start with. Was the 10-meter antenna connected to this jack?"

She nodded in the affirmative so I continued playing Sherlock Ohms (sorry about that). "I would guess that the lead was touching the solder initially because the SWR was only 2 to 1. It would have been much higher if the connection had been completely open. At some point in your QSO, heat caused the wire to move slightly and break the contact, which led to the arcing at the contact. That would account for the hissing sound you heard. Part of the time, the only *antenna* connected to the rig would have been the switch wafer and connecting leads. This would have induced some heavy voltages or currents in the switch wafer. You are lucky that the switch went instead of turning your finals into *crispy-cridders*."

All that Glitters is Not . . .

Julie still looked depressed; her voice was weak and high-pitched: "Guess I should have looked inside this thing before buying it. I see what you mean about the poor workmanship now. I'm not sure that I would have known what to look for before. Come to think of it, I now know what should not be inside, but

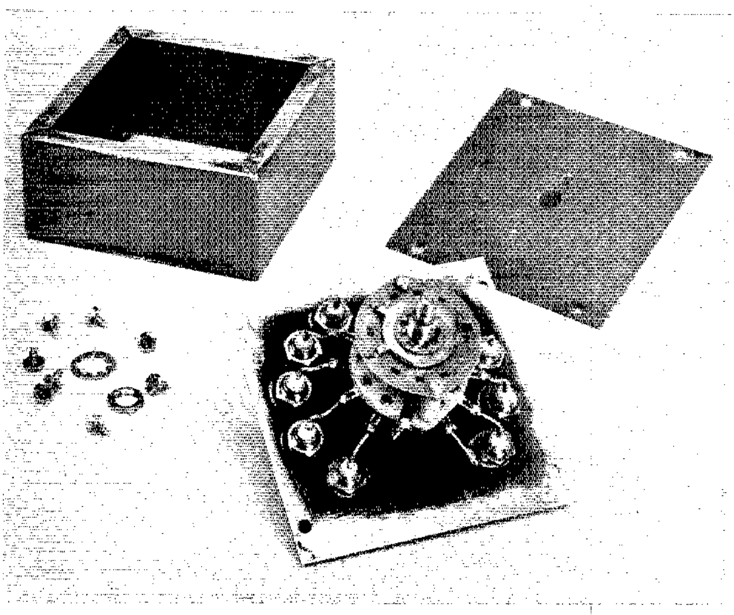


Fig. 1 — It's what's inside that counts.

I still don't know what *should* be there."

"I'm going to let you find out the same way I found out," I said as I reached for a small box on the shelf behind me. (That box is pictured on page 30.) I handed Julie the box, an Allen wrench and a screwdriver, but I didn't have to say one word. She quickly removed the set screw with the Allen wrench and pulled the knob off. I had been so busy thinking how smart I was that I had goofed.

"Julie, guess you will need this too," I said meekly as I handed her an adjustable wrench. She had the retaining nut off in seconds. After removing the four screws on the front, she was somewhat surprised to find that the switch did not come loose with the removal of the front plate. She is not one to spend time contemplating the whys and wherefors; she quickly removed the four screws on the back plate and pulled it away from the housing. (See Fig. 1.)

"Gee, this switch is different. What's it made of? Some kind of ceramic?" She answered her own question before I had a chance to say anything.

"Yes. It is a ceramic wafer with silver-plated contacts. Is that all you notice about it?" My challenge was accepted in an instant as she began analyzing it.

"Obviously, this switch has BNC jacks, but I would assume that any standard coaxial jack could be used. I believe you mentioned in class one night that you are partial to BNCs?" I merely nodded and let her continue without interruption.

"Compared to the Gargler, the lead length is quite short. With the exception of the lead connecting one jack located in the middle of the back panel to the top of the wafer, none of the leads are much over an inch long. Before you ask, that is about 25 mm, right?" She didn't have to ask. Smart aleck!

"Okay, the one long lead that's connected to the top wafer is the input. The rest of the lugs are on the bottom of the wafer and are connected to jacks. Whoops! One of the lugs is grounded. That doesn't make any sense." My sophisticated design had stumped her — well, it really isn't that sophisticated, but she couldn't see the bottom of the wafer clearly.

I handed her an unused wafer (Fig. 2). "Here, this wafer is identical to the one I used to build this switch. Notice that the top of the wafer has only one lug connected to it. The rotor on the top is an unbroken disk that always makes contact with the lug. Flip the wafer over to the bottom side. There are 11 lugs on this side. The rotor on this side is horseshoe shaped with a small rotating contact that is set between the ends of the horseshoe! Ten of the contacts always touch the rotating horseshoe while the small rotating contact always touches one of the stationary contacts. As you've probably guessed, the small rotating contact is electrically connected to the disk on the top side. Any idea of what you can do with the horseshoe portion?"

It didn't take her long to figure out the general direction of things. "Well, the horseshoe would short all the other antennas together and might reduce the interaction somewhat. All but the selected antenna would be at ground potential because one of the contacts is tied to ground."

"You are on the right track. Shorting them together might or might not affect the degree to which they interact. Because there is feed line separating the switch and the antennas, they probably would not be at rf ground."

Julie thought for a minute and said, "That still would make everything connected to the unselected jacks at dc ground." I nodded. She continued, "Wow! That would be great because that would mean you would be protecting your station from any lightning damage."

"Whoa! Slow down, young lady. Let's go back to our discussions of lightning in the class. Lightning is probably the most concentrated, violent and destructive force in nature. I don't know of anything that could sustain a direct hit and survive unscratched. If one of your antennas took a direct hit, chances are you would not find any of the antenna or feed line. In the process it would probably destroy most of the equipment in your shack whether or not it was connected to the antenna or whether or not the antenna was grounded at the switch. The only protection from a direct hit is to disconnect all cables and wires completely and throw them out in your yard every time a storm is brewing. For most people that is not very practical. But it is practical to stay out of the shack and away from the equipment during a storm."

"What will this switch do for me, then?" Julie was puzzled now.

"It should protect you and your equipment from the indirect or secondary hits. It should also protect you from voltages that can be induced in an antenna and feed line by nearby lightning strikes. It can also help dissipate static voltages that tend to build up. It can do a lot for your safety. Just don't ask it to do the impossible. Secondary or indirect hits account for most of the damage to amateur equipment that I know of. That grounded horseshoe helps in another way, too. It improves the isolation between the selected switch lug and the others."

"Where can I get the parts to make a switch like this?" Julie asked. That's what a salesman would call a buying

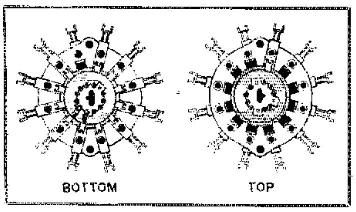


Fig. 2 — Top and bottom views of the Centralab switch wafer.

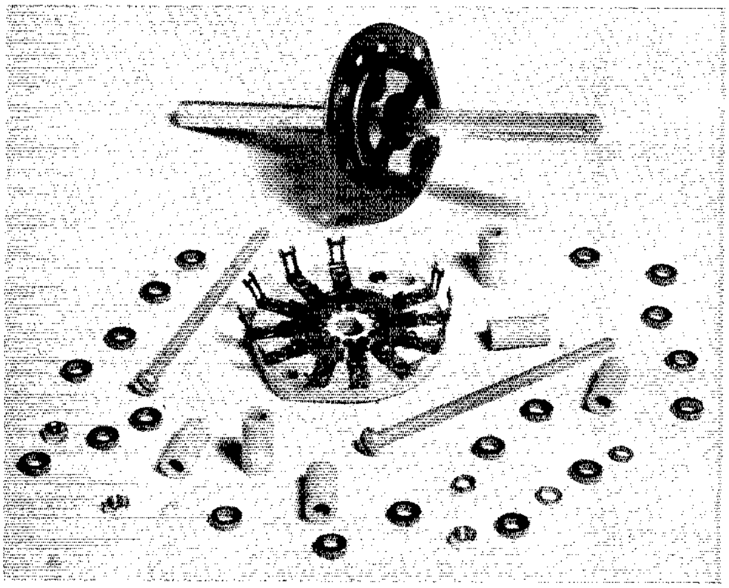


Fig. 3 — The switch wafer, mechanical index and associated hardware. It will be necessary in most cases to trim the length of both ends of the shaft of the mechanical index. This can be done with a hacksaw. Rough edges can be removed with a file or bench grinder.

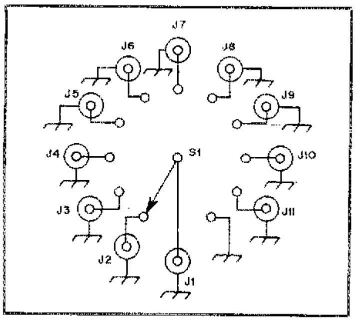


Fig. 4 — Simplified schematic diagram of the switch. (The grounded "horseshoe" of the wafer is not shown.) J1-J11 can be any type of coaxial jack of the builder's choice. S1 is a ceramic rotary switch (shorting) constructed from a Centralab FFD (1 pole, 11 position) "DD" Steatite and a Centralab P-270 mechanical index. The switch is housed in a Bud Aluminum Utility Cabinet (AU-1083-H.G.) which is 2 × 4 × 4 inches (51 × 102 × 102 mm). Any appropriately sized metal housing is acceptable as a substitute. Tests in the ARRL lab indicated that this unit provides at least 30 dB of isolation between selected and unselected ports at 30 MHz and somewhat higher levels of isolation at lower frequencies.

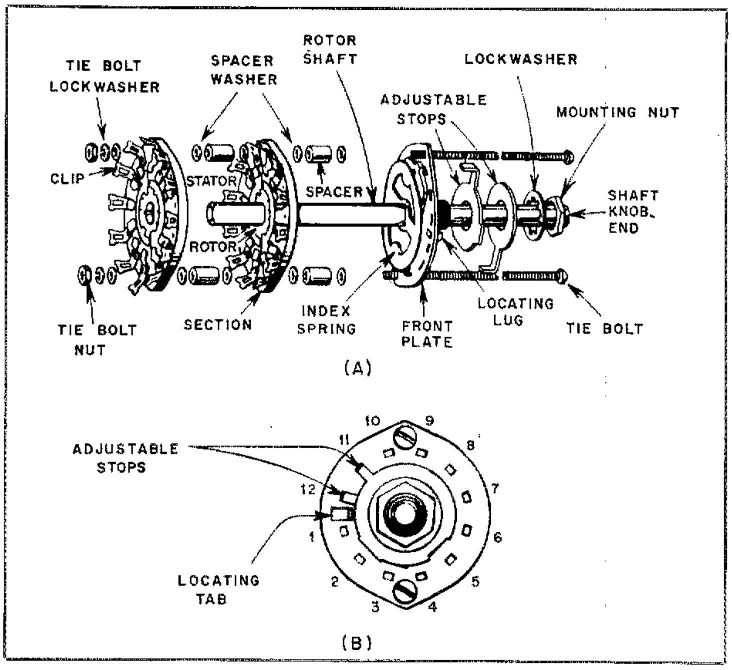


Fig. 5 — Assembly instructions for the Centralab switch wafer and mechanical index at A. More than one wafer may be stacked for complex switching requirements. At B, closeup view of the top of the mechanical index.

signal.[1]

"Centralab makes the switch wafer and the mechanical index which ensures that the contacts are always aligned. It is an old, reliable company that produces top notch parts. Here is the rest of the parts you will need for the switch." (See Fig. 3.)

Julie looked like a totally different woman than the one who had crawled in 30 minutes earlier. She was about to dash out and run for the soldering iron. "Slow down. Think this thing through before you plug in your soldering iron. What else do you need?"

"Let's see. I have five SO-239s that I picked up at the last flea market. I have solder and wire. Ooops, I only have five SO-239s and I need 11. And I need some sort of case to put it in. Guess I am jumping the gun, huh?"

I didn't want to do anything to extinguish her enthusiasm, because I am convinced that is the one quality that an individual needs to be successful at any endeavor. On the other hand, if I let her jump into the project blindly, without adequate preparation, the inevitable setbacks and delays could easily destroy her enthusiasm. "This Bud box is ideally suited for this project because the front and back come off so easily and give full access to anything mounted on either panel. You really should document anything that you build for your station. This is a schematic diagram of the switch (Fig. 4). It may seem silly, but should the need ever arise, a readily available diagram can save lots of time. Everything seems obvious now, but will it be obvious three years from now?"

Julie smiled, "Correct as usual, teach." I don't think she was aware that I often play baby-sitter for my four-year old grandson, who loves to watch *Mr. Rogers*. It is her whimsical way of retaliating against my occasional lapses into pomposity.

I pretended not to notice the jab and went on with my discourse, perhaps slightly more on the humble side. "Centralab provides this diagram with the mechanical index." (See Fig. 5.) "It shows the method for assembling the index and wafer. You can add a second wafer if you have something complex requiring more than one closure at the same time. A good example of that would be band-switching an amplifier or a transceiver. An antenna switch is much simpler and requires only the one wafer."

She nodded. I continued: "Perhaps the only tricky thing is assembling the wafer and index such that the locating tab is in the right position. I wasn't paying attention when I put this switch together and got the index and wafer 180 degrees off. It is no real problem. I just had to determine experimentally where to put the adjustable stops."

Whirlwind Aftermath

The look on her face told me that I had omitted explaining the adjustable stops. "Oh, I forgot to tell you about those, didn't I? The adjustable stops are the washer-like devices with the tabs on them. The tabs fit into holes in the top of the index and limit the switch rotation. If you have three antennas to switch now, limit the rotation to three positions. Later, if you add more antennas, you merely add another jack and move the adjustable stops. So you don't need 11 jacks just yet. How many do you need?"

"I have four antennas so I only need four jacks — ooops, I need five jacks because of the input line. Right?"

"Right! Very good. You could add a sixth jack and use one of the switch positions to select your dummy load. You are all set now. Any questions?"

Julie thought for a minute. "Yes. How did you find out what is inside an antenna switch?"

"Chuck Bender, the chief operator at W1AW suggested that I take one apart and look at it. Several years ago, he was replacing a defective switch at W1AW. He took it apart and found what was inside. Instead of replacing the whole switch, he replaced the wafer. Now he builds all the switches for the W1AW antenna system. This style of construction is fine for frequencies through 10 meters at legal amateur power into 50-Ω systems." She waved good-bye and dashed home for her soldering iron.

It took me a few minutes to collect my thoughts and return to testing my own project. That lady is like a whirlwind! QST

[1]The wafer, mechanical index and housing along with complete kits are available from Radiokit, Box 411Q, Greenville, NH 03048.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

FUME DISPOSAL FOR THE DESK FAX

☐ Back in 1976, I fell heir to some very excellent "burn-off" facsimile paper for weather satellite pictures.[1] Although the pictures were of high quality, the fumes from the arc irritated my respiratory system. I resolved this annoyance with the development of the fume-disposal unit described below.

My first effort to eliminate the fumes was satisfactory for operation with the 240-rpm GOES picture format but was unwieldy when tied to the TIROS-N real-time system described in August 1979 *QST*. With this system you must be able to obtain access to the little rubber roller hidden well beneath the Desk-Fax cover. Consequently, a new "in-line" disposal method (Figs. 1 and 2) replaced my initial disposal system.

This paper is almost identical to Xerox no. 3R830, obtainable in ream quantities from Xerox outlets.

At the heart of the arrangement in Fig. 2 is a Poly-Paks "turbo-jet" blower (cat. no. 92CU5871). It fits frictionally into the end of a coupling for 1-1/4-inch (32-mm) PVC pipe. Reaming the pipe to fit is done with a rotary rat-tail file inserted in an electric drill. After the fitting is completed, this coupling is clamped to a 3 × 3/4-inch (76- × 19-mm) galvanized strap that extends diagonally from the shelf originally occupied by the Desk-Fax transmitting light and a microscope. Existing screws are used.

In order to adapt the 1-1/4-inch brass fittings for coupling to the exhaust hose, a 1-inch (25-mm) PVC coupling will provide a loose fit that becomes tight when wedged with three toothpicks. To secure these picks in place I applied a small amount of Weldwood epoxy. At the other end of the coupling I cemented the female end of a 1-1/4-inch plated brass solder-type sink tail pipe.

A 6-foot (1.8-m) length of 3-inch (76-mm) dia dryer venting hose conducts the fumes away from the Desk-Fax. An empty 3-inch tomato can, with the ends removed, is placed at each end of the hose for interfacing. An appropriate diameter hole is cut in the end of one of the cans to accommodate a length of 1-1/4-inch (32-mm) diameter tail pipe which can be soldered in place with acid-core solder. This piece of tail pipe fits into the female end that is part of both versions of the Desk-Fax modifications. The other can is prepared in a similar manner except that, to reduce air friction, a 1-1/2-inch (38-mm) tail pipe is used.

Being able to vent the fumes outdoors is most desirable, but in some cases this may not be possible. An alternative is to force the fume-laden air through a filter consisting of a substance like kitty litter. Activated charcoal such as that used for aquariums could also serve for filtering out the fumes. Where the burn-off system is used, do provide a means for venting the fumes to protect your lungs. — *Lindsay Winkler, W7AVE, Walla Walla, Washington*

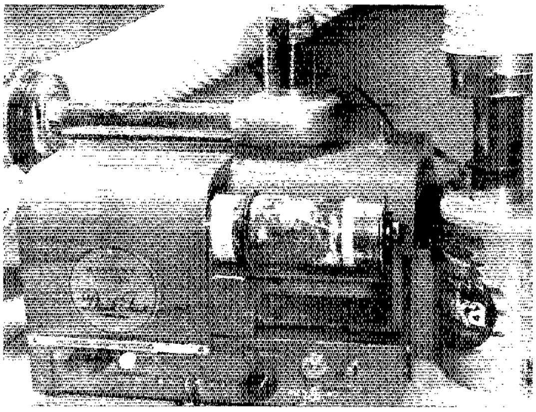


Fig. 1 — To avoid respiratory irritation from facsimile fumes, Lindsay Winkler, W7AVE, devised this exhaust system and that in Fig. 2. This system is for use with the 240-line GOES WEFAX picture system. A surplus blower forces the fume-laden air through the experimental absorption canister shown attached. For more than casual use a canister with less air resistance is needed.

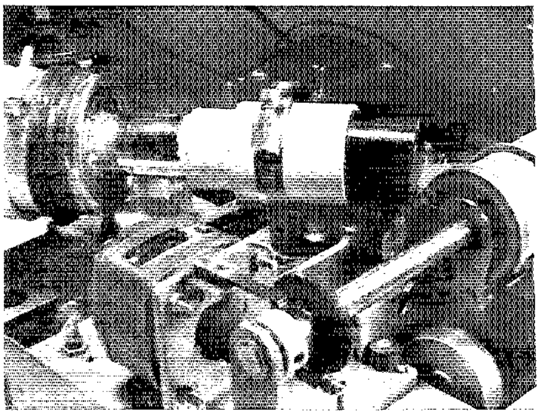


Fig. 2 — The W7AVE in-line fume disposer eliminates the use of the Desk-Fax cover, giving access to the little rubber roller and the "beheaded" screw. See Technical Correspondence, August 1979 *QST*, p. 43 for related information concerning orbiting NOAA satellites having the same picture format as TIROS-N. The blower shown above is adequate for outdoor venting but not for use with the canister shown in Fig. 1.

TR-7 SWR SENSOR PROBLEM CURED

☐ I've had my TR-7 since April of 1980 and have had trouble "talking myself off the air" on voice peaks. The SWR was within the prescribed limits of the owner's manual. It happened so fast that I couldn't see any reflected-power indication, and I became quite discouraged. It was suggested to me that I was experiencing rf feedback, with the peaks too rapid to observe on an SWR meter.

I made extensive checks and changed the ground system, with no results. Finally I decided to change my "Ultimate Transmatch" to the improved "SPC" version by W1FB in July 1980 *QST*. This did the trick! As a bonus, the TVI I previously had on my shack TVI-monitor receiver (channels 2, 3, 4 and 5) vanished! I am much happier with the SPC Transmatch.

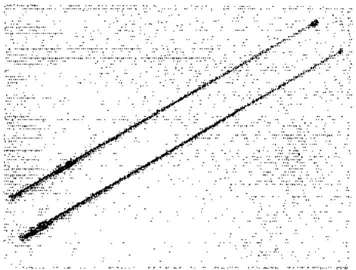
Another effect I noticed before the change was during "barefoot" operation with the TR-7, at which time the rf feedback was worse than when I operated the TR-7 through the SB-200 linear amplifier. This was also cured by changing to the SPC Transmatch. — *Clayton C. Gordon, W1HRC, Millbury, Massachusetts*

[Editor's Note: The TVI cure resulted from the higher Q and band-pass response of the SPC Transmatch, which was the purpose of the original design effort. It is difficult to say just why the rf feedback problem was cured by changing Transmatch circuits, but W8EEF of St. Joseph, Michigan, reported the same cure for his rf-feedback problem when converting from the Ultimate Transmatch to the SPC circuit.]

REPLACEMENT ANTENNA FOR S-1 AND S-5 HANDHELDS

☐ Occasionally I beat Mr. Murphy at his own game. I was quite annoyed when I broke the top section of the telescoping whip from my S-5 hand-held transceiver. Sally, KB1O (she says the rig belongs to her), insisted that I order a replacement. It so happened there were a couple of telescoping whips in my junk box. These

*Assistant Technical Editor



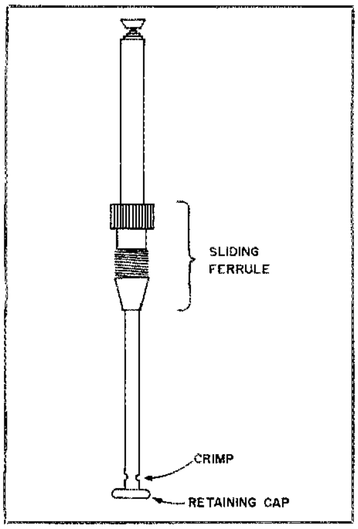


Fig. 3 — The photograph shows the similarity of the modified surplus antenna to the original Tempo antenna as described by Pete O'Dell, KB1N, in the accompanying text. Additional details are provided by the drawing.

had been acquired from Diamondback Electronics[2] for 79 cents each. A quick check revealed that these were exactly the same diameter and the same length as the original. (See Fig. 3.)

In the S-5, the whip slides up and down inside a ferrule that is threaded and mates with the body of the S-5. A retaining cap is crimped inside the bottom of the largest section of the whip to keep the ferrule from sliding off. A tubing cutter easily removed the bottom of the section containing the cap. I slid the ferrule off the original whip and installed it on the replacement antenna. A pair of diagonal cutters made short order of removing the retaining cap. The task was completed by inserting the retaining cap into the bottom of the whip and crimping it in place with the diagonal cutters. Gotcha this time, Murphy! — *Peter O'Dell, KB1N*

HIGH SB-401 PLATE CURRENT TRACED TO CATHODE RESISTORS

☐ Recently I reconditioned an SB-401 transmitter. The two corrections I made may be of interest and assistance to owners of such units.

First, the plate current (actually cathode current) appeared too high. With the transmitter fully loaded and correctly tuned, the plate-current reading was 400 mA instead of 220 mA. The cause of this turned out to be an increase in value of each of the six 10-ohm cathode resistors connected to the 6146 sockets. These resistors are denoted R7 through R13. All six measured anywhere from 14 to 21 ohms. New resistors restored the proper meter reading.

My second correction concerns neutralization. Even with the neutralizing capacitor (C23) fully meshed, true neutralization was not actually accomplished although the sensing meter had gone through a minimum at that point. The solution was the addition of a 10-pF fixed capacitor in parallel with the series fixed capacitor, C24 (7.5 pF), making a total capacitance of 17.5 pF in series with the variable neutralizing capacitor. The result of this was true neutralization occurring with C23 only half meshed. Possibly the 7.5-pF capacitor, C24, had decreased in value but there was no readily available way for me to measure it. Incidentally, operators should reneutralize the SB-401 whenever the 6146s are changed. — *Arthur H. Pedley, W2ZZG, Canajoharie, New York*

IMPROVED PL-259

☐ Until I tried the following modification, I always had trouble removing PL-259 connectors. The addition, shown in Fig. 4, provides better leverage and makes installation and removal of these coaxial connectors much easier. To make the elongated PL-259, begin by removing the sleeves from two PL-259s. Carefully align and clamp the sleeves together with the knurled portions at the outer ends. Solder the two ends together as shown in Fig. 4. After the metal cools, remove any extra solder. Be sure the joint is secure, then test assemble the modified connector. Attach the coaxial cable in the usual manner. — *Cecil D. Magargee, K3TUA, Sharpsville, Pennsylvania*

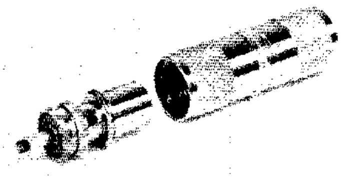


Fig. 4 — An elongated PL-259 can be made by soldering the sleeve portions of two connectors together as shown above. The elongated sleeve enables the operator to obtain better leverage when installing or removing a coaxial cable.

A FAST CHARGER AND REGULATOR FOR THE TEMPO S-1

☐ The fast-charger circuit in Fig. 5 is designed for the Tempo S-1 and S-2 transceivers. It can, however, be made to work with many other hand-held sets. It will power such equipment continuously in both receive and transmit modes while applying a tapered charge to the batteries that can bring a dead pack to full charge in less than an hour and then keep it on trickle charge. No modification of the S-1 is required. The current limiting protects the charger from the inevitable short that occurs as the charger is plugged into the S-1. (See Fig. 5.)

Use of a specially chosen pnp pass transistor (Q1) with low $V_{ce(sat)}$ characteristics allows proper regulation with input voltages as low as 12.3 V, such as might be found in a car when the engine is turned off. Do not install a substitute for this component. Furthermore, be sure to provide an adequate heat sink to ensure thermal stability. Q1 (Motorola TIP42 or equivalent) is available from Motorola MRO (formerly HEP) distributors.

The 14-pin DIP packaged 723 must be used and not the 10-pin unit. It is available from

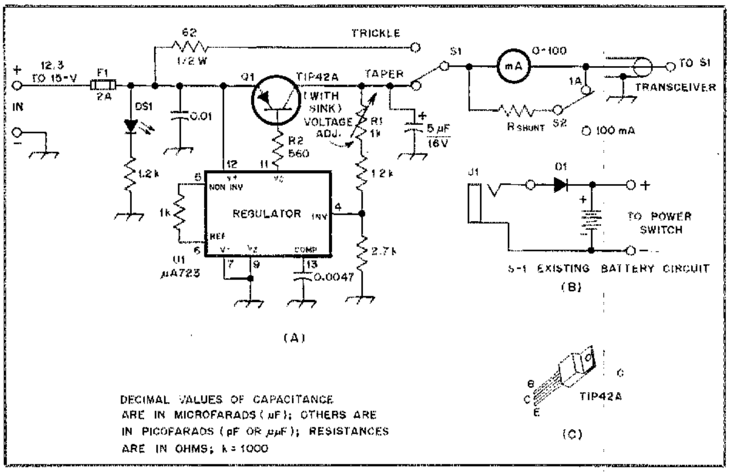


Fig. 5 — Circuit for the fast charger and regulator for the Tempo S-1. Author Joe Moell advises against substituting another transistor for Q1, a TIP42A with heat sink. All resistors are 1/4 watt except as noted. The Tempo S-1 battery circuit is shown at B. The terminal pins of the TIP42A are shown at C.

[2]Diamondback Electronics Co., Box 12095, Sarasota, FL 33578, tel. 813-953-2829. Antenna is part no. B-6311.

Radio Shack (no. 276-1740). Also Radio Shack's pc board potentiometer no. 271-333 is satisfactory for R1. Their no. 276-1363 heat sink will meet the needs of Q1. A nice, but optional, item is the LED indicator, DS1.

For the meter, choose one that has a 100-mA, full-scale movement and make a shunt of Nichrome wire or low-value resistors in parallel to give a switchable 1-ampere range. For best regulation, the unshunted internal resistance of the meter should be less than 2 ohms.

The diode in the S-1, which protects the pack from the momentary short when the charger is plugged in, has a voltage drop of 0.71 V at 25 mA. Therefore, R1 should be adjusted to set the unloaded output of the regulator (measured at the collector of Q1) at 1.43 V × 8 + 0.71 V, which equals 12.15 V. If you don't have a digital voltmeter, you can set R1 in the following manner: (1) Charge the pack with the trickle charger for 14 hours, then unplug it; (2) set the regulator output for 10 V, then connect it to the S-1 in the taper charge mode and slowly adjust R1 upward until the current meter indicates 15 mA.

To check the current limit, connect a 10-watt (or larger) 10-ohm power resistor to the regulator output. The current meter should indicate between 650 and 850 mA. If the indicated current is not within this range, change the value of R2. The value of R2 is not critical.

Depending on how you package the unit, rf can affect the regulator. If rf does affect the operation, install a 0.01-µF bypass capacitor at the input, another at the output and one directly across the 723 regulator supply pins 12 and 7. One of these is included in the diagram.

When using this charger/regulator circuit with other than Tempo hand-held sets, be sure there is a diode between the regulator and the battery pack to prevent damage to the regulator when the input voltage is off. Choose a diode with at least a 1-ampere rating, such as the 1N4001. With the added diode, the charger should work with the Kenwood TR-2400. Be sure, however, you are aware that the battery plug on this radio is "backwards," with the center pin grounded. ICOM has two NiCad packs for the IC-2: The standard one has seven cells and the higher power pack has nine cells. The seven-cell pack requires a lower regulator voltage setting. To accommodate the nine-cell pack, change R1 to a 2-kΩ potentiometer. The input voltage should be at least 13.7 V. Also, note that the two screws on the bottom of an IC-2 battery pack are connected directly to the + and − battery terminals. For this reason a charger stand is practical.

As a final word of caution, do not overcharge NiCads, even with a trickle charger. Unless the radio is in actual use, do not leave it connected to the charger for long periods after charging is completed. — *Joe Moell, K0OV/WA6JFP, Fullerton, California*

CENTURY 21 DRESS-UP

☐ The analog dial and meter faces of the Ten-Tec Century 21 may be made more eye-catching by attaching pieces of colored plastic in front of the cutouts on the subpanel. I used some red plastic (from a discarded box) that I cut to the proper sizes. Quick-drying epoxy, spotted around the perimeter of the plastic, is sufficient to hold it in place. The resultant coloring is quite appealing, especially in low ambient light areas.

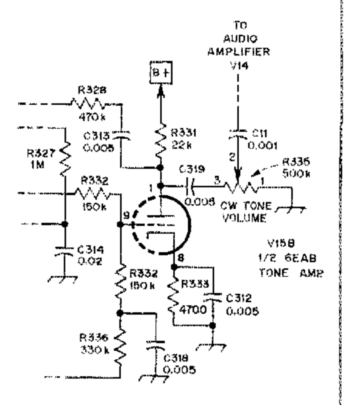
Some '21 owners may have found as I did that the ZERO-BEAT and SET DRIVE push buttons stick or become intermittent after a period of use. Replacement of the switches is the route to follow. Substitutions for the original switches may be found at the local Radio Shack store. Two types of switches are available — momentary contact types (275-618) like the originals or push-on/push-off (275-617). The type to use is a matter of personal preference. Some might prefer to use the push-on/push-off switch for the SET DRIVE control; it will maintain a key-down situation without the need for the operator to keep the button depressed during drive or antenna matching network adjustment. Aesthetically, the switches offer a contrasting red/black styling, which adds some pizzazz to the rather conservative gray/black front panel of the transceiver.

The knobs, control nuts and front panel must be removed to gain access to the switch mounting clips. Since these clips are difficult to loosen, it is easier to cut them off with a pair of diagonal cutters. The removal and replacement process should take less than a half hour. — *Paul K. Pagel, N1FB, ARRL Hq.*

REDUCING HW-101 SIDETONE VOLUME

☐ If the cw sidetone volume of your HW-101 is too loud, add this simple and inexpensive modification that was dropped by Heath when the product line was switched from the SB-101 to the HW-101. The circuit boards in the HW-101 still have the holes for the additional components to be added. No retuning is necessary. (See Fig. 6.)

Begin by locating the audio circuit board. Then remove and discard R326 (1 MΩ). Refer to your manual. Temporarily remove R336 (330 kΩ); it will be replaced later. Add C319 (0.005 µF/disc) as shown — this is Heath part no. 21-27 or Radio Shack no. 272-130.



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k = 1000, M = 1 000 000

Fig. 6 — Control of the sidetone volume of the HW-101 is accomplished with the addition of a potentiometer, as indicated in the diagram. Stan Smith, VE3IOI, provides the details in the text.

Next, add the volume control, R335 (500 kΩ), which can be Heath no. 10-149, Radio Shack no. 271-1723 or the equivalent. Mount the control from the foil side of the circuit board; space is available adjacent to R336. Be sure to solder the rear of the control cover to the foil. Have the shaft project up through the board. Replace R336 (330 kΩ) as shown. Then pack up, fire up and enjoy! — *Stan Smith, VE3IOI, New Market, Ontario*

ANOTHER APPROACH TO GETTING ON 10 METERS WITH A CB YAGI

☐ Several people advised me at the time I got my ticket in April 1979, to modify an 11-meter CB antenna for use on the 10-meter amateur band. Because I had not seen the WB3GCN antenna modification in March 1979 *QST*, I set about the task in a slightly different way than outlined by Mr. Inverso, but with equally satisfactory results. Luck assisted me in obtaining a very nice 11-meter, three-element aluminum Yagi from a dealer's dusty shelf for $30, and the project was launched.

The elements were shortened according to formulas in *The ARRL Antenna Book*. These state that the driven-element length in feet equals $475/f_{MHz}$, the director length in feet equals $455/f_{MHz}$ and the reflector length in feet equals $500/f_{MHz}$. Since the elements are composed of telescoping sections, the outer section was simply slipped inward slightly and firmly clamped by stainless steel, gas line clamps obtained at an auto parts store. These clamps also permit easy tuning of the elements as needed by loosening the clamps and altering element lengths.

Turning to the *Antenna Book* table entitled "Optimum Element Spacings for Multielement Yagi-Arrays," I found that the element spacing had to *increase* over the spacing distance the CB designer posted. Guided by the graph for spacing from the director to the fed element, I chose a spacing of 0.177 wavelength. This meant the element spacing had to be "blown open" about 5 feet (1.5 meters) over the CB design. An appropriate length of aluminum tubing, therefore, was bolted to the boom to lengthen it.

Information in the back of the *Antenna Book* indicated that the gamma match had to be moved out from 3-3/4 inches (95 mm) to 4 inches (102 mm), accomplished with the cutting of a couple of new straps.

With just simple tools the work can be done in an hour. Time for mounting is additional. The method of mounting is left to the builder.

Although placed deep among 100-foot (30-m) oaks and pines, the antenna really sparkles. On the first try the SWR ranged from 1.0 to 1.3, so it was left alone. West Coast reports jumped to consistent S-9s from previous S-6.

Amateur Radio has its foundation well set on experimentation and ingenuity. My hope is that this simple experiment will be of value to you, increasing your enjoyment of 10-meter operation. — *Dr. F. W. Shield, KA4HIP, Hampton, Virginia*

MARITIME ANTENNA FOR 2 METERS

☐ For some time I searched for a good 2-meter antenna for my boat. Requirements were simplicity, low SWR, insensitivity to location, a single mast without radials and resistance to corrosion. Simple coaxial antennas, as you

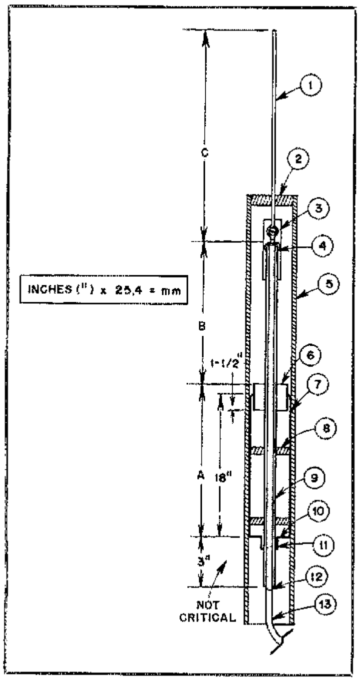


Fig. 7 — When Andy Griffith, W4ULD, operates maritime mobile from his boat, he maintains 2-meter communication with the help of an antenna made in the manner of the drawing. No special tools or materials are required to make this antenna. Identification information related to the encircled numbers of the drawing is as follows: (1) 3/32-in. (2.38-mm) stainless steel welding rod; (2) phenolic or Lucite disc waterproofed with windshield sealer; (3) phenolic or Lucite block; (4) coaxial cable shield soldered to copper tubing with center conductor soldered to lug attached to welding rod; (5) 3/4-in. (19-mm)[1] CPVC pipe, the length determined by the mounting system at the bottom and desired antenna height; (6) tuning sleeve made of brass shim stock soldered in place after adjustment; (7) 3/4-in. OD copper pipe or tubing wrapped with a small amount of tape at the top and bottom to fit snugly; (8) Lucite or phenolic spacing discs (four required) equally spaced; (9) 1/4-in. (6-mm) OD copper tubing; (10) copper disc soldered in place; (11) brass sleeve, 1/4-in. ID hobby tubing or made from shim stock with sleeve soldered in place after adjustment; (12) seal with windshield sealer and tape and (13) RG-58/U coaxial cable with the outer covering removed from the section inside the copper tubing (overall length is not critical).

know, have feed line and location problems. I knew from tearing apart a broken commercial vhf marine antenna that isolation of the feed line was accomplished by a 1/4-wavelength stub at the bottom. I tried this approach, but scaling the commercial antenna dimensions to 2 meters just wouldn't work with readily available materials. Neither did the use of conventional stub and antenna formulas help me to zero in on the three critical dimensions of A, B and C of the accompanying sketch. (See Fig. 7.)

Starting from scratch, I wound up with the 100% adjustable antenna shown in the drawing. The only difference between the prototype and the final antenna is the top half of the original version, which was made from aluminum ground wire with an adjustable sleeve over the top end. Also the experimental model was not enclosed in plastic pipe.

As you can see, the 1/4-wavelength stub at the bottom is adjustable with a sleeve in the top end. The length B is adjustable by sliding the 1/4-inch (6-mm) copper tubing through the sleeve at the bottom of the stub. The top half is adjustable as mentioned above. With all of these adjustments and an SWR meter, it took only 10 or 15 minutes to zero in on the proper lengths. During the tests, the antenna was mounted in a vise placed on a picnic table. The vise gripped the bottom inch of the stub. The minimum SWR at resonance (146.16 MHz) was 1.2:1. Bandwidth for a 2:1 maximum SWR appears to be ± 1 MHz.

With the antenna placed in the plastic pipe, the resonant frequency dropped slightly but came back to the desired frequency by nipping 1/8 inch (3 mm) from the top. The final dimensions for 146.16 MHz were:

A = 18-9/16 inches = 2713.1/f
B = 20-1/8 inches = 2941.5/f
C = 19-3/8 inches = 2831.9/f

where f = MHz, and millimeters = inches × 25.4.

The antenna works well on my boat. I have it mounted on an aluminum railing around the center console and held in place by two screw-type pipe clamps. By the way, no special tools are needed to make this antenna. The materials are common, everyday items available to almost anyone. I would add that an ordinary standard-size faucet washer can be substituted for the Lucite disc in the stub. — *Andy S. Griffith, W4ULD, Kinston, North Carolina*

[1] Plastic pipe sizes may vary from those on the labels. The 3/4-inch CPVC used for this antenna measured 7/8-inch OD (22 mm) and 21/32-inch (16.7-mm) ID, a good fit for the 5/8-inch OD stub.

BATTERIES IN THE FREEZER?

☐ The Hints and Kinks item by Glenn Jacobs, WB7CMZ, in January 1981 *QST* under "Extending Battery Life" is the exact opposite of extending life. According to information from the Union Carbide Corporation, batteries do freeze and may become useless if frozen for a period of time. The recommended temperature for maximum storage life is 40°F (4° C). So if you wish to store batteries for a long time, do so in your *refrigerator* — not in the freezer. In addition, be sure to wrap the cells in a plastic bag to prevent moisture formation while in the cold. These batteries should be allowed to warm up in the bag before being used. — *Jordan Kaplan, W9QKE, Chicago, Illinois*

EXTENDING THE HW-22A FREQUENCY COVERAGE

☐ Unfortunately the HW-22A does not cover all of the Advanced portion of the 40-meter band. A simple modification will allow coverage from 7125 to 7220 kHz. Lift the ground side of C205, which is across L6 (the VFO coil), and place an spst switch in series with it to ground. I mounted my switch immediately under the BIAS SET/OPERATE TUNE switch. A ground lug for this modification can be attached to one of the bolts holding the switch. With the switch open, the transceiver covers the frequencies mentioned above. With it closed, the HW-22A will cover the normal 7200 to 7300 kHz. This modification is based on the fact that the VFO operates on the high frequency side of the mixer. I replaced C205 with a silver mica capacitor of the same value as the original disc type (47 pF). — *Ev G. Taylor, W6DOR/W7BYF, Davis, California*

CHARGING NICADS FROM ELECTRICAL SYSTEM IN A CAR

☐ Often when using a battery-powered portable transceiver such as my Kenwood TR-2200A in my car, I have felt the need to operate simultaneously from the electrical system in the car and safely charge the internal NiCad battery pack. The circuit shown in Fig. 8 permits operation from the power system in the automobile, while at the same time providing a tapering charge for a 12 V NiCad pack. The circuit includes reverse voltage protection, a hash filter for transceiver operation, and a voltage and current regulator for NiCad charging. The output color markings are for the TR-2200A accessory cable. — *Leo Finkelstein Jr., WA4AOL, East Greenbush, New York*

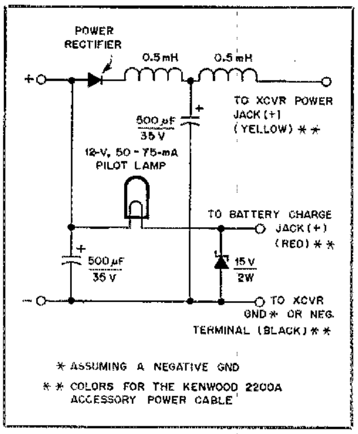


Fig. 8 — Leo Finkelstein Jr., WA4AOL, uses the electrical system of his car to charge his NiCad power pack with the help of this circuit. This arrangement is for use with a negative ground (*). The wiring colors at the right (**) are for the TR-2200A accessory power cable. The power rectifier should be rated at 50 V, 2 A.

DRAKE TRANSMITTER MODIFICATION JUST FOR VOICE OPERATION

☐ The "Hints and Kinks" column for November 1977 contains a suggestion by WA2YPO for improving VOX operation of Drake transmitters by replacing the 6EV7 with a 6AQ8. I did this and it works fine — *on phone*. On cw, with the 6AQ8, the VOX locks up and won't let go, regardless of the control settings. Those who use Drake transmitters on cw should *not* change the VOX tubes. Those working only phone (and missing half the fun of ham radio!) can switch tubes and get improved performance — but *only* on phone! — *Roy Williams, W6VON, La Mesa, California*

Technical Correspondence

Conducted by
Jerry Hall,* K1TD

The publishers of QST assume no responsibility for statements made herein by correspondents.

INSTALL RADIALS AND PROTECT YOUR VERTICAL ANTENNA AGAINST UFOs

□ I had a technical problem that was beyond my grasp; I was unable to make any contacts on 40 meters. I used a low-cost vertical antenna that is advertised in *QST*, and my ground system was a single ground rod. My SWR indicator showed 1.3:1, and with an antenna tuner I could adjust it to a near-perfect match. However, my field-strength meter showed no output, even though my wattmeter indicated 100 watts! I wrote to ARRL Hq. for help.

The reply suggested I first go outside and look up in the sky to see if a UFO was above my house and sucking up all the 40-meter energy. Then some helpful suggestions were given about the sensitivity of my field-strength meter versus frequency, bad connectors, bad coax and so on. Finally, this tip was offered: Shortened (loaded) verticals without radials are rather inefficient, and there was a possibility that most of my 40-meter energy was merely heating up the earth.

In order to check this last suggestion I epoxied an ordinary general-purpose diode to my ground rod (at a point just under the ground). I waited a day to be sure the temperature had stabilized. I also placed a second diode in the ground as a control (at a considerable distance from the antenna system). I measured the forward resistance of both diodes. Then I went to the radio room, tuned, loaded and called CQ. After receiving no reply I went outside to measure the resistance of the diodes. The control diode showed negligible change, 0.1 Ω but, lo and behold, the diode at the antenna showed a decrease of 3.2 Ω. This told me that the ground *was* heating up (diode resistance decreases with an increase of temperature). Possibly this test could be of help to other amateurs.

Installation of radials *did* restore 40-meter operation. At least now I can stop running outside and looking for that UFO above my antenna. — *Rick Collins, KA8IVZ, 287-1/2 E. State St., Montrose, MI 48457*

EXPANDING THE "NONLINEAR" TO 21 AND 28 MHz

□ After our article appeared,[1] we received several inquiries about the feasibility of using the amplifier on 15 and 10 meters. We have not tried it; however, the MRF476 transistors are designed for CB service and will perform as rated through 10 meters. It will be necessary to add the appropriate filter for each additional band. Table 1 gives values for 15- and 10-meter filters, based on data taken from Wetherhold.[2]

There have also been inquiries regarding band switching for the Universal Transmitter.[3]

[1]DeMaw and O'Dell, "The Basic 'Nonlinear' Amplifier," February 1981 *QST*, page 40.
[2]Wetherhold, "Low-Pass Filters for Amateur Radio Transmitters," December 1979 *QST*, page 44.
[3]DeMaw and Shriner, "Transmitter Fundamentals," December 1979 *QST*, page 11.

*Technical Editor, *QST*

Table 1

15- and 10-Meter Component Values

Band	C1, C4	C2, C3	L1, L3	L2
15 m	100 pF	240 pF	0.486 μH, 11 t. no. 20 enam. wire on T50-6 core	0.588 μH, 12 t. no. 20 enam. wire on T50-6 core
10 m	68 pF	160* pF	0.323 μH, 9 t. no. 20 enam. wire on T50-6 core	0.388 μH, 10 t. no. 20 enam. wire on T50-6 core

*160 pF is not a standard value. Connect two or more standard-value capacitors in parallel to total 160 pF, e.g., 10 pF plus 150 pF. All capacitors should be either silver mica or polystyrene. The inductors are wound on Amidon or Palomar toroid cores as indicated.

This is certainly a possibility. It requires addition of a four-pole switch (two poles for the input and two for the output of the PA) with the appropriate number of positions. Use miniature RG-174/U coaxial cable to connect the filters to the switch. For those desiring to know more about the filters, we suggest consulting Wetherhold,[4] the *ARRL Electronics Data Book* and chapters 2 and 6 of *The Radio Amateur's Handbook* for 1981. — *Doug DeMaw, W1FB, and Peter O'Dell, KB1N, ARRL Hq.*

WHEATSTONE BRIDGE SWR INDICATOR

□ The fascination of VSWR for hams is endless, and no issue of a ham magazine seems to be complete without a description of some VSWR-measuring instrument. All of them certainly are worthy, but by far the cheapest, simplest and most easily constructed device has been neglected. This is the simple Wheatstone bridge, first described in *QST* in the 1950s and appearing in a few subsequent *Handbooks*. See Fig. 1.

The Wheatstone bridge was described in *QST* primarily as a null indicator, but it can be calibrated directly in VSWR. Commercial versions of the Wheatstone bridge are used up to 3 GHz. There are two constraints on the use of a Wheatstone bridge as a calibrated VSWR meter. First, all measurements must be made at the same power level. Second, the signal source must have an impedance of 50 Ω.

The first constraint is easily satisfied by either short-circuiting or open-circuiting the "unknown" terminals and adjusting the applied power for a full-scale reading. This is also a good test for how well the bridge has been built; with no "unknown" connected, the meter should indicate full scale whether the terminals are open or shorted.

The second constraint precludes the use of a grid-dip meter as a signal source. However, even a moderately priced signal generator (the kind having a calibrated step attenuator) will be close enough to 50 Ω to give accurate results.

[4]See footnote 2.

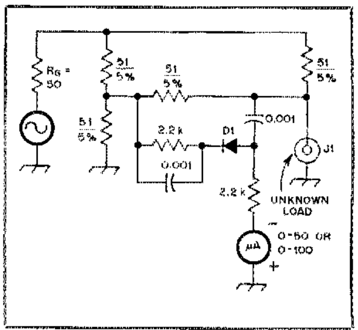


Fig. 1 — The Wheatstone bridge circuit for rf. Resistances are in ohms (k = 1000) and capacitances are in microfarads. See text regarding 51-Ω resistors.
D1 — Germanium small-signal diode, 1N34A or 1N270 or equiv.
J1 — Rf connector of builder's choice.

Either selected 51-Ω composition resistors or 51.1-Ω film units (1% tolerance) may be used. Both types have negligible reactance up to the low vhf region. As with any bridge, construction and layout are all-important. The bridge is calibrated in the normal manner, by connecting known resistances across the "unknown" terminals. — *Harry R. Hyder, W7IV, 1638 W. Inverness Dr., Tempe, AZ 85282*

HUMAN-ENGINEERING THE SWR INDICATOR

□ Since using an aircraft blind-landing indicator in the IMI,[5] I have received many letters discussing the use of special meters in common SWR bridges. This is a summary of those discussions.

The special meter I used is not suitable for the ordinary SWR bridge. Many SWR bridges use only one meter. I believe two meters, one for "forward" (FWD) and one for "reverse" (REV) power, greatly increase the convenience of the bridge. In one form, Fig. 2A, two good-sized meters are nicely balanced on the front panel of the indicator. The ideal 1:1 SWR is indicated with the meter pointers in the position shown. However, during tune-up the meters will swing in the same or different directions. Ideally the FWD will reach full scale while REV goes to zero. Scale switches, wide-spaced meters and pointer movements cause eyestrain.

Use of a combined meter, such as a surplus stereo "level" meter, brings the movements closer together. Replacement of the scale switch with ganged FWD and REV sensitivity potentiometers improves convenience greatly (Fig. 2B).

Note that for a given power level, the connections of the pot cause both meter pointers to rotate in the same direction as the pot knob. Tuning changes may still cause divergent

[5]Geiser, "The Impedance-Match Indicator," July 1980 *QST*, page 11.

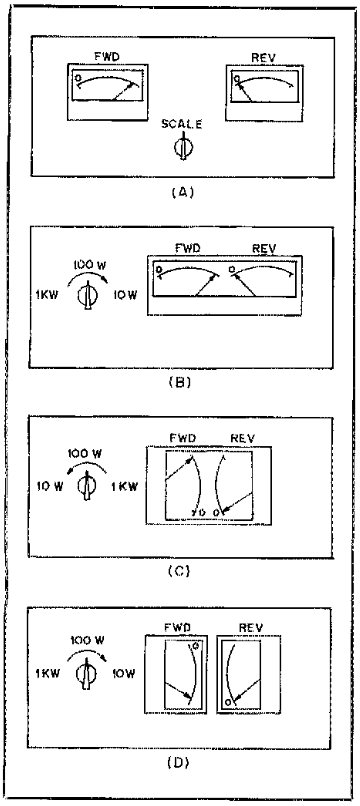


Fig. 2 — At A, a common arrangement of separate forward and reverse power indicators in an SWR instrument. The zeros at the left of each scale indicate the zero-current or resting position of the pointer. Note that a 1:1 SWR is indicated with the meter pointers as near to each other as possible. At B, the use of a small stereo-level meter allows the user to pay more attention to both pointers. The sensitivity pot permits FWD adjustment to full scale. At C, a vertical stereo meter makes meter pointers diverge. Common meters oriented as shown at D seem to make SWR adjustment more natural. Some users prefer this layout upside-down, as it then gives an agreeably positive (upward) deflection for a 1:1 SWR.

meter-pointer movement, but the closeness of the meters makes this less annoying.

Some stereo balance meters have vertical scales with bottom zero. The meter scales are close, but the desirable 1:1 SWR separates the meter pointers as far as possible (Fig. 2C). Reversing both sets of pot connections allows the FWD meter to rotate in the same direction as the pot shaft, but the REV meter moves (properly) in the opposite rotation but same direction (up or down).

Rotating the tops of a pair of conventional zero-left meters toward each other (Fig. 2D) seems to be the most acceptable arrangement. As tuning proceeds, the adjustment pot is rotated clockwise from its counterclockwise position and the FWD pointer follows it: The goal of tuning is to bring both pointers to the lower ends of their scales. Practically, the user seems to develop an urge to keep the pointers together. Pointer divergence resulting from tuning the antenna or matching network in the improper direction soon creates an irresistible sense of wrongness and encourages proper tuning. The foregoing are personal observations and opinions not necessarily supported by any psychological or statistical studies.[5] — *David T. Geiser, WA2ANU, ARRL TA, R.D. 2, Box 787, Snowden Hill Rd., New Hartford, NY 13413*

PORTABLE QUAD FOR 2 METERS, PART 2

☐ Since publication of my article on the portable quad[1] I have received letters from several readers who have built the antenna, and there appears to be room for improvement in the SWR characteristics. Unfortunately, when I built the antenna I did not have an SWR bridge suitable for use at vhf. Consequently, I relied on data from various publications (*The ARRL Antenna Book*, *The Radio Amateur's Handbook*, and the *World Radio News* article referenced in my article). These publications indicate that quad driven elements may be excited directly by RG-58/U coax (50-Ω

[5]Two useful references to the results of systematic human engineering design are *MIL-HDBK-759 Human Factors Engineering Design for Army Materiel* and *MIL-STD-1472B Human Engineering Design Criteria for Military Systems, Equipment and Facilities*. I do not represent that these references support the above note.

[1]Decesari, "A Portable Quad for 2 Meters," September 1980 *QST*, page 26.

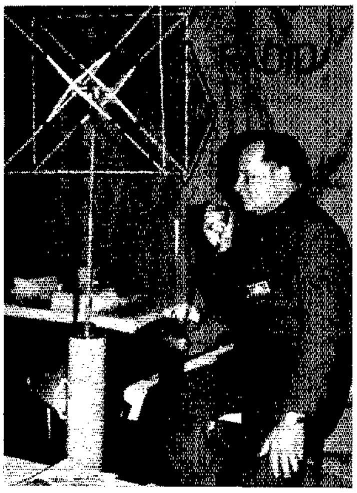


Fig. 4 — Irv Neitlich, N1ATS of Stamford, Connecticut, displays his portable 2-meter quad constructed from Decesari's *QST* article. (In the background is the ARRL booth at the Hudson Division Convention in South Fallsburg, New York.) Immediately after Irv completed the antenna, he fired up his 1-W hand-held and proceeded to access a repeater in Pennsylvania, 65 miles (105 km) away, across hilly and wooded terrain. (*Photo courtesy of K1TD*)

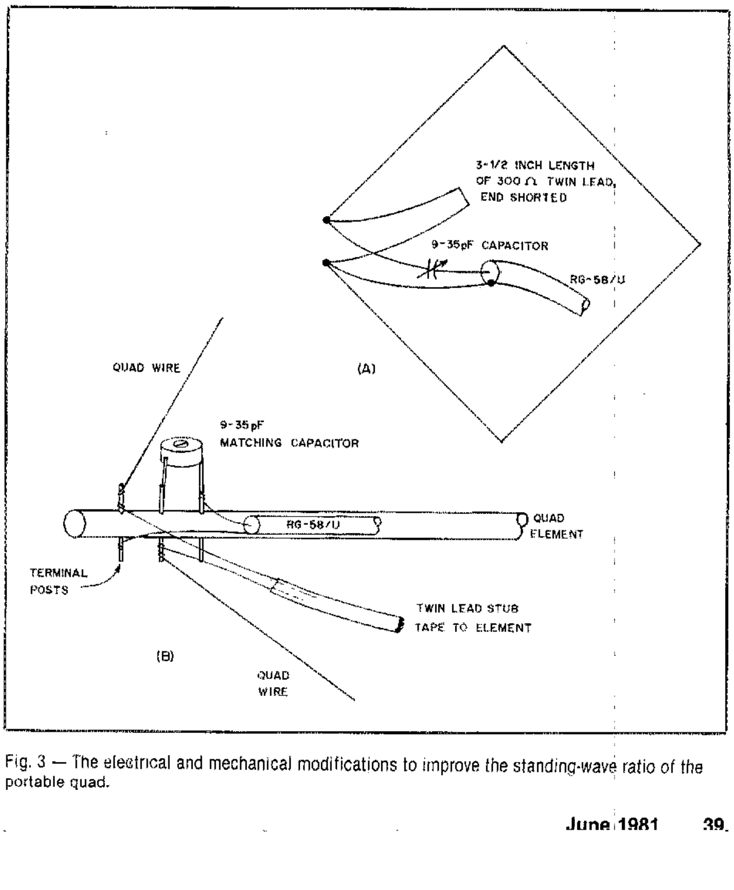


Fig. 3 — The electrical and mechanical modifications to improve the standing-wave ratio of the portable quad.

impedance), thereby implying that a satisfactory impedance match may be obtained. However, the quads built by various readers exhibited typical SWR values of about 3:1.

After receiving these reports, I investigated further. According to the 21st edition of the *Radio Handbook* by Bill Orr, W6SAI, the feed-point impedance of the basic quad loop is about 140 Ω. The value will change somewhat with the addition of a reflector or director element, but it is not really close to 50 Ω. This mismatch would account for the higher SWR readings with the original antenna design.

What is needed, therefore, is an impedance-matching device at the antenna feed point. A 3.5-inch (90-mm) length of 300-Ω twin-lead may be used as a stub and a 9- to 35-pF variable capacitor may be connected in series with the feed line. Fig. 3 illustrates the arrangement. The capacitor is adjusted for minimum SWR, typically 1.5:1 or better.

Mechanically, an additional mounting post is added to the quad element support to permit mounting and soldering the capacitor. The 300-Ω stub may be simply taped to the support, along with the coax line. Although the quad will work well as described in the article (see Fig. 4), improved electrical performance can be obtained by matching more closely. — *Bob Decesari, WA9GDZ/6, 3941 Mt. Brundage Ave., San Diego, CA 92111*

NONPOLARIZED CAPACITORS MADE EASILY

☐ Hams have always been a resourceful lot, often able to improvise and come up with good results. It is in this tradition that I offer the following information for obtaining otherwise hard-to-get values of nonpolarized capacitors, particularly in the tens or hundreds of microfarads range.

It is probably well known that you can make your own nonpolarized capacitors by connecting two equal values of electrolytics back to back, as shown in Fig. 5A. So long as both units maintain their electrical integrity, this is a fine solution. When C1 sees its correct polarity, it offers a low-impedance path to current, thus shunting C2 and preventing C2 from seeing otherwise potentially destructive values (pun intended) of wrong-polarity voltage. When alternating current is applied, the roles of the two capacitors are reversed on each half cycle.

Bear in mind that although this seems to be a parallel connection of capacitors, actually it is not. Current flows first in one, then in the other, so it is not a true parallel connection; the total effective capacitance is the same as that of an individual capacitor. Furthermore, as a rule of thumb, the ac working voltage should be kept below about 0.7 times the dc working voltage rating of the capacitor. For a 450-wVdc electrolytic, applications with 315 V ac should be the top limit. Also, because of the nature of electrolytics, do not operate them far below their rated voltage. For example, if your ac requirement is around 30 volts, don't use 450-V capacitors; select ones with a 50-wVdc rating.

Perhaps now comes a surprise. You can also "roll your own" nonpolarized capacitors by connecting two units in series. Again they work one at a time, so they are not series connected functionally, and the total capacitance is that of the individual unit. The previous remarks about voltage rating apply here as well.

Note the circuit of Fig. 5B. Considering terminal A to be positive, D1 blocks the path to the negative end of C2 while D2 conducts and

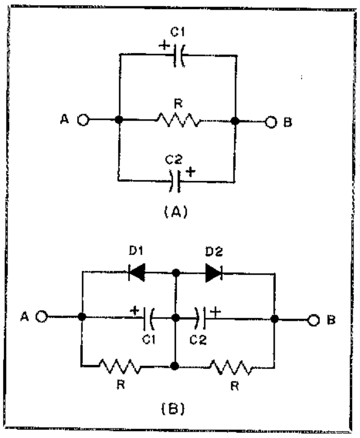


Fig. 5 — At A, a nonpolarized capacitor made by connecting two electrolytic capacitors back to back, and at B by connecting them in series.
D1, D2 — Polarity-guarding diodes, silicon rectifier types suitable.
R — Bleeder resistor; 100 kΩ to 470 kΩ, depending upon the active potentials; 1- or 2-W rating.

shunts C2. Both actions protect C2, which otherwise is presented with reverse polarity every other half cycle. The opposite components do their thing on alternate half cycles.

Both circuits do the same job, but the circuit of Fig. 5B is attractive for two reasons. First, extra protection is afforded by the blocking and shunting diodes, and second, this circuit permits you to make use of electrolytics having a common negative lead — something not possible with the arrangement of Fig. 5A.

Bear in mind that if you use the metal-can electrolytics, the can is "hot" — so take due steps to insulate it or to stay clear of it. There is not such a problem with the tubular cardboard-enclosed capacitors with pigtail leads.

A practical application for these capacitors is in the typical antenna rotator, where a nonpolarized capacitor feeds the drive motor. If it loses capacitance, as all do eventually, the drive motor will not develop proper torque. Operation will be sluggish, or perhaps the rotator won't work at all in a really sad case. Rather than having to special-order a capacitor, you can make your own. — *A. W. (Bill) Edwards, K5CN/MM, Radio-Electronics Officer, R/V Knorr, Woods Hole Oceanographic Institute, Woods Hole, MA 02543*

MODIFICATIONS FOR THE PLESSEY IC RECEIVER

☐ In the April 1981 *QST* article, "Receiving with Plessey ICs," author DeMaw mentioned that an abnormal amount of 120-Hz hum was present in the receiver audio, as well as an agc lockup problem in the presence of strong signals. These remarks were based on the performance of a receiver that I built in the ARRL lab. A recent letter from coauthor Chadwick suggested two circuit changes to correct these anomalies.

The hum may be reduced by removing the 270-kΩ resistor from pins 1 and 5 of the SL6310, and replacing it with a 150-kΩ resistor in series with a 120-kΩ resistor. The junction of the two resistors is bypassed with a 2.2-µF electrolytic capacitor to ground. In the original receiver circuit, a 100-µF electrolytic capacitor is connected from pin 12 of the SL6700 IC to ground (the capacitor was accidentally left out of the lab-built receiver and *QST* schematic). This capacitor should be replaced by one with a value of 4.7 to 20 µF to eliminate the agc lockup problem. These modifications were tested in the ARRL lab, and receiver performance was exceptional with no noticeable hum or agc lockup. — *Gerry Hull, AK4L, ARRL Hq.* QST

Feedback

☐ The May 1981 Product Review of the Kenwood TR-2400 2-meter transceiver incorrectly stated that 12 of the 16 keys of the keypad function as a Touch-Tone generator. Actually, all 16 keys (digits 0 through 9, *, #, and the standard A, B, C and D signaling tones) perform a particular Touch-Tone function.

☐ With reference to Royle's article, "SSTV in Colour," November 1980 *QST*, Tom V. Segalstad, LA4LN/W3, points out that the deck (those lines in large type beneath the title) and a photo caption are misleading. The wording implies that color SSTV is brand new, when in fact it has been around for years. Tom mentions that one of the earliest long-distance 2-way color SSTV contacts was made between LA2BK in Norway and LA2PH/MM in the China Sea south of Japan, a distance of 5000 miles (8000 km), on August 7, 1973. Monitoring of the received color picture involved the taking of a triple-exposure color photograph of a red, a green and a blue color frame as received and viewed on an ordinary black-and-white SSTV monitor. An appropriate color filter was placed in front of the camera lens for each exposure. Upon development of the color print, the image could be viewed in full color. The Royle article described the first long-distance 2-way color contacts monitored by electronic methods.

☐ In "Results — 1980 Simulated Emergency Test," April 1981 *QST*, the Southwest CW Traffic Net was listed incorrectly under Arkansas. The net should have been listed under Arizona/New Mexico. The ARES report for Rockdale and Newton Counties should have been included with the local activity report from Georgia, not Alabama. The adjusted totals for these two ARRL sections are Georgia — 560, Alabama — 2045.

☐ In "Results, 1980 ARRL November Sweepstakes," May 1981 *QST*, ABØS (plus KØWA), with a final score of 233,988, should have been listed as the top multioperator station on the phone portion of the Sweepstakes. ABØS should also have been listed as the phone multioperator winner in the Midwest Division.

☐ The call sign of Ray Dumas should have read WA1BPG instead of WB1BPG as listed in April 1981 *QST*, "Silent Keys."

☐ In the "W1AW Schedule" in April *QST*, page 94, UTC Slow Code Practice should read Sn; 0200 rather than S;0200. QST

Product Review

Conducted By Paul K. Pagel,* N1FB

Yaesu FT-707 Transceiver

Do good things still come in small packages? Well, with respect to the FT-707, that old saying could be considered noteworthy depending upon one's point of view — objective, subjective or a little bit of both.

Our review model arrived at Hq. in late October of 1980, just in time for this writer to bundle it up and carry it to Tortola, British Virgin Islands, for a two-week "hamcation" as VP2VGT. It was definitely the proper size for traveling by air after packing it into a portable electric typewriter case along with a keyer, paddle, microphone, antenna wire, coaxial cable and some hand tools. The parcel fit handily under the seat of the 727 jet. The power supply was carried in another suitcase and made the trip in the belly of the plane.

Long Bay Hotel on Tortola proved to be a good testing ground for the FT-707, because the temperature ranged from 75° F (24° C) at night to 95° F (35° C) in the daytime giving the internal cooling fan plenty of exercise whenever the heat sensor actuated it. The fan noise was minimal, but audible, and was considered acceptable in the interest of protecting the transistors in the power amplifier. Also the ac line voltage on the island ramped from as low as 95 to as high as 125 depending on the peak demand at various times of the day. The transceiver continued to operate properly, except for a drop in output power during periods of low line voltage. There were no noticeable effects from the salt air and high humidity respective to overall performance.

We didn't realize it when we left Connecticut, but that particular FT-707 did not contain a cw filter (an accessory). A fair amount of nail biting followed, since 90% of the operation was to be on cw! Fortunately, the FT-707 has an i-f width control, which varies the passband from approximately 300 Hz to 2.4 kHz. This feature made it possible to obtain sufficient selectivity for cw reception, and the problem was solved. It would have been much better, however, to have the 350- or 600-Hz accessory filter installed for enhanced skirt selectivity and ultimate rejection. Both filters are available from Yaesu — so is an i-f filter for a-m reception.

The only anomaly we observed during the two weeks of vigorous operation with the first unit (serial no. OFO20793) was VFO drift. From a cold start to approximately two hours later, the drift was roughly 1.5 kHz. It was gradual enough after the first 15 minutes to pose only minor problems. A second FT-707 (serial no. OJO80841) was obtained after we returned to the USA, and it drifted in a like manner. Scattered reports of substantial drift were also received from owners in the field. We checked this out with Yaesu, and were told that there was no case history problem with drift. We were sent a third review unit, and it drifted only 10 Hz (measured at the antenna jack, key down, 25 watts of output). The test period was one hour long. Close inspection of the VFO interior revealed no evidence of circuit changes

or "customizing" of the third review unit. Perhaps the later FT-707s contain different compensating capacitors in the VFO, or the drifting units simply had defective capacitors.

The FT-707 receiver exhibited good dynamic range during the VP2VGT operation. There was no IMD or overloading evident from the strong Region 2 commercial stations to the south of us. Even more dramatic was the ability of the receiver to function satisfactorily when W8JUY/VP2VGW and the reviewer operated the same band (one on cw and the other on ssb). The two stations were only 30 ft (9.1 m) apart and the antennas were even closer. Of course, there were IMD products and hash in the receiver, but no cross-modulation or high-order desensing was noted.

FT-707 Features

The operating modes are ssb and cw, with a rating of 100 watts output. There is also an a-m mode, for which the output power is specified as 50 watts. Frequency readout is by means of a digital display, but analog readout is also provided.

The S meter uses a string of LEDs, illuminating left to right in accordance with the incoming signal strength. Green, yellow and red banks of lights indicate different regions of signal strength. We had fun giving out signal reports such as, "you're Q5 and S red." The LED "meter" also indicates relative power output and the alc level during ssb operation. There is a built-in speaker, noise blanker, RIT and crystal calibrator. The VOX controls are located on the front panel for easy access.

One can purchase the FP-707 ac-operated power supply as an accessory. It delivers 13.5 volts dc and has a built-in speaker. Another accessory is the synthesized outboard VFO (FV-707DM), which has 12 memory channels. The resolution is 10 Hz. When using the YM-35 mating microphone and FV-707DM synthesizer, the operator can shift the frequency up or down by means of QSY buttons on the microphone — ideal for mobile operation. Yaesu also sells an FC-707 mating Transmatch. The entire setup can be mounted in a special

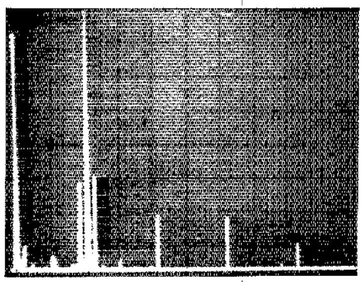


Fig. 1 — Worst-case spectral output of the Yaesu FT-707 operating at 10.1 MHz. Vertical divisions are each 10 dB. Horizontal divisions are each 5 MHz. Worst-case harmonic output is approximately 61 dB down from the fundamental. Worst spurious output is approximately 49 dB down from the fundamental. The Yaesu FT-707 complies with present FCC specifications for spectral purity. All measurements were taken in the ARRL lab.

*Assistant Technical Editor

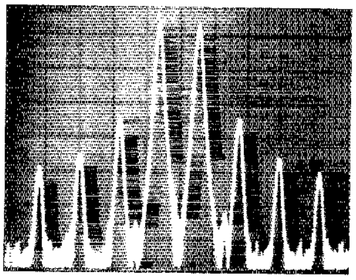


Fig. 2 — Spectral photograph of the two-tone, third-order transmitter IMD characteristics of the FT-707. Vertical divisions are each 10 dB; horizontal divisions are each 1 kHz. Third-order IMD products are down approximately 34 dB from the PEP level, and fifth-order products are down approximately 44 dB. Each tone is 6 dB below the PEP level.

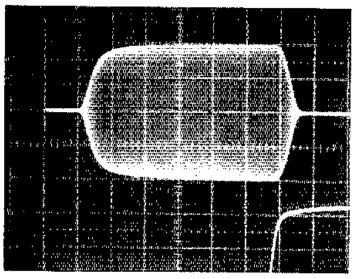


Fig. 3 — Cw keying waveform of the FT-707. The partially visible lower trace is the switching waveform at the key jack, and the upper trace is the output envelope. Output is generated approximately 5 ms after key closure. Good rise and fall times as indicated produce a clickless wave.

Yaesu FT-707 Transceiver Serial No. OJ100772

Manufacturer's Claimed Specifications	*ARRL Lab Measurements*
Frequency coverage: 80-10 meters, inclusive of WARC bands.	As specified plus approx. 60 kHz on low ends of bands and 10 kHz on high end of 80 m. 150 kHz or more on high end of remaining bands.
Readout: Analog and digital.	As specified.
Resolution: Analog — 1 kHz; digital — 100 Hz.	As specified.
KHz, one turn of knob: Not specified.	15
Backlash: Not specified.	Nil.
RIT/XIT range (kHz): ±3	−3 to +3.5
I-f width control: 300 Hz to 2.5 kHz.	As specified.
Receiver attenuator: None.	—
S-meter sensitivity (μV/S9): Not specified.	80 m — 30; 40 m — 27; 30 m — 27; 20 m — 40; 17 m — 45; 15 m — 45; 12 m — 45; 10 m — 71.
Receiver sensitivity: Ssb/cw — 0.25 μV for 10 dB S/N; a-m — 1.0 μV for 10 dB S/N.	Dynamic range measured with optional 600 Hz i-f filter installed.

	80 M	20 M
MDS (dBm):	−126	−127
Blocking DR (dB):	noise limited	noise limited
IMD DR (dB):	77 lo 76 hi	83 lo 80 hi
3rd-order input intercept (dBm):	−10.5 lo −12.0 hi	−1.5 lo −6.0 hi

Manufacturer's Claimed Specifications	*ARRL Lab Measurements*
Audio power output (4 ohms): 3 watts.	As specified. Quality good.
Power consumption: At 13.5 volts dc, 20 A (transmit) and 1.5 A (receive).	Not measured.
Transmitter power output (watts): Not specified. Input: 240 watts for ssb and cw; 80 watts a-m.	80 m — 135; 40 m — 120; 30 m — 120; 20 m — 120; 17 m — 120; 15 m — 120; 12 m — 125; 10 m — 125.
Spurious suppression: At least 50 dB.	Approximately 49 dB (see spectral photograph).
Harmonic suppression: Not specified.	>60 dB
Transmitter two-tone, 3rd-order IMD: At least −31 dB.	−34 dB. See spectral photograph.
Key-down limitation: 30 seconds with a 2-minute pause between key-down periods.	Not measured.
Frequency stability: 300-Hz drift over 30 minutes after 10-minute warm-up; then 100-Hz drift after 30-minute warm-up.	10-Hz drift from cold start to 1 hour later. Measured at antenna jack with transmitter key down, 25 watts output.
Size (HWD): 3-5/8 × 9-1/2 × 11-5/8 in. (93 × 240 × 295 mm).	As specified.
Weight: 15 lb (6.5 kg).	Not checked.
Color: Two-tone gray.	As specified.

mainframe that is available from the manufacturer.

Other Considerations

No mention of use with an external amplifier is found in the instruction book, and two letters to Yaesu inquiring about the use of outboard amplifiers elicited no response. There are no terminals available for actuating the T-R circuitry of an outboard amplifier. It appears, however, that the operator could connect an external 12-V relay in parallel with the FT-707 VOX/PTT relay for use in controlling a separate amplifier.

The three WARC-sanctioned amateur bands (10, 18 and 24 MHz) are included in the 80-through 10-meter coverage of this transceiver. *Warning: The U.S. Government has yet to authorize amateur use of these bands!*

The FT-707 appears to be an excellent unit for mobile operation and field use. It can serve nicely as a home-station transceiver as well, and should appeal particularly to those who favor compact equipment. — *Doug DeMaw, W1FB*

THE KLM KT-34XA TRIBAND YAGI ANTENNA

□ When one thinks of the usual triband antenna, a vision of compactness and compromise generally comes to mind. Not so with the KLM KT-34XA. This antenna is a direct descendant of the KT-34A (a KT-34A to XA conversion kit is available for $225). For a tribander, the '34XA is big: It weighs 68 pounds (31 kg), has a longest element length of 24 feet 8 inches (7.5 m), a 3-inch (76-mm) diameter, 32-foot-long (9.6-m) boom (braced by means of overhead cables) and a projected wind surface area of 9 square feet (0.84 m^2). The turning radius is 21 feet 6 inches (6.5 m), and KLM rates the antenna at a 4-kW capability and a wind survivability of 100 mi/h (161 km/h). A full-sized, 10-meter element has been added as has another tri-resonant element. There are now six working elements on 10 meters and five elements on 15 and 20 meters. KLM suggests that suitable rotators may include the TR-44, Ham M types, HD and KR-400.

Assembly

If your usual plan for antenna erection is from box to tower in one day, forget it! It took about an hour to open and empty the single carton and check the contents against the parts list. There are *many* parts. Approximately 25 hours were required to bring the antenna to the

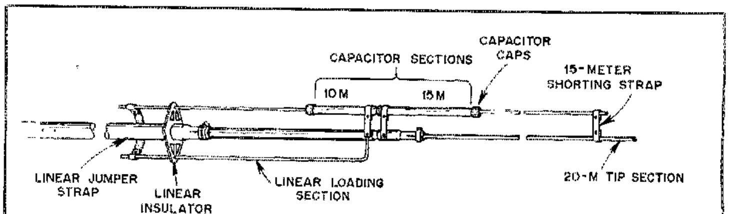


Fig. 4 — A tri-resonant section of the KT-34XA antenna. There are two of these sections in each of five elements. The sixth element is a separate 10-meter director.

point where it was ready for the final test. The excellent instructions include fully detailed drawings of each step of assembly. They are, without a doubt, the best instructions I've seen supplied with any antenna. There are no ambiguities, and it would be difficult to imagine anyone having a comprehension problem despite the antenna complexity.

The hardware is aluminum and stainless steel, with the exception of the cadmium-plated U bolts. This antenna is first class, from nuts to bolts.

The KT-34XA is fed by means of 50-ohm coax through a 4:1 balun (supplied). Transposed aluminum straps are used to drive the second and third elements from the rear, out of phase with respect to each other. The design permits full coverage of 15 and 20 meters and optimized 10-meter coverage from 28 to 29 MHz for the DXer. (Measurements at W1SE indicated the SWR rising only to 1.8:1 at 29.3 MHz.)

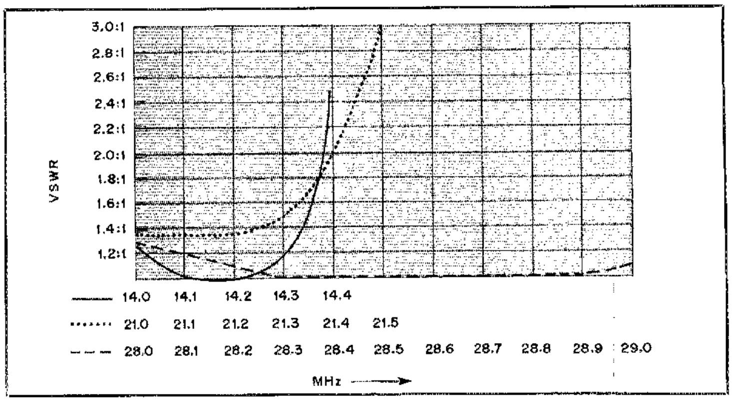


Fig. 5 — SWR curves of the KLM KT-34XA triband Yagi antenna.

Testing

After assembly, following the final test on a short mast, it was necessary for me to partially disassemble the right side of the elements and to remove the elements from the boom. (Marking element lengths and their position on the boom with an indelible marker is a great time saver.) Everything was then taken to the other side of a small brook, over which my tower folds. Here the boom was installed on the tower mast, and the left side of the elements were mated with the boom. The tower was then raised progressively to permit the installation of the right side of the elements. At the point where the top of the mast was approximately 13 feet above ground, the antenna was high enough to permit the insertion of the right-side element tips. Following this, the tower was brought erect, and the installation was complete. Depending on tower type, one could be faced with a different set of circumstances in the final mounting of antenna to tower. At W1SE, the antenna is 60 feet (18.3 m) above the earth.

The first SWR measurements were a disappointment. The SWR at the low end of each band was 2:1 or more. Discussion with KLM disclosed that they had made a change in the plastic material used to form the concentric tubing capacitors in each element. It turned out the plastics supplier had not given them all the information on the characteristics of the plastic. Subsequent changes that KLM made in the plastic material, after the design was "frozen," brought about changes in the resonant frequencies. Changes in the SWR resulted at the most desirable points. KLM did, however, recognize its responsibility to provide kits containing new plastic caps, several larger pieces of aluminum tubing and a new set of instructions and assembly measurements. The old plastic caps are black, while the new ones are off-white and UV resistant.

The antenna was subsequently removed from the tower, the tri-resonant sections disassembled, then reassembled with the new hardware, and the entire erection procedure repeated. Fortunately, this was all during the late summer and early fall; at least we beat the New England winter!

Results

The KT-34XA has now been in use for several months, and extensive operations have been conducted on each band. Operating "barefoot," this reviewer has been able to crack countless DX pileups, frequently with only a second or third call, on both ssb and cw. The number of responses to "first-time" calls has been very gratifying.

Repeated, careful observations at W1SE appear to indicate good gain, front-to-back and front-to-side ratios. Signals that arrive at a high angle will, of course, reduce these ratios. On those occasions, however, when the band is either just opening or closing and the angle of signal arrival is lowest, the ratios appear greatest, and the true performance of this antenna is realized. The KT-34XA triband Yagi antenna is manufactured by KLM, 17025 Laurel Rd., Morgan Hill, CA 95037. Price class: $570. — *Lee Aurick, W1SE*

ICOM IC-551 6-METER TRANSCEIVER

□ Do you remember the excitement of working DX on the 50-MHz band back in cycle 19 or 20? During those days the standards of comparison were such rigs as the Drake TR-6 and the Heath SB-110. As the sun cranks down after a flurry of activity during the peak of cycle 21, many new DX achievements have been made on 6 meters, and no doubt the ICOM IC-551 played a role in helping vhf operators reach their goals. The size and complexity of the '551 make it light-years ahead of the older tube-type transceivers, yet costs less than, for example, the Drake TR-6 (relative to 1960s prices).

Compact, portable and versatile are the catchwords to describe this transceiver. Operating modes include ssb (both upper and lower sideband), cw, a-m and fm with an optional fm board installed. Frequency control is accomplished by means of two built-in digital PLL VFOs, sharing a common tuning dial. The VFOs may be selected separately, or each used

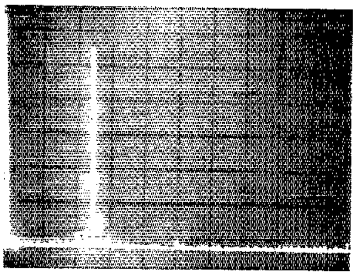


Fig. 6 — Worst-case harmonic and spurious output. At 10 watts output all spurious outputs are at least 63 dB down. Vertical scale is 10 dB per division. Horizontal scale is 20 MHz per division. The tall pip at the extreme left of the photo is the spectrum analyzer zero reference. The IC-551 complies with current FCC spectral purity requirements.

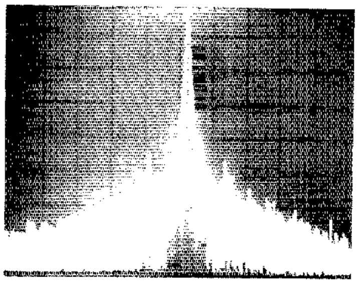


Fig. 8 — Single-tone, narrow-band spectrum of the IC-551. The excessive noise around the carrier is probably from noise generated in the synthesized local oscillator. Vertical scale is 10 dB per division. Horizontal scale is 2 kHz per division.

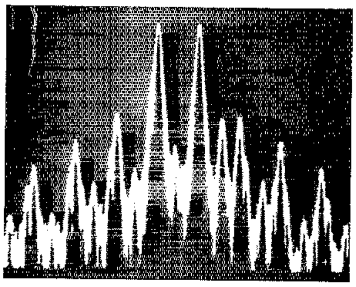


Fig. 7 — Two-tone, third-order IMD spectral photograph of the IC-551. Each tone is 6 dB below the rated PEP output. The test tones are 700 and 1900 Hz. Vertical scale is 10 dB per division. Horizontal scale is 1 kHz per division.

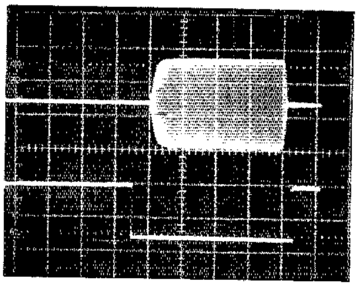


Fig. 9 — Rf envelope and switching waveform of the IC-551. Horizontal divisions are 5 ms. Rise time is approximately 1.5 ms and decay time 1.0 ms. There is 2.5 ms delay between key down and the start of the rf envelope. This waveform will produce key clicks.

ICOM IC-551 Transceiver Serial No. 01575

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: 50-54 MHz.	As specified.
Modes of operation: Ssb/cw/a-m/fm	As specified.
Readout: 6 digit, fluorescent-blue digital display.	0.25-in. (6.4-mm) digits.
Resolution: 100 Hz on ssb, cw and a-m; 1 kHz on fm.	As specified.
KHz/turn of knob: Not specified.	On ssb, cw and a-m: selectable, 5 or 50; on fm: 50 or 500.
Backlash: Not specified.	Nil.
RIT range: ± 1 kHz.	± 1 kHz.
S-meter sensitivity (µV/S9): Not specified.	50.01 MHz, 3.9; 53.9 MHz, 3.
Receiver sensitivity: <0.5 µV for 10 dB S + N/N ratio.	Noise floor (MDS) dBm: − 134 Blocking DR (dB): 108 Two-tone third-order IMD DR (dB), high (h) and low (l) products: 82(l), 81 (h). Third-order input intercept: − 11 (l), − 10 (h).
Audio power output (8 ohm load): More than 2 watts.	1.5 watts.
Power consumption: Receive: Dc — 1 1 A; Ac — 41 W Transmit: Dc — 3.3 A; ac — 98 W	Not measured.
Transmitter rf power output: ssb, cw, fm — 10 W, a-m 4 W.	Ssb, cw, fm — 11.4 W, a-m — 4 W.
Spurious suppression: Better than 60 dB.	63 dB.
Carrier suppression: Better than 40 dB.	Not measurable because of in-band noise.
Third-order IMD: Not specified.	− 34 dB (see spectral photos).
Key-down time limitation: Not specified.	No excessive heating noted at 10 W output for 1 hour.
Frequency stability: < ± 500 Hz for 60 min, <100 Hz per hour thereafter.	140-Hz drift from cold start to 1 hour later at 5-W cw output.
Size (HWD): 4.3 × 9.5 × 12 in. (111 × 241 × 311 mm).	
Weight: 13.4 lbs. (6.1 kg).	
Color: Black.	

as a transmit or receive "remote" for split operation. Popular frequencies may be programmed into three memories available to the user. The memories may be recalled by means of a front-panel switch, or monitored by means of a built-in scanning function. Scanning may also be used to search for signals contained in a specific frequency block. The user selects the frequency block by storing the upper and lower frequency limits in two of the three internal memories.

Other features include dual-speed tuning, an electronic dial lock (useful for mobile operation), fast or slow agc speed selection and RIT. Optional equipment included with the review unit was the VOX unit, the fm unit and the passband-tuning/rf-speech-processor unit.

Some Highlights

A unique feature of modern transceivers is the use of microcomputers to control the frequency selection circuitry and so forth. The IC-551 is no exception. It uses a microcomputer to control its two VFO circuits, the scan and memory functions, and the frequency display. The microcomputer in the radio is a dedicated device: in other words, the user can "program" it only by use of the front-panel controls.

The '551 is one of the first amateur transceivers to use a switch-mode power supply. A switch-mode power supply differs from the standard power supply in that it operates at a much higher frequency than the 60-Hz line. This allows the inductors in the supply to be very small, resulting in high efficiency.

I would suggest that the prospective or new owner sit down and read the instruction manual thoroughly before firing up the rig. Without reading it you will be able to operate the '551, but no doubt you will miss some of its unique functions.

Performance

On-the-air operation with the '551 was a pleasure, with a few exceptions. The receiver performed well in the presence of strong signals — W1AW is just 3/4 mile (1.2 km) from the reviewer's QTH — and the sensitivity was adequate except for the most demanding weak-signal work. (Jacks are provided for the addition of an external preamplifier.) There is no fixed attenuator in the receive line, but the rf gain control provided enough range for the signals encountered. When the review unit was first operated in the ssb mode, the transmitted audio reports received were very poor, and the passband tuning unit did not function properly. Tests in the ARRL lab confirmed that a problem existed. The unit was shipped to ICOM, and within a few weeks it was returned with defects corrected. According to ICOM, it had been misaligned and had a few bad components. Further checks with the unit operating in the SSB mode resulted in good audio reports being received, but distant stations could not see any signal improvement with the rf speech processor turned on. A-m operation can be quite difficult to use because the transmitted a-m is actually lower sideband with carrier (A3H), and during receive the unit is in the lower sideband SSB mode. This results in having to zero beat the received a-m carrier, but is a problem only if the a-m station is using older gear that tends to drift.

When using the '551 in the cw mode the operator may select either semi-break-in (VOX) or manual transmit/receive switching. The RF POWER control varies the cw output power, which is useful for trying QRP operation. No cw filter is included with the unit, and there are no provisions for the addition of a filter. Nearby stations reported that the keying of the IC-551 sounded very hard and produced clicks in their receivers. Tests in the ARRL lab confirmed the reports. The keying waveform is shown in Fig. 9. When informed of the keying problem, ICOM America told us they would look into the problem, but we have, to date, received no circuit modifications.

One glitch was found in operation during memory scanning in the SSB mode. If two frequencies separated by more than 1.5 MHz (such as the 50.110- and 52.525-MHz ssb and fm calling frequencies) are loaded into memory and you wish to scan these frequencies, you may experience a problem. The frequency synthesizer randomly does not lock quickly when jumping over a large frequency range. The receiver then "cracks" audibly because of the excessive lock-up time, and this "crack" causes the squelch to open, halting the scanning. This can be quite annoying.

The optional fm unit worked well, and audio quality on both transmit and receive sounded very good. During fm operation the S meter serves a dual purpose — as a signal strength meter and as a zero-center discriminator meter.

Overall, I am pleased with what ICOM has done with such a small package. An optional i-f cw filter would have been nice. On this model ICOM left out the remote frequency-control provision, which makes computer interfacing difficult. Those amateurs who are just gaining an interest in the vhf bands, or old-timers looking for a new 50-MHz rig, should take a serious look at this piece of equipment — not just as a 6-meter radio, but as a tunable i-f for the higher frequency bands. The IC-551 is available from ICOM dealers throughout the U.S. and Canada. In the U.S., the manufacturer's address is: ICOM East, Inc., Suite 307, 3331 Towerwood Dr., Dallas, TX 75234. Price class: IC-551, $480; VOX unit, $55; fm adapter, $105; passband tuning and rf processor, $105. — *Gerry Hull, AK4L*

New Books

☐ *The Art of Electronics*, by P. Horowitz, W1HFA, and W. Hill, published by Cambridge University Press, 32 E. 57th St., New York, NY 10022. Hard-cover edition, 7-1/4 × 10 inches, 716 pages, $24.95.

Paul Horowitz is well known among amateurs for his expertise in circuit design: He developed an amateur-built cw keyboard keyer described in August 1965 *QST*. He is a professor of physics at Harvard University. His co-author, Winfield Hill, is president of Sea Data Corporation.

The authors have demonstrated clearly that a technical book does not need to be saturated with lofty terms, stilted narrative and "yard-long" equations in order to fit the measure of much of today's professional writing. *The Art of Electronics* gets immediately to the point in simple language for each subject treated. It contains the most lucid narrative that this reviewer has found in any similar professional volume in recent years. The presentation of theory and application is not unlike that in *The Radio Amateur's Handbook* (ARRL). In fact, this book would serve nicely as an extension of the *Handbook*. Furthermore, exercises, provided throughout the text, serve as a learning and testing aid. D. Larson of the University of Virginia said that the text of this book "succeeds in taking the student from very close to zero knowledge of electronics (or even electricity) to a point where he would be considered fully knowledgeable, and perhaps even an expert, by typical researchers in the physical sciences."

The book contains 14 chapters, 11 appendices and 44 tables. Chapter 1 covers *E*, *I* and *R*; signals; capacitors and ac circuits; inductors and transformers; impedance and reactance; diodes and other passive components. Chapter 2 deals with basic transistor circuits. Chapter 3 treats feedback and op amps. Active filters and oscillators are discussed in chapter 4. The list goes on and on as one advances through the book. For example, thorough discussions are given on the subjects of power circuits and regulators, FETs, low-noise techniques, digital electronics, digital interface to analog, microcomputers and electronic construction methods. In chapter 13 the authors address the subjects of high-speed and high-frequency techniques, while measurements and signal processing are covered in chapter 14. Each chapter subject has many subheadings and texts that deal with the many facets of overall chapter titles.

This book is highly recommended to amateurs who want to learn modern circuit techniques. It is also an excellent course book for those wishing to teach electronics. You may want this volume in your Amateur Radio library. — *Doug DeMaw, W1FB*

☐ *Seven Steps to Designing Your Own Ham Equipment*, by L. B. Cebik, W4RNL. Published by Howard W. Sams & Co., Inc., Indianapolis, Indiana. Soft cover, 6 × 9 inches, 218 pages plus index, $9.95.

In the last few years political pundits have been fond of saying that the most oppressed group in the United States is the middle class — the rich have no money worries and can afford to pay for anything that they might need, while the poor have no money and the government will take care of their needs. The middle class is left to fend for itself on an insufficient income. Of course, such a statement is a gross oversimplication; however, there is enough truth to it for it to have become a popular cliche.

An analogous situation exists in Amateur Radio. Electrical engineers already know the basics of design and need little help with it. The technically inept appliance operator lets the professional engineer supply all technical information and consideration for him. Heaven help the ambitious, enthusiastic hobbyist who is not a professional engineer but who does not wish to be relegated to the ranks of the appliance operator or perennial kit builder! It is to this audience that L. B. Cebik has addressed *Seven Steps to Designing Your Own Ham Equipment*.

The main purpose of the book is to give the reader a practical *method of thinking* that will result in successful home-designed and -built equipment. This is a "how-to" book on developing a philosophy for dealing with a technical subject, as opposed to being a "how-to" book on a technical subject. Although the book is chock full of schematic diagrams of everything from simple audio oscillators to computers, it is unlikely that anyone would build a circuit from this book. The diagrams are there for instruction, not construction.

Cebik takes the reader from base zero through the final stages in logical, well-laid-out steps. Those beginning design work must first collect a large number of ideas and thoughts. Cebik shows how to go about doing so, but more importantly he shows how to organize and keep them so that the reader can get maximum use from them. The author has included a great deal of information designed to help the reader get maximum benefits from his limited time.

Once the information has been gathered, Cebik feels that the next step is setting goals for the particular piece to be designed. Logical, well-thought-out plans come next. What parameters are important in any given circuit? What aren't? How does one go about logically approaching the layout stage? What is the difference between a good layout and a bad one? Which building techniques will work best? What portion of the circuit should be built first? Why test? Why document? Cebik answers all these questions and more.

Some people (particularly theory-oriented engineers) may disagree with Cebik's seat-of-the-pants approach, but I have found it to be quite useful. I would recommend this book to anyone who wants to build and design, but who has been intimidated by the awesome complexity of modern electronic technology. The little guy in the middle asks, "How do you eat an elephant?" Cebik answers, "One bite at a time. Here is a knife and fork." — *Pete O'Dell, KB1N*

QST

July 1981 $2.50

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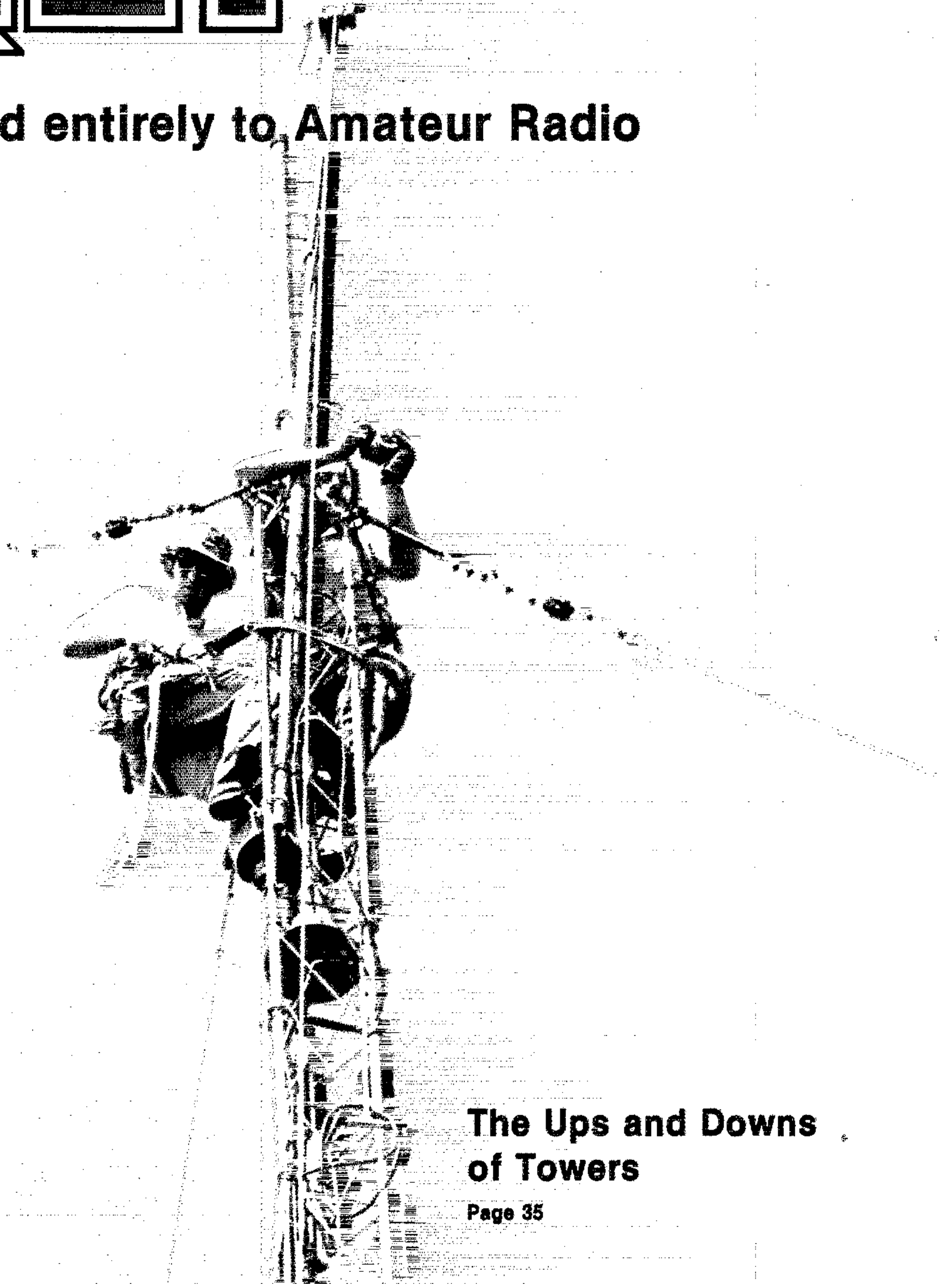

The Ups and Downs of Towers

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ARRL

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July 1981 Volume LXV Number 7

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THE COVER

A tower will bring many years of good operating — if you know the right way to put it up, and if you can protect it from restrictive ordinances. See pp. 35, 48 and 50. (K1WA photo)

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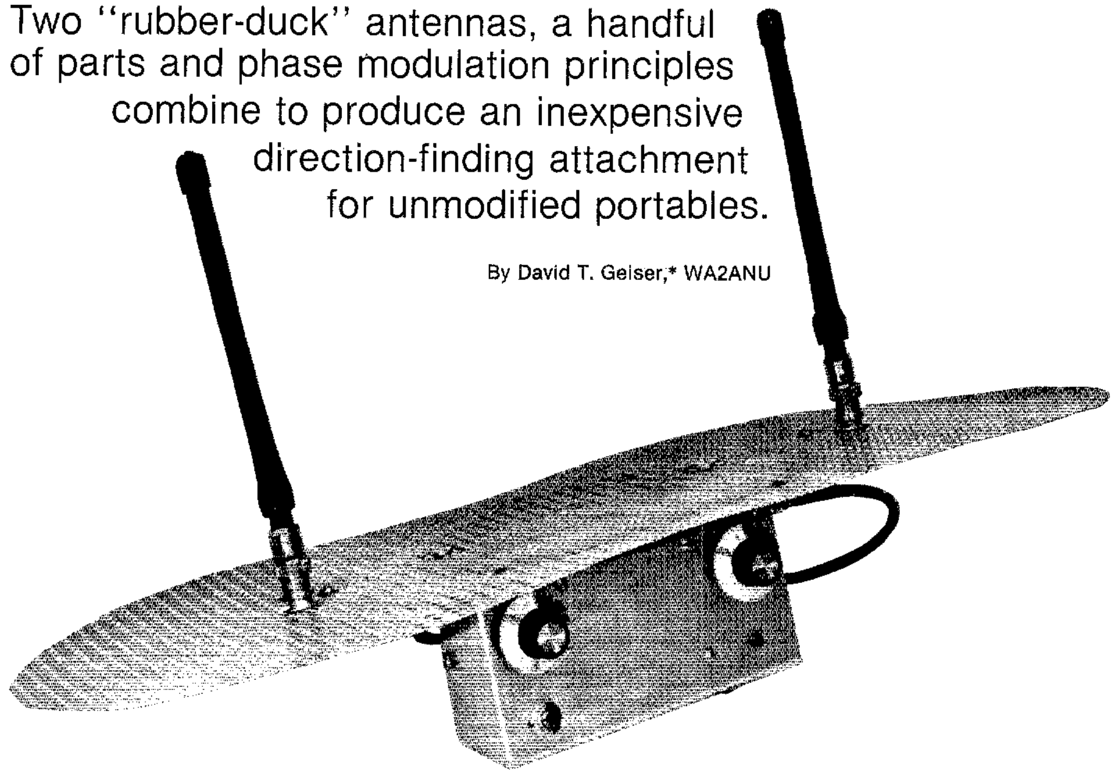
Double-Ducky Direction Finder

Two "rubber-duck" antennas, a handful of parts and phase modulation principles combine to produce an inexpensive direction-finding attachment for unmodified portables.

By David T. Geiser,* WA2ANU



Most amateurs use antennas having pronounced directional effects, either a null or a peak in signal strength, for direction finding. Fm receivers are designed to try to eliminate the effects of amplitude variations and are difficult to use for direction finding without looking at an S meter. Most modern portable transceivers do not have S meters.

This "Double-Ducky" direction finder (DDDF) is different in that it switches between two nondirectional antennas, creating phase modulation on the incoming signal that is heard easily on the fm receiver (Fig. 1). When the two antennas are exactly the same distance (phase) from the transmitter (Fig. 2), the tone disappears.

*ARRL TA, RD 2, Box 787, Snowden Hill Rd., New Hartford, NY 13413

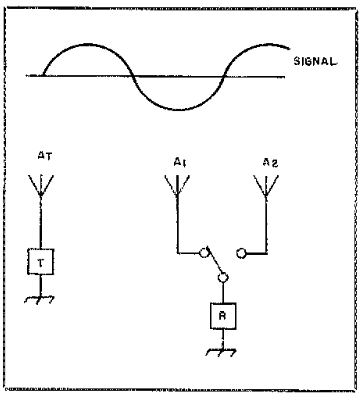


Fig. 1 — Rapid switching between antennas samples the phase at each antenna creating a pseudo-Doppler effect, which an fm detector will detect as phase modulation.

Fm receiver detectors usually fall into either the "discriminator" or "phase-detector" categories. The phase-detector will convert audio-rate changes in phase to an audio tone. Discriminators look upon changes in phase as if they were

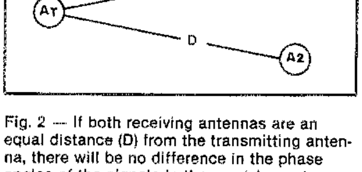


Fig. 2 — If both receiving antennas are an equal distance (D) from the transmitting antenna, there will be no difference in the phase angles of the signals in the receiving antennas; therefore, the detector *will not detect* any phase modulation, and the audio tone will disappear from the output of the detector.

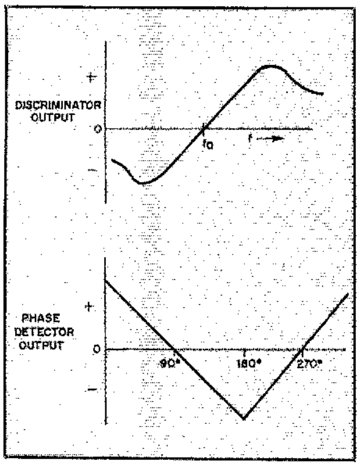


Fig. 3 — Typical discriminator and phase detector response curves.

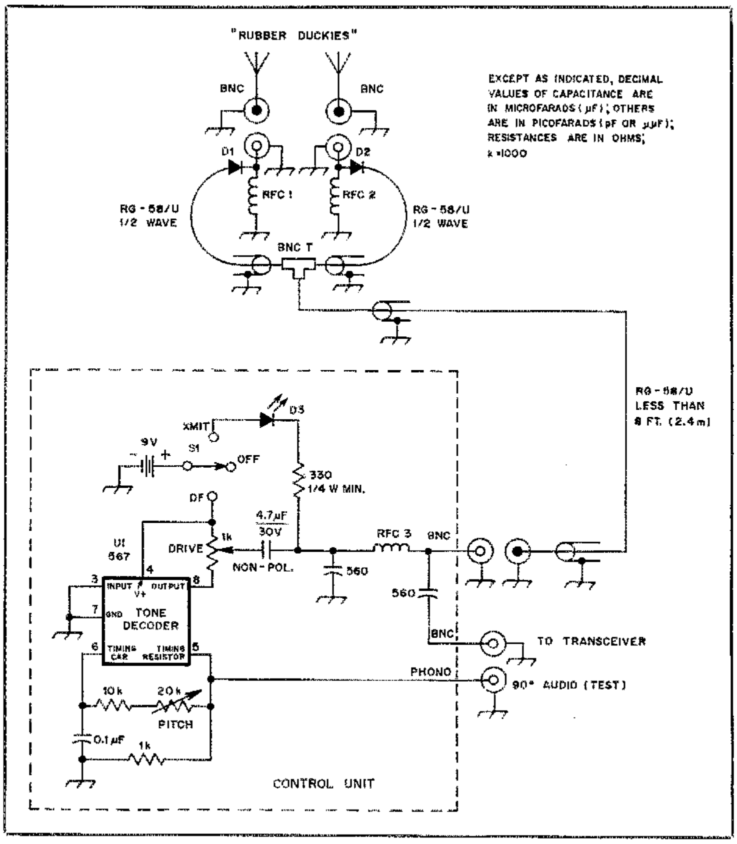


Fig. 4 — Schematic diagram of the DDDF circuit. Construction and layout are not critical. Components inside broken lines should be housed inside a shielded enclosure. Most of the components are available from Radio Shack, except D1, D2, the antennas and RFC1-RFC-3, which are discussed in the text. S1 — See text.

changes in frequency and, if the phase changes happen at an audio rate, will give alternately reversed pulses at that same rate. Both detectors give audio output from the speaker that disappears only when the phase doesn't change as a result of the switching (Fig. 3).

In theory the antennas may be very close to each other, but in practice the amount of phase modulation increases directly with the spacing, up to spacings of a half wavelength. While a half-wavelength separation on 2 meters (40 inches or 1020 mm) is pretty large for a mobile array, a quarter wavelength in my experience gives entirely satisfactory results, and even a one-eighth wavelength (10 inches or 250 mm) is acceptable.

I think in terms of a fixed spacing between the antennas, mount them on a ground plane and rotate that ground plane. The ground plane held above the hiker's head or car roof reduces the needed height of the array and the directional-distorting effects of the searcher's body or other conducting objects.

Direct pickup of the signal by the receiver does not have much effect. Such pickup with minimum/maximum systems (S meters) smears nulls and peaks, but only provides a convenient beat for the phase modulation in this system.

The basic principle is not new, though I have seen only one Amateur Radio article on the topic.[1] Commercial direction finders similar to the DoppleScAnt are offered (usually costing upwards of $1000) giving directional indication to a fraction of a degree. (The DoppleScAnt gives unidirectional indication and is an interesting "post-graduate" course in this principle.)

The DDDF is bidirectional and, as described, its tone null points both to and away from the signal origin. An L-shaped search path would be needed to resolve the ambiguity. Probably a reflector could be added, putting some asymmetry into the pattern and giving a sense indication.

Specific Design

It is not possible to find a long-life mechanical switch operable at a fairly high audio rate, such as 1000 Hz. Yet we want an audible tone, and the 400- to 1000-Hz range is perhaps most suitable considering audio amplifiers and average hearing. Also, if we wish to use the transmit function of a transceiver, we need a switch that will carry perhaps 10 watts without much problem.

A solid-state switch, the PIN (positive-intrinsic-negative) diode, has been developed within the last few years. The intrinsic region of this type of diode is ordinarily bare of current carriers and, with a bit of reverse bias, looks like a low-capacitance open space. A bit of forward bias (20 to 50 mA) will load the intrinsic region with current carriers that are happy to dance back and forth at a 148-MHz rate, looking like a resistance of an ohm or so. In a 10-watt circuit, little enough power is dissipated in the diode for it to survive.

Because I intended to use only two antennas, the obvious approach (Fig. 4) was to connect one diode "forward" to one antenna, to connect the other "reverse" to the second antenna and to drive the pair with square-wave audio frequency ac. Rf chokes (Ohmite Z144, J. W. Miller RFC-144 or similar vhf units) were used to let the audio through to bias the diodes while blocking rf. Of course, the reverse bias on one diode is only equal to the forward bias on the other, but in practice this seems sufficient.

A number of PIN diodes were tried in the particular setup built. These were the Hewlett-Packard HP5082-3077, the

[1] T. Rogers, "A DoppleScAnt," *QST*, May 1978, p. 24. [There are a number of errors in the DoppleScAnt diagram, Fig. 4. A corrected diagram is available upon request from ARRL Hq.]

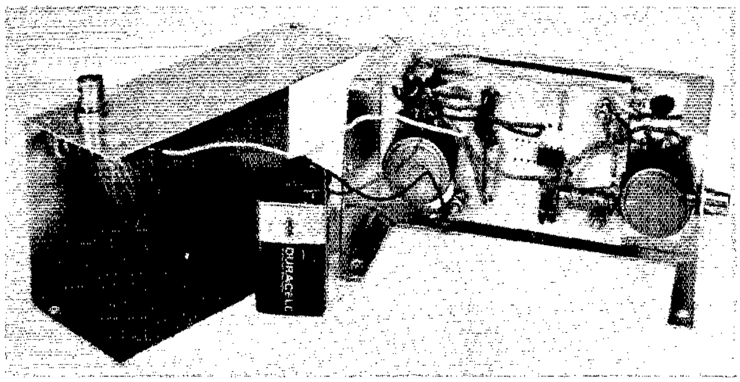
Alpha LE-5407-4, the KSW KS-3542 and the Microwave Associates M/A-COM 47120. All worked well, but I left the HP diodes in the finished equipment because they provided a slightly lower SWR (about 3:1) during my testing. Rigs accustomed to working with "rubber duckies" will not be dismayed with such an SWR.

The square-wave generator should put out good square waves — each diode should be equally (or nearly equally) biased. The generator should be tunable with a variable resistor, and the bias should be adjustable. After some survey of various ways to do this, I settled on the 567 IC as the best compromise. The output does have a dc bias that had to be removed with a nonpolarized coupling capacitor. This minor inconvenience was more than rewarded by the ability of the IC to work well with between 7 and 15 volts (a nominal 9-V minimum is recommended).

The nonpolarized capacitor also proved useful for blocking dc when the function switch was set to XMIT. I placed D3, a light-emitting diode (LED), in series with the transmit bias to indicate I had selected its high battery current drain (20 mA or so).

I originally chose an ordinary center-off toggle switch for S1, but am now of mixed mind whether I should have used a locking type. Certainly the ordinary switch is more convenient if rapid transmit/receive is desired, but the batteries I have worn out by accidentally leaving the switch on would have paid for the more expensive locking type.

"Rubber duckies" are not very efficient antennas, but they were chosen for two reasons. Full quarter-wave whips were used in one of the early models, but they whipped and were too tall. The whipping confuses the null (even on a relatively small excursion), but rubber damps vibration. Better pickup results from better antennas; I have done 60-mile (96-km) DFing with the 1/4-wave whips.



Internal "workings" of the DDDF. Simplicity of design, along with a minimum of components, makes this a simple one- or two-evening project.

Cables going from the antenna to the coaxial T connector were cut to an electrical 1/2 wavelength (about 2/3 of a free-space half wave) to help the open circuit, represented by the reverse-biased diode, look open at the coaxial T. (The length of the line within the T was included in the calculation.)

The length of the line from the T to the control unit is not particularly critical. I, however, like to keep the total of the cable length from the T to the control unit to the transceiver under 8 feet (2.4 m) because the capacitance of the cable does shunt the square-wave generator output. (I have a prejudice in favor of square waves having square edges.)

My choice for the size and shape of the ground plane (Fig. 5) was arbitrary, guided by instinct and the size of scrap metal in the junk box. The metal really should extend away from the base of the antennas a distance at least equal to their height, 8 inches (200 mm), but thoughts of wind resistance and spending more money argued for the smaller size.

The size and shape of the control box are unimportant; all that matters is the shielding. The 5-1/4 × 3 × 2-1/8 inch (133 × 76 × 54 mm) standard Minibox is convenient and widely available. I powered the unit with a common 9-volt, transistor-radio battery mounted in the box.

Other Variations

The first model used shunt PIN diodes to short out the antenna (Fig. 6). This is good for receiving and eliminates the need for two rf chokes, but the power-handling capability on transmit is only about 2.5 watts. Quarter-wave coax lines are run from the antennas to the T so that the shorted antenna will appear like an open

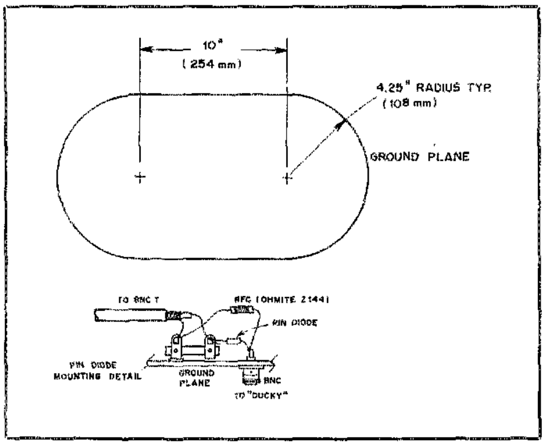


Fig. 5 — Ground-plane layout and detail of parts at the antenna connectors.

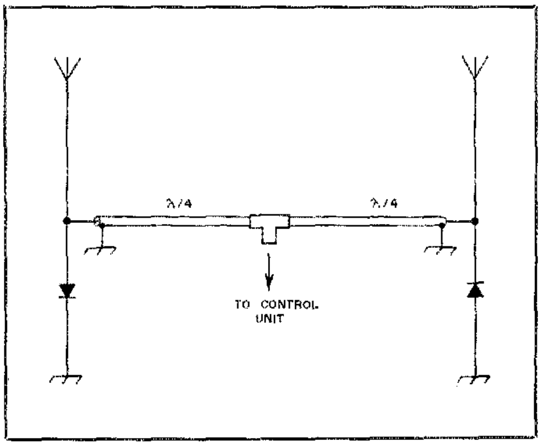


Fig. 6 — This variation of the basic design uses PIN diodes to shunt the antennas.

circuit at the junction of the T.

A shorted quarter-wave line may be used in place of the antenna rf chokes in the present design. This will look like a fairly high reactance (capacitive or inductive) over most, if not all, of the band, while still looking like a short circuit to the square wave (Fig. 7).

Increasing the spacing between the pickup antennas will give the greatest improvement. Every doubling (up to a half wavelength) will cut the width of the null in half. A 20-inch (500-mm) spacing has given me nulls about 1° wide.

I succumbed to temptation and mounted an automobile compass between the two antennas so I would have a true direction finder! The idea didn't work out because the magnetic material in my "rubber duckies" made the compass always indicate north, regardless of which way was north! (The compensators didn't have enough range.)

Perhaps the most interesting variation is to add right/left indication. The receiver audio output is put through a phase shifter (if necessary) and run to a balanced modulator that uses the quadrature output of the square-wave generator as a reference. As the dc polarity output changes when the antenna swings through the null, a dc microammeter on the mixer output can be used to give a right/left indication (Fig. 8). (For reasons discussed later, the indication is good only in the region of linear operation of the detector in the receiver.)

Usage Instructions

Switch the control unit to DF and advance the drive potentiometer until a tone is heard on the desired signal. Do not advance the drive high enough to distort or "hash up" the voice. Rotate the antenna for a null in the fundamental tone. Note that a tone an octave higher may appear. The cause of the effect is shown in Fig. 9. At A an oscilloscope synchronized to the "90° Audio" shows the receiver output with the antenna aimed to one side of the null (on a well-tuned receiver.) Fig. 9B shows the null condition and a twice-frequency (one octave higher) set of pips, while C shows the output with the antenna aimed to the other side of the null.

If, on the other hand (Fig. 10), the incoming signal is quite out of the receiver linear region (10 kHz or so off frequency), the off-null antenna aim may present a fairly symmetrical af output to one side (A). It may also show a near null with instability (indicated by the broken line on the display) at a sharp null position (B) and, aimed to the other side, give a greatly increased af output (C). This is caused by the different parts of the receiver fm detector curve used. The sudden tone change is the tip-off that the antenna null position is being passed.

Even in difficult nulling situations where a lot of second-harmonic af exists, rotating the antenna through the null position causes a very distinctive tone change. With the same frequencies and amplitudes present, the quality of the tone (timbre) changes. It is as if a note were first played by a violin, and then the same note played by a trumpet. (A good part of this is the change of phase of the fundamental and odd harmonics with respect to the even harmonics.) The listener can recognize differences (passing through the null) that would give an electronic analyzer indigestion.

The user should practice with the DDDF to become acquainted with how it behaves under known situations of signal direction, power and frequency. Some will want to tune the signal with the function switch in XMIT position and then switch to DF. In an unknown situation I like to use the tone to tell me a signal is present — my transceiver (IC-211) will both whine and DF on signals more than 10 kHz off frequency. Use of the 5-kHz synthesizer step then helps keep the tone spectrum less complicated.

I find that the whine (or tone) the DDDF adds to a carrier gives an unexpected dividend — I can receive cw telegraphy with its help on any fm receiver. When I hear the tone (and I can recognize it below the fm threshold) I turn the antennas for maximum volume and start copying. It's fun. Try *that* with your S meter!

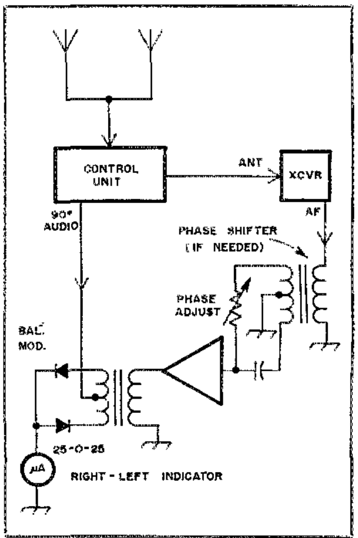


Fig. 8 — Block diagram of a simple right/left indicator. Depending on the setting of the potentiometer, the phase shift may range from 0° to near 180°. In general, one half the full value of resistance of the potentiometer should equal the capacitive reactance of the capacitor at the audio frequency used. Readers with questions should send an s.a.s.e. directly to the author.

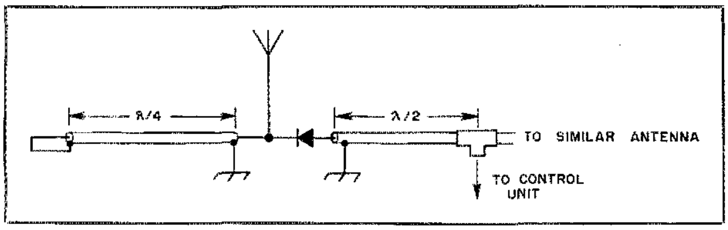


Fig. 7 — Another variation of the basic design. Here, a shorted quarter-wavelength section of coaxial cable replaces the rf choke at the antenna.

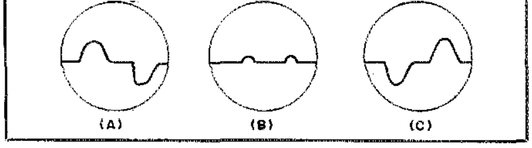


Fig. 9 — Typical on-channel responses. See text for discussion of the meaning of the patterns.

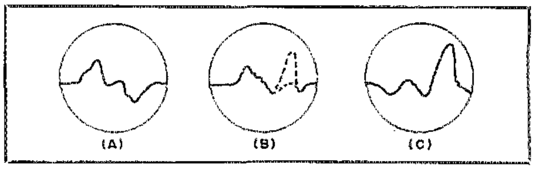
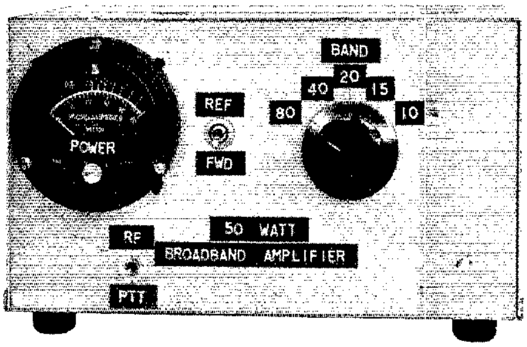


Fig. 10 — Representative off-channel responses. See text for discussion of the meaning of the patterns.

Boots for QRP Rigs



There comes a time when you have to put your QRP feet into some QRO boots to wade through the QRM. Here's a way to do it and enjoy a building experience, too.

By Steve Kapplin,* W4YVP

Many hams enjoy both phone and cw QRP operation. Occasionally, they may desire a bit more power than the 2.5 watts available from rigs such as the popular Ten-Tec Argonaut. Before the 1978 FCC rulings regarding linear amplifiers went into effect, Ten-Tec manufactured a companion amplifier for the Argonaut; but these amplifiers are no longer being made, and finding a used one for sale is nearly impossible. Building an amplifier might seem like a difficult task, and most articles detailing construction of solid-state rf power amplifiers are limited to the 100-watt (or more) output class. Low-power amplifiers, which have appeared in the amateur journals, tend to be Class C types and are therefore unsuitable for ssb use.

The need for design and construction information is a particular one for those interested in a compact, medium-power amplifier. From the author's experience, there appears to be a need for more design criteria, which would enable any prospective builder to design rf power amplifiers around any suitable power device without having to rely on circuit duplication as a guarantee of success. These thoughts initiated the design and construction of the amplifier presented here.

Designed to be a companion to my Ten-Tec Argonaut transceiver, this amplifier can also follow any suitable 2-watt driver. Although a pair of Motorola MRF449A transistors is used, sufficient information is provided for accommodating necessary design changes to meet the specifications of other power devices. I felt that most other power amplifier design articles are too "cookbook" in the sense that prospective builders usually have no way to discern from them if device substitutions are possible. Thus, you are discouraged from the attempt because you cannot make an exact duplicate. Some design criteria are presented here to aid prospective builders, and you are encouraged to substitute wherever feasible in the interest of reducing costs and using the contents of your "junkbox." If you are a good scrounger, you can build this amplifier for less than $100. The transistors can be purchased for less than $12 each and represent the largest single component cost. I have not provided a circuit board pattern because this unit is a prototype.

General Description

Motorola MRF449A transistors are employed in a push-pull, broadbanded circuit. Broadbanded, ferrite-loaded transformers are used for both input and output impedance matching. Input gain compensation networks and negative feedback are used to provide an almost flat response across a frequency range of 3 to 30 MHz. The amplifier is followed by a set of band-switched, 5-section Chebyshev filters. Although push-pull operation reduces even-order harmonics, odd-order harmonics will not be adequately suppressed without the use of the filters.

Class AB operation is established by providing forward bias to the transistor bases so that the transistors will draw a small amount of quiescent collector current. Provisions are made for antenna switching using a built-in relay. The relay can be activated either by using an external control voltage controlled by the driver PTT line (not to exceed 9 volts) or by an internal, rf-activated relay driver; a front-panel mounted switch provides selection. The builder can, of course, use any control method that is convenient. Nominal specifications of the amplifier are detailed in Table 1.

Table 1
Amplifier Operating Specifications

Input/output impedance:	50 ohms
Output power (50-ohm load):	50 watts PEP
Driving power required:	1.25 watts PEP (± 1 dB)
Input VSWR:	1.5:1
Frequency coverage:	80 to 10 meters
Power requirements:	12 to 14 V dc at 8 A

Circuit Description

The power amplifier schematic diagram is shown in Fig. 1. An input matching transformer, T1, is followed by the input correction networks (two 3.3-ohm resistors and two 0.0033-μF mica capacitors) and a bias feed network consisting of RFC1, RFC2 and R2. T2 is the shunt-feed transformer, and T3 is the output impedance-matching transformer. The two 6.8-ohm resistors in the base circuits provide base stabilization and a ground return path for the bias supply. With R2 in the bias feed network, sufficient current will stand in the biasing diodes to stabilize the bias voltage under full base current. It is essential that the base bias be regulated to within 0.1 volt from idle to full base current. For transistors such as the MRF449A and MRF450A, an H_{fe} of 30 is typical. Thus, base current varies from a value of less

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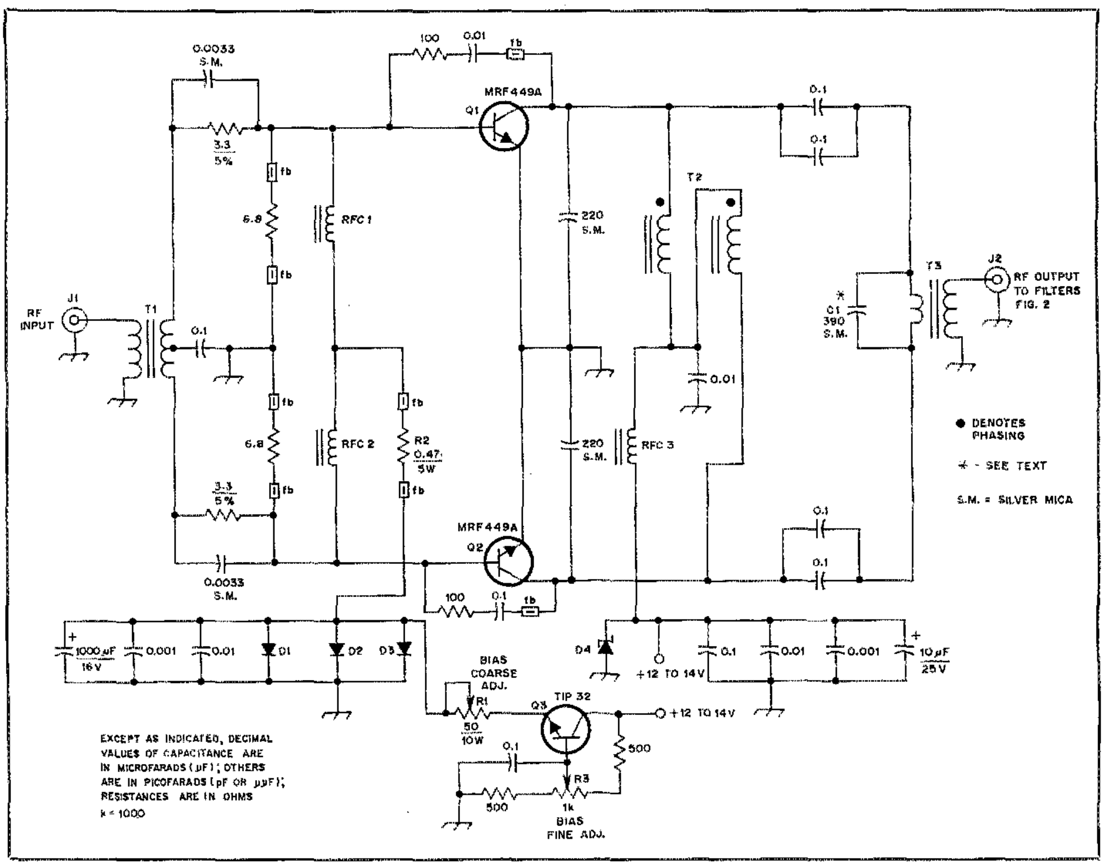


Fig. 1 — Schematic diagram of the linear amplifier. The ferrite beads in the feedback networks are slipped over one lead of each capacitor, which has a length of 1/2 to 1 inch (13 to 25 mm).

D1-D3, incl. — Silicon, 50 PIV, 1A (1N4001 or equiv).
D4 — 15-V, 10-W Zener (ECG5191A or equiv).
J1, J2 — Phono jacks.
Q1, Q2 — Silicon rf power transistor, 60 W (Motorola MRF 449A or equivalent, see text).
Q3 — Silicon af power transistor, 50 W (TIP 32 or equiv).
R1 — 50 Ω, 10 W, adjustable.
R2 — 0.47 Ω, 5 W, wire wound (Radio Shack 271-130).
R3 — 1 kΩ pc-mount potentiometer.
RFC1, RFC2 — Ferrite core type, 10 µH minimum inductance (see text).
RFC3 — 3 turns no. 16 or 18 enameled wire on Amidon FB2401-43 bead.
T1, T2, T3 — See text.

than 5 mA to over 250 mA peak during ssb operation. Regulation of the base bias voltage is provided by the shunt diodes (D1, D2 and D3), which act as a Zener regulator. The diodes are forward biased through the dropping resistor (R1) and the emitter follower (Q3) which provides a small range of adjustment.

Perhaps the most perplexing aspect of solid-state power amplifier design is represented by the input correction networks and the feedback networks. Without the aid of computer simulation programs, the design of these networks resembles minor surgery coupled with a twist of voodoo! Transistors exhibit increased gain at lower operating frequencies. Over the nearly four-octave range of a broadband amplifier, transistor gain will typically vary from 15 dB at 30 MHz up to 28 dB at 3 MHz. The purpose of the correction and feedback networks is to improve the broadband characteristics by flattening out the gain curve and improve stability across the operating frequencies. Component values are chosen to provide a reduction in gain that is proportional to the increase in transistor gain at decreased operating frequencies. The total amount of gain compensation is split between the input correction and feedback networks. No more than about 6 dB of feedback should be used with power devices operating at power levels of approximately 50 watts; more than that tends to increase harmonic production.

The MRF449A exhibits a change in gain of approximately 8 dB from 4 to 30 MHz. If this amount of gain is split between the correction and feedback networks, then 4 dB of input correction is required. According to the MRF449A data sheet, the 30-MHz gain of the device is 17 dB. Therefore, the device gain at 4 MHz will be about 25 dB. For 50 watts of output power and a power gain of 25 dB, the driving power required is 50/316 = 0.16 watt. The push-pull input impedance for the MRF449A is about 13.5 ohms at 4 MHz. (This value was not available from the data sheet and was "guesstimated" by averaging input impedances of other transistors for which data were provided.) For transistors in this general power class, this estimate should do for an initial design. Network design is accomplished as follows:[1]

1) Find the required base-to-base drive voltage:

$$V_{b\text{-}b} = \sqrt{P_i \times R_{b\text{-}b}} = \sqrt{0.16 \times 13.5}$$

[1]Notes appear on page 20.

2) Find the drive current:

$I_{b\text{-}b} = V_{b\text{-}b}/R_{b\text{-}b} = 1.48/13.5 = 0.11A$

where

$V_{b\text{-}b}$ = drive voltage, base-to-base.
$R_{b\text{-}b}$ = input impedance, base-to-base.
$I_{b\text{-}b}$ = drive current, base-to-base.
P_i = input drive power.

The gain change of 4 dB will be absorbed in the correction network. The required resistance is found by:

$$R = \frac{(V_{b\text{-}b} \times 4\ dB) - V_{b\text{-}b}}{I_{b\text{-}b}}$$

$$= \frac{(1.48 \times 1.58) - 1.48}{0.11} = 7.8\ \Omega$$

or 3.9 ohms in each base lead. (Note that the 4-dB voltage ratio is used in the formula.)

Because of the feedback network, input correction resistors of 3.3 ohms were found to be sufficient. Although the absolute value is not critical, carefully matched resistors should be used. Each resistor is shunted by a mica capacitor. The reactance of the capacitor at midband (15 MHz) should equal the resistance that it shunts.

The value of the resistors used in the feedback network was chosen experimentally. Once the amplifier is completed and ready for bench testing, the gain curve can be measured and the amount of feedback or input correction can be changed to produce a reasonably flat response across the bandwidth of the amplifier. It should be possible to provide a gain curve that is flat within 2 or 3 dB from 3 to 30 MHz. With the component values given here, this amplifier was flat within ± 1 dB.

It is better to compensate the gain curve with the correction networks than to use feedback. Excessive feedback will increase the level of harmonics and can degrade the third-order IMD performance, while insufficient feedback leads to instability. Both the feedback and input correction networks aid in providing stable operation. You could start by using the feedback networks only, experimenting with resistor values until you provide about 4 dB or so of gain compensation. Then add the input correction network and experiment with resistor-capacitor combinations until the additional gain compensation is provided. It is possible to produce a relatively flat gain curve. If you choose to extend operation down to 160 meters, the input networks described here may have to be changed.

The input transformer must provide a midband impedance transformation from the base input impedance to 50 ohms. The MRF449As exhibit a base impedance of about 3 ohms each at midband or 6 ohms in push-pull. This would require a 9:1 impedance transformation for a good match to 50 ohms. However, the input correction networks are in series with the base and add to the base-to-base impedance, while feedback tends to reduce input impedance. At midband the impput impedance appeared to be about 13 ohms, base-to-base. This value can be matched fairly well with a 4:1 transformer. A simple conventional transformer having a 2:1 turns ratio, or a 4:1 balun, can be used. The conventional transformer used in this design provided a reasonable input VSWR of less than 1.5:1 from 80 to 10 meters.

Biasing Network

The biasing network incorporates three 50-V, 1-A diodes in parallel, which act as a Zener diode. The diodes are forward biased by applying a dc voltage from the +12-volt supply through dropping resistor R1. The emitter follower, Q3, provides a small range of adjustment by means of R3. Initially, bias is set at 0.68 volt as measured at the bases of Q1 and Q2. Motorola does not publish data for the MRF449A in ssb service, so the best setting for collector idling current must be guessed at. Setting the bias at 0.68 volt should ensure proper operation for this transistor. Where possible, however, a data sheet should be consulted for the appropriate idling current.

Dc collector current passes through T2 rather than through the center tap of the output transformer, T3. This arrangement provides better balance and improved suppression of even harmonics, particularly important if the transistor pair isn't matched. T3 may also be made physically smaller since it does not have to carry dc as well as rf currents; it matches the collector output impedance of Q1 and Q2 to a 50-ohm load. The output load impedance for push-pull operation is found by:

$$R_L = \frac{2(V_{CE} - V_{CEsat})^2}{P_{out}}$$

$$= \frac{2(13.6 - 1.6)^2}{50} = 5.76\ \Omega$$

where

V_{CE} is the collector-to-emitter voltage.
V_{CEsat} is the collector-to-emitter saturation voltage.
P_{out} is the output power.

This impedance can be matched by using a transformer with a 9:1 impedance ratio (3:1 turns ratio). The compensating capacitor, C1, is used to improve the high-frequency characteristics of the transformer. A value of 390 pF worked well in this unit. A small trimmer capacitor (such as an ARCO 469) might be used to first find the optimum value. The trimmer can then be replaced with a fixed-value silver mica unit.

The amplifier output is fed to the filter board, which contains five band-switched, 5-pole Chebyshev low-pass filters as shown in Fig. 2. Design information for these filters may be found on pages 6-11 and 6-12 of the 1981 *Radio Amateur's Handbook*. ARRL lab tests of the completed amplifier showed the third-order IMD products down at least 30 dB during a two-tone test at 50 watts PEP output. Second harmonic suppression is at least 45 dB and third harmonic suppression more than 50 dB. These are worst-case conditions which were measured on 80 meters.

Construction

The power amplifier circuitry should be contained on a separate, double-sided pc board. Leave the bottom foil intact to act as a ground plane. Modular construction was used in my unit with the antenna changeover relay, relay drivers and the biasing network built on small pc boards. Between-board connections are made with short lengths of small-diameter coaxial cable (RG-174/U) fitted with shielded phono plugs that mate with jacks at the proper places. This type of interconnection provides servicing ease and ensures good grounding and minimal rf leakage, which can otherwise lead to rf feedback problems or other stray currents. The output filters should be built on single-sided pc board; their construction will be covered later.

As may be seen in the photo on page 18, the amplifier board is mounted in a vertical position on the back panel of a 6 × 6-1/2 × 7-inch (152 × 165 × 178-mm) enclosure. The transistor mounting studs and flange project through the pc board, where they are able to lie flush against the panel with the studs projecting through the panel and heat sink mounted on the opposite side. The heat sink should be bolted securely to the rear panel to ensure that both the sink and the chassis will dissipate the heat. A judicious amount of heat-sink compound should be used at the point where the transistors bolt to the sink. The heat sink I used was a "junk box" item and measures 1 × 4 × 3 inches (25 × 102 × 76 mm). By itself, this heat sink is inadequate, but with the chassis sharing the work, sufficient heat sinking is available. Two-tone tests, several minutes in length with the amplifier operating at full output, did not raise the sink temperature over 110° F (40° C).

Physical layout of the amplifier is not critical, but it should be symmetrical and linear — input at one end, output at the other end. The transistor strip leads should be soldered flush to the pc board. First, lay out the board and etch it. Then drill a 3/8-inch hole in the center of the transistor mounting area. The transistor flange will push through so that the strip leads will lie flush on the pc board. Before soldering the leads to the board, bend a 1/16-inch (1.6-mm) tab up on each lead. This will make any future removal of the

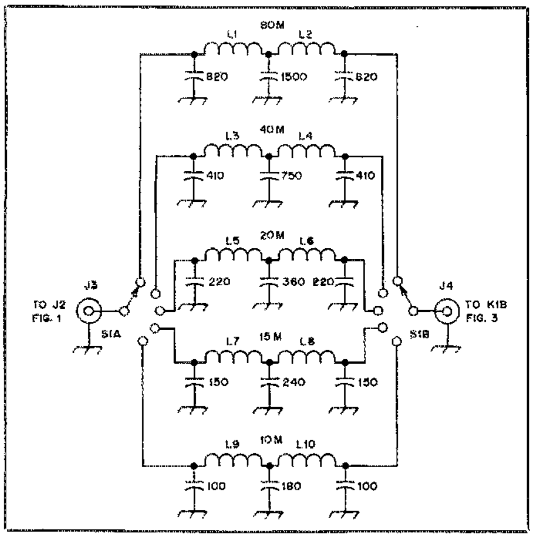


Fig. 2 — Schematic diagram of the 5-pole Chebyshev output filters. All capacitors are silver mica types. Note: All inductors are wound on Amidon T 68-2 cores using no. 24 enameled wire.
L1, L2 — 21 turns (2.4 μH), f_c = 4.5 MHz.
L3, L4 — 15 turns (1.28 μH), f_c = 8.5 MHz.
L5, L6 — 11 turns (0.64 μH), f_c = 17 MHz.
L7, L8 — 9 turns (0.44 μH), f_c = 25 MHz.
L9, L10 — 7 turns (0.31 μH), f_c = 35 MHz.
S1 — 2-pole, 5-position ceramic rotary.

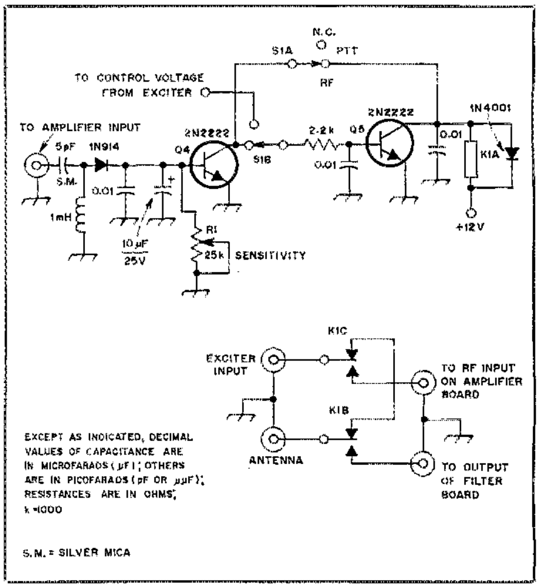
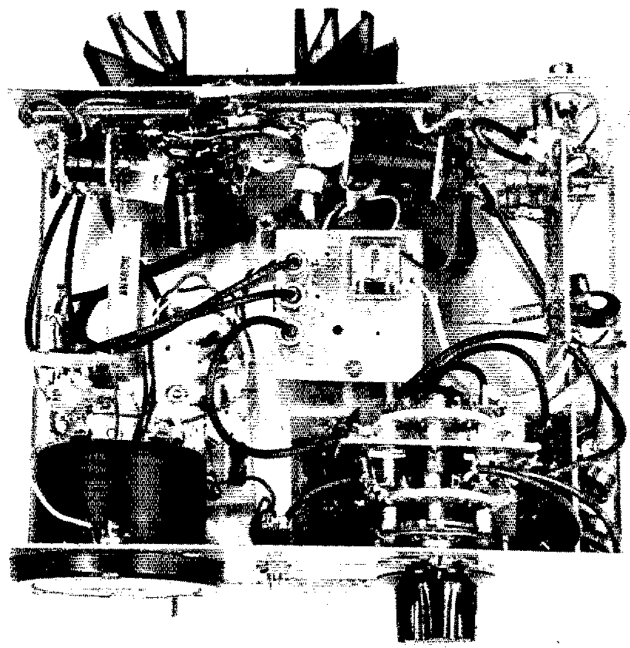


Fig. 3 — Schematic diagram of the antenna switching circuitry. S1 provides a means of selecting either the control voltage from the exciter or the rf input to the amplifier to energize K1.
K1 — Dpdt relay, 2-A contacts, 12-V, 100-ohm (minimum) coil (Radio Shack 275-206 or equiv).
S1 — Dpdt miniature toggle switch (Radio Shack 275-1546).



This topside view of the amplifier shows its modular construction. The bias circuit components are mounted behind the panel meter. Next in line is the board containing the rf sensing circuitry for the antenna changeover relay. The relay itself is on a separate board behind the band switch and output filter board. At the far right is the power-output/SWR-meter board. The final-amplifier board is secured to the rear panel of the enclosure as described in the text.

transistor much easier. Be sure to heat sink the transistors while soldering.

Ferrite Transformer Construction

The three ferrite-loaded transformers can be constructed from Amidon FB2403-43 beads (μ = 950), some pc board material and 0.19-inch (4.8-mm) diameter brass thin-wall tubing. Such tubing can be purchased at a hobby shop or 3/16-inch (4.8-mm) copper tubing may be substituted; the brass tubing is preferred. (Amidon FT50-43 toroids may be used instead of the beads and 1/4-inch (6.4-mm) copper tubing in place of the brass tubing.) Six beads are required for T1, four for T2 and 10 for T3. If the more expensive toroids are used, only two are needed for T2 and eight for T3 at this power level. A pictorial description of the mechanical construction of these transformers may be found in chapter two of *The Radio Amateur's Handbook*, 1979 through 1981 editions.

T1 consists of two stacks of three FB2401-43 beads on lengths of brass or copper tubing. The end plates are made from two pieces of pc board material drilled to accept the tubing. One end plate has the foil left intact while the other end plate has the foil cut in the middle. Thus, the tubing acts as a one-turn winding. The second winding consists of two turns of no. 24 insulated wire, which is carefully threaded through the tubing. This transformer has a 4:1 step-down ratio from the primary (2-turn winding) to secondary. The center tap on the secondary is made by soldering the leads of C1 and RFC1 to the center of the foil on the pc board end plate.

T2 uses two stacks of two FB2401-43 beads each. No tubing or pc board end plates are used. The two stacks are held together with electrical or masking tape. Two turns of a twisted pair of no. 20 insulated or no. 18 enameled wire are bifilar wound and wired as a 4:1 balun.

T3 is made from two stacks of five FB2401-43 beads each, constructed similarly to T1. The secondary consists of three turns of no. 24 insulated wire. This transformer has a 9:1 impedance step-up ratio.

If you decide to use toroids instead of beads, then use two FT50-43 stacked toroids for T2. Two turns of a twisted pair of no. 18 or 20 wire are wound as a 4:1 balun. T1 and T3 are constructed similarly except that 1/4-inch (6.4-mm) copper tubing is used. The transformers are not difficult to construct, but require a bit of care. T1 and T3 should be constructed before the board layout is made so they may be used during that process. RFC1 and RFC2 are small chokes wound on Amidon six-hole beads. Alternatively, use a twisted pair of no. 24 wire and wind 4 turns on an FB2403-43 bead.

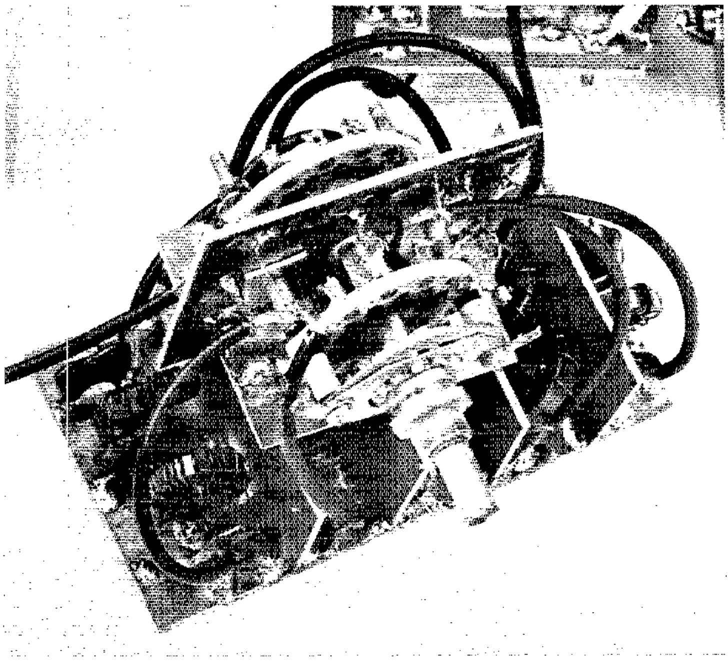
The 0.47-ohm, wire-wound resistor is a stock Radio Shack item; do not omit it. This resistor provides a slight voltage drop so that when 0.68 volt is present at the bases of Q1 and Q2, the current through the diodes is slightly higher than if the resistor were not there. Its presence provides a slightly higher standing current in the diodes, which helps to regulate the bias voltage as Q1 and Q2 draw more base current.

The output filter board is a single-sided pc board. Do not use two-sided board because it will degrade filter performance. A two-wafer switch should be used with a shield of double-sided pc board between the wafers. The pc board not only acts as a shield, but also is a convenient ground point for the braid of the coaxial cables interconnecting the switch to the individual filters. Shields were also placed between each filter. The shielding between the individual filter sections may not be necessary, but the switch shield is. Be sure that all coaxial cable braids are grounded at both ends. At this power level, any leakage seems to degrade the filter action.

Fig. 3 is the schematic diagram of the antenna relay circuitry. S1 is mounted on the front panel of the amplifier enclosure. Both the transistors and relay are available from local Radio Shack outlets.

A Breune-type wattmeter[2] is installed between the antenna jack and the antenna relay; the circuit is shown in Fig. 4. Before installing the wattmeter, it should be balanced using a 50-ohm load and an accurate wattmeter. This simple wattmeter has excellent linearity and will provide reasonably accurate power measurements down to the 1-watt level. If you use a standard 50-μA meter as shown, you can calibrate the meter face by simply choosing the desired full-scale power reading (P_{FS}); power measurement is then determined by:

$$(I/50)^2 \times P_{FS}.$$



A close-up look at the output filter board. The pc board shield section between the switch wafers is required to ensure proper output filter performance.

Adjustment and Operation

First disconnect RFC3 from the dc line and set R1 at maximum resistance. Set the bias trimming potentiometer (R3) at midrange. Apply +12 volts to the amplifier and, while monitoring the voltage at the bases of Q1 and Q2, adjust R1 for a voltage reading of about 0.68 volt. R3 may be used for a fine adjustment. Remove the +12 volt supply, reconnect RFC3 and install an ammeter in the dc supply line. Reapply the +12 volts to the amplifier and check for 0.68 volt at the transistor bases; readjust R3 if necessary. The ammeter in the line should read about 0.75 A. The value is not critical, but it should be greater than 0.6 A for good regulation.

Attach a 50-ohm dummy load (capable of dissipating 50 watts) and the exciter to the amplifier. Ensure that both the exciter and the amplifier are set for the same band of operation. With power applied to the amplifier, slowly increase the exciter output while carefully monitoring the output meter and the dc line ammeter. As

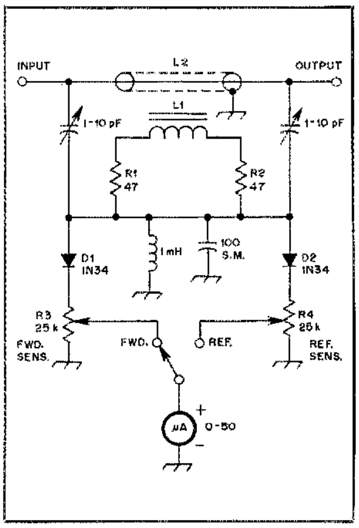


Fig. 4 — The optional wattmeter schematic diagram. The diodes, D1 and D2, should be closely matched in forward and reverse resistance characteristics; an ohmmeter check will suffice. R1 and R2 should also be matched closely for best performance.
L1 — 18 turns no. 26 enameled wire on FT50-43 core or FB2401-43 bead.
L2 — Short length of RG-58/U (for use with toroid core) or RG-174/U (for bead); a 1-3/4-inch (45-mm) length is sufficient. The shield braid is left on the cable and grounded only at the output-port side.
R3, R4 — 25-kΩ pc-mount potentiometers.

drive increases, output power and collector current will increase. Increase the drive until about half-power (25-watts) output is indicated. At this point, the collector current should be close to 6 A; 5.1 A for the collector current, 0.75 A of standby current drain and a relay current drain of 0.1 A. If you obtain similar readings, everything should be working properly. Turn off the drive and check that the amplifier current drops quickly to the standby level. If the current doesn't drop back quickly (within 30 seconds or less) you have a thermal runaway problem and should shut off the power immediately. I encountered no such problem, but if you do, it can be cured by placing a small amount of resistance in the transistor emitter leads. Start with a fraction of an ohm (0.2 to 0.5 ohm) and increase the value until you find one that allows the devices to operate properly. (You will have to readjust the base bias for 0.68 volt). Motorola transistors designed for ssb service within this frequency range are not likely to exhibit thermal runaway problems.

If all is well so far, full-power tests can be run. It is preferable to conduct these tests using a two-tone signal because that reduces power dissipation. If you use single-tone tests, do not prolong them. While the heat sink I used is quite adequate for ssb operation with a 50% duty cycle, it is not large enough to heat sink the transistors during protracted, full-power, key-down tests. On each band, set the drive to deliver 50 watts of output power and switch the wattmeter to read reflected power. Gradually back off the drive and observe the reflected power reading, looking for any "bumps." These are signs of instability. The cure for this is usually in the feedback networks. Insufficient feedback is the likely culprit.

C1 is used to compensate the output matching transformer on the 10-meter band. Adjust C1 for an output power and VSWR readings on 10 and 15 meters, which closely approximate each other. The 10-meter VSWR will probably be somewhat worse than on 80 to 15 meters.

Full-power output should be obtainable on each band with about 1.5 watts of driving power. If you are able to measure the input VSWR, it should not exceed 1.5:1. Cw efficiency of the amplifier will be approximately 45 to 50%, while two-tone efficiency will approximate 35 to 40%. Collector idling current should be about 100 to 150 mA, two-tone collector current 4.8 A and single-tone current about 7.6 A. These figures will vary, of course, and are meant only as benchmarks.

Final Notes

Not all readily available transistors will make good linear amplifiers. Avoid using transistors designed for operation above 175 MHz; stick with transistors designed for the hf bands. Vhf transistors such as the 2N6084 should work well, as will the MRF450A, MRF458A, PT9796A, A50-12 and BLW60. The MRF450A can produce upwards of 35 watts PEP output with good IMD performance and is very clean at the 25-watt power level. It can dissipate 115 watts compared with 60 watts for the MRF449A. (The "A" designation denotes stud mount.) The circuit components used with the MRF449As may not be appropriate for these other transistors, however, requiring some trial and error in component selection. Also, some transistors are flange-mount types and might be a bit more difficult to work with mechanically. The Motorola *RF Data Manual* is a good reference text.

The general design considerations and techniques given here can be applied to any power level up to about 75 watts. At higher power levels there are other design problems to confront. With power levels of 50 watts and less, simpler designs can be used and duplicated successfully. I hope that many dedicated QRPers who operate phone will find this compact, solid-state amplifier a useful accessory.

Notes

[1]The base impedance used in the push-pull case is the series input impedance, which is found in the data sheet. In the absence of a data sheet, an approximation for medium-power transistors is about 1.5 to 2 ohms at 30 MHz, rising to about 6 to 8 ohms at 3 MHz. Though not perfectly accurate, these estimates will suffice for deriving the initial component values.

[2]W. B. Bruene, "An Inside Picture of Directional Wattmeters," *QST*, April 1959, p. 24.

Strays

TA PROFILES

Do you find it frustrating to chase DX when band conditions are poor? Well, ARRL Technical Advisor John Battle, N4OE, can chase DX even if the bands are dead — he has a collie whose name happens to be "DX"!

John has been a TA since 1979. His field of expertise is rf/microwave, circuit/system design and communication systems. He has published technical articles in both Amateur Radio and trade journals, and has delivered talks at hamfests and other ham gatherings on a variety of technical subjects.

TA N4OE smiles at the prospect of having time to work in his home laboratory.

As an active radio amateur since 1961, John holds an Extra Class license as well as phone and telegraph commercial licenses. His Amateur Radio activities include contesting, DX, traffic handling and just plain rag chewing. He is currently Activities Manager for the Southeastern DX Club. John shares his hobby with his wife Nancy, WA4WQH, who holds an Advanced class license and is an active contester and DXer.

In addition to his operating activities, John spends a great deal of his spare time building and experimenting with electronics in his home laboratory. He also has interests in astronomy, music and science fiction.

Residing in Norcross, Georgia, John is employed by the Georgia Institute of Technology as a research engineer; he specializes in communications systems and radio propagation. He holds a BSEE degree from the University of Texas, and has done graduate work at various schools in engineering and astronomy. John is a registered professional engineer. — *Marian Anderson, WB1FSB*

QST congratulates . . .

William A. Wilson, K6ARO, of Los Angeles, who was recently appointed by President Reagan as Ambassador to the Vatican.

Bob Gunderson, W2JIO, recipient of the Armstrong Pioneer Award for his outstanding contributions to Amateur Radio via his work with, and for, blind hams.

Andrew Freeman, WØGFE, who was recently named the electric industry's "Man of the Year."

Wire Line — A New and Easy Method of Microwave Circuit Construction

Simple tools and techniques provide access to the microwave frequencies.

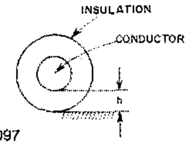
By Robert C. Wilson,* KL7ISA, and Hal Silverman,** W3HWC

In our branch of the Communications Satellite Corporation (COMSAT), hams are not plentiful. So when the authors met and found that a common interest in amateur microwave techniques existed, we formed a lunch-time technical society at the plant. After a lot of discussion, research and breadboarding, we came up with a new technique that will certainly put microwave circuit construction within easy reach of any amateur.

"Wire line" is a greatly simplified transmission line construction technique which does not require extreme precision or pc-board etching and uses commonly available parts and tools. By using only a soldering iron, diagonal cutters and a ruler, it is possible to build microwave mixers, oscillators, super-regenerative detectors and other microwave rf circuits with surprisingly good results.

Table 1

Required Wire Spacing for a 51.5-Ohm Impedance Line



Wire Gauge (AWG)	*Diameter (in.)*	*Dielectric Constant (e)* 1	2	3	4	5
12	0.080	0.007	0.027	0.049	0.072	0.097
14	0.064	0.006	0.022	0.039	0.057	0.077
18	0.040	0.004	0.014	0.024	0.036	0.048
22	0.002	0.002	0.009	0.015	0.022	0.030
30	0.010	0.001	0.003	0.006	0.009	0.012

The required wire-to-ground-plane spacing (h) in inches is shown below the various dielectric constant values. Inches × 25.4 = mm.

Theory

Transmission line circuits are necessary at microwave frequencies to keep the circuit losses under control, to conduct the signals from one place to another and to match one circuit to the next. One of the more popular microwave transmission-line techniques is called stripline. Stripline employs an etched copper strip transmission line over a ground plane. Literature is available describing stripline techniques and circuit design.[1] Much of this information may be useful in understanding wire line techniques.

The wire-line approach employs single-wire transmission lines using a ground-plane image. Theory indicated that there was no reason this technique would not work at microwave as well as at audio frequencies. The formula

$$Z_o = \frac{138}{\sqrt{e}} \log_{10} \frac{4h}{d}$$

where

Z_o = line impedance
e = dielectric constant of the medium
h = height above ground
d = diameter of the wire

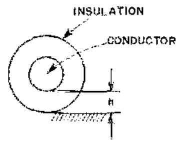
would closely approximate the final results.

If the wire is insulated and the insulation is brought into contact with the ground plane, a simple, stable and adjustable circuit element is formed. The spacing of the wire above the ground plane is determined by the insulation on the wire. We found that the effective value of the dielectric constant, e, may be

Table 2

Spacing Versus Impedance Using No. 14 Wire

Impedance (Z_o) in ohms	*Spacing (h) in inches*
30	0.006
40	0.019
50	0.036
70	0.089
100	0.256
120	0.481



This table gives the required spacing (h) in inches for no. 14 AWG wire with a dielectric constant (e) of 3 to provide a specific impedance. Inches × 25.4 = mm.

[1]Notes appear on page 23.

*5805 Ipswich Rd., Bethesda, MD 20014
**Rte. 7, Box 199, Mt. Airy, MD 21771

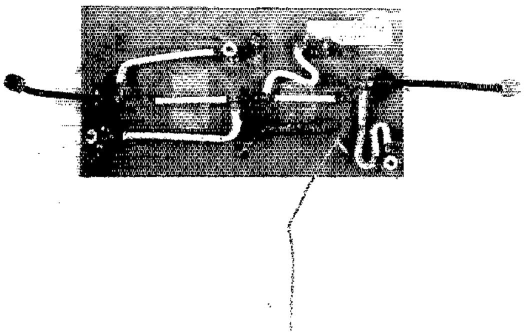


Fig. 1 — A wire line 1296-MHz rf amplifier. The simplicity of construction is quite evident.

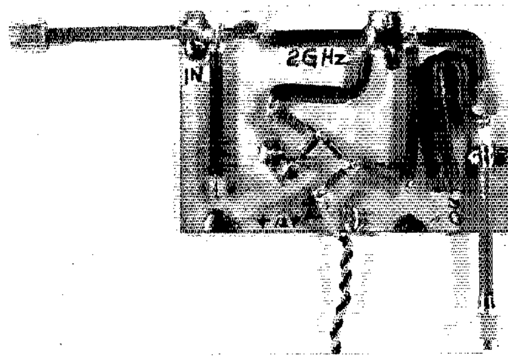


Fig. 3 — Another wire line amplifier, this one constructed for 2 GHz. Note the absence of tuning capacitors; it was tuned by cutting the stubs to proper size.

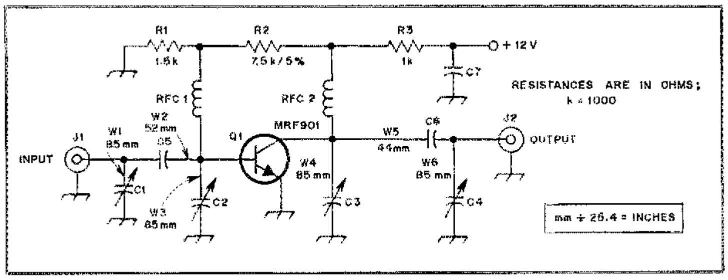


Fig. 2 — Schematic diagram of the 1296-MHz amplifier. If the dimensions shown for W1 through W6 are followed closely, excellent results should be obtained. All resistors are 1/2-watt types.

C1-C4, incl. — 15 pF polypropylene trimmer.
C5, C6 — 47 pF disc ceramic ("zero" lead lengths should be used).
C7 — 0.01 μF disc ceramic.
J1, J2 — SMA connectors.
Q1 — Motorola MRF-901, npn silicon transistor, f_T = 4.5 GHz.
RFC1, RFC2 — 10 turns no. 30 enam., 1/8-inch (3-mm) dia, close wound.

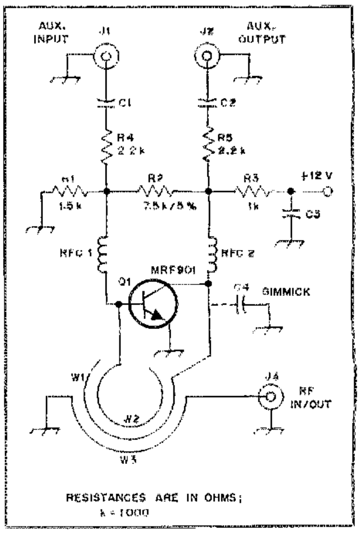


Fig. 4 — The "triple-threat oscillator." Description and arrangement of the lines (W1-W3) and the tuning procedure are discussed in the text. All resistors are 1/2-watt types.

C1-C3, incl. — 0.01 μF, 100 V.
C4 — Gimmick capacitor made from an 8-32 screw threaded into the pc board near W1.
J1-J3, incl. — SMA connectors.
RFC 1 — 10 turns no. 30 enam., 1/8-inch (3.2 mm) dia.
RFC2 — 10 turns no. 30 enam., 1/4-inch (6.4 mm) dia.
W1 — 1.85 inches (47 mm) no. 14 wire (see text).
W2 — 1.46 inches (37 mm) no. 14 wire (see text).
W3 — See text.

adjusted to take into account the amount of the field both in the air and in the insulation.

Experimental results indicated that a piece of no. 14 AWG, PVC-insulated house wire glued to a copper ground plane has an impedance of 58 ohms. This produces an effective dielectric constant of about 2 for PVC in this configuration. Table 1 shows the general range of results that may be expected using common wire sizes with varying types of insulation. Table 2 indicates that a maximum impedance in the range of 100-120 ohms is expected because of spacing and radiation problems; at the low end, 30 ohms could be considered a limit.

One item of interest is the double-stub tuner, a short section of transmission line about 3/8 wavelength long with an adjustable stub tuning line attached at either end. This produces a matching system much the same as a pi-network tuner, but one that will operate in the microwave range. Using small ceramic,[2] glass or polypropylene tuning capacitors on the ends of the stub lines (each about 3/8 wavelength long) will allow a wide range of impedance matching. If a different impedance-matching range is necessary, the lines may be shortened or lengthened easily. Using this method, it is possible to "screwdriver adjust" most microwave circuits for best results.

An RF Amplifier and Oscillator

Amplifiers that have been designed and built using wire line have surpassed initially expected results and have often exceeded the specification sheet gain for the transistor used. The amplifier shown in Figs. 1 and 2 was built using ordinary house wire, polypropylene variable capacitors and an ion-implanted Motorola MRF-901 transistor. This unit works very well at 1296 MHz and, if the dimensions given are duplicated, similar results should be obtained. Other amplifiers (such as the 2-GHz unit shown in Fig. 3) have been built for use at frequencies up to 3 GHz. The total cost of such a project is about $5.50.

The "triple-threat" oscillator shown in Fig. 4 will function as an ordinary oscillator, as a crystal injection-locked oscillator and as a super-regenerative detector. In order to build a receiver, one must have a local oscillator and its output should be clean.[3] Bipolar devices often produce parametric parasitic frequencies and noise, and our first conventionally developed circuits were no exception.

Therefore, the circuit shown was designed. This circuit uses a minimum of high-cost devices and eliminates items like chip capacitors. A bias network similar to that of the amplifier prevents accidental burn-out.

The "tricks" involved here are making the lead lengths as short as possible on the rf side of the circuit. Wrap W1 on a 3/8-inch (9 mm) form and adjust the diameter so that it reaches from the collector to within 1/8-inch (3 mm) of the base of Q1. (Always pre-tin the component leads and use as little heat as possible when soldering.) Do the same for the base lead, W2, and position it inside the collector lead. Glue down the collector lead using only "instant" glue.[4] For maximum output, push the base lead tightly against the collector lead and do the same for the output lead, W3; then glue them down. (W3 is simply a wire line run to the output connector at the edge of the board.) If a signal with very low harmonic content is required, the base lead, W2, may be spaced away from the collector lead until the oscillator almost stops.

The oscillator range has not been tested fully, but we have built some that work from 1 GHz to 2.5 GHz. By feeding a 100-kHz sine wave into the auxiliary input, and placing a 3-kHz low pass filter and an audio amplifier at the auxiliary output, it becomes a super-regenerative detector. We have been able to receive signals at levels as low as −90 dBm with no problem. Like all super-regenerative receivers, this one may cause RFI and is recommended only for short-term experimental operation.

Combined Circuits

The rf amplifier, mixer and oscillator might be combined into a down-converter. If a more stable down-converter is desired, it is possible to crystal lock the oscillator by injecting a 100-MHz-range signal into the auxiliary input. The oscillator must then be tuned for lock. This is evident only when using more sophisticated observation methods such as noticing if received signals are stable when the frequency trim screw is moved slightly.

We hope that the methods described here will provide a solid starting place for amateurs interested in microwave experimentation and activities. We would like to thank the management of COMSAT for releasing the data offered here and for providing the equipment used during the experimental stages.

Notes

[1]*Reference Data for Radio Engineers*, Howard W. Sams Co., sixth edition, chapter 24.
[2]Some ceramic capacitors have poor Q at microwave frequencies.
[3]R. C. Wilson, "Parasitic Oscillations in High-Power Transistor RF Amplifiers," *Ham Radio*, September 1970.
[4]Use only a cyanoacrylic glue similar to Eastman 910® to prevent detuning or loss of Q.

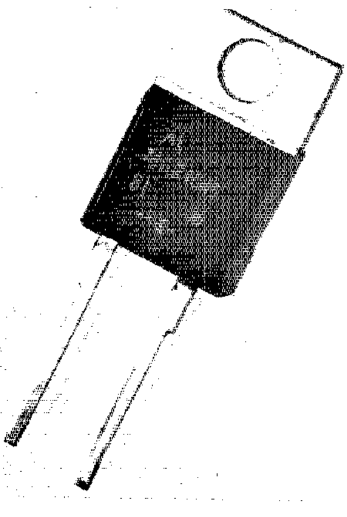
New Products

MOTOROLA SCHOTTKY RECTIFIERS

☐ Low-cost Schottky diodes are now available in plastic cases from Motorola Semiconductor Products Inc. They are designated MBR1020, 1035 and 1045, and are packaged in the familiar TO-220AC style case. The series of devices is rated at 10 A (case temperature of 135° C) with voltage ratings from 20 to 45. Prices are roughly 60% lower than those for equivalent-characteristic Schottky rectifiers in metal cases.

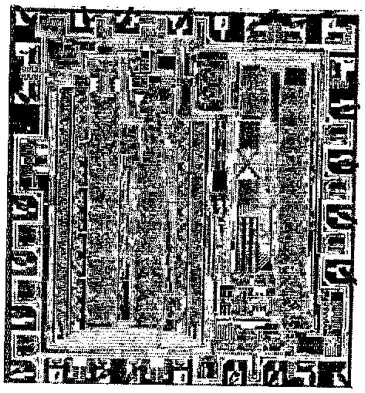
The main feature of interest to designers is the low forward voltage of Schottky diodes. For the Motorola units under discussion, the forward voltage drop is typically 0.2 at 0.5 A and increases to only 0.5 V at 10 A (instantaneous). Silicon rectifier diodes of standard design have a forward voltage drop of 0.6 to 0.7 V. The lower drop of the Schottky diodes is of value in circuits where a minimum drop is mandatory — such as the gate diode between a solar-electric panel and the storage battery (buffer), or when a diode is used in series with a dc line to protect against circuit damage from reverse-polarity power supply connection. There are many other applications that call for a low-forward-voltage type of diode, so the new MBR series may be entirely suitable for the need.

The 100 to 999 lot cost for the MBR diodes is $1.35, $1.70 and $2, respectively, for the 1020, 1035 and 1045 devices. Data sheets are available from Motorola Semiconductor Group, Box 2953, Phoenix, AZ 85062. — *Doug DeMaw, W1FB*



NEW MOTOROLA LSI SYNTHESIZER FAMILY

Motorola has introduced two new frequency-synthesizer ICs, the first of a series of seven devices. The MC145155 and MC145156 use LSI technology to reduce synthesizer costs, fostering the implementation of PLL circuitry in equipment that still relies on tuned circuits and multiple crystals.

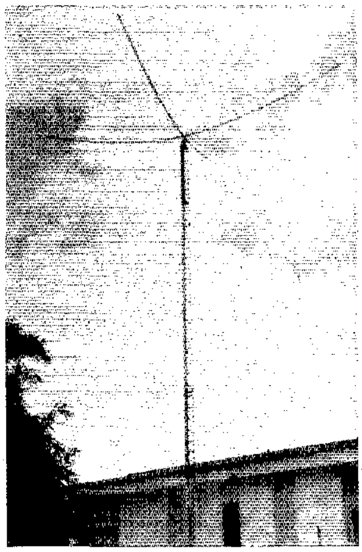


The inside of an LSI chip resembles an aerial view of an ancient Egyptian temple.

The devices are programmed with a clocked, serial input bit stream. Other members of the family are still under development but are due for introduction in 1980. Common family features include a crystal reference oscillator, reference divider, digital phase detector, lock detection circuitry and the necessary programmable divide-by-N counters. The reference oscillator also serves as an input buffer when the use of an external reference source is desired. Other family highlights include: 3- to 9-V dc operation, low dc power drain, −40 to +85° C operating temperature range, improved phase/frequency detector design, operation with low input drive levels (500 mV p-p), and on-chip latches and shift registers for the serial and data bus designs.

The MC145155 and MC145156 are available in both ceramic and plastic DIPs. Availability is through OEM sales offices and authorized Motorola distributors. Further information may be obtained from: Motorola Semiconductor Products, Inc., Box 20912, Phoenix, AZ 85036. — *Paul K. Pagel, N1FB*

The Telerana — A Broadband 13- to 30-MHz Directional Antenna



This lightweight, high-gain antenna won't tax your patience, budget or construction ability. You'll like the results!

By Ansyl Eckols,* YV5DLT, ex-W5DLT

My friendship with George Smith, W4AEO, spanning many years, is directly responsible for the development of the Telerana, a rotatable log-periodic antenna that is lightweight, easy to construct and relatively inexpensive to build. Not only does it cover the range of 13 to over 30 MHz with an acceptable SWR, but in my opinion, based on my observations and those of many amateurs, it also outperforms other antennas of equal size.

During one of our QSOs back in the early 1970s, George had expressed his interest in log-periodic antennas. Indeed I was impressed by the signal strength his antenna put into South America. Appreciating his enthusiasm for the log periodic, I offered to take signal readings in Venezuela whenever he performed tests. After a year of almost daily schedules and comparison checks, George, as a token of his gratitude, made a log-periodic antenna that he kindly shipped to me. Upon its arrival, I wasted little time in suspending it above the roof of my home. The results were noteworthy. Put up in an inverted-V configuration, the array quickly was dubbed "the spiderweb" by my wife, Graciella. Being aesthetically inclined, she was rather displeased by the appearance of wires spreading over the house. Admittedly, it lacked the status of an ornament. What then to do?

*[Editor's Note: After accepting Mr. Eckols' article for publication, we were saddened to learn of his passing.]

Table 1

Shopping List for the Telerana

1 — 1-1/4-inch (32-mm) galvanized, 4-outlet cross or X.
4 — 8-inch (203-mm) nipples.
4 — 15-ft (4.6-m) long arms. Vaulting poles suggested. These must be strong and all of the same strength [150 lb (68 kg)] or better.
1 — spreader, 14.8 ft (4.5 m) long (must not be metal).
1 — 4:1 balun unless open-wire or TV cable is used.
12 — feed-line insulators made from Plexiglas or fiberglass.
36 — small egg insulators.
328 ft (100 m) copper wire for elements, flexible 7-22 is suggested.
65.6 ft (20 m) no. 14 Copperweld wire for inter-element feed line.
164 ft (50 m) strong 1/8-inch (3-mm) dia cord.
1 — roll of nylon monofilament fishing line, 50 lb (22.7 kg) test or better.
4 — metal tubing inserts to go into the ends of the fiberglass arms.
2 — fiberglass fishing-rod blanks.
4 — hose clamps.

After considerable thought, study of available information and frequent consultations with George, an alternative came to mind. This called for a more compact, rotatable version of the antenna that could be mounted atop my tower in place of the three-band Yagi installed there. The Telerana (Spanish for "spiderweb") came into being as a result.

An Efficient Antenna with Good F/B and F/S Ratios

The YV5DLT spiderweb antenna is a

Table 2

Impedance Checks with Palomar Bridge and Collins 51J4 Receiver

Without Balun			*With 4:1 Balun*		*SWR with SECO Tester*	
Frequency	*R*	*jX*	*R*	*jX*	*Frequency*	*SWR*
12	250	70	55	+40	14.0	1.4
13	80	−30	30	−10	14.1	1.3
14	250	70	90	?	14.2	1.3
15	60	0	35	+10	14.3	1.4
16	250	−10	80	−7	14.4	1.5
17	150	−10	45	0	14.5	1.6
18	150	−20	45	−10	21.0	1.5
19	150	20	45	+10	21.1	1.5
20	150	−20	45	−10	21.2	1.4
21	140	0	45	+10	21.3	1.3
22	200	−20	60	−10	21.4	1.3
23	120	−20	40	−5	21.5	1.2
24	220	−20	50	0	28.0	1.1
25	150	−25	40	−10	28.1	1.1
26	100	−20	35	+10	28.2	1.1
27	175	0	50	+10	28.3	1.1
28	140	−30	45	−10	28.4	1.1
29	90	−10	40	+20	28.5	1.2
30	160	70	70	+10	28.6	1.2
					28.7	1.2
					28.8	1.2
					28.9	1.3
					29.0	1.3
					29.1	1.3
					29.2	1.4
					29.3	1.4
					29.4	1.4
					29.5	1.4
					29.6	1.4
					29.7	1.4
					29.8	1.5
					29.9	1.5
					30.0	2.0

Measurements made with bridge connected to antenna input; SWR measured with Seco tester.
Note that the SWR does not exceed 1.5:1 up to 30 MHz.

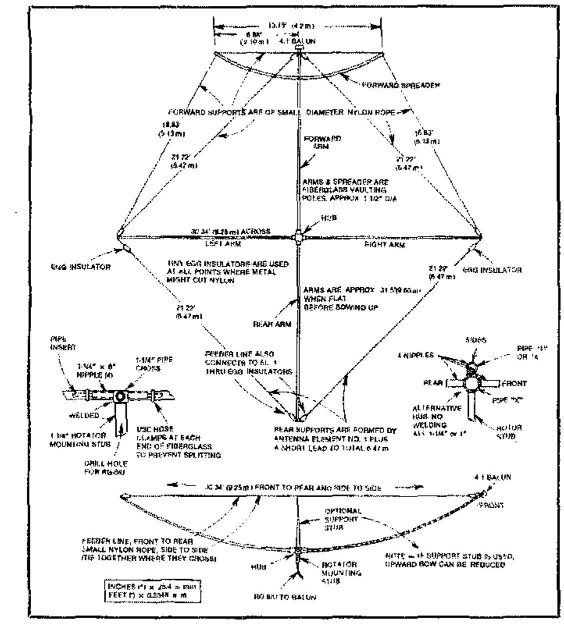


Fig. 1 — Configuration of the YV5DLT spiderweb antenna. Nylon monofilament line is used from the ends of the elements to the nylon cords. Solder all metal-to-metal connections. Use nylon line to tie every point where the lines cross. The forward fiberglass feeder lies on the feeder line and is tied to it. Note that both metric and English measurements are shown except for the illustration of the feed-line insulator. Use soft-drawn copper wire for elements 2 through 12. Element 1 should have no. 7/22 flexible wire or no. 14 Copperweld.

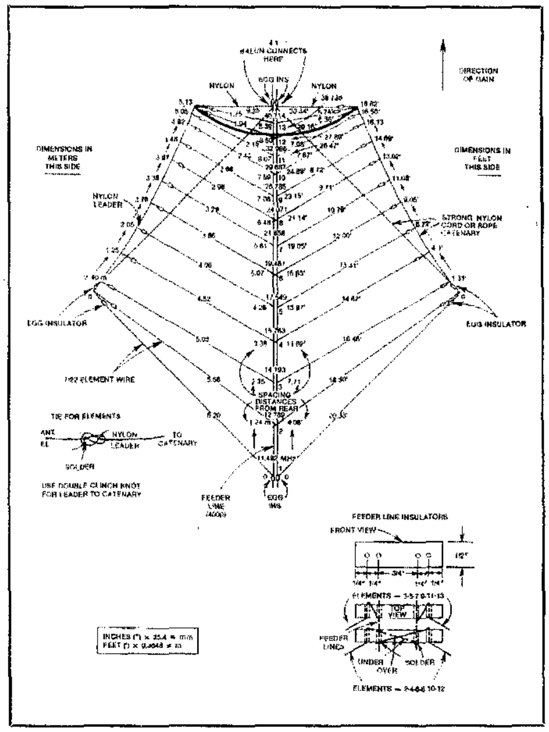


Fig. 2 — The frame construction for the YV5DLT spiderweb antenna. Two different hub arrangements are illustrated.

very efficient high-gain, broadband antenna developed from the log-periodic family. It has a 90% taper and a 0.05% wavelength spacing with the elements swept forward. Because these terms are not always found in Amateur Radio literature on log-periodic design, it will be helpful to the reader who is just being introduced to the terminology to understand that a 90% taper refers to a taper factor of 0.90, and the 0.05% refers to a spacing factor of 0.05. These terms originated in early log-periodic experimental work (about 1958). They are, however, part of the terminology of antenna engineering texts today. For the benefit of readers who may wish to find additional background information on log-periodic antennas, attention is called to the articles by Peter Rhodes, K4EWG, which appeared in *QST* for November 1973, December 1976 and October 1979 and the 13th edition of *The ARRL Antenna Book.*

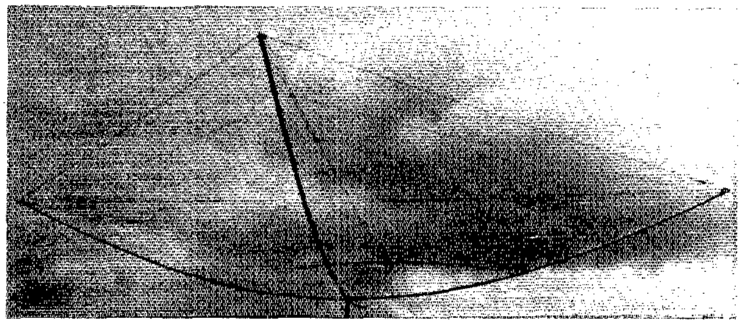


Fig. 3 — The spiderweb antenna, as shown in this somewhat deceptive photo, might bring to mind a rotatable clothesline. Of course it is much larger than the clothesline, as indicated by Figs. 1 and 2. It can be lifted by hand.

This version of the YV5DLT Telerana, shown in the accompanying drawings and photographs, actually is usable from near 12 MHz to 30 MHz, the cutoff frequency of the balun. Without the balun, the frequency range would be higher. The SWR ranges from near unity to 2:1. A perfectionist may wish to use an impedance matching network (tuner) to lower the SWR at the transmitter end of the feed line, but it is hardly worth the effort of retuning. In fact, some Amateur Radio writers frown on the use of both a balun and a tuner. See Table 2 for impedance and SWR measurements.

Log-periodic antennas have reduced gain at the low-frequency end. For that reason, the Telerana was designed with two elements resonating at a frequency lower than the 20-meter band to ensure good performance on 20 meters (≈10 dB). Gains are slightly higher on the 10- and 15-meter bands. The front-to-back and front-to-side ratios are very acceptable.

The 18- and 25-MHz Bands Included

Not overlooked in the design of this antenna are the future 18- and 25-MHz bands, which are within the range of the spiderweb. It can be made to operate at frequencies of 10 or even 7 MHz merely by adding the necessary longer elements with proportional increase in the physical size. A 40-meter antenna would be about 65 × 65 ft (20 × 20 m) or slightly smaller because of slant.

The Telerana array consists of 13 dipole elements properly spaced and transposed along an open-wire, interelement feeder having an impedance of approximately 400 ohms. See Figs. 1 and 2. The array is fed at the forward (smallest) end with a 4:1 balun and RG-8/U cable placed inside the front arm and leading to the transmitter. An alternative feed method is to use open wire or ordinary TV cable and a tuner, eliminating the balun. The direction of gain or forward lobe is away from the small end.

The frame (Figs. 3 and 4) used to support the array consists of four 15-ft (4.6-m) fiberglass vaulting poles slipped over short nipples at the hub, appearing like wheel spokes (Fig. 5). Instead of being mounted directly into the fiberglass, short metal tubing sleeves are inserted into the outer ends of the arms and the necessary holes drilled to receive the wires and nylon.

For my first antennas, I was unable to obtain fiberglass and was forced to use aluminum tubing that I insulated into short sections to prevent resonance. They worked fine, but after a while became permanently formed into the upward bow and lost the tension needed for tightening the array. The fiberglass vaulting poles used now are excellent for the purpose. They can be obtained through suppliers' ads in *QST* Ham-Ads. Other materials just as good as fiberglass may exist.

Any builder of the YV5DLT spiderweb will be pleasantly surprised and gratified with the results. It opens possibilities for each builder to incorporate his or her own ideas. The only absolute law for this antenna is that alternate elements must be transposed exactly as shown in the drawings.

Wind Resistance

Although this array seems to offer less wind resistance than a quad, in some areas of high-wind velocities making the array in a flat plane instead of bowed upward may be a better arrangement. This definitely would eliminate metal arms being used because of the proximity of the elements. Anything selected for the arms should be strong enough to prevent drooping. Also, a vertical stub could extend upward from the hub to the plane of the array, securing the feeder and crossbow string to it. This method would permit less upward bowing. My antenna has withstood several high-velocity windstorms without damage.

Materials

A shopping list is provided for the convenience of those amateurs who wish to build the spiderweb antenna. The center hub of my antenna is made from a

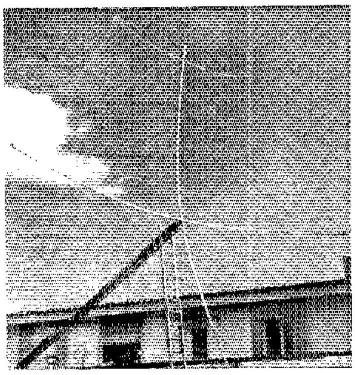


Fig. 4 — The spiderweb antenna resting on a ladder in preparation for preliminary tests. A block and tackle, barely visible in the picture, extends from the house to the tower.

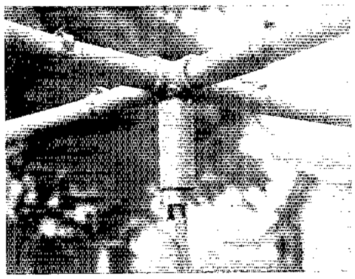


Fig. 5 — The simple arrangement of the hub of the YV5DLT spiderweb. See Fig. 2 and the text for details.

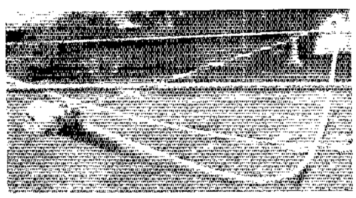


Fig. 6 — The elements, balun, transmission line and main bow of the spiderweb antenna.

1-1/4-inch (32-mm) galvanized four-outlet cross or X and four 8-inch (208-mm) nipples (Fig. 5). A 1-inch (25.4-mm) dia X may be used alternatively, depending on the diameter of the fiberglass. A hole is drilled in the bottom of the hub to allow the cable to be passed through after welding the hub to the rotator mounting stub.

All four arms of the array must be 15 feet (4.6 m) long. They should be strong and springy for maintaining the tautness of the array. If vaulting poles are used, try to obtain all of them with identical strength ratings.

The front spreader should be approximately 14.8 feet (4.5 m) long. It can be much lighter than the four main arms, but must be strong enough to keep the lines rigid. If tapered, the spreader should have the same measurements from the center to each end. *Do not use metal for this spreader.*

Construction

Building the frame for the array is the first construction step. Once that is prepared, then everything else can be built onto it. Assemble the hub and the four arms, letting them lie flat on the ground with the rotator stub inserted into a hole in the ground. The tip-to-tip length should be about 31.5 feet (9.6 m) each way. A hose clamp is used at each end of the arms to prevent splitting. Insert the metal inserts at the outer ends of the arms, with 1 inch (25.4 mm) protruding. The mounting holes should have been drilled at this point. If the egg insulators and nylon cords are mounted to these tube inserts, the whole antenna can be disassembled simply by bending up the arms and pulling out the inserts with everything still attached.

Choose the arm to be at the front end. Mount two egg insulators at the front and rear to accommodate the interelement feeder. These insulators should be as close as possible to the ends.

At each end of the crossarm on top, install a small pulley and string nylon cord across and back. Tighten the cord until the upward bow reaches 39.4 inches (1 m) above the hub. All cords will require retightening after the first few days because of stretching. The crossarm can be laid on its side while preparing the feeder line. For the front-to-rear bowstring, it is important to use a wire that will not stretch such as no. 14 Copperweld. This bowstring is actually the interelement transmission line. See Fig. 6.

Secure the rear ends of the feeder to the two rear insulators, soldering the wrap. Before securing the fronts, slip the 12 insulators onto the two feed lines. A rope can be used temporarily to form the bow and to aid in mounting the feeder line. The end-to-end length of the feeder should be 30.24 feet (9.25 m).

Now, lift both bows to their upright position and tie the feeder line and the crossarm bowstring together where they cross, directly over and approximately 39.4 inches (1 m) above the hub.

The next step is to install the no. 1 rear element from the rear egg insulators to the right and left crossarms using other egg insulators to provide the proper element length. Be sure to solder the element halves to the transmission line. Complete this portion of the construction by installing the nylon cord catenaries from the front arm to the crossarm tips. Use egg insulators where needed to prevent cutting the nylon cords.

In preparing the fiberglass front

spreader, keep in mind that it should be 14.75 feet (4.5 m) long before bowing and is approximately 13.75 feet (4.2 m) when bowed. Secure the center of the bowstring to the end of the front arm. Lay the spreader on top of the feed line, then tie the feeder to the spreader with nylon fish line. String the catenary from the spreader tips to the crossarm tips.

At this point of assembly antenna elements 2 through 13 should be prepared. There will be two segments for each element. At the outer tip make a small loop and solder the wrap. This will be for the nylon leader. Measure the length plus 0.4 inch (10 mm) for wrapping and soldering the element segment to the feeder. Seven-strand no. 22 antenna wire is suggested for use here. Slide the feed-line insulators to their proper position and secure them temporarily.

The drawings show the necessary transposition scheme. Each element half of elements 3, 5, 7, 9, 11 and 13 is connected to its own side of the feeder, while elements 2, 4, 6, 8, 10 and 12 cross over to the opposite side of the transmission line.

There are four holes in each of the transmission-line insulators (see Fig. 1). The inner holes are for the transmission line, and the outer ones are for the elements. Since the array elements are slanted forward, they should pass through the insulator from front to back, then back over the insulator to the front side and be soldered to the transmission line. The drawings show how the transpositions have the element end go over and under the opposite line.

Everywhere lines cross, they are tied together with nylon line, whether copper/nylon or nylon/nylon. This makes the array much more rigid. All elements should be mounted loosely before you try to align the whole thing. Tightening any line or element affects all others. There will be plenty of walking back and forth before the array is aligned properly. Do not expect it to be real taut.

Concluding Notes

The spiderweb antenna weighs no more than 40 lbs (18 kg). My antenna is 3 lbs (1.3 kg) heavier at the front than at the rear. Consequently I provided a 3-lb counterweight in the rear arm.

My transmitter output is connected through RG-8/U, which terminates in a 4:1 balun at the antenna. I have used a tuner to lower the SWR at the transmitter end feed point of the coaxial cable, but I prefer the broadband feature of the antenna and willingly accept the slight mismatch that, after all, results in very little loss.

Perhaps I should also mention that the YV5DLT Telerana antenna performs well enough at heights of 5 to 10 feet (1.5 to 3 m) that all preliminary testing can be done at this level. This is a real convenience to the builder.

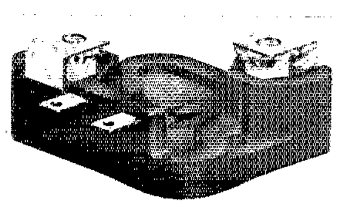
I wish to thank George Smith, W4AEO, for his many years of collaboration in numerous projects; Paul Scholz, W6PYK, for his help; and Al Ray, KB5Z, for his patience in helping me with on-the-air tests during the past three years. I do suggest that you review the numerous articles by George Smith, Paul Scholz and Peter Rhodes that have appeared in *QST* and other radio publications.

New Products

MOTOROLA HIGH-CURRENT, SILICON POWER TRANSISTORS

☐ Motorola has announced a series of new high-current power transistors. The MJ10050, MJ10100 and MJ10200 are npn Darlingtons that are designed to operate at collector currents of 50, 100 and 200 amperes and have V_{CEO} ratings of 850, 450 and 250 volts respectively. They are capable of dissipating 500 watts. These devices are aimed at six-step, ac-motor speed/torque controls and low-frequency inverters.

The transistors are housed in a unique "User-Designed Package." Some of the features are: single-sided mounting with isolated mounting holes, bussable terminals (1/4-inch or 6.4-mm bolt with captured nut), separate drive terminals (1/4-inch or 6.4-mm fast-on terminals), drive terminal capable of accepting a no. 6 bolt, extra large heat-sink contact area, hybrid free-wheeling diode and spacing and creepage distances to meet equipment standards



These devices are rated to operate from 120-, 220- and 440-volt lines. They key transistor parameters such as leakage, saturation voltages and switching times are specified at elevated temperatures, enabling the designer to predict performance under practical conditions. In addition, the rated overload capability of the devices is published for design considerations.

Further information may be obtained from Mr. Jack Takesuye, Motorola Semiconductor Products Inc., P. O. Box 20912, Phoenix AZ 85036. — *Paul K. Pagel, N1FB*

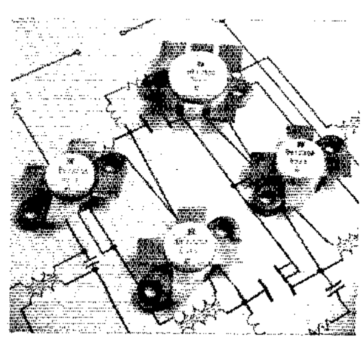
NEW VMOS POWER FETS BY SILICONIX

The long-awaited 12-V versions of the Siliconix, Inc., VMOS Power FET transistors have finally hit the market. Previously, the manufacturers of VMOS devices directed their efforts at the 28-V dc market. This made it somewhat impractical for amateurs or land-mobile equipment manufacturers to employ VMOS components in their equipment.

The new Siliconix devices are designed for maximum efficiency at 12 V dc. They deliver their rated power output up to 175 MHz, operating Class A, B or C. These units, the DV1210, 1220, 1230 and 1240, are conservatively rated at 10, 20, 30 and 40 watts, respectively. They are packaged in the familiar flange ceramic strip-line package. They are available also in the new "stripline" TO-220 style of package, called the "C-220."

The significant virtues of VMOS Power FETs are high gain, low baseband noise and immunity to burnout from mismatch. Furthermore, they are not subject to thermal runaway.

The 100-lot price class of the new VMOS parts is $11.69 (DV1210), $15.37 (DV1220), $19.22 (DV1230) and $23.38 (DV1240). The manufacturer is Siliconix, Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054. Tel. 408-988-8000. — *Doug DeMaw, W1FB*



The Burglar Alarm that Resets Automatically

"Curses! Foiled again!" says the would-be thief as he runs away. This alarm is smart enough to reset itself and wait for the next intruder.

By Dan Sanderson,* KM5T

Although insurance is now available for Amateur Radio mobile equipment, it is not pleasant to have your rig stolen. Even with replacement-type insurance, there is a deductible amount — usually a minimum of $50. You may want to take additional precautions to protect your mobile radio gear.

Start with the obvious. If you don't already do it, make it a habit to lock your doors each time you leave your car unattended. You might also consider one of my camouflage ploys. Before leaving my car, I use a dark towel to cover my equipment. Even though these two steps probably reduce greatly the likelihood of theft, I was still not satisfied. I wanted some kind of alarm system.

When the Thief Has Fled

Most alarm construction projects have no provision for shutting the alarm off automatically after the thief has fled. The alarm continues to drone on and on until the owner shuts it off, the battery wears down or irate passersby make unauthorized modifications to the electrical system of your car. Alarms that must be switched on and off manually each time you enter or leave the car seem like a pain to me. On the other hand, an alarm that has a delay of a few seconds built into the system can be left on continuously. The underlying assumption is that the thief would leave the door open while removing the equip-

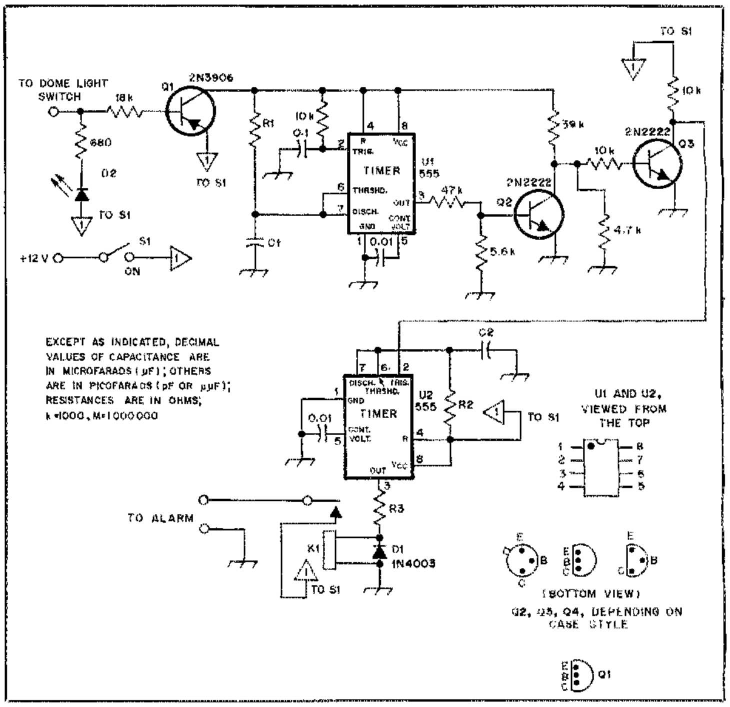


Fig. 1 — Schematic diagram of alarm circuit. Capacitors are disc ceramic except those numbered, which are chosen on the basis of availability for a particular value (see text for discussion). Resistors are 1/4-watt carbon-composition types, except for R3, which is a 2-watt power resistor.

D1 — Silicon power diode, 1 A, 200 PIV, 1N4003 or equiv.
K1 — See text.
Q1 — Silicon pnp general-purpose bipolar transistor, 600 mW, 2N3906 or equiv.
Q2, Q3 — Silicon npn general-purpose bipolar transistor, 500 mW, 2N2222 or equiv.
U1, U2 — Linear timer IC, type 555 or equiv.

*Box 2462, Victoria, TX 77901

ment — a reasonable assumption for an unsuspecting thief.

My design objectives for the alarm were that it be fairly simple to construct using few parts, be reset automatically in case it was triggered, be tolerant by allowing a few seconds grace to enter and leave the car, be left on at all times and be immune to false triggers. After some thinking and experimenting, I came up with this circuit using two NE555 timers (Fig. 1). The first timer is turned on by opening the car door. Pin 3 of U1 goes high immediately and stays high for about 13 seconds. As long as the output of U1 is high, Q2 is on and Q3 is off. After 13 seconds the output of U1 goes low, triggering U2. The output of U2 goes high and turns on the alarm via K1, an spst relay. The alarm stays on for about one and a half minutes and can be reset only by opening S1 during this time. Then the output of U2 goes low and the alarm is ready for the next thief.

Q1 can be almost any medium-power pnp switching transistor. A 2N3906 would be ideal and is easy to obtain. D2, an LED, will light only when the door is open, to remind you that the alarm is set.

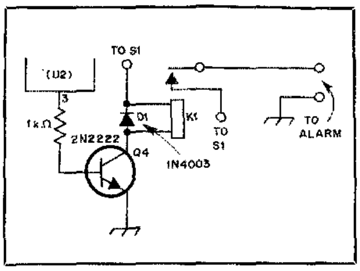


Fig. 2 — Circuit modifications necessary if relay K1 draws more than 100 mA. See Fig. 1 for discussion of component characteristics.

The time delay for U1 is adjusted by R1 and C1. I used 100 kΩ and 100 μF at R1 and C1 respectively to provide a timing period of about 13 seconds for U1. Other timing periods can be had by changing the value of these components. I used 470 kΩ and 100 μF at R2 and C2 respectively to produce a timing period of about 90 seconds for U2. The dropping resistor, R3, should be eliminated if you use a 12-V relay. I use a 6-V, 500-Ω relay (Radio Shack 275-004); R3 is 470 Ω. If you use a relay that draws more than 100 mA, I suggest that you adapt the circuit as shown in Fig. 2. I attached a burglar alarm bell mounted in the trunk, but there is no reason why you couldn't use the output of K1 to operate the horn relay or any other device that you choose.

The circuit is enabled by opening the door, which causes a spring-loaded switch to close. This closure drops the potential of the "cold" side of the dome light (and the input of the alarm) to ground. I suspect that most cars are wired in a similar manner. Layout is not critical. I mounted the circuit inside a small, flat plastic box. An etching pattern and parts placement guide are shown in Fig. 3.

So far, I don't think I've foiled any would-be thieves, although I have forgotten about the alarm a few times while unloading groceries. On the other hand, I still have my equipment — some people can't make that claim! [QST]

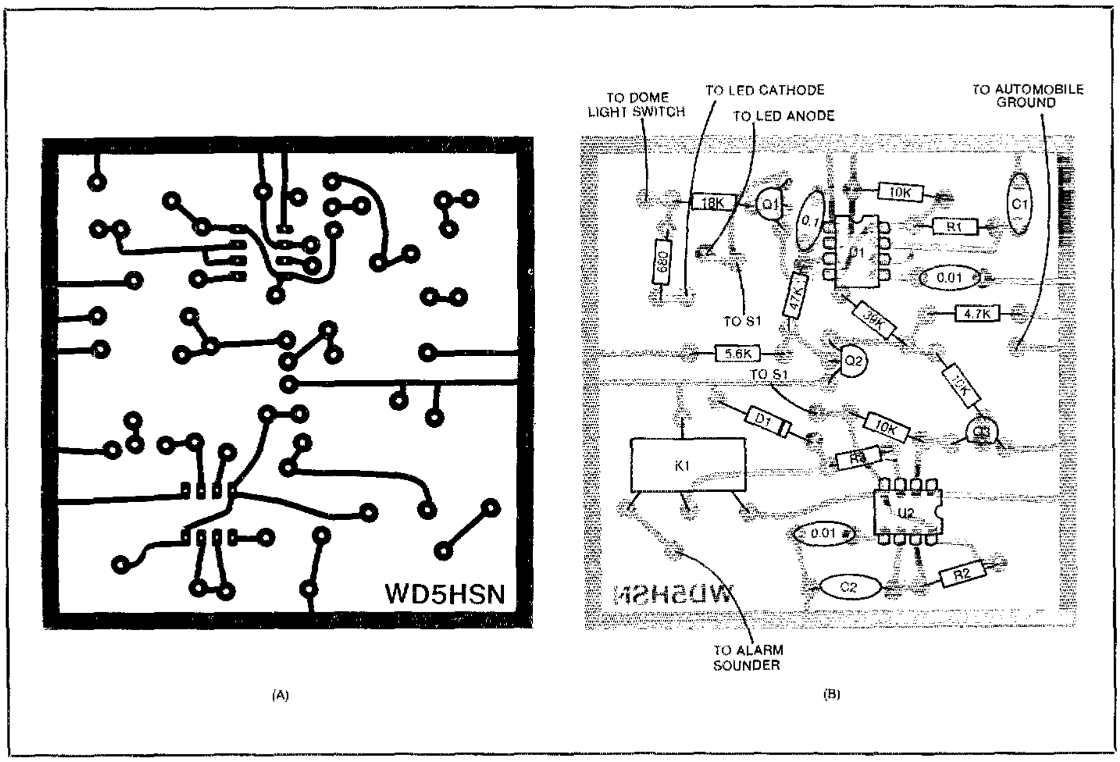


Fig. 3 — At A, circuit-board etching pattern for the burglar alarm. Black represents copper. The pattern is shown at actual size from the foil side of the circuit board. At B, the parts-placement guide. Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. Resistances are in ohms; k = 1000. Capacitors without numbers are in microfarads.

Microcomputer QSO Robot

Ever dream of a completely automatic station that would make QSOs while you sit back and watch? Today's microcomputers make it easier than you might think.

By J. C. Sprott,* W9AV

This presentation concerns the use of a BASIC program enabling radio amateurs who are TRS-80 owners to make automated cw QSOs. Little or nothing is required to interface the computer to the station equipment. Because of the simplicity of the technique employed, it does have limitations, but for many, this information could open the way to an exciting new area of amateur communication.

In a few years, a microcomputer is likely to be considered an indispensable part of any well-equipped Amateur Radio station. Although *microprocessors* are finding their way into many ham products such as programmable scanners and Morse keyboards, only a true *microcomputer* can be adapted conveniently to the diverse needs of enterprising hams.

One of the more popular microcomputers in use today is the Radio Shack TRS-80 model I, level II. I hadn't had mine long before setting out to fulfill a longtime dream of a completely automated cw station that would make QSOs while I sat back and watched. I expected (at least) a modest hardware interface construction project and a lot of tedious assembly-language programming. After thinking about the problem for a while and playing with the BASIC INPUT and OUT functions, I realized that my goal could be reached without modification or hardware construction and without resorting to the use of assembly language. A similar approach may be used with the TRS-80 model III.

*5002 Sheboygan, Apt. 207, Madison, WI 53705

Keyboard-Generated Morse

My first task was to generate Morse code in response to input from the computer keyboard. That is relatively easy. Table 1 contains the BASIC transmit program. Each of the 47 code characters is stored as six elements of the array X(I,J). Six elements permit the longest characters (such as the comma) to be stored using a coding of 1 for a dot, 3 for a dash, and 0 to fill in spaces. For example, the letter "Q" would be: 3, 3, 1, 3, 0, 0. The characters are generated by the OUT function in a loop, the length of which is controlled by X(I,J). Speed of transmission is adjustable up to about 60 wpm.

When using the program with a real-time keyboard, some limitations exist: lack of a buffer, a variation in weighting, a "Lake Erie" swing and "choke up." The "choke up" occurs when a key is pressed while a character is being transmitted and is actually caused by a programming error in the ROM interpreter.

Table 1

TRS-80 Level II BASIC Program for Generating Morse Code from the Computer Keyboard

```
400 DEFINT A-Z: DIM X(47,6): CLS: INPUT "SPEED (WPM)";S: SI=400/S-5: FF=255: F4=
4: IF PEEK(293)=73 THEN FF=236: F4=2
410 FOR I=1 TO 47: FOR J=1 TO 6: READ X(I,J): NEXT J,I
420 CLS: PRINT "KEYBOARD ACTIVE"
430 X$=INKEY$: IF X$="" THEN 430
440 I=ASC(X$)-43
450 IF I<1 OR I>47 PRINT" ";: FOR J=14 TO 7*SI: NEXT: GOTO 430 ELSE PRINT X$;
460 FOR J=1 TO 6: IF X(I,J) THEN FOR K=2 TO SI*X(I,J): OUT FF,F4: NEXT: OUT FF,0
: FOR K=2 TO SI: NEXT
470 NEXT: FOR J=6 TO 3*SI: NEXT: GOTO 430
480 DATA 3,3,1,1,3,3,1,3,1,3,1,0,1,3,1,3,1,3,3,1,1,3,1,0,3,3,3,3,3,0,1,3,3,3,3,0
,1,1,3,3,3,0,1,1,1,3,3,0,1,1,1,1,3,0,1,1,1,1,1,0,3,1,1,1,1,0,3,3,1,1,1,0,3,3,3,1
,1,0,3,3,3,3,1,0,3,3,3,1,1,1,3,1,3,1,3,1,1,3,1,1,1,0,3,1,1,1,3,0
490 DATA 1,1,1,3,1,3,1,1,3,3,1,1,0,0,0,0,0,1,3,0,0,0,0,3,1,1,1,0,0,3,1,3,1,0,0
,3,1,1,0,0,0,1,0,0,0,0,1,1,3,1,0,0,3,3,1,0,0,0,1,1,1,1,0,0,1,1,0,0,0,0,1,3,3,3
,0,0,3,1,3,0,0,0,1,3,1,1,0,0,3,3,0,0,0,0,3,1,0,0,0,0,3,3,3,0,0,0,1,3,3,1,0,0
500 DATA 3,3,1,3,0,0,1,3,1,0,0,0,1,1,1,0,0,0,3,0,0,0,0,0,1,1,3,0,0,0,1,1,1,3,0,0
,1,3,3,0,0,0,3,1,1,3,0,0,3,1,3,3,0,0,3,3,1,1,0,0
```

This program is suitable for both models I and III.

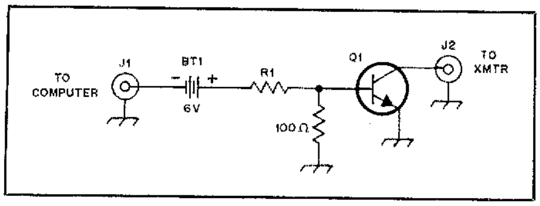


Fig. 1 — Keying circuit for use between the TRS-80 and a transmitter. Q1 is selected to meet transmitter key circuit voltage and current requirements. Use the largest ohmic value for R1 that provides reliable keying. For negative-polarity keying circuits, use a pnp transistor and reverse the polarity of BT1. J1 and J2 may be phono connectors.

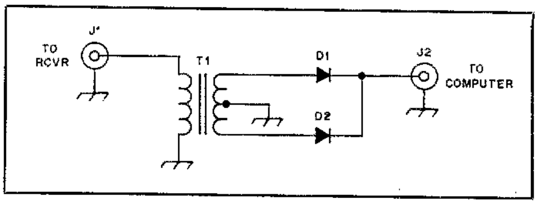


Fig. 2 — An impedance-matching circuit for use between a receiver low-impedance speaker output and the TRS-80 cassette input.
D1, D2 — Silicon, 50 PIV, 1 A, Radio Shack 276-1101 or equivalent.
J1, J2 — Phono connectors.
T1 — Miniature audio transformer, 8Ω to 1-kΩ c.t., Radio Shack 273-1380 or equivalent.

This anomaly is almost nonexistent in the model III TRS-80, which provides much smoother operation in the keyboard mode, copies a slightly higher (14%) range of speeds and appears to accept a somewhat larger range of input frequencies through the cassette port. The mentioned limitations could be corrected, but at the expense of a much more complicated and obscure machine-language program and a much more exotic hardware interface. This would void the constraints under which the system was developed. I wanted the program to be entirely in BASIC so that others could understand and modify it easily. I also desired that little or nothing be required to interface the computer to the station equipment so that any amateur with a TRS-80 could try it.

Computer To Transmitter

Transmitter keying is accomplished by the contacts of the relay, which the TRS-80 uses to control the cassette recorder motor. Measurements showed that a potential of 6 volts and a current of 100 mA existed at the recorder jack. I assumed that the relay contacts could safely handle any transmitter keying circuit exhibiting similar voltage and current characteristics. My Ten-Tec Century 21 meets this requirement, and no problems have arisen during many months of operation. For a transmitter having higher keying-circuit voltages or currents, a second relay or a switching transistor could be used, as shown in Fig. 1.

The task of converting received Morse code to a character that can be displayed on the video monitor is a bit more complicated. For hardware simplicity, it would be nice to be able to feed the detected cw audio signal directly from the receiver to the cassette recorder earphone jack on the computer. This can be done, provided the receiver can supply a 1-volt peak-to-peak, 2-kHz signal across the 100-ohm input resistance. (A correspondingly larger voltage is required at lower frequencies.) For a receiver or transceiver with a low-impedance speaker output (8 ohms or less), the circuit shown in Fig. 2 provides impedance matching and a doubling of the audio frequency.

Table 2 contains the BASIC receive program listing. The program has a number of timing loops that measure the duration of each dot, dash and space. Values of I and J are then generated, and the character is looked up in the string table Y$(I,J). Speed of reception is adjusted automatically. A top speed of about 25 wpm is the practical limit of a TRS-80 Morse receive BASIC program. A number of hardware modifications are available that will increase system speed by a factor of two or more.[1,2] Copy is nearly perfect from machine-sent cw such as W1AW transmissions, but one should not expect miracles in the presence of QRM, QRN or QSB, or when the code is being sent with the wrong foot.

Automated QSOs

For this type of operation, VOX keying or QSK cw operation is used. Messages are stored in a string such as: CQ CQ CQ THIS IS A ROBOT DE W9AV W9AV K. The computer generates the code characters one at a time, and at the end of the message switches to the receive mode.

During receive, a string is generated from the incoming characters. Before deciphering the call of the received station, the computer looks for your station call or a portion of it in the first half of the string. This prevents the calling of a station incorrectly when the QRM is heavy. The string is searched for the last occurrence of a numeral, and the characters between the numeral and final character (usually a K or AR) are counted. If there is one such character, the call is a 2 × 1.

[1,2]Notes appear on page 32.

Table 2

Level II BASIC Program for Copying Morse Code

```
600 CLEAR 100: DEFINT A-Z: DIM Y$(6,63): CLS: B=7
610 Y$="ETINAMSDRGUKWOHBLZFCP VX Q YJ 56>7   8 /-    94=      3   2 10"
620 N=0: FOR I=1 TO 5: FOR J=0 TO 2[I-1: N=N+1: Y$(I,J)=MID$(Y$,N,1): NEXT J,I
630 Y$(5,13)="KN": FOR J=1 TO 63: Y$(6,J)="  ": NEXT: Y$(6,7)=":"
640 Y$(6,12)="?": Y$(6,21)=";": Y$(6,40)="<": Y$(6,42)=".": Y$(6,51)=","
650 FOR I=0 TO 6: J(I)=2[I: NEXT: PRINT "RECEIVE ACTIVE"
660 I=0: J=0
670 OUT 255,0: IF INP(255)<128 THEN N=N+1: IF N<2*B THEN 670
680 OUT 255,0: N=0: IF INP(255)<128 PRINT " ";: GOTO 670
690 OUT 255,0: N=N+1: IF INP(255)>=128 THEN 690
700 IF N>=B THEN J=J+J(I): B=(9*B+2*N+6)/12 ELSE B=(3*B+2*N+2)/4
710 N=0: I=I+1: IF I>6 PRINT " ";: GOTO 660
720 IF INP(255)<128 THEN N=N+1: IF 2*N<B THEN 720 ELSE 740
730 OUT 255,0: IF INP(255)>=128 THEN N=0: GOTO 670
740 PRINT Y$(I,J);: N=N+1: GOTO 660
```

Table 3

Sample of an Automated QSO Using the QSO Robot

```
QRL?
^^^^^
CQ CQ CQ THIS IS A ROBOT DE W9AV W9AV K
^^^^^  W9AV W9AV DE W1AW W1AW -
W1AW DE W9AV TNX FER CALL = U ARE IN QSO WITH A TRS 80 COMPUTER
= UR RST 599 599 = PSE ONLY MY RST? BK
^^^^^  BK R FB ES TNX     =  UR RST 589  589 BK
QSL 589 TNX = QTH MADISON, WI ? MADISON, WI = UR QTH? BK
^^^^^  BK QTH IS  NEWINGTON, CT ?  NEWINGTON, CT  BK
R FB = NAME IS CLINT ? CLINT = UR NAME? BK
^^^^^  BK  FB  CLINT  = NAME  HR IS JOE ? JOE BK
R OK JOE TNX FER QSO ES HPE U ENJOYED TALKING TO A COMPUTER 73 W
1AW DE W9AV <
^^^^^ 73      TNX QSO ES PSE QSL  W9AV DE W1AW <EE
TNX ES QSL SURE < EE
```

Otherwise, it is assumed it is a 2 × 2 or 2 × 3 unless the first and last characters are the same, in which case it is probably a 1 × 2 or 1 × 3. The call of the received station is then stored in a string for future use.

Transmit speed is adjusted automatically to the speed of the received signal (between 10 and 24 wpm) and displayed on the monitor. Whenever 10 spaces in a row are received, the computer assumes that the received station has finished transmitting and the program switches to transmit. This creates a slightly awkward pause that sometimes causes an impatient operator at the other end to begin transmitting again, but it seems to be the only practical solution.

The computer asks a short series of questions such as those in Table 3. Responses can be varied from one QSO to the next to make the computer seem to be more "human." A considerable amount of program logic is required to extract the relevant information from all the extraneous comments that are inevitably made by those who have never had a computer QSO before. Trial and error, lots of ingenuity and quite a few frustrating QSOs are required before wisecracks about the computer being a "lid" begin to subside!

Operation

In the first two months of operation, my computer made over 250 QSOs, and the comments received were almost uniformly favorable. Except for a few occasions when I interrupted the computer to answer a particular question, it was on its own. About all I ever had to do was to retune the receiver occasionally when someone called too far off the received frequency. In fact, the system works so well that I was tempted to leave it on all night while I slept, but the FCC requires an appropriately licensed control operator to monitor transmissions.[3]

I prefer to operate on 10 or 15 meters when the band is not crowded and to operate for only an hour or two at a time. Although another robot has yet to answer mine, I'm sure it's only a matter of time. Upon receipt of an s.a.s.e., I'd be happy to provide further information about this and similar programs that are available at low cost on cassette tapes.[4] I welcome any comments from readers who can improve the operation of the system without greatly increasing its complexity. It would be a contribution we should all welcome.

Notes

[1]Archbold Electronics, 10708 Segovia Way, Rancho Cordova, CA 95670.

[2]Simutek, P. O. Box 13687, Tucson, AZ 85732.

[3]FCC rules and regulations, §97.3(m)(3): "*Automatic control*" means the use of devices and procedures for control so that a control operator does not have to be present at the control point at all times. (Only rules for automatic control of stations in repeater operation have been adopted.)"

[4]The ARRL and *QST* in no way warrant this offer.

Strays

CALL FOR PAPERS ON PACKET RADIO AND COMPUTER NETWORKING

☐ The ARRL is sponsoring a conference on Amateur Radio Computer Networking on October 16, 1981, at the National Bureau of Standards in Gaithersburg, Maryland. The purpose is to explore the possibilities of an integrated amateur computer network using hf, vhf and satellite packet radio as primary transmission means. The network would consist of radio amateurs in both the U.S. and Canada and would provide means of public service by handling third-party traffic, including that of computer amateurs and the deaf. Papers are sought on both technical and operational topics including: network structure, protocols, message handling, equipment design and selection, integration with the National Traffic System, interconnection with computerized bulletin board systems and other topics. This event will be hosted by the Amateur Radio Research and Development Corporation (AMRAD) and by the Radio Amateur Satellite Corporation (AMSAT), whose annual meeting will be held on October 17 at the nearby Goddard Space Flight Center. Those wishing to present papers should send a special letter of intent to Paul L. Rinaldo, W4RI, President, AMRAD, 1524 Springvale Ave., McLean, VA 22101, before August 15, 1981.

INSTRUCTIVE UPDATE

☐ The Club and Training Department at Hq. has an update sheet available, which can be obtained free for an s.a.s.e., for the 1976 General Class Instructor Guide. The reading assignments match the newest editions of the *License Manual* and *The Radio Amateur's Handbook* and point out additions and deletions. — *Maureen Thompson, KA1DYZ, Training Assistant*

I would like to get in touch with . . .

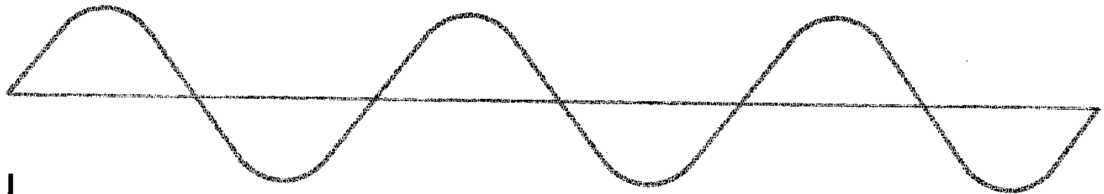
☐ amateurs interested in forming a Heathkit users net for the purpose of sharing information and modifications. Tom Collins Jr., KA3CMR, P.O. Box 10203, Wilmington, DE 19850.

• *Basic Amateur Radio*

Phase Versus Frequency Modulation

Think there is no real difference between phase and frequency modulation? You may be in for a few surprises.

By Harry R. Hyder,* W7IV



I have heard hams make the statement that phase and frequency modulation are the same thing, or that the only difference is in the way they are generated at the transmitter. This is not strictly true, although the differences are somewhat subtle. For instance, if we were to phase or frequency modulate a single sine wave on a carrier, there is no way someone at the receiving end could tell whether it was generated by either a pm or fm transmitter — even with a spectrum analyzer. A sine wave would be produced at the output of either a pm or fm receiver.

Basic Difference

Let us look at two transmitters; one has a phase modulator and the other a frequency modulator. Their modulation circuits have response all the way down to dc. What happens when we apply a dc voltage to their inputs? The fm transmitter will jump to a new frequency and stay there. The pm transmitter, on the other hand, will jump towards a new frequency, but immediately return to the original frequency and stay there. This is the basic difference.

If we were to carry this further and apply square waves to the inputs, a graph of frequency versus time would look like that shown in Fig. 1. At first glance the pm waveform doesn't look very useful; spikes at the rise and fall of the square waves are all that we get. And this is what we would actually see at the output of an fm receiver tuned to a square-wave-modulated pm transmitter. But a receiver designed for pm detection would produce square waves.

Most of our 2-meter rigs have pm transmitters and fm receivers; therefore, we need some way out of this impasse if we wish to use square-wave modulation. At the present, we do not usually square-wave modulate our transceivers, although we may do so in the future when digital communication becomes more widespread. But square waves best illustrate the basic principles; they are the acid test for any modulation system.

Suppose, before we applied the square wave to the pm transmitter, we put it through an integrator. (An integrator is merely a low-pass filter with a response that falls off at the rate of 6 dB per octave.) A square wave coming out of an integrator looks like a triangular wave, as

*1638 W. Inverness Dr., Tempe, AZ 85282

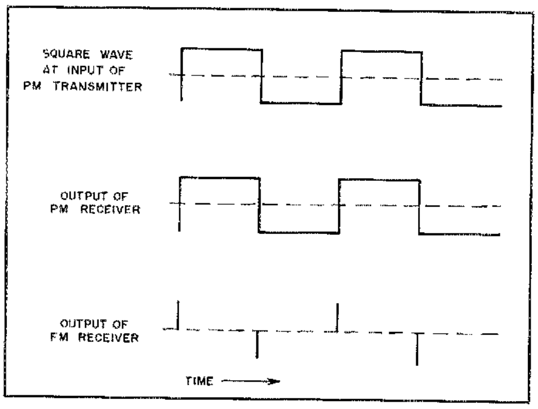


Fig. 1 — Diagrams showing the output of pm and fm receivers when detecting a square-wave-modulated pm signal. Broken lines indicate unmodulated carrier condition.

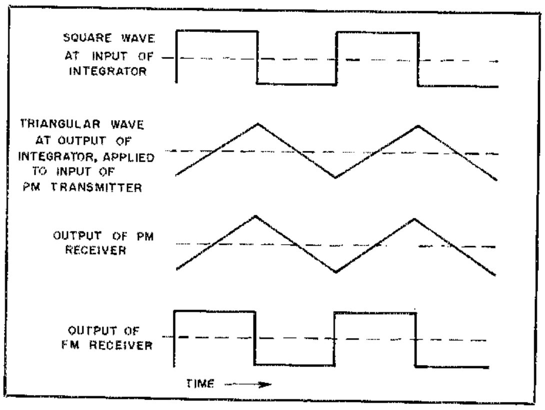


Fig. 2 — Diagram illustrating the use of an integrator in the modulation section of a pm transmitter. Broken lines indicate unmodulated carrier condition.

shown in Fig. 2. When this triangular wave is used to modulate a pm transmitter, what kind of demodulated signal does an fm receiver produce? A square wave!

Therefore, the way to make a pm transmitter produce fm is by integrating the modulating waveform before it is applied to the phase modulator. Integrators are easily built these days with op amps, but a simple, passive R-C filter will do just as well over the audio range.

Why

The explanation for these seemingly mysterious things is quite simple. Frequency can be defined as the rate of change of phase. It is usually expressed in cycles per second (Hz), but it can also be expressed in degrees per second (one cycle equals 360°). Radians per second is the most common format of this angular approach. There are 2π radians in a cycle, which explains why $2\pi f$ appears in so many equations.

Imagine that we have two identical audio amplifiers and that we apply the same sine-wave signal to both. We view the individual outputs on a two-channel oscilloscope. They are of the same frequency, but they differ in phase because of minor internal differences of the amplifiers. For our purposes, we want the outputs to be exactly in phase. To this end, we have equipped the amplifiers with adjustable phase shifters, so it is merely a matter of adjusting one of the phase shifters until the two waveforms are in phase as viewed on the oscilloscope.

Now, during the brief interval when we were turning the knob of the phase shifter, the frequency of the output signal was actually higher than the input signal, or lower, depending on which direction we turned the knob. But as soon as we took our fingers off the knob, the input and output frequencies were the same. It is like hastening my step in the street to catch up with a friend. I have to walk faster than he does, but when I do catch up, we walk together at the same pace. So a fixed phase difference does not represent a frequency difference, but a changing phase difference does. To produce a frequency deviation in a transmitter, we must have a means of making the phase of the signal change *continuously* with respect to the phase of the unmodulated carrier.

Fig. 3 shows elementary frequency and phase modulators. The varactor or capacitance diode in either case varies its capacitance in accordance with the modulating signal. The frequency modulator is understood easily. Varying the capacitance across the oscillator tank circuit changes the frequency of oscillation. The phase modulator is not so obvious. It is completely isolated from the oscillator and cannot affect its frequency. How does it produce frequency deviations?

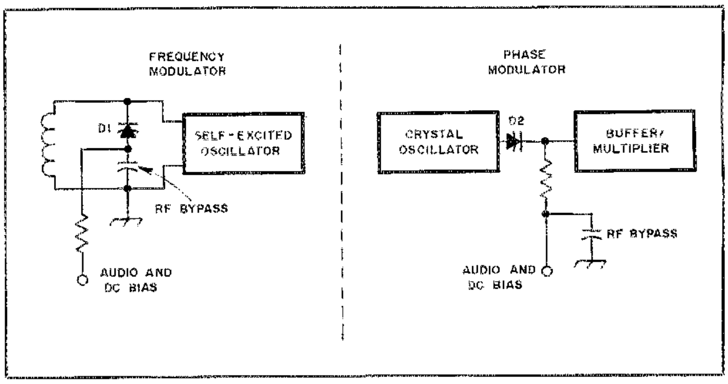


Fig. 3 — Typical frequency- and phase-modulator circuits. D1 and D2 are varactor or capacitance diodes.

The varactor diode in this case is an interstage coupling capacitor. There is always a phase shift across a coupling capacitor in any amplifier; the amount of shift is equal to the angle whose tangent is X_C/R. Thus the phase shift varies with capacitance. When we vary the phase shift continuously by applying an audio signal to the varactor, we produce frequency deviations; the phase is changing continuously with respect to the unmodulated frequency, at an audio rate.

This also explains why applying a dc voltage to the phase modulator produces no deviation — it just produces a fixed phase shift, which is the same as changing the value of a coupling capacitor! The more rapidly the varactor capacitance changes, the more rapid is the phase change, and, hence, the greater the frequency deviation.

With a square wave applied to the phase modulator, the phase changes very rapidly at the leading and trailing edges of the wave, producing spikes. But during the "flat top" portion, the phase remains at a different but constant value. When we integrate the square wave, creating a triangular wave form, the phase changes at a constant rate, increasing and decreasing, which results in fixed positive and negative frequency deviations of the carrier. The net result is a square wave at the output of the fm receiver. The deviation is proportional to the rate of change of the modulating signal — the slope of a triangle in this case.

Modulation Index

The ratio of the frequency deviation to the modulating frequency is called the "modulation index." It is also equal to the peak phase deviation in radians. Obviously, it is meaningful for only one frequency. This is taken to mean the highest desired modulating frequency. Fm broadcast transmitters are designed on the assumption that the highest desirable frequency is 15 kHz. Because they deviate 75 kHz, the modulation index is 5. Voice communication fm uses a lower modulation index, as does TV sound.

Almost unlimited frequency deviations can be produced by direct fm of an oscillator, but such an oscillator would be inherently unstable. Fm transmitters almost universally use phase modulators, with integrators in the audio channel to simulate fm. Even Armstrong's first fm transmitter of the early 1930s used a phase modulator. Actually, fm broadcast stations "pre-emphasize" audio frequencies above 1 kHz at the rate of 6 dB per octave. This means that these frequencies are really phase modulated. The purpose of this is to improve the signal-to-noise ratio in the high audio range. An fm broadcast receiver contains an R-C network to "de-emphasize" these frequencies at the same rate, making the received audio spectrum "flat."

Phase modulators have one disadvantage — the degree of phase shift they can produce is small. It is obvious that changing the value of a coupling capacitor in an amplifier cannot produce a phase shift of even 90°. A simple phase modulator is limited to about one-half radian (roughly 30°). Thus, a phase modulator with a 3-kHz audio input could produce only 1.5 kHz of deviation. Higher desired values are obtained by frequency multipliers that also multiply the deviation.

Pm has no particular advantage over fm. Fm merely got there first, perhaps because it is intuitively easier to understand. In digital communication, some forms of pm have advantages over fm when used with receivers designed for pm. We may see more of pm in the future when digital techniques overtake Amateur Radio. "Pm is the same thing as fm!" will not be heard so often then.

• *Basic Amateur Radio*

The Ups and Downs of Towers

Thinking about erecting a tower? Confused by the wide variety of types and accessories? Here are some basic facts that may help you decide.

By Peter O'Dell,* KB1N

On a calm morning after a violent storm, a friend walked out of his house to check his antenna farm. In the past he had lost an occasional dipole leg, but nothing more serious. This morning it was different: He looked up to find that his tower now extended vertically 60 feet (18 m) and horizontally 30 feet (9 m) from the top of the vertical portion. Although he may not have considered himself lucky, he was. The only real damage was to two sections of the tower. Cleanup consisted of removing everything above the fifth section. Oh, it wasn't easy, but he managed to do it safely.

At the time, he may not have thought so, but things could have been a lot worse. I've heard a story of an Amateur Radio operator who lost his life when his tower crashed through the roof of his house, causing the 20-meter reflector to impale him in his bed as he slept. I have no idea whether this really happened or not, but it certainly isn't out of the realm of possibility. I say my friend was lucky, not because he escaped unharmed, but because he had tempted fate for years and still came away unscathed. How had he tempted fate? His choice of tower was light-duty "TV tower." Instead of obtaining the manufacturer's recommended procedures for installation, he merely dug a small hole, filled it with two bags of hand-mixed concrete and set the bottom section of the tower in the hole. He installed large (projected surface area) antennas that far exceeded the maximum ratings that the tower could safely handle. His guy-wire choice, the small type normally used for roof-mount TV antenna installations, was just as overly optimistic. He was indeed lucky that things had lasted this long without major damage to property (or people).

Destructive Forces

Probably the most destructive force that your tower will have to withstand is wind. It is difficult to imagine the magnitude of force that wind can have as it pushes against a tower. The force is related to the projected surface area and the square of the velocity of the wind as it moves past the tower. Much more rigorous discussions of wind loading have appeared in Amateur Radio literature and are suggested for those interested in a more in-depth approach to the topic.[1,2]

Towers must be built to withstand such forces. The Electronic Industries Association (EIA) has set forth guidelines and standards for antenna structures.[3] Based on meteorological data collected over the years, the EIA standards are more stringent for various areas of the country, depending on the highest velocity of wind that can be expected. Fig. 1 depicts these areas graphically. Consult the manufacturer's installation instructions to determine the erection procedures

[1]Notes appear on page 39.

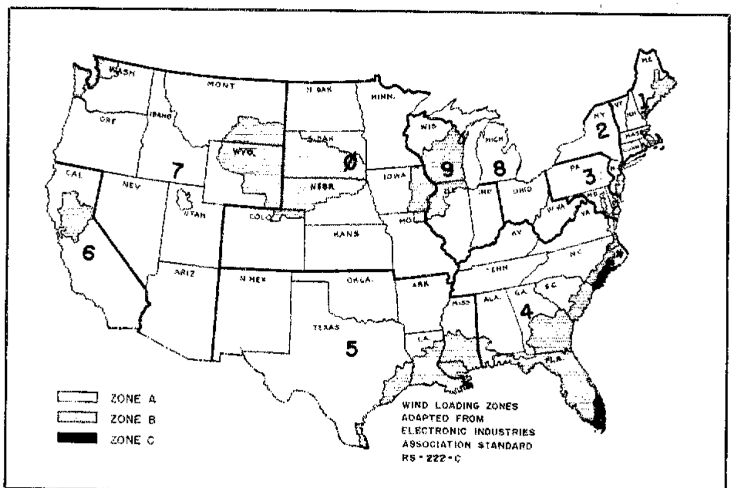


Fig. 1 — Wind-zone map of the continental United States. Structures under 300 feet (91 m) high should be built to withstand winds up to 87 miles per hour (140 km/hr) for zone A; up to 100 miles per hour (161 km/hr) for zone B; and 112 miles per hour (180 km/hr) for zone C. If you are unable to determine which zone you live in because of the limited resolution of this map, you should consult the breakdown by counties in EIA RS-222-C (see Note 3).

*Basic Radio Editor

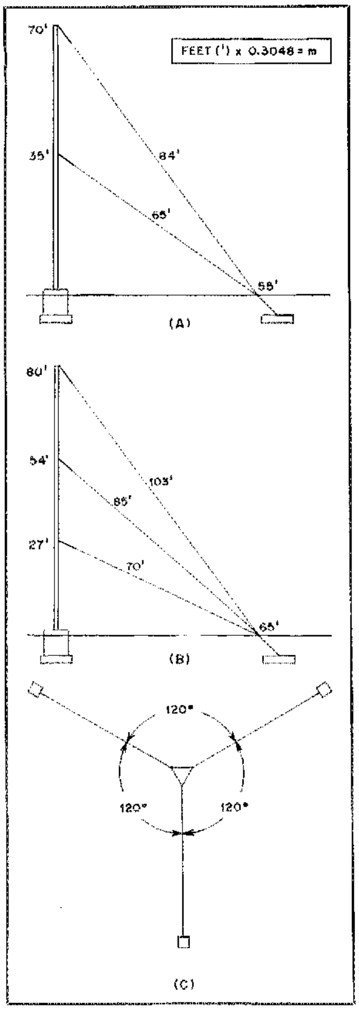


Fig. 2 — Diagram depicting proper method of installation of a typical guyed tower.

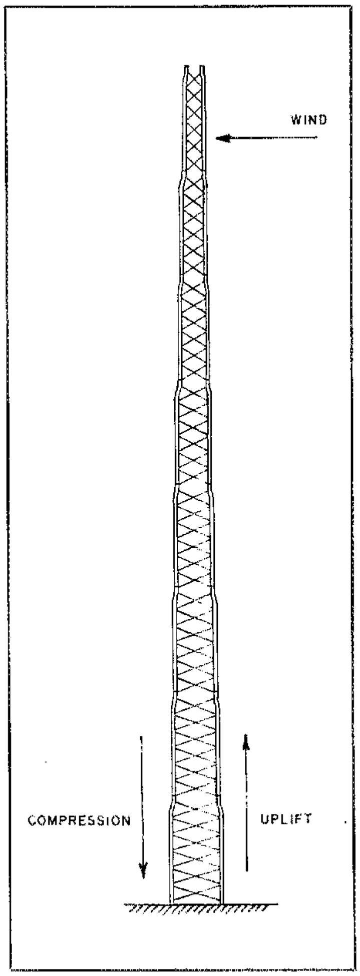


Fig. 3 — Diagram of typical free-standing (unguyed) tower. Arrows indicate the directions of the forces acting upon the structure. See text for discussion.

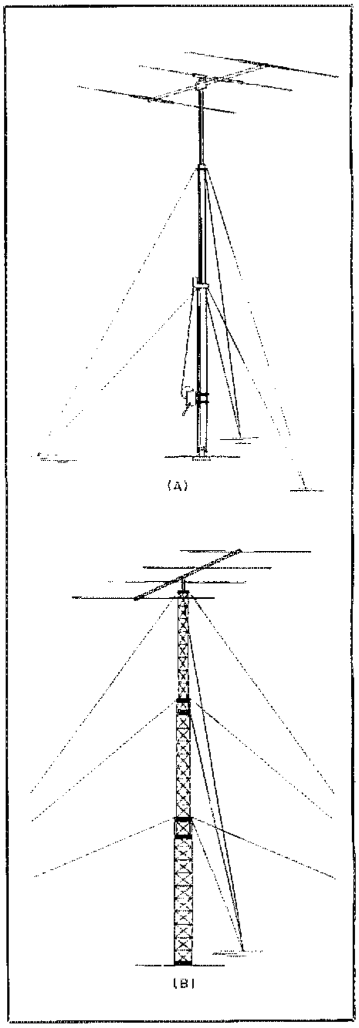


Fig. 4 — Two examples of "crank-up" towers.

for your tower at your particular location. If you are not sure which zone your location is in, you may want to go directly to the EIA pamphlet; it breaks the zones down by county.

Most tower manufacturers specify their products on a "maximum square feet" basis. (In countries using the metric system of measurement, the ratings will be in square meters.) This statistic tells you how many square feet of antenna (projected surface area) you may safely place atop your tower. Most antenna manufacturers provide the square footage of their antennas. If you overload your tower, you run the risk of having it damaged or destroyed in a heavy windstorm. Several manufacturers and dealers have told me that this is the single largest cause of tower failure at Amateur Radio stations.

Types of Towers

The most common variety of tower is the guyed tower made of stacked identical sections. The information in Fig. 2 is based on material from Rohn's catalog. Rohn calls for a maximum vertical separation between sets of guy wires of 35 feet (10.5 m). At A, the tower is 70 feet (21 m) high, and there are two sets of evenly spaced guy wires. At B, the tower is 80 feet (24.5 m) high, and there are three sets of evenly spaced guy wires. Exceeding the vertical spacing requirements could result in the tower buckling.

This may not seem like a reasonable possibility unless you understand the functioning of the guy wires. The guy wires restrain the tower against the force of the wind and translate the lateral force of the wind into a downward compression that forces the tower down onto the base. Normally, the manufacturers specify the initial tension in the guy wires. This is another force that is translated into the downward compression on the tower. If there are not enough guys and if they are not properly spaced, a heavy gust of wind may turn out to be the "straw that breaks the camel's back." Fig. 2C is an overhead view of a guyed tower. Manufacturers usually call for equal angular spacing between radials. If it is necessary to deviate from this spacing, you would be well advised to contact the engineering staff of the manufacturer or a civil engineer.

Some types of towers are not normally guyed — these are usually referred to as free-standing or self-supporting towers. The principles involved are the same regardless of the manufacturer's choice of names. The wind blowing against the side of the tower creates an overturning moment that would topple the tower if it were not for the anchoring at the base. Fig. 3 details the action and reaction involved. The tower is restrained by the base. As the wind blows against one side of the tower, the opposite side is compressed downward much as in the guyed-type setup. Because there are no guys to restrain the top, the side that the wind is blowing against is simultaneously being pulled up (uplift). The combination of the force of the wind and the structure is creating a moment that tends to pivot about a point in the base of the tower. The base of the guyed tower simply must hold the tower up, but the base of the free-standing tower must simultaneously hold one side of the tower up and the other side *down*! It should not be surprising that manufacturers often call for a great deal more concrete in the base of free-standing towers than they do in the base of guyed towers.

Fig. 4 shows two variations of another popular type of tower, the crank-up. In regular guyed or free-standing towers, each section is bolted atop the next lower section. The height of the tower is the sum of the heights of the sections (minus any overlap). Not so with the crank-up towers. The outer diameter of each section is smaller than the inner diameter of the next lower section. Instead of bolting together, the sections are attached with a complex set of cables and pulleys. The overall height of the tower is adjusted by using the pulleys and cables to "telescope" the sections together or apart.

Depending on the design, the manufacturer may or may not require guy wires. The primary advantage of the crank-up tower is that the owner must do the antenna work near the ground. A second advantage is that the tower can be kept retracted except during use, which reduces the guying needs (presumably, you would not try to extend the tower and use it during periods of high winds). The disadvantages include mechanical complexity and cost (usually). It is extremely dangerous to climb on a crank-up tower, even if it is extended only a small amount. Should the hoisting system fail, the inner sections could come crashing down like the blade of guillotine! (There are cases on record where amateurs have lost their lives by climbing extended crank-up towers on which the hoisting system failed.)

Another convenience feature that some towers have is a hinged section that permits the owner to fold over all or a portion of the tower. The primary benefit is in allowing antenna work to be done closer to ground level without the necessity of removing the antenna and lowering it. Fig. 5 shows a hinged base; of course, the hinged section can be designed for portions of the tower other than the base. Also, a hinged feature can be added to a crank-up tower.

Several dealers and experts have commented to me that misuse of hinged sections during tower erections is a common problem among radio amateurs. Unfortunately, these episodes often end in accidents. If you do not have a good grasp of the fundamentals of physics, it might be wise to avoid hinged towers (or to consult an expert). It is often far easier (and safer) to erect a regular guyed tower or self-supporting tower with gin pole and climbing belt than it is to try to "walk up" an unwieldy hinged tower. Think seriously about hinged towers before you take the plunge!

The Base

Each manufacturer will provide his customers with detailed plans for properly constructing the base. Fig. 6 is an example of one such plan. This plan calls for a hole that is 3.5 × 3.5 × 6.0 feet (1 × 1 × 1.8 m). Steel reinforcement bars are lashed together and placed in the hole. The bars are positioned such that they will be completely embedded in the concrete, yet will not contact any metallic object in the base itself. This is done to minimize the possibility of a direct discharge path for

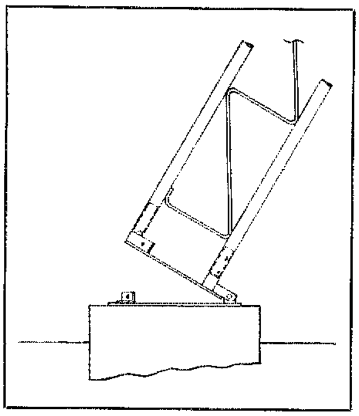


Fig. 5 — Fold-over or tilting base. There are several different variations of hinged sections permitting widely different types of installation. Great care should be exercised when raising or lowering a tilting tower.

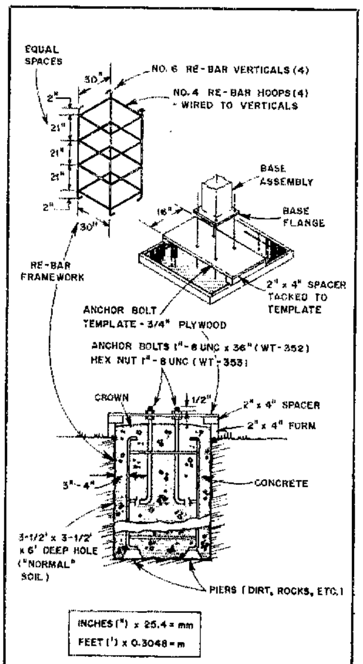


Fig. 6 — Plans for installing concrete base for Wilson ST-77B. Although the instructions and dimensions will vary from one tower to the next, this is representative of the type of concrete base specified by most manufacturers.

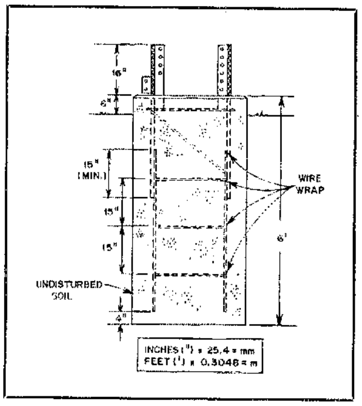


Fig. 7 — Another example of a concrete base (Tri-Ex LM-470).

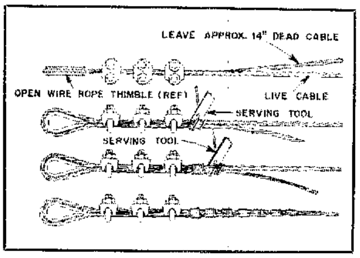


Fig. 8 — Traditional method for securing the end of a guy wire.

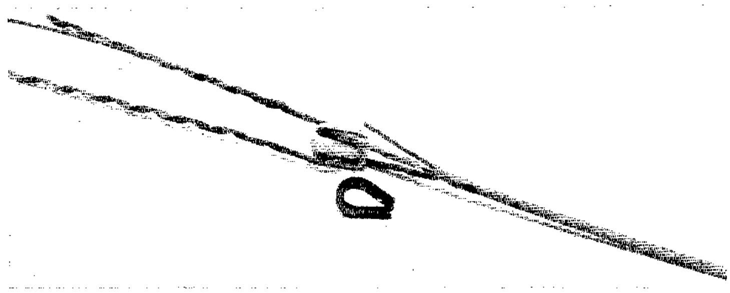


Fig. 9 — Alternative method for attaching guy wires using preformed guy grips. The grip on the right is completely assembled (the end of the guy wire was left extending from the grip for illustrative purposes). On the left, one side of the grip has been partially attached to the guy wire. In front, a thimble for use where a sharp bend might cause the guy wire or grip to break.

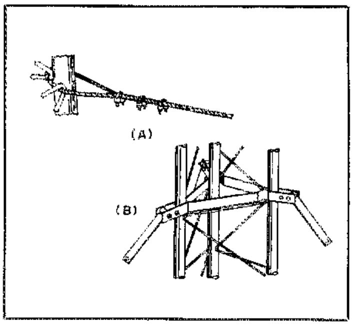


Fig. 10 — Two methods of attaching guy wires to tower. See text for discussion.

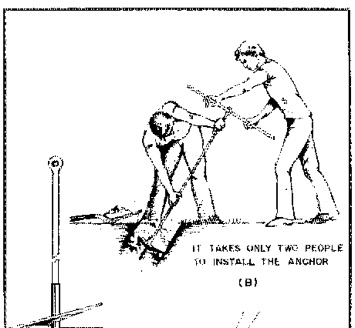


Fig. 11 — Two standard types of guy anchors. The earth screw shown at A is easy to install and widely available, but it may not be suitable for use with soil deviating from normal. The concrete anchor is more difficult to install properly, but it is suitable for use with a wide variety of soil conditions and will satisfy most building code requirements.

lightning through the base. Should such a discharge occur, the concrete base would likely explode and bring about the collapse of the tower.

A strong wooden form is constructed around the top of the hole. The hole and the wooden form are filled with concrete so that the resultant block will be 4 inches (102 mm) above grade. The anchor bolts are embedded in the concrete before it hardens. Usually it's easier to ensure that the base is level and properly aligned by attaching the mounting base and the first section of the tower to the concrete anchor bolts. Each manufacturer will provide specific detailed instructions for the proper mounting procedure. Fig. 7 provides a slightly different design for a tower base.

The one assumption so far is that you have normal soil. "Normal soil" is a mixture of clay, loam, sand and small rocks. A technical discussion is beyond the scope of this article, but you may want to adopt more conservative design parameters for your base (usually, more concrete) if your soil is sandy, swampy or extremely rocky. If you have any doubts about your soil, contact your local agricultural extension office and ask for a more technical description of your soil. Once you are armed with that information, contact the engineering department of your tower manufacturer or a civil engineer.

Attaching Guy Wires

In typical Amateur Radio installations a guy wire may experience "pulls" in excess of 1000 pounds (450 kg). Under such circumstances, you do not merely twist the wires together and expect them to hold. Fig. 8 depicts the traditional method for fixing the end of a piece of guy wire. A thimble is used to prevent the wire from breaking because of a sharp bend at the point of intersection. Three cable clamps follow to hold the wire securely. As a final backup measure, the individual strands of the free end are unraveled and wrapped around the guy wire. It is a lot of work, but it is necessary to ensure a firm connection.

Fig. 9 shows the use of a device that replaces the clamps and twisted strands of wire. These devices are known by various names — guy grips, preforms or deadends. Regardless of what you call them, they are far more convenient to use than are clamps. You must cut the guy wire to the proper length. The preform is installed into whatever the guy wire is being attached to (use a thimble, if needed). One side of the preform is then wrapped around the guy wire. The other side of the preform follows. The savings in time and trouble more than make up for the slightly higher cost.

Guy wire comes in different sizes, strengths and types. Typically, 3/16-inch (5-mm) EHS guy wire will be adequate for the moderate tower installation found at most Amateur Radio stations. Some amateurs prefer to use 5/32-inch (4-mm) "aircraft cable." Although this cable is somewhat more flexible than 3/16-inch EHS, it is only about 70% as strong. We recommend that you stay with standard guy wire and that you use nothing smaller than 3/16-inch (5-mm) EHS.

Fig. 10 shows two different methods for attaching guy wires to towers. At A, the guy wire is simply looped around the tower leg and terminated in the usual manner. At B, a "torque bracket" has been added. There probably isn't much difference in performance for wind forces that are tending to "push the tower over." If you happen to have more projected area (antennas, feed lines, etc.) on one side of the tower than the other, then the force of the wind will cause the tower to tend to twist into the ground. The torque bracket will be far more effective in resisting this twisting motion than will the simpler installation. The trade-off, of course, is in terms of initial cost.

There are two main types of anchors used for guy wires. Fig. 11A depicts an earth screw. It usually measures 4 to 6 feet (1.2 to 1.8 m) long. The screw blade at the bottom typically measures 6 to 8 inches (150 to 200 mm) in diameter. Fig. 11B illustrates two people installing the anchor. The shaft is tilted such that it will be in line with the guy wires. Earth screws are suitable for use in "normal" soil where permitted by local building codes.

The alternative to earth screws is the concrete block anchor. Fig. 11C shows the installation of this type of anchor; it is suitable for any soil condition, with the possible exception of a bed of lava rock! Consult the instructions from the manufacturer for the precise method of installation.

Turnbuckles and associated hardware are used to attach guy wires to anchors and to provide a convenient method of adjusting tension on the guy wires. Fig. 12A shows a turnbuckle of a single guy wire attached to the eye of the anchor. Turnbuckles are usually fitted with either two eyes or one eye, and one jaw. The

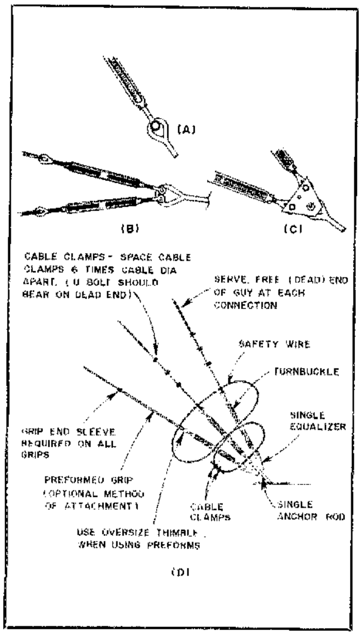


Fig. 12 — Variety of means available for attaching guy wires and turnbuckles to anchors.

Sources of Information

Data for this article was compiled from the literature made available by the following manufacturers. For more information and particular specifications, we suggest that you contact them or their dealers directly.

Aluma Tower
Box 2806
Vero Beach, FL 32960

Hy-Gain Division
Telex Communications, Inc.
9600 Adrich Ave., S.
Minneapolis, MN 55420

Tristao and Pratt Tower Company
P. O. Box 3715
Visalia, CA 93278

Wilson Systems, Inc.
4286 S. Polaris Ave.
Las Vegas, NV 89103

Heights Manufacturing Co.
4516 N. Van Dyke
Almont, MI 48003

Unarco-Rohn
P.O. Box 2000
Peoria, IL 61601

Tri-Ex Tower Corp.
7182 Rasmussen Ave.
Visalia, CA 93277

Universal Manufacturing Company
12357 E. 8 Mile Rd.
Warren, MI 48089

eyes are the oval ends, while the jaws are U-shaped with a bolt through the tips. Fig. 12B depicts two turnbuckles attached to the eye of an anchor. The procedure for installation is to remove the bolt from the jaw, pass the jaw over the eye of the anchor and reinstall the bolt through the jaw, through the eye of the anchor, and through the other side of the jaw. For two or more guys attached to one anchor, it is recommended that you install an equalizer plate (Fig. 12C). In addition to providing a convenient point to attach the turnbuckles, the plate will pivot slightly and tend to equalize the tension on the guy wires. Once the installation is complete, a safety wire should be passed through the turnbuckles in a "figure-eight" fashion to prevent the turnbuckle from working loose

Summary

We've presented a short overview of towers and accessories. There is no way to answer all of your questions in an article of this scope. Hopefully, we have put you in a position to ask more (and better) questions of the person who has all the answers — the tower manufacturer. Before putting down the first dollar on your tower, do some research and make sure that your planned installation will be safe and will suit your needs. Please do not construe this article as an endorsement of any particular manufacturer, type of tower or type of accessory. We cannot and will not tell you which tower to buy. That is your decision. Make sure you don't wake up after a heavy storm and find that you've been impaled by your 20-meter reflector. QST

Notes

[1] R. A. Lodwig, "Wind Force On A Yagi Antenna," *QST*, July 1974, p. 46.
[2] J. J. Nagle, "How to Calculate Wind Loading on Towers and Antenna Structures," *Ham Radio*, August 1974, p. 16.
[3] *Structural Standards for Steel Antenna Towers and Antenna Supporting Structures*, EIA Standard RS-222-C, Electronic Industries Association, March 1976, available from EIA, 2001 Eye St., N.W., Washington, DC 20006, price $7.40.

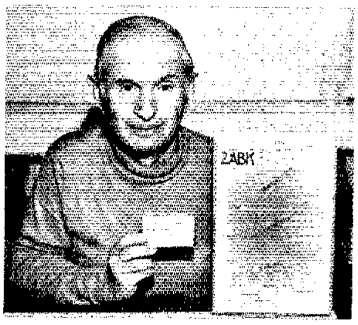
Strays

TECHNICAL CORRESPONDENCE NEEDED

☐ Technical Correspondence Editor Hall, K1TD, is looking for letters that treat subjects of technical interest to *QST* readers. He is particularly interested in receiving letters dealing with solutions to technical problems, new design techniques and improvements to existing modern circuits. Constructive criticisms of published *QST* articles (technical aspects) are used in the column when appropriate and are welcomed. Our objective is to make the column interesting and useful by publishing material of high quality.

We are always happy to receive contributions for our Hints and Kinks column, too. If you have developed an innovation that might be of interest to other amateurs, please write a description of the gadget or concept and send it to Hints and Kinks Editor Leland, W1JEC, at ARRL Hq.

Technical Correspondence is the spot in *QST* to have your ideas or opinions aired. K1TD is waiting to hear from you! — *Doug DeMaw, W1FB*



Talk about luck! While preparing to throw out some old books, Robert Hertzberg, K4JBI, unexpectedly found his original ham ticket folded up in one of them. Issued by the Department of Commerce, it was dated December 18, 1919. The former 2ABK has run the gamut from spark gap to sideband and is still an ardent operator and experimenter. *(photo courtesy of K4JBI)*

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☐ Clubs wishing to take a commission for their treasury must send membership/subscriptions, new or renewal, to Hq. They must be sent by a club officer. Foreign remitters please write us promptly when sending money, stating the amount sent and clearly indicating what it covers. This will enable us to fill your request more quickly. — *Marion Bayrer, ARRL Circulation Department*

I would like to get in touch with . . .

☐ amateurs interested in forming a German language net. Harry Hinz, WB6LNZ, P. O. Box 546, Rio Vista, CA 94571.

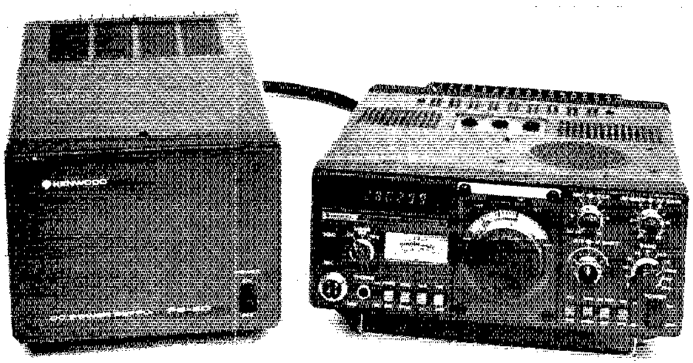
☐ an amateur I worked in Panama in 1979. My log information is as follows: date, 7-29-79; time, 1645Z; call, KZ5KB; RST, his-569, mine-569; frequency, 21.195 MHz; name, Ken; QTH, Ft. Gulick. Dick MacWilliams, KA3CDQ, 4905 Ashford Dr., Upper Marlboro, MD 20870.

☐ other hams who would like to learn or practice foreign languages on the air. Gabe Gargiulo, WA1GFJ, 160 Elm St., North Haven, CT 06473.

Product Review

Conducted By Paul K. Pagel,* N1FB

Kenwood TS-130S HF SSB Transceiver



Conventional wisdom has it that filmmakers often follow a successful movie with a sequel having much the same cast, roughly the same plot and none of the spontaneity that made the original popular. Usually, such imitations are dubbed by the critics as "Son of . . ." movies. The TS-130S could easily be tagged as "The Son of the TS-120S,"[1] but the TS-130S is in no way an inferior copy of the original. Kenwood has kept the solid foundation of the TS-120S and added features that greatly enhance its performance.

Refinements

Perhaps the most obvious change is in terms of frequency coverage: The '130 deletes the 15-MHz band and adds the new WARC bands.[2] For the time being, the only significance this has is that the operator will use the 10-MHz WWV signal for time and frequency reference instead of the 15-MHz signal. Factory-installed diodes prevent accidental transmission on the WARC bands before they become available for use. The owner's manual has instructions for removing each diode to enable transmission on a particular band. If the operator desires to simultaneously enable transmission on all three bands, he merely removes one jumper. Either way, it is a relatively minor procedure that the average amateur can perform in a few minutes.

In terms of flexibility, the most advantageous feature added to the '130 is the provision for optional filters and the means to switch them. Like the '120S, the user can add either the 500-Hz (YK-88C) or the 270-Hz (YK-88CN) filter for cw operation. The user can also choose to add the 1.8-kHz ssb filter (YK-88SN) to use as an alternative to the built-in 2.4-kHz ssb filter. With the '120, the cw filter was selected automatically when the rig was placed in the cw mode. Not so with the '130! A push-button switch located on the front panel allows the operator to choose between narrow and wide filters. In the WIDE position, the '130 automatically selects the 2.4-kHz ssb filter regardless of the setting of the MODE switch. Switching to the NARROW position causes the '130 to select either the optional cw or ssb filter, depending on the setting of the MODE switch. The receiver will be disabled if the NARROW position is selected without the corresponding filter installed. I used this feature to get a rough idea of the isolation of the ports on the filters. If the ports were not isolated, there would be a great deal of leakage of signals around the filters, defeating their purpose. This would be indicated by being able to hear signals in the NARROW position with no filter installed. I found that the only signals I could hear were the ones that had been "pegging" the S meter. My personal opinion is that the isolation is good enough that the filters are not compromised.

The table of specifications shows the noise floor to be −138 dBm at 80 m. This is more sensitivity than could ever likely be needed on this band; in fact, it contributes to the likelihood that the receiver will suffer from front-end overload in the presence of strong signals. Kenwood has added a 20-dB attenuator to the '130 that can be selected with another push-button switch located on the front panel. By using the attenuator and judiciously adjusting the RF GAIN control, the operator can avoid the problems associated with the front-end overload.

Another handy addition to the '130 is the built-in speech processor. As with most speech processors, results were not always predictable. On-the-air tests indicated that at times the processed signal was more effective than the unprocessed signal. At other times, the unprocessed signal seemed to do better. Presumably, varying band conditions, degrees and types of interference, and perhaps "black magic" account for the apparent inconsistencies. Nonetheless, having the processor available at the press of a conveniently located button gives the operator one more weapon for crashing the pileups.

The '120 did not always display the correct frequency on the digital readout when beyond the edges of the specified band. This minor annoyance has been alleviated in the '30. For instance, if you are listening to WWV on 10 MHz and move the VFO 100 Hz below the WWV signal, the digital display will switch from 10,000.0 to 9,999.9. For the average amateur this is probably of little importance; however, one of my primary on-the-air activities is participating in Army MARS nets, which are

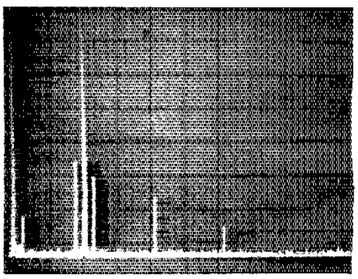


Fig. 1 — Worst-case spectral photograph of the TS-130S transmitter output on 14 MHz at 100-watts output. Vertical divisions are 10 dB each; horizontal, 10 MHz. Close-in spurs are down approximately 45 and 50 dB, respectively. The second harmonic is down about 55 dB. The TS-130S meets current FCC requirements for spectral purity.

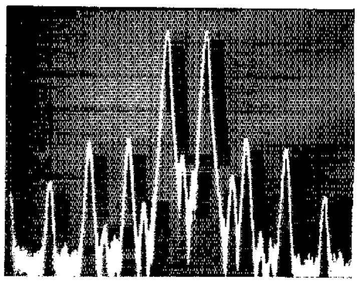


Fig. 2 — This photo represents 20-meter two-tone testing of the TS-130S at 100-watts PEP output. Each vertical division is 10 dB; horizontal, 1 kHz. Third-order products are about 38 dB down from the PEP output level.

[1] P. K. Pagel, "Product Review," *QST*, February 1980, p. 38.
[2] R. L. Baldwin, "It Seems to Us . . ." *QST*, January 1980, p. 9.

*Assistant Technical Editor

located just above and below the amateur bands. It is certainly convenient to "dial up" the given frequency of a net with no guesswork or mental gymnastics. As with the '120, the analog dial would be adequate (temporarily) should a problem develop with the digital readout.

On the '120, the operator used the MODE switch to select between cw, usb and lsb. The markings on the '130 MODE switch read: CW SSB REV. Diode switching selects the "normal" sideband for any given band when the switch is in the SSB position. If the operator desires to operate on the other sideband, he switches to the REV (reverse) position. This feature is hardly earthshaking, but it does facilitate rapid band changes.

Constants

Most of the basic parameters of the '120 have not been changed in the '130. The '130 has the built-in VOX controls located on the top cover of the rig. This presents no problem for fixed or mobile use. The optional MB-100 mobile bracket is designed such that the operator should have no trouble reaching the VOX controls while the rig is installed in it, should that be necessary. I found the built-in noise blanker to be quite effective in taking out ignition noises from nearby automobiles.

The TS-130S is delightfully simple to operate. The transmitter is broadbanded, so tune-up is limited to selecting the appropriate band, picking a frequency and choosing the appropriate mode. Because the finals are solid-state, Kenwood has taken precautions to protect them from conditions that might lead to their destruction. A large and quite effective heat sink is attached to the finals. In fact, the heat sink on the finals is larger than the heat sink on the companion PS-30 power supply. A very quiet fan is mounted on the heat sink of the '130. Normally the fan is off; when the temperature of the heat sink rises above a predetermined level, the fan is switched on automatically. For the first couple of months that I used the rig, the fan did not come on. I had begun to suspect that it might be defective. During the lab tests we locked the transmitter on at full output power (into a dummy load, of course). The heat sink warmed up rapidly, and the fan did come on. It is an extremely quiet, but effective, fan.

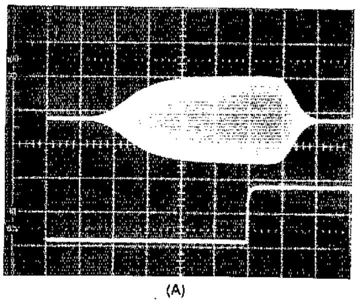
The '130 has built-in circuitry that protects it from high VSWR levels. The circuitry senses the high VSWR and automatically reduces the drive level. At my station, one of the antennas failed in the midst of a QSO. The operator at the other end reported a sudden drop in my signal level. I checked the SWR and found that it was well above 5:1. I tested the '130 on a dummy load and found that the unit performed normally. The protective circuitry had passed the acid test!

Another feature carried over from the '120 that is quite useful is the IF SHIFT, which moves the i-f crystal filter center frequency ± 1 kHz. This allows the operator to adjust the tone or eliminate interference. At the beginning of one of my cw QSOs, there was relatively little activity on the band, and I was using the ssb filter. As the ragchew progressed, additional stations appeared nearby. I switched to the 500-Hz cw filter, which removed the distraction. Then, suddenly, a very loud station came on top of the station I was working and began calling CQ. I decided to try taking him out with the IF SHIFT. It worked like a champ: I could tell he was still there, but he was so far down the slope that the station I was working was once again armchair copy. I was impressed.

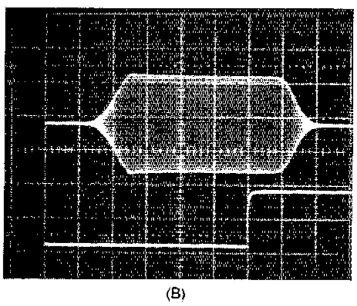
The '130 has a built-in, 25-kHz crystal calibrator that can be adjusted to WWV. It also has provisions for installation of four crystals for fixed frequencies of operation. The S meter also doubles as an indicator for transmit conditions. On transmit, the meter can read either collector current or alc (automatic limiting control). The alc meter

Kenwood TS-130S Transceiver Serial No. 1020547

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*		
Frequency coverage: 80-10 m, WARC bands included.	As specified plus approximately 70 kHz beyond upper and lower band edges.		
Modes of operation: Ssb/cw.	As specified.		
Readout: Analog and digital; 6-digit, fluorescent blue digital display.	0.25 inch (6.4 mm) digits.		
Resolution: Analog, 1 kHz; digital, 100 Hz.	As specified.		
Kilohertz per turn of knob: Not specified.	25.		
Backlash: Not specified.	Nil.		
RIT range: ± 2 kHz.	± 2 kHz.		
Receiver attenuator: 20 dB.	As specified.		
S-meter sensitivity (μV/S9): Not specified.	80 m, 100; 40 m, 100; 30 m, 100; 20 m, 100; 17 m, 100; 15 m, 102; 12 m, 102; 10 m, 100.		
DB/S unit: Not specified.	From S1 to S9, 6 dB; from S9 to +30 dB, linear; above +30 dB, nonlinear.		
Receiver sensitivity: 0.25 μV for 10 dB S + N/N.	Receiver dynamics measured with optional YK-88C i-f filter installed.		
		80 M	*20 M*
	Noise floor (MDS) dBm:	−138	−138
	Blocking DR (dB):	109	110
	Two-tone, third-order IMD DR (dB):	79	78
	Third-order input intercept (dBm):	−19.5	−21
Audio power output (8 ohm load): 1.5 W.	As specified.		
Power consumption: Receive, 9.66 W; transmit, 248.4 W.	Not measured.		
Transmitter rf power output: Not specified.	80-12 m, greater than 100 W; 10 m, greater than 90 W.		
Spurious suppression: Better than 40 dB.	45 dB.		
Harmonic suppression: Better than 40 dB.	Approx. − 55 dB on 20 m (worst case).		
Carrier suppression: Better than 40 dB.	As specified.		
Third-order IMD: Not specified.	Approximately − 38 dB (see photo).		
Key-down time limitation: Not specified.	See text discussion of built-in protective circuitry.		
Frequency stability: Within 1 kHz during the first hour after 1 minute of warm-up; within 100 Hz during any 30-minute period after warmup.	− 110 Hz after 10 minutes, − 337 Hz after 1 hour. (Measured with transmitter operating at 20-W output into 50-ohm load.)		
Size (HWD) 3.8 × 9.6 × 11.7 inches (94 × 241 × 293 mm).			
Weight: 12.4 lb (5.6 kg).			
Color: Gold brown/gray.			



(A)



(B)

Fig. 3 — The keyed cw waveform of the TS-130S. At A, the carrier level control was adjusted so that the alc meter barely deflected upscale. The waveform is "soft and mushy." At B, the carrier level control was fully advanced. The alc meter was "pegged," yet the waveform remained relatively soft, indicating that it is difficult to overdrive the TS-130S. The best waveform was obtained by adjusting the carrier level control to the point that resulted in the alc meter reading being in the upper limit of the alc zone. Horizontal divisions are 5 ms each. As with the '120, roughly 7 ms after key up, the wave starts to decay. No key clicks were discernible. Because of the delay, the weighting may be a little heavy — that is probably unnoticeable below 40 to 50 wpm.

reading is most useful in adjusting the microphone gain control for ssb operation. In the ARRL lab, we found that the best cw waveform could be obtained by setting the carrier level control so that the alc meter rested at the upper boundary of the alc zone (see photo).

A wide variety of accessories for the TS-130S are available in addition to the PS-30 power supply and MB-100 mobile bracket already mentioned. These include VFO-120 external VFO and the DFC-230 digital frequency controller. A DIN socket on the rear panel provides the means for controlling an external amplifier.

The only glitch noticed during several months of operation occurred one evening shortly after KB1O and I checked into a MARS net. I looked up at the rig and noticed that smoke was streaming out the air vent on the top. In a flash, I turned the rig off and unplugged it. I removed the top and bottom covers and looked for visible signs of damage — none. I reconnected the power supply and turned the unit on. Like a hawk, I watched for the first sign of smoke to pinpoint its source. I waited . . . and waited . . . and waited some more. Nothing. I connected a dummy load and tested the transmitter. Everything seemed normal. So I put it on the air and got excellent signal reports. Still no sign of smoke. For several weeks I operated the '130 with the top and bottom covers removed. There was never a recurrence of the smoke. I've found nothing abnormal in the unit's operation. I concluded that a small varmint had crawled into the innards and met an untimely end.

If I had a complaint it would not be about the rig at all, but about the documentation that goes with it. The owner's manual provides clear text and detailed pictorial drawings that indicate how to connect the TS-130S to various options and environments. It has a block diagram and schematic diagrams of the various boards, and one large diagram of the whole radio. Here the '130 falls short of the '120; its manual at least had an abbreviated description of the circuit. Kenwood does sell an optional service manual. If this radio were destined for the CB market or another service where no technical expertise is expected of the operator, then I think they would be justified in limiting the owner's manual to the information contained in this one. That is not the nature of the amateur market, though. I think that Kenwood and the other manufacturers who do not automatically provide good technical documentation of their equipment are doing a disservice to the amateur population and the Amateur Radio Service in general.

As with the '120, the '130 seems to have been designed with the mobile operator in mind. Over the years, mobile rigs have often implied compromise. The TS-130S is not the top of the Kenwood line in terms of receiver performance (see the receiver figures of the TS-830[1]). But the difference in performance is balanced by the added versatility. The TS-130S is convenient, easy to operate and ideal for mobile installations. The TS-130V, a low-power version with most of the features of the TS-130S, is available for the QRP enthusiast. Additional information about the TS-130S may be obtained from Trio-Kenwood Communications, Inc., 1111 West Walnut St., Compton, CA 90220. Price class for the TS-130S is $750. — *Peter O'Dell, KB1N*

[1]P. K. Pagel, "Product Review," *QST*, May 1981, p. 38.

J. W. MILLER AUTOMATIC ANTENNA TUNER AUTO-TRAK MODEL AT2500

□ The moment I saw the AT2500 in operation I recognized that it was going to be a challenge to describe. The input and output capacitor knobs turning as if by magic, without a hand guiding them, surely implied a high degree of complexity and sophistication. It was not a disappointment. The past few months have been spent observing the operation of the tuner with a variety of loads, power levels and modes of operation at W1SE.

Eighteen pages of the 20-page instruction manual describe each circuit in explicit detail. The manual is extremely well organized, and includes schematic and circuit-board layouts with every component identified.

General Description

Two primary assemblies make up the AT2500. The main tuner assembly houses the rf components and two circuit boards, which contain circuitry to control the motor-driven capacitors. During operation the tuner band switch, lettered A through K, must be set to the correct band before automatic operation may begin. The capacitors may be operated manually, with or without the automatic feature disabled and for minor "touch-up" by those who just can't keep their hands off the knobs. This feature is handy should there ever be a control-circuit malfunction. Manual operation of the tuner is possible with the boards removed for repair or replacement. The impedance-matching circuit is a conventional T network.

The second assembly is the remote directional bridge coupler which, though separate, is connected to the main tuner assembly by means of a captive plug-in cable.

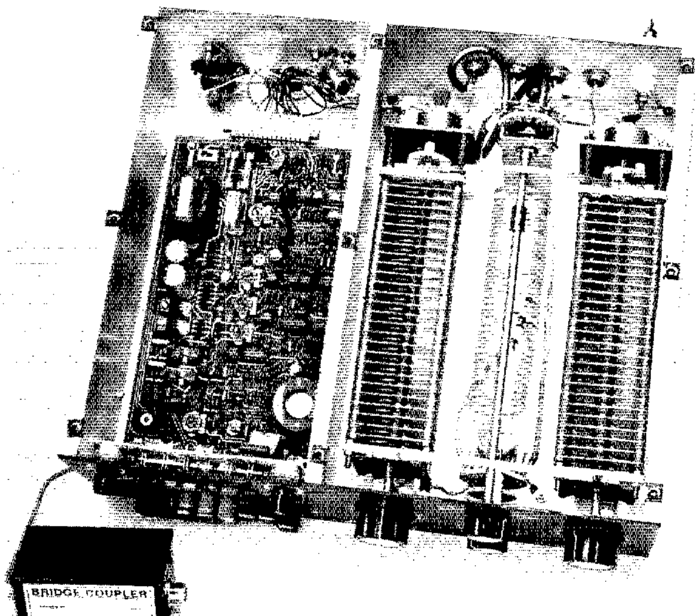
Circuitry

A very brief description of each circuit will provide the reader with an idea of what the AT2500 does. The remote directional bridge coupler is a separate package, designed to be inserted in the coax line at the output of the rf source, i.e., transmitter, transceiver or amplifier — the point in the feed line where it is most important to exhibit a low SWR. The bridge generates dc voltages that are proportional to the forward and reflected rf voltages present on the cable. Ultimately, these dc voltages are used to actuate the motors that drive the capacitors in the rf section.

An SWR analog computer circuit automatically calculates the SWR as derived from the dc voltages developed by the bridge. The calculated SWR is in turn displayed on the front-panel SWR meter.

These same dc voltages also drive the power logarithmic amplifier to provide in excess of 60 dB of compression, enabling the front-panel power meter to read either 1 to 250 or 10 to 2500 watts on a single scale. Each range is selected by a panel switch.

As the motors turn the capacitors, the dc voltage developed by the bridge circuit is changing constantly. The slope detection circuit monitors these changes, and as a decending voltage begins to change, that is to increase, the particular motor operating at that moment is stopped, and the other motor is started. As the SWR is reduced, by alternate starting and



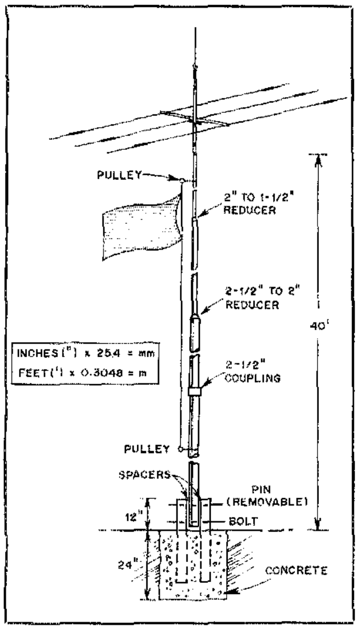


Fig. 4 — A combination flag pole and antenna mast is designed by John Reisenauer, Jr., KA7BKI. See text for details.

tions of the mast is 165 lb (75 kg), plus 25 lb (11 kg) for the antennas. A strong step-ladder is essential for supporting the mast in the initial stages of pulling the structure upright.

Although the sketch shows a 24-inch (0.6-m) depth for the concrete base, a greater depth may be essential for regions where deep frosts are common. The footing for the base should be below the normal frost line.

For those who may wish to duplicate this mast, I strongly urge the use of all safety precautions, especially in connection with overhead power lines. I recommend that you read "Excavation Litigation" in February 1980 *73*. — *John Reisenauer, Jr., KA7BKI, West Richland, Washington*

MORE ON THE W5LW TS-520 MODIFICATION

☐ In response to Warren Bone's (KQ4X) comments on the TS-520 cw modification that appeared in Hints and Kinks for December 1980, I reviewed the article by Lyle Smithers, W5LW, in *QST* for September 1977.[1] I must agree with Warren that there most likely would be a loss of power when the cw filter is switched out of the circuit. The cw filter, however, is not actually being switched out of the circuit but is being paralleled by switching the ssb filter into the circuit also. I have serviced some Kenwood TS-520s and Yaesu FT-101s with the complaint that the output power was down or the receiver was weak, only to find a shorted switching diode that had placed both the cw and ssb filters in the circuit simultaneously. Replacing the shorted diode corrected the condition. Lyle and Warren set up this same condition when they modified the TS-520.

I modified my TS-520 in 1975 by using the fixed frequency switch to switch the cw and ssb filters in and out of the circuit. It is accomplished by first removing the top cover and locating the FIXED FREQUENCY/AVR circuit board. On the AVR board locate and remove the purple wire at C, the yellow wire at 1, the brown wire at 2, the orange wire at 3 and the green wire at 4. Next locate the brown wire attached to the terminal marked cw on the i-f circuit board (if the cw filter has already been installed) or on the terminal marked ssb (if you are just installing the cw filter). Remove this brown wire and attach it to the purple wire removed from the AVR board. Next, find the yellow wire removed from the AVR board and attach it to the terminal marked ssb on the i-f board. Locate the brown, orange and green wires removed from the AVR board, twist the ends together, and attach another piece of hookup wire to these ends so as to reach the terminal marked cw on the i-f board. Connect this wire to the cw terminal. Where wires were spliced, they should be insulated with heat-shrink type tubing or with tape. The modification explained above has the ssb filter in the circuit when the fixed frequency switch is in position 1 and the cw filter is switched to positions 2, 3 or 4. — *"Livie" Larkin, W6TAS, Garden Grove, California*

[Editor's Note: Livie was formerly service manager for Henry Radio, Anaheim, California.]

[1] L. Smithers, "Using a CW Filter with the TS-520," Hints and Kinks, Sept. 1977 *QST*, p. 44.

TIP FOR 2-METER ANTENNA

☐ I found Peter O'Dell's 2-meter direction-finding cardioid antenna most interesting as I perused the March 1980 issue of *QST*. When using small diameter material such as brass rod for the radiator and ground plane, I find it advisable to screw wire nuts (electrician's wire connectors) to the end of each element to present a blunt surface. Without some protection at the ends of the tubing or rod, there is a very serious potential for eye damage when the antenna is being swung about at arm's length. These nuts come in various sizes to fit common tubing or rod sizes. — *Charles M. Currier, W1QKK, Rockland, Maine*

ETCHANT RESIST PENS

☐ After buying two etchant resist pens in a row that were dried up and useless, I noticed that they are very similar to indelible ink pens. I have run tests not only on indelible ink pens but also on several Magic Markers. I am happy to report that I find they all can be used to make circuit boards, eliminating the need for a special pen. I imagine that any ink that won't rub off after drying will protect the copper from the etchant, but I do find indelible ink works best. — *James N. Greene, AJ5I, Muskogee, Oklahoma*

LUBRICATION FOR SLOW-TURNING ROTATORS

☐ I read somewhere that Canadian amateurs have used snowmobile grease on their antenna rotators to avoid slow turning in cold weather. I believe that I have found something better! After several tests at −12° F, I found that speedometer cable grease maintained its viscosity at low temperatures while snowmobile grease tended to get thicker. Other amateurs in my area have complained about their slow-moving rotators when the mercury dropped below zero, but my rotator turned as fast and smooth as it does in July's heat. — *Earl P. Anderson, WD9DID, Milwaukee, Wisconsin*

SWITCH MODIFICATION FOR STATE-OF-THE-ART TERMINAL

☐ Regarding the State-of-the-Art Terminal Unit described in December 1980 *QST*, I would like to suggest a switching improvement. By making S4 in Fig. 2 a 3pdt switch, wired as shown in Fig. 5 here, it is possible to use S4 to transmit without regard to the position of S2. In addition to the corrections indicated in "Feedback" (March 1981 *QST*, page 51), I suggest that the voltage rating of C3 be increased from 50 V to 200 or 300 V inasmuch as this capacitor is in the 120-V loop circuit. — *Bud Weisberg, K2YOF, Bergenfield, New Jersey*

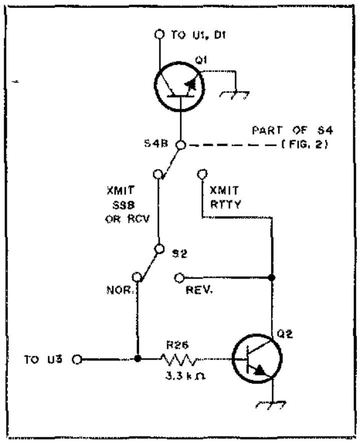


Fig. 5 — This modification of the terminal unit circuit shown in December 1980 *QST*, page 21, provides a single switch for transmitting.

AVOIDING WIND DAMAGE TO BEAM ANTENNAS

☐ Beam antennas should be turned in the direction that will produce the least wind resistance when strong winds prevail. The objective is to reduce element movement as a means of minimizing possible wind damage to the antenna. The procedure is to point the *element ends* in the direction of the wind. — *Al Kaufman, W1JVQ, Bridgeport, Connecticut*

FERRITE BEAD CURES KEYER PROBLEM

☐ An Amidon FB-73-101 ferrite bead slipped over the dot and dash paddle leads inside the box cured a very annoying intermittent habit of my K3CU keyer (February 1978 *QST*) that caused it to pause before making a dash. This happened only while I keyed my transmitter, indicating the troublemaker was rf energy possibly coming from my antenna system. I wish to caution anyone seeking to apply the same solution that a ferrite bead should *not* be placed on the common (ground) lead. — *William G. Schuchman, W7YS, Flagstaff, Arizona*

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

TEST BOX

☐ So that I could experiment with transistors in some orderly fashion, I assembled a "Test Box" (Figs. 1 and 2). On a comparison basis, this device supplies useful information from one transistor to another. The user can select ac or dc coupling, vary the resistance from base to ground, control the voltage V_{cc} to base and adjust the outputs from collector or emitter follower with or without capacitance. Additionally, it provides for adjustment of the feedback from base to V_{cc} or collector. Another provision permits switching from pnp to npn configurations and vice versa.

From audio to 40 MHz, the parameters may be adjusted quickly for best performance, gain and collector loading. Transistors can be checked for use as substitutes or duplicate operation. Moreover, similar transistors can be checked operationally prior to installation in a particular circuit.

Because any transistor inserted in the socket can be removed easily, there is no problem in checking the various potentiometer settings with an ohmmeter. A center-zero milliammeter for use with the tester is illustrated in Fig. 2B. This meter is mounted externally and is connected to the tester through pin jacks J3 and J4. Power is supplied from an external, variable-regulated power supply.

My test box contains mainly junk box components. The enclosure is a 4- × 6-inch (102- × 152-mm) cabinet, but this can be a builder's choice. All rf leads should be short and rigidly supported. You may use whatever type of transistor socket is available. — *Gene Shapiro, WØDLQ, Leawood, Kansas*

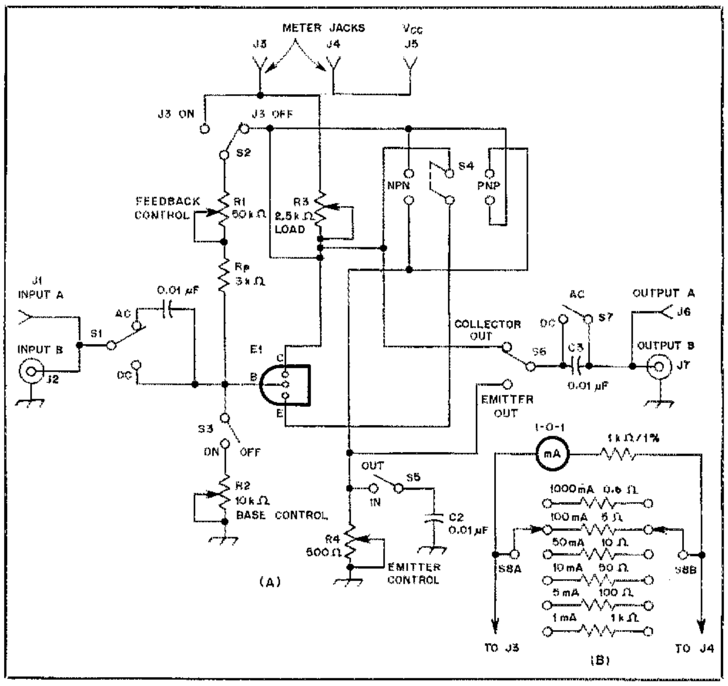


Fig. 2 — Schematic diagram (A) of the WØDLQ text box. Components are housed in a 4- × 6-inch (102 × 152-mm) enclosure. The metering circuit (B) is housed separately. It may be connected to the test box through J3 and J4. A center-zero meter (Weston 301) is arranged in a circuit adapted from the 1964 *Handbook*. There are six separate ranges provided by the 1%, 1/4-watt resistors. Rp is a protective resistor guarding against transistor damage. J1 and J3-J6, incl., are pin jacks. J2 and J7 are BNC connectors.

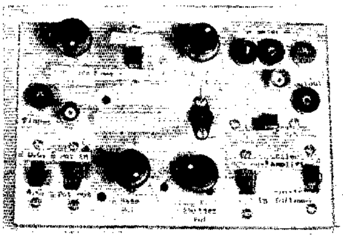


Fig. 1 — An experimenter's test box. This versatile device facilitates making value and circuit changes where transistors are used. Parameters can be adjusted quickly for best performance, gain and collector loading. See text for explanation.

HINT FOR THE AVANTI ON-GLASS ANTENNAS

☐ The Avanti glass-adhesive antenna is a good design for the ham who doesn't like a "mag" mount or who doesn't want to drill holes in the body or trunk of his or her car. I had some difficulty in getting the mounting foot for my Avanti 2-meter on-glass antenna to adhere well to my windshield. Here's how I cured the problem.

The mounting-foot casting may not have been dressed adequately in some cases to make it really flat. The easiest way to check for this is to pass the foot carefully over a medium-cut metal file. (See Fig. 3.) If the bottom of the foot isn't flat, filing will take care of that. Also, take note of the indentations on the bottom of the foot — they should appear as in the drawing, with an edge similar to a dado joint you'd see in woodworking. This is so the adhesive will have something to "grab." Place the foot in a vise and carefully hacksaw the edges a bit deeper. Now, there'll be plenty of "edge" for the adhesive to make contact. — *Sandy Gerli, AC1Y, ARRL Hq.*

Fig. 3 — Sandy Gerli, AC1Y, suggests this modification of the mounting foot for the Avanti 2-meter on-glass antenna. The change increases adhesiveness.

A COMBINATION FLAGPOLE AND TILT-OVER TOWER

☐ Being a true-blue American and an homeowner, I decided to install a flagpole so Old Glory could be proudly displayed. I was also tinkering with the idea of constructing a low-cost antenna tower to accommodate several antennas that were eyesores mounted on top of my roof. After considerable thought and manipulations on the drawing board, I arrived at the design shown in Fig. 4. Not only is this combination flagpole and antenna mast intended to support the 10-, 15- and 20-meter tribander shown in the drawing, but also an AR2 Ringo will be mounted above the tribander and a single-wire antenna will be suspended from the pole solely for "SWLing."

Raising the mast to a full upright position requires a team of five people. Two can raise it manually, two are needed to handle ropes for steadying while a fifth person's task is to insert the locking bolt through the base uprights and the mast. Total weight of the 10-foot (3-m) sec-

*Assistant Technical Editor

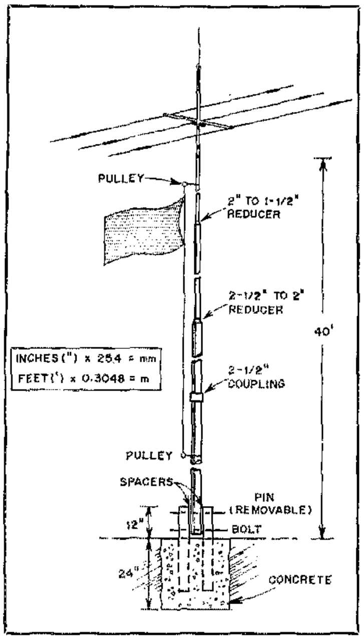


Fig. 4 — A combination flag pole and antenna mast is designed by John Reisenauer, Jr., KA7BKI. See text for details.

tions of the mast is 165 lb (75 kg), plus 25 lb (11 kg) for the antennas. A strong step-ladder is essential for supporting the mast in the initial stages of pulling the structure upright.

Although the sketch shows a 24-inch (0.6-m) depth for the concrete base, a greater depth may be essential for regions where deep frosts are common. The footing for the base should be below the normal frost line.

For those who may wish to duplicate this mast, I strongly urge the use of all safety precautions, especially in connection with overhead power lines. I recommend that you read "Excavation Litigation" in February 1980 *73*. — *John Reisenauer, Jr., KA7BKI, West Richland, Washington*

MORE ON THE W5LW TS-520 MODIFICATION

☐ In response to Warren Bone's (KQ4X) comments on the TS-520 cw modification that appeared in Hints and Kinks for December 1980, I reviewed the article by Lyle Smithers, W5LW, in *QST* for September 1977.[1] I must agree with Warren that there most likely would be a loss of power when the cw filter is switched out of the circuit. The cw filter, however, is not actually being switched out of the circuit but is being paralleled by switching the ssb filter into the circuit also. I have serviced some Kenwood TS-520s and Yaesu FT-101s with the complaint that the output power was down or the receiver was weak, only to find a shorted switching diode that had placed both the cw and ssb filters in the circuit simultaneously. Replacing the shorted diode corrected the condition. Lyle and Warren set up this same condition when they modified the TS-520.

I modified my TS-520 in 1975 by using the fixed frequency switch to switch the cw and ssb filters in and out of the circuit. It is accomplished by first removing the top cover and locating the FIXED FREQUENCY/AVR circuit board. On the AVR board locate and remove the purple wire at C, the yellow wire at 1, the brown wire at 2, the orange wire at 3 and the green wire at 4. Next locate the brown wire attached to the terminal marked cw on the i-f circuit board (if the cw filter has already been installed) or on the terminal marked ssb (if you are just installing the cw filter). Remove this brown wire and attach it to the purple wire removed from the AVR board. Next, find the yellow wire removed from the AVR board and attach it to the terminal marked ssb on the i-f board. Locate the brown, orange and green wires removed from the AVR board, twist the ends together, and attach another piece of hookup wire to these ends so as to reach the terminal marked cw on the i-f board. Connect this wire to the cw terminal. Where wires were spliced, they should be insulated with heat-shrink type tubing or with tape. The modification explained above has the ssb filter in the circuit when the fixed frequency switch is in position 1 and the cw filter is switched to positions 2, 3 or 4. — *"Livie" Larkin, W6TAS, Garden Grove, California*

[Editor's Note: Livie was formerly service manager for Henry Radio, Anaheim, California.]

[1] L. Smithers, "Using a CW Filter with the TS-520," Hints and Kinks, Sept. 1977 *QST*, p. 44.

TIP FOR 2-METER ANTENNA

☐ I found Peter O'Dell's 2-meter direction-finding cardioid antenna most interesting as I perused the March 1980 issue of *QST*. When using small diameter material such as brass rod for the radiator and ground plane, I find it advisable to screw wire nuts (electrician's wire connectors) to the end of each element to present a blunt surface. Without some protection at the ends of the tubing or rod, there is a very serious potential for eye damage when the antenna is being swung about at arm's length. These nuts come in various sizes to fit common tubing or rod sizes. — *Charles M. Currier, W1QKK, Rockland, Maine*

ETCHANT RESIST PENS

☐ After buying two etchant resist pens in a row that were dried up and useless, I noticed that they are very similar to indelible ink pens. I have run tests not only on indelible ink pens but also on several Magic Markers. I am happy to report that I find they all can be used to make circuit boards, eliminating the need for a special pen. I imagine that any ink that won't rub off after drying will protect the copper from the etchant, but I do find indelible ink works best. — *James N. Greene, AJ5I, Muskogee, Oklahoma*

LUBRICATION FOR SLOW-TURNING ROTATORS

☐ I read somewhere that Canadian amateurs have used snowmobile grease on their antenna rotators to avoid slow turning in cold weather. I believe that I have found something better! After several tests at −12° F, I found that speedometer cable grease maintained its viscosity at low temperatures while snowmobile grease tended to get thicker. Other amateurs in my area have complained about their slow-moving rotators when the mercury dropped below zero, but my rotator turned as fast and smooth as it does in July's heat. — *Earl P. Anderson, WD9DID, Milwaukee, Wisconsin*

SWITCH MODIFICATION FOR STATE-OF-THE-ART TERMINAL

☐ Regarding the State-of-the-Art Terminal Unit described in December 1980 *QST*, I would like to suggest a switching improvement. By making S4 in Fig. 2 a 3pdt switch, wired as shown in Fig. 5 here, it is possible to use S4 to transmit without regard to the position of S2. In addition to the corrections indicated in "Feedback" (March 1981 *QST*, page 51), I suggest that the voltage rating of C3 be increased from 50 V to 200 or 300 V inasmuch as this capacitor is in the 120-V loop circuit. — *Bud Weisberg, K2YOF, Bergenfield, New Jersey*

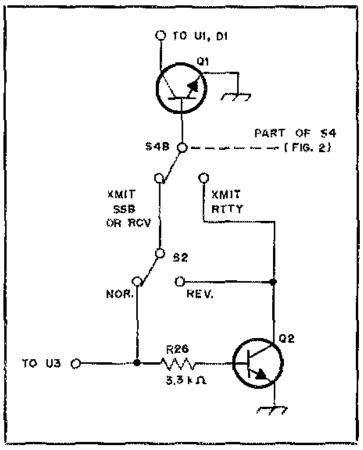


Fig. 5 — This modification of the terminal unit circuit shown in December 1980 *QST*, page 21, provides a single switch for transmitting.

AVOIDING WIND DAMAGE TO BEAM ANTENNAS

☐ Beam antennas should be turned in the direction that will produce the least wind resistance when strong winds prevail. The objective is to reduce element movement as a means of minimizing possible wind damage to the antenna. The procedure is to point the *element ends* in the direction of the wind. — *Al Kaufman, W1JVQ, Bridgeport, Connecticut*

FERRITE BEAD CURES KEYER PROBLEM

☐ An Amidon FB-73-101 ferrite bead slipped over the dot and dash paddle leads inside the box cured a very annoying intermittent habit of my K3CU keyer (February 1978 *QST*) that caused it to pause before making a dash. This happened only while I keyed my transmitter, indicating the troublemaker was rf energy possibly coming from my antenna system. I wish to caution anyone seeking to apply the same solution that a ferrite bead should *not* be placed on the common (ground) lead. — *William G. Schuchman, W7YS, Flagstaff, Arizona*

Technical Correspondence

Conducted by Jerry Hall,* K1TD

The publishers of QST assume no responsibility for statements made herein by correspondents.

SMOKE DETECTOR SENSITIVITY

☐ Thank you for a copy of the article in November 1980 *QST*.[1] The smoke detector industry is aware that smoke detectors using electronic components are subject to some degree of influence by radio-frequency interference. To address this matter, Underwriters Laboratories has included in their test procedure of all smoke detectors a transient test involving radio-frequency interference. This should eliminate the problem on smoke detectors that are built today.

I would caution your readers about modifying the circuit to eliminate the problem on some of the older detectors. A change in the electronics to eliminate the radio-frequency interference could alter the sensitivity setting of the smoke detector. It is not enough to blow smoke into a detector to check its operation since the concentration of smoke from a cigarette could be far in excess of the normal setting of the smoke detector. For instance, the smoke detectors are required to respond within the range of 0.2% to 4% per foot of smoke. A cigarette could produce 40% to 50% per foot of smoke, leading the homeowner to a false sense of security that the smoke detector is operating properly when in fact it would not be. A further caution: In addition to eliminating the warranty, any listing by a testing laboratory would be voided as soon as the detector circuit was changed. — *Charles E. Zimmerman, PE, Fire Protection Engineer, National Fire Protection Assn., 470 Atlantic Ave., Boston, MA 02210*

[1]P O'Dell, "SDI — Dangerous Crippler of Radio Amateurs," November 1980 QST.

*Associate Technical Editor

FREQUENCY-COUNTER CLOCK PHASE LOCKED TO WWV

☐ I would like to present to your readers a block diagram of a proposed system which phase locks a counter clock crystal to WWV (Fig. 1). With this system, the counter reads all frequencies with the accuracy of our national standard.[2] While I have never been involved in frequency measurement competitions, I am aware that ARRL operates these events and that there is a considerable following among the amateur fraternity. I assume that somewhere in this activity there would be interest in a measurement scheme which is absolute and does not involve zero beating crystals, and so forth.

With reference to Fig. 1, instability caused by drift in the local oscillator cancels in mixer no. 2; the output of this mixer is exactly twice the 10-MHz frequency received from WWV, phase locked. Since only carrier is wanted, the intermediate-frequency filter should be as sharp as the local-oscillator stability permits — hence the crystal-controlled local oscillator.

Processing within the shield is done at frequencies remote from the input and intermediate frequencies to avoid feedback problems. The multiplier is a "linear" push-push type so that near-zero amplitudes are not lost. Effective buffering is required to prevent residual 455-kHz energy from reaching the input. The clock crystal is phase locked to provide short-term memory, allowing the crystal to "run through" momentary disruptions of the WWV transmission. Operation can be switched to a fixed capacitor when transmissions are unusable.

[2][Editor's Note: Because of propagation phenomena, the approximate accuracy of the received 10-MHz WWV skywave signal under typical conditions is at best a few parts in 10^7.]

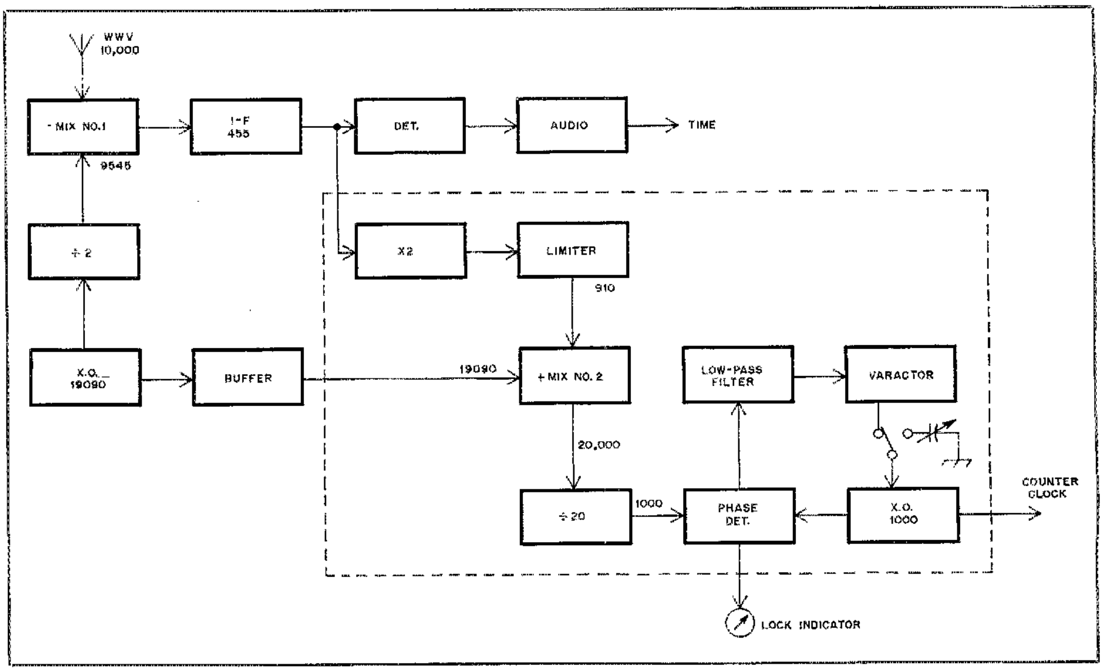


Fig. 1 — Noble's proposed scheme for phase locking a frequency-counter clock to WWV signals. X.O. indicates crystal oscillator; frequencies are indicated in kilohertz. The 1000-kHz crystal oscillator may be switched to operate with the variable capacitor when received WWV signals are unusable.

As in mountain climbing, the scheme is here, to be followed up by those who may be qualified in solid-state design and who have a direct application for the device. — *Frank Noble, W3MT, 10004 Belhaven Rd., Bethesda, MD 20034*

NOISE IN ACTIVE FILTERS

☐ Many common types of active filters can generate noise of much higher amplitude and wider bandwidth than the filter and active device characteristics would indicate. The reason for this is that although the signal is applied at the filter input, the device noise appears at the device (e.g., op-amp) input. The response to excitation at these two points is quite different, as I'll illustrate.

Fig. 2A shows a common low-pass filter[3] using an operational amplifier as a unity-gain buffer. With the values shown, the filter has a peak frequency, F_o, of about 650 Hz, a Q of five, and a voltage gain of five at f_o. The response of the filter is shown in Fig. 3A.

In Fig. 2B, op-amp noise is shown in simplified form as a voltage source in series with one input lead. The corresponding frequency response is given in Fig 3B. Note that the noise response is more than 20 dB greater than the signal response at f_o, and that it continues at unity above, as well as below, the filter cutoff frequency. So although the active filter does limit the noise from the preceding stages, it generates in itself a disproportionate amount of noise that extends beyond the desired bandwidth.

The peak noise response will depend on the component values, but a voltage gain of $1 + 2Q^2$ is a typical number, and it can't be reduced below $1 + Q^2$ for this filter type. Multiple-feedback low-pass and band-pass[4] types were analyzed with the same results.

The effect shown here won't be noticeable in "add-on" audio filters because of the high level of signal present. However, this does indicate the need for a fairly large amount of low-noise gain (on the order of 30 to 50 dB) preceding the active filter in direct-conversion receivers or other applications where high audio gain is involved. — *Roy W. Lewallen, W7EL, 5470 SW 152nd Ave., Beaverton, OR 97007*

[3] W. Hayward and D. DeMaw, *Solid State Design for the Radio Amateur,* ARRL, 1977, Fig. 17, p. 80.

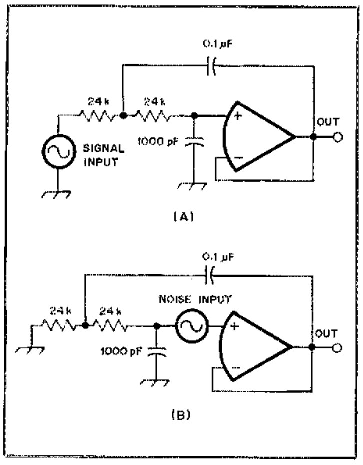


Fig. 2 — Common circuit for a low-pass active filter at A, and simplified diagram illustrating device noise, B.

PACKET RADIO AND BIT ERRORS

☐ The announcement of an operational amateur packet radio system in the April issue of *QST*[5] was welcome news in that it reaffirms the interest of the radio amateur in state-of-the-art communications. I fear, however, that the casual reader may not fully appreciate that the "highly reliable and nearly error-free communications" mentioned in this announcement requires an automatic request for repeat (ARQ). Packet radio does not solve the problem of bit distortion, bit dropout and "hits" in the received serial bit stream. Such errors are characteristic of RTTY operation, and arise from the effects of ionospheric propagation, multipath and interference.

The use of cyclic redundancy checkwords (CRC) facilitates the detection of errors in the transmitted message without the need for prior knowledge of the message content. This is somewhat like the parity bit in each ASCII character, except that in this case the checksum extends over the block of characters transmitted and is typically a 16-bit word rather than a single bit. If a checksum error is detected at the receiving station, the entire message packet is rejected, or, if the address of the sender is known, the receiving station can automatically request a repeat. Thus, "highly reliable and nearly error-free communications" are achieved by accepting and forwarding only those message packets that have the correct checksum.

At vhf and uhf, where multipath distortion on the leading edge of each bit transition lasts for only 5 microseconds or less, rates approaching 100 kilobaud can be used for packet radio. At hf, however, the useful or uncorrelated bandwidth of an ionospheric propagation path frequently limits RTTY speeds to less than 100 wpm (74.2 baud), or to bit lengths greater than 13.5 milliseconds. Thus, at hf it is doubtful that the baud rates for packet radio will differ from those now used for RTTY.

I do not intend the above comments to dampen the enthusiasm for experimenting with packet radio. On the contrary, I am pointing out some interesting and challenging problems for the amateur to be thinking about. Clearly this is a new area, and the possibilities of blending Amateur Radio with hobbyist computer techniques are, with the approval of the FCC, unlimited. — *Jack H. Priedigkeit, W6ZGN, 441 Sherwood Way, Menlo Park, CA 94025*

[4] *Ibid.*, Fig. 21, p. 81.

[5] H. Magnuski and P. O'Dell, "First Packet Repeater Operational in U.S.," April 1981 *QST*, p. 27.

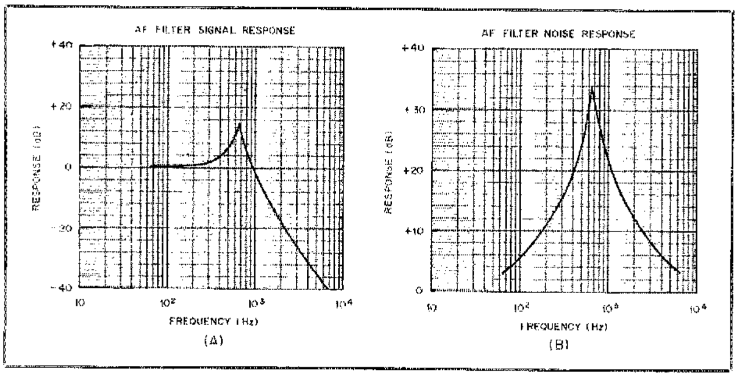


Fig. 3 — Calculated frequency-response curves. At A and B, respectively, are the curves for the circuits of Fig. 2A and 2B.

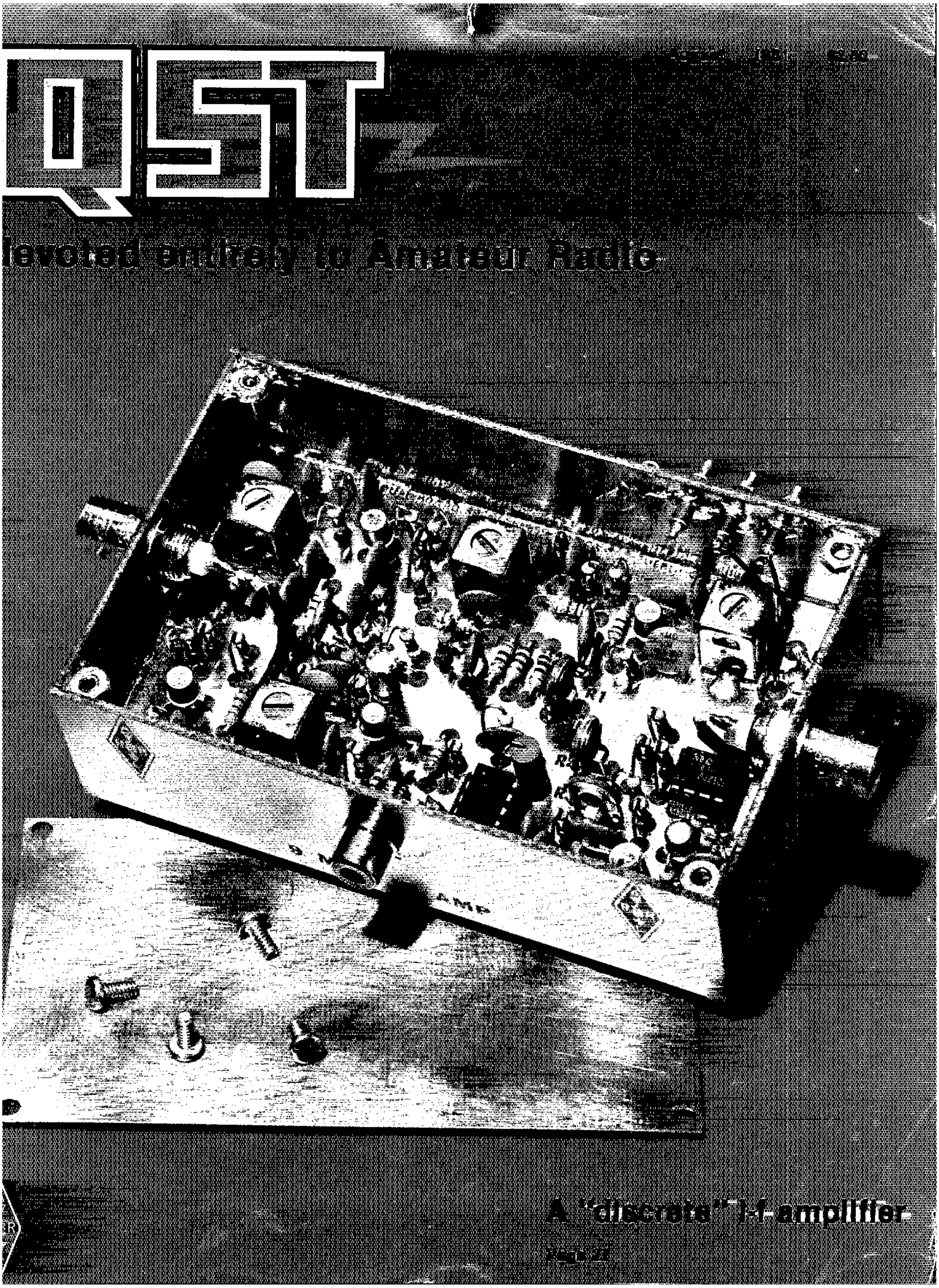
Feedback

☐ In "General-Coverage Reception with the Drake R-4C Receiver," May 1981 *QST*, C2 should have a value of 5 to 100 pF, not 0.5 to 100. Author Luetzow points out that Daytapro Electronics, Inc., 3029 N. Wilshire Ln., Arlington Heights, IL 60004, will supply an etched circuit board for the construction of the unit. (The ARRL and *QST* in no way warrant this offer.)

☐ Reference is made to the Product Review column in the May 1981 issue of *QST*. Fig. 2 on page 38 is *not* an accurate depiction of the noise about the carrier frequency of the TS-830S. The picture really shows the noise sidebands of the spectrum analyzer. Noise output of the review unit is actually so low it cannot be measured with the instrumentation on hand in the ARRL laboratory.

☐ The Technical Correspondence column carries an item by V. Bhatt, VU2RX, in the October 1980 issue of *QST* entitled "A 4:1 Unun." Key words were omitted from the 8th and 9th lines of that item. The sentence should read, "This simple device, used to match 50 ohms output impedance of a transceiver to about 200 ohms input impedance of a typical linear amplifier, had totally escaped my attention . . ."

☐ In "QST Profiles," May 1981, the line reading ". . . to frequencies as great as 100 nanohertz" should read ". . . gigahertz."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A "discrete" I-f amplifier

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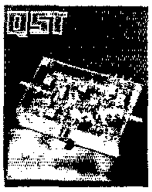
THE COVER

Whether or not you have plans to design and build a receiver, this MOSFET i-f module should be of interest. It features discrete components, unconditional stability and low cost. See page 27.



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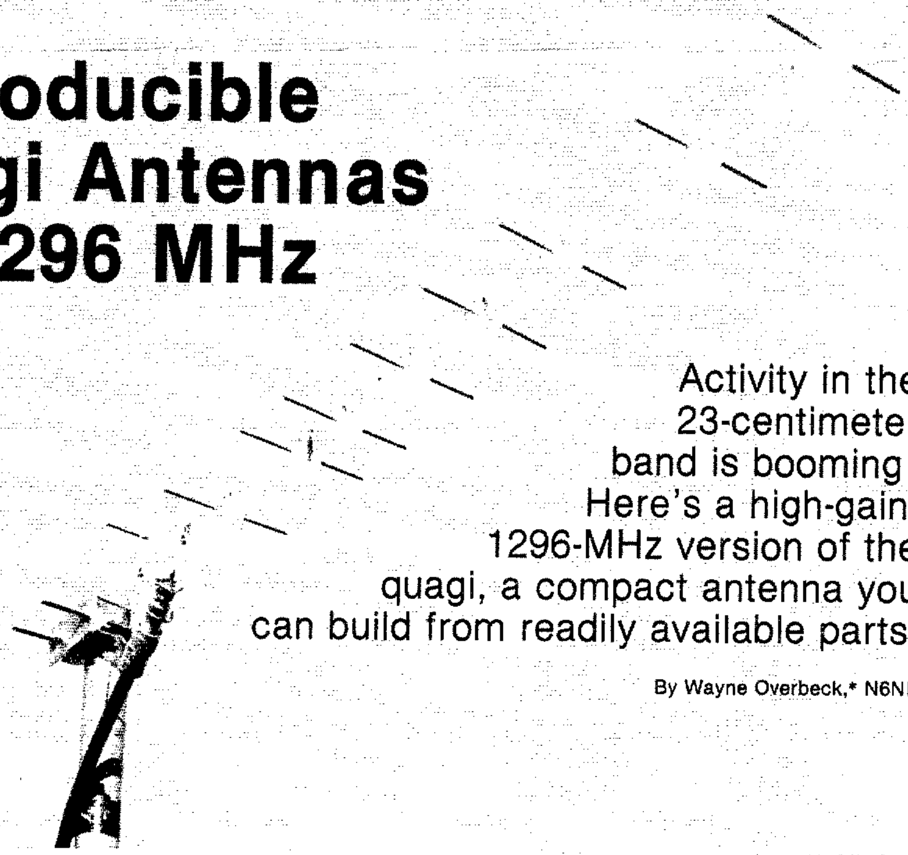
Reproducible Quagi Antennas for 1296 MHz



Activity in the 23-centimeter band is booming! Here's a high-gain, 1296-MHz version of the quagi, a compact antenna you can build from readily available parts.

By Wayne Overbeck,* N6NB

The 1296-MHz band — 23 centimeters if you prefer — is bustling with activity. In many areas, there are more stations on 1296 MHz today than there were on 432 MHz only a few years ago. Two brands of ssb/cw transverters for 1296 MHz are now available off the shelf, and hundreds of these units have been sold. Meanwhile, commercial varactor triplers and receiving converters are also selling briskly. Many uhf enthusiasts, of course, wouldn't think of buying a "turn-key" system; they build their own, thank you.

Antennas for 1296 MHz can, however, present a dilemma. Helical and parabolic dish antennas work well there, as do various horn and collinear designs. But they can be bulky, offering relatively little gain for their size. Furthermore, even though most of these antennas are broadband types, they present enough construction, feed and impedance-matching difficulties to discourage some builders.

Yagis? Building an efficient Yagi for 1296 MHz is even more difficult. As recently as 1979, the leading 432/1296-MHz moonbounce newsletter dismissed Yagis as generally impractical at 1296 MHz. Yet, parasitic beam antennas do work at 1296 MHz, and they offer excellent gain in small packages. A wide-spaced, 10-element beam is only about *2 ft* (0.6 m) long on this band. One commercial manufacturer's 28-element loop-Yagi has become something of a standard of performance on 23 cm. Also, a 1296-MHz version of the respected F9FT Yagi is now available. These are excellent designs, but they do not lend themselves to amateur construction. Those lacking special uhf expertise and sophisticated test equipment have had trouble duplicating antennas of this sort. Some amateurs have wondered if the quagi antenna, which has become known for its simplicity, is suitable for 1296 MHz.

*Department of Communications, California State University/Fullerton, Fullerton, CA 92634

The Quagi Antenna

Since the original article on the quagi was published in *QST*,[1] thousands have been built worldwide. The quagi is described in *The Radio Amateur's Handbook* and the *Antenna Handbook*[2] by Orr and Cowan. This design has been republished in amateur journals in such diverse countries as the Soviet Union, India and South Africa. A Japanese firm is now making quagis commercially.

[1]Notes appear on page 15.

The quagi (pronounced with a hard "g" so that it rhymes with Yagi) is a hybrid antenna combining some of the advantages of the cubical quad and the conventional Yagi. Perhaps its best attribute is ease of construction. The driven loop can be fed directly with 50-Ω coaxial cable without any impedance-matching device. Numerous vhf newcomers have built the quagi as their first homemade antenna for any frequency above 30 MHz.

The quagi has been used in vhf work from fm to moonbounce. German EME enthusiast Johann Bruinier, DL9KR, who has become known for his outstanding signal off the moon, has published the design of his quagi-based 432-MHz EME array.[3]

Because of its simplicity and good performance, the antenna would seem to be an ideal home-constructed one for 1296 MHz. However, the original article only presented dimensions for 144, 220 and 432 MHz. Some amateurs who tried to scale mathematically the original quagi design to 1296 MHz have experienced disappointing results.

Table 1

Dimensions, 1296-MHz Cubical-Quad and Quagi Antennas

Note: All lengths are gross lengths. See text and photos for construction technique and recommended overlap at loop junctions. All loops are made of no. 18 AWG solid-covered copper bell wire. The Yagi-type directors are 1/16-in. brass brazing rod. See text for a discussion of director taper.

Feed: Direct with 52-ohm coaxial cable to UG-290 connector at driven element; run coax symmetrically to mast at rear of antenna.

Boom: 1/4-in.-thick Plexiglas, 30 in. long for 10-element quad or quagi and 48 in. long for 15-element quagi. 84 in. for 25-element quagi. Inches × 25.4 = mm

10-Element Quagi for 1296 MHz

Element	*Length (in.)*	*Construction*	*Element*	*Interelement Spacing (in.)*
Reflector	9.5625	(loop)	R-DE	2.375
Driven El.	9.25	(loop)	DE-D1	2.0
Director 1	3.91	(brass rod)	D1-D2	3.67
Director 2	3.88	(brass rod)	D2-D3	1.96
Director 3	3.86	(brass rod)	D3-D4	2.92
Director 4	3.83	(brass rod)	D4-D5	2.92
Director 5	3.80	(brass rod)	D5-D6	2.92
Director 6	3.78	(brass rod)	D6-D7	4.75
Director 7	3.75	(brass rod)	D7-D8	3.94
Director 8	3.72	(brass rod)		

15-Element Quagi for 1296 MHz

The first 10 elements are the same lengths (inches) as above, but the spacing from D6 to D7 is 4.0 in. here; D7 to D8 is also 4.0 in.

Director 9	3.70		D8-D9	3.75
Director 10	3.67		D9-D10	3.83
Director 11	3.64		D10-D11	3.06
Director 12	3.62		D11-D12	4.125
Director 13	3.59		D12-D13	4.58

25-Element Quagi for 1296 MHz

The first 15 elements use the same element lengths and spacings as the 15-element model. The additional directors are evenly spaced at 3.0-in. intervals and taper successively by 0.02 in. per element. Thus, D23 is 3.39 in.

10-Element Cubical Quad for 1296 MHz

Reflector	9.563	(loop)	R-DE	2.375
Driven El.	9.25	(loop)	DE-D1	2.0
Director 1	8.5	(loop)	D1-D2	3.94
Director 2	8.375	(loop)	D2-D3	2.94
Director 3	8.34	(loop)	D3-D4	3.625
Director 4	8.31	(loop)	D4-D5	2.875
Director 5	8.125	(loop)	D5-D6	2.625
Director 6	8.0	(loop)	D6-D7	2.5
Director 7	8.125	(loop)	D7-D8	3.25
Director 8	8.0	(loop)		

Thus, the author set out empirically to optimize the antenna for 1296.[4] The result was a family of quagi antennas offering excellent forward gain for their small size. As is true of their lower-frequency counterparts, these 1296-MHz quagis require neither exotic construction materials nor elaborate test equipment. A number of amateurs, including some new to the band, have already duplicated the antennas described here.

The photos (Figs. 1 to 4) show these quagis, which range from a 27-in. (686-mm) long, 10-element design to a 25-element array on a 7-ft (2.1-m) boom. Table 1 gives the dimensions for each design. As with parasitic antennas designed for other frequencies, a point of diminishing returns is evident here. The gain increases rapidly for the first several wavelengths of boom, but then additional gain becomes increasingly difficult to attain. The 10- and 15-element quagis are probably the best compromises between high gain and compactness. The gain of the little 10-element version is amazing for its size.

A Cubical Quad for 1296 MHz

This may not be the time to reopen the old quad-vs.-Yagi controversy, *but* the author also devoted considerable effort to designing a reproducible, homemade cubical quad (or loop-Yagi, if you wish) for 1296 MHz. The result was a 10-element quad design, an antenna virtually identical to the 10-element quagi in both boom length and measured gain. If you want to be able to say you're using a cubical quad on 1296 MHz, Table 1 includes the dimensions for one that works well.

Some years ago, a Danish scientist reported that the gain of an antenna varies only a little when loop-type directors are substituted for Yagi-type rods if the driven element is a quad *loop*.[5] He found that the rods made slightly better directors, but that the difference was less than 1 dB. My conclusion is much the same, although I eventually came up with a cubical-quad design that equalled the forward gain of a similar-size quagi at 1296 MHz.

To get the quad to perform that well, I had to depart somewhat from the typical quad design. In Table 1, you'll note that the 10-element quad uses director loops that are *tapered* in length. Many quad designers specify that all directors are to be uniform in length, but it seemed apparent during the antenna-range work for this article that more gain could be achieved by varying the director lengths. Note also that the directors do not taper uniformly from long to short. Rather, there were instances where variations in that pattern produce better gain. In particular, the seventh director is a little longer than the sixth one. Repeated experiments with a seventh director shorter than the sixth one failed to produce as much gain as was obtained when the seventh director was slightly longer.

What about a pure Yagi at 1296 MHz? There's no question that a dipole type of driven element can be made to work at that frequency. But getting high efficiency and a good impedance match presents a difficult challenge. Since the goal was to come up with easy-to-duplicate 1296-MHz antennas, I stuck to quads and quagis.

Construction Details

Just about everyone who has ever written a construction article for an Amateur Radio magazine has received at least one letter that begins, "I built your antenna (amplifier, keyer or whatever) just like you said in *QST* except . . ." The letter writer then says it doesn't work and asks for help in fixing it.

At 1296 MHz even slight variations in design or building materials may cause substantial changes in performance. The 1296-MHz antennas described here will work every time — but only if you use the same materials and build them exactly as described here. This is not to discourage experimentation. Innovation and experimentation are part of Amateur Radio. But if you want to modify these 1296-MHz antenna designs, you might consider building one antenna *exactly* as described here, so that you have a reference against which to compare your variations.

The quagis (and the cubical quad) are built on 1/4-in. (6-mm)-thick Plexiglas booms. The driven element and reflector (and also the directors in the case of the cubical quad) are made of insulated no. 18 AWG solid-copper bell wire, available at hardware and electrical supply stores. Other types and sizes of wire will work equally well, but the dimensions will vary with the wire diameter. Even removing the insulation usually necessitates changing the loop lengths.

Quad loops are approximately square (Figs. 2 and 5) although the shape is relatively noncritical. However, the element lengths *are* critical. At 1296 MHz, variations of 1/16 in. (1.6 mm) may alter the performance measurably, and a 1/8-in. (3.2-mm) departure can cost several decibels of gain. The loop lengths given are *gross* lengths. Cut the wire to these lengths and then solder the two ends together. There is a 1/8-in. (32-mm) overlap where the two ends of the reflector (and director) loops are joined, as shown in the photographs.

The driven element is the most important of all. The no. 18 wire loop is soldered to a standard UG-290 chassis-mount BNC connector as shown in the photographs. This exact type of connector must be used to ensure uniformity in construction. Any substitution may alter the driven-element electrical length. One end of the 9.25-in. (235-mm) driven loop is pushed as far as it will go into the center pin and soldered. Then the loop is shaped and threaded through small holes drilled in the Plexiglas support. Finally, the other end is fed into one of the four mounting holes on the BNC connector and soldered. In most cases, the best VSWR is obtained if the end of the wire just passes through the hole so that it is flush with the opposite side of the connector.

If you have a Bird wattmeter, even one without an element calibrated for 1296 MHz, you can adjust the driven-element

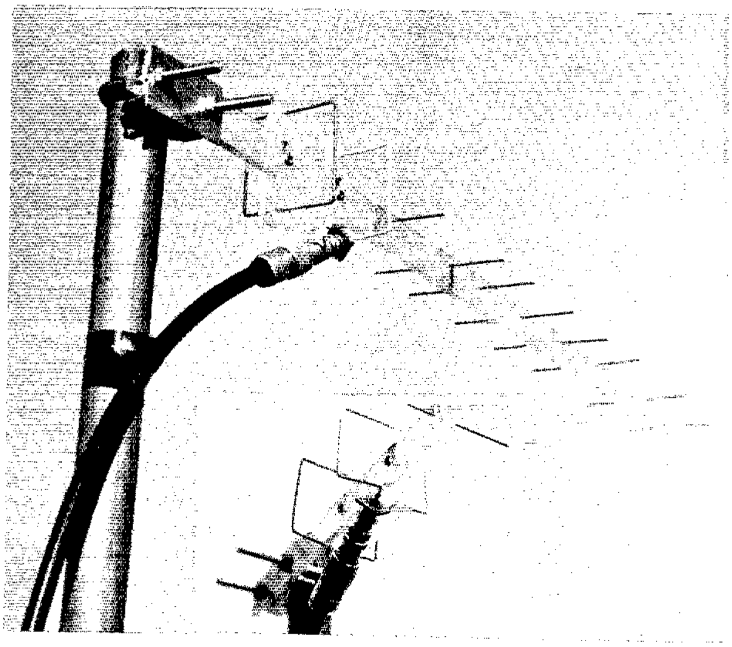


Fig. 1 — A closer view of the 10-element version of the 1296-MHz quagi shown in the lead photograph. It is mounted on a 30-in. (760-mm) Plexiglas boom with a 3- × 3-in. (76- × 76-mm) square of Plexiglas to support the driven element and reflector. Note how the driven element is attached to a standard UG-290 BNC connector. The elements are held in place with silicone sealing compound.

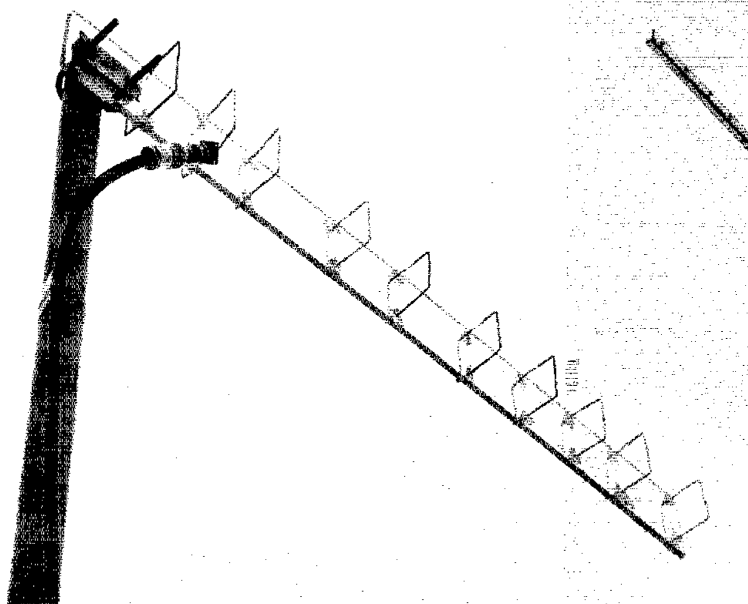


Fig. 2 — This 10-element cubical quad is virtually identical in performance to the 10-element quagi. A 3- × 30-in. (76- × 760-mm) sheet of Plexiglas supports the elements, which are offset slightly to allow room for the feed point on the driven element. All elements are made of insulated no. 18 AWG solid-copper wire.

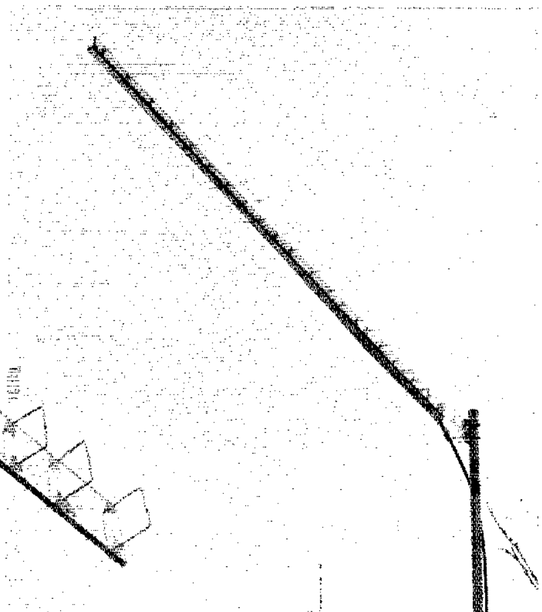


Fig. 3 — The largest quagi tested on 1296 MHz. This 25-element model is built on two tapered 7-ft (2.1-m) lengths of Plexiglas that form a right angle for additional mechanical stability. In case you're thinking of building one like it for the 20-meter band instead of 23 centimeters, the boom length will be a mere 650 ft (198 meters)!

loop to resonance. First, build the complete antenna and mount it a few feet above the ground, pointing away from all obstructions. Attach a 2-ft (0.6-m) length of RG-8/U cable from the driven element to the wattmeter and provide some strain relief for the cable, perhaps by taping it securely to the supporting mast. Before soldering the driven loop into a mounting hole on the BNC connector, apply some power and adjust the end of the loop in and out of the mounting hole for minimum reflected power. After each adjustment, step away from the antenna to get an accurate reading. It should be possible to approach unity VSWR with 50-Ω coaxial cable. Even without making this adjustment, however, the VSWR will be close to unity if the wire is cut to the proper length and soldered to the connector as shown in the photographs.

In developing these quagi designs, I tried several other connector types, including the SMA. Measuring the difference in gain or VSWR between a driven element using an SMA and one with a less expensive BNC connector was impossible. A number of dealers who advertise in *QST* sell the UG-290 BNC connector, usually for about $2 each.

The quagi directors are made of 1/16-in. (1.6 mm) brass brazing rod, available at welding shops. Lengths of the directors are critical, but a ruler with 1/16-in. or 1-mm scale divisions is adequate for the job.

A good way to obtain the correct director lengths is to cut one piece of welding rod slightly less than 4 in. (102 mm) long, and then file it down to the specified length for the first director. This length should be 3.91 in. (99.3 mm), about halfway between the 3-7/8- and 3-15/16-in. marks on a ruler. Make as many additional directors as needed for the particular size quagi you are building, filing each director down until it is just perceptibly shorter than the previous one. You need not measure each director exactly, provided the first and last ones are the correct lengths, and the ones in between are tapered evenly from the longest to the shortest. If you have access to a bench grinder, the director-making process goes much faster, but the work can be done accurately with only a hand file.

The entire antenna is mounted in front of the supporting mast, since the mast may be nearly a quarter wavelength in diameter at 1296 MHz. The feed line runs directly away from the driven element, passing below the reflector on its way from the BNC connector to the mast.

A 3- × 30-in. (76- × 762-mm) sheet of Plexiglas is sufficient for either the 10-element quad or quagi. It may be cut to 1 in. (25.4 mm) or less where it supports the quagi directors. A 48-in. (1219-mm) length of Plexiglas will be required for the 15-element quagi, while the 25-element array is made by gluing two 7-foot (2.1-m) pieces of Plexiglas together at right angles (forming a T) for additional mechanical stability.

Other Observations

The idea of feeding the driven element of a cubical quad directly with coaxial cable troubles some amateurs: They feel a balun is absolutely essential. While a *well-designed* balun will reduce feed-line radiation and increase the antenna efficiency somewhat, the losses introduced by adding a balun may offset any increase in efficiency, even at frequencies much lower than 1296 MHz. Many builders are better off feeding a quad or quagi directly with coaxial cable, especially at uhf. If the feed line is routed to the antenna in a symmetrical fashion, there should be no problem of pattern skewing, nor should there be any measurable performance degradation because a balun isn't used.

Another question that is asked about the quagi is whether or not other materials can be used for a boom. At lower frequencies, bamboo and fiberglass have become popular as alternatives to the wooden booms specified in the original article. But at 1296 MHz, Plexiglas seems to be one of the few readily available and inexpensive materials that work well. Some other insulators are not very effective at 1296 MHz. For instance, I mounted one 1296-MHz quagi on a fiberglass boom (a commercial spreader for a 20-meter quad) and measured an immediate 2.5-dB performance degradation. A metallic boom will work, but only if the director lengths are adjusted appropriately.

Some readers may want to phase multiple bays of 1296-MHz quagis for additional gain. For the 15-element quagi, the proper stacking distance is 20 to 24 in. (508 to 610 mm). However, making a phasing harness that will perform well at 1296 MHz may be difficult. The velocity factors of coaxial cables can vary slightly from the nominal values, but even small variations can cause serious problems on a frequency where 2 in. (51 mm) amount to more than a quarter wavelength for most cables. The best advice for those who lack an accurate means for determining electrical lengths of cables at 1296 MHz is to use identical lengths of 50-Ω cable (cut from the same roll) to feed each bay. Then bring each of the four feed lines together at a power divider similar to the ones made by KLM Electronics. At this writing, KLM is not marketing a 1296-MHz power divider, but the RSGB *VHF/UHF Manual* describes how to build one.[6]

Another very simple matching network

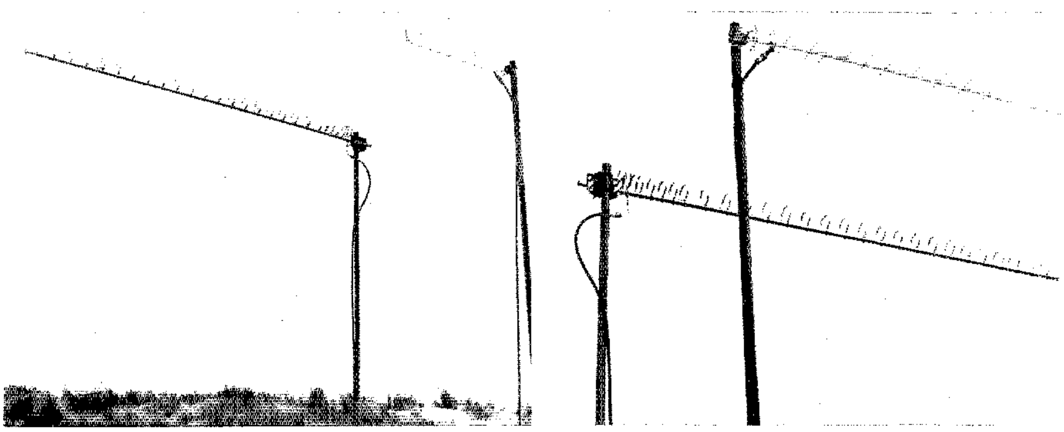


Fig. 4 — Returning to the seaside antenna range where the 432-MHz quagi designs were tested several years ago, the author used this location to measure the performance of a 15-element quagi and a 10-element cubical quad against a commercially made 28-element loop-Yagi. Although much smaller, both approached the gain of the 8-ft (2.4-m) long loop-Yagi. With a 4-ft (1.2-m) boom, the 15-element quagi is an excellent compromise between gain and physical size.

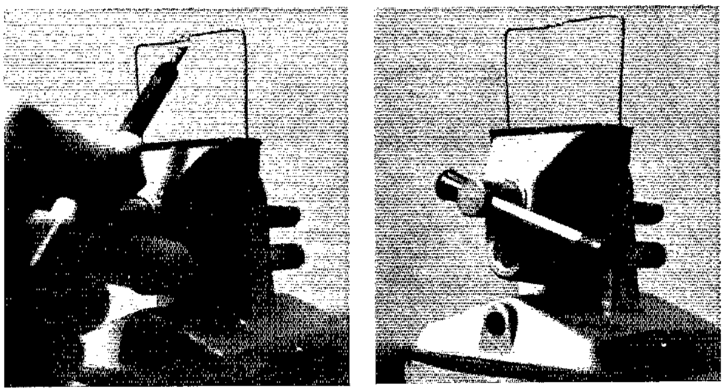


Fig. 5 — These photos show the construction method used for the 1296-MHz quad type parasitic elements. The two ends of the no. 18 AWG copper wire are brought together with an overlap of 1/8 in. (3 mm) and soldered.

for 1296 MHz, this one made from nothing more complicated than three UG-107A/U coaxial T connectors, was described some years ago by Reed Fisher.[7] Feeding his antenna with identical lengths of 50-Ω cable, Fisher simply brought each pair of feed lines to a UG-107 and then joined the two UG-107s with a third one. This works, because paralleling each pair of cables drops the impedance to 25 Ω, but each half of a UG-107 is about one-quarter wavelength at 1296 MHz. Thus, the center UG-107 acts as two quarter-wave transformers, raising the impedance on each side to 100 Ω. That value is again divided by two at the center point, getting the system back to 50 Ω. This is probably the best way to phase four bays if you have access to UG-107A/U connectors.

Performance and Conclusions

In both forward gain and directivity, typical 1296-MHz quagis, built and described here, come very close to the performance level of the 144-, 220- and 432-MHz quagi designs.

The author used a commercially made 28-element loop-Yagi as a reference in developing these 1296-MHz antennas. Gain for the 25-element quagi is similar to that of the commercially made loop-Yagi, while the smaller 15-element quagi is only about 1.5 dB down from the loop-Yagi. The 10-element quagi is another dB down, as is the 10-element cubical quad. In terms of gain per ounce, the 10-element, 1296-MHz quagi is in a class by itself. The TV type of U bolt that attaches the antenna to a mast weighs almost as much as the entire antenna.

How much gain over a dipole do these antennas develop? The manufacturer of the 28-element loop-Yagi rates the gain at 20 dB over an isotropic source, or 17.8 dB over a dipole. At the various conference sessions on vhf antenna measuring held in recent years, these loop-Yagis and most other 1296-MHz antennas have usually exhibited something less than their theoretical gain figures. Loop-Yagis typically are measured at 14- or 15-dB gain over a dipole. Using that number as a reference, the long quagi also delivers 14- or 15-dB gain over a dipole, while the smaller 15-element version offers about 13 dBd of gain. The 10-element quagi or quad will deliver about 12 dBd of gain.[8] When you compare these little quads and quagis with helical, horn and dish antennas big enough to provide that kind of gain at 1296 MHz, the difference in size is remarkable.

It hasn't been long since the adage among vhf people was, "Yagis don't work at 432 MHz." Maybe conventional Yagis are a little tricky at uhf, but Yagis that use quad loops, log-periodic cells and folded dipoles as driven elements have revolutionized our thinking about 432-MHz antennas in the last few years. Now the same sort of rethinking is going on at 1296 MHz. The day when you had to find a way to support (and aim) a 6-ft (1.8-m) dish to get decent gain at 1296 MHz is history. QST

Notes

[1]W. E. Overbeck, "The VHF Quagi," *QST*, April 1977, pp. 11-14.
[2]W. Orr and S. Cowan, *The Radio Amateur Antenna Handbook* (Wilton, CT: Radio Publications, 1978).
[3]*432 and Above EME News*, Jan. 1980.
[4]For a description of the antenna-range techniques used to design these antennas, see Overbeck, "Measuring Antenna Gain with Amateur Methods," *QST*, October 1977, p. 11.
[5]J. Appel-Hansen, "The Loop Antenna with Director Arrays of Loops and Rods," *IEEE Transactions on Antennas and Propagation*, July 1972, p. 516.
[6]D. S. Evans and G. R. Jessop, *VHF/UHF Manual*, (London: Radio Society of Great Britain, 1976), p. 8.49.
[7]R. E. Fisher, "A Successful 1296-MHz Yagi," Ham Radio, May 1972.
[8]After this was written, some of these antennas were tested at the 1981 West Coast UHF Conference in Sunnyvale, California. The 15-element 1296-MHz quagi was measured at 14.0 dB gain over a dipole. The 10-element model was measured at 13.5 dBd gain.

Strays

PICTURES FROM SATURN

☐ Voyager II, an interplanetary spacecraft, will make its closest approach to Saturn on August 25, 1981. To celebrate this event, the Jet Propulsion Laboratory ARC station (W6VIO), in Pasadena, California, will re-form and transmit, from August 15 through 30, SSTV images of Saturn and its rings and satellites as the pictures are received from Voyager II. The SSTV operation will be on or about 14,235, 21,340 or 28,680 kHz as conditions allow. Ssb and cw on 40-10 meters, ssb and fm on 2 meters, and fm on 220 MHz will also be used. Most of the activity will be conducted each day between 1830 and 2030 UTC. A color photo QSL will be available for an s.a.s.e. to W6VIO, 4800 Oak Grove Dr., Pasadena, CA 91103. DX stations QSL via ARRL bureau. — *Dr. Norman L. Chalfin, K6PGX*

MISSING SLIDE SHOW

☐ The ARRL slide show, *Arecibo* (stock number SC-16), was lost at the Dayton Hamvention. Anyone with information of its whereabouts please contact Joyce Martin, ARRL Film Librarian, tel. 203-666-1541, ext. 219.

Richard Ward, W6DZH, of Van Nuys, California, contemplates the view from about 3000 feet above the Mojave Desert. Ward had just completed what is thought to be the first successful transcontinental, direct-dial telephone call from a hot air balloon. Using his 2-meter HT, the call was made from Southern California to East Windsor, Connecticut, on March 28, 1981. *(photo by Howard Stapleton)*

Let's Measure Beam-Antenna Gain with a Reference Dipole

A reference dipole, receiver, attenuator and signal source — that's all we need for this simple method of gain measurement!

By Gerd Schrick,* WB8IFM

What's the best and most straightforward method of measuring the gain of a specified antenna? Directly substitute the antenna under test with a reference dipole? Most antenna designers say "yes." While this can be done with relative ease where small vhf/uhf beams are concerned, the method is troublesome and awkward when using hf antennas. Placing the reference antenna on a separate support side by side[1] with the antenna to be measured is perhaps the next best thing to do. Such a support is not often available, however, and if it is, it may not be of the same height as the test antenna. In any case, each antenna "sees" a different foreground. As we will learn, the interaction of shortwave antennas with the ground is important and has to be accounted for!

Let's go one step further and mount the reference antenna on the same support (mast or tower) as the test antenna. This procedure can be duplicated easily by the average one-tower ham. Here we have, in essence, the same problems encountered with the side-by-side method. If the reference dipole is mounted lower than the test antenna, and though the same ground is in front of both antennas, the higher antenna sees more ground — and at a distance farther out — than seen by the lower antenna (Fig. 1). By stacking the two antennas vertically, a rather strong influence is exerted by the beam on the dipole, and a proportionally smaller influence is exerted by the dipole on the beam. Practical measurements have shown that even when the respective capture areas were considered and the antennas spaced so that there would be no overlap, the influence of the beam on the dipole was still on the order of 1 dB. Simultaneously, because of the larger difference in height above ground, the size and surface of the reflecting areas typically would introduce 1- to 2-dB of error into the measurements. Being aware of these facts greatly facilitates the understanding of the whole antenna-testing problem.

What To Do

There is a way out of this dilemma: One can space the two antennas relatively close (1/4 to 1/2 λ apart), thus bringing the reflecting surfaces closer in agreement. To eliminate the large influence of the beam on the dipole, we can rotate the beam out of the way of the dipole (90° to the dipole). With the positioning problem solved, we still have to account for the difference in height above ground.

Consider how the gain measurements are carried out. A source a few miles away will provide a stable, horizontally polarized signal, and if a beam antenna is used, less than 1 W of cw power is needed to provide a strong signal for reception. No other parameters, such as the height of the source antenna, need be observed. This method represents a measurement at the

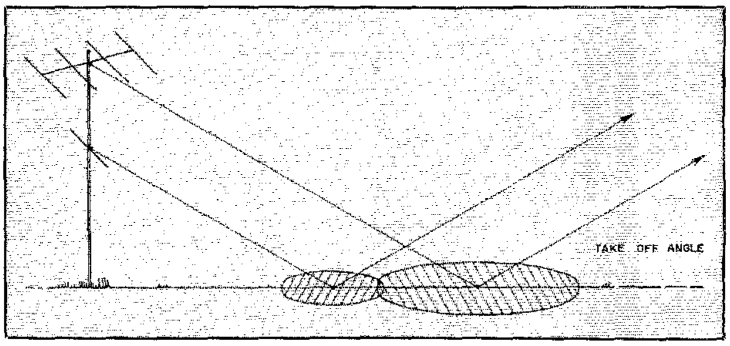


Fig. 1 — Ground-reflection zones for antennas at different heights. These zones are farther away at low angles of radiation.

[1]Notes appear on page 17.
*4741 Harlou Dr., Dayton, OH 45432

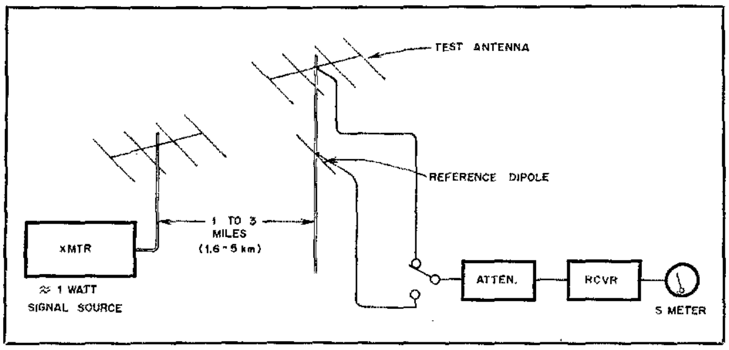


Fig. 2 — Test-equipment setup for measuring beam-antenna gain, as described in the text.

"grazing angle," which is just over zero degrees. Because of the law of reflection, true measurements of all pertinent antenna parameters can be made — gain, front-to-back ratio and horizontal-pattern plotting. Moreover, at this grazing angle a simple relationship exists[2] for the height factor of the antennas, namely

$$\text{Height factor} = \left(\frac{h_{beam}}{h_{dipole}}\right)^2$$

or in decibels,

$$20 \log \frac{h_{beam}}{h_{dipole}}$$

Let's refer to Fig. 2 and examine a hypothetical case. Here we have a 70-ft (21-m) tower with the rotary beam antenna on top and a reference dipole mounted at about 50 ft (15 m), with the broad side directed toward the signal source. Both antennas are resonated and matched (SWR less than 2:1), connected with approximately the same type and length of cable (to ensure equal losses) and can be switched alternately to an S-meter-equipped receiver preceded by a 1-dB step attenuator. The attenuator can be built[3] or purchased. Our signal source is located about 1.5 miles (2.4 km) away and radiates a 1-W cw signal from a beam antenna pointed in our direction. The test antenna is pointed toward the signal source, and the attenuator adjusted to produce a convenient reading on the receiver S meter, say S6. Then the receiver is switched to the dipole and the test antenna is rotated 90°. A signal-strength change on the order of a few decibels will be noticed. The attenuator is adjusted to produce the same S-meter reading as was obtained with the test antenna pointed toward the source. We obtain a preliminary gain figure by calculating the difference between the two attenuation figures. Now the height factor must be subtracted. In our case this is

$$\text{Height factor (dB)} = 20 \log \frac{70}{50}$$

$$= 2.9 \text{ dB}$$

Assuming we measured a 10-dB difference in attenuator settings, the actual gain of the test antenna over a dipole would be approximately 7 dB.

This is a relatively simple measurement procedure: Once everything is in place, it should not take much longer than a few minutes to complete. It is then possible for us to measure the antenna gain at various frequencies across a particular band of frequencies. Naturally, one should perform these measurements without any interference to or from other signals. The best time is when the band is dead.

Practical Application

I applied this method with good results when checking and improving a commercial 5 element, 15 meter beam and a homebuilt 4 element, 10 meter beam. It was helpful to know the gain of the homemade antenna at different frequencies. After two alterations, mainly adjusting element lengths, performance of the antenna had improved noticeably. (Readers might be interested in a series of articles that will be quite helpful in understanding Yagi antenna design.[4]) I'd like to acknowledge the help of Bruce Lundy, KA8EDE; Ralph Study, WA8IGB; and Jack Bender, K8TUY, in making the measurements during this study.

Notes

[1]W. E. Overbeck, "Quads vs. Yagis Revisited," *Ham Radio*, May 1979, pp. 12-21.
[2]G. H. Schrick, "Calculating Gain vs. Height of DX Antennas," *Ham Radio*, Nov. 1973, pp. 54-55.
[3]*The Radio Amateur's Handbook*, 58th ed. (Newington: American Radio Relay League, 1981), p. 16-38. Resistor data from *QST*, Nov. 1967, p. 52.
[Editor's Note: The resistor data may also be obtained from the *ARRL Electronics Data Book*, p. 32.]
[4]J. L. Lawson, "Yagi Antenna Design," *Ham Radio*, May, June, July and Dec. 1980.

Strays

TA PROFILES

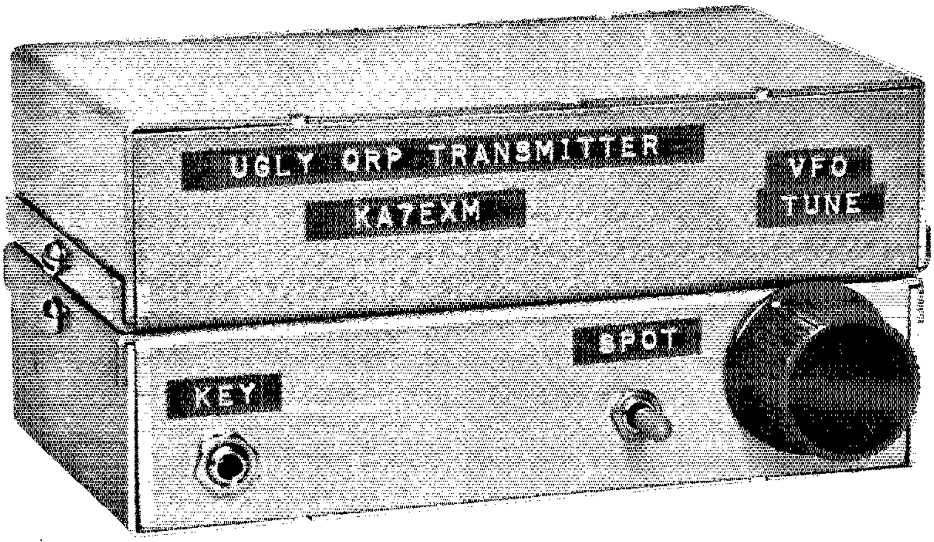
□ We appreciate the services of our fast-scan TV (ATV) expert, ARRL Technical Advisor Tom O'Hara, W6ORG. First licensed in 1957, Tom got on ATV in 1960 with a converted APS-13 transmitter. Since that time he has authored many articles on ATV and uhf for ARRL technical publications, *QST* and various journals. As a result, Tom received numerous requests for pc boards and assembled modules. After trying to supply the orders on a part-time basis, he decided to resign as director of engineering for the Vega division of CETEC Corporation to open his own business, P.C. Electronics.

Tom enjoys all modes of Amateur Radio including RTTY, Air Force MARS, RACES, civil defense and hf ssb phone patching. However, ATV has remained the mode of his primary activity and interest. Tom has also put ATV to work in public service: He built a solid-state ATV transmitter used in a helicopter at the 1968 Tournament of Roses Parade, equipped two boats with color ATV to coordinate the Congressional Cup yacht races and worked on equipment that received Voyager I Flyby data. His future plans are to help coordinate the sailing events for the 1984 Olympics.

Tom resides in Arcadia, California. He earned a BS degree in business management after completing courses in mathematics and electronics. He holds a First Class Radio Telephone license with a Radar endorsement. Leisure-time activities are shared with his wife, MaryAnn, WB6YSS, and family, who all enjoy Enduro motorcycle races in the Mojave Desert, plus skiing and snorkeling. Tom has a commercial pilot's license and takes ATV along while flying! — *Marian Anderson, WB1FSB*

TA Tom, W6ORG, at the workbench, tuning up an ATV exciter.

The "Ugly Weekender"



Winter in Oregon brings rain showers and cool temperatures — a fine time to build ham gear! A QRP rig is a good choice for a rainy-weekend project, at any time of year.

By Roger Hayward,* KA7EXM, and Wes Hayward,* W7ZOI

There are many obstacles for the builder in spite of the simplicity of a small QRP transmitter. Some published designs are less than optimum, having poor keying and chirps, perhaps a result of oversimplification. Other designs are mechanically complex, and parts procurement is an ever-present problem.

Simple transmitters often use crystal control, but today this is somewhat impractical, owing to the high cost of crystals: A VFO can be built for the price of but one or two crystals. The largest obstacle to some builders, however, is the circuit-board layout. The use of circuit boards has become so popular over the last decade that many amateurs are afraid to attempt a project that is not accompanied by a board layout or referenced to a source where an etched board may be purchased. This is unfortunate!

An Alternative

Numerous methods may be used in the construction of electronic equipment. The assumption that a design might function better if built on an etched and drilled circuit board is false.

The purpose of this article is to present a simple, good-performance QRP transmitter design, and to illustrate some "ugly" construction methods that may be used for whatever the builder might want to assemble. These methods are especially attractive for weekend projects that are to be completed while the weather is similarly ugly!

A virtue of "ugly" construction is great flexibility. The builder may use the parts on hand, something that is often difficult to do with projects utilizing etched boards. The circuit may be changed with ease to facilitate experimentation, as was done with the transmitter described here. The design can be duplicated easily. Speed is the greatest virtue of "ugly" construction. This transmitter was designed and built in two winter afternoons during the KA7EXM Christmas vacation from high school. Contacts were made before the end of that period. Estimated construction time was less than half that required for projects using boards that had been etched and drilled.

Overall Design

The transmitter, shown in Figs. 1 and 2, operates in the 7-MHz cw band. VFO control is utilized for operating flexibility and economy. The VFO is well buffered, then routed to a second enclosure containing a keyed driver and an output amplifier. Shaped keying is used to provide a click-free signal. The output power is 1.5 watts, low enough to add sport to the operation but high enough to be practical. Efficiency was considered important for battery conservation, as the authors often take their rigs into the mountains on backpacking or snowshoe trips (weather permitting). Finally, electronic transmit-receive switching is employed. This allows for near-QSK operation; it's also less expensive than using a relay. Slight modifications will allow the transmitter to be converted to a direct-conversion transceiver.

*7700 SW Danielle Ave., Beaverton, OR 97005

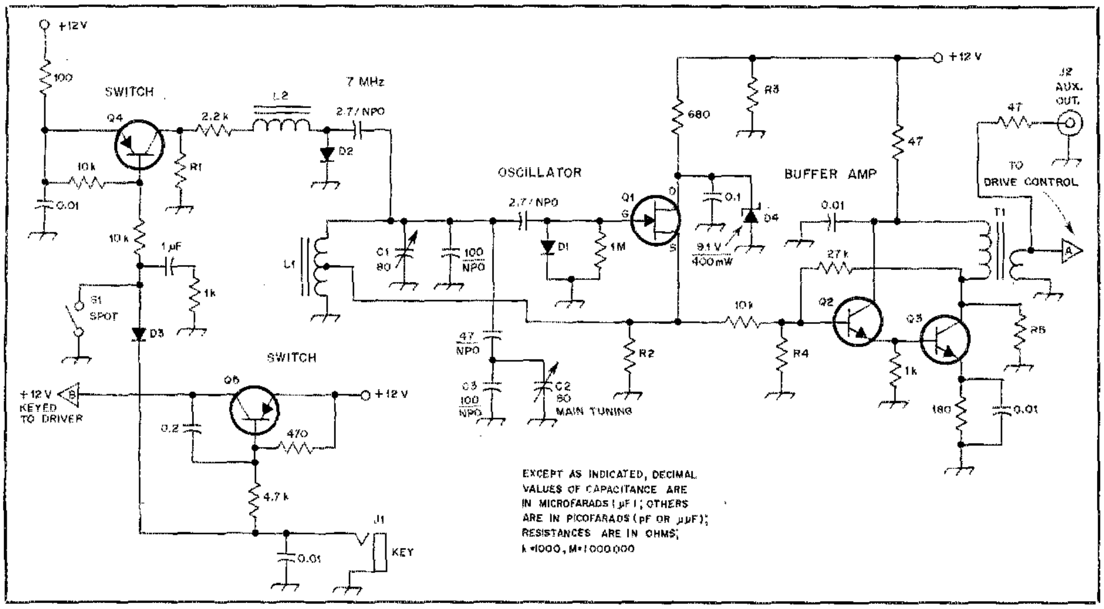


Fig. 1 — Schematic diagram of the VFO and control circuits for the QRP transmitter. Fixed-value capacitors are disc ceramic unless specified otherwise. Resistors are 10% tolerance composition.

C1, C2 — Miniature air variable, 75 pF max.
D1, D2, D3 — Silicon switching diode, 1N914, 1N4152 or equiv.
D4 — Zener diode, 1N937 or equiv.
J1 — Phone jack.
J2 — Phono jack or jack of builder's choice.
L1 — Toroidal inductor, 25 turns no. 22 enam. wire on Amidon T50-6 powdered-iron toroid core.
L2 — Toroidal inductor, 20 turns no. 26 enam. wire on Amidon ferrite toroid core, FT-37-43.
Q1 — JFET, 2N4416, MPF102, TIS88 or equiv. See text.
Q2, Q3 — General-purpose npn transistor, such as 2N2222 and 2N3904.
Q4, Q5 — General-purpose pnp transistor, such as 2N2907 and 2N3906.
R1-R5, incl. — Resistors as insulating tie points (see text).
T1 — Broadband ferrite toroidal transformer. Collector winding has 20 turns no. 28 enam. wire on Amidon FT37-43 toroid. J2 winding has 5 turns no. 28 enam. wire over primary winding.

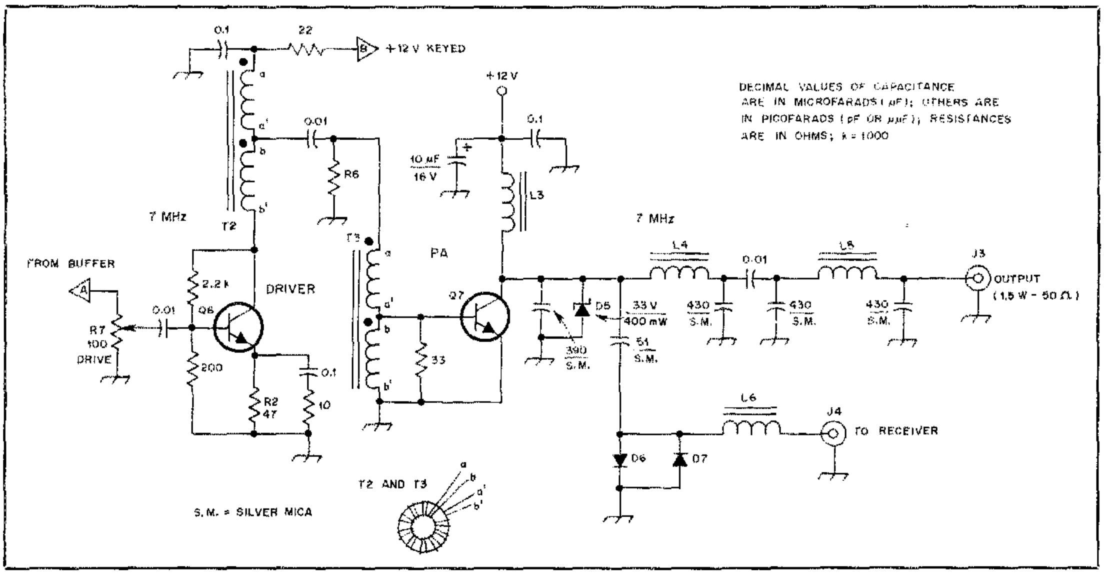


Fig. 2 — Schematic diagram of the driver and power-amplifier portion of the QRP transmitter. Fixed-value capacitors are disc ceramic unless noted otherwise. Polarized capacitors are electrolytic or tantalum. Fixed-value resistors are 10%, 1/2-watt composition.

D5 — Zener diode, 1N973B or equiv.
D6, D7 — Silicon switching diode, 1N914, 1N4152 or equiv.
J3, J4 — Phono jack or connector of builder's choice.
L3 — Collector rf choke, 35 turns no. 22 enam. on Amidon T68-2 toroid.
L4, L5 — 16 turns no. 22 enam. on Amidon T50-6 toroid.
L6 — 45 turns no. 26 enam. wire on Amidon T50-2 toroid.
Q6 — Npn transistor, 2N2222, 2N3904 or equiv.
Q7 — Rf power transistor, 2N3553, 2N3866 or equiv. Use small heat sink.
T2, T3 — Transmission-line broadband transformer, 10 bifilar-wound turns no. 28 enam. wire on Amidon FT37-43 ferrite toroid core.

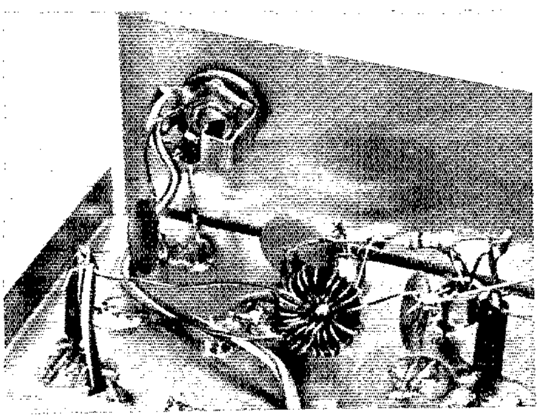


Fig. 3 — Close-up view of the assembly technique discussed in this article. Components are soldered to the circuit-board material and used as tie points.

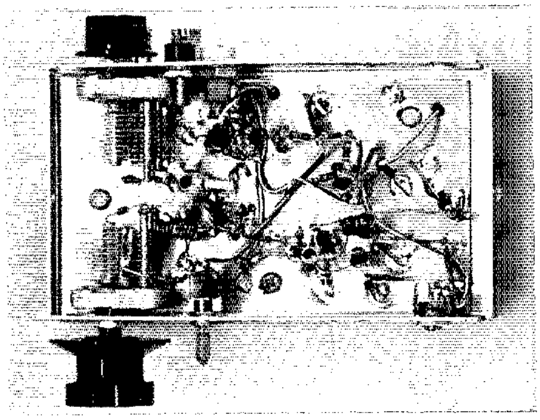


Fig. 4 — Interior of the VFO portion of the transmitter. The variable capacitors are shown at left.

This transmitter is based largely on a transceiver designed and built (with "ugly" methods) by a Field Day partner, Roy Lewallen, W7EL. The reader should review Roy's article for design details.[1] The writers mention those places where they have departed from the W7EL circuit. This transmitter is not as compact as Roy's is, but then few are!

Circuit Details and Construction

The transmitter is built by means of point-to-point wiring (Fig. 3). The foundation is a pair of small aluminum boxes, LMB type 139, 1-1/2 × 3 × 5-1/2 inches (38 × 76 × 140 mm). The boxes are bolted together, each containing a scrap of copper-clad circuit-board material. Bolted directly to the aluminum boxes, the boards serve as a low-impedance ground for all of the circuitry: They contain no etched patterns.

Examination of the circuit shows numerous components attached to ground. These serve their desired circuit function and provide mechanical support for the other components that are attached to the ungrounded ends (additional tie points are sometimes required). High-value resistors serve this function. The value is not critical if it is high enough not to disturb circuit operation. We used 1.1-MΩ, 1/2-watt parts. Any value from 220-kΩ upward (1/2 or 1/4 watt) will function well. The resistors are shown for reference in the schematic diagrams as R1-R7, inclusive. They have no bearing on circuit operation, but provide the needed mechanical support. Some builders may wish to insert resistors as tie points at other places in the circuit. Tuning is provided by a pair of 80-pF air variables from the authors' junk box. C2 is the main-tuning control, and C1 is a coarse band-set adjustment. C2 spans about 80 kHz with the components shown (see Fig. 4).

The FET type is not especially critical at Q1. However, reports from others indicate that the oscillator output may be low when the popular MPF102 is used: A 2N4416 is preferred. The TIS-88, essentially a plastic version of the 2N4416, is used in this transmitter.

All fixed-value capacitors in the VFO are NP0 ceramic types, chosen for optimum stability. Silver-mica capacitors should be avoided. Polystyrene capacitors would probably be suitable, but they may degrade the stability.

Most VFO drift occurs when the power is applied initially. This warm-up drift is minimized by allowing the VFO to operate continuously. The frequency is shifted downward by paralleling the oscillator tuned circuit with an additional 2.7-pF capacitor during key-down periods. This is added to the circuit by D2, a diode switch that is activated by Q4, a transistor switch attached to the key line. The timing components associated with Q4 force the oscillator frequency to be constant between characters, but to shift upward by about 25 kHz during longer key-up periods.

The VFO output is buffered with a two-transistor feedback amplifier, Q2 and Q3. This circuit provides an output of 10 to 15 mW, which is more than enough to drive the following stage. The reverse isolation is excellent. This circuit is a refinement of the first one by W7EL, and was published in a later *QST* "Feedback."[2]

The transistor type is not critical: 2N2222As or 2N3904s will work well at Q2, Q3 and Q6. The builder should be careful about transistors purchased at local electronics stores. Often devices sold as a "2N2222A" do not meet actual 2N2222A specifications.

The keying transistor, Q5, is also contained on the VFO board. The capacitor between collector and base forces an integrator action that ensures clean keying.

Construction of the VFO section is non-critical. Builders are often advised to keep all leads as short as possible. This is generally an exaggeration, especially for hf equipment. Some leads must be short, while others may be relatively long with no harm. Specifically, the leads on bypass capacitors should be short.

Consider the buffer amplifier, a circuit that has two bypass capacitors. One decouples the positive supply from the circuit. This capacitor should have a short lead to the ground foil. The other end should be connected directly to one end of T1 and to the collector of Q2. Similarly, the emitter bypass on Q3 needs to have reasonably short leads. Other leads may be longer, with no ill effects.

The output stages are shown in Fig. 2. This part of the circuit is built in the second box. The isolation aids in preserving VFO stability and preventing variations in output loading from shifting the oscillator frequency. Holes for leads (between sections) are drilled through the two boxes and the adjacent ground foil circuit boards. A bare wire is passed through the hole where the buffer output connects to R1, and is soldered to both ground foils. An insulated wire passes through the same hole, from T1 directly to R1.

The drive control, R7, is a necessary part of the circuit. Adjustment is described later. The value is not critical, with 100 to 1000 ohms being suitable.

The driver stage is a departure from the W7EL design: The original circuit was tuned. There is, however, no need for selectivity at this point, so a broadband design was adopted. The original circuit had a tendency toward instability (self-

[1]Notes appear on page 21.

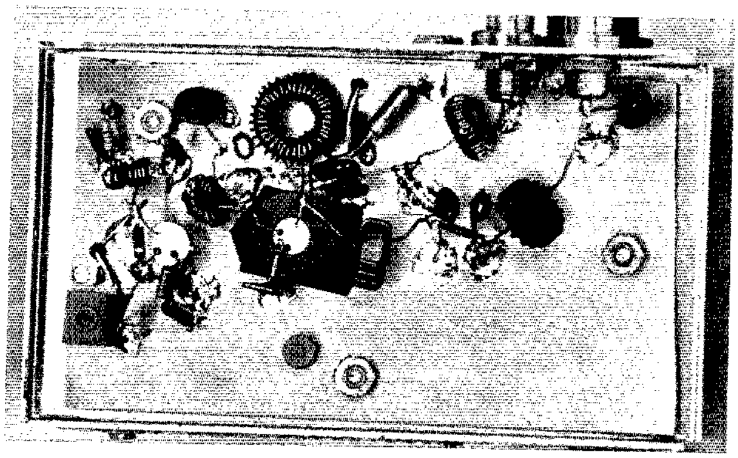


Fig. 5 — Photograph of the driver and PA assembly. Drive control R1 is visible at the lower left.

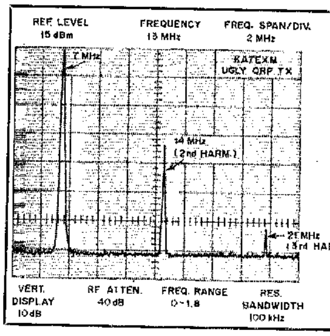


Fig. 6 — Spectral representation of the transmitter output energy. Worst-case harmonic data is presented with an operating voltage of 14. This presentation was made while using a Tektronix 492P analyzer, 4052 computer and 4662 plotter. The authors thank Dave Green, KA7IYT, for his assistance in doing the spectrum analysis.

oscillation). This is eliminated by using an amplifier with negative shunt feedback from collector to base, via the 2.2-kΩ resistor.

Two bifilar-wound transformers are used in this part of the transmitter (T2 and T3). The winding details are shown in the insert of Fig. 2. The two wires forming the bifilar windings may be twisted together, although this is not important at this low a frequency. Ferrite cores (*not powdered iron)* should be used for all three transformers.

The final amplifier is virtually identical to that described by W7EL. The emitter lead on Q7 should be short, although it is moderately long in this rig, owing to the method of transistor mounting. The 385-pF capacitor at the collector of Q7 should be attached close to the transistor.

L4 and L5 form a double pi-network for output filtering. The network is designed to present an impedance of 50 ohms to the collector of Q7. The T/R circuit is formed by L6 and the 51-pF capacitor. The two components are series-resonant at 7 MHz, so there is minimum attenuation during receive periods. High rf voltages appear at the collector of Q7 when Q6 is keyed on. This causes the T/R switching diodes, D6 and D7, to conduct alternately. The 51-pF capacitor now becomes part of the transmitter output network. There is less than 1 mW of power available at the receiver coax connector during key-down periods: This level will not damage most receivers. The receiver should have an excellent agc system or separate muting facilities if proper QSK operation is desired.

The beginning builder might be tempted to construct the transmitter using a "shotgun" approach. That is, the complete circuit would be built, then the power applied. The builder would be confused when the system did not work, or amazed if it did. This transmitter was built and tested in a sequential manner, exactly opposite to that outlined, which permits problems to be identified easily.

The VFO was built first. Power was applied, and the actions of C1 and C2 were checked by listening to the signal in the station receiver. The buffer (Q2 and Q3) was then constructed and tested. Output power into a 50-ohm load was measured using an rf probe and voltmeter. The keying circuit, including the frequency-offset components, was then built. It was tested with a dc voltmeter and by listening to the signal in the station receiver.

Next, the driver was built (see Fig. 5) and the output was measured into a 50-ohm load (about 70 mW with R7 at maximum). This measurement was performed with a diode detector and attenuators. Both are described in chapter 7 of *Solid-State Design for the Radio Amateur.*[3] The PA was constructed next. The output power was measured with the same home-built instrumentation. The total power-supply current was also monitored. The drive was set for an output of 1.5 watts with a corresponding current of 200 to 250 mA, indicating reasonable efficiency.

Power output may be increased to over 2 watts by advancing the drive control. The current rises to over 500 mA, however, indicating degraded efficiency. The output network should be redesigned if higher output is desired. A different transistor could then be used at Q7. Some of the devices intended for the output of CB transmitters should yield 5 to 10 watts. The available power from the driver is increased to 150 mW by changing R2 to 15 ohms.

What Next?

The transmitter is now ready for use. It yielded numerous contacts for the writers with stations up and down the West Coast of the U.S. and Canada in just a few days of casual operation. Reports indicated that the note was stable, clean and crisp — certainly far from ugly! (See Fig. 6.)

The builder may wish to convert this unit to a direct-conversion transceiver. An auxiliary VFO output is shown in Fig. 1. The power from this point is suitable to drive a diode ring product detector, as is used in the W7EL transceiver. The offset, now about 25 kHz, is easily reduced to the 800 Hz needed for a direct-conversion transceiver by shunting D2 with a capacitance of 150 pF.

Few of the components in this circuit are critical. Many substitutions are possible. For example, the main tuning capacitor, C2, may be a standard 365-pF broadcast-band replacement type. C3 should then be increased to 220 pF to retain the present 80-kHz tuning range. A vernier drive may be added. It is surprisingly practical (and simple!) to do without it, however, if the tuning range is restricted.

Whatever is being built, it is always worth questioning the need for an etched circuit board. More often than not the "ugly" methods presented here will do as well, with considerable savings in time and money and absolutely no compromise in performance. Construction is also simplified if extreme miniaturization is avoided.

The authors wish to acknowledge the comments of Roy Lewallen, W7EL. It's always enlightening to share experimental results with others who have similar interests. QST

Notes

[1]R. Lewallen, "An Optimized QRP Transceiver," *QST,* Aug. 1980, pp. 14-19.
[2]See "Feedback," *QST,* Nov. 1980, p. 53.
[3]W. Hayward and D. DeMaw (Newington, CT: The American Radio Relay League, Inc., 1977).

Experience 10-Meter FM Operation!

Like to build and modify equipment? Here is an inexpensive project that will give hours of building fun — and put a CB radio to good use, too!

By Bob Heil,* K9EID

Remember the "good old days"? Many operators built their own equipment, or at least modified surplus rigs. I think operators who "paid their dues" were more responsible on the air than some of today's "appliance" operators are. Notes were exchanged on modifications and improvements. Things just seemed more congenial. On the other hand, modern-day technology allows the amateur to pick up a miniature hand-held unit and communicate with noise-free, full-quieting fm. Which is better?

10-meter FM: A Different Experience

Perhaps neither is better, but 10-meter fm operation now has the best of both worlds. Most operators use equipment originally designed for other bands and/or other modes. Much of the casual talk relates to modifications and improvements. Most of the people on this band have "paid their dues" with their equipment. I think respect for the other fellow runs higher here than on most of the other bands.

I recently worked LA9SC; both stations were portable with less than 2 watts of power into "rubber duck" antennas. How could we work across thousands of miles with so little power? We were using 2-meter hand-held units to access 10-meter fm remote bases. It is this melding of modern technology with the "home-construction" philosophy that seems to make 10-meter fm what it is today.

History

Ten-meter fm is not a new mode; amateurs were experimenting with this mode and band in the late 1940s.[1] Why does it seem so new? A few hardy souls have been using equipment converted from the business "low band" since the early days. This is similar to the start of the 2-meter fm boom. Wide availability of surplus commercial equipment, however, did not popularize 10-meter fm as it did 2-meter fm.

The CB boom came. Digital synthesis rapidly became the standard frequency-generation scheme for CB sets. Cybernet, a Japanese firm, dominated the market. Few people outside the electronics import industry heard of the company, because it did not market equipment under its own name. Cybernet specialized in producing circuit boards. Kraco, Hy-Gain and similar companies purchased completed circuit boards from Cybernet. These companies put the boards in their own cabinets and sold them.

Cybernet had a "universal" board that they sold to anyone. The board could function as a stripped-down, low-cost basic transceiver or a full-feature, top-of-the-line radio, depending on the options added. The Cybernet factory was totally automated and capable of producing thousands of boards each day. This one board was the heart of radios that ranged in price from $75 to $350; the only differences were the "bells and whistles"!

The CB market declined at the same time that the FCC introduced changes in the requirements for purity of emissions and the number of channels allocated to the service. Cybernet engineers found an easy, straightforward modification to the board that changed it from 23 channels to 40. However, the FCC would not type-accept modified boards. Hundreds of thousands of radios, varying from bare boards to completed sets, were in the "pipe line." They could not be sold legally after a specified date. Everyone left holding the bag began "dumping" radios and component boards.

In the meantime, Cybernet had made a new version of the basic board and that met FCC requirements. They were gearing up for the anticipated boom in 40-channel rigs.

The Boom That Fizzled

One by one, the U.S. companies marketing radios that were built around the Cybernet board began to fold. Hy-Gain had stockpiled a huge quantity of the 40-channel boards. When the business failed, the overseers sold the stockpile to surplus dealers, further complicating matters. As the CB market declined, many store owners faced the question of what to do with radios in inventory that could not be sold legally at any price. I worked out a deal with a local department store to the benefit of everyone involved. The store manager donated their inventory of 83 "illegal" radios to our club. Our members had the radios for conversion to 10 meters, and the store had a "write-off."

Originally, we planned to change the operating frequency, and to leave the mode of operation alone (a-m). While researching the situation, however, I came across the Knickerbocker et al. article describing the conversion of CB transceivers to 10-meter fm units.[2] Our radios corresponded to the ones described in the article. Most of our club members decided to make the fm conversion. That was our introduction to 10-meter fm.

What Do You Find When You Get There?

Most of the activity on 10-meter fm is simplex. The major calling frequency is

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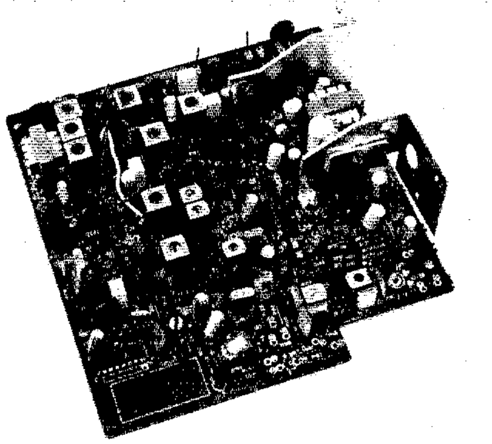
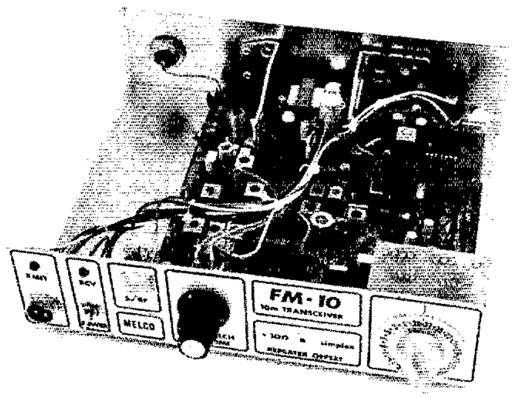
[1]Notes appear on page 26.



The Cybernet CB board. The clear silk-screen markings on the board make component location and circuit tracing easy. The PLL is located in the lower-left corner. The modulation transformer (T110) is visible between the heat sinks.



A completed 10-meter fm transceiver built from a kit. The fm modulator board is mounted above the main board near the rear panel. This unit uses a CB channel-selector switch to program the PLL.

29.6 MHz, with 29.5 MHz as a back-up. Typically, users establish contact on one of these frequencies and quickly move to another spot for the QSO. I think the hands-on approach for building equipment instills a level of pride and responsibility not found on some other bands and modes where "appliance operators" predominate.

Repeaters do exist on 10-meter fm, but they are not the towering influence that they are on 2-meter fm. The 10-meter fm repeater band is only 200 kHz wide (29.5 to 29.7 MHz), so the input and output frequencies are much closer together than they are for the other repeater bands. Furthermore, worldwide communications (using only a few watts) is a normal occurrence during much of the sunspot cycle. Most 10-meter fm systems use separate sites for receive and transmit to eliminate the need for large, expensive duplexers. Most repeaters have a CTCSS (PL) decoder at the receiver to keep DX signals from locking up the system. It is common for 10-meter fm repeaters to be linked with repeaters on other frequencies. (Consult the ARRL *Repeater Directory* for the 10-meter repeater band plan, the 10-meter CTCSS plan and a list of active 10-meter fm repeaters.)

Remote Bases

Remote bases are not the same as repeaters, but the distinction is subtle and may be overlooked. A remote base functions like your home station; it can work other stations simplex or *through* a repeater system. The major difference between your home station and a remote base is how the station sends and receives information to and from you. In your home station, you are interfaced to the radio by sound waves (microphone and speaker). In the case of the remote base, you are interfaced with a vhf or uhf radio link (your end of the link uses the speaker and microphone). Of course, a remote base can have various levels of sophisticated controls.

What About DX?

I have made contact with all continents in a single afternoon. Europe and Japan seem to be the areas with the most 10-meter fm'ers. Unlike their U.S. counterparts, many of the foreign operators seem to be using Yaesu FT-901DMs or Comtronix FM-80s. There is plenty of DX!

One thing that is noticeable on 10-meter fm DX contacts is the phase shift of a signal as it passes through the ionosphere. Full-quieting signals will fade suddenly, only to return to full strength in a few seconds. The reason for these fades has to do with the polarity of the signal at the receiving end. If the incoming signal and the receiving station antenna are both vertically (or horizontally) polarized, everything is copacetic. If one is vertically polarized and the other is horizontally polarized, reception deteriorates. This is particularly noticeable on fm. As the signal passes through the ionosphere, the polarity rotates. Shifting levels in the ionosphere cause different degrees of rotation. In a period of minutes the incoming signal may "rotate" through several cycles. These shifts cause the deep fades. Dual diversity receiving systems can overcome this problem, but they are beyond the scope of this article.[3]

Equipment For 10-Meter FM

Most hf ssb transceivers with RIT can be made to transmit on 10-meter fm with minor modifications. In a typical RIT circuit, a varactor diode acts like a variable capacitor when a small voltage is applied to it. There are two things necessary to frequency modulate such a transmitter: You must enable the RIT circuit on transmit, and you must couple an audio-voltage to the varactor diode. Receiving fm signals is not quite so easy for these rigs. If the transceiver has an a-m detector, you can tune slightly off frequency and use slope detection to demodulate the fm. A better solution is to add an fm detector that can be switched in and out of circuit.

I think the best procedure is to convert a CB transceiver built around the Cybernet board. Second best is to convert the board and "build up" the radio. There are thousands of these radios and boards available now. Many show up at flea markets; some are collecting dust on the shelves of pawn shops. Anyone in the U.S. should have little trouble locating one of these radios. The quickest way to determine if you have a radio with the proper board is to take the case apart and look at the board. On the foil side of the board you should find the numbers 33AOX, 36AOX or 39AOX (except for some of the Hy-Gain boards marked 75A080). On the component side you should find three crystals: 10.240 MHz, 11.806 MHz and 10.695 MHz. Some later versions have only two crystals. The new circuit was designed to prevent bootleggers from moving the radios to "hfer" channels. This also makes it difficult to put the radio on 10 meters. The older multiple-crystal rigs are difficult to modify and should be avoided. Unfortunately, the manufacturers used the same model number for radios based around all three circuits. That's why I say it's best to pull the cover off and look at the board before you pay for the radio.

The other alternative is to use one of the Cybernet or Hy-Gain boards sold by the surplus houses. Again, look for a board with the appropriate marking, three crystals and the 02A (MC145109 or 760136) PLL. The first-time converter should avoid Hy-Gain board 750096. It appears to be identical to the other boards, except for a few differences in the area of the PLL chip, marked 58141. This chip is not the PLL! It is a decoder. Hy-Gain used this board in their "one armed bandit," which had the PLL in the microphone. Modifying this board is more extensive than is the case with the regular boards.

Conversion

There are five steps to converting a Cybernet board to a functioning 10-meter fm transceiver. First, you must hook up the board and make sure it is working. If you have a complete CB transceiver, you can move ahead to the next step and convert the operating frequency to 10 meters. Slope detection will work (with RIT), but I advise constructing a simple fm detector. You must also defeat the a-m circuit and "fm" the transmitter. Finally, you will need a scheme for programming the PLL.

A schematic diagram for the Cybernet board appears in Fig. 1. Please note that this diagram has not been redrawn in *QST* style; consequently, some of the symbols and terminology differ from those normally used. On the drawing, numbers inside circles refer to the "pin outs" of the board and are called pins in the remainder of the article (most are actually drilled holes and pads). The component side of the circuit boards have been silk-screened to provide a good indication of parts location. Fig. 2 is a pictorial diagram of the Cybernet board and shows major connecting points.

Board Hookup

Refer to Figs. 1 and 2 and to the parts numbers on the component side of the board for the following steps. Where needed, use appropriate lengths of hookup wire. Solder two short wires to the terminals of a no. 47 pilot lamp. Connect one lead to pin 5 and the other to pin G2 on the board. The lamp will serve as a dummy load and power output indicator.

Attach the 50-kΩ squelch potentiometer to pins 7 and G3. Connect one side of the 50-kΩ volume control to pin 19 and the wiper to pin 21. Solder the other side to the squelch-control ground lug. If either or both of the controls "turn backwards" after completing the other steps, reverse the connections on that particular potentiometer. Attach a speaker to pins 23 and

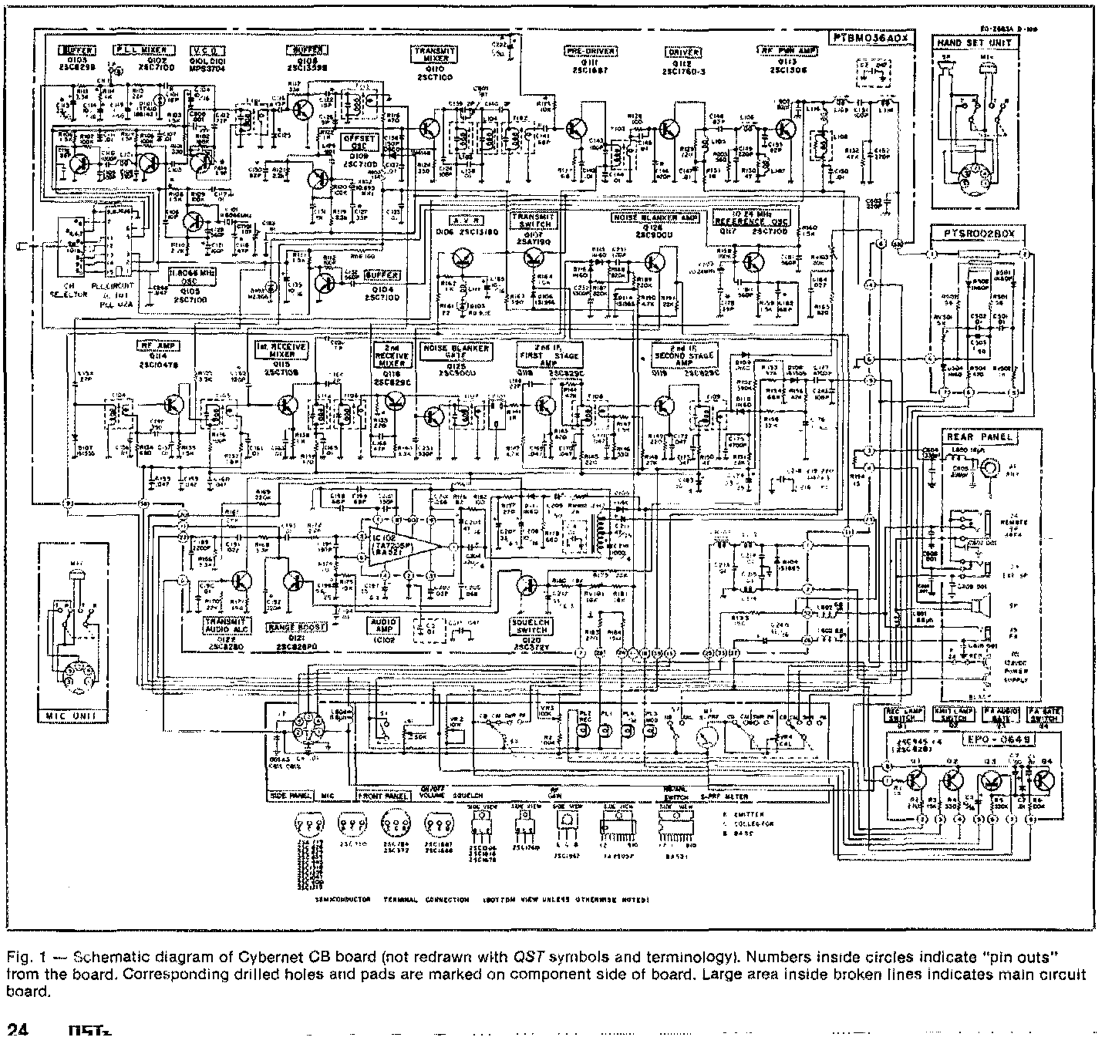


Fig. 1 — Schematic diagram of Cybernet CB board (not redrawn with *QST* symbols and terminology). Numbers inside circles indicate "pin outs" from the board. Corresponding drilled holes and pads are marked on component side of board. Large area inside broken lines indicates main circuit board.

Table 1

Preliminary Coil-Slug Adjustments

T101 — 1 turn cw	L108 — 1 turn ccw
T111 — 3/4 turn cw	L109 — 2 turns ccw
L103 — 1 turn cw	L110 — 2 turns ccw
L104 — 1/2 turn cw	T104 — 1 turn cw
T102 — 1/4 turn cw	T105 — 1 turn cw
T103 — 1 turn cw	

G2. Install jumpers between pins 9 and 20, and between 23 and 3. Connect a 50-kΩ potentiometer between pins 38 and 39 for an rf gain control. You may omit the rf gain control by installing a jumper between these two pins. Temporarily wire a microphone cartridge or an audio-frequency generator to pins 22 and G3.

Initial Frequency Adjustment

Determine whether your board is a 23- or 40-channel model. Your board is a 23-channel type if pin 7 of the PLL is grounded and if pins 8, 9 and 10 are connected to a 1.5-kΩ resistor. If you have the 23-channel variety, modify it to 40 channels by cutting the foil between pin 7 of IC-101 and chassis common and disconnecting pins 8, 9 and 10 of IC-101 from the 1.5-kΩ resistor. Attach a short wire to pin 7 and another one to pins 8, 9 and 10.

Once the 40-channel modification is complete, set the PLL for channel 20 (27.205 MHz), which will become 29.5 MHz after the 10-meter conversion. If you do not have selector switches, jumper D102 (cathode) to pins 8, 9, 10, 11 and 12 of the PLL (IC-101).

Initial Testing

Apply +13 V dc to pin 1 and power-supply common to pin 2. The receiver should be operational at this point. If not, recheck your wiring for errors. Troubleshoot and repair any section of the receiver that isn't functioning normally. (Hint: I have found 95% of the troubles with these boards to be crystal failures.) Detach the speaker lead that goes to G2. Connect G2 to pin 13 (PTT). This should key the transmitter, and the lamp should glow. If not, check for wiring errors, troubleshoot and repair. Use a high-impedance voltmeter to measure the voltage at TP8. If it does not read exactly 1.5 V, adjust T101 until it does.

Frequency Conversion

Replace crystal 3 (11.806 MHz) with a 12.571-MHz crystal. Use a proper-size nonmetallic alignment tool to gently adjust the transmit and receive coil slugs. *The slugs break easily*! Use the information in Table 1 to preadjust the transmit inductors. Once the prealignment process is completed, restore power to the board and (with PTT still connected to G2) tune the transmit coils for maximum output power, as indicated by the pilot lamp.

Use the voltmeter to check the voltage at TP8 again. It should indicate 1.5 V. If not, adjust T101 for this reading. For a final peaking of the circuit, observe the S meter of a nearby receiver or use a wattmeter. Disconnect the power.

Receiver Alignment

Remove the lead from pin 13 and reattach it to the speaker. Connect pin 7 to G2 and apply power. The receiver should be unsquelched (the background noise may be at a low level, though). Tune, in order, T104, T105, L112, T106, T107, T108 and T109 for maximum background noise. Disconnect pin 7 from G2. This rough alignment is adequate for the remainder of the conversion process. Once the board is installed in a metallic cabinet, it will be necessary to "tweak" the receiver. The preferred method is to use a signal generator, but if one is not available, use a weak on-the-air signal. The receiver will function "as is" for slope detection if it has RIT.

FM Demodulator

The simple demodulator detailed in Fig. 3 will provide superior service compared

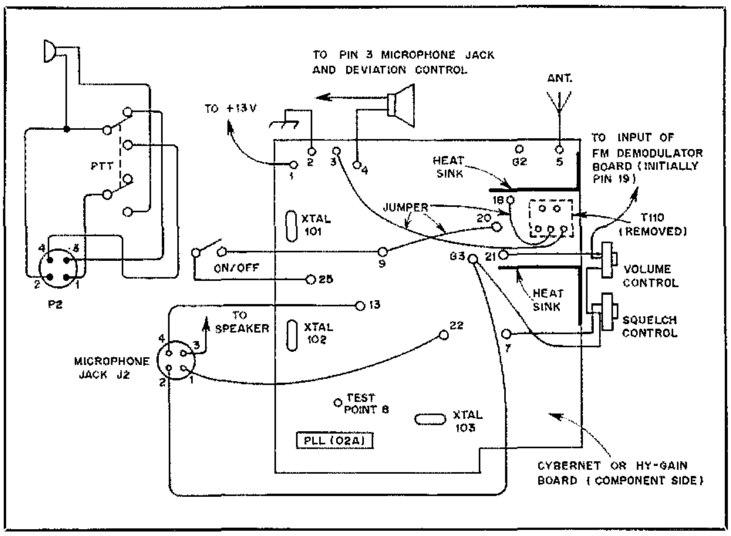


Fig. 2 — Pictorial diagram of component side of Cybernet CB Board and modifications needed to "hook it up." The volume control and squelch control are 50-kΩ potentiometers (wattage and type are not critical). The speaker is an 8-Ω type (size not critical). Crystal 103 (11.8066 MHz) is replaced with a 12.571-MHz crystal (fundamental type, HC-18/U holder). Jacks, plugs and enclosure are the choice of the builder.

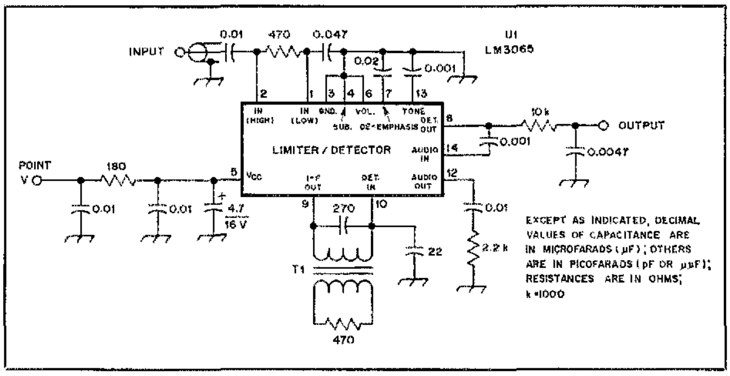


Fig. 3 — Schematic diagram of fm demodulator board. This circuit will work with any receiver having a 455-kHz i-f and may be employed in radios having i-fs other than 455 kHz by making the appropriate changes in the components associated with pins 9 and 10. All capacitors are disc ceramic, except those with polarity marked, which are electrolytic. Resistors are carbon composition, 1/4 watt.

T1 — Miniature 455-kHz i-f transformer, 680 μH. U1 — Limiter/detector IC, LM3065 or equiv.

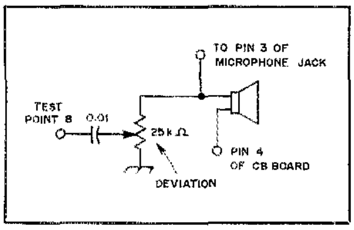
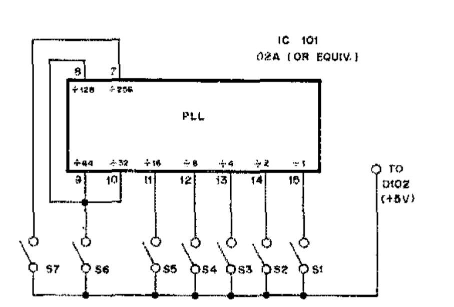


Fig. 4 — Diagram of method of frequency-modulating the transmitter. Audio voltage from the audio amplifier is taken from the speaker terminal and fed through the voltage divider (deviation control) and coupling capacitor to TP8, where it modulates the VCO. The coupling capacitor is a 0.01-μF disc ceramic. The deviation control is a pc-board style, 1/4-watt, 25-kΩ variable resistor.



OPERATING FREQUENCY (MHz)	CLOSE SWITCHES
29.50	4, 5, 6
29.51	4, 5, 6, 1
29.52	4, 5, 6, 2
29.53	4, 5, 6, 2, 1
29.54	4, 5, 6, 3
29.55	4, 5, 6, 3, 1
29.56	4, 5, 6, 3, 2
29.57	4, 5, 6, 3, 2, 1
29.58	7
29.59	7, 1
29.60	7, 2
29.61	7, 2, 1
29.62	7, 3
29.63	7, 3, 1
29.64	7, 3, 2
29.65	7, 3, 2, 1
29.66	7, 4
29.67	7, 4, 1
29.68	7, 4, 2
29.69	7, 4, 2, 1

Fig. 5 — Wiring diagram for programming the PLL for the proper frequency. S1-S7, inclusive, are spst toggle switches. Binary-coded arrangements and diode-matrix encoders are two of the many alternatives to this circuit.

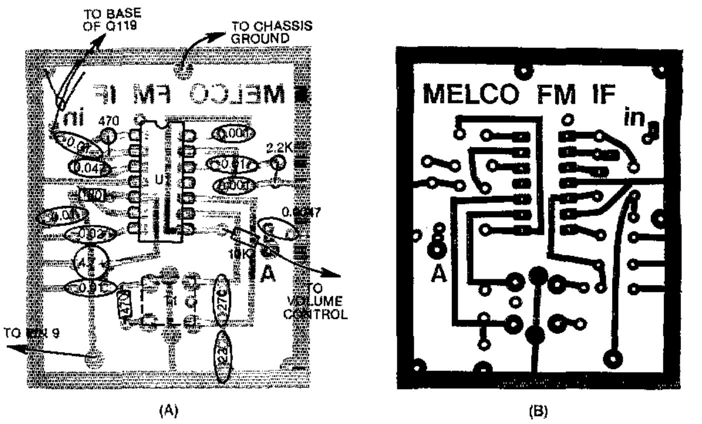


Fig. 6 — At A, parts-placement guide for the fm demodulator board. Parts are placed on the non-foil side of the board; the shaded area represents an X-ray view of the copper pattern. Resistances are in ohms; k = 1000. Capacitors with whole-number values are in picofarads except those with polarity shown, which are electrolytic with values in microfarads. Capacitors with decimal-value numbers are in microfarads. At B, circuit-board etching pattern for the fm demodulator board. Black represents copper. The pattern is shown at actual size from the foil side of the circuit board.

to slope detection.[4] It is built around the LM3065 (MC 1358) limiter/detector IC. Layout is not critical, so any of the usual construction techniques may be used as an alternative to the pc board.

Perform the following steps to disable the a-m detector and to enable the fm demodulator. Connect V of the demodulator to pin 9 of the Cybernet board. Attach ground of the board to a convenient chassis "common" on the radio. Disconnect the wiper of the volume control from pin 19 and attach it to the output of the fm board. Use a short piece of coaxial cable (RG-174/U or similar) to connect the input of the detector circuit to the base of Q119.

Transmitter FM

Carefully remove the modulation transformer, T110. Remove RV102. I use a solder sucker for desoldering, but solder wick should work as well. Attach a wire from pin 3 to the positive terminal of C204 (use the hole and pad at T110). Move the speaker lead from pin 23 to pin 4. Solder a jumper between pin 18 and pin 20 (use the hole and pad at T110). Removing T110 prevents the amplified microphone audio from amplitude modulating the rf final amplifier. The jumpers restore the audio path to the speaker and the dc path to the rf final amplifier.

Locate TP8 near the VCO in Fig. 1. Notice that a changing voltage at TP8 will cause the VCO to change frequency. Fig. 4 shows the circuit used to couple audio from the output of IC-102 to TP8. The 25-kΩ variable resistor acts as a deviation control.

Fig. 2 provides hook-up data for the microphone, microphone jack and the ON/OFF switch. Prepare a suitable package for the unit. The microphone is a low-impedance type. Replace the dummy load with an antenna jack. Jacks and plugs can be added to suit your needs.

Fig. 5 provides data for programming the PLL for most frequencies typically used by fm'ers on the 10-meter band. Assuming that you do not wish to be "locked" onto one frequency, the diagram shows the simplest arrangement for changing frequency quickly. This design requires seven spst toggle switches.

There are several other popular schemes for changing frequency. If available, a 40-channel CB switch may be used. Digital readout and scanner circuitry may be added, if you desire. You may need or want a repeater offset circuit. This is just the beginning! Numerous modifications, improvements and accessories can be added. There isn't enough room to list, let alone to describe, them. The fastest way for you to find out about them is to put the basic radio on the air and ask questions. Everyone I know on the band loves to talk about modifications. Grab your soldering iron and come join us! QST

Notes

[1] *FM & Repeaters for the Radio Amateur*, 2nd ed. (Newington, CT: The American Radio Relay League, Inc., 1978), pp. 7-10.

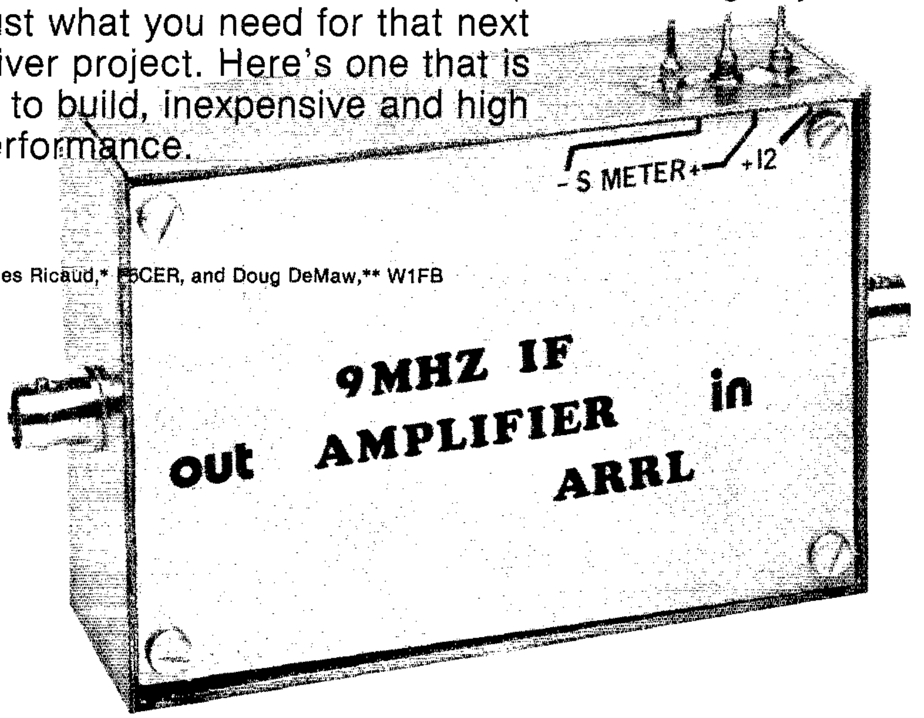
[2] H. Knickerbocker, A. Weise and R. Stielau, "CB-to-10 FM best conversion yet?" *73*, January 1980, p. 117.

[3] B. Heil, *The 10 Meter FM Handbook*. (Marissa, IL: MELCO Publishing, 1980), p. 31.

[4] Parts, partial kits, complete kits and manual available from MELCO, Box 26, Marissa, IL 62257, tel. 618-295-3000.

A Universal MOSFET I-F Amplifier

A 40673 or 3N211 MOSFET i-f amplifier and agc system may be just what you need for that next receiver project. Here's one that is easy to build, inexpensive and high in performance.



By Georges Ricaud,* F6CER, and Doug DeMaw,** W1FB

Do you prefer to work with "discretes" rather than ICs during experimental efforts? Certainly, it allows somewhat more freedom with respect to changing the operating parameters of a circuit, and discrete transistors make the layout of a pc board less challenging in some instances. Perhaps you simply enjoy working with FETs and bipolar transistors because you're able to get a better "feel" for what's happening in the circuit. Whatever your outlook, this circuit could be what you've been seeking as the core of that new homemade receiver!

This i-f module was designed by author Ricaud. His circuit was published in French and later translated by him for use in *QST*.[1] The ARRL staff duplicated the design, then made minor changes to permit the use of parts available in the USA. The latter version is presented here, with additional information added by author DeMaw. The layout for the ARRL version in Fig. 2 was developed by G. Hull, AK4L, of the Hq. technical staff.

This i-f system is suitable for use from below 5 MHz to frequencies above 10.7 MHz by merely changing the parallel capacitance across the i-f transformers to an appropriate value for resonance. The design objective was to provide a low-noise i-f strip for use in a high-dynamic-range receiver. Care was taken to ensure unconditional stability and to provide fast-acting agc with a wide control range (100 dB plus). Overall gain is approximately 110 dB. Provision is made for a linear-reading S meter.

Circuit Information

Fig. 1 contains the schematic diagram of the F6CER i-f system. Three dual-gate MOSFETs are used to develop the desired overall gain. The 40673s are recommended for best stability. The ARRL version employs 3N211s, but they have somewhat greater gain capability (high transconductance) than the 40673s, and may encourage instability if care is not taken with the layout and lead lengths of the components.

To obtain the required agc control range it is necessary to bias Q1, Q2 and Q3 for an effective gate no. 2 swing of −2 to +6 volts. To accomplish this action it is mandatory to reference the sources of the FETs at approximately +2 volts. This is done by inserting D1, D2 and D3 as shown; the barrier voltage of the diodes establishes a regulated positive bias. Most LEDs will yield a 1.5-volt reference, but some that were tested in the ARRL lab provided a 2.1-volt reference (large red LEDs). Alternatively, three silicon diodes, such as 1N914s, can be used in series at D1, D2 and D3. Zener diodes are not available for 2.1-volt operation, but 2.5-volt ones would probably work okay.

Vhf parasitic oscillation is discouraged by using 100-Ω resistors at the gates and

[1]Notes appear on page 29.
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**Senior ARRL Technical Editor

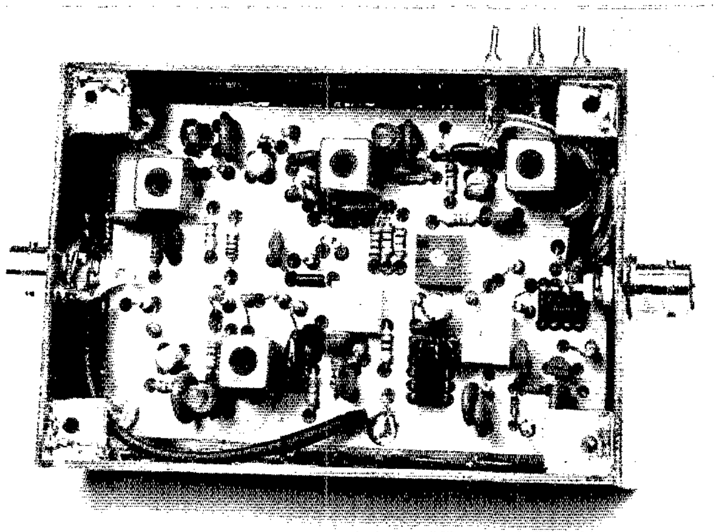


Fig. 2 — Interior view of the ARRL model of the F6CER i-f system. Double-sided pc board is used to contain the circuit and to fabricate the box that houses the unit. Pc boards, negatives and complete parts kits for this project are available (see note 3).

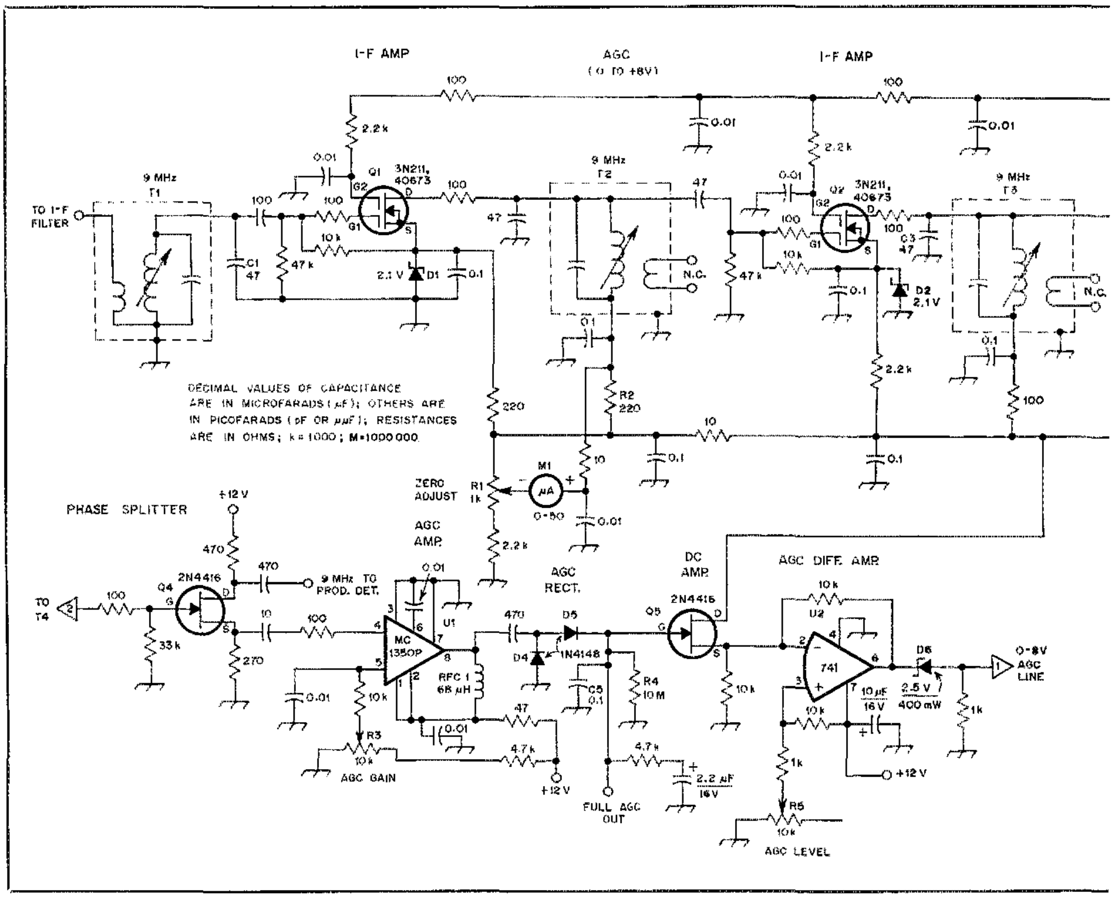
drains of the FETs. The drain-supply lead of each i-f amplifier stage is decoupled with an RC network to discourage instability at or near the i-f (9 MHz).

T1, T2 and T3 are J. W. Miller Co. 10.7-MHz miniature i-f transformers. Similar transformers from junked pocket-size fm radios should work satisfactorily in this circuit. C2, C3 and C4 are placed in parallel with the built-in capacitors in the transformers to effect resonance at 9 MHz. Larger values of capacitance can be added for lower intermediate frequencies. No other circuit changes should be required.

The output signal from Q3 is buffered by means of phase-splitter Q4 (a technique used by W7ZOI) to isolate the agc amplifier (U1) from the outboard product detector. A 2N4416 JFET or equivalent type is suitable for use at Q4 of Fig. 1.

AGC Circuit

One JFET and two ICs are used in the agc circuit of Fig. 1. U1 can be considered a fourth i-f amplifier. Its rf output is rectified by voltage doubler D4/D5. The resultant dc voltage is routed to a JFET dc



amplifier, Q5, which in combination with U2 forms the familiar control circuit used by W7ZOI and W1FB in their high-performance receivers.[2]

Op amp U2 samples the level across the Q5 source resistor and responds in accordance with the setting of R5. This control determines the dc voltage swing at the output of U2, and hence the agc control-voltage range. R3 is used to set the agc threshold with respect to the incoming signal level at the receiver front end. The actual threshold will depend on the operator's preference, but usually dictates that agc action commences when the receiver input signal is somewhere between 0.5 and 2 μV.

The agc "hold" time is determined by the values selected for R4 and C5. The time constant is a subjective matter, and is left up to the builder. With the values shown it is 1 second, but R4 can be increased in value for longer decay times.

A 2.5-volt Zener diode (D6) is used in series with the output of agc difference amplifier U2. It helps set the lower limit of the agc voltage range. In the original F6CER design this point in the circuit employed three series-connected 1N4128 silicon diodes for the same purpose. If the agc circuit is functioning correctly, the output swing of U2 will be 0 (no rf signal at the U1 input) to +8 volts at full receiver input-signal level. Because of the D1, D2 and D3 action, the effective agc swing on the MOSFET i-f amplifier no. 2 gates is −2 to +6 volts.

Construction Notes

If the 9-MHz i-f filter is to be contained within the agc-system shield box, care must be taken to prevent the filter can from touching the sides and top cover of the box. This will help prevent unwanted ground loops from degrading the ultimate-attenuation characteristics of the filter. Also, it is recommended that a small shield plate be soldered to the pc board (ground) across the center of the filter to aid the input/output isolation of the filter. The input lead to the filter should be miniature coax such as RG-174/U. The shield braid is soldered to the *inner* wall of the i-f module box.

A parts-placement guide for this circuit is not available, but a pc board and parts kit can be obtained for this project.[3] A homemade shield box can be built easily from pieces of double-sided pc board. A die-cast aluminum box will also serve well as an enclosure.

Selecting the Semiconductors

It is prudent to use only the top-quality active devices that are available. Many surplus or bargain ICs and transistors perform poorly, or not at all. An inferior 741 op amp, for example, will not provide the required agc voltage swing. If the FETs are grade-outs or defective parts, the amplifier will have low gain and poor agc range. It may also be very noisy.

Since it is nearly impossible to obtain matched MOSFETs, it is recommended that the builder adjust the I_{dss} (drain current) of each i-f amplifier stage for 10 to 12 mA. The current can be determined by measuring the voltage drop across the 100-Ω drain-supply resistors. The current of the three stages can be matched by changing the value of the 47-kΩ gate no. 1 resistors. A lower value will reduce the I_{dss}, and a higher value will increase it.

Alignment

A 9-MHz signal is applied to the input of Q1 with the i-f module being operated from a 12-volt dc supply. It is assumed that a product detector, BFO and audio amplifier are connected to the output of the i-f system during these tests. T1, T2 and T3 are adjusted for maximum signal response as noted at the output of the audio amplifier.

R3 and R4 are not adjusted until the i-f/agc module is operating in the composite receiver for which it was built. R1 is then adjusted so that M1, the S meter, reads zero when no receiver input signal is present. The meter response is quite linear with the circuit shown in Fig. 1.

An additional agc line is available at the output of D4 and D5. The dc voltage range at this point will be much smaller than at the output of D6 — roughly 0 to +3 volts. This agc takeoff point is useful for supplying delayed agc to the rf amplifier of a receiver. A series R-C network is used from this line to ground to establish the decay time of this leg of the agc system.

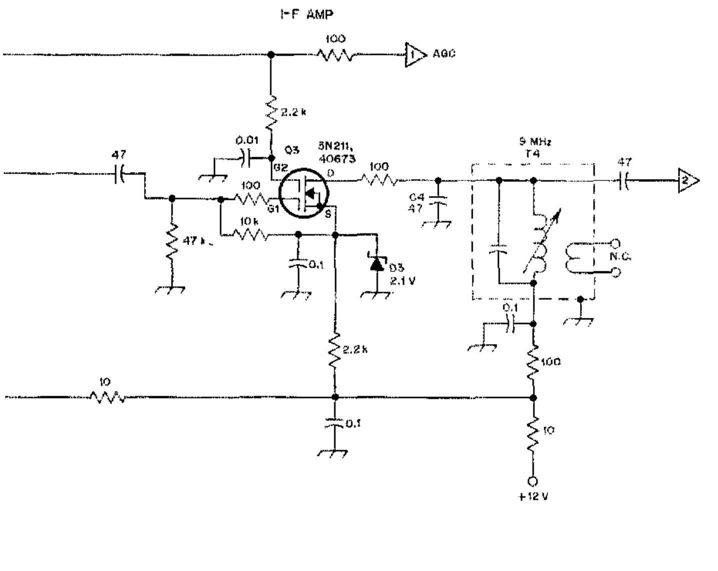


Fig. 1 — Schematic diagram of the F6CER i-f amplifier and agc system. Capacitors are disc ceramic. Fixed-value resistors are 1/4-watt composition types.

C1-C5, inc. — See text.
D1-D3, incl. — See text.
D4, D5 — Silicon small-signal diode (1N4148 or 1N914).
D6 — 2.5-volt, 400-mW Zener.
M1 — Dc meter, 50- or 100-μA type.
R1, R3, R5 — Pc-board linear-taper composition control.
RFC1 — Miniature rf choke, 68 μH.
T1-T4, incl. — Miniature 10.7-MHz i-f transformer, untuned secondary. Primary padded to resonate at 9 MHz. (J. W. Miller Co. no. 8852 or equiv.)
U1 — Motorola MC1350P IC.
U2 — Type 741 op amp.

Acknowledgments

W1FB wishes to thank Georges Ricaud for making this circuit available to the ARRL for use in *QST*. Appreciation is expressed also to Gerald Hull of the ARRL staff for building and testing this circuit.

Notes

[1]*Radio REF*, March 1980.
[2]W. Hayward, "Competition-Grade Receiver," and D. DeMaw, "His Eminence, the Receiver," *Solid State Design for the Radio Amateur*, ARRL.
[3]Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002.

An Ash-Proof Keyer Paddle — Something New for CW Operators!

Now you can say good-bye to mechanical keyer paddles and troublesome dirty contacts. Go electronic with this weekend project!

By Roy Lewallen,* W7EL

Having experienced difficulty with mechanical switch contacts during Field Day operation on the huge pile of volcanic ash known as Mount Hood (near Portland, Oregon), and thinking about the effect of the ash from Mount St. Helens, I designed a keyer paddle that would be immune to the effects of ash. Those of you who aren't contending with ash may be pleased to know this paddle is immune to ordinary dirt, too!

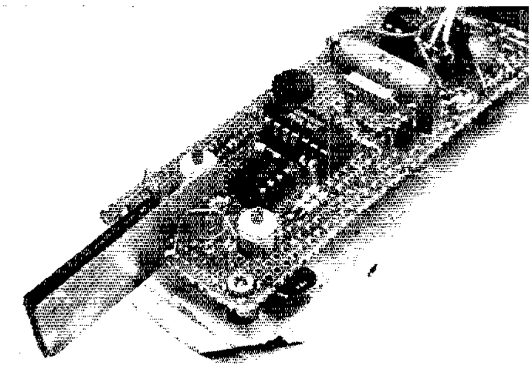
*5470 SW 152 Ave., Beaverton, OR 97007

This keyer paddle has no moving parts. It can be completely insulated and sealed, is built easily and will work with iambic keyers. But, perhaps most important, it has a feel much like a conventional paddle!

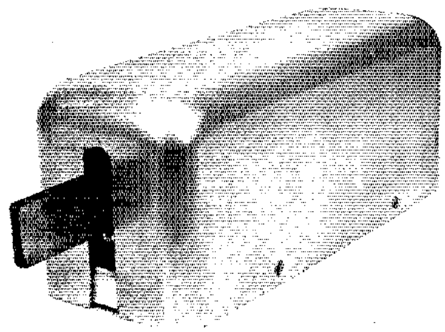
The "electronics" consist of two ICs and a pair of transistors. With a continuous current drain of only 1 mA, the paddle may be powered by a self-contained 9-volt transistor-radio battery, which will last a long time. Even if the paddle is inadvertently left on overnight, you won't find a "dead" paddle in the morning. If desired, the paddle can be powered from the keyer supply if it provides a positive potential of 5 to 15 volts.

Theory of Operation

Refer to Fig. 1. Capacitive coupling to



An inside view of the workings of the ash-proof paddle. The two cylindrical objects on either side of the paddle are trimmer capacitors C1 and C2.



No, it's not a bunker or an armed juggernaut, but the paddle safely ensconced beneath a housing that would make an armadillo jealous!

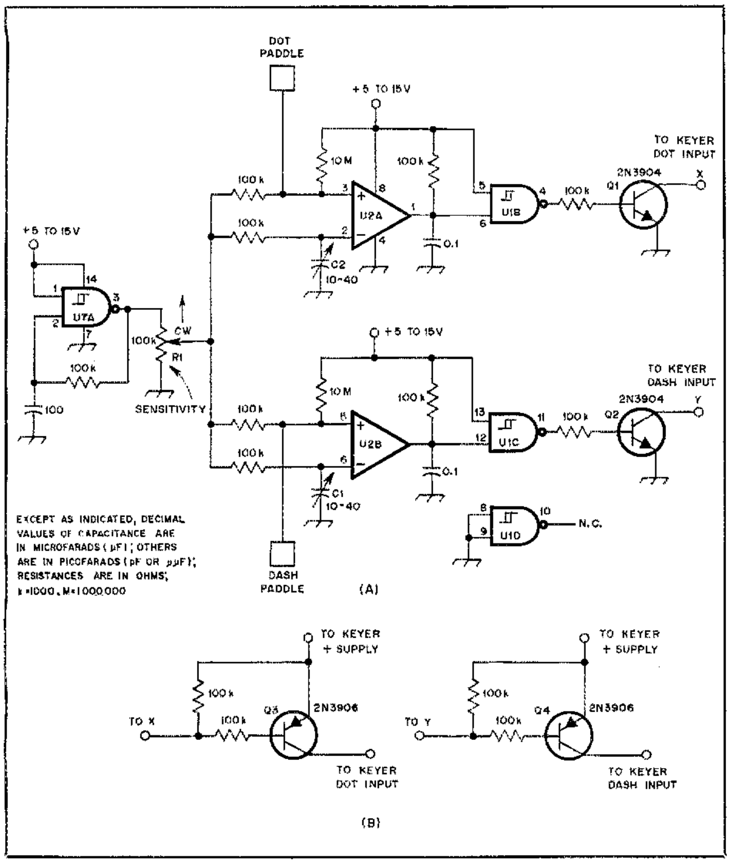


Fig. 1 — Paddle-circuit simplicity is evident at A. Q1 and Q2 are used with keyers requiring a contact closure to ground. The circuit at B may be added to points X and Y for keyers having the paddle common connected to the positive supply.

C1, C2 — 10-40 pF trimmer.
Q1, Q2 — Silicon general-purpose npn transistor, 500 mW. Radio Shack 276-2009 or equiv.
Q3, Q4 — Silicon general-purpose pnp transistor, 600 mW. Radio Shack 276-2032 or equiv.
U1 — CD4093 quad 2-input NAND Schmitt trigger, ECG4082B or equiv.
U2 — LM393 dual differential comparator. Two sections of an LM339 (ECG834) quad differential comparator may be used, but pin numbers will be different. The LM393 is an 8-pin IC and the LM339 is a 14-pin IC.

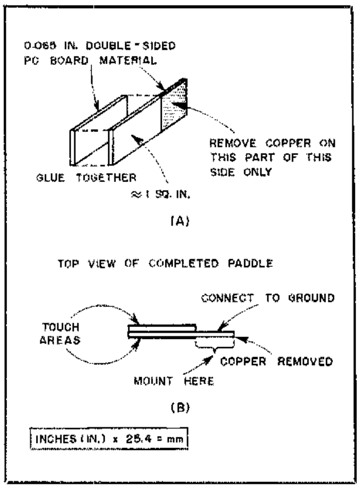


Fig. 2 — Mechanical details of the capacitive paddle. The completed assembly should be sprayed with two coats of clear lacquer.

the operator's body (grounded or ungrounded) by touching the paddle triggers the circuit. The paddle itself should be insulated, making operation independent of such variables as humidity and skin resistance.

U1A forms a simple free-running oscillator, which operates at approximately 300 kHz. Oscillator output is fed equally to both inputs of comparators U2A and U2B, with the trimmer capacitors (C1, C2) balancing out the paddle capacitance. The comparators are slightly prejudiced by the 10-MΩ pullup resistors: They stay in the high-output state when the inputs are balanced. When the paddle is touched, the inputs to the affected comparator are unbalanced, causing it to change state at a 300-kHz rate. Comparator output is filtered by the 0.1-μF capacitors and cleaned up by U1B and U1C.

Most modern keyers have a positive supply and are activated by a switch closure to ground. If yours is of this type, the circuit as shown in Fig. 1A may be used. If the center of the paddle normally connects to the positive supply, use the alternative circuit of Fig. 1B. Other situations will require appropriate ingenuity.

Construction

The mechanical portion of the paddle is constructed as a three-layered sandwich as shown in Fig. 2. Ordinary pc-board material is adequate and readily available, but other materials can be used if desired. The center layer is needed to shield the two sides from each other and is connected to ground.

Paddle sensitivity to touch is inversely related to the capacitance of the paddle assembly itself. Using ordinary 0.065-in. (1.7-mm) glass-epoxy board with each side of the paddle having an area of one square inch (645 sq. mm), sensitivity is more than adequate. Increasing the paddle area or decreasing the material thickness will reduce the available sensitivity.

U2 should be mounted close to the paddle to minimize lead lengths. Each comparator input should be laid out symmetrically to aid balance. Layout is otherwise uncritical. My paddle circuit, along with a simple keyer, is built on perforated board and mounted in a small metal box.

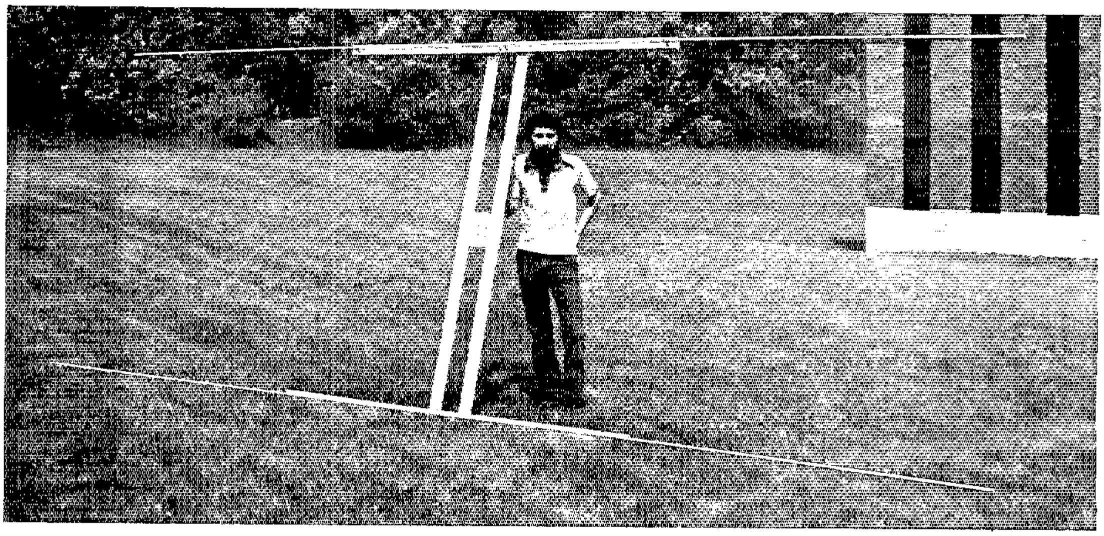
Adjustment

Advance the SENSITIVITY control (R1) until one side of the paddle operates spontaneously. Adjust the appropriate trimmer capacitor until operation stops or changes from dot to dash or vice versa. If the keyer operation is reversed, adjust the other trimmer; otherwise, increase the sensitivity. Repeat this procedure until R1 is at maximum and no spontaneous operation occurs. R1 may then be adjusted to suit your personal tastes. No readjustment of the trimmers is necessary. You may want to experiment with the SENSITIVITY control to find the setting that feels best for you.

That's all there is to it! This paddle should provide many hours of operating enjoyment. With no contacts to clean (or mechanisms to adjust), you've got a trouble-free paddle! QST

• *Basic Amateur Radio*

Simple Gain Antennas for the Beginner



You need not be a structural engineer or invest an absurd amount of money to build a beam type of antenna. Good performance can be obtained with simple antennas made from some very ordinary materials.

By Doug DeMaw,* W1FB

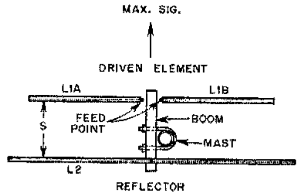
Let's refer to the antennas discussed here as inexpensive types rather than cheap ones. There's a difference! Cheap denotes inferiority, but an inexpensive antenna can be superior in performance. We will focus our attention this month on directional antennas that can provide gain. The expression "superior performance" has significance here. "Superior to what?" we might ask. Well, a gain antenna with directivity is superior to a wire antenna (Basic Radio, May 1981 *QST*, pp. 26-29) that has no gain and may exhibit mediocre directivity. What's the advantage of this superior style of antenna? The answer is, rejection of unwanted QRM off the sides and back of the antenna, plus some forward gain. The gain provides the same effect as increasing the transmitter output power, and all of us can use a few extra dB (decibels) when the going gets difficult on our favorite ham band!

*Senior Technical Editor, ARRL

Directivity and Gain

For the purpose of this discussion let's think of directivity as an antenna characteristic that permits us to concentrate the radiated signal energy in a favored direction. With a properly designed beam type of directional antenna the energy radiated off the *sides* of the antenna will be substantially lower (20 to 30 dB typically) than off the front of the antenna. Similarly, the response from the back side of the beam will be much lower than off the front, typically 10 to 20 dB. Nice way to reduce QRM (interference), eh?

The expression "gain" will refer to the effective increase in the power of the transmitted wave or signal. For example, if we had a 100-W output power from the transmitter, and increased it to 200 W, our signal would be 3 dB louder in the other station's receiver. (A 3-dB increase is just discernible to the human ear.) Now, if our *beam antenna* had a 3-dB gain characteristic, our 100-W transmitter would sound like a 200-W rig to the other station. If the gain antenna could produce a 9-dB signal enhancement (a forward gain of 9 dB or greater is not uncommon), our 100-W transmitter would be equivalent to an 800-W transmitter connected to a half-wave dipole antenna (no gain with a dipole). We can see from this that it would cost less to improve our signal strength with an antenna than to do it at the expense of a big power amplifier. From a moral point of view we would be helping to reduce consumption of precious natural fuel, and the monthly utility bill would be more acceptable! Finally, your signal might end up somewhat louder than the others (when several stations call a particular one) if you are using a gain antenna. This does not mean that the dog-eat-dog concept should be endorsed, but there is a definite advantage in being loud (or louder) in a crowded amateur band when the DX is rolling in! A stronger signal will also help you to *hold* the frequency on which you're having a QSO: Unwanted CQers won't survive long on your frequency if you have a robust signal!



$L1A + L1B = \frac{474}{f(MHz)}$ FT.

$0.3048 \times$ FT. = M

L1, L2 DIA. = 0.5-1.25 IN. (13-32 mm)

$L2 = \frac{495}{f(MHz)}$ FT.

$S = 0.15\,\lambda$ (WAVELENGTH) FT.

$\lambda = \frac{984}{f(MHz)}$ FT.

GAIN ≈ 5.4 dB

$Z \approx 25\,\Omega$

F/B RATIO ≈ 15 dB

DESIGN EXAMPLE (21.1 MHz):

$L1A + L1B = \frac{472}{21.1} = 22.37$ FT. (6.8 M)

$L2 = \frac{495}{21.1} = 23.46$ FT. (7.1 M)

$S = 0.15 \times 46.6 = 7.0$ FT. (2.1 M)

Fig. 1 — Basic design data for a 2-element hf-band Yagi antenna. (Gain figures are theoretical.)

Yagi-Uda Antennas

Perhaps the most common of the amateur gain antennas is the Yagi, which at its inception was known as the Yagi-Uda antenna, named after the Japanese inventors who developed it. Nowadays we hams refer to it simply as a "Yagi." It consists of two or more conductive elements, with the simplest type containing a driven element (radiator) that is one half wavelength long electrically, and a reflector (longer) or director (shorter). Fig. 1 shows one type of simple 2-element Yagi. In this example we find a driven element (split) and a reflector. The term "driven" means that power is fed to it. The reflector is called a "parasitic" element because it is not connected to the rf power source (transmitter). A director is also a parasitic element.

The simple antenna of Fig. 1 is easy to build and will work nicely for DXing on 20, 15 or 10 meters, depending on which band we design it for. The theoretical forward gain with the "S" spacing given will be roughly 5.4 dB. This would be equivalent to increasing the transmitter output power from 100 W to 350 W in the favored direction of the beam!

The various characteristics specified in Fig. 1 depend on the diameter of the beam elements, the spacing "S" and the height of the antenna above ground. For this discussion we will assume that the diameters of the driven element and reflector are between 0.5 and 0.75 in. (13 and 19 mm). However, wire could be used instead of tubing (if supported properly). We could also use tubing that is greater or smaller in diameter than that specified. The conductor cross-sectional area has a direct effect on the electrical length of the elements and on the *bandwidth* of the antenna. The bandwidth is generally thought of in amateur work as the frequency over which the VSWR (voltage standing-wave ratio) is 2:1 or less. The larger the antenna elements are in diameter, the lower the Q (quality factor) of the antenna, and hence the greater the bandwidth. The highest Q would be obtained when using, say, no. 16 wire as opposed to large-diameter tubing. Whatever conductor we may choose to use for the beam elements can be employed satisfactorily. Some experimenting may be necessary, however, to get maximum performance. This can be done by observing a field-strength meter (see "measurements" chapter of the *Handbook*) and adjusting spacing "S" and the element lengths for maximum forward gain from the beam. The dimensions given in Fig. 1 will yield good performance without any adjustments.

Beam Radiation Patterns

All directional antennas exhibit a specific radiation pattern. The approximate pattern for the 2-element Yagi of Fig. 1 when mounted for horizontal polarization is shown in Fig. 2. There are two *significant* lobes. The larger one at the left is in the favored direction of the beam. The rear lobe is shown at the right in Fig. 2. It is much lower in magnitude, which gives us what is known as a *front-to-back ratio*, expressed in decibels. A typical theoretical ratio for a 2-element Yagi that uses a driven element and a reflector is 15 to 16 dB. The spacing "S" (Fig. 1) has a marked effect on the front-to-back ratio.[1] We can envision the pattern shown in Fig. 2 as one we would see if we were directly above the antenna, looking toward ground. We are assuming also that our eyes could see the rf (radio frequency) energy as it was radiated from the antenna.

Very deep nulls are observed directly off the sides of the beam antenna, as indicated in Fig. 2. This gives us what is known as the front-to-side ratio of the beam, based on field-strength measurements that are taken in decibels. It can be seen that maximum rejection takes place off the sides of the antenna, but that approximately 15 dB of rejection is also available off the rear of the antenna. These ratio characteristics aid us in rejecting QRM from all directions other than the favored one. Therefore, a beam that had no gain, or even had a loss, would be useful if it had a front-to-back and front-to-side ratio.

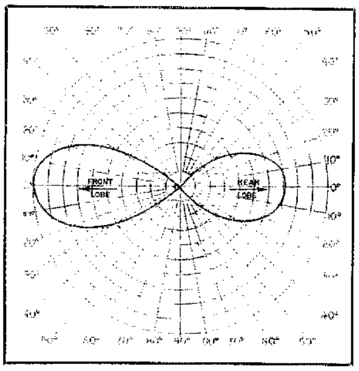


Fig. 2 — Directivity characteristics of a horizontally polarized 2-element Yagi antenna. The major (front) lobe is at the left.

Another important radiation characteristic is depicted in Fig. 3. This is known as the *radiation angle*. We are concerned here with the angle at which the lobe leaves the antenna, respective to ground. Since we are bouncing our signal off the ionosphere in an oblique manner to work distant DX, the lower the radiation angle, the greater the distance we can work. This phenomenon is known as "skip." The vertical pattern in Fig. 3 is that of a 2-element Yagi of the type shown in Fig. 1. The height above ground is 1.25 wavelengths. The radiation angle of the main lobe is 12° for the height specified. The rear lobe is approximately the same in degrees. We can also see two *minor* (higher) lobes in Fig. 3. These are useful for working DX that is closer in, depending upon band conditions (propagation) at a given time of the day. These smaller

[1]Notes appear on page 35.

lobes have radiation angles that are between 30° and 40°.

Impedance Matching

The feed point of any antenna has a characteristic *radiation resistance* in ohms. This is referred to commonly as the feed-point impedance. To have maximum transfer of power from the feed line to the driven element we must have a *matched condition*. That is, if the feed point is 50 Ω, we should use a feed line that has a 50-Ω characteristic impedance. If the antenna feed impedance is nonstandard with respect to available types of feed lines, then we must include some type of matching network or device between the antenna feed point and the feed line. This can be done in a number of ways.

Various matching systems for Yagi antennas are described in detail in *The ARRL Antenna Book*. The reader is referred to that publication for tutorial guidance. But, for our immediate interest, we will consider a simple technique that will give us a reasonably close match between 75-Ω coaxial feed line and the antenna of Fig. 1. With the dimensions specified in the diagram we will have an antenna feed impedance of roughly 25 Ω. An easy way to obtain the required 2:1 transformation ratio is to insert a *quarter-wavelength transformer*. If we insert a quarter wavelength of 50-Ω cable between the feed point and a 75-Ω feed line, the system will be closely matched, and the system VSWR will be close to 1:1 (optimum).

Our matching transformer will be cut to a length dictated by the velocity or propagation factor of the cable we use for the transformer. Sections of transmission line that are cut for a particular wavelength dimension will always be shorter than a free-space length for the same frequency. This is because the insulating material in the feed line has a pronounced effect on the electrical length of the line. The matching transformer in Fig. 4 must be 7.69 ft (2.34 m) long for 21.1 MHz (Fig. 1), whereas the free-space dimension for one quarter wavelength would be 11.65 ft (3.55 m). This is because the velocity factor of RG-8/U cable is 0.66. Hence, 0.66 × 11.65 = 7.69 ft, or 7 ft, 8-1/4 in. The 75-Ω line (RG-11/U or RG-59/U) can be any convenient length. RG-58/U can also be used for the matching transformer. The larger coax cables will be best for reduced feed-line losses and high-power operation. The required impedance of the cable used in the matching transformer is determined by:

$$Z_o = \sqrt{Z_r Z_s}$$

where

Z_o = impedance of the cable used in the transformer.

Z_r = antenna feed-point impedance.

Z_s = characteristic impedance of the feed line.

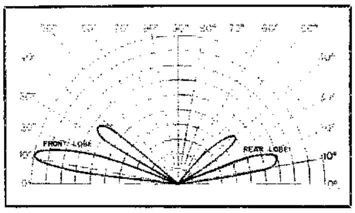


Fig. 3 — Major and minor lobes of a 2-element Yagi showing the radiation angles of the lobes (see text).

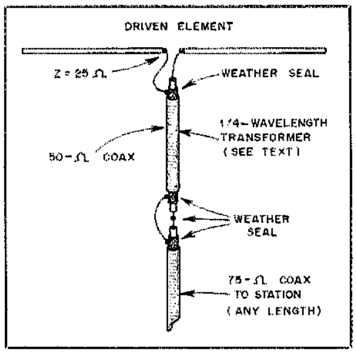


Fig. 4 — Method for using a quarter-wavelength matching transformer between the antenna feed point and the transmission line. The illustration shows how to effect a close match between a 25-Ω antenna and a 75-Ω feed line.

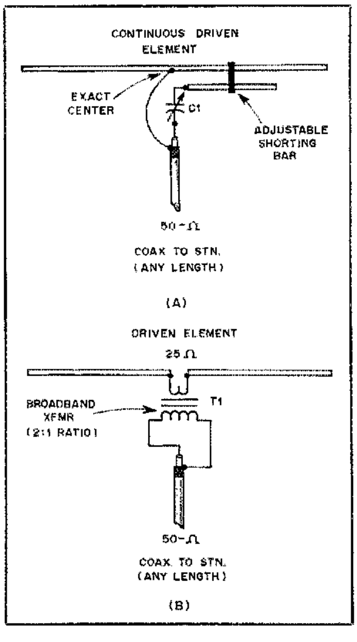


Fig. 5 — A gamma match is shown at A for use with a continuous length of conductor as the driven element. T1 at B is a broadband toroidal transformer that can be used to match 25 Ω to 50 Ω in this example. A split driven element (dipole) is used at B.

From this we find that the calculated impedance of the transformer coax cable is 43.3 Ω, using 25 Ω for Z_r and 75 Ω for Z_s. This will be close enough to the desired 50 Ω to provide a low VSWR. The VSWR can be calculated simply by:

$$VSWR = Z_0/R$$

where

Z_0 = impedance of cable used for the transformer.

R = desired impedance of the cable (43.3 Ω).

This yields a VSWR of 1.15:1 on the line, which is entirely acceptable. If we connected a 50-Ω feed line directly to the 25-Ω feed point of the antenna we would have a VSWR of 2:1 as a best-case condition. Although we would probably work plenty of DX with a VSWR this high or slightly higher, we would lose even more transmitter power in the feed line. Furthermore, if our solid-state transmitter contained an SWR protective circuit, the output power would be reduced automatically by that circuit.

Other Matching Schemes

If the driven element in Fig. 1 were not split (continuous length of tubing or wire) we could employ a *gamma match* of the kind shown in Fig. 5A. Its length and the setting of C1 would be adjusted to provide a VSWR of 1:1. Simple formulas for calculating the dimensions of a gamma match are given in *The ARRL Antenna Book*. An alternative matching method is shown at B of Fig. 5. This involves the use of a toroidal broadband 2:1 matching transformer. Recent editions of *The ARRL Radio Amateur's Handbook* contain practical information on broadband-transformer design.

The matching technique illustrated in Fig. 4 requires the use of 75-Ω line to the ham shack. This means that a 50-Ω VSWR indicator will not yield accurate readings, since the line impedance is not right for the VSWR instrument. Transmitters with tubes and a pi network in the final-amplifier section will work fine into 75-Ω line. If the rig has a solid-state final amplifier designed for a 50-Ω load, there will be a slight power loss caused by the SWR-shutdown circuit. This is because when the 75-Ω cable is connected to the 50-Ω termination provided by the transmitter, a VSWR of 1.5:1 will be present. Chapter 19 of the 1981 *Handbook* contains data on building a simple 75-50 Ω broadband transformer that can be used between the VSWR indicator/transmitter and the 75-Ω line to correct the 1.5:1 mismatch condition. It can be used to solve the aforementioned problem.

Adding Yagi Elements

Although our intent in this article is to highlight the simple 2-element Yagi, we should mention the more popular 3-element version of this antenna. What will an additional parasitic element do for us? Basically, it will improve the front-to-back ratio and increase the forward gain. A beam pattern for a 3-element Yagi (director, driven element and reflector) is shown in Fig. 6. We can see that the back lobe is substantially smaller than that of the 2-element Yagi of Fig. 2. Also, the gain has increased to approximately 7.2 dB over a dipole. This would be like increasing our 100-W transmitter output power to 525 W, but without the aid of an amplifier.

With the antenna represented in Fig. 6 we would use a director-to-driven-element spacing of 0.1 wavelength. The height above ground for the pattern shown would be 0.5 wavelength. The beamwidth remains about the same as when using a 2-element Yagi. At a height of 0.5 wavelength the radiation angle is fairly high — about 28°, but by increasing the antenna height to 1 wavelength it becomes

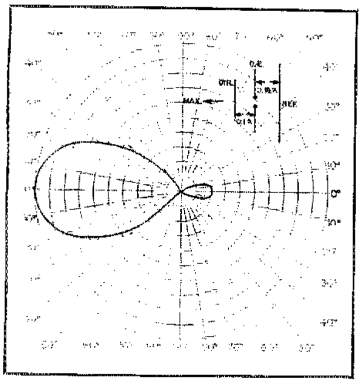


Fig. 6 — Radiation pattern for a 3-element Yagi. Note how much smaller the rear lobe is than that of the 2-element Yagi (Fig. 2). Also, the 3-element beam has greater forward gain than the 2-element one.

12°, as is the case with the 2-element Yagi of Fig. 1. This illustrates the importance of antenna height versus DX capability. The spacing between the elements determines the feed-point impedance. With the antenna arranged for maximum gain we will find the feed impedance quite low — on the order of 10 Ω. By trading gain for element spacing we can raise the feed impedance considerably. But, it is better to adjust the Yagi for maximum gain and to use a matching system at the feed point. A gamma match is recommended for use with the 3-element Yagi. The driven element would then be a continuous length of tubing (Fig. 5A).

Simple 2-Element Yagi

A 2-element Yagi is easy to build and to erect. It is probably the best starting point for that first directional gain antenna. A number of construction methods are available to the builder. For example, one can obtain bamboo fishing poles, put a continuous wrapping of aluminum foil on the bamboo and use these poles as Yagi elements. This was described years ago in amateur literature as a "Catfish Beam." The aluminum foil can be taped firmly at intervals to affix it to the bamboo poles. The foil would of course have to be opened at the center of the driven element. Homemade aluminum clamps can be attached at the feed point (around the foil and poles) to provide a connection to the coax cable. Each clamp would be equipped with a screw, nut and solder lug for this purpose.

Aluminum tubing is expensive and sometimes hard to find. If you don't have a supply of it available, you can use thin-wall steel electrical conduit (aluminum conduit is also manufactured) for the Yagi elements. Of course this material will make the antenna much heavier than an aluminum version, and rust will form on the elements eventually. A coating of spar varnish or polyurethane lacquer can be applied to inhibit oxidation and rusting.

Fig. 7 illustrates a wooden frame we could build to serve as a foundation for tubing or wire Yagi antennas. Wooden elements "C" need not be nearly as long (about 0.33×) as the antenna tubing. They can be varnished to prevent deterioration from the weather. The hardware for holding the sections of the frame together can be 1/4-in./20 bolts. Items "B" are ceramic standoff cones. Other types of insulators can be used, such as plastic blocks. The insulating material must be strong enough to sustain the stress imposed by the driven element and director. A 1-in. (25.4-mm) pipe flange can be attached to plate "A" to allow the builder to employ 1-in. diameter water pipe as a mast.

Wire antenna elements can be used for the Yagi if wooden members "C" are as long as the wire elements. The weight of the antenna would be somewhat excessive if this were done, and could prove impractical for operation on 20 or 15 meters. At 10 meters and higher it should be an acceptable technique. For vhf Yagis we could use a single 2 × 2-in. (51 × 51-mm) section of wood as a boom, with 1/4-in. (6.3-mm) diameter tubing for the elements. Yagis with good performance on 144 MHz have been built in this manner by using coat-hanger wire for the antenna elements.[2] An 8- or 10-element 2-meter Yagi can be built inexpensively in this fashion.

Some Final Comments

Certainly there are other types of gain antennas we could have described in this article, but space doesn't permit such an in-depth treatment of the general subject. The intention was to present some fundamentals of gain-antenna design and performance.

Those who don't want to build a rotatable Yagi of the type shown in Fig. 7 may choose to construct a 2- or 3-element stationary Yagi from wire. It could be oriented toward Europe, Japan or some other favored direction. Antennas of this type have been used successfully on 160, 80 and 40 meters for many years. There is no reason why they wouldn't work nicely on 20, 15 or 10 meters as well.

The important consideration is to erect whatever type of Yagi we build as high above ground as possible, and well away from nearby conductive objects. An attempt should be made to match the antenna to its feed line to minimize losses and obtain a low VSWR. The DX awaits you, so perhaps now is the time to build your first Yagi!

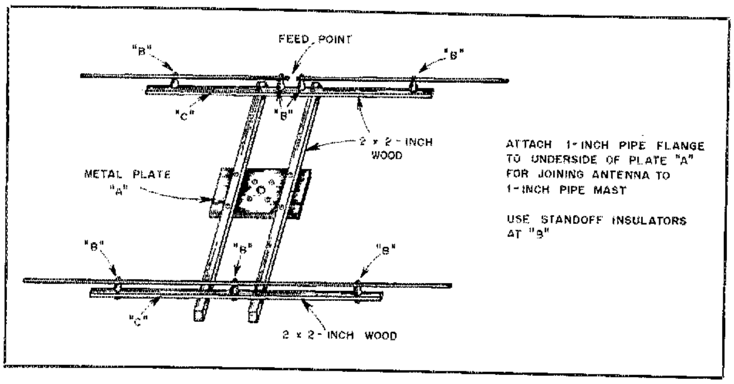


Fig. 7 — Details for building a wooden frame on which to assemble a 2-element Yagi. Readily available, inexpensive materials are specified. Some innovation will improve this design and perhaps reduce the cost. The cone insulators, B, can be replaced by blocks of plastic or phenolic material. Inches × 25.4 = mm.

Notes

[1]See *The ARRL Antenna Book*, chapter 4, 13th edition, for in-depth data on Yagi-antenna element spacing and conductor size.

[2]L. McCoy, W1ICP, "A Five-Element Two-Meter Beam for $1.50," *QST*, Oct. 1962, p. 17.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

TWO-TONE GENERATOR FOR SSB TESTING

☐ A two-tone signal is well suited for quick visual tests of transmitter performance and IMD measurements. The circuit (Fig. 1) combines low parts cost with low distortion (typically 0.2%, which is adequate for our commercial ssb equipment). The output is 0 to 1 V peak to peak, for a 600-Ω load.

The frequency of the Wein bridge oscillator is determined by R1, R2, C1 and C2. Although 1% values are shown, 5% components may be used if the frequency tolerance is not too critical. A Trimpot, R5, serves as a tuning adjustment to compensate for component variations in the oscillator and filter. Other components in the circuit are not critical. A single-tone generator may be built by eliminating the balance control (U2) and associated components.

This generator is made using printed-circuit-board construction. It should be enclosed in a shielded case. The LC networks for the power and output leads are recommended to prevent feedback when high rf fields are present. Often the operating voltage can be obtained from the equipment under test. A battery may be installed in order to make a self-contained unit.

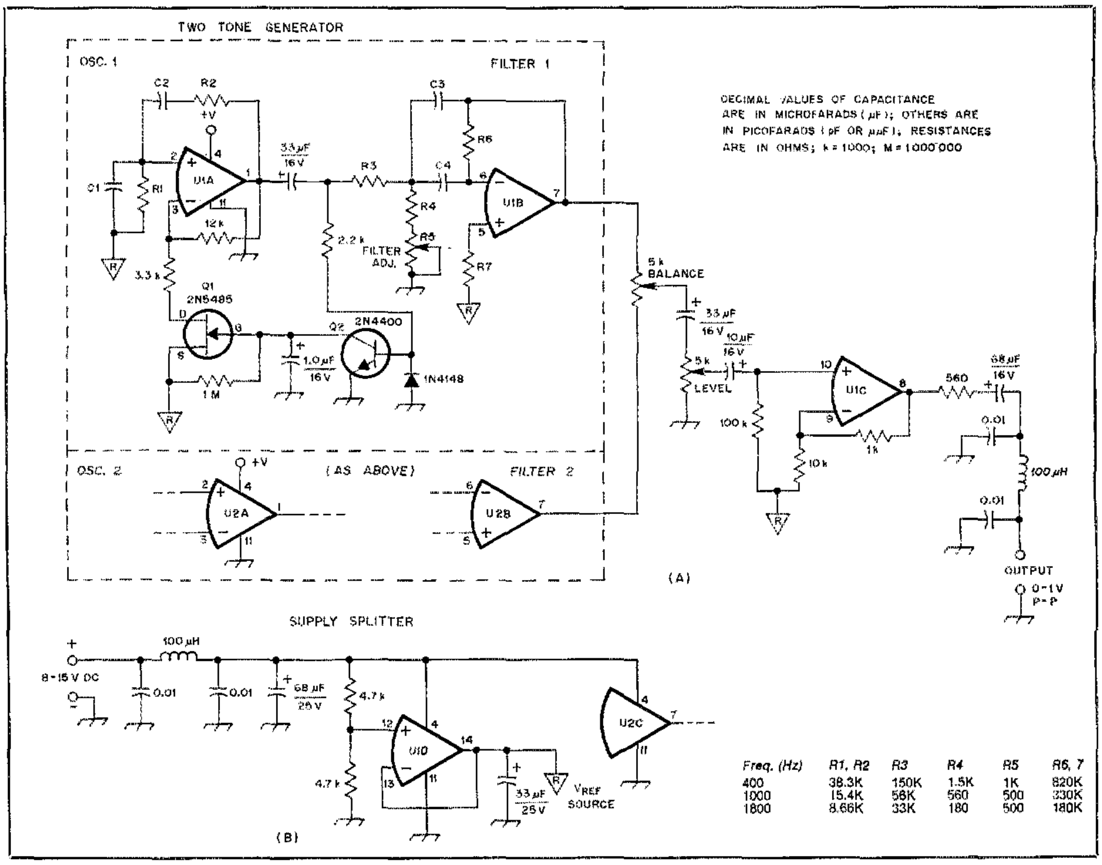
Alignment consists of setting R5 for maximum output of the respective tone. Balance and level controls are adjusted as required. — *Thomas Bavis, Test Engineer, Scientific Radio Systems, Rochester, New York*

A MONITOR FOR COMPUTER-OPERATED RTTY

☐ *Being able to monitor the outgoing signal for proper cw i-d is a convenience for the* RTTY operator working with a computer. Although a second receiver (with the antenna disconnected) could serve the purpose, I took a hint from Tony Toulis, KI4X, and decided to mount a small monitor circuit inside my Crown ROM-116 RTTY/CW Operating System. He obtained the idea from another amateur.

My monitor is the result of the basic plan Tony showed me when I visited his shack. Added to this is the technical assistance of Jim Sladek, WB4UBD. The circuit (Fig. 2) consists of a standard NE555 oscillator mounted on a small, ready-made circuit board obtained from Radio Shack. Since there is ample room inside the ROM-116 cabinet, location of the monitor can be a builder's choice. A tiny speaker, driven by the NE555, can be mounted on the inside back wall of the ROM-116 enclosure: I placed mine over an empty slot, conveniently left there by the manufacturer. An ON-OFF

*Assistant Technical Editor



Freq. (Hz)	R1, R2	R3	R4	R5	R6, 7
400	38.3K	150K	1.5K	1K	820K
1000	15.4K	56K	560	500	330K
1800	8.66K	33K	180	500	180K

Fig. 1 — A two-tone signal generator for quick visual checks of transmitter performance and IMD measurements. Part B of the drawing shows how the supply voltage is split and includes additional filtering. Resistance values are in ohms and are 1/4 watt. More-precise indications can be obtained with 1% resistances, but 5% resistors are satisfactory. U1 and U2 are LM348 or MC4741 ICs. C1-C4 are 0.01 μF and may be either 1% or 2% (Mylar or P.C.). A frequency/resistance chart is included with the drawing.

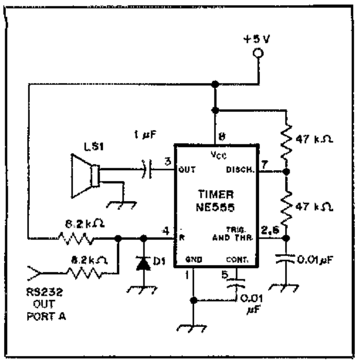


Fig. 2 — This simple circuit, built around an NE555 timer, may be added to an ROM-116 for monitoring the output.

switch for the speaker can be placed on the front panel. The operating voltage (+5 V) may be taken from the ROM-116. Input signals come from the RS-232 terminal point Port A, not the DB-25 connector. The extra LED on the front panel, used for cw, flashes as the RTTY signal is transmitted, as described on page 45 of the operating manual. — *Gay E. Milius, W4UG, Virginia Beach, Virginia*

DIRECT-CONVERSION RECEIVER HUM

☐ Ac supply hum in direct-conversion receivers is not uncommon. Wes Hayward described it as local-oscillator energy mixing with 60-Hz energy in the power-supply diodes, and reradiating at the local-oscillator frequency with mixer products.[1] He suggests a bifilar choke in the power supply leads to the direct conversion receiver. Lack of a suitable ferrite toroid in the junk box prevented me from trying this solution.

Douglas Kohl suggests for a receiver very sensitive to noise[2] that bypassing the power-supply diodes is necessary to eliminate noise from this source. He uses a 0.1-µF capacitor placed directly across each diode.

Each of the three power supplies in my shack produced a similar hum problem. Bypassing the rectifier diodes with 0.01µF capacitors cured the problem in each case.

My direct-conversion receiver is an 80-meter version of the W7EL transceiver. I also found that I had to bypass the diodes in the power supply of a K1LBH keyboard connected to this unit. — *Joel R. Anderson, N1JA, Old Saybrook, Connecticut*

GO TO MARS ON THE ICOM IC-2A

☐ The new ICOM IC-2A, in my opinion, is one of the best 2-meter, hand-held-transceiver buys on the market today. An investment of 15 minutes of your time can provide an extra bonus for the 2A, an advantage especially for MARS members.

As designed, the ICOM IC-2A is limited to the regular amateur band (144 to 148 MHz) even though the thumbwheel switch may lead you to believe otherwise. This limitation, provided by the manufacturer, is accomplished by strapping the binary 4 output on the thumbwheel switch to V_{cc} and by opening the binary 8 output to the PLL chip of the same section.

To modify the set, begin by removing the battery pack, exposing the metal battery mounting clip at the bottom of the unit. Take the clip off by unscrewing the four outer screws. The back cover is removed by unscrewing the two recessed smaller screws along the outer edges. Pull the cover down and away from the radio. Next, pull the front cover down and slightly away from the frame. Be careful not to strain the connecting wires going to the front. See Fig. 3.

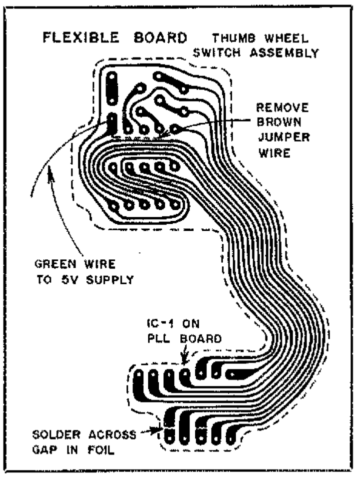


Fig. 3 — This foil-side view of the IC-2A transceiver circuit board shows the location of the few simple changes that enable the 2A to operate on the MARS frequencies. It takes about 15 minutes to make the modification according to Larry Waggoner, WØKA, who provides the details in the accompanying text.

Closely observe how the black push-to-talk lever fits into the case parts. You will need to remember the arrangement when you reassemble the radio. The next step is to look into the front side of the frame at the area just below the thumbwheel switches. Find a brown wire jumper connected between two sets of switch contacts. Carefully clip this from the circuit. *Do not disturb* the green wire that shares a common contact with the brown jumper. It may be easier for you to reach the lower contact by removing the two screws on the side of the frame. The two pc boards may now be spread apart by opening them like a book. Your IC-2A is ready to operate below 144 MHz.

Now, turn the radio over to the back or PL side. You will see a flexible circuit board that goes to an integrated circuit in the lower-middle, left-hand side. Solder across a gap in the foil on the bottom set of contacts. This contact is at the lower center of the chip and is the fifth, or last, away from the frame. The radio will now perform above 148 MHz.

As you reassemble the radio, insert the push-to-talk lever halfway into the front case. Slide the top edge of both the front and back case into the frame and bring the bottom together. Make sure both case parts fit tightly together against the radio top. Your IC-2A will now operate from about 141.50 MHz to 149.995 MHz. My unit, with 2-W output at 146 MHz, still puts out over 1 W at both frequency extremes. The receiver sensitivity holds almost constant throughout the range.

Offering a transmitter offset for the MARS repeaters is beyond the scope of this easy conversion. Working into repeaters on simplex with some fast thumbwheel switch work is possible. I use my IC-2A to listen to MARS activity while I am away from the big rig. I find this MARS conversion is well worth the time spent. — *Larry Waggoner, AFB3FP/WØKA, Wichita, Kansas*

FASTER AGC ACTION FOR THE DELTA 580

☐ The new Ten-Tec Delta 580 has a very slow "hang" agc circuit that works well on ssb. On cw, however, no provision has been made to disable the agc. As a result, when receiving strong cw signals, the initial character received is uncomfortably loud before the agc can take hold. The agc decay time is also very slow. Consequently, in net QSK operation where weak and strong stations are mixed, the agc holds down the weaker stations.

My solution to the problem is simple. Install a miniature toggle switch through the rear of the set. Connect a small 5000-Ω potentiometer in series with the switch, with one end of the potentiometer wired to chassis ground. This combination is then in parallel with the 3.9-MΩ agc resistor (R12) on the detector/agc board. The potentiometer can be adjusted to prevent overloading on strong signals. This arrangement will provide very fast, but reduced, agc action for excellent cw reception without the initial blast from strong signals. See Fig. 4. By opening the switch, you have the original operation on ssb. — *Ced Justis, W3QQ, Newport, Delaware*

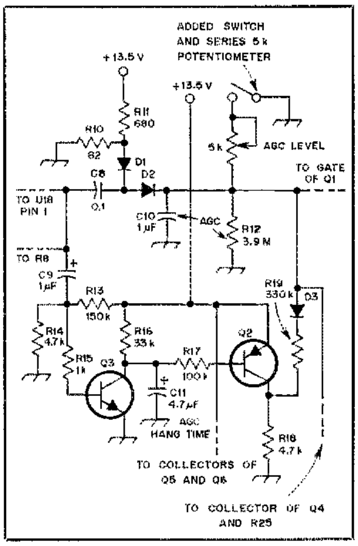


Fig. 4 — By adding a small toggle switch and a 5000-Ω potentiometer to the Ten-Tec Delta 580, the "hang" time can be shortened for better cw operation. Resistance values are in ohms. Component designations, except for the modification, are those of the manufacturer.

[1] W. Hayward, "Common Mode Hum in Direct-Conversion Receivers," QST, July 1977, p. 51.
[2] D. Kohl, "The Amateur Scientist," *Scientific American*, Sept. 1980, p. 232.

Product Review

Conducted By Paul K. Pagel,* N1FB

Yaesu FRG-7700 Communications Receiver

The general-coverage communications receiver has always been a welcome addition to the ham shack. Depending on your operating habits and interests, such an addition might be looked on as a luxury or necessity. Though many of the older receivers are still performing "yeoman service" today, you might admit they are large, power-hogging heavyweights with faces only a radio enthusiast could love. In contrast, today's general-coverage receiver is compact, lightweight and perhaps attractive enough to occupy a place in the family living room. The Yaesu FRG-7700 fits the latter description.

General Description

Yaesu's '7700 is an ac-operated, dual-conversion, PLL frequency-synthesized receiver, that permits reception over the range of 150 kHz to 30 MHz in thirty 1-MHz bands. Ten 1-MHz bands on one sector of the BAND switch are assigned specifically for coverage of the hf amateur frequencies, while another sector of the switch has all 30 positions. This feature eliminates needless stepping of the BAND switch should the operator be interested in listening only to the amateur frequencies at a given time.

The optional 12-channel memory unit (MU-7700) was supplied with the review unit. This option easily and quickly installs on the rear panel of the receiver; it is a useful accessory. Particular frequencies on any band of operation may be stored and recalled by the push of a button without the need to index the BAND switch no matter what the frequency difference is between that to which the receiver is tuned and the memorized frequency. A ±1 kHz FINE tuning control permits the memorized frequency to be "rubbered." Unfortunately, no fine tuning or BFO control exists for VFO operation. A readily accessible three-cell battery clip (batteries not supplied) provides memory-unit backup when the receiver power is turned off or disconnected from the line.

Controls and Features

Front panel layout is attractive and the controls are well placed. Two pairs of concentric controls exist: AF GAIN/TONE and MEMORY FINE/SQUELCH. Square and rectangular brushed aluminum push buttons are used for many other functions.

A 12-hour clock with A.M. and P.M. indicators and a 59-minute sleep timer is built in. The clock may be programmed and set from the front panel push-button switches and used to turn the '7700 on and off. The FUNCTION switch determines whether the digital readout displays the received frequency or one of the several clock functions. A DIM push button reduces the illumination of the S meter and both the analog and digital dials. Beneath the front-panel-mounted speaker and adjacent to the POWER switch are a 1/4-inch (6.4-mm) PHONES jack and a miniature RECORD jack (used

*Assistant Technical Editor

Yaesu FRG-7700 Communications Receiver Serial No. OMO314224

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: 150 kHz-30 MHz.	As specified plus 50-kHz overlap at high and low band edges.
Modes of reception: A-m, ssb, cw, fm.	As specified.
Frequency readout: Analog and digital; 5-digit, orange LED digital display.	0.3-in. (8-mm) digits.
Resolution: Analog, 10 kHz; digital, 1 kHz.	As specified.
KHz/turn of knob: Not specified.	38
Backlash: Not specified.	Nil
RIT range: ±1 kHz with optional memory unit.	As specified.
Attenuators: Rear panel, switchable 20 dB; front panel, continuously variable.	Rear panel, 26 dB; front panel, as specified.
S-meter sensitivity (μV/S9): Not specified.	2000 m, 1500; 160 m, 660; 80 m, 24; 40 m, 27; 30 m, 37; 20 m, 40; 17 m, 49; 15 m 66; 12 m, 66; 12 m, 68; 11 m 80; 10 m 100.
DB/S unit: Not specified.	Variable from 1 to 6 dB from S1 to S9; each 20-dB step above S9 measured 10 dB.
Receiver sensitivity (μV/50Ω), 2-30 MHz: A-m, 5; ssb/cw, 0.5; fm, 1.	Receiver dynamics measured with 2.7-kHz ssb/cw filter. No narrow bandwidth cw filter available.

	80 M	*20 M*
Noise floor (MDS) dBm:	−126	−114
Blocking DR (dB):	noise limited	noise limited
Two-tone 3rd order IMD DR (dB):	75	82
Third-order input intercept (dB):	−13.5	9

Audio power output (8-ohm load): 1.5 W.	1.1 W.
Frequency stability: < ±1 kHz from 1-30 min. after power applied; < ±300 Hz after 30 min. warm-up.	600 Hz from a cold start to one hour later.

Power requirements: 100/120/220/240 V ac, 50/60 Hz, 39 VA with memory unit.
Size (HWD): 5 × 13 × 8.9 inches (129 × 334 × 225 mm).
Weight: 13.2 lb (6 kg).
Color: Gold-brown.

for tape recording received stations). The output level of the RECord jack is fixed and unaffected by the position of the AF GAIN control.

The rear panel supports a 3-prong male ac socket (the line cord is detachable), ac operating voltage selection switch, fuse holder and EXTernal SPeaker jack (miniature type). Two phono jacks provide access to a set of internal relay contacts. An SO-239 coaxial antenna connector; the fixed, switchable ATTenuator (also labeled DX/LOCAL); a 5-pin DIN jack for ACCessory connections (two for antenna attachment, one for a ground wire and another connected to the receiver muting line) are also on the rear deck.

Circuit Description

Incoming signals are either routed around or through the fixed, switchable front-end attenuator. It then passes through an L-C low-pass filter and through one of six diode-switched band-pass filters before reaching the rf amplifier. Up-conversion to 48 MHz takes place in the first mixer. The signal is then passed to the first i-f crystal filter, which has a 20-kHz bandwidth. The signal proceeds to the second mixer for conversion to the second i-f of 455 kHz. A 20-kHz-wide ceramic i-f filter, noise blanker circuitry and switch-selected ceramic filters for the different modes are next in line. A-m selectivity positions of 12, 6 and 2.7 kHz are provided with 2.7 kHz being used for ssb and cw reception. For fm signals, a 15-kHz-wide filter is used. The signal is then demodulated, amplified and passed on to the audio chain.

Operational Comments

While the 38-kHz-per-turn tuning rate of the VFO is somewhat rapid, it is manageable. I found the analog dial to be somewhat superfluous with its 10-kHz increments, and noted the skirt could easily be knocked out of calibration by a hasty hand on the tuning knob. The addition of a BFO or fine-tuning control would be an asset. Since the BFO frequency is not counted in the mixing scheme, a frequency readout error of 1 kHz on usb and 2 kHz on lsb (as read from the display) exists when zero beating a particular frequency.

A number of "birdies" were noted, primarily on 10 meters. Most of them were weak, and none was strong enough to cause deflection of the S meter. I also heard quite a few weak RTTY "signals" (images), which appeared to populate the 10- and 12-meter bands during operation from a suburban location. A trap tribander and 40-meter, half-wave sloping dipole were used for antennas.

The agc time constant may be switched between FAST and SLOW, but no OFF position is provided. Some agc popping occurs, but I did not find it to be annoying. Noise-blanker action appeared to be ineffective against most types of noise encountered.

Overall mechanical and electrical stability is very good. There's lots of audio power available, and the quality of the recovered audio while using the built-in speaker did not leave me wanting. It's too bad the manufacturers of general-coverage receivers haven't recognized the desire many prospective buyers have for owning a receiver that has a 24-hour clock instead of the 12-hour types being supplied presently.

A capacitively coupled antenna input circuit is used. Thus, there is no dc discharge path to ground for antenna static build up.

The fm reception capabilities of the '7700 should be an attraction to many who might like to copy the ever-growing number of fm stations on 10 meters. Also, by placing a converter ahead of the '7700, you can extend your listening range into the vhf spectrum. The SQUELCH control operates only in the fm mode.

The rear panel has a rectangular plug fitted over a hole, above which a DC label appears. Though the manual makes no mention of this and the plug and label cannot be seen in the rear-panel photograph, a 12-V dc option is available from Yaesu. Many prospective purchasers, I'm sure, will want to add this low-cost feature. The unit certainly is designed for going places, with the built-in carrying handle and feet mounted on opposite ends of the cabinet.

I'm sure a number of amateurs and SWLers will be adding the FRG-7700 to their "desirables" list. The FRG-7700 is manufactured by the Yaesu Electronics Corp., 6851 Walthall Way, Paramount, CA 90723. Price class: $550; dc kit, $6; MU-7700, $150. — *Paul K. Pagel, N1FB*

THE RADIO SHACK DX-302

☐ This synthesized, triple-conversion, general-coverage receiver is designed to receive cw, a-m and ssb signals at frequencies from 10 kHz to 30 MHz. The '302 will operate from 117-volt house current or from a 12-volt supply. An external 12-volt supply may be used or eight C-size batteries may be installed internally. Should the ac power fail, the internal battery supply will be switched in automatically.

Front panel controls include: PRESELECTOR BAND, PRESELECTOR TUNE, BFO PITCH, RF GAIN, VOLUME, MODE, WIDE/NARROW SELECTIVITY, 0-20-40 dB ATTENUATOR, LIGHT/BATTERY TEST and MAIN TUNING. A PRESELECTOR tuning dial, signal strength and battery meter, phones jack and five-digit frequency display complete the layout. At the rear of the receiver is the access door for the battery compartment, an EXTERNAL SPEAKER jack, a TAPE OUT jack for interconnection with a tape recorder, and a KEY jack. With the proper control setting, the receiver may be used as a Morse code practice oscillator! An SO-239 connector is provided for use with antennas exhibiting a 50- to 75-ohm impedance. A terminal strip is used for mute, ground and single-wire antenna connections. The ac line cord, fuse holder and 12-volt external dc supply jack are also mounted on the rear panel.

[1]"Kenwood R-1000 General Coverage Receiver," Product Review, *QST*, Dec. 1980, pp. 46-47.

Frequency Selection and Display

Tuning in a station with the '302 is different from most receivers — except for its predecessor, the DX-300. The PRESELECTOR BAND switch is first to set to the band of interest. Then, the PRESELECTOR TUNE is adjusted to the approximate frequency of the desired signal (it never gave a very definite peak). Next, the main tuning control comes into play. It consists of two concentric knobs, an outer MHZ knob and an inner KHZ knob. By means of the outer knob, the synthesizer is incremented in 1-MHz steps, and the inner knob tunes the receiver within the 1-MHz block you have chosen. The tuning rate of the inner knob is approximately 65 kHz per revolution. The outer knob does not have a positive detent, and the adjustment is critical. Sometimes the proper position was found at a point just on the edge of synthesizer lock.

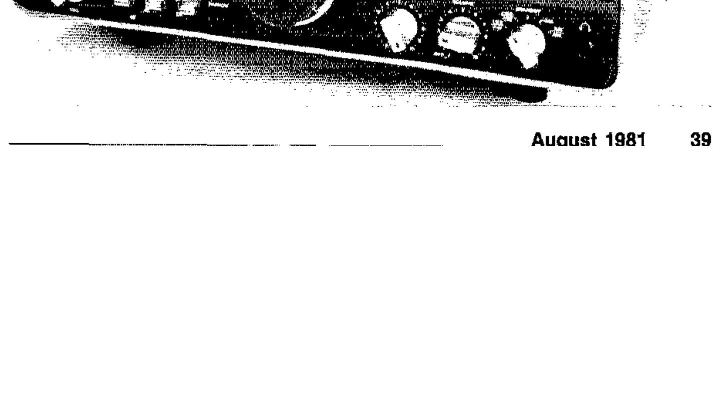
The BFO is not accounted for in the frequency-mixing scheme. When it is used, the displayed frequency differs from the actual received frequency by 2 kHz. Therefore, when receiving lsb signals, 2 kHz must be added to the displayed frequency and subtracted when receiving usb signals.

Operational Notes

The nonswitchable agc time constant is fast, but "comfortable." Received audio was found to be somewhat unpleasant because of distortion, but not unduly so. The '302 overloads in the presence of strong signals. While using the receiver coupled to a 5-foot (1.5-m) long indoor antenna (five blocks away from W1AW), the station made its presence known even when it was not tuned in. On the 10-meter band, W1AW was heard as far as 200 kHz away from its actual operating frequency. Interestingly enough, the tuned-in signal registered only 25 dB over S9, which indicated the meter to be somewhat unresponsive.

Receiver "birdies" were found throughout the range of the '302. Usually a "birdie" could be eliminated by careful tweaking of the MHZ knob. Two exceptions worth noting occurred at 910 and 1000 kHz. The instruction manual mentions these responses and states that they are normal because of the Wadley Loop synthesizer circuit used in the receiver.

Use of the high-impedance antenna input is recommended by the manufacturer for long-



Radio Shack DX-302 Receiver Serial No. 000281

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*	*80 M*	*20 M*
Frequency coverage: 10 kHz-30 MHz, continuous.	As specified.		
Modes of operation: Ssb/cw/a-m.	As specified.		
Readout: Digital, five 7-segment LEDs.	Red 0.5-inch (12.8-mm) digits.		
Resolution: 1 kHz	As specified.		
KHz/turn of knob: Not specified.	65		
Backlash: Not specified.	Nil.		
Agc auto/man. selected: Not specified.	No.		
BFO range: ± 1 kHz.	As specified.		
Receiver attenuator: 0-20-40 dB.	As specified.		
S-meter sensitivity (μV/S9): Not specified.	80 m, 50; 40 m, 50; 20 m, 50; 15 m, 110; 10 m, 175.		
Receiver birdies/spurs: Not specified.	Multiple, each segment: None registers on meter.		
Receiver sensitivity: Ssb, 0.03 μV for 10-dB S/N.	Noise floor (MDS) dBm:	−129	−127
	Blocking DR (dB):	Not measurable.	
	Two-tone third-order IMD DR (dB):	37	52
	Third-order input intercept (dB):	−71.5	−49
Audio power output (8-ohm load): 0.8 watts.	As specified.		
Audio quality: Not specified.	Fair.		
Power requirements: Ac — 120 volts 60 Hz, (220/240 volts 50 Hz for European/Australian models).			
Dc — 8 "C" cells or external 12-V supply, negative ground only.	As specified.		
Power consumption: 120 V, 15 W; 12 V dc, 8 W.			
Frequency stability: Within 1 kHz during the first hour after 60 min. of warm-up; within 2 kHz during 10 min. after initial turn-on.	Within 4.55 kHz from cold start to one hour later.		
Size (HWD): 6 × 14.5 × 10 in. (146 × 362 × 254 mm).			
Weight: 13.2 lb (6 kg).			
Color: Black.			

wave reception. Some beacons were heard in that range, but local QRN ruled out the possibility of any DXing.

The DX-302 is suitable for *casual* listening on the amateur bands. It comes supplied with a telescoping whip antenna and a 30-foot (9-m) wire antenna. While not technically oriented, the instruction manual adequately introduces the owner to the operation of the receiver and the wonders of shortwave listening and Amateur Radio. The DX-302 is manufactured by Radio Shack, 1800 One Tandy Center, Fort Worth, TX 76102. Price class: $400. — *Bruce Kampe, WA1POI*

THE AEA MORSE MEMORY KEYER MODEL CK-1

☐ It is difficult not to use words like "amazing" and "impressive" in describing this compact electronic keyer. A few minutes spent with it will just begin to uncover its unusual flexibility. It takes some familiarity to tease the most out of the nearly shirt-pocket-size device, but the excellent instruction manual does a fine job of making you feel right at home with it.

Many features of the CK-1 have been designed for the dedicated cw operator. They include an extremely versatile memory-load and edit capability, automatic serial numbering, rapid cw speed changes and full weighting control.

The front panel of the CK-1 is little larger than the key pad that is used to call up each of the features. There are two other controls: a top-mounted power ON/VOLUME (sidetone) control and a memory-load switch on the left side.

Speed Change and Adjustment

At turn-on, the keyer has set into it two speeds, 20 and 30 wpm. Either of these speeds may be called up by pressing two buttons for each speed. If these speeds are not desired, any speed from 1 to 99 wpm may be inserted in the two preset speed positions. A variable speed feature provides speed selection within the above range of speeds. Alternating dots and dashes are automatically sent during the change to advise the operator of the increasing or decreasing speed.

Sidetone Change

The starting sidetone frequency is set at 500 Hz. The pitch may be lowered or raised through a range of approximately 50 tones. It would be difficult not to find a tone to please the most finicky operator.

Automatic, Semiautomatic and Iambic Operation

Here I had a little fun. When first turned on, the keyer is set for automatic, iambic operation. The keyer may be set for "bug" operation by pressing three keys. The exclusive use of a keyer for more than 20 years has reduced me to a "fumble fingers" when attempting to use a "bug." However, the instruction manual says one may set up for "bug" operation and put a message in memory. The keyer will revert to automatic operation when the message is sent from that memory. Deciding that a real test was in the making, I keyed in a message, very poorly. When it was sent by the memory, out came perfect cw, in no way resembling the poor job done in storing the message. Ah, there's hope for all! More about the message memories in a moment.

Iambic keying fans haven't been forgotten either. A dash may be inserted in a string of dots, and similarly, a dot may be inserted in a string of dashes. If one chooses, these memories may be disabled.

Dot-Space, Dash-Space Ratios

Though it might not be apparent from listening to some of the signals on the bands, good cw is supposed to be formed by making a dot equal to the space between parts of characters, and a dash equal to three dots. Therefore, a dash is equal to three intra-character spaces. In the CK-1 these dot-space and dash-space ratios may be tailored to suit individual preferences, though why anyone would wish to use any spacing other than the perfect (and *correct*) 1 to 3 ratio is difficult to understand. The dot-space ratio (normally at 1.0) is adjustable from 0.5 to 1.5. The dash-space ratio, initially at 3.0, may be adjusted between 2.0 and 4.0. In other words, one may select short or long dots, and short or long dashes.

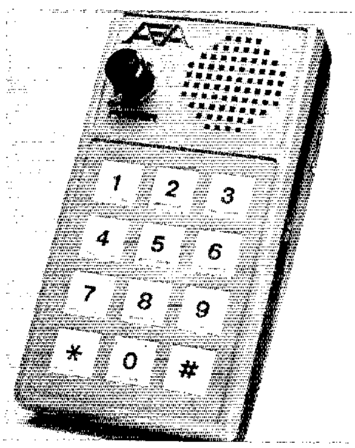
Transmitter Tuning and Message Memories

The * and 5 keys place the CK-1 in a key-down condition that may be used to turn one's transmitter on for tuning. Touching any key pad or the paddle terminates the tune procedure.

The CK-1 has an approximately 500-character memory, which may be divided up into 10 random-length memories. This is known as "soft partitioning." Actual memory length depends upon the length of stored characters, the number of pauses and the length of each pause. The memory length of each message location is adjusted automatically during loading.

Real-time memory loading or automatic character and word-space loading may be selected. In real-time loading, all pauses will be recorded. The keyer powers up in automatic memory mode. In this mode a pause longer than two space lengths records a character space. A pause longer than five space lengths records a word space. At this point, loading stops until the next character is sent.

Maintenance of the memories requires constant application of the 12-volt power source.



If power is removed, or momentarily interrupted, all memories will be dumped. In testing the CK1 at W1SE it was found that just turning the VOLUME control to its lowest point was sufficient to dump the memories. The manufacturer offered the explanation that the power switch actually starts to open at the point of lowest volume, well before the "click" of the switch is audible. He suggested wiring across the switch. This was done with a 1/2-inch (13-mm) length of wire. Now, no more inadvertent memory dumps. Actually, the CK-1 is designed to be left on continuously, and has been for many months at W1SE. To erase one of the memory locations requires only that one switch to MEMORY LOAD, press the number of that memory and the pound sign, #. Random characters appear in each memory when the keyer is first turned on. These should be erased by the technique mentioned above, before loading is begun.

Automatic Serial Numbering

Tailor-made for the contester, the automatic serial-number function alone is probably worth the price of the keyer. The keyer will automatically increment from 01 to 9999, or it can be started at any number one may choose. The serial number may be inserted anywhere in a message, to appear as many times as one selects, and it also may be repeated upon demand. Once the memories are loaded, the touch of only one button at the desired memory location is required to send a message from a memory containing a serial number. This remarkable keyer has even more features, including editing, extra word and character spaces, and a "memory full" warning.

In the past several months of operation at W1SE, only one problem arose, and the manufacturer advises that this problem has been solved. He had been supplied about 50 faulty 0.01 μF capacitors. Most never made it out of the plant, but one of them was in the keyer reviewed. The capacitor was replaced with a new one supplied by the manufacturer. He tells me that all keyers that fail as a result of this capacitor will be repaired free of charge.

The capacitor is located on the bottom-right side of the circuit board. It is across the paddle dash input line. Failure of the capacitor is evidenced by continuous dashes from the keyer.

The CK-1 is manufactured by Advanced Electronic Applications, Inc., P.O. Box 2160, Lynnwood, WA 98036. Price class: $130; AC-2 power supply, $10. — *Lee Aurick, W1SE*

HAL MESSAGE STORAGE OPTION

☐ The folks at HAL have come up with a new addition to their line of sophisticated gear, aimed primarily at the RTTY/ASCII gang. The MSO-3100 Message Storage Option, a factory installed accessory for their DS-3100 ASR terminal,[2] will provide more than 32,000 characters (approximately 450 lines) of additional memory. The MSO-3100 was designed with Electronic Mailbox operation in mind.

Messages may be stored in the MSO in variable-length files with passwords for security if desired. The contents of a file may be accessed locally or remotely, read on the DS-3100 screen, or printed out on an external printer. A directory is available that gives a complete listing of all your files and the level of security for each, and lets you know how much file space has been used and how much is still available. When a file is deleted, the remaining files are compressed so that all the remaining space is in one block.

Once the MSO is activated, a valid command in the receive buffer of the DS-3100 will be obeyed. Thus, it may be inserted by typing it on the DS-3100 keyboard and transferring it to the receive buffer, from another keyboard or tape locally, or by a signal received from a remote station. Just a few commands are necessary to operate the MSO, and a couple of hours of experimentation will show just how simple and versatile it is. First, the DS-3100 is set in the "MSO Enable" mode. Now, a simple letter-group command, such as MSOWPR, indexed to the left margin in the receive buffer, will activate the MSO. The DS-3100 has a real-time clock, so the correct time and date should be entered. Each file will carry both the time and date it was originated and that it is read. A valid command must be indexed to the left margin and consists of a period (.) followed by the command and file name and "Newline" symbol. For example, to store your brag tape into the file, simply type ".Write Brag" and hit the "Newline". Then copy your tape into the buffer and at its conclusion type "Newline" followed by "Endfile" and "Newline" again. Your brag tape is now in the file and the terminal will tell you how many bytes were used and how many remain. If you want to see your file, ".Read Brag" will show it on the receive portion of the screen. ".Send Brag" will transfer it to the transmit buffer ready to be sent on the air. ".Delete Brag" will delete the file and the terminal will again tell you how much space is left. ".Exit" will return the MSO to ENABLE status. Other commands allow you to control relays, read the full directory or a shortened version of it, print a couple lines of RY,*U (the ASCII equivalent of RY), or "The Quick Brown Fox." ".Help" and ".Filehelp" commands will bring assistance if you run into a problem.

The basis of Electronic Mailbox operation is that you leave your receiver and copying equipment on while the station is otherwise unattended. With the use of the AUTOSTART and SELCAL features of your terminal unit and DS-3100, stations knowing your MSO Enable code may activate your MSO and store messages in your files. Later, when you (or another control operator) are present, stations may call in and access whatever files they are interested in. Since you, as control operator, are responsible for the proper operation of your station, you want to be able to screen the files to prevent transmission of any illegal files. These could be in the form of "commercial" messages or messages involving third parties with countries with which we do not have third-party agreements. Thus the file security provisions of the MSO are very important. The "Brag" file we entered was an "Open" file. It could be copied by anyone or deleted by anyone having access to the MSO. The second level of security is the "Read" status. "Brag/Bill" could be copied by anyone, but only a person knowing the password "Bill" would be able to delete the file. Two passwords give a file "Private" status. Thus, "Brag/Bill/Mike" could be copied only by someone using either password and deleted only by someone using the first. If someone attempts to copy or delete a file without the proper password, the MSO merely prints out "File is protected". A directory listing is available in a full form listing all the files, the length of each, its password status, and date and time of origin; or in a short form listing just the file names and password status.

A couple of questions come to mind. What happens if another station enters a file with passwords without telling me what they are? The MSO has thought of this! When you enter the directory from the DS-3100 keyboard all the files are listed, along with their passwords. Well, then, what's to keep somebody from accessing the directory and finding the passwords and copying or deleting a file against my wishes? Again, the MSO is a jump ahead. When a remote input activates the directory, the passwords are omitted. There is another possibility. Suppose you find a "Private" message listed in your directory but with no passwords listed? This is the result of using a string of spaces as the password, and the file may be copied or deleted as appropriate by a similar string, or by "Brag//".

While transmission to and from another station on the air must be carried on at the data rate of the mode being used, usually 45-baud RTTY or 110-baud ASCII on the hf bands, local operations such as accessing the directory or reading a file may be done at computer speed. The MSO may also be used for cw operation by using the symbol B̅T̅ in place of "Newline".

The MSO-3100 is available only as a factory installed option. Price class: $600. Manufacturer: HAL Communications Corp., Box 365, Urbana, IL 61801. — *Charles R. Bender, W1WPR*

K5SMG CODE PRACTICE TAPES

☐ The prospective Amateur Radio operator of today frequently asks how licensed amateurs learned the Morse code. Many attended classes and had Elmers to help them or they might have found assistance within the few home study courses available to them. The latter area is where the K5SMG code tapes enter the picture.

If you are in the market for beginner code practice cassettes, you might want to focus your attention on John Tarvin's course. This set of two 90-minute cassettes introduces the alphabet and numbers in Morse code at a rate of 2.5 wpm. This speed sounds slow (and it is). Tarvin uses what he calls the HI/LOW system to emphasize character sound recognition, however. The dots and dashes of each character are sent at the rate of 15 wpm, but each letter or number is equally spaced to the 2.5-wpm speed.

The teaching method can cause confusion to beginners at times, since they would try to group similar sounding letters together and the randomly sent code practice sometimes goes on seemingly indefinitely, with few breaks to review what was just learned.

Outside of that, there are a lot of pluses. Since the code is randomly sent, one cannot memorize the text. A check list, as well as an introductory sheet that briefly explains the purpose of the course and provides helpful study-ing tips, accompanies the course. All the cassettes are first-generation duplicates for the best signal-to-noise performance, and the code is computer generated.

Once you learn the code and want to increase your speed of reception, K5SMG offers a complete line of upgrading practice cassettes with speeds to 50 wpm. Each is priced at $5.95. A free catalog can be obtained by writing to John Tarvin, K5SMG, 14480 Shadowlane Ct., Morgan Hill, CA 95037. — *Maureen Thompson, KA1DYZ*

[2]"Product Review," *QST*, April 1980, p. 49.

Technical Correspondence

Conducted By
Gerald L. Hall,* K1TD

THE ULTIMATE VS. THE SPC TRANSMATCH

☐ In the March 1981 issues of both *QST*[1] and *WorldRadio News*, Lew McCoy, W1ICP, has directed unwarranted criticism toward the 1981 ARRL *Handbook* and recent issues of *QST*. The criticism concerns the Ultimate Transmatch, DeMaw's SPC Transmatch, T networks, a link-coupled balanced antenna matching network and other topics. McCoy's critical remarks cannot go unchallenged because they are technically incorrect.

In *QST* McCoy claims that, with the dual-section capacitor in the Ultimate Transmatch,[2,3] the capacitor section in shunt with the input provides 10 dB of second-harmonic rejection. He also claims that, without the shunt capacitor, the remaining T network has little or no rejection.

The schematic diagram of the Ultimate Transmatch is shown in Fig. 1, with its customary dual-section capacitor connected in parallel with the variable inductor. From this unfortunate arrangement of the components in the drawing, many amateurs inferred incorrectly that this apparent parallel circuit is a resonant tank — an inference that has led to erroneous explanations of its matching function. However, a slight rearrangement of the drawing without changing the circuit (Fig. 2) clearly shows the Ultimate to be a simple T network of the high-pass configuration with an extra shunt-arm capacitor, C2, across the input. My analysis and measurements have proved that C2 is not only useless in the impedance-matching function, but actually causes a slight degradation in efficiency.

Keep in mind McCoy's claim that C2 provides the 10 dB of second-harmonic rejection he attributes to the Ultimate Transmatch, and his further claim that without C2 the resulting T network (Fig. 3) has little or no rejection. Also bear in mind that since C2 must equal C1 (two sections of a dual capacitor), the value of C2 is determined only by whatever the value of C1 might be when adjusted for any random matching condition. Thus the value of C2 has no relationship whatever to any value required to obtain effective harmonic filtering. Furthermore, as the shunt arm of a filter with no series arm preceding it, the reactance of C2 remains too large to contribute substantially to harmonic rejection for the range of values normally encountered. For example, with C2 at 100 pF, the improvement in second-harmonic rejection of an 80-meter signal effected by adding C2 is less than 0.25 dB, and the third harmonic only 0.5 dB. Thus, contrary to McCoy's claim that 10 dB of second-harmonic rejection is provided by C2, we see that C2 may be omitted with no noticeable detriment to harmonic rejection. It follows that if 10 dB of second-harmonic rejection is provided by the T network with C2 added, as McCoy claims, the network must also provide substantially the same rejection *without* C2. Thus McCoy's further claim, that the T network without C2 provides little or no rejection, is also unfounded.

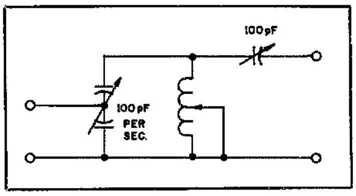


Fig. 1 — Original McCoy Ultimate Transmatch circuit.

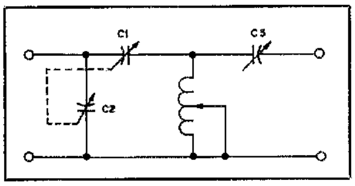


Fig. 2 — The circuit of Fig. 1 redrawn. The Ultimate Transmatch is actually a T network with a shunt input capacitor.

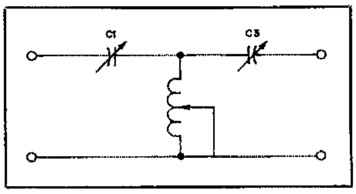


Fig. 3 — Simple T network of high-pass configuration, resulting from the removal of C2 in Fig. 2.

Using my own equipment, which includes a General Radio model GR-1606A rf impedance bridge, I demonstrated the ineffectiveness of C2 in the ARRL laboratory in October 1975.[4] To alert those Ultimate builders searching for a dual-section capacitor, I subsequently published information in *QST* about the lack of need for a shunt capacitor.[5]

The series capacitance arms and shunt inductance arm of the T network, which remain after dropping C2 from McCoy's Ultimate Transmatch, comprise the basic high-pass configuration shown in Fig. 3. Recognizing this, Doug DeMaw, W1FB, added a shunt capacitance, C4, in parallel with the inductance, as shown in Fig. 4. DeMaw calls this new configuration the SPC, for series/parallel capacitance.[6,7] C4 substantially improves the harmonic rejection of the network. The improvement is obtained because the shunt reactance of C4 in the SPC follows the series-arm reactance of C1, thus providing a voltage drop for the unwanted frequencies. McCoy's C2 in Fig. 2 is connected directly across the input line, with no series reactance arm to provide a similar voltage drop.

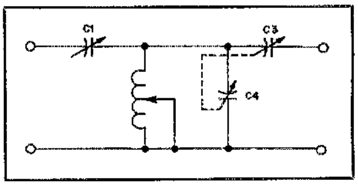


Fig. 4 — DeMaw's SPC Transmatch circuit.

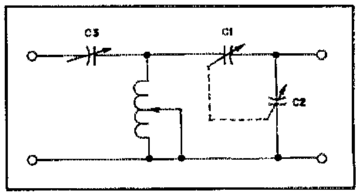


Fig. 5 — McCoy's Ultimate Transmatch circuit drawn backwards from the usual configuration, which would show the input on the left, output on the right.

Thus, contrary to McCoy's claim as quoted by Brooks, K6FO, in *WorldRadio News* (and as stated by Orr in his Fig. 7 of "Ham Radio Techniques," *Ham Radio*, July 1981, p. 30), it is clearly evident that DeMaw's SPC Transmatch is not simply the Ultimate Transmatch of Fig. 2 drawn backwards. In the Ultimate drawn backwards, shown in Fig. 5, C2 is in parallel with the *output* terminals of the network, and not in parallel with the shunt inductor as it is in the SPC Transmatch of Fig. 4. Therefore, because of the difference in the circuitry of the two Transmatches, the frequency response of the SPC Transmatch[8] does *not* represent the response of the Ultimate Transmatch, as McCoy further claims. On the contrary, the response of the T network of Fig.

[1] L. G. McCoy, "Set the Record Straight," "Correspondence," *QST*, March 1981, p. 56.
[2] L. G. McCoy, "The 50-Ohmer Transmatch," *QST*, July 1961, p. 30.
[3] L. G. McCoy, "The Ultimate Transmatch," *QST*, July 1970, p. 24.

*Associate Technical Editor

[4] See "Murch UT-2000-B Transmatch," Product Review, *QST*, April 1980, p. 50.
[5] M. W. Maxwell, "Another Look at Reflections," *QST*, August 1976, p. 18, Fig. 11B.

[6] D. DeMaw, "Ultimate Transmatch Improved," Technical Correspondence, *QST*, July 1980, p. 39.
[7] "A Transmatch for Balanced or Unbalanced Lines," *The Radio Amateur's Handbook*, 1981 ed., ch. 19.
[8] Ibid., Fig. 26B, p. 19-12.

3 is substantially the same as the response of the Ultimate, indicated in the reference,[9] considering the insignificant contribution of C2 in the Ultimate circuit.

It is now time to ask the question, "Since the T network resulting from the Ultimate Transmatch without C2 is of the high-pass configuration, can it really provide any harmonic rejection?" With its capacitive series arms and its inductive shunt arm, one would believe intuitively that no harmonic rejection is possible — yet harmonics are attenuated. As in any matching network consisting of reactive elements, this T network is also a frequency-selective filter. By utilizing mismatch reflections, the network attenuates power flow to some degree at all frequencies except the one at which it performs its intended impedance match. The theory behind wave reflections and complementary mismatches in filter networks may be an appropriate subject for another time. Suffice it to say here that the basic T network of the McCoy Ultimate Transmatch does provide some harmonic rejection. This is true because the network provides a complementary mismatch (or a conjugate match) at only the fundamental frequency. The harmonic energy is not matched. However, the harmonic mismatches provided by the McCoy configuration are not very severe, and thus the harmonic rejection is not too great. C4, which DeMaw added in his SPC Transmatch, increases the mismatch at the harmonic frequencies quite substantially, because the shunt-arm reactance of C4 decreases as frequency increases. In addition, C4 affords a greater shunt attenuation by following the series attenuating reactance of C1 than if an equivalent C2 were directly in shunt with the 50-Ω source line as in McCoy's configuration. The marked difference in response between the Ultimate and SPC circuits is shown in the *Handbook* spectographs.[10]

Concerning the link-coupled matching network, McCoy claims that the circuit shown in Fig. 28 of the reference[11] cannot remain balanced when the tap switch to the link-coupling coil is switched over to one side of the link. I believe McCoy is perturbed unnecessarily.

The only contribution toward unbalance that I can perceive is that, as a result of the coil construction, fewer turns of primary winding L2 are used to couple energy into L1 and L3 on the higher bands. The active portion of L2 is closer to L3 than to L1, and thus L3 is a bit more tightly coupled to the primary than L1. This simply means that, of the total voltage supplied to the feeders, L3 develops somewhat more voltage than L1. However, the voltages developed by both L1 and L3 are in series, and *floating relative to ground.* There is no ground connection at the junction of L1 and L3 that would force a neutral ground reference to appear at that point. Therefore, since any inequality between the voltages developed by L1 and L3 is not referenced to ground at the junction of L1 and L3, the voltage inequality cannot contribute to any unbalance of feeder current. Even if the junction of L1 and L3 were grounded, the unbalance in feeder current resulting from the difference in coupling would likely be insignificant when compared to the unbalance that results from bends in the feeders and unequal stray coupling to nearby objects in a practical installation. — *Walt Maxwell, W2DU, ARRL TA, 243 N. Cranor Ave., DeLand, FL 32720*

[9]Ibid., Fig. 26A, p. 19-12.
[10]Ibid., Fig. 26, p. 19-12.
[11]Ibid., Fig. 28, p. 19-13.

RFI TO AUTOMOBILE CRUISE CONTROL, PART 2

☐ After reading the item by Baker, W5QPX,[12] I felt a great deal of empathy for him, because this is the same problem that I had with the Sears control I put into my Ford. Since I am running essentially the same type of equipment, I thought my experience would help him and others. I put a Pace 25-W rig in my Mustang, with a Hustler collinear antenna. I noted that when I was transmitting with an SWR greater than 1.5:1, I had the lag or bogging down of the cruise control with a speed loss until I unkeyed. When I readjusted the antenna to a 1:1 SWR, the bogging disappeared. I also found that when I got close to 11-meter operators using too much power and modulation, I experienced the bogging down of the cruise control. Feeling that this interference was from harmonics in the uhf region, I watched carefully for uhf repeaters while mobile, and I did experience the same lag or bogging when I crossed the path of a uhf system. The effect was a loss of power to the control, necessitating a resetting adjustment.

A simple cure was foremost in my mind; hence I wrapped the control unit in aluminum baking foil to provide some shielding of the previously unshielded solid-state unit from rf. I have not experienced the problem since. The local repeater group still chuckles over the RFI problem another operator had in his car. Rf would get into his electric broadcast antenna system, and the antenna would glide up and down during his amateur transmissions. — *Bill Richards, II, WB5ZAM, 1925 Juanita, San Angelo, TX 76901*

BATTERY-CHARGER TVI

☐ One day as I was charging a battery with my Sears 12-V automobile battery charger (model 608.71280), I noticed some interference on the TV screen. I was watching channel 38 at the time. The interference was a herringbone pattern with 60-Hz modulation. When I unplugged the charger from the ac outlet the modulation stopped, but the interfering carrier remained until I disconnected the charger from the battery. A pair of 2N3903 transistors in the charger are connected as a differential amplifier, with a common connection for their emitters. It seemed that these transistors were oscillating. I opened the case and lifted the emitter leads of the 2N3903s. Then I slipped a ferrite bead over each lead and resoldered each back to the board. This modification cleared the problem.

If you are accused of causing TVI with your amateur transmitter and you know your station is clean, you might consider a battery charger as the potential culprit. — *Gerard E. Buchand, K1YYT, 7 Atwood Terr., Cherry Valley, MA 01611*

COMMUNICATION VIA UNGUIDED LIGHT BEAMS

☐ Of course we're all aware that fiber-optics have been used as effective parts of communications systems that use guided beams of light, but there hasn't been much said about "unguided" light beams since amateurs did some early work with modulated light sources, such as flashlights.

The *Wall Street Journal* for January 30, 1981, carried an interesting commentary by Richard A. Shaffer under the column heading, "Technology." It discussed at length the renewed interest in unguided light beams for a number of communications purposes. Owing to the innovative character of radio amateurs and the ability of hams to lead the way in some technical areas, it seemed worthwhile to provide this update. Perhaps some amateurs will be inspired to do experimental work with light beams. Those who are already conducting guided light-beam experiments are urged to let the ARRL know what you have achieved in this area.

One of the practical uses to which "unguided light" is presently being put include computer linking to permit computers to "talk" to one another from room to room or from office building to office building. American Laser Systems, Inc. of Santa Barbara, California, believes that this technique could become important in Third World countries where microwave transmissions are too easily monitored. It would certainly cut down the cost of communications systems where telephone cables would otherwise be used.

Some of the industrial work being done today with light beams is carried out at infra-red (between visible light and heat in frequency). Siemens AG is testing a cordless telephone that uses infra-red light. Another German company (Sennheiser Elektronic KG) is already selling infra-red headsets to permit wireless listening to TV and stereo. Meanwhile, Texas Instruments is working on infra-red circuits that will permit invisible linking of computer keyboards (portable) to a computer anywhere in the same room. Blue-green light beams are being experimented with by the U.S. Defense Department for underwater communications between submarines and shore stations.

Some believe that the greatest present potential for unguided light-beam communication is in the area of satellites. In this regard lasers could be used to send large numbers of messages quickly between orbiting satellites. This would make possible the sending of signals around the world without bouncing them back to earth, as is done now. This more direct means involving unguided optics would eliminate the delay that results now from returning the signals to earth and retransmitting them. A spokesman from MIT stated recently that such a system should be practical by 1985.

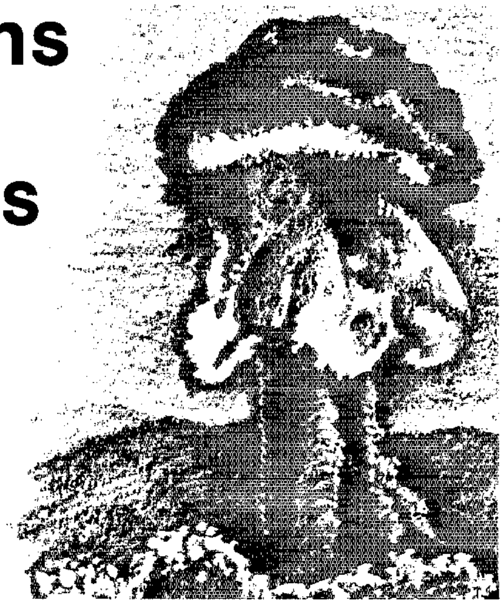
Another application for unguided light that is being researched at present is microwave linking. This could be especially significant in geographical areas where temperature inversions are common, since this phenomenon disturbs the signal path and causes problems.

No doubt there are countless amateur applications for unguided light beams. We'd be happy to hear about practical applications and improvements in existing techniques. Edmund Scientific Co.[13] and others sell low-cost parts to those who want to experiment with infra-red light communications. This seems to be an untapped area of amateur experimentation during an era when many hams lament because experimenting has waned. — *Doug DeMaw, W1FB, ARRL Hq.*

[12]G. L. Baker, "RFI to Automobile Cruise Control," Technical Correspondence, *QST*, June 1979, p. 44.

[13]101 E. Gloucester Pike, Barrington, NJ 08007

Nuclear Weapons Effects on Communications Systems



If the unthinkable should happen, how would Amateur Radio communication be affected? A great deal, says the author.

By Robert Hendrickson,* AG3U

The Amateur Radio Service is well known for providing emergency communications resources in times of need. Radio amateurs have responded well to the local and national disasters of the past. Of all these incidents none can rival the potential destruction released by an atomic weapon. Fortunately the United States has never had to recover from such a disaster. However, we must not allow our good fortune to dissuade us from preparing for yet another challenge. As a public service, Amateur Radio incurs the responsibility to ready itself to provide vital communications functions during all emergencies, including operation during or after a nuclear explosion. The purpose of this article is to acquaint the reader with the major damaging or disrupting effects that nuclear weapons inflict on communications systems.

Many of the "side effects" of nuclear explosions were detected during developmental testing of weapons used against Japan in World War II. Since that time, atmospheric and underground tests performed by the United States and other countries have permitted the study of many direct and indirect nuclear impacts on man, his environment and equipment. One of the major, long-reaching effects on electronic systems was evidenced during atmospheric tests in the Pacific, when it was discovered that high-altitude explosions thousands of miles away were responsible for the popping of local circuit breakers and other system malfunctions, with no other discernible effects. Scientists named this phenomenon *Electromagnetic Pulse (EMP)*, an intense, short-duration burst of electromagnetic energy, capable of traveling thousands of miles and damaging or disrupting sensitive electronic systems.

NWE Can Be Pervasive

EMP is only one of a number of *Nuclear Weapons Effects (NWE)* that owners or operators of vital communications systems are concerned with. NWE are capable of disrupting message paths (both wire and radiated), introducing errors in data streams, kicking off circuit breakers, burning out vulnerable components or otherwise preventing electronic systems from performing their intended purposes. Some NWE are effective thousands of miles away from an explosion and can render systems useless while their operators remain physically unaffected. Thus, vital electronic systems can be attacked (intentionally or unintentionally) without incurring a single human casualty!

Unfortunately, there are a number of possible events that could result in the generation of NWE. Most governments are extremely concerned with the possibility of nuclear weapons use as an act of terrorism. Additionally, it is believed that NWE might be used to advantage by an aggressive country without resorting to a full-scale nuclear attack. An example might be the use of one or two weapons to produce EMP for the purpose of disabling communications defenses while simultaneously launching a conventional (non-nuclear) force. A third possibility is that a nuclear-tipped antimissile, deployed in defense against a conventional weapon, would produce NWE capable of disrupting most offensive and defensive systems in the vicinity of the explosion. Thus, the chance that a nuclear explosion might take place, with or without full-scale nuclear war, is more than a remote possibility.

Fig. 1 shows some of the primary products of a nuclear weapon detonation. The visible light, audible noise and associated mushroom cloud are familiar to many. Invisible emanations (such as heat, neutrons, and so on) are deadly to both

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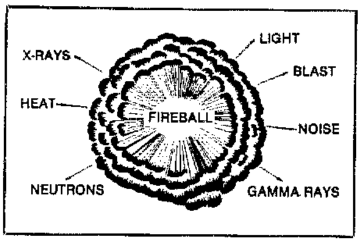

Fig. 1 — The invisible products of a nuclear detonation can be deadly — to both living things and electronics systems such as Amateur Radio equipment.

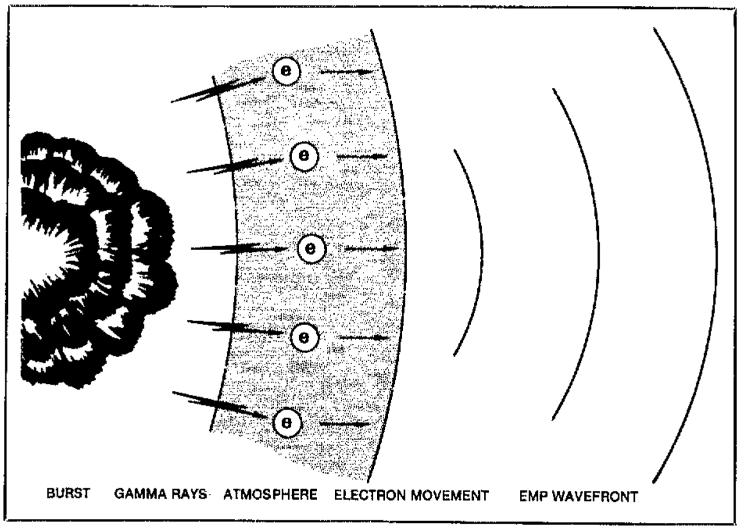

Fig. 2 — An electromagnetic pulse occurs when fast-moving free electrons created by the blast form an intense electromagnetic wave.

man and electronics systems. Secondary effects (that is, effects not produced directly by the weapon), such as EMP and disruptions of the ionosphere, are capable of rendering selected electronic systems useless while having no biological effects on man.

Nuclear explosions are responsible for increasing or decreasing the levels of ionization in the atmosphere, not only locally but at large distances away. Communications systems that rely on the "normal" characteristics of the ionized atmosphere may find that the intended propagation path is disrupted for a period of time varying from seconds to hours. Such disruptions might include an increase in noise level, raised or lowered reflection-producing ionospheric levels, signal absorption or blackout. The area affected may be local to the explosion or may cover very wide areas.

An Electromagnetic Pulse is generated when gamma rays resulting from the thermonuclear reaction produce free electrons (called Compton electrons) in the atmosphere surrounding the explosion. See Fig. 2. The outward movement of these fast-moving electrons, influenced by the earth's magnetic field, creates an intense electromagnetic wave whose spectral content extends from a few hertz to several hundred megahertz. A high-altitude detonation of moderate strength (yield) is capable of producing field amplitudes of up to 50,000 volts per meter at ground levels, over a diameter of thousands of miles, as illustrated in Fig. 3. This field couples into all metallic structures (pipes, wires, rain gutters and especially antennas) and may burn out sensitive front-end electronic components or at least cause internal disruptions to normal operation.

Nuclear weapons are known to produce energetic, liberated neutrons (subatomic particles) as a result of the thermonuclear reaction of the weapon. These uncharged subatomic particles travel at high speeds and may physically damage everything they meet. Solid-state electronics devices are particularly susceptible to neutron damage. So is the operator.

Gamma rays (an electromagnetic emanation) are produced directly by the weapon. Both prompt and delayed gamma rays are produced by the initial explosion and the debris, respectively, of the weapon. Gamma rays penetrate materials deeply and cause transients to be generated across semiconductor p-n junctions. The end result is the production of interference or false signals. Damage from burnout by intense transients is also possible.

Neutron and prompt gamma radiation induced responses are also called *Transient Radiation Effects on Electronics (TREE).* It is possible for TREE phenomena to permanently damage or disrupt electronic systems while the operator survives. TREE impacts are especially important to managers of repeaters or other unmanned communications systems. Other weapon products such as heat, blast and shock wave are not treated here, as they do not have such a long-reaching impact as those effects discussed.

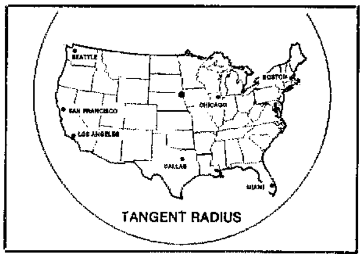

Fig. 3 — A high-altitude nuclear blast centered on the continental U.S. would create field amplitudes that could couple into antennas and damage sensitive communications equipment.

End Result: Trouble

The end result of this collection of effects is trouble for communications systems and their operators. Many miles away from a detonation operators may find their radio links unusable owing to blackout, abnormal reflections or absorption of signals in the atmosphere, phase distortion or increased noise. They may discover that EMP has burned out sensitive microprocessor-controlled equipment or field-effect transistor front ends of receivers. If they are close enough to the explosion, they may discover that temporary or permanent electronics damage prevents them from using solid-state equipment. Data stored in semiconductor memories may be altered or lost. Given the variety of possible problems, two or more of these effects may combine to produce a synergistic result, a product of simultaneous influences of more than one effect. The following paragraphs describe why these problems may occur.

In all radio-frequency communication systems, the atmosphere either helps or hinders in some way. The ionosphere aids hf communications by refracting (or "reflecting") signals from the ground, permitting propagation over long distances by multiple hops. At the same time, the atmosphere (particularly the lower or D layer of the ionosphere) also hinders communications by absorbing signals and by propagating undesired noise such as that from lightning. Nuclear explosions in the atmosphere generally

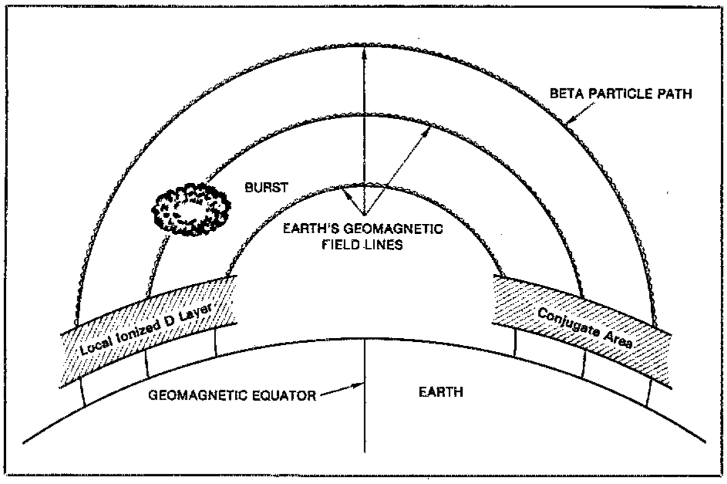

Fig. 4 — Local and remote ionization caused by an air burst is influenced by the earth's magnetic field. Propagation in the affected area may change suddenly — or make radio communication impossible.

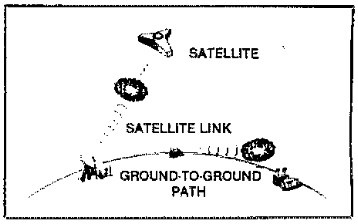

Fig. 5 — Although less susceptible to ionospheric disruptions, vhf, uhf and satellite communication may also be affected by a nuclear explosion.

produce free electrons and increase the level of ionization in the atmosphere. This results in either degradation or enhancement of the normal reactions of the atmosphere to radio signals.

A nuclear fireball carries an intense level of ionization that both increases radio-frequency thermal noise in the area and produces an opaque spherical volume that radio signals will not penetrate. A low-altitude burst at night within the D layer of the ionosphere may case absorption or refraction of ground signals by enhancing the level of ionization. A high-altitude burst near the F region of the ionosphere may either increase or decrease the "reflectivity" of the region depending upon yield, time of day, existing conditions, and so on. Users of the hf bands rely on F-layer reflectivity (skip) to work long distances as the signal reflects from the sky to ground with one or more hops. A high-altitude explosion also will generate beta particles, or free electrons, which spiral along the field lines of the earth's magnetic field. This creates an increase in the ionization of the D layer of the ionosphere, not only at the local area but also at the area known as the magnetic conjugate in the opposite hemisphere! The free electrons spiral along the earth's magnetic field lines and cause ionization at the two regions above the earth's surface where the lines touch the surface. See Fig. 4. This results in either an increase in the ability of the layer to absorb signals or an increased ability of the D layer to refract local signals and thus change the direction of propagation. An operator in both the local and the opposite hemisphere from a nuclear conflict may also find a sudden loss in his ability to communicate.

VHF, Satellites May Be Affected

Ionospheric disruptions mostly concern the hf band. Vlf, lf and mf bands are not as susceptible. Vhf and uhf communications links that rely on ground-to-ground line-of-sight links are also generally immune. However, it is possible for vhf-uhf links to be blocked, scattered or attenuated by explosions between the points of transmission and reception. Likewise, a satellite link that must penetrate or pass through a disrupted ionosphere may become impaired. Figs. 5 and 6 illustrate these concepts.

EMP is a nuclear effect that is somewhat similar to lightning, although EMP has a faster risetime and less power. It is a radio-frequency electromagnetic wave and as such has all the characteristics communications systems operators are already familiar with. It is of short duration, and if the equipment is not susceptible to damage or upset, the operator will otherwise not know of its existence. Its high-amplitude field intensity and wide spectral content cause it to couple to wires and other electrical conductors, pass through apertures and cause circuits to ring at their resonant frequencies. When large currents are allowed to couple to sensitive circuits there may be physical damage caused by overheating of low-power devices or arcing between conductors. All high-impedance, low-power, non-radio-frequency-shielded circuits are susceptible. Small calculators and commercial-grade processors with their plastic cases are notoriously affected.

If no damage occurs, the simultaneous coupling of large numbers of transients of high amplitude is likely to cause improper operation of all sensitive electronic systems. Commercial data processing equipment without error-correcting designs are quite susceptible.

Prompt gamma radiation produces a transient signal across p-n junctions in semiconductors. Vacuum tubes are immune from this effect. This transient is similar to semiconductor photoresponse and is thus known as a *photocurrent*. It is evidenced as a leakage current across the junction. In transistors with grounded emitters, it appears across the collector-base junction where it is called a primary photocurrent. It then couples to the base-emitter junction where it may be amplified and is then known as a secondary photocurrent. Primary and secondary photocurrents appear almost simultaneously across many semiconductor junctions in a typical electronics system, causing disruption of normal operation. Additionally, if the transients are of sufficient amplitude, permanent damage may occur. Or, if the power supply must support the amplification of many transients, it may become overloaded and trip circuit breakers. Operational impacts of a collection of simultaneous transients vary according to the function of each electronic system. A wide variety of equipment errors or disruptions is possible. Integrated circuits sometimes behave as discrete circuits as far as transients are concerned. Their construction, however, generally reduces their susceptibility compared to discrete circuits of similar function.

Fast neutrons affect semiconductors by physically altering the molecular structure of the bulk silicon material. The neutrons collide with and dislodge atoms from their normal positions and place them in abnormal spaces, called interstices, within the structure. Intersticial defects cause an increase in the resistivity and a decrease in the minority-carrier lifetime of the material. These changes, in turn, could cause an increase in the saturation voltage of a diode, or in transistors, a loss of gain might be experienced. Loss of gain could cause loss of function or failure in amplifiers, oscillators, regulated power supplies, and so forth. A decrease in gain might also cause integrated circuits to display reduced performance.

Not all components in systems are affected by TREE impacts. Electromechanical parts, transformers, passive components and other non-semiconductor components are practically immune. Also, different types of semiconductors respond with more or less vulnerability. In general, those with small junction sizes and/or higher gain-bandwidth products (F_T) are more immune.

Hardening

Despite the variety of complex problems the communications operator is faced with, there are a number of useful approaches to prevent or work around difficulties caused by nuclear weapons. Using established guidelines, it is possible to design modern solid-state equipment with reduced susceptibility to nuclear effects. When a piece of equipment is designed to operate within a nuclear environment without degradation it is said to be "hardened." A number of hardening techniques have proven to be effective. As far as impacts on the atmosphere are concerned, there is not much that can be done except to be knowledgeable as to the effects one might experience and to alter operational methods (switch bands, for example) to bypass the impacts of such disturbances.

As discussed previously, altered ionization levels in the atmosphere will impact various bands differently. The probability of successful communications during ionospheric disruptions will be maximized when the operator has a choice of the medium-, high- and very-high-frequency bands and beyond. Terrestrial line-of-sight communications paths will generally be the most reliable. Additionally, being able to change antenna directivity will help. Barring other approaches, the method of waiting for the disturbance(s) to subside may be effective. Ionospheric effects may last from several seconds to several hours.

As far as TREE effects are concerned, it is not practical to consider major alterations internal to amateur station equipment to achieve hardness, or immunity to such influences. Perhaps the simplest approach might be to avoid discarding vacuum tube equipment when its apparent useful life has been reached. Such gear is not nearly as susceptible as solid-state equipment to TREE damage or disruption. An awareness that transient radiation may upset or damage equipment may explain why communications gear refuses to function properly. Some TREE effects are temporary. Under certain conditions the operator would be well advised to apply power and test the equipment after a few seconds have passed to determine if the phenomenon was truly transient or whether it had produced permanent damage.

Equipment can be "hardened" against EMP as well as TREE by protecting sensitive circuits against unusual voltage or current spikes. Again, for commercial equipment without rf-shielded cabinets this may not always be practical. Backup equipment may also be useful in this case, especially if it has been stored on a shelf, disconnected from antennas or power sources. The main threat is that of upset or disruption, which may de-energize equipment if circuit breakers pop. In such cases, normal operation may be restored by resetting the breaker.

Although there is a general awareness of nuclear weapons effects in the communications industry, there seems to be little protection of our valued resources in the event of a nuclear weapon explosion, outside of military circles. Thus, the impacts of such effects will be distributed more or less equally among all communications systems users. The Amateur Radio Service has provided vital communications functions in areas previously thought to be protected from communications disruptions. It is possible that this service might be one of a few that would survive such a powerful influence. The amateur community certainly possesses the flexibility to work around many obstacles through the use of diversified communications media.

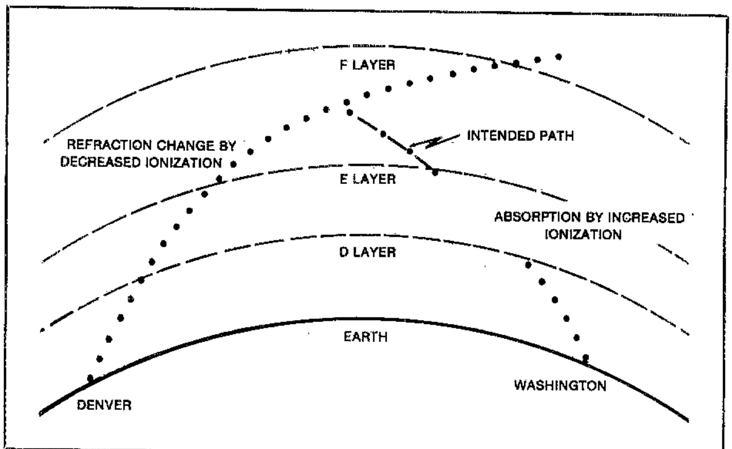

Fig. 6 — Propagation may be affected in various layers of the ionosphere.

Protecting Your Gear

The first step in solving a problem must be to acquire the knowledge that the problem exists. It is hoped that this introductory article has served that purpose. The hardening of Amateur Radio systems en masse as a result of public education would be as improbable as motivating the public to build private fallout shelters. Yet, there are simple practical approaches to ensure the survivability of either commercial or home-built equipment.

The first is to obtain *flexibility*. Maintain communications capability in more than one band. Participate in local traffic nets, if even only occasionally. Establish line-of-sight communications functions on vhf or ground-wave frequencies.

The second is to acquire *redundancy*. Don't discard old "spare" equipment, especially vacuum-tube equipment. Even backup solid-state gear may be valuable if it remains disconnected while not in use.

The third is to achieve independence, especially from utilities. Capitalize on any battery-powered equipment, or better yet build and maintain your own source of emergency commercial grade power. A word about microprocessors. These powerful communications-aiding devices are sure to be utilized more frequently in the future, but strict dependence on a single processor to control a communications station will probably increase the station's vulnerability.

Finally, awareness is needed to understand what is happening and why. Once the source of difficulty is identified most problems are easier to overcome. More descriptive information may be found in the references.

Author Hendrickson is a communications engineer and nuclear survivability specialist employed at the Arlington, Virginia branch of ORI, Inc., a firm that specializes in defense-related research.

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QEX: The ARRL Experimenters' Exchange

Do you want to keep abreast of the state of the art in Amateur Radio? Would you like to share your experiments and technical ideas with other hams of similar interests? Then this new League publication is for you.

By Paul L. Rinaldo,* W4RI

The ARRL is underscoring its long-standing commitment to Amateur Radio experimentation by launching a new publication to be known as *QEX: The ARRL Experimenters' Exchange*. *QST* and other Amateur Radio magazines carry technical articles, so why isn't that sufficient? The facts are that magazines select and edit technical articles to appeal to their general readership and try to achieve a balance between many different interests. Controversial, highly technical or perishable articles may not be judged as appropriate for publication in a magazine. So, how do we help experimenters get the word around to others about their concepts, designs and test results? We need a newsletter by and for experimenters to meet this need among ARRL members and others who wish to join in.

QEX is to begin publication in December 1981. Its objectives are to:

1) act as a catalyst for technical development in the Amateur Radio and Amateur Satellite Services, by providing a medium for the exchange of ideas and information between Amateur Radio experimenters who may be geographically isolated from one another;

2) document advanced technical work in the Amateur Radio field that is not of sufficiently broad interest to permit detailed documentation in the pages of *QST*;

3) demonstrate the League's commitment to, and support for, efforts to advance the state of the Amateur Radio art.

The Content

QEX will contain technical articles and correspondence from Amateur Radio experimenters in the U.S., Canada and overseas. Editing of these contributions will be limited to correcting of obvious grammatical, spelling or minor technical errors. The editing may also include substitution of standard technical terms and explanation of terms that would not be widely understood by most readers. In some cases, minor editing will be done to improve the comprehensibility of the material. But, the basic goal is to do the minimum amount of editing in order to expedite the publication of the authors' ideas. Submitted material that requires more extensive editing or rewriting will be returned to the author. This arrangement places most of the burden on the author to prepare the article in clear English with technical ideas properly introduced and supported.

All the articles and correspondence will be the work of the authors. Any opinions expressed will be those of the individual, not necessarily those of the editor or the League. That's not just a legal disclaimer. The whole idea is to give the experimenter a forum to air technical ideas and information. Also, authors will be the ones to defend their own material. So that we can benefit from each other's mistakes, follow-up correspondence to and from the authors will be included to the extent that it furthers an understanding of the topic. So, copies of such correspondence will be welcomed by the editor.

There will also be some regular columns on subjects of continuing interest to experimenters. Columnists will endeavor to keep up with developments within their areas of expertise and to report who is doing what. They will also be expected to get out front and pull whenever they feel it important to focus attention on technical problems.

QEX will sponsor competitions to stimulate activity in specific technical areas. Design competitions will be announced from time to time for hardware and software needed to fill a particular void in Amateur Radio technology. Recognition will also be given to individuals who make the greatest contributions to the state of the art through their articles published in *QEX*.

Information on new products of interest to experimenters will be included. This may include both news releases supplied by manufacturers and tips by experimenters. New product information will be published without ARRL endorsement and without any implication that the products have been examined in the ARRL laboratory. Before you buy, it will be advisable for you to check out both the seller and the product.

Initially, *QEX* will contain no advertising, either classified or display ads. After the newsletter is established, limited advertising may be considered by the League.

Call for Articles

Prospective contributors are invited to submit articles on a wide variety of technical topics including, but not limited to, the following:

*Editor, *QEX*, 1524 Springvale Ave., McLean, VA 22101

- data communications and packet switching techniques;
- advanced modulation techniques such as spread spectrum;
- computer hardware and software related to interests of the radio amateur;
- space communications;
- microwave and optical communications;
- details of Special Temporary Authorities issued by the FCC for amateur experimentation as well as results of these tests;
- experimental conferences and events;
- image transmission techniques;
- state-of-the-art components and devices;
- signal conversion and processing;
- voice recognition, synthesis and compression;
- analog and digital circuit design;
- advances in antenna and propagation technology;
- spectrum management (including electromagnetic compatibility [EMC] and radio frequency interference [RFI] reduction techniques);
- sources, conversion and conservation of energy for electronic equipment; and,
- how-to-do-it and where-to-find-it information of interest to the experimenter.

It is preferable that the articles be written by the individuals doing the experimentation. In cases where writing is not a particular experimenter's cup of tea, we would like to see prospective writers work with experimenters to document their projects. Local Amateur Radio clubs can help by organizing this type of teamwork and by sponsoring technical projects.

You Want It When?

Material for the premier issue of *QEX* (with a cover date of December 1981) should be in the editor's hands no later than October 25, 1981. The first-in-first-out (FIFO) principle will apply to some extent, so the earlier you get your article in the mail the sooner you'll see it in print. The deadline of five weeks before the cover date will hold for subsequent issues as well.

Manuscripts should be typewritten and double spaced. Try to use everyday English as much as possible, but don't be afraid to use technical language and even math to get your point across. Standard ARRL abbreviations found on page 65 of the December 1980 issue of *QST* should be used and need not be explained. Nonstandard terms and abbreviations should be properly introduced the first time they are used in an article. For the most part, any artwork (schematics, flow charts, graphs and so on) submitted by the author should be camera ready (rendered in black ink, not pencil) and usually will not be redrawn by an artist. This is intended to minimize processing time and cost. When essential to the article, photographs may be included. Contributors should supply glossy, black-and-white positive prints of good definition and contrast, somewhat larger than the usual snapshot print.

All material for publication in *QEX* should be mailed to the editor's mailing address, which appears at the beginning of this article.

Subscriptions

QEX subscriptions will be available to ARRL members at the special rate of $6 for 12 issues. For nonmembers, the subscription rate is $12 for 12 issues. The foregoing rates apply only to subscribers with mailing addresses in the U.S. and possessions; Canadian and Mexican subscribers must add $1.74, and will be serviced by First Class mail. Overseas subscribers should add $6.78 for air mail delivery or $2.34 for surface mail. All rates are quoted in terms of 12 issues because the frequency of publication may change. The plan is to publish *QEX* at least every other month and to move to monthly issues as soon as possible.

Applications for subscriptions to *QEX* should be sent to the American Radio Relay League, Newington, CT 06111. Members are asked to include their membership control number, or a mailing label from their *QST* wrapper.

Warts and All

True experimenters probably win the prize for the messiest shacks. Their projects may follow a crooked trail. *QEX* may hit a pothole every now and then and will contain some flaws. But it promises to be an important exchange medium for experimenters as well as a record of Amateur Radio technical activities. Your participation is needed, both in contributing material describing your projects and by subscribing to *QEX*. QST

25 Years Ago

August 1956

☐ Welcome information is provided by "Notes on the Development of Yagi Arrays," by Telrex chief engineer Carl Greenblum. This 7-1/2-page part 1 considers multi-element beams; the second part will treat stacked arrays.

☐ " 'Tattoo' — Automatic C.W. Transmitter Control," by Laird Campbell, W1CUT, is a description of "The Automatic Transmitter Turner Onner Offer," which does just that. Using two relays and a dual triode, it can be used with any transmitter, keyed in any circuit.

☐ "Changing the 6146 Oscillator into an Amplifier" is Lew McCoy's detailed account of the necessary modifications to a popular 75-W, one-tube transmitter he described a year ago.

☐ Lloyd Colvin describes the "Multiple V beams" he uses at DL4ZC to cover the world. It helps to have a little real estate available; each leg is 584 feet long! The four legs are switched at the apex by two dpdt relays.

☐ Ed Tilton, W1HDQ, tells about his "Portable Beam for 50 and 144 Mc." that he stores in a golf bag and sets up alongside his car for hill-top operation. There are three elements on 6, and 5 elements on 2, with gamma match and a 16-foot mast.

☐ "An Outboard Automatic Band Scanner" by Charles Arnold, W3YDF, tells how he drives his Collins receiver tuning with a 1 r.p.m. reversible motor. Adjustable stops permit excursions as small as 2 kc. or as much as 300. — *Byron Goodman, W1DX*

50 Years Ago

August 1931

☐ "Duplex Phone on 56 Mc." is Ross Hull's exciting account of the latest experiments in the 5-meter band. A companion transmitter (push-pull '71-As in a TNT circuit modulated by parallel '47 pentodes) to last month's super-regenerative receiver permitted two-way communication between the survey vehicle and the lab. By setting one transmitter near the 56-Mc. edge and the other near 60 Mc., duplex operation was readily obtained. The 5-page article concludes with the reminder that a special portable license is required for operation from other than the home location and, of course, mobile operation of a portable amateur transmitter is illegal.

☐ "A Companionable Portable Receiver," by Robert Brooke, W9CH, is a self-contained, battery-powered, detector-and-one-audio receiver using a pair of '30s. It covers 0.6 to 18 Mc. with six plug-in coils and is housed in a 5 × 6 × 9-inch aluminum box. The author uses it for everything — for checking man-made QRN, as a substitute or loaner receiver for another ham, for listening on vacations and for checking crystals.

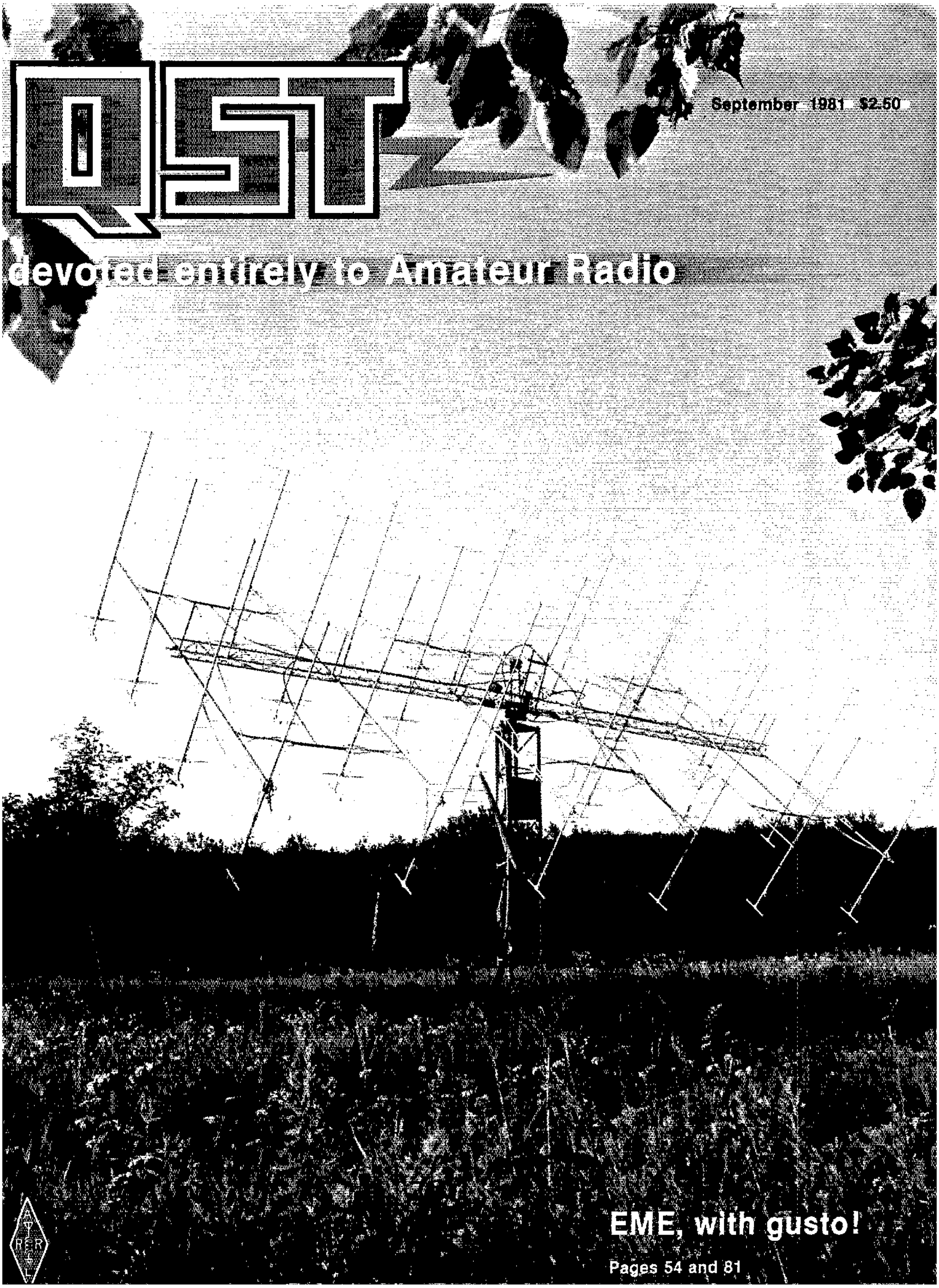
☐ In the first of a two-part article, "The Standard Frequency Transmitter at W1XP," author Paul Hendricks describes the design considerations and the mechanical construction of the four-tube exciter. A separate article reminds the readers of the Frequency Measurement Tests scheduled for October, and it includes a list of frequency-measurement reference articles.

☐ Boyd Phelps, W2BP, asks "Why Not Frequency Tripling?" He points out that a crystal that triples to the 14-Mc band has good stability and can save one stage over the usual doubler-doubler approach.

☐ "Adding an Amplifier to the Low-Power Transmitter" is George Grammer's description of an '03-A breadboard job intended to follow the popular '10 high-C Hartley oscillator. It includes the author's usual complete treatment of construction and tuning considerations.

☐ James McLaughlin and Technical Editor Jim Lamb take 5-1/2 pages to give their answer to "What Is This Thing Called Decibel?" Written with a light touch but illustrated with graphs, tables and a few formulas, it probably scared off many readers who would have enjoyed it.

☐ Ev Battey reports on the "Fourth International Relay Competition Results" and calls the two-week affair a big success. *Six* U.S. stations, including leader W9UM and runner-up W8BKP, managed WAC during the struggle. G5BY led the entire world, with CM8UF second. VE2CA was first among the Canadians, followed by VE5AW (British Columbia). QST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September 1981 $2.50
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EME, with gusto!
Pages 54 and 81

September 1981 *Volume LXV Number 9*

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THE COVER

The 336-element (count 'em!) array at K1WHS was good for 90 QSOs during the last EME Contest. Complete results appear on p. 81. One man's view of the art of moonbouncing is on p. 54. (photo courtesy *Dave Olsen, K1WHS*)

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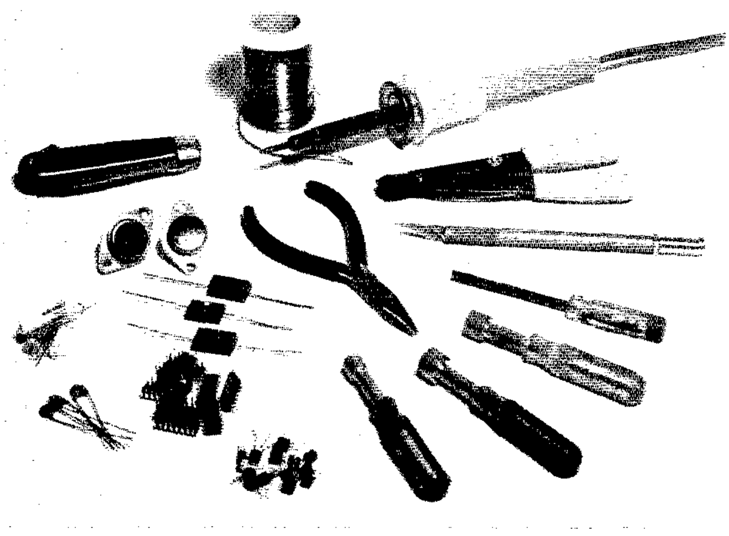
Experimenting for the Beginner

Experimenting is half the fun of Amateur Radio! QRP (low power) gear is great for the newcomer to this fine art. Here's how to get started.



By Doug DeMaw,* W1FB

What's this? You've never built a piece of amateur equipment? You don't know anything about circuits, so you just operate? Well, if this description fits you, at least half the thrill of being a ham has eluded you! For many of us the greatest excitement in amateur work came from building and using that first transmitter. There's a special feeling connected with telling the other guy or gal, "The rig here is homemade." If you haven't been able to make this statement over the air, perhaps it's time you did!

Most experimenters start out with relatively simple projects, and rightfully so. In the old days some of us tinkerers enjoyed building one-tube transmitters. Often, the name of the game was "power output." That is, we tried to extract more output power from a single oscillator than the tube was designed to deliver. A number of popular transmitters of this type were described in *QST* by F. Sutter.[1] But today it's prudent to use transistors and to operate them within their safe maximum ratings. QRP equipment (generally 5 watts or less of rf output power) can provide many interesting and exciting hours of operation, and it's easy and inexpensive to build. Therefore, QRP is the theme of our article this month on basic radio learning.

How to Experiment

We need not have college degrees in engineering to conduct experiments in nonprofessional electronics work. We can assemble suggested circuits, test them, learn their characteristics, and then make changes and observe the results. Familiarity with fundamental circuits can lead to circuit improvements and innovations, and perhaps later to some original design work. Many of the early-day inventors of electrical and electronic devices and systems followed this approach, which supports the validity of the precept, "Learn by doing."

We amateurs have the advantage of trying our ideas at home rather than at work. So, if the circuit is a flop, no need to contemplate the unemployment line! Furthermore, if the equipment is a transmitter for one of the amateur bands, we are licensed to put it on the air and to give it a true "environmental test," an advantage not enjoyed by many engineers and technicians.

The simplest approach we can take to experimenting is to adopt the breadboarding technique.[2] This allows us to tack a test circuit together quickly and easily. In the process we cut down on expense and eliminate the chore of laying out and etching a circuit board. The final product may not look like a work of art, but it can be used on the air just as effectively as a commercial-looking version of the same circuit.

Bargain-bag assortments of 1/4- and 1/2-watt resistors are a vital part of the experimenter's workshop. Likewise with assortments of disc ceramic capacitors, trimmer capacitors, volume controls and small electrolytic capacitors. Of course, we need a small pencil type of soldering iron (40 watts), some solder and a few feet of light-gauge, insulated hookup wire. Bargain assortments are often available from Radio Shack, Poly Paks and other prominent vendors. The best deals are often available at Amateur Radio flea markets, so we must be on the alert when browsing at hamfests and conventions.

An important item in our workshop is a VOM (volt/ohm/milliampere meter). Even a low-cost imported instrument will suffice if cost is an important consideration. For rf measurements it is wise to have a VOM that can be used with a

[1]Notes appear on page 15.
*Senior *QST* Technical Editor

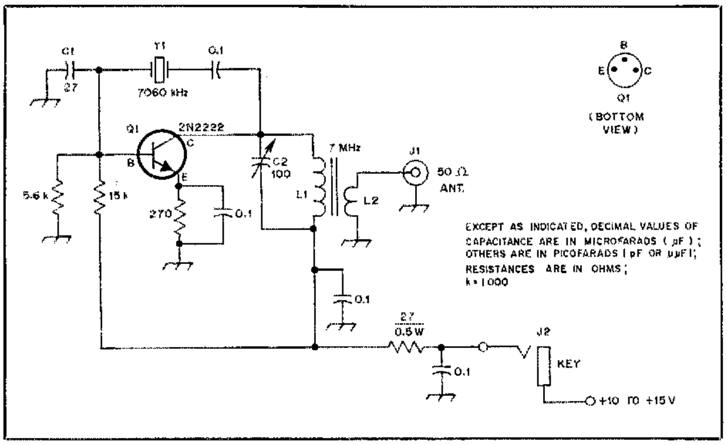


Fig. 1 — Circuit of a one-transistor QRP transmitter. Fixed-value capacitors are disc ceramic, 50 volts or greater. Resistors are 1/4- or 1/2-watt composition, 10% tolerance. C1 described in text. C2 is a 100-pF mica trimmer. L1 is a 6-µH winding of 34 turns of no. 26 enam. wire on an Amidon or Palomar T50-2 toroid core. L2 is 6 turns of no. 26 enam. wire, wound over L1 winding (see text). J1 is a phono jack, and J2 is a 2-circuit phone jack. Y1 is a fundamental surplus or new crystal for the standard 40-meter QRP frequency (7060 kHz).

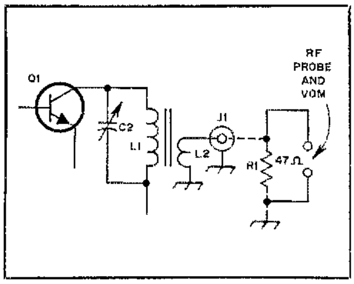


Fig. 2 — Details for measuring transmitter output power with a dummy load (R1), an rf probe and a VOM (see text).

homemade rf probe.[3] This will permit us to measure rf voltages in oscillators and transmitters when performing initial checkout or debugging. A frequency counter is very useful to the experimenter, and should be acquired if the expense can be justified.

We will need a dc power supply for our workbench, and for most of our experiments we can manage nicely with a 12-volt, 1-ampere regulated supply.[4] If the output voltage can be made variable, so much the better.

Bargain assortments of transistors, ICs and diodes aren't likely to be of much use to us unless we have a way to locate the defective ones: Most "bargains" of this type contain manufacturer's rejects, and 50% or more of the semiconductors in a bag are often open, shorted or leaky. Therefore, we're better off to buy parts of known quality for each of our experiments. This practice will help us to avoid confusion and despair.

The Simplest Transmitter

How uncomplicated can a transmitter be for experimental work? Factually, a one-transistor oscillator qualifies as a transmitter. Many beginners have had exciting results with such a circuit while operating with only 50 milliwatts (0.05 watt!) of power output. For example, the circuit in Fig. 1 was tacked together one lunch hour in the ARRL lab and was connected to a 28-foot (8.5-m) base-loaded vertical antenna with buried radials. On the third CQ an answer came from a W8 in Ohio. A signal report of RST 569 was received for our 50-mW signal on 7060 kHz. A second QSO with a W2 station in New Jersey netted an RST 589 report!

Y1 of Fig. 1 determines the operating frequency. C2 tunes L1 to the approximate frequency of Y1. If it is set for resonance at exactly 7060 kHz in this example, the cw signal may become chirpy. With this type of oscillator it is best to tune the C2/L2 circuit for the best sounding note consistent with reasonable power output. Maximum power will not coincide with the cleanest cw note when connecting an antenna to this type of oscillator unless very light coupling is used (L2) between the tuned circuit and the antenna. The lighter coupling will, in itself, reduce the available power to the antenna.

The circuit of Fig. 1 can be used on 160, 80, 40 or 20 meters by using a fundamental-cut crystal for the desired frequency. C1 is part of the feedback network and will have to be chosen for the crystal we use. This is because some crystals are more active than others. The more sluggish a crystal is, the greater the feedback voltage required to make the circuit oscillate reliably. Values between 15 and 100 pF are typical for use at C1 in this particular circuit. We can experiment with the number of turns in L2 to extract maximum rf power output from the circuit.

Fig. 2 shows how we can use a 47-ohm resistor as a dummy load to measure the output power. An rf probe (mentioned earlier) and VOM are connected across R1 with the key closed. Output power can be calculated from:

$$P = E^2/R$$

where P is in watts, E is in rms volts and R is in ohms. Therefore, if we measured 1.53 volts across R1, we would have an output power of 50 milliwatts (0.05 W). The accuracy of our measurement depends on the purity of the sine wave from the transmitter. A distorted waveform will

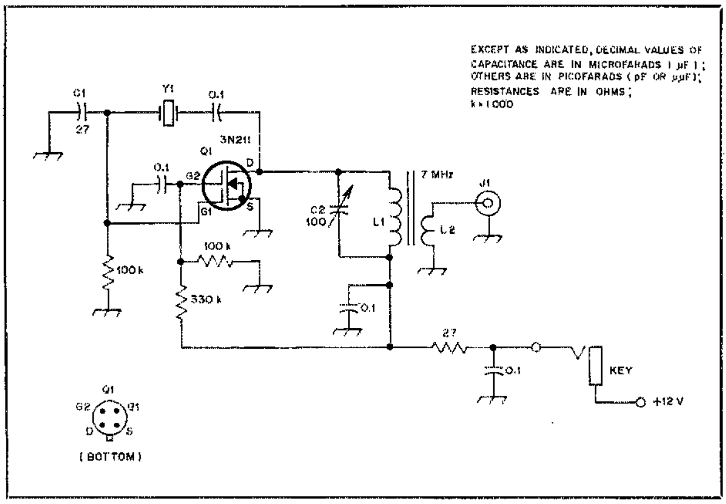


Fig. 3 — Same circuit as Fig. 1 except that an FET is used at Q1.

yield only approximate power-output readings on the VOM. A 51-ohm resistor could be used at R1, but that is a 5% tolerance (gold-band) value, and would cost more than a silver-band (10% tolerance) resistor. So, we can use a 47- or 56-ohm resistor. Either value is close enough to 50 ohms for our purposes. Here again is an example of the joy of *experimenting* versus designing!

We can also use field-effect transistors as oscillators of the kind illustrated in Fig. 1. The version seen in Fig. 3 contains a dual-gate MOSFET. Output power from this circuit will be somewhat lower than that from the bipolar-transistor oscillator of Fig. 1, but plenty of QSOs can be had with this simple transmitter. Other dual-gate MOSFETs could be used in place of the 3N211, such as a 40673.

If we decided to use a VFO to control the operating frequency of the transmitter in Fig. 1, we could make the modifications shown in Fig. 4. Y1 and C1 are removed to prevent oscillation at the crystal frequency. A dc-blocking capacitor (C3) is added as shown. The rf voltage (rms) developed from the base of Q1 to ground (with the VFO connected and operating) should be between 1 and 3 volts for best results. This shows just another way we can experiment with simple circuits.

Additional experiments can be conducted with the one-transistor transmitters by trying various types of transistors in the basic circuits of Figs. 1 and 3. One important transistor characteristic is the maximum operating voltage (V_{ce}), which should never be rated less than two times the supply voltage for cw work. This will allow for the voltage swing (peak to peak) during the rf sine-wave cycle at the collector or drain. If the voltage is allowed to rise beyond the specified safe value, the transistor can "go away" instantly! We must be concerned also with the upper frequency rating of the semiconductor. This is usually specified as f_T. A good rule of thumb for obtaining maximum oscillator or amplifier performance is to use a transistor that has an f_T at least five times higher than the chosen operating frequency. Thus, for 7-MHz operation the f_T should be 35 MHz or higher. Most FETs are rated for a maximum upper frequency in terms of gain. Generally, they are good from audio frequencies up to that limit for amateur experiments.

The maximum safe current of a transistor is important to us also. This is specified as I_c (collector current) for bipolar transistors, and as I_d (drain current) for FETs. At no time should we allow the transistor to draw more current than the specified safe value. In fact, it's wise to operate the device somewhat below (25% or more) that maximum value. This will help to prevent failures from excessive heating of the transistor junction.

A good safety rule is to do all initial circuit testing at reduced operating voltage. For a 12-volt circuit we might want to start our testing at 6 or 8 volts until we were certain that there were no wiring errors. If things seem to be working normally, we can increase the supply voltage to 12.

An "Experimenter's Special"

Thus far we've discussed two rather unprofound transmitter circuits. Once we've finished tinkering with them we may want to move ahead to something more spectacular in simple circuitry. Fig. 5 shows the circuit of a two-stage, solid-state QRP transmitter that was designed by Wes Hayward, W7ZOI.[3] Some modifications have been made for this article, but the circuit is essentially as he designed it. This experiment should give us hours, weeks or even months of fun in the workshop and on the air. It delivers slightly more than 1 watt of output to a 50-ohm antenna, and can be made to operate on any band from 160 to 10 meters by using the parts values specified in Table 1. Actually, this is a three-transistor circuit if we count the keying transistor, Q3. But, there are so few parts in the circuit that we can assemble it in short order.

Q1 is a tuned-collector crystal oscillator. Its output energy is fed to the base of Q2, which operates as a Class C amplifier. A pi network (C3, L3 and C4) serves as a harmonic filter (low pass) rather than as an impedance-transformation network, as is more often the case with tube and transistor output amplifiers.

Q3 functions as an electronic switch. When its base resistor is grounded by the cw key it conducts and allows the dc to reach the amplifier stage, Q2. This method helps to reduce the possibility of shorting out the 12-volt supply accidentally, as could happen with the circuits of Fig. 1 and 3 where J1 is in the 12-volt line.

Fundamental crystals are used on 160, 80, 40 and 20 meters. For operation on 15 and 10 meters we will need to use third-overtone crystals at Y1. The oscillator is permitted to run continuously, and keying is applied only to the amplifier, Q2. This prevents chirp on 15 and 10 meters, which would occur if the oscillator stage were keyed.

Feedback capacitor C5 is used only on 160 and 80 meters. All of the component values are the same for 10 and 15 meters: Oscillator trimmer C1 has ample range to provide resonance on both bands.

Construction Thoughts

Experimentation can continue after the transmitter is built and tested — we may want to try our skills at cabinet making, or the unit can be enclosed in a small commercial case, such as one finds at Radio Shack stores. But we can use pieces of double- or single-sided circuit board to fashion a homemade cabinet. We can flow a continuous bead of solder (darned expensive stuff these days!) along the inside seams (corners) of the box to join the side and bottom walls. The lid can be a U-shaped piece of metal (furnace ducting or aluminum). Spray paint or contact paper may be applied to the outer surfaces

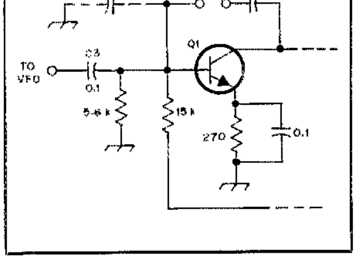


Fig. 4 — Method for attaching a VFO to the circuits of Fig. 1 and Fig. 3. Q1 is thus changed from an oscillator to an amplifier.

Table 1

Fig. 5 Circuit Component Values for Various Bands

	C1 (pF)	*C2 (pF)*	*C3 (pF)*	*C4 (pF)*	*C5 (pF)*	*L1*	*L2*	*L3*	*R1*	*RFC1*
160 m	400	1800	1800	1800	360	73 t No. 28 T50-2	8 t	30 t No. 26 T50-2	18 Ω	30 t No. 28 FT-37-61 (50 μH)
80 m	400	100	750	750	200	43 t No. 26 T50-2	5 t	21 t No. 22 T50-2	39 Ω	21 t No. 28 FT-37-61 (25 μH)
40 m	180	100	470	470	—	35 t No. 26 T50-2	4 t	14 t No. 22 T50-2	39 Ω	30 t No. 28 FT-37-63 (15 μH)
20 m	60	33	210	210	—	27 t No. 24 T50-6	3 t	12 t No. 22 T50-6	47 Ω	30 t No. 28 FT-37-63 (15 μH)
15/10 m	60	33	105	130	—	17 t No. 24 T50-6	3 t	9 t No. 22 T50-6	47 Ω	30 t No. 28 FT-37-63 (15 μH)

Toroid cores are used in L1, L2 and L3. These are powdered-iron cores available from Amidon Associates and Palomar Engineers (T50-2, etc.). RFC1 is wound on a small ferrite core (FT-37-67), and so on), available from same suppliers. The letter "t" signifies the number of wire turns in the winding.

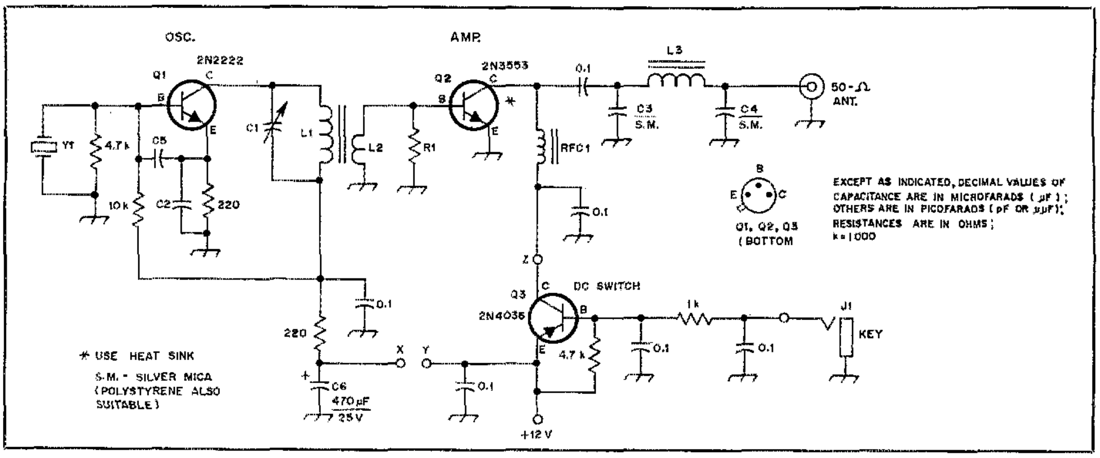


Fig. 5 — Circuit of the W7ZOI "Universal QRP Transmitter." It can provide up to 1.5 watts of rf output when using a 12- to 14-volt dc supply. Fixed-value capacitors are disc ceramic unless otherwise indicated. Resitors are 1/4- or 1/2-watt composition, 10% tolerance. Values not given are listed in Table 1. C6 is electrolytic or tantalum. C1 is a mica trimmer. Q2 is a Motorola transistor, but other brands and numbers with equivalent characteristics can be used.

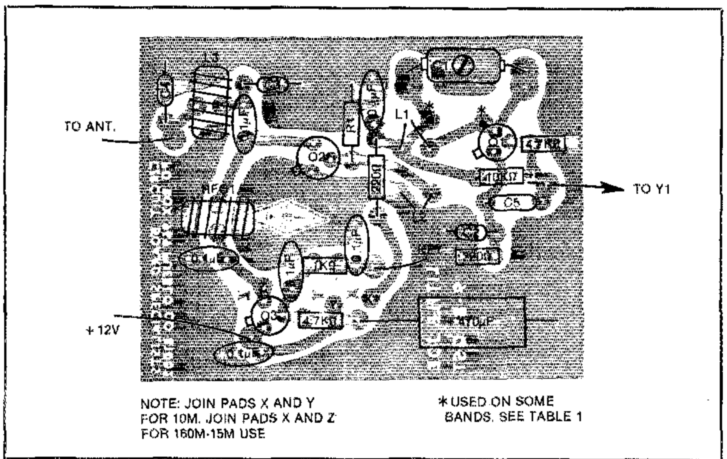


Fig. 6 — Parts-placement guide for the circuit of Fig. 5. The shaded areas represent an X-ray view of the etched side of the board.

of the box to impart that professional look some of us prefer. Press-on decals are excellent for labeling the controls, but Dymo tape labels are suitable also, especially if they are the same color as the panel.

The circuit of Fig. 5 can be assembled on a sheet of pc board using the type of point-to-point wiring described in an earlier *QST* article[6] if a "masterpiece" is not essential to our purpose. But, if pc-board construction of the classic style is preferred we can duplicate the pattern shown in Fig. 6 and in the Hints & Kinks section of this issue.[7] If point-to-point breadboard assembly is our choice we must be careful to keep the input and output components of amplifier Q2 (Fig. 5) separated from one another. Straight-line wiring (not bunched up) is preferable to achieve this: Too-close spacing can cause unwanted feedback and amplifier instability. All of the rf leads in the circuit need to be kept as short and direct as possible. This is especially important when installing the bypass and coupling capacitors.

Caution: When applying operating voltage to the circuits in this article, *check the polarity!* There is no more effective way to send our transistors and electrolytic capacitors on a permanent leave of absence than cross-polarizing the dc voltage connections! Once you have the misfortune of becoming a member of "Junction Busters, Amalgamated," you'll never repeat your mistake!

A Word About QRP Operation

The 1-watt transmitter of Fig. 5 will be 20 dB weaker in signal strength than your transceiver that delivers 100 watts of output. So if you would be heard at 30 dB over S9 with your 100 watts, you will be only 10 dB over S9 with the QRP rig. Or assume your bigger rig was being heard S9 by the other operator. When you switched to the QRP transmitter your signal would drop to roughly S5 or S5-1/2, depending on the accuracy of the S meter (assuming 6 dB per S unit). So you could still be heard well enough under quiet band conditions to be copied "Q5."

Patience and tenacity are the better virtues we can adopt when running low power. Find clear frequencies on which to call CQ. Don't expect answers from stations with weak or marginal signals, unless they are also using QRP. Unless you're a super operator, it's unlikely that you'll fare very well in DX pileups.

Good antennas are important in successful QRP work. Many first-time QRPers capitulate after a few days of poor results when using mediocre antennas. Erect the antenna high and in the clear, and use a directional, gain type of antenna (beam) on 20, 15 and 10 meters, if you have one available. A good antenna will help to make up for the deficiency in power when using QRP equipment.

The ARRL would welcome clear photographs and reports of the best DX worked with the circuits of Fig. 1 and Fig. 3. Perhaps if we can get enough input on this subject we can run a page of photos, calls and DX records in an issue of *QST*. We

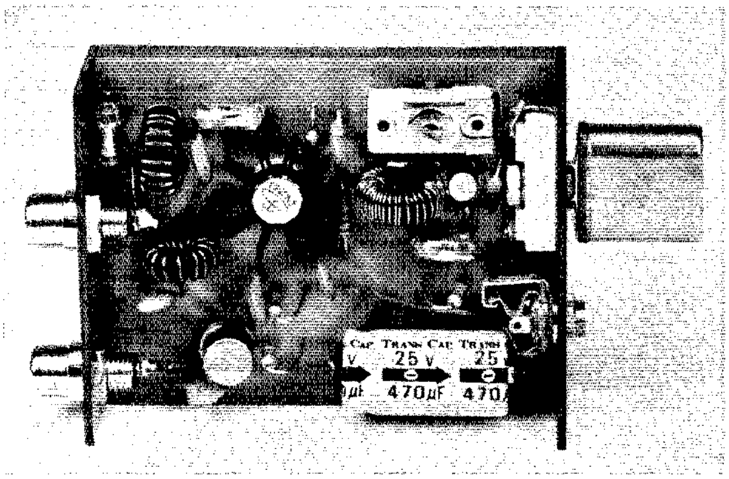


Fig. 7 — Photograph of the assembled kit version (note 7) of the W7ZOI QRP transmitter, as laid out and built by WAØUZO. The panels are made from pieces of double-sided pc board. The dimensions (HWD) are 7/8 × 2-1/4 × 3 inches (22 × 57 × 76 mm).

hope you will soon be able to say, "I've built my first piece of amateur gear, and it works great!"

Notes

[1]F. Sutter, " 'The Runt Sixty' and the 'QSL Sixty,' " *QST*, Sept. 1939, p. 50.

[2]The expression "breadboard" has confused some newcomers to Amateur Radio. It originated in the early days of the amateur service when hams built their transmitters on wooden foundations, such as the ends from orange crates. The kitchen breadboard became popular for that purpose, and thereafter any wooden chassis base was called a breadboard.

[3]Details for building a simple diode rf probe can be found in the measurements chapter of the past several editions of *The Radio Amateur's Handbook*.

[4]D. DeMaw and R. Shriner, "A Simple Utility Power Supply," *QST*, Nov. 1979. Parts kits available from supplier in note 7.

[5]W. Hayward and D. DeMaw, *Solid State Design for the Radio Amateur*, (Newington, CT: American Radio Relay League, Inc., 1977). ch. 2, p. 26. This publication is recommended for experimenters because it contains a wealth of basic theory and many practical examples of simple transmitters, receivers and test equipment.

[6]D. DeMaw, "Quick and Easy Circuit Boards for the Beginner," *QST*, Sept. 1979, p. 30.

[7]Etched and drilled circuit boards for the transmitter are available from Circuit Board Specialists, Box 969, Pueblo, CO 81002.

New Products

SILICON MICROWAVE TUNING VARACTORS

☐ Microwave Associates, Inc., has announced the development of a new series of silicon abrupt-junction microwave tuning varactors designed to obtain the highest Q possible. According to the manufacturer, each device in the series has a high-density silicon dioxide passivation which results in exceptionally low leakage currents and low post-tuning drift.

The silicon tuning diodes are ideally suited for frequency-tuning applications at vhf through K bands. These devices are designed for use in solid-state electronic tuning of transistor, Gunn and IMPATT oscillators. They may also be used in tunable filters, phase shifters, up/down converters and low-order multipliers. For additional information and complete specifications, request bulletin no. 4603 from Microwave Associates, Inc., South Ave., Burlington, MA 01803.

NPN SILICON PLANAR TRANSISTORS

☐ Microwave Associates, Inc. has announced the MA-42000 series of npn silicon planar transistors. These devices are designed to provide minimal noise figures (0.8 dB typical at 60 MHz according to the manufacturer) at frequencies from 10 to 700 MHz. Moreover, they feature a low noise figure as a function of current, which results in an extremely quiet transistor exhibiting a wide dynamic range — typically +25 dBm at the 1-dB compression point. The lf noise level is also low; 1.0 dB is typical at 10 kHz. Such low noise specifications make them ideal for use as i-f, TV, vhf, uhf and rf amplifiers.

For additional information, including complete specifications, request bulletin no. 5211 from Microwave Associates, Inc., South Ave., Burlington, MA 01803.

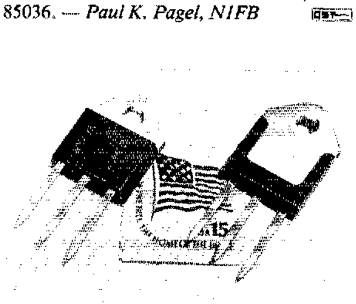
MOTOROLA MEDIUM-POWER DARLINGTONS

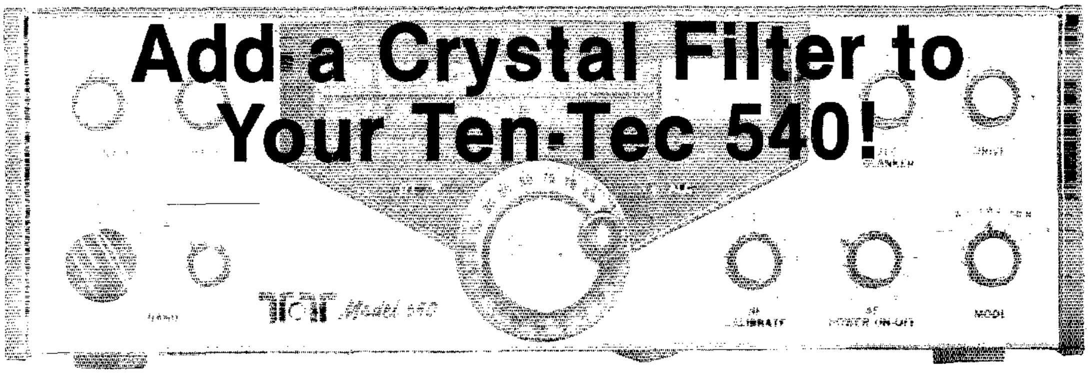
☐ A series of complementary TO-92 Darlington transistors has been announced recently by Motorola. These units are designed specifically for preamplifier applications that require a high dc current gain and an input impedance of several megohms. The manufacturer claims excellent current-gain linearity from 1 mA to 100 mA for these units. They are plastic-packaged types and are available with breakdown voltage ratings of 40, 50 and 60 volts, with a dc current gain of 10,000.

Npn device types are the MPS-A25, -A26 and -A27; pnp types are the MPS-A75, -A76 and -A77 in ascending order of breakdown voltage. Immediate delivery may be obtained from OEM and authorized Motorola distributor stocks.

PLASTIC HIGH-VOLTAGE POWER TRANSISTORS

☐ The Motorola MJE4340 and MJE4350 series of plastic-packaged transistors are complementary types with a continuous collector current rating of 10 A, V_{CEO} ratings from 100 to 160 V and power dissipation ratings of 125 W. These devices are available in the JEDEC TO-218AC plastic package which has a large die-mount and heat-sink area. This packaging, similar to the smaller TO-220 style, offers the convenience of single-sided mounting. Available through OEM and authorized Motorola distributors, further information may be obtained from Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036. — *Paul K. Pagel, N1FB*





Add a Crystal Filter to Your Ten-Tec 540!

This "no-holes" modification provides an easy way to sharpen the cw and ssb selectivity of a popular rig.

By Steven E. Mann,* N4EY

I've been happy with the Ten-Tec equipment I've owned: an Argonaut 505 and the Model 540, formerly known as the Triton IV. Happy in all respects that is, save one — cw selectivity! Audio filters are used to obtain the required degree of cw selectivity. This method is effective under average band conditions, but, during contests and other heavy QRM situations, better skirt selectivity is needed. The ssb i-f passband, which is 2.5 kHz wide, allows too many unwanted signals to be amplified before they reach the audio filter during cw reception. Better skirt selectivity is obtained when a filter does its job *before* unwanted signals have been amplified, as when the filter is located *before* the i-f amplifier.

Adding An I-F Filter

My decision to install a crystal filter in the '540 i-f strip was followed by a call to Ten-Tec. Dick Frey, Ten-Tec's chief engineer, suggested I use the Model 217 filter. This unit is a 500-Hz, 8-pole crystal filter designed for the OMNI transceiver, but compatible with the '540. My own research indicates that this filter may also be used with the various Argonaut and Triton models.

*P.O. Box 141, Burlington, NC 27215

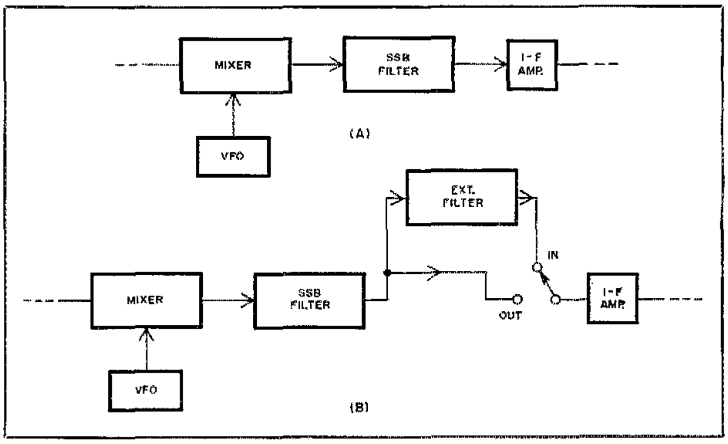


Fig. 1 — At A, a block diagram of the unmodified Ten-Tec 540. The modified circuit, incorporating the added crystal filter, is shown at B.

I purchased a filter and designed an amplifier to compensate for the insertion loss of the additional filter, and to provide isolation. The application scheme is shown in block-diagram form in Fig. 1, and the schematic may be seen in Fig. 2. Note that the transmitted signal does not pass through the new filter because it is inserted in the *receiver* i-f signal path only.

Some '540 owners might wish to increase the receiver selectivity for ssb operation. The circuit of Fig. 2B may be employed with the Ten-Tec Model 218 filter, which, according to manufacturer's specifications, is 1.8 kHz wide at the −6 dB points. It has a shape factor of 1.8:1, measured at the −6/−60 dB points.

Modification is accomplished without drilling additional holes in the '540 cabinet. The new filter(s), amplifier and

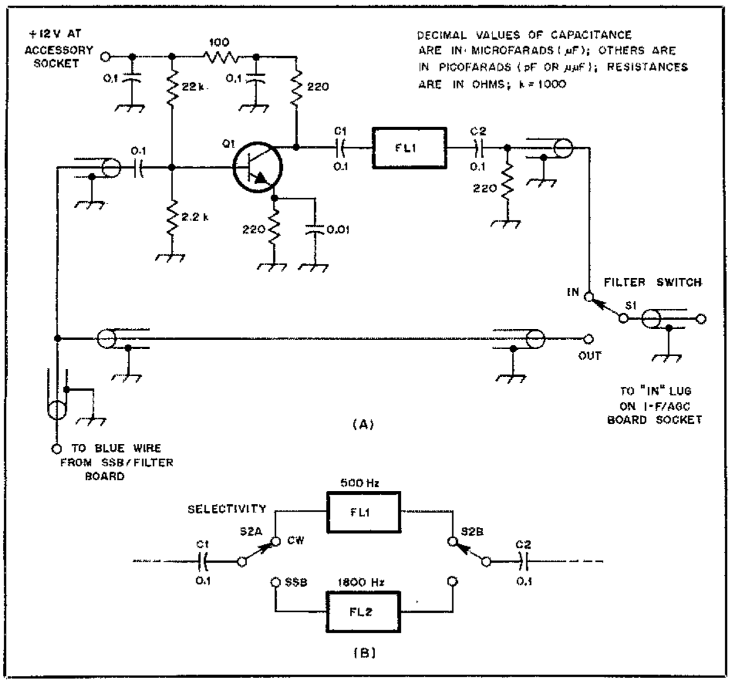


Fig. 2 — Schematic diagram of the filter-modification circuit. Be sure to connect the appropriate points of the filter to chassis ground. Q1 is an amplifier that is used to compensate for the signal loss created by the addition of FL1. The circuit at B may be used to add cw and ssb filters.

FL1 — Ten-Tec model 217, 500-Hz crystal filter. Available from Ten-Tec, Inc., Sevierville, TN 37862.
FL2 — Ten-Tec Model 218, 1.8-kHz crystal filter.
Q1 — Silicon, npn, general-purpose, 350-mW transistor, Radio Shack 276-2013 or equiv.
S1 — Spdt toggle switch.
S2 — Dpdt toggle switch.

switch(s) are mounted in a shielded external enclosure. Connections between the two units are made with RG-174/U coaxial cable. Power for the amplifier in the filter unit is obtained from the transceiver AUX 12 V DC jack.

Internal changes to the '540 are few and simple. The two shielded interconnection cables are passed into the transceiver cabinet through the centers of the PTT and SIDETONE accessory phono jacks. (There are no wiring changes made to the jacks.) Unplug the I-F/AGC board from its socket. Disconnect the wire from the SSB GENERATOR/FILTER board that was connected to the IN lug of the socket; in my unit this was a blue wire. The shielded lead to the filter-unit input is connected to the blue wire and insulated with tape. Connect the output of the filter unit to the IN lug on the socket. The shield braids from both cables are connected to a nearby ground lug. (Refer to the Ten-Tec owner's manual for additional information on socket connections.) Finally, the I-F/AGC board is replaced, and the rig is ready to go.

Summary

The combination of the added cw crystal filter and the standard RC active audio cw filter provides excellent cw selectivity. In today's crowded bands the sharper ssb selectivity is most welcome!

I would appreciate hearing from others who make these modifications or who have other modifications to use with Ten-Tec gear. An s.a.s.e. would be appreciated.

Strays

☐ We are pleased to introduce one of our mountaineering ARRL Technical Advisors, John Grebenkemper, KA3BLO. (W7ZOI and W6JTH are also climbers.) John has climbed extensively in the mountains of the western United States and in Peru. His areas of expertise are solar activity and microwave communications (earth-based and earth-satellite systems.)

First licensed in 1961, John currently holds an Advanced class license. His main operating interest is in QRP hf-band communications. He has worked numerous Field Day operations from the summits of the highest mountains in California, Nevada and other states.

John received his PhD in Electrical Engineering from Stanford University, where he did research in radio astronomy. He participated in the construction of a five-antenna interferometer, which operated at a frequency of 10.69 GHz. Each antenna was 60 feet in diameter. He then used this interferometer to study radio emissions from solar-active regions and solar flares.

TA KA3BLO on his way to the top of 14,018-foot Mt. Tyndall for Field Day.

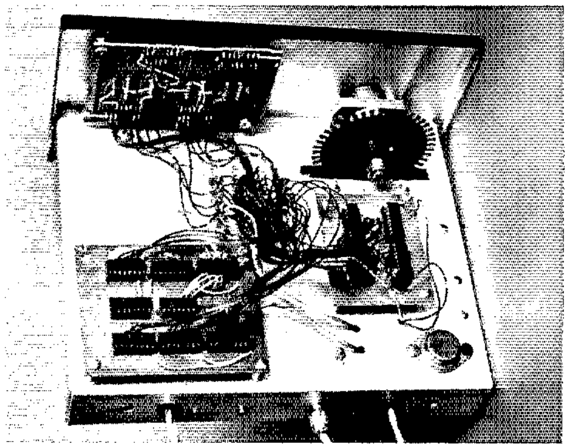
Residing in Palo Alto, California, John works in the area of microwave radio receivers and microwave communications systems. He has published many articles in *QST* and other journals. — *Marian Anderson, WB1FSB*

I would like to get in touch with . . .

☐ anyone who could send me a copy of manuals for the SG RF Signal Generator and T-3 Visual-aural Signal Tracer by Heath. W. P. Champlin, WD6FUZ, 4603 Darien St., Torrance, CA 90503.

☐ amateurs interested in forming a net to discuss the construction of composite aircraft. Rick Gentz, WBØNPM, 9523 Yorkshire La., Eden Prairie, MN 55344.

The Universal Synthesizer



Planning to use synthesis in your next transmitter or receiver project? Try this dual-modulus divider and prescaler circuit to provide frequency coverage beyond 500 MHz.

By Al Helfrick,* K2BLA

This "universal synthesizer" is the result of a design effort to produce a synthesizer system for amateur use that would have flexibility and adaptability to many frequency ranges and resolutions. Printed circuit boards can be fabricated for common parts such as the programmable divider and the reference divider. These can be programmed via jumpers for the divisions necessary.

The synthesizer chosen for this task is the dual-modulus divider that uses low-power Schottky TTL logic. A more elegant system could have been constructed around some of the newer LSI synthesizer chips, which owe their flexibility to the use of a microcomputer for programming. Hard-wired logic is used in this design because many amateurs do not have access to microprogramming equipment. In the programmable divider, both the main counter and the auxiliary counter may be programmed either from a frequency-selection device (such as thumb-wheel switches) or a shaft-encoder system. Permanent receiver i-f offset programming may be obtained through use of jumper wires.

Circuit Details

The universal synthesizer (Fig. 1) has a dual-modulus programmable divider for all frequency ranges. Aside from offering flexibility, the dual-modulus divider offers high-frequency capability. The divider will operate up to 150 MHz with a 10/11 prescaler. Use of other prescalers, such as 20/21 and 40/41, can increase the frequency range of the programmable divider beyond 500 MHz. All of the universal-synthesizer schemes are single-loop systems with the VCO operating in the vhf region. The vhf synthesizers generate the desired output directly, while the high-frequency synthesizers produce a signal with a frequency in the vhf region. It is divided by digital logic down to the desired hf range.

A 50-MHz VCO is presented in this article. It is built into the 6-meter and 5-MHz versions of the synthesizer. The VCO described in the September 1980 *QST* article, "A High-Performance Synthesized Two-Meter Transmitter,"[1] is suitable for the 2-meter version of the synthesizer. VCOs for other frequency ranges can be made by changing the values for the tuned circuit or by adapting circuits from other sources. The VCO should supply about 400 mV, peak-to-peak, for the programmable divider and should have at least two stages of buffer/amplifier to isolate the VCO from the digital logic. The VCO should be capable of driving two ECL dividers when used in hf-band synthesizers. The VCO is required to cover the desired tuning range with a control voltage of 3 to 10.

The reference-frequency generator consists of a single IC oscillator/divider. Any crystal frequency up to several megahertz may be used and divided by powers of two. Practically any reference frequency can be programmed by selecting a crystal frequency and the appropriate power of two. Selecting a crystal frequency above 3 MHz is desirable. Crystals for frequencies higher than 3 MHz tend to be less expensive.

Another subsystem of the universal synthesizer is the loop amplifier — an op amp that can be constructed with practically any value of feedback components. The loop filter is a simple lead-lag filter that will handle numerous values of natural frequencies and damping factors. Other breakpoints, usually well above the natural frequency, may be connected at the VCO.

This article is not aimed at the beginning amateur nor is it intended as a step-by-step construction project. The synthesizer described here is an example of the type that is suitable for a universal synthesizer. It would be impractical to provide construction data for every application. The dual-modulus divider, frequency-division technique for obtaining a fast lock-up time and the method of reference pulling, plus other techniques, are presented as an aid in applying these ideas to various synthesizers.

Synthesizer Considerations for HF Communications Equipment

Synthesizers for hf transmitting and receiving equipment are used for ssb, cw, SSTV and RTTY. When a builder is planning a synthesizer, thought must be given to the following stipulations.

Resolution: All of the modes indicated in the foregoing text require high-resolution synthesizers. The maximum frequency step acceptable for ssb and cw operation is about 100 Hz. This will produce a definite less-than-perfect tuning for ssb, but will be adequate for cw with

*RD 1, Box 87, Boonton, NJ 07005

[1]Notes appear on page 23.

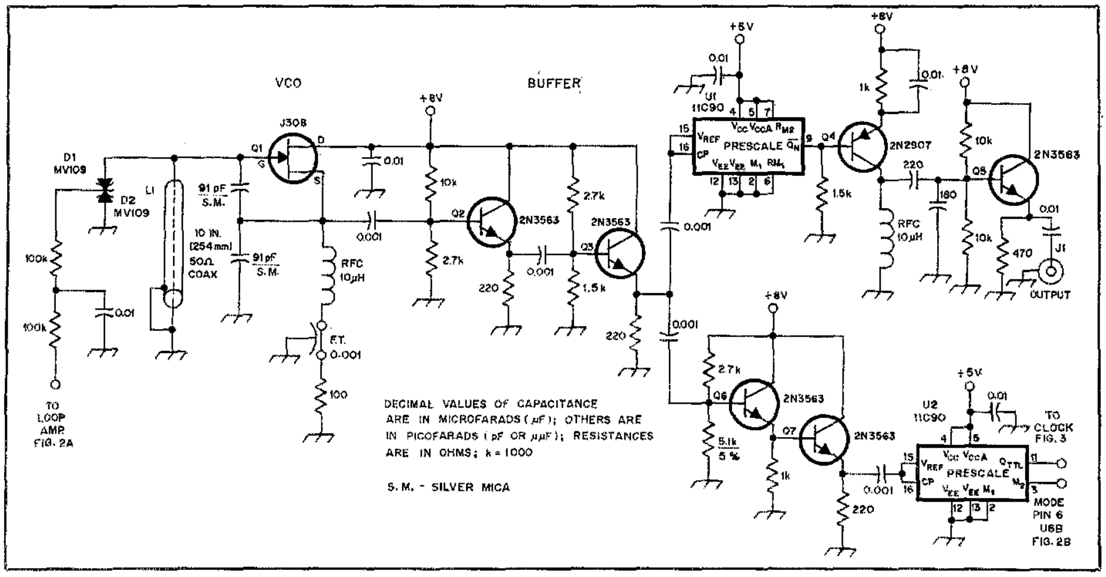


Fig. 1 — Circuit diagram for the Universal Synthesizer.
D1, D2 — Varactor diode, Motorola Epicap MV109 or equiv.
L1 — 10-in. (254-mm) length of 50-ohm coaxial cable.
Q1 — N-channel JFET rf amplifier, Siliconix type J308 or equiv.
Q2, Q3, Q5, Q6, Q7 — Npn silicon rf/i-f amplifier, type 2N3563.
Q4 — Pnp silicon af preamplifier/driver, type 2N2907.
U1, U2 — ECL 650-MHz dual-modulus prescaler, Fairchild 11C90 or equiv.

filters in the 300- to 500-Hz bandwidth range. A clarifier control is required for the best ssb reception; it is absolutely necessary for RTTY and SSTV operation! Fifty-hertz steps will be sufficiently small for all but the narrowest of cw filters, and will provide good ssb performance. For RTTY, it is debatable that even a 50-Hz resolution is sufficient. A 10-Hz step is adequate for all applications, but has significant design problems associated with it. Providing 10-Hz steps requires a large number of synthesizer steps per revolution of the tuning dial if an acceptable tuning rate is to be attained. Some type of dual-rate tuning system must be used. Furthermore, constructing a 10-Hz-step synthesizer with an acceptable lock-up time is difficult. For amateur operation, synthesizer steps between 25 and 50 Hz represent a compromise between adequate resolution and circuit complexity.

Lock-up Time: Another consideration, important with the hf synthesizer but not so much for the vhf synthesizer, is lock-up time. Vhf synthesizers usually are programmed to a frequency and are left alone, whereas hf radio equipment is tuned constantly. An excessive lock-up time can be an annoyance. In addition, the damping of the loop can have a pronounced effect on the tunability. The underdamped loop can accentuate the digital nature of the loop, whereas an overdamped loop will have considerable time lag between the programmed frequency and the actual operating frequency. A good compromise is an overdamped loop with a dual time constant, using diodes that temporarily change the damping when the difference between the programmed frequency and the actual operating frequency becomes large.

Spurious Signals: Spurious output is another consideration for hf synthesizers. Of course, spurious outputs are undesirable in any synthesizer, but they are more likely to occur in hf synthesizers because these designs often use multiple loops and mixing. Spurious output can be generated by noise sidebands, reference sidebands, sidebands caused by microphonics and other internal signals from the mixing and logic circuits. These spurious signals will cause undesired responses in a receiver and will cause emission of spurious energy when the synthesizer is used to control the transmitter. The amount of spurious-response reduction for a transmitter signal would be about 60 dB in order to reduce the spurious output level to the legal limit. However, for receivers of high dynamic range, the reduction should be on the order of 80 to 90 dB. Lowering the spurious-response level to this value is difficult. If a synthesizer were constructed to provide 100-Hz steps, the 3-dB frequency of the loop filter would have to be very low in order to suppress adequately the reference sidebands if a 100-Hz reference were used. This would, undoubtedly, produce an excessively long lock-up time. In addition, the very low loop bandwidth would not allow for elimination of microphonics or low-frequency noise...

Frequency Division: The most effective method of achieving narrow frequency steps without a long lock-up time (or excessive noise) is to operate the phase-locked loop at a very high frequency and to divide the frequency down to the desired range with high-speed digital dividers. The frequency division will reduce the actual operating frequency, the frequency steps and the noise. For example, the 5-MHz version of the universal synthesizer uses a 50-MHz VCO and divides the frequency to 5 MHz with a high-speed, divide-by-10 chip. A 1-kHz reference is divided into 100-Hz steps at 5 MHz. Additionally, any noise becomes reduced by a factor of 10. The lock-up time is under 100 ms, which corresponds to a natural loop frequency of less than 100 Hz, with a damping factor of 7. If a 5-MHz VCO were used with a 100-Hz reference, the lock-up time would be about one second with the same order of sideband suppression. Even with a reduction of noise from the 50-MHz VCO, the relatively sharp 100-Hz bandwidth requires that the VCO be as free of microphonics as possible.

Another method of increasing the resolution of a synthesizer, without increasing the lock-up time or adding excessive noise to the system, is to use the technique of *reference pulling.* This involves slightly pulling the reference-frequency crystal so that the output moves an amount equal to the smallest synthesizer step. In the case of our 5-MHz synthesizer, the reference crystal is pulled an amount equal to 50 Hz at the output.

This technique does not provide the same frequency shift on all channels. If the shift is selected to be exact at the center of the tuning range, the shifted frequency will be low at the lower band edge and too high at the upper edge of the synthesizer range. The error will be slight if the number of channels divided by the value of the programmable divider is small. In the case of the 5.05- to 5.55-MHz synthesizer, the 50-Hz step is in error a maximum of 2.5 Hz at the band edges.

Tuning: Tuning the hf synthesizer requires more than just selector switches. Because of the popular method for tuning hf radio systems, some form of up/down counter and switches (or a shaft encoder) must be used. Among the schemes invented for tuning an hf synthesizer, the incremental shaft encoder most closely resembles the tuning characteristics of a conventional VFO, and is the easiest to use. This is an encoder that causes a counter to count up when rotated clockwise and down when rotated counterclockwise. The number of segments on the shaft encoder and the step size will determine the tuning rate. For a step size of 50 Hz, which is considered to be a reasonable compromise for amateur use, about 200 steps are required to have a tuning rate of 10 kHz per revolution (also acceptable for amateur use).

Synthesizer Considerations for VHF Communication Equipment

Most vhf-equipment synthesizers will be used in channelized fm communications where channel spacing is from 15 to 30 kHz. The vhf synthesizer requires a 5-kHz reference because of the arrangement of most channels. Unlike the hf synthesizer, the vhf unit will be programmed with selector switches or a computer, then left on one frequency. There are exceptions, specifically in the case of a scanning receiver, but these are not common. Therefore, lock-up time in the vhf synthesizer is not an important parameter. Noise and spurious outputs should, however, be reduced to a minimum. Spurious output can cause spurious responses in the receiver and cause emission of spurious energy from the transmitter. Noise in the VCO will be heard on incoming signals, and will appear as modulation on the transmitted fm signal. Since many vhf transceivers are used in mobile applications, freedom from microphonics is also important. Reference sidebands are particularly detrimental. This is because reference sidebands that are even as much as 60 dB down can cause out-of-band spurious signals when the transmitter is operating near the band edge.

Some spurious receiver responses are the result of signals being radiated from the logic elements in the synthesizer. In the synthesizer any energy that is a fraction of the operating frequency of the receiver, or a fraction of the i-f, can become an interfering signal. The solution is thorough shielding of the entire synthesizer.

Synthesizers used in transceivers often are required to shift the frequency as much as 10.7 MHz (or more) between transmit and receive. Such large frequency excursions require a well controlled lock-up time. Overshoot and time lag can be controlled to an extent by switching a fixed-value reactance (usually a capacitor) in or out of the VCO. This reduces the amount of frequency shift that has to be generated solely by the phase-locked loop. Nominally, the switched reactance will provide a 10.7-MHz shift with only small corrections from the phase-locked loop.

In addition to the i-f shift, vhf synthesizers are often required to provide a frequency shift for repeater offset. In general, the vhf synthesizer will seldom provide the frequency set on the programming switches. Repeater offsets, i-f offsets and the like are almost always involved. Many schemes are used to provide the necessary arithmetic required to provide the proper local-oscillator frequency from the synthesizer. The dual-modulus synthesizer allows offset frequencies to be programmed into the main counter, while the auxiliary counter is used for normal frequency programming. For synthesizers using a 10/11 prescaler and a 10-kHz reference, offset frequencies may be programmed with 100-kHz resolution, which takes care of all the standard i-fs and repeater offsets.

Making an Adaptable Synthesizer

The universal synthesizer implies that the programmable divider and the reference source be adaptable to practically any amateur application. With this goal in mind, the dual-modulus programmable divider was chosen as the technique. The design provides for up to four counters in both the main counter and the auxiliary counter. A standard 74LS series up/down counter was chosen for the individual counters. This chip, the 74LS168/9, is available as a decade counter (74LS168) or a four-bit binary counter (74LS169). A large variety of divisions and programming formats are available by mixing binary and decade counters in the programmable divider. In a synthesizer for a 2-meter receiver, for example, the first counter would be a binary counter programmed for 13, which would be the tens of megahertz for 130 MHz. The remaining counters would be normal decade counters.

The division of the programmable divider using a 10/11 prescaler is given by:

$$\text{division} = 10M + N$$

where M is the number programmed into the main counter, and N is the number programmed into the auxiliary counter. The only restrictions on M and N are that the counters be capable of achieving the count, and that M is greater than N. Channeling of the synthesizer can be accomplished by changing M, N or both. Table 1 shows the programming arrangements of some of the synthesizer applications. In some cases the tuning is done strictly with the N counter. This usually is done when an i-f offset is programmed into the main counter.

Programming Circuits

The programmable divider of the universal synthesizer requires TTL-compatible BCD information. This is typically either logic or switch closures where the switch is closed when a logic 0 is required and open when a logic 1 is needed. The inputs to the programmable divider are pulled up to the 5-volt supply with 10-kΩ resistors. When a logic element such as an up/down counter is used to program the divider, the connections are direct without any resistors.

The programming circuits used with the universal synthesizer shown in Fig. 2 are diagrammed in Fig. 3. An incremental shaft encoder using a serrated disc from a junked facsimile machine is used to increment or decrement an up/down counter. The counter provides information for the readouts on the front panel as well as the programmable divider. The digits read from 000.0 to 499.9, which corresponds to 5.0500 to 5.4999 MHz for use with a

Table 1.

Possible Universal Synthesizer

Frequency Ranges and Resolutions

Synthesizer Frequency (MHz)	*VCO Frequency (MHz)*	*Resolution*	*Readout*	*Crystal Freq. Ref. Divider*	*Notes*
5.0-5.5	50-55	50 Hz	100 Hz	$2.048/2^{11}$	Ssb transceiver
5.05-5.55	50.5-55.5	50 Hz	100 Hz	$2.048/2^{11}$	Drake TR7
7.0-7.5	70-75	50 Hz	100 Hz	$2.048/2^{11}$	40-m xmtr
7.455-7.955	74.55-79.55	50 Hz	100 Hz	$2.048/2^{11}$	40-m rcvr
50-54	50-54	10 kHz	10 kHz	$5.12/2^{9}$	6-m xmtr
60.7-64.7	60.7-64.7	10 kHz	10 kHz	$5.12/2^{9}$	6-m rcvr
133.3-137.3	133.3-137.3	5 kHz	5 kHz	$5.12/2^{9}$	2-m rcvr
144.0-148.0	144.0-148.0	5 kHz	5 kHz	$5.12/2^{9}$	2-m xmtr

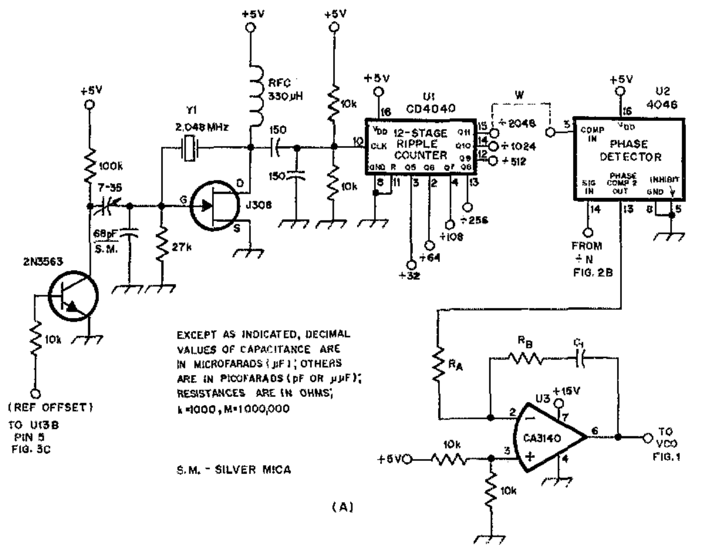


Fig. 2A — Frequency reference and phase detector for the universal synthesizer. R_A, R_B and C1 are to be determined.[3]
Q1 — Npn silicon rf/i-f amplifier, type 2N3563.
Q2 — N-channel JFET rf amplifier, Siliconix type J308 or equiv.
U1 — CMOS 12-stage ripple counter IC, type CD4040.
U2 — CMOS PLL, type 4046.
U3 — MOS operational amplifier, type CA3140.
Y1 — 2.048-MHz xtal.

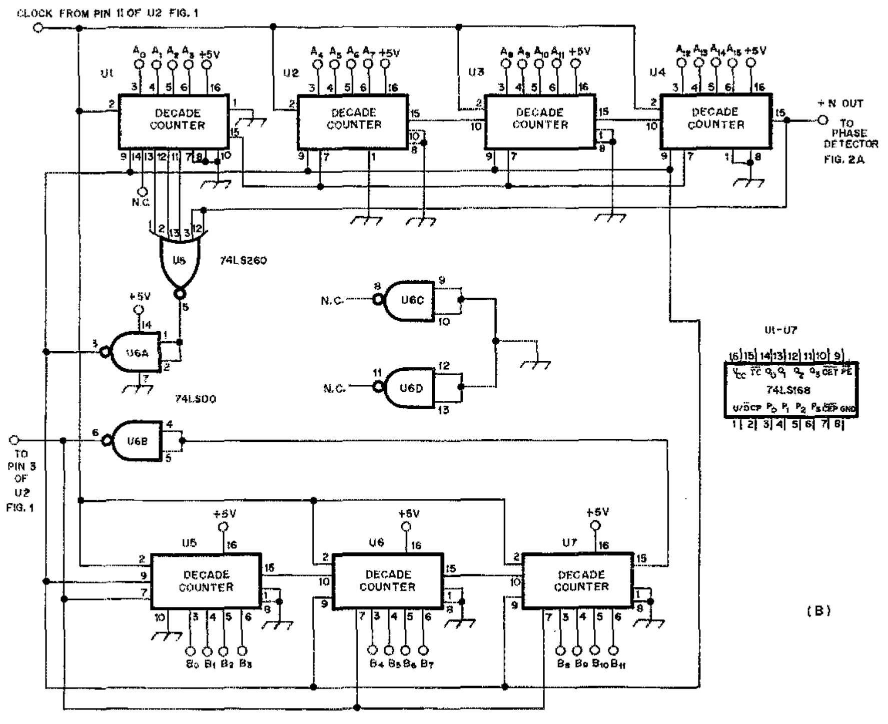


Fig. 2B — Programmable divider for the synthesizer.
U1-U4, incl. — TTL synchronous bidirectional BCD decade counter IC type 74LS168.
U — TTL dual five-input NOR gate IC, type 74LS260.
U6 — TTL quad two-input NAND gate IC, type 74LS00.
U7-U9, incl. — TTL synchronous bidirectional BCD decade counter IC, type 74LS168.

Drake TR-7 transceiver. For further information on programming circuits, the reader is referred to C. B. Opal's article, "Rotary Dial Mechanism for Digitally Tuned Transceivers."[2]

Synthesizer Construction

The synthesizer is logically divided into three sections. Programming electronics and the readout, if they are used, comprise the first section. This section does not have to be shielded from any receiver or transmitter stages since the logic is purely static. The programmable divider consists of another section, and should be shielded from the rest of the circuits because of the many high-speed waveforms capable of causing interference to communications equipment. The VCO constitutes the third section, and must be shielded from the other stages because of the sensitivity of the VCO to noise. In order to achieve a low-noise synthesizer, the VCO must not be allowed to pick up extraneous signals from any source. In some cases it is useful to add the dual-modulus prescaler from

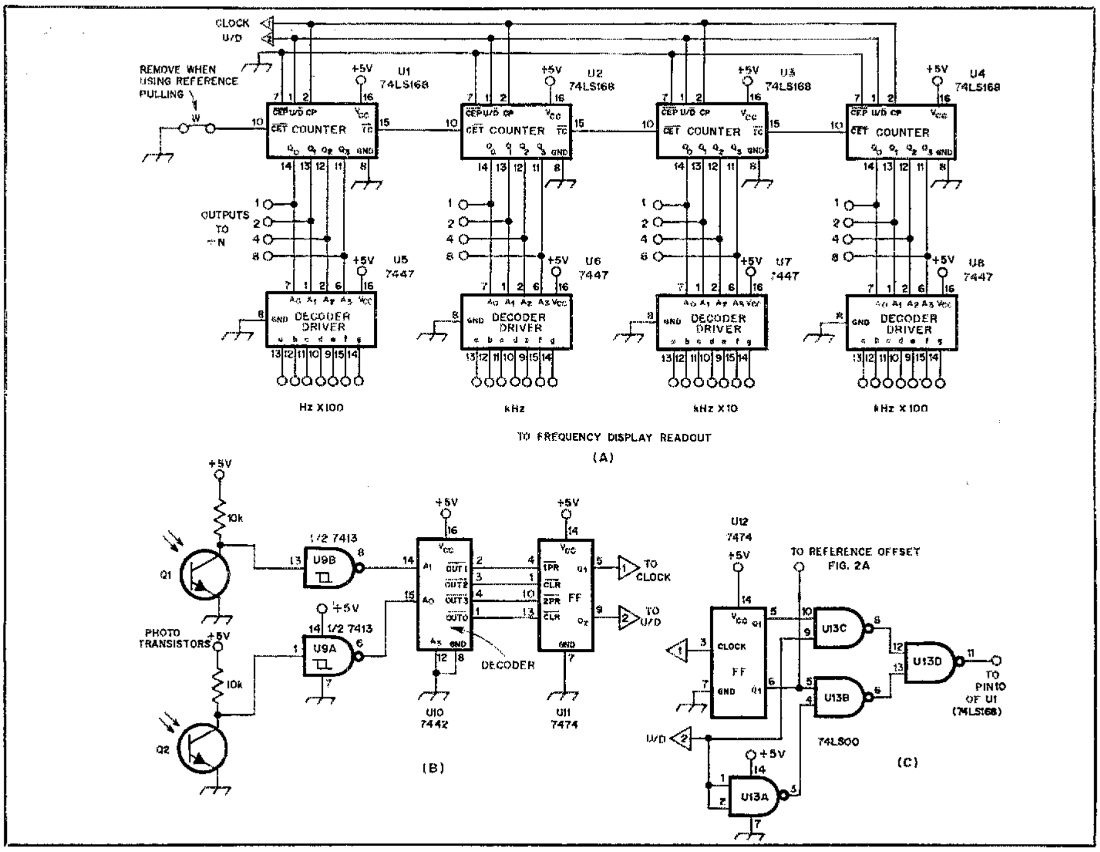


Fig. 3 — Programming circuits using up/down counters and incremental shaft encoder.
Q1, Q2 — Phototransistor.
U1-U4, incl. — TTL synchronous, bidirectional BCD decade-counter IC, type 74LS168.
U5-U8, incl. — TTL BCD to seven-segment decoder/driver IC, type 7447.
U9 — TTL dual Schmitt trigger IC, type 7413
U10 — TTL decoder IC, type 7442.
U11, U12 — TTL dual FF IC, type 7474.
U13 — TTL quad dual-input NAND gate IC, type 74LS00.

the programmable divider in the VCO shield.

Intended to be used as a part of a transmitter or receiver, the universal synthesizer should be built into the equipment rather than to stand alone. There are no special precautions other than those pertaining to shielding. Be sure, however, that the power supplies are free from noise and ripple. Power supplies that will operate an rf power amplifier reliably may not be suitable for a synthesizer. An isolated power supply, for *only* the synthesizer, is the best solution.

Several versions of the universal synthesizer have been constructed by the author. The lead photo and Fig. 1 show the 5.05- to 5.55-MHz version made to complement a Drake TR-7. In this case, the synthesizer is tuned with an up/down counter, and uses incandescent readouts. The entire synthesizer is contained in the 9- × 4-1/2- × 7-in. (229 × 114 × 178 mm) box except for the power supply, which is mounted remotely. Most of the shielding of this synthesizer is obtained by mounting the VCO and prescalers within the attached chassis. With this arrangement, spurious output is on the order of 80 dB down, as shown in the spectrum analyzer photo (Fig. 4).

The 2-meter version was used in the transmitter described in September 1980 *QST*.[4] In this case, since the synthesizer was being used in a transmitter, very little shielding was used, with the transmitter case providing most of it.

The chart in Table 2 can serve as a guide to program the synthesizer for other frequency ranges. The first column indicates the frequency range of the synthesizer output. This is not necessarily the frequency range of the VCO. In Table 1, the two 5 -MHz ranges have VCOs operating at 10 times the output frequency, and they are divided down. The second column indicates the proper connections for the MHz switch. The third column indicates the connections for the 100-kHz switch, and so on. Connections are made to +5 volts and ground, as indicated in columns 7 and 8.

The values for the loop amplifier depend on the lock-up time and spectral purity required. Synthesizer builders are advised to consult *Phaselock Techniques*, by F. M. Gardner,[5] for the proper loop-constant formula.

Spectrum Analysis of the 5-MHz Synthesizer

The spectral purity of the 5-MHz example synthesizer is shown in photos 4A, 4B and 4C. Photo 4A shows the noise and sideband spectrum out to 2500 Hz from the carrier. This is a major area of concern for communications equipment, since this is the area occupied by a typical ssb signal. As can be seen in the photo, the noise contained in the 50-Hz analyzer bandwidth is more than 70 dB down, greater than 500 Hz from the carrier. Photo 4B shows a very narrow sweep with a 5-Hz filter, in which a pair of sidebands at ± 60 Hz are visible. These sidebands are more than 50 dB down. Noise and sideband energy over 2.5 kHz removed from the carrier can cause reciprocal mixing and can reduce

Table 2

Guide for Using the Synthesizer for Other Frequencies

Switch Connections

Synthesizer Output Frequency Range	*MHz*	*100 kHz*	*10 kHz*	*kHz*	*100 Hz*	*Connnect to +5 V*	*Connect to Ground*
5.0-5.5		A8,9,10,11	B8,9,10,11	B4,5,6,7	B0,1,2,3,	A12,14	A13,15,4,5,6,, A7,0,1,2,3,
5.05-5.55		A8,9,10,11	B8,9,10,11	B4,5,6,7	B0,1,2,3,	A12,14,4,6	A13,15,5,7,0,1 A2,3
50-54	A4,5,6,7,	A0,1,2,3	B0,1,2,3			A8,10	A9,11
60.7-64.7	A4,5,6,7,	B4,5,6,7	B0,1,2,3			A9,10,0,1,2	A8,11,3
133.3-137.3	B8,9,10,11	B4,5,6,7	B0,1,2,3			A11,10,8,5 A0,3	A9,2,3,6,7,4 A2,1
144-148	B8,9,10,11	B4,5,6,7	B0,1,2,3			A11,10,9,6	A8,4,5,7,0,1,2 A3

If none of the programming pins of a divider IC is assigned, then that chip is not required and may be deleted. Both 2-meter synthesizers use reference pulling for generating 5-kHz steps. U3 in both 2-meter synthesizers is a 74LS169 IC.

the sensitivity of a receiver. Photo 4C shows the noise and sideband energy that is *up to 50 kHz away from the carrier.* This photo shows the noise dropping to 74 dB below the carrier at 10 kHz from the carrier. It drops to 80 dB below the carrier at ±50 kHz.

Establishing certain limitations of the analyzer is important whenever a spectrum analyzer is used for wide dynamic-range measurements. When spectrum photograph 4C was taken, the input signal was removed to determine the analyzer noise floor. The display level with no input signal was more than 80 dB below the analyzer reference. This does not represent the actual noise level of the analyzer. Because of reciprocal mixing in the spectrum analyzer, the actual noise floor of the analyzer will be a combination of the noise level observed when there is no input signal and of the noise of the local oscillator of the analyzer. The real noise floor of the analyzer may be determined by inserting a low-noise signal at the maximum imput level and by observing the noise level. The spectrum analyzer 10-MHz crystal calibrator was used for this check, and the resultant spectrum is shown in photo 4D. As may be seen, the noise floor of the spectrum analyzer is only 70 dB down near the carrier, and slowly decreases to near 80 dB down. In fact, the spectrum of the crystal oscillator appears to have more noise than the synthesizer. This may not be the case. The crystal oscillator operates at 10 MHz, and the synthesizer output is at 5 MHz. Possibly, the synthesizer in the spectrum analyzer, which is the most likely noise contributor, has slightly different noise characteristics at these frequencies. As a result of the limitations of the spectrum analyzers used for tests, some comments are in order concerning noise and sidebands of the synthesizer. The noise level shown in photo 4C does not show the noise level of the synthesizer. The actual noise level of the synthesizer is better than the 70 dB shown. From experience with the unit and some other tests, the noise level in a 50-Hz Gaussian bandwidth is estimated to be more than 80 dB below the carrier.

As previously mentioned, there is discussion among designers concerning what constitutes acceptable noise and sideband performance of a synthesizer used for hf receivers. This synthesizer has been in operation for more than a year (transmitting and receiving) during casual activity and contests. Comparisons have been made with a conventional PTO, and no significant differences have been noted. The 60-Hz sidebands, aside from being relatively far down in level, cannot be heard. Many amateur transmitters, and especially those that overdrive a linear amplifier, contain some 60-Hz sideband energy. This is usually the only 60 Hz component that is noticeable on received signals.

Although the entire sideband/noise story of the synthesizer is not known, the performance of the unit is sufficient for all but the most critical communications receiver or transmitter application. The vhf versions of the synthesizer are also being used on the air with excellent results. It is hoped that amateurs will use the universal synthesizer in new designs, improve the performance to suit their application and pass along the information to others.

There are many possibilities for the basic synthesizer design. Adapting the synthesizer to other frequencies will not be difficult if the builder has a good understanding of the principles involved. For a discussion of the dual-modulus synthesizer, see the article, "A High-Performance Synthesized Two-Meter Transmitter."[4]

Notes

[1]A. Helfrick, "A High-Performance Synthesized Two-Meter Transmitter," *QST*, Sept. 1980, pp. 17-21.
[2]C. Opal, "Rotary Dial Mechanism for Digitally Tuned Transceivers," *Ham Radio*, July 1980, pp. 14-17.
[3]F. Gardner, *Phaselock Techniques* (New York: John Wiley and Sons, 1966).
[4]See note 1.
[5]See note 3.
[6]See note 1.

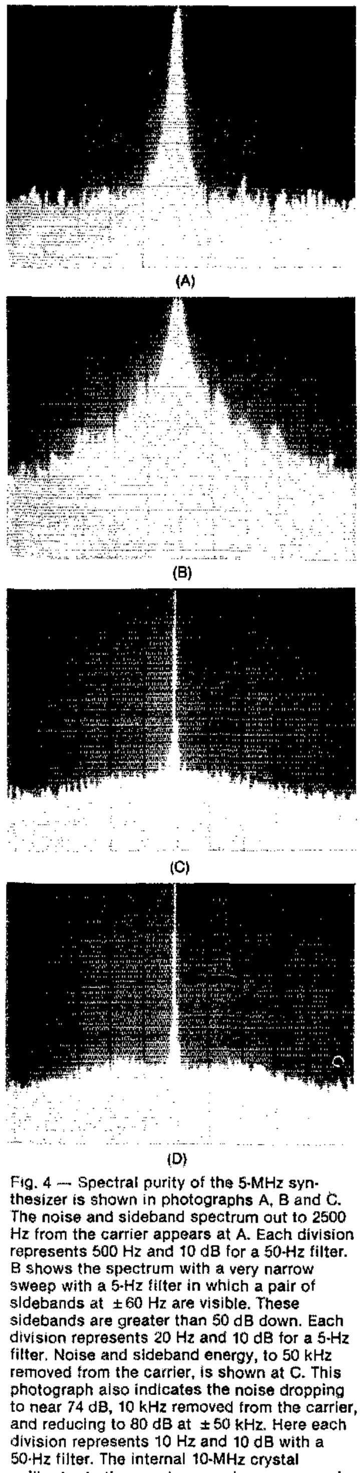


Fig. 4 — Spectral purity of the 5-MHz synthesizer is shown in photographs A, B and C. The noise and sideband spectrum out to 2500 Hz from the carrier appears at A. Each division represents 500 Hz and 10 dB for a 50-Hz filter. B shows the spectrum with a very narrow sweep with a 5-Hz filter in which a pair of sidebands at ±60 Hz are visible. These sidebands are greater than 50 dB down. Each division represents 20 Hz and 10 dB for a 5-Hz filter. Noise and sideband energy, to 50 kHz removed from the carrier, is shown at C. This photograph also indicates the noise dropping to near 74 dB, 10 kHz removed from the carrier, and reducing to 80 dB at ±50 kHz. Here each division represents 10 Hz and 10 dB with a 50-Hz filter. The internal 10-MHz crystal calibrator in the spectrum analyzer was used for making photo D (see text). In this case each division represents 100 Hz and 10 dB with a 50-Hz filter.

Variations in a Single-Loop Frequency Synthesizer

Planning to use frequency synthesis in your next transmitter or receiver? Here is some pertinent plain-language information, plus suggestions for design variations.

By Wes Hayward,* W7ZOI

Frequency synthesis is not new to the radio amateur. It has been used in 2-meter equipment for years. Recently, there has been commercial use of synthesis in amateur transceivers. The performance demands are more severe, although it appears that few manufacturers have met the challenge adequately.

The purpose of this article is to examine the fundamental concepts of a single-loop synthesizer; a complete analysis is not sought. Rather, the loop is examined with possible variations in mind. While the departures suggested are not offered as an ultimate solution to synthesizer problems, they may offer interesting, and perhaps unusual, avenues to the experimenter. We assume the reader is familiar with the basic concepts of the phase-locked loop (PLL) synthesizer. Details can be found in the references listed at the end of this article.

The traditional, single-loop, divide-by-N synthesizer is shown in Fig. 1. Output from a voltage-controlled oscillator (VCO) is applied to a frequency divider, usually programmable, with the result applied to a phase-frequency detector. The phase-detector reference comes from a crystal oscillator that is divided by a factor M. Detector output is filtered in the so-called H(s) or loop filter and then routed to the VCO for control. The system is described by:

$$f_v = f_x \frac{N}{M} \quad \text{(Eq. 1)}$$

where the VCO frequency is f_v and the crystal oscillator is at f_x. M is usually a fixed integer. The spacing between VCO

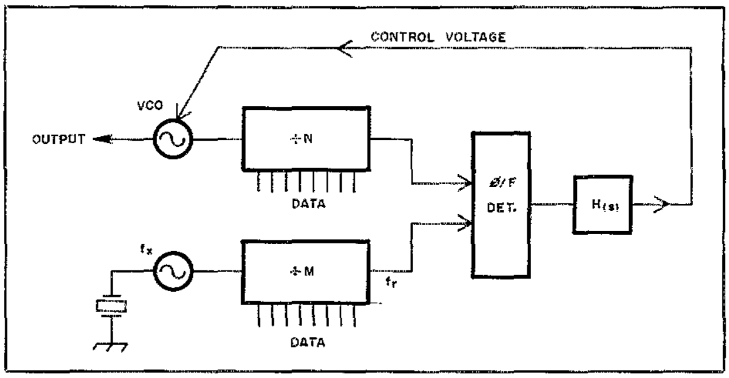


Fig. 1 — A simple, single-loop frequency synthesizer using a phase-locked loop.

frequencies (the resolution) is determined by:

$$\Delta f_v = f_x\left(\frac{N+1}{M}\right) - f_x \frac{N}{M} = \frac{f_x}{M} \quad \text{(Eq. 2)}$$

This is also f_r, the reference frequency at the phase detector if M is constant. Herein lies a major problem with the usual loop synthesizer. The reference frequency must be low if closely spaced channels are desired.

An Example

Consider a numerical example, a 5- to 5.5-MHz synthesizer with a resolution of 100 Hz. The crystal oscillator operates at 1 MHz. Hence, M = 10,000, and N will range from 50,000 to 55,000. The loop filter must be configured so that the overall PLL has unity gain, usually termed the "loop bandwidth," at well below 100 Hz. This system might have a loop bandwidth of 3 Hz. Response time is severely restricted. Very careful design must be employed to suppress the reference sidebands (spurious VCO outputs) occurring at a separation equal to the 0.1-kHz reference frequency.

A common method for reducing the problem outlined is to operate the VCO at 50 to 55 MHz, with a 1-kHz reference frequency. Loop bandwidth may be correspondingly larger, allowing for an improved response time. The VCO output is divided by 10 before being used.

Although vhf operation is popular, it is only an initial step in the process. Ideally, a reference frequency of 10 kHz or higher is preferred. Most modern synthesizers use several PLLs with a combination of mixing, division and filtering to achieve satisfactory performance. While excellent performance may be obtained, this is not typical of amateur equipment. Multiple-

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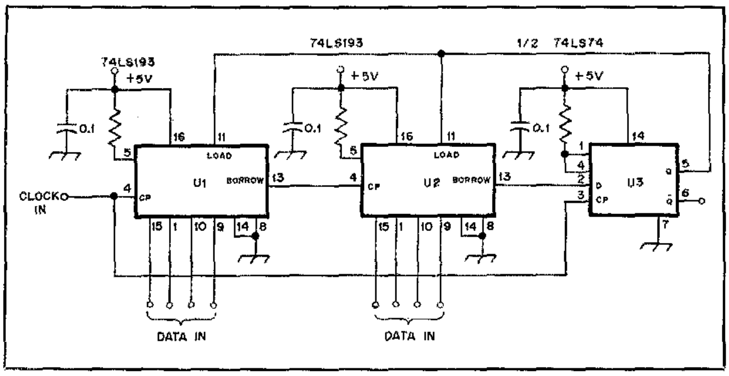


Fig. 2 — A simple, high-speed programmable divider using TTL or LS-TTL logic.

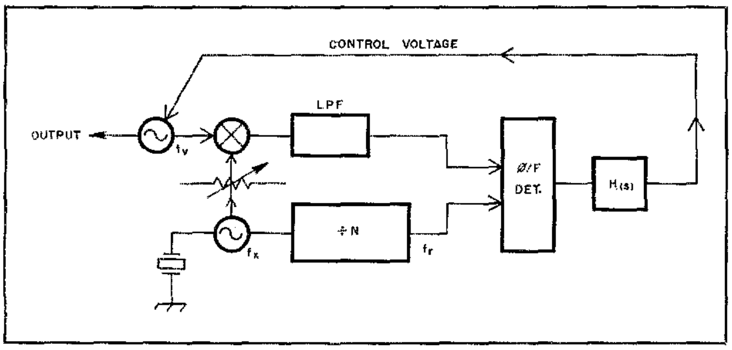


Fig. 3 — A simple synthesizer offering high resolution and a high reference frequency at the phase detector.

loop systems are complicated and costly.

Variations

Owing to the difficulties outlined, it is natural to consider design variations. There is no firm need for a synthesizer to produce frequencies that are separated by a fixed increment, neglecting traditional vhf fm applications. The major requirement is that the channel spacing be sufficiently small. The reference frequency must still be as high as possible.

These seemingly inconsistent goals, high resolution with a high reference, are possible if M of Fig. 1 becomes a variable. There are many ways that M could be controlled. One approach allows M to be simply related to N. Specifically, let N = M + K where K is a relatively small integer. Then, using equation 1,

$$f_v = f_x \left(1 + \frac{K}{M}\right) \quad \text{(Eq. 3)}$$

The channel spacing or resolution is given by:

$$\Delta f_v = f_x \left(1 + \frac{K}{M + 1}\right) - f_x \left(1 + \frac{K}{M}\right) \approx \frac{f_x K}{M^2} \quad \text{(Eq. 4)}$$

The reference frequency is:

$$f_r = \frac{f_x}{M} \quad \text{(Eq. 5)}$$

Two programmable dividers are required for this system. They are, however, simple and virtually identical. The implications are evident from the equations. The reference frequency is related to 1/M, but the channel spacing is proportional to $1/M^2$!

Consider an example. M varies from 128 to 256, and f_x is set at 4980.5 kHz. K is set at 1. Then, the VCO output will vary from 5000 kHz (M = 256) to 5019.5 kHz (M = 128). In spite of the close channel spacing, the reference frequency will be high, ranging from 19.5 kHz at M = 256, to 38.9 kHz at M = 128. A high loop bandwidth is now practical, providing improved transient response. Gaps between channels are filled in easily with VXO action applied to the crystal oscillator. Additional flexibility results from the programming of K.

Practical Details

A simple programmable divider is shown in Fig. 2. The 74LS193 four-bit binary counter operates in the down-count mode with two stages used in the example. The U2 "borrow" output drives a D flip-flop, U3, operated as a single stage shift register. The U3 output, which is one full clock cycle in length, actuates the "load" inputs of U1 and U2. The U3 output is synchronous with the high-speed clock, reducing phase-jitter problems that might result from variations in divider propagation delay. The division ratio is N + 2 where N is the data programmed into the divider.

The M, M + K synthesizer is easily constructed with dividers like those in Fig. 2. The M divider is the one shown. The M + K divider uses K more stages in the shift register. The same programming is then applied to both.

Other systems may be used to achieve similar results. For example, only one programmable divider is required if K = 1. This system is shown in Fig. 3. Analysis shows that:

$$f_v = f_x \left(1 + \frac{1}{N}\right)$$

This simple form might be especially attractive for portable applications where power consumption is critical.

A synthesizer of the M, M + K type is now in the writer's home receiver. M varies from 513 to 1025, while K is set at 23. Shift registers replace the D flip-flop of Fig. 2. The VCO operates at 10 MHz, while the crystal is in a voltage controlled crystal-oscillator circuit at 9.77 MHz, providing extra resolution. The 10-MHz output is divided to 5 MHz for use in the receiver. The loop is configured for a gain crossover of approximately 100 Hz.

The performance has been entirely satisfactory. Reference-sideband suppression exceeds 100 dB, while the phase noise is −145 dBc/Hz at a 10-kHz spacing from the carrier.

VXO Operation

It was mentioned earlier that a VXO could replace the crystal oscillator in Fig. 1. There will be a slight compromise in stability if this is done, but the usual VXO is still much more stable than a free-running LC oscillator. Once a VXO-based synthesizer is considered, the question arises as to what the proper N and M values should be.

A graph is presented in Fig. 4 to illustrate the problem. A VXO tuning range is shown. A desired operating-frequency range is also shown above the VXO span. This will be divided into sub-bands corresponding to changes in N or M. Three possible situations are presented. The curves at A show tuning segments that overlap. Plots at B present the opposite extreme — adjoining segments with gaps. The plots at C show the desired condition, exactly adjoining the ranges.

The equations that define N and M for the desired, exactly adjacent ranges or sub-bands are easily derived with results

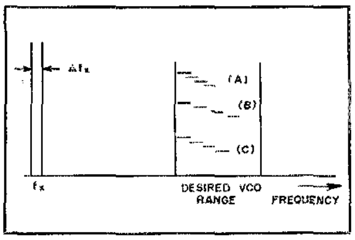


Fig. 4 — Horizontal lines within the VCO range represent sub-bands resulting from tuning the VXO over its range. Different sub-bands arise from changes in the M and N parameters of the synthesizer.

that are surprisingly practical. The minimum N value is given in terms of the VXO parameters by:

$$N_{min} = \frac{f_x}{\Delta f_x} \qquad \text{(Eq. 6)}$$

The required M value for a desired output frequency, f_v, is then:

$$M = \frac{f_x N_{min}}{f_v} \qquad \text{(Eq. 7)}$$

The most significant detail is found in Eq. 7. The minimum N is not a function of the output frequency, f_v. The equations will generally predict irrational numbers for both N_{min} and M. They must be rounded off to integers for simple synthesizes.

Consider a numerical example — a transceiver using a 9-MHz i-f that should operate in the 7- and 21-MHz ranges. The LO (VCO) required will then operate at 16 and 12 MHz. Assume the VXO has a lower frequency of 11 MHz and a range of Δf_x = 11 kHz. This is reasonable performance; the tuning range is only 0.1%. Eq. 6 shows that N_{min} = 1000. Integer approximations of Eq. 7 show that M should be 688 for f_v = 16 MHz, and 917 for f_v = 12 MHz. Results for changing N are shown in the table.

An overlap between tuning segments appears as N increases beyond N_{min}. It is, however, small. This synthesizer could be especially practical. M is chosen for a particular band. Tuning within the band is then realized by moving the VXO and by changing the N value over a small range that does not depend upon the band. The tuning rate will change with band changes — the penalty for this simplicity. Examination suggests that this system would be practical even if used without a digital readout.

Concluding Remarks

This paper presents some ideas that were used experimentally by the writer. Clearly, the goal has not been to present construction information; rather, it has been to communicate details of possible simplifications. It is practical to achieve reasonable performance, even with a single-loop synthesizer, if some of the traditional requirements are ignored.

Table 1
Example of a VXO-Based Synthesizer

M	*N*	f_{lower} (kHz)	f_{upper} (kHz)
688	1000	15,988.37	16,004.36
688	1001	16,004.36	16,020.36
688	1002	16,020.35	16,036.37
688	1003	16,036.34	16,052.37
917	1000	11,995.64	12,007.63
917	1001	12,007.63	12,019.64
917	1002	12,019.63	12,031.65
917	1003	12,031.62	12,043.66
917	1010	12,115.59	12,127.71
917	1011	12,127.59	12,139.72

f_{lower} and f_{upper} for a given set of N and M values show the frequency range realized by VXO tuning.

Even greater flexibility is offered by multiple-loop designs.

Topics not covered are the design of the VCO and of the loop filter. Both are vital in the design of systems with good suppression of reference sidebands and low phase noise.

References

[1]R. Petit, "Frequency-Synthesized Local-Oscillator System," *Ham Radio*, Oct. 1978. (A good example of a carefully designed traditional synthesizer.)

[2]Manassewitsch, *Frequency Synthesizers, Theory and Design* (New York: John Wiley and Sons, 1976).

[3]W. Hayward, *An Introduction to Radio-Frequency Design*, Prentice-Hall, Inc., tentative publication in 1982. See ch. 7, Oscillators and Frequency Synthesizers.

Strays

"CQ, calling CQ, Maritime Mobile, Region 2 aboard the 'Love Boat' . . ." A mid-March cruise on the *Island Princess*, of TV's "Love Boat" fame, was combined with an operating event for seven California, and one Irish, amateurs. Enjoying the balmy weather and the DX are (l-r) Dick Brinkman, N6AYV; Gene Clark, W6DQH; and Jim Walden, W6ESJ. Approximately 1500 contacts, and unknown quantities of tanning lotion, were enjoyed on the voyage from San Juan, Puerto Rico, to Los Angeles, via the Panama Canal. *(photo courtesy W6CFK)*

CODE IN CAPTIVITY

☐ In a much-publicized incident during the Vietnam military actions, former POW Jeremiah A. Denton, Jr., now a U.S. Senator from Alabama, blinked out the word "torture" with his eyelids during a forced TV interview during his captivity. In response to a letter I wrote, Senator Denton declares that he is wholeheartedly in favor of keeping the code requirements for Amateur Radio. "In my particular case," he states, "had I not known the Morse code, I would have been denied the one viable option of communication open to me, while a prisoner of war. I am definitely in favor of it." — *Russell Crom, AG9N, Mt. Prospect, Illinois*

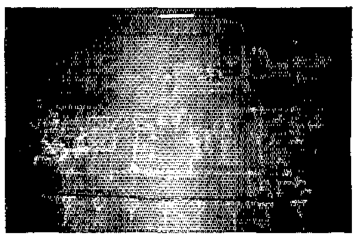
QST congratulates . . .

☐ John W. Ferguson, WØQWS, of Independence, Missouri, who was named Director of Libraries by the trustees of the Mid-Continent Public Library.

☐ D. R. Allen, K4HJM, who was named "Southern Section Country Cousin of the Year" for his contributions to the net, which is dedicated to "the service and help for all mankind."

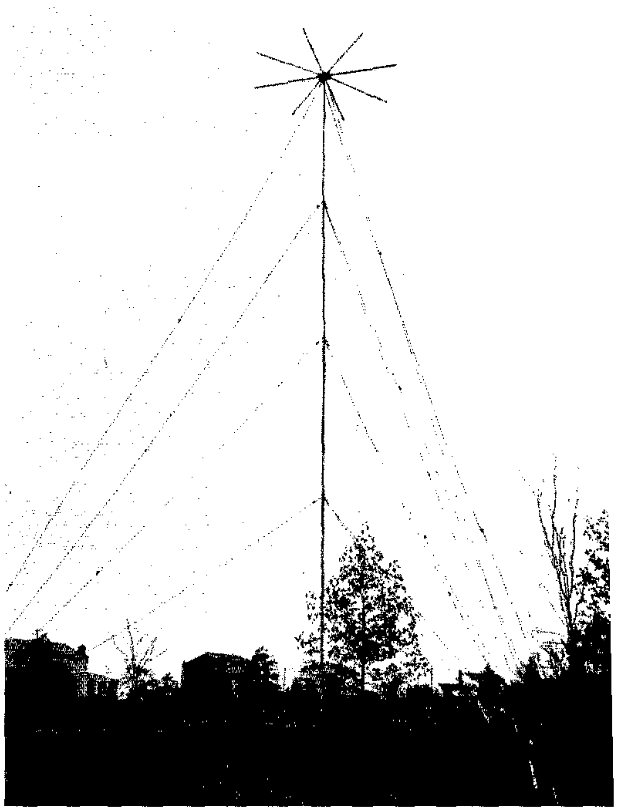
JOURNEY INTO SPACE

☐ The Club and Training Department announces the addition of a new NASA slide show to the library. *NASA: Journey Into Space* contains 80 slides and is 30 minutes long. Quantities are limited, so please list alternate dates. — *Joyce Martin, Club and Training Dept.*



Cortland E. Richmond, KA5S/DA1GI, will never forget his first radio, a two-tube regenerative receiver featured in *How to Become A Radio Amateur* almost 25 years ago. His mother, Jinx, hooked this rug using his radio's circuit diagram for a pattern; she later even included the power supply in the design. *(photo courtesy KA5S/DA1GI)*

A Modest 45-Foot DX Vertical for 160, 80, 40 and 30 Meters



If it's DX you want, this low-angle radiator will put it in your lap! Build it now and collect DX dividends this winter.

By Wayne H. Sandford, Jr.,* K3EQ

Twenty years is a long time to be away from Amateur Radio! But, fortunately, when I returned to the airwaves in December 1975, the season for working distant stations had arrived. The allure of finding signals from other continents became almost magnetic, and before long, the DX bug had clearly bitten me again. With a 120-watt homemade cw rig and a 120-ft end-fed wire strung 28 ft above the ground,[1] I worked what countries I could while being constrained by the nature of this "sky wire." Without question, a better antenna was needed for my DXing efforts. What to do?

Improvements began with the construction of a 36-ft wooden tower I built to support a 2-element quad for 10, 15 and 20 meters. From the top of this tower, I hung a 40-meter vertical antenna, followed by the installation of twenty-four 50-ft radials. DXing on 40 meters improved noticeably as a result of this effort.

For awhile I was satisfied to leave my 80-meter inverted L alone. It was strung between the quad tower and a mast supporting one end of my end-fed wire. Admittedly, results with this antenna were mediocre. During the winter of 1979-80, as I approached the requirements for Five-Band DXCC on all bands except 80 meters (only 50 confirmed), I began to think about better DX antennas for the lower frequencies.

Research

I looked through back issues of *QST* and other publications for antenna articles: A *QST* article by Hollander[2] triggered thoughts of constructing a multiband vertical antenna. Radiation patterns of 1/8-, 1/4-, 1/2- and 5/8-wavelength vertical antennas indicate that an antenna having this configuration would give low-angle radiation on four bands. Calculations indicated these fractional lengths could be applied to 160-, 80-, 40- and the new 30-meter band that will become available sometime during 1982. A 5/8-wavelength vertical antenna for 30 meters is nearly 60 ft high. A half wavelength for 40 meters is 70 ft; 1/4 wavelength for 80 meters is 70 ft; and 1/8 wavelength on 160 meters is 68 ft. Therefore, if a pole 60 ft high were used, series inductance could be added to obtain the required electrical length on all four bands. But as much as I desired to have a vertical antenna 60 ft tall or greater, I decided to see if an antenna as short as 40 ft would serve my purpose. Furthermore, although not too much has been said by the neighbors about the 2-element quad, I feared that a 60-ft vertical antenna might stimulate a barrage of adverse comments!

After pondering the matter for some time and studying radiation resistance and reactance plots for vertical antennas,[3] the solution of the problem came into focus. For an antenna shorter than 60 ft some form of loading was needed. A "top hat" provides an efficient means for doing this.[4]

This multiband antenna should first be calculated for 5/8 wavelength on 30 meters. It will give an almost perfect match to a 50-ohm line by adding a small

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[1]Notes appear on page 31.

Table 1

Dimensions for Optimum Height of the Vertical Radiator

Radiator Height (ft)	*Top-hat dia (ft)*	*Calculated Heights for 10.125 MHz (Deg.) (Sum = 225 Deg.)* Height	Top Loading	*Calculated Heights for 7.025 MHz (Deg.)* Height +	Top Loading	= Sum	*Calculated Heights for 3.525 MHz (Deg.)* Height +	Top Loading	= Sum	*Calculated Heights for 1.8125 MHz (Deg.)* Height +	Top Loading	= Sum
43	11	159.5	65.5	110.6	56.7	167.3	55.5	37.4	92.9	28.5	21.4	49.9
44	9.6	163	62	113.2	52.6	165.8	56.8	33.2	90	29.2	18.6	47.8
45	8.2	166.9	58.1	115.8	48.1	163.9	58.1	29.2	87.3	29.9	16	45.9

Meters = feet × 0.3048

Table 2

How Top-Hat Loading Is More Effective on Lower Bands in Increasing Effective Height

F (MHz)	*Top Loading (Deg.)*	*Top Loading (ft)*	*Ant. Effect. Height (ft)*	*Ant. Effect. Height (λ)*
1.8125	18.6	28	72	0.133
3.525	33.2	25.7	69.7	0.249
7.025	52.6	20.5	64.5	0.456
10.125	62	16.7	60.7	0.625

Meters = feet × 0.3048

inductance in series with the antenna at the feed point, then tuning out the capacitive reactance with a shunt inductor. If the antenna is a half-wavelength long at 40 meters (the length at which reactance is zero), it could be adjusted easily by using a parallel-tuned tank in series with the ground lead, and by tapping the feed line at a point on the tank just a few turns up from the ground end. The tap and tuning adjustments are arranged to give the best match. It seemed that if the antenna were 1/4 wavelength long at 80 meters, it could be increased in length to provide a 50-ohm feed point by means of a small series inductor and a shunt capacitor to tune out the reactance. In addition, since it would be considerably shorter than 1/4 wavelength on 160 meters (on the order of 1/8 wavelength) it could be made to look like a 1/4-wavelength antenna by adding series inductance to ground. Matching could be effected by tapping the line a few turns up on the coil. Many dyed-in-the-wool DXers would not consider a 1/8-wavelength vertical antenna, but Sevick[5] has shown that this can be an efficient radiator when used with an effective ground system and a low-loss, base-loading inductor.

Design Procedure

I could not remember having seen details of vertical antennas that explained how to calculate the effect of the "top hat." But in past issues of *QST* I found an article by Schulz,[4] which was just what I needed. Although his design was for a 1/4-wavelength antenna, the equations are presumed applicable for calculating the "top-hat" effects on 1/2- and 5/8-wavelength antennas. Calculations with his equations indicated that a 44-ft vertical antenna loaded by a 9.6-ft diameter "top hat" would give the results I wanted. My aim was to have a vertical antenna that would be 5/8 wavelength on 30 meters, 1/2 wavelength on 40 meters, 1/4 wavelength on 80 meters and 1/8 wavelength on 160 meters. Table 1 shows calculated electrical lengths and required "top-hat" diameters for vertical radiators from 43 to 45 ft high, showing that the 44-ft height is about right to give the required four-band performance. Table 2 shows that the "top hat" is more effective in increasing the length of the radiator as the frequency goes down.

Since this design promised a high degree of success, the preliminary circuit (Fig. 1) was prepared. A parts list was compiled (Table 3), and material collection was begun.

Construction

Purchases for the project included a 40-ft telescoping TV mast (its extended length turned out to be 38.5 ft) and a 6-ft galvanized fence post, which would just fit inside the lower mast section. With 6 in. of the post telescoped inside the mast,[7] the overall length was the required 44 ft. To secure the mast to the fence post, two slits were made in the lower section of the mast with the aid of a hacksaw. A stainless-steel radiator hose clamp and a 1/4-20 bolt, 2-1/2 in. long, were used to clamp the mast firmly to the fence post.

The eight-spoke "top-hat" is constructed in a manner similar to that used by Hollander.[8] There are eight 5-ft lengths of 1/2-in. diameter conduit fastened to an 11-in. square, 1/8-in. thick aluminum plate. The spokes are held firmly against the plate by means of 6-32 stainless-steel hardware. Aluminum angle stock is used to fasten the plate to the top of the upper mast section. This stock, which is 1/8 in. thick by 1-1/2 in. wide, is cut into four 1-in. lengths. Two 1/4-20 stainless-steel bolts, 2 in. long, are used to fasten the angles to the upper mast section. I suggest the use of lock washers in all cases where the bolts are used. Good electrical contact can be assured by connecting all "top-hat" radials together and to the mast with 1/4-in. wide braid using stainless-steel, self-tapping screws. Three 48-in. long heavy-duty, screw-in steel anchors are used for the guy points. They are located 25 ft from the tower base. Four sets of guys are used. They are made from no. 12-1/2-gauge steel wire. A total of 42 egg insulators are installed to break the guys into lengths no longer than 19 ft. The base of the mast sits on a 7-in high, heavy-duty standoff insulator, which in turn rests on a 6-in. diameter concrete base that is 3 ft deep, with 4 in. protruding above ground.

Installation of the Mast

First, stand the mast upright and attach the lower set of guys to the anchors. The three top sections of the mast are pushed up from a ladder resting against the mast. Proceed by attaching the next set of guy wires to the anchors. The ladder is then extended to the second guy level, and the upper section is pushed up next. A piece of 1/4-in. braid is fastened across the joint between the top and second section of the mast, using self-tapping, stainless-steel screws. Follow this by pushing the second and top sections up together. Next, a strap is connected across the other two joints to ensure good electrical contact. Complete this part of the installation by connecting all guys to the mast, then adjust them so that the mast stands vertically.

All tuning components are mounted in a fiberglass box. Fig. 2 shows the open tuning box and components. Fig. 3, a photograph of the base of the antenna, shows how the box is attached to the 3/4-in. galvanized water pipe ground rod, and how the radial wires are terminated on a square aluminum plate (similar to the method used by Sevick).[9] The plate is fastened to the ground rod with aluminum angle brackets, stainless-steel hardware

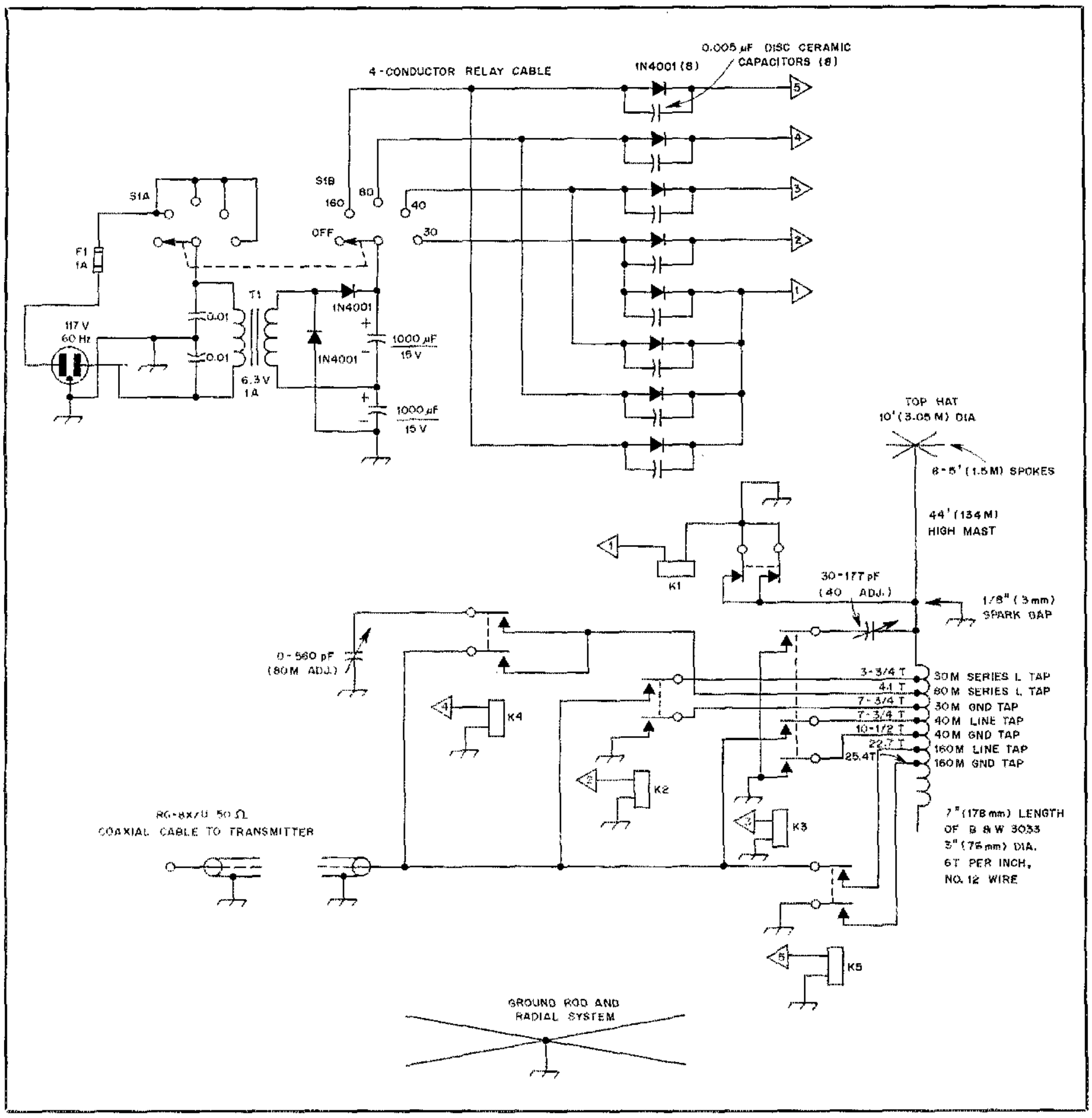

Fig. 1 — Schematic diagram for the K3EQ 160-, 80-, 40- and 30-meter vertical antenna. The circuit for remote band switching is included. There are 52 radials and a ground rod in the system. Low-angle radiation makes this an effective DX antenna.

and a stainless-steel hose clamp. All four corners of the aluminum plate are connected to the ground feedthrough in the bottom of the tuning unit with heavy copper braid. This insulator, as well as the one for the lead going to the base of the mast, is sealed against moisture by applying silicone compound. The relay control cable and the 50-ohm coaxial line enter the bottom of the tuning box through small holes that ensure a snug fit. The completed antenna, as shown in the photograph, has the capacitance hat resting atop the mast. The mast is stabilized by careful positioning of the guy wires. A wooden fence is placed around the base of the mast to help protect people and animals from possible rf burns.

Radial System

Installation of the mast took place during the driest Pennsylvania summer in 15 years. As fall approached, the soil was still too hard to bury the radials, so they were laid on the surface. Each wire was stretched tightly and fastened with several 6-in. lengths of heavy bus wire, which had been formed into hooks. When rain eventually fell, the radials were buried 2 to 3 in. in the ground.

All radials are 100 ft long except those toward the sides of the lot (which is only 150 ft wide). One side has 70-ft radials, while the other has 80-ft radials. Some 4800 ft of wire makes up the 52 radials. I used insulated hookup wire, but aluminum clothesline[10] or galvanized electric fence wire is satisfactory.

According to Stanley,[11] the efficiency

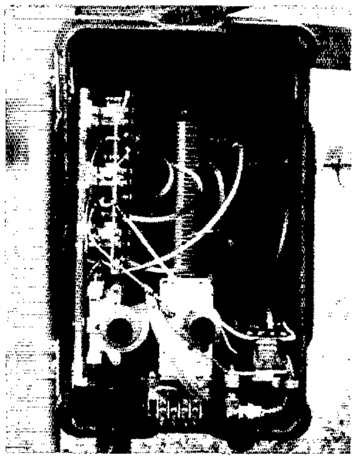

Fig. 2 — A view of the vertical antenna tuning network. Components are mounted on a framework of 1/4-in. thick Plexiglas, which slides into the fiberglass box.

Table 3
Shopping List

1 — telescoping TV mast, 40 ft long, Montgomery Ward no. 63A19735R, $39.95.
1 — galvanized fence post, 6 ft long, 2-in. dia., $6.
4 — lengths of thin-wall conduit, 10 ft long, 1/2-in. dia. Each length is to be cut into 5-ft sections. Montgomery Ward no. Z83A1004R, size no. 2, $1.89 ea.
1 — length of 3/4-in. galvanized water pipe for ground rod, 10 ft long, Montgomery Ward no. 81A40103R, $12.
2 — rolls of no. 12-1/2 gauge galvanized steel wire for guys, Sears no. 32H10125, $6.29 ea.
3 — earth anchors, screw type, 48-in. long, Sears no. 32H21946C, $7. ea.
42 — strain insulators for guy wires, Radio Shack no. 270-1518. Price with 10% quantity discount, $13.04.
120 ft (36.5m) RG8X-50 coaxial cable available from Texas Towers, Plano, Texas, $18.
120 ft four-conductor control cable for relay circuit, gray vinyl jacket. Sold by Fair Radio Sales, Lima, Ohio, $14.40. A substitute would be TV rotator cable, Sears no. 57H6732, 10¢ per foot.
5000 ft no. 18 vinyl-covered hook-up wire for radials, sold by Fair Radio Sales, $75. A less expensive (but less durable) substitute is no. 17 gauge galvanized steel wire. This is available from Sears, no. 32H22056C, at $16 per roll. Each roll has 2640 ft of wire.
1 — B & W coil no. 3033, 10 in. long, 3-in. dia, no. 12 wire, 6 tpi, available from Barker and Williamson, 10 Canal St., Bristol, PA 19007, $7.97.
1— fiberglass case, 14-1/2 × 14 × 4-1/4 in., available from Fair Radio Sales, $5.
5 — relays, dpdt plus spst, N.O., 12 V dc, Leach no. 1077, available from Fair Radio Sales, $2 each.
1 — variable capacitor, 30-177 pF with both sections in parallel, 0.094-in. air gap. Fair Radio Sales, no. C-221/T-195, $3.95.
1 — variable capacitor, 0-563 pF, 0.03-in. air gap, Fair Radio Sales, no. 76348-C, $2.95.
2 — cone-style feedthrough insulators, Fair Radio Sales, no. 3G584IN-84, 25¢ each.
1 — standoff insulator, 7-in. × 1-1/4 in. dia, Fair Radio Sales, no 5970-405-8992, $4.

Miscellaneous: parts for control box purchased from Radio Shack, $20.
Stainless-steel hardware from Elwick Supply Co., Somerdale, New Jersey, $12.
Aluminum angle stock and 1/8-in. aluminum plates from local metal suppliers, hose clamps, ready-mix concrete, copper shielding and braid, $10.

Note: The total cost was approximately $300 at the time the antenna was built. It is reasonable to expect the present costs to be about 10% higher. By "scrounging" parts from your junk box, and from friends and flea markets, the cost can be reduced.

of a 160-meter antenna might be improved by using more or longer radials. For the other bands, however, not much improvement is likely to be achieved by increasing the lengths or adding radials. For 160 meters, the radials are only 0.184 wavelength, but for 80 meters they are a respectable 0.352 wavelength long. Ground losses are probably on the order of 2 dB on 40 meters and about double that on 160 meters. Table 4 is a chart of the wavelengths of the 100-ft radials versus frequency.

Tuning

Tune-up is done on 160 meters first, then progressively on the higher bands. I used the K4KI[12] tune-up bridge and a dummy load at the base of the antenna to make the adjustments. My transmitter was in the second-floor shack. I should have carried it to the base of the antenna to make the matching process easier. Finding the correct coil taps for 160 meters while using the bridge seemed almost impossible. By tightly coupling a grid-dip oscillator to a two-turn link in the ground lead, the correct ground tap point was located. The line tap was then positioned properly with the aid of the tune-up bridge. Adjustments for the other bands followed without difficulty. The required inductances were close to the calculated values. Fig. 4 shows an SWR plot for the antenna. Refer also to Table 5.

This data was obtained in the shack at the end of the 120-ft length of RG-8X coaxial feed line. The SWR might be brought closer to 1:1 on 30 meters by further adjustments for that band. After the tap points on the coil were found, I soldered miniature alligator clips to the coil. A purist might prefer to remove the

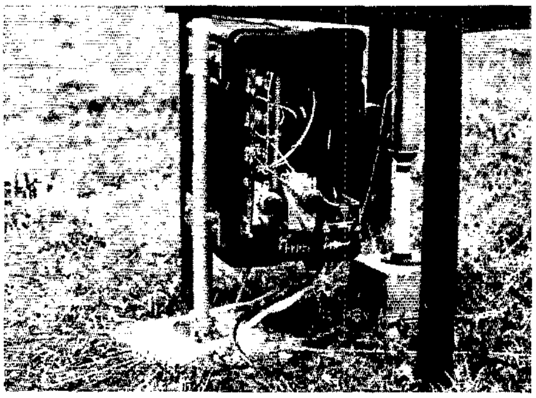

Fig. 3 — Base of the vertical antenna with the tuning-component box mounted on the ground rod. The radials terminate on a square aluminum plate.

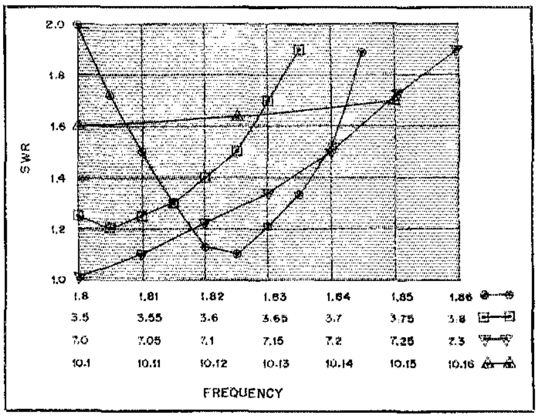

Fig. 4 — SWR curves for the K3EQ vertical antenna. See Table 5 for related information.

clips and solder the braid directly on the coil. I left the clips there to facilitate future adjustments.

The antenna is resonant outside the low ends of the 30- and 40-meter bands. This apparently results from the extra foot or so of wire from the base of the mast to the tuning box and ground. Additionally, I did not cut the "top hat" to the calculated 9.6-ft diameter, but left it at 10 ft. Shortening the mast 1 foot should bring the resonant points within the 30- and 40-meter bands. If additional correction is needed, then remove 2.5 in. from each of the "top-hat" spokes. This change may require repositioning of the taps from the points indicated on the schematic diagram (Fig. 1).

Afterthoughts

Phone operators may think this article has nothing to offer them. Therefore, I went through an exercise to determine the optimum configuration to cover the new 30-meter band and the 160-meter band, and also to allow adjustment for the lowest SWR at the center of the 40- and 75-meter phone bands. To accomplish this, the mast must be lengthened to 47.5 ft, and the top-hat diameter reduced to 5.8 ft. Table 6 charts the calculations that lead to this conclusion.

Of course the tuning network would allow this configuration to be tuned to the 40- and 80-meter cw bands by those operators who might like to tune the antenna to any part of these bands. For 80-meter cw, more series inductance would be needed for the 44-ft version. For 40-meter cw, some series inductance would have to be inserted between the mast base and the parallel-tuned tank. This requires only moving all three 40-meter coil taps down the coil a few turns. Proper adjustment for operation anywhere in the 40- or 80-meter bands can be made with this configuration.

The full 40-meter band could be covered with an SWR of 1.4:1 or less if this matching network is tuned for the lowest SWR at 7.15 MHz. This can be verified by extrapolating the SWR curves of Fig. 4. Likewise, it appears that if the configuration were tuned for the lowest SWR at 3.8875 MHz, all of the 75-meter phone band could be covered with an SWR of 1.7:1 or less.

Conditions were not favorable for evaluating its DX qualifications when I conducted tests with this antenna. Results obtained were nevertheless gratifying. Europe and South America have been worked with very good reports on 80 and 40 meters. On 160 meters, with 100-watts input to a TX4C, I received an RST 589 report from KP2A followed by a 549 from VP9KA. To the west, my circle of contacts has been from Minnesota (559) through Wisconsin (579), Iowa (559), Kansas (539) and Arkansas (559). A 339 report came from New Mexico, and a station in Florida gave me a 579. All of these contacts were made in the early evening.

I have shown none of the math calculations; only the results in the form of tables. Amateurs who desire a copy of these calculations should send a request to the ARRL Technical Department. Enclose an s.a.s.e. and $1.

If you wish to enhance your DX capabilities on the lower bands without erecting a "monster antenna," to be prepared for the new 30-meter band when it becomes available or to try the recently expanded "top band" for the first time, then this may be just the antenna for you. Build it, and you'll be ready for some good DXing!

Table 4

Length of Ground Radials in Wavelengths Versus Frequency

F (MHz)	*100-ft (30-m) Radials (length in λ)*
1.8125	0.184
3.525	0.357
7.025	0.712
10.125	1.029

Notes

[1]meters = feet × 0.3048.
[2]D. Hollander, "A Big Signal from a Small Lot," *QST*, April 1979, pp. 32-34.
[3]Editors of *73 Magazine, The Giant Book of Amateur Radio Antennas* (Summit, PA: Tab Books).
[4]J. Sevick, "The W2FMI Ground-Mounted Short Vertical," *QST*, March 1973, pp. 13-18, et al.
[5]J. Sevick, "Short Ground-Radial Systems for Short Verticals," *QST*, April 1978, pp. 30-33.
[6]W. Schulz, "Designing a Vertical Antenna," *QST*, Sept. 1978, pp. 19-21.
[7]millimeters = inches × 25.4.
[8]See note 2.
[9]See note 4.
[10][Editor's Note: In regions where the soil has a high acid or alkaline content, rapid disintegration of aluminum wire will occur, sometimes within a few months. Neoprene-jacketed no. 8 aluminum wire (sold by Sears as overhead power wiring for outdoor applications) is relatively inexpensive and is highly resistive to corrosion.]
[11]J. Stanley, "Optimum Ground Systems for Vertical Antennas," *QST*, Dec. 1976, pp. 13-15.
[12]W. Vissers, "Tune Up Swiftly, Silently and Safely," *QST*, Dec. 1979, pp. 42-43.

Table 5

Data for SWR Curves in Fig. 4

Frequency (MHz)	*SWR*
1.8	2.0
1.805	1.72
1.81	1.5
1.815	1.3
1.82	1.13
1.825	1.1
1.83	1.21
1.835	1.33
1.84	1.52
1.845	1.89
3.5	1.25
3.525	1.2
3.55	1.25
3.575	1.3
3.6	1.4
3.625	1.5
3.65	1.7
3.675	1.9
7.0	1.01
7.05	1.1
7.1	1.22
7.15	1.34
7.2	1.5
7.25	1.72
7.3	1.9
10.1	1.6
10.125	1.64
10.15	1.7

Table 6

Chart for Selecting Optimum Radiator for Phone Bands (7.225 and 3.8875 MHz)

Radiator Height (ft)	*Top Hat Cap (pF)*	*Top Hat Dia (ft)*	*Calculated Heights for 10.125 MHz (Deg.) Sum — 225 Deg.*		*Calculated Heights for 7.225 MHz (Deg.)*			*Calculated Heights for 3.8875 MHz (Deg.)*			*Calculated Heights for 1.8125 MHz (Deg.)*		
			Height	Top Loading	Height	Top Loading	Sum	Height	Top Loading	Sum	Height	Top Loading	Sum
47	49	6	174.3	50.7	124.39	41.08	165.47	66.93	25.13	92.06	31.2	12.27	43.47
47.5	46	5.8	176.17	48.83	125.7	39.2	164.9	67.64	23.69	91.33	31.54	11.56	43.1
48	43	5.3	178.02	46.98	127	37.36	164.36	68.35	22.33	90.68	31.87	10.84	42.7
49	37.7	4.75	181.73	43.27	129.68	33.88	163.56	69.78	19.86	89.64	32.53	9.56	42.09

Note: Subtract length of lead into tuning unit plus ground lead from calculated radiator height.

A Phase-Locked-Loop Demodulator and Modulator

Out of phase with today's trends? Locked into a loop with your computer? Get back on the air with this simple project!

By Rodney A. Colton,* WA1SXW

When the FCC approved the use of ASCII on the amateur bands, I searched for a quick and inexpensive method of interfacing my computer and transceiver. I chose the simple PLL circuit in Fig. 1. It decodes an audio signal (tones) into TTL-compatible bits. All one needs to do is feed the data stream to a computer, and half the system is operating! The simple VCO circuit in Fig. 2 converts the data stream at the output of the computer into tones. One can inject the tones into the microphone jack of a transceiver, and the complete system is operating. Both the modulator and the demodulator could be implemented with the same VCO. ICs are inexpensive, however, and I wanted to reduce the switching requirements. This makes the alignment and testing easier, also.

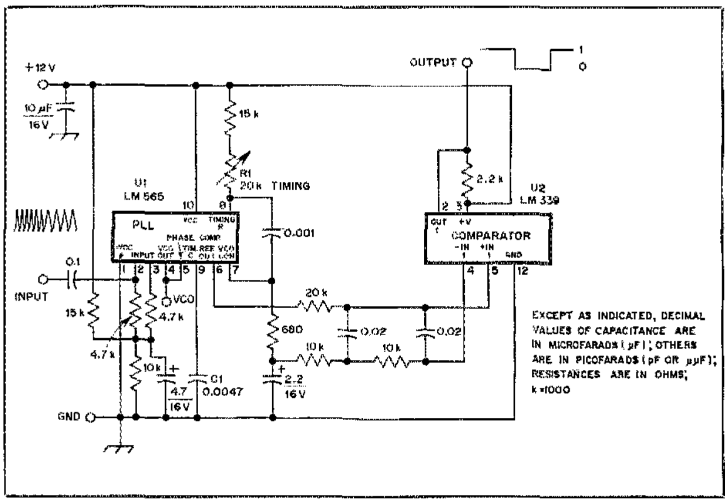

Fig. 1 — Schematic diagram of the demodulator circuit. Resistors are 1/4-watt or 1/2-watt carbon-composition type. Capacitors are disc ceramic. Component numbers not appearing in parts list are for identification purposes only.

R1 — Linear-taper, 10-turn potentiometer, 20 kΩ.

U1 — Phase-locked-loop IC, TTL compatible, type 565 or equivalent.

U2 — Voltage comparator IC, TTL compatible, type LM339 or equivalent.

Circuit Operation

With no signal at the input of the circuit in Fig. 1, adjust the timing resistor (R1) so that the free-running VCO frequency is between the fsk mark and space frequencies. The VCO control voltage at pin 7, generated by the comparator, is the same as the reference voltage at pin 6 when there is no input signal. The output of the comparator circuit may be either a mark or space.

If a mark signal (higher tone) is applied to the input, the control voltage (pin 7) goes lower than the reference voltage (pin 6). This causes the comparator output to go high. If a lower tone appears at the input of the PLL, the voltage at pin 7 swings in the other direction, and a low appears at the comparator output.

This circuit works well with various common values of frequency shift at rates up to 300 bits per second. If the data stream is inverted, insert an inverter between the demodulator output and the computer input, or use the computer to make the conversion once the data has been loaded. (Computers are very efficient at making conversions involving Baudot, ASCII, parity bits and so forth.)

Modulator Circuit

The heart of the circuit in Fig. 2 is the LM566 VCO. Timing-capacitor (C1) and

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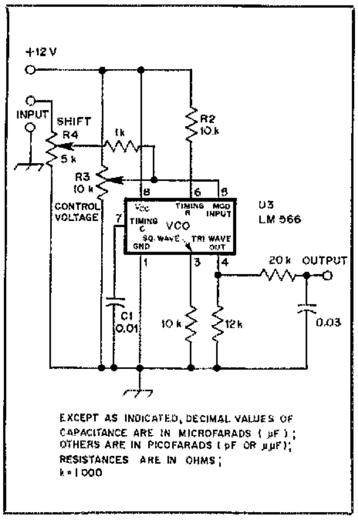


Fig. 2 — Schematic diagram of the modulator circuit. Resistors are 1/4-watt or 1/2-watt carbon-composition type. Capacitors are disc ceramic. Component numbers not appearing in parts list are for identification purposes only.
R3 — Linear-taper, pc-board style potentiometer, 10 kΩ.
R4 — Linear-taper, pc-board style potentiometer, 5 kΩ.
U3 — Voltage-controlled oscillator IC, TTL compatible, type LM566 or equivalent.

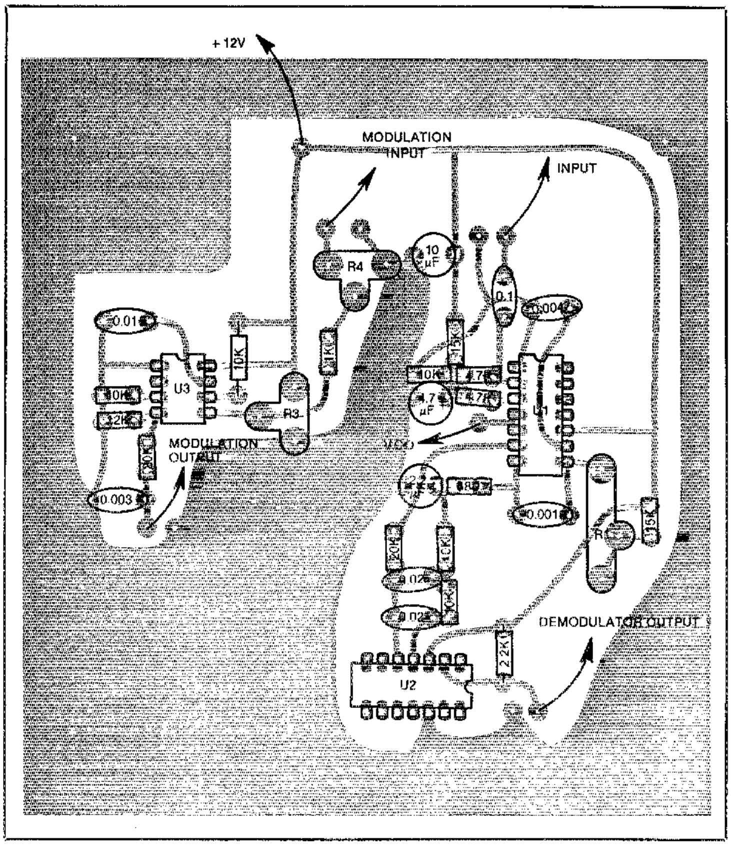


Fig. 3 — Parts-placement guide for the demodulator and modulator. Parts are placed on the non-foil side of the board; the shaded area represents an X-ray view of the copper pattern. (The etching pattern appears in the Hints and Kinks section of this issue.) Resistances are in ohms; k = 1000. Capacitors with whole-number values are in picofarads. Capacitors with decimal-value numbers are in microfarads.

timing-resistor (R2) values establish the free-running frequency range of the VCO. Operating voltage at pin 5 also affects the VCO frequency. The control voltage and the free-running frequency can be adjusted by means of R3.

The TTL data stream is injected at the input (R4). Adjusting R4 changes the effect that each bit (high or low) has on the voltage at pin 5. The number of hertz shift between mark and space will vary with changes in the R4 setting. Adjusting the mark and space frequencies is an iterative process because of the interaction of R3 and R4.

The output of the VCO is a square wave at pin 3 and a triangular wave at pin 4. The harmonic content of a triangular wave is lower than that of a square wave. Because it is easier to filter, the triangular wave is used to drive the transmitter. A low-pass filter between the output of the VCO and the input of the transmitter removes the harmonics.

Construction

I developed the prototypes of these circuits on breadboards. After testing for proper demodulator operation, I transferred the circuit to a pre-etched, predrilled circuit board (Radio Shack 276-170). Once the component values of the modulator were verified experimentally on the breadboard, I transferred this circuit to an etched circuit board. I mounted both boards in a small aluminum box. An etching pattern for a circuit board (with both circuits on it) is included in the Hints and Kinks section of this issue. Fig. 3 provides a parts-placement guide for this board. I installed banana jacks for the input and output ports and also added two jacks for monitoring the VCO and TTL data streams.

Operation

Connect the demodulator input directly to the speaker terminals of the receiver. Adjust the volume control of the receiver for a normal listening level. Set the VCO (U1) free-running frequency to midrange. Tune the receiver so that the VCO frequency falls midway between the mark and space frequencies. Fine tune the unit by "tweaking" the receiver frequency or the free-running VCO frequency (R1). Verify proper tuning by attaching a monitor scope to the output and by observing equal numbers of marks and spaces.

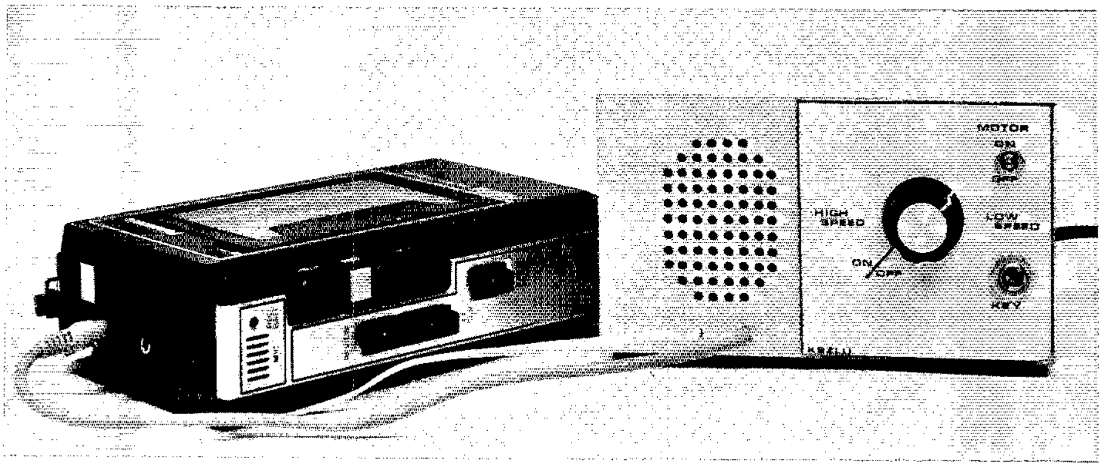
Connect the modulator input to the computer output and the modulator output to the microphone input of the transmitter. Adjust audio and/or drive gain to prevent over-driving the transmitter.

Refinements

Some predetection filtering before the demodulator in the form of a band-pass filter should increase the effective signal-to-noise ratio and should improve system performance. The output of the demodulator could easily be adapted to drive a current-loop Teletype system with a peripheral driver, such as the Motorola MC75461 or MC75462.

This is a quick and easy way to interface your computer with your station. Here's your chance to get in on the exciting new world of over-the-air ASCII transmissions!

A Variable-Speed Code-Study Program



Take those code-practice tapes, speed 'em up, slow 'em down, record "clean" off-the-air copy and more — inexpensively!

By Robert H. Luetzow,* K9ZLU

Using cassette tapes for code practice can be frustrating when the practice tapes are too fast to copy or too slow to be challenging. The code-practice system described here can help those who are attempting to increase their code-copying proficiency. It enables one to slow the speed of fast code tapes, increase the speed of slow tapes and produce code tapes at speeds up to 45 wpm. An optional relay circuit also permits keying a transmitter with the control unit while using prerecorded code tapes or a key. The complete unit can be built for about $25 ($30 with the relay option) if all new parts must be purchased. Almost any of the currently available cassette recorders are suitable for use with the unit.

Builder's Dream

This is the kind of project that is almost intoxicating! To some readers it will have immediate appeal; to others, the attractions will be hidden until applications other than the original one come to mind. How about — just building the speed controlling section, using the unit as a memory keyer, employing the audio section to regenerate received cw signals directly . . . ? Build it and see what you can do! — *Ed.*

Recorder Requirements

The cassette recorder must meet two important requirements to be compatible with this system. First, the recorder needs to have a remote-control jack. Second, the audio amplifier of the recorder must not be connected to the remote-control circuit. In some of the less expensive cassette recorders that have been tried with this system, the audio amplifier circuit is connected in parallel with the motor. When you try to slow the motor speed, the audio amplifier stops working. This problem can be overcome by rewiring the remote-control circuit so it cannot interrupt the operation of the audio amplifier.

Circuit Description

Refer to Figs. 1 and 2. Two basic circuits are included in the system-control unit shown in Fig. 1. One is the motor-control circuit, which employs Q1 and Q3. The transistors are connected as a Darlington pair and are used as a series voltage regulator, which controls the voltage applied to the cassette-recorder

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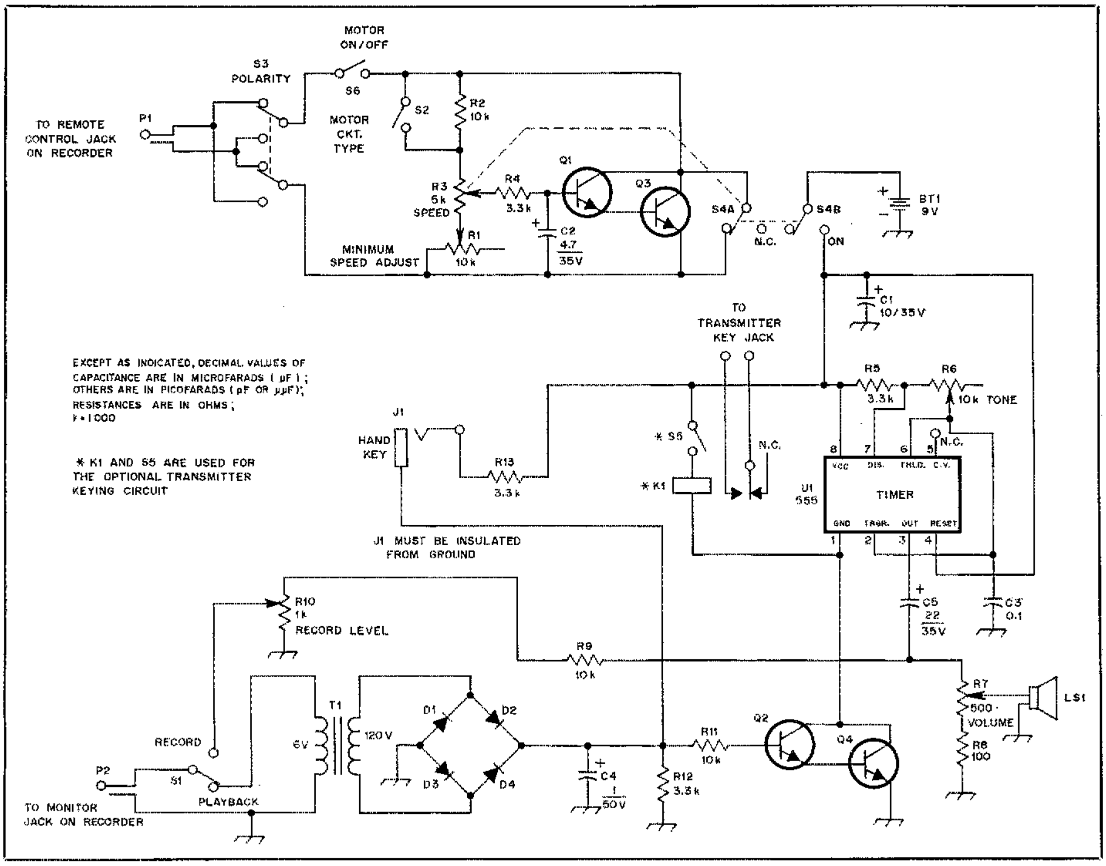


Fig. 1 — Schematic diagram of the code-study-system control unit. Note the isolation between the speed-controlling section and the audio section; a common ground does not exist.

motor. Because all recorder remote-control circuits are not wired similarly, S3 is used to select the proper voltage polarity.

Cassette recorder motor circuits are generally connected in one of two ways as shown in Fig. 2. When wired as in 2A, S2 (Fig. 1) must be closed; if as in Fig. 2B, S2 must be open.

R3 functions as the SPEED control and ON/OFF switch; S4 is part of R3. S4A shorts Q3 when it is in the OFF position, so you can rewind the tape at full speed. S4B interrupts the 9-V supply in the OFF position. R1 sets the minimum motor speed allowed.

The second portion of the circuit of Fig. 1 is that of a keyed oscillator. Transistors Q2 and Q4 comprise an audio-keyed switching circuit, and U1, a 555 timer IC, operates as an audio oscillator. U1 is keyed by applying an audio voltage from

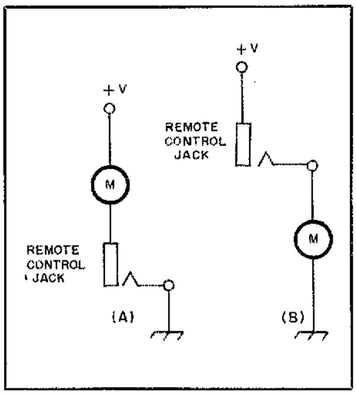


Fig. 2 — Two possible ways in which the remote-control circuit of the cassette recorder may be wired. The text explains another difference that may exist.

the cassette recorder monitor output to the keying circuit, through P2. Incoming audio voltage is stepped up via T1, rectified and filtered. The resulting dc voltage forward biases Q2/Q4, which in turn keys U1. For sending practice, a hand key may be plugged into J1; a positive voltage is supplied to the transistor switching circuit when the key is closed.

R6 varies the tone of the oscillator while R7 controls the speaker volume. A wide range of pitch is available, and the volume is sufficient to fill a small room. S1 selects PLAYBACK or RECORD modes. R10 sets the record output signal level.

S5 and K1 may be included if the transmitter keying option is desired. Precautions should be taken to ensure the transmitter keying circuit voltage and current requirements are within the contact ratings of the relay used. For most

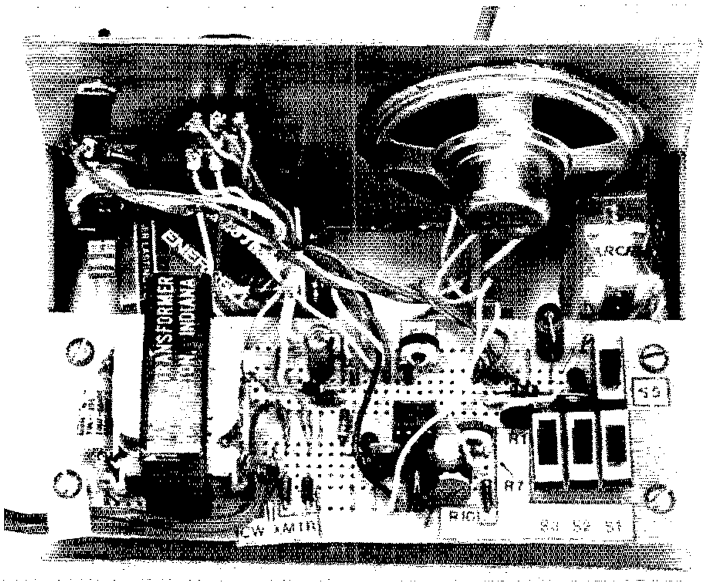


Fig. 3 — A close-up of the component layout. The components should be identified easily in the schematic, with a bit of study.

Table 1

Code-Study System Shopping List

Note: Part numbers in parentheses are Radio Shack.
BT1 — 9-V battery (23-553).
C1 — 10 μF, 35 V electrolytic (272-1013).
C2 — 4.7 μF, 35 V electrolytic (272-1012).
C3 — 0.1 μF, 50 V (272-1069).
C4 — 1 μF, 50 V (272-996).
C5 — 22 μF, 35 V (272-1014).
D1-D4, incl. — Silicon diode, 100 PIV, 1 A (276-1102).
J1 — 1/4-inch phone jack (274-280 or 274-252).
K1 — Spdt high-sensitivity relay, 6-9 V dc, 500-Ω coil, 12 mA (275-004).
LS1 — 8-Ω speaker (40-245/246/247 or 40-262).
P1 — 3/32-inch (2.4-mm) phone plug (274-290 or 274-291).
P2 — 1/8-inch (3.2-mm) phone plug (274-286 or 274-287).
Q1, Q2 — Npn silicon, general purpose, high-gain transistor (h_{FE} = 250), 360 mW, 2N2484 or equiv. (276-2010).
Q3, Q4 — Npn silicon power transistor, 40 W, TIP 29 or equiv. (276-2018).
R1, R6 — 10-kΩ, pc-mount potentiometer (271-218 or 271-335).
R2, R9, R11 — 10-kΩ, 1/4-W resistor (271-1335).
R3 — 5-kΩ miniature potentiometer with dpdt switch (271-214).
R4, R5, R12, R13 — 3.3-kΩ, 1/4-W resistor (271-1328).
R7 — 500-Ω pc-mount potentiometer (271-226).
R8 — 100-Ω, 1/4-W resistor (271-1311).
R10 — 1-kΩ, pc-mount potentiometer (271-227 or 271-333).
S1-S3, incl., S5 — Dpdt slide switch (275-407).
S4 — Dpdt switch. Part of R3.
S6 — Spst switch (275-324).
T1 — Power transformer, 120 V pri., 6.3 V sec., 300 mA (273-1384).
U1 — 555 timer IC (276-1723).
Miscellaneous: Battery connector (270-325), experimenter's circuit board (276-170), pc board (276-1587, two required), knob (274-415).

modern transceivers, the relay specified should suffice.

Construction and Testing

The control system is built on an experimenter's circuit board (Radio Shack 276-170), which is mounted on an L-shaped frame assembly made from pc-board material.[1] A 3-3/8 × 6-inch front panel is soldered to a 3-5/16 × 6-inch bottom panel and braced with triangular-shaped pieces of board material.[2] Speaker holes are drilled at the left side of the front panel. If the layout shown here is followed, the templates of Fig. 4 may be used conveniently. LS1, R3/S4 and J1 are attached to the front panel of the unit. Component placement is not critical. If the layout shown in Fig. 3 is followed, some of the circuit-board pads will have to be cut; a sharp knife will suffice. Pads are removed easily, so be careful not to be hasty. Although some switch sections need not be used (as for S2 and S3), you might wire the terminals of these dpdt switches in parallel to provide extra tie points. Short lengths of wire are attached to each switch lug, are passed through holes in the perf board and are soldered to foil pads. Soldering all lugs of the switches to foil pads provides additional mechanical rigidity.

It's a good idea (especially if this is the first time you have used an experimenter's circuit board) to build the individual circuit sections one at a time and test each one as you progress. Care should be taken not to short the cassette recorder remote-control-jack voltage to the common of the code-oscillator circuit because there is no fuse in the recorder and one can "smoke" the power supply.

First construct the motor-control circuit. When it is completed, set R1 at full resistance and the SPEED control (R3) to the OFF position. Start the cassette recorder and insert P1 into the REMOTE control jack. At this time, the recorder should function as if nothing had changed. Next, rotate the SPEED control to the ON position. If the cassette motor stops, change the position of the POLARITY switch (S3); the motor should restart. If the motor will not run at full speed, change the position of S2. Finally, turn the SPEED control to the LOW setting and adjust R1 for the minimum motor speed desired.

Wire the code oscillator circuit next. Test the operation of the oscillator by grounding pin 1 of U1. An audio tone should be heard in the control-unit speaker. Once the oscillator is functioning properly, construct the audio keying circuit. It is checked by plugging a hand key into J1 and keying the oscillator. Then, place a prerecorded code tape in the recorder. Set the recorder VOLUME control to midrange and depress the PLAY button. Insert P2 into the MONITOR jack of the cassette unit, and you should hear the regenerated code through the control-system speaker with S1 in the PLAYBACK position.

To check the record function, close the hand key and adjust R6 for a desired tone from the speaker. Insert P2 into the MICROPHONE jack of the recorder and place the recorder in the RECORD mode. With S1 in the RECORD position and the oscillator keyed, adjust R10 for the proper recording level, as indicated on the cassette-recorder meter, or until the recorded tones sound good during playback.

Operation

All you need do is place a code tape into the cassette recorder, insert P1 into the cassette REMOTE jack and P2 into the MONITOR output jack. When the system is working properly you should be able to slow the tape speed to less than half the fast speed. You'll note that insertion of P1 causes an immediate 1- to 2-wpm loss of speed, but this should not present a problem.

In addition to slowing the speed of a replayed code tape, you can also speed up

[1]Notes appear on page 37.

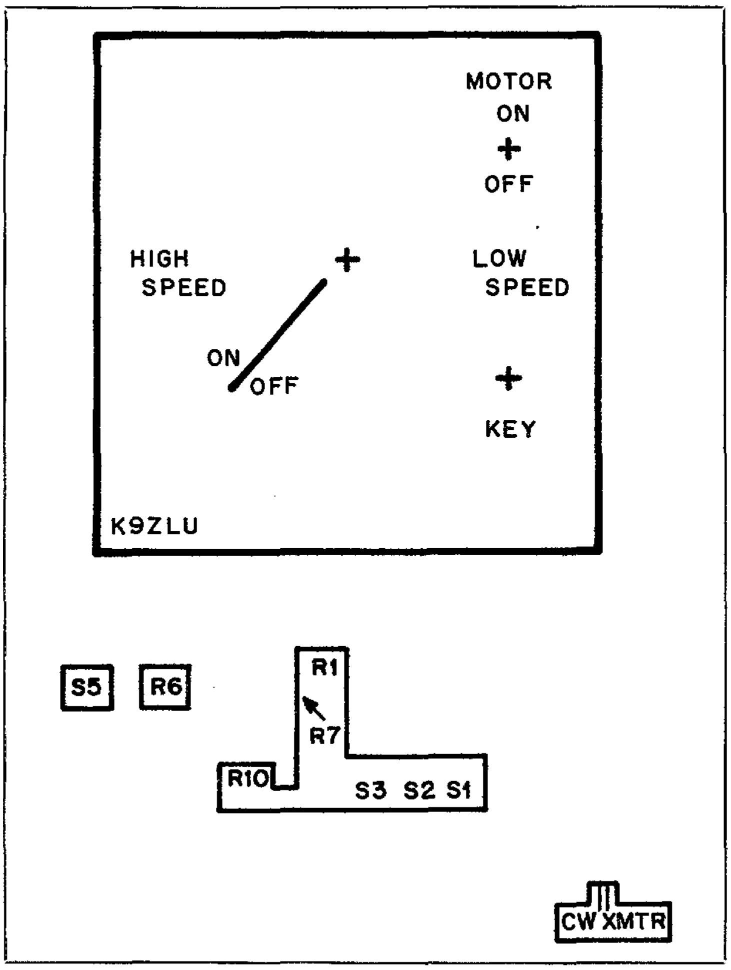


Fig. 4 — These templates may be used if the layout employed by the author is followed. Templates are shown full size.

a tape or record your own tapes. To record, insert P2 into the MICROPHONE jack of the recorder and place S1 in the RECORD position. Adjust the SPEED control so the cassette motor runs at approximately two-thirds speed and place the recorder in the RECORD mode. You can now send code at that slower speed for which your "fist" is perfect (at least nearly so!). When the tape is played back at full speed you'll have a perfectly challenging code tape!

You will need two cassette recorders to speed up a prerecorded code tape. Place the code tape to be speeded up in recorder A and a blank tape in recorder B. Plug recorder A into the audio-keyed code oscillator and adjust the tone of the oscillator to about half the frequency of the code-tape tone, as heard in the cassette speaker. Recorder B is plugged into the speed-control circuit, and the tape speed is reduced to half speed. Position recorder B so that its microphone is close to the control-unit speaker and place recorder B in RECORD. Start recorder A and play it through to the end of the tape. When the new tape from recorder B is played back at full speed, you'll have a code tape that is twice as fast as the original. If you record a W1AW code transmission, the recorded tape will play back on the system without all the QRM and QRN you'd normally hear.

You can use prerecorded tapes to play back selected information and key your transmitter — much like using a memory keyer. Cassette recorders with turns counters make the job easier. Have fun! I'll listen for you between 7.0 and 7.025 MHz.

Notes

[1]A pc board is available from Daytapro Electronics, Inc., 3029 N. Wilshire La., Arlington Heights, IL 60004.

[2]mm = inches × 25.4

Strays

NEED 88-mH TOROID COILS?

☐ If you've had difficulty finding 88-mH telephone toroids for your passive audio filters, get in touch with ARRL Technical Advisor Ed Wetherhold, W3NQN. He has these inductors available in Amateur Radio filtering circuits. Ed is supplying these coils at no charge other than the shipping expenses — he is merely serving as liaison between the Chesapeake and Potomac Telephone Co. of Maryland and *QST* readers.

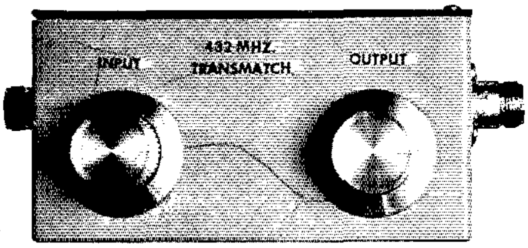
Articles describing filters in which these toroids are used can be found in December 1980 *QST* and in April 1981 *Ham Radio*. Those desiring the toroids are asked to drop a line to Ed, explaining their need and the proposed application. An s.a.s.e. must be included with the letter of inquiry. W3NQN's address is 102 Archwood Ave., Annapolis, MD 21401. — *Doug DeMaw, W1FB*

EASTERN STATES EXPOSITION

☐ The Mount Tom (MA) Repeater Association will have an Amateur Radio exhibit at the Eastern States Exposition in West Springfield, Massachusetts, from Sept. 16-27. The booth and station, WA1KGR, will be in the New England (formerly Youthrama) Building. Amateur Radio will be displayed for the first time at the "Big E," perhaps the biggest event of its kind in New England. — *Larry Soltz, WB1CJH, Longmeadow, Massachusetts*

Gary Owens (right), popular television and radio personality, receives an ARRL plaque for his recording of a public service announcement on behalf of Amateur Radio. Presenting the plaque, which even includes a brass key, is Loyd Sigman, W6LQ, who had been manager of station KMPC (Hollywood) where Gary's career began. *(photo by Bob Jensen, W6VGQ)*

A Transmatch for 432 MHz — Why Not!



Have you been looking for a way to use 75-ohm CATV hardline in your 50-ohm, 432-MHz system? Or is a fussy solid-state rig giving you headaches? This neat little Transmatch will solve both problems.

By Carmen F. Moretti,* W2AIH

The Transmatch described here can solve a number of problems confronting the 432-MHz enthusiast. Not only will matching your amplifier to the transmission line make the final amplifier "happy," the added selectivity provided by the tuner will aid in suppressing unwanted signals in your receiving system. At the author's location a harmonic from a nearby fm broadcast station was heard in the 432-MHz band. The installation of the uhf Transmatch eliminated the unwanted signal.

I developed this circuit after discovering the SWR at my amplifier was higher than I cared to have it be. The Transmatch will cancel the reactance at the transmitter end of the feed line, and can also provide an impedance transformation. Many hams still lean toward the idea that a "match box" or Transmatch is a cure-all for every antenna problem. It is not! This belief is fostered in part by the appearance of a large number of Transmatches on the amateur market. These units range from simple, inexpensive tuners to sophisticated "ultra tuners" costing hundreds of dollars. No matter how expensive, a Transmatch cannot correct a mismatch between the antenna and the transmission line.

Circuit Description

Unlike low-frequency antenna tuners that use large-value capacitors and rotary inductors, the 432-MHz Transmatch had to be approached using uhf techniques. Fig. 1A shows the circuit of the Ultimate Transmatch as described by McCoy.[1] Fig. 1B is the author's uhf version. Note that the Ultimate circuit has the bottom, or "cold" end, of C_{in} and L grounded and uses direct coupling between the input and output circuits. In the uhf version C1 is floating and L1 is tapped at the desired point to ground. Furthermore, inductive rather than direct coupling is used between the input and output circuits.

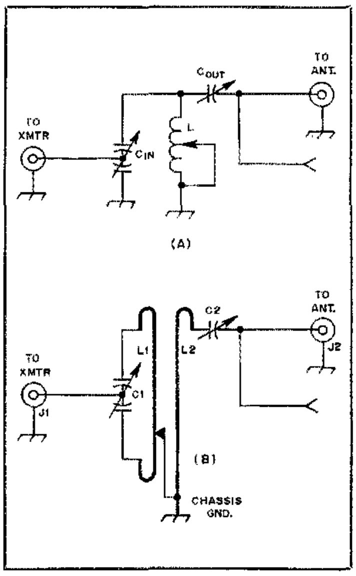


Fig. 1 — Circuit diagram of the popular Ultimate Transmatch (A) and the uhf version covering 420 to 450 MHz (B).

C1 — Dual-section variable capacitor (Johnson 167-0051-001 or equiv., with all but two stator and two rotor plates removed).

C2 — 2- to 15-pF variable capacitor (Johnson 148-1 or equiv.).

J1, J2 — Type N coaxial chassis connector.

L1 — Copper strap, 5-1/8 × 9/16 × 0.052 inches (126 × 14 × 1.3 mm) formed as shown in Fig. 2.

L2 — Copper strap, 5-3/8 × 9/16 × 0.052 inches (132 × 14 × 1.3 mm) formed as shown in Fig. 2.

Construction

Construction details are shown in Figs. 2 and 3. The input and output capacitors and associated copper-strap inductors are mounted on a 3-7/8 × 4-7/8 × 1/4-inch (95 × 119 × 6-mm) piece of Plexiglas, which is fastened inside a 4 × 5 × 2-1/2-inch (98 × 123 × 61-mm) metal enclosure. Do not make the enclosure smaller than this. I made the mistake of using a smaller box, only to discover that the input circuit wanted to function as a resonant cavity. If you do not wish to fabricate your own box, a Bud type CU-500A Minibox can, with a little ingenuity, be adapted.

To assemble the Transmatch, first form L1 as shown in Fig. 2 and solder it to the stator sections of C1. Next, form L2 and solder the "hot" end to the stator of C2, leaving the ground end unattached. Fasten the two capacitors and their inductors to the Plexiglas base, leaving a

*1619 Boulevard, Peekskill, NY 10566

[1] L. G. McCoy, "The Ultimate Transmatch," *QST*, July 1970, p. 24.

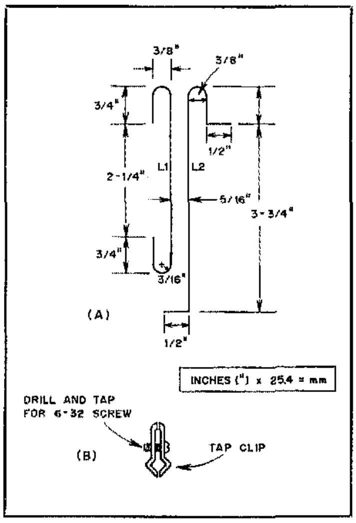


Fig. 2 — At A, the formation details for the copper-strap inductors. The tap clip, used to make the ground connection to L1, is shown at B. It is made from 3/32-inch (2.3-mm) brass stock, 1/4 × 5/8 inches (6 × 15 mm), formed as shown.

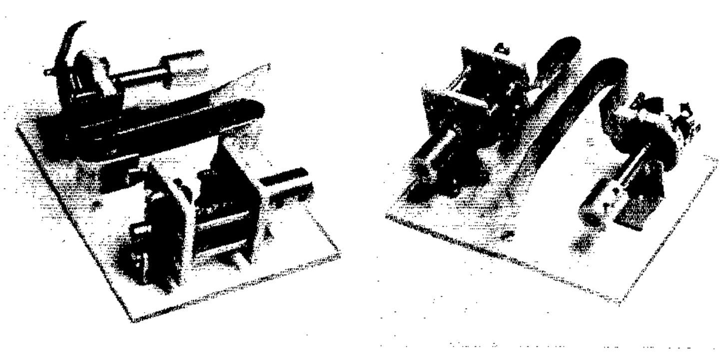


Fig. 3 — Interior views of the uhf Transmatch showing the strap inductors, L1 and L2, connected to the input and output capacitors, C1 and C2.

5/16-inch (8-mm) space between L1 and L2 (see Fig. 3). After mounting J1 and J2, the completed subassembly can be mounted on the inside bottom of the enclosure. Fasten or solder the ground end of L2 and the tap lead for L1 to the chassis. Make the connections to J1 and J2. Run two pieces of insulating rod from the capacitors to the front-panel knobs. This completes the Transmatch.

Adjusting the Transmatch

Once the construction is complete, connect the antenna feed line to J2. Connect the transmitter output, through an SWR indicator, to J1. Remove the cover from the unit and set C1 and C2 at maximum capacitance. Start with the tap on L1 set near the end closest to the grounded end of L2. Apply enough power to obtain an SWR reading and adjust C1 and C2 for minimum SWR. By moving the tap on L1 and readjusting the capacitors you should be able to obtain a proper match. With the unit adjusted you can now apply full power; this Transmatch will handle 200 to 300 watts safely. If higher power levels are desired, the plate spacing of C1 and C2 can be increased accordingly.

You will find that the input circuit tunes rather sharply while the tuning of the output circuit is quite broad. In fact, C2 could be eliminated if the coupling between L1 and L2 could be made adjustable. Because this is not very practical, I chose to use the variable capacitor. Nothing is more effective than having a proper match between your antenna and the transmission line. But let's face it: There are going to be times when the match is not exact, or the transmission line is of an impedance other than that for which the transmitter was designed. So when you don't have that proper match in your 432-MHz setup, use the uhf Transmatch. Not only will you like it, but so will your final amplifier! QST

Strays

TIS DO'S AND DON'TS

☐ The ARRL Technical Information Service is offered free to members. Although we are eager to help newly licensed amateurs with technical problems, in fairness to members we cannot respond to continuing requests for assistance from those who choose not to join the League.

For us to respond promptly to your inquiries we must have: (1) your name, (2) your amateur call and license class (tell us if you're not licensed), (3) your membership expiration date, and (4) a stamped, business-size envelope bearing your mailing address for our reply (IRCs acceptable from outside the U.S.).

When writing, we ask that you observe the following guidelines so we may provide the best possible service to the greatest number.

1) Before writing for technical assistance, search your files of *QST* and other ARRL publications. The answer you need may be there, available immediately. Consult the annual index of articles in each December issue.

2) Please do not ask for comparisons between commercial products. Choice of equipment is largely a matter of personal preference. Consult Product Review information in *QST*; compare manufacturers' specifications in their brochures.

Do not ask for information on articles published in other magazines. Write to the editor or author of that article.

Do not request custom designs for amateur gear.

Do not ask advice on nonamateur matters. We cannot respond to questions about CB, marine radio, hi-fi, etc. (unless they concern interference caused by amateur gear).

3) Use a typewriter when possible; otherwise, write or print *clearly*. Please be reasonable in the number of questions you ask; try to limit your questions to three per letter.

4) When writing, please come right to the point, and be sure to share with us whatever experience you have had with the problem in question. This will avoid our reply covering ground you've already been over.

5) Address all technical questions to: Technical Information Service, American Radio Relay League, 225 Main St., Newington, CT 06111. — *Mike Kaczynski, W1OD*

QST congratulates . . .

☐ Perry Brittain, W5STI, who was recently elected president of the Texas Utilities Company of Dallas.

☐ Richard Cyril Kirby, WØLCT, recipient of the 1981 IEEE Award in International Communications. The award is presented "for sustained leadership in the development and management of international radio communications." Mr. Kirby is Director, CCIR, ITU, Geneva, Switzerland.

• *Basic Amateur Radio*

Meet the Friendly Oscilloscope!

Give an orphan a home, have fun doing it, and learn more about electronics! How? Quite simple . . .

By Julian N. Jablin,* W9IWI

At the next hamfest or club auction, buy an oscilloscope. I don't mean a shiny new solid-state version with dual trace and triggered sweep. I have in mind a 1950-60 vintage instrument, which will probably have a round 5-inch (127-mm) CRT face on the front panel. It may weigh about 25 pounds (11 kg), and may be painted gray or brown. It will be rather ugly and unwanted by today's standards.

Does It Work?

You will have to use your own criteria for determining this. Having an experienced ham friend along will help, and knowing the seller can be an advantage. I bought my oscilloscope through a newspaper advertisement. When I went to see it, the owner obligingly fed an audio signal into it, so I saw the sine wave on the screen. Try to find a scope with a manual, of course. An instrument made from a kit is okay, but because you may have extensive rebuilding or troubleshooting to do, the manual will be important.

It is impossible to tell exactly how much money to spend or which models to buy. I would look in the $30-or-less price class. Chapter 16 of the 1981 *Radio Amateur's Handbook* contains a section on oscilloscopes that will provide valuable background information. I've noticed several "How To . . ." books on scopes written in the 1950s and '60s. These can often be found at hamfests at low cost, and will quickly pay for themselves if it is necessary to troubleshoot your scope.

*9124 Crawford Ave., Skokie, IL 60076

What Does An Oscilloscope Do?

Basically, an oscilloscope displays an image on a CRT (cathode-ray tube) that permits you to observe alternating or pulsed-voltage waveforms. Because it can respond rapidly, it is more useful in some situations than an analog meter (VOM or VTVM) or a digital voltmeter. It can be calibrated approximately, but it will not give you the resolution or accuracy that many meters provide.

Many modern oscilloscopes will respond to voltages from dc to at least 10 MHz. Typically, the older, inexpensive variety will respond to ac ranging in frequency from 5 Hz to about 5 MHz. This is a restricted, but useful, range.

Power Up

Having read the instruction manual, chapter 16 of the *Handbook* and, perhaps, a text on oscilloscopes, you are ready to turn on your new "toy." Your scope may not have the same control labels that I use, but don't worry. Most scopes have controls that fulfill these functions, and many will have *similar* if not identical, nomenclature.

Do not advance the INTENSITY control (which may include the ON/OFF switch) too far. The trace should be bright enough to be seen, but not so bright that it harms the coating inside the CRT. Once the tubes have warmed up, adjust the INTENSITY for the desired trace brightness.

If you have a test lead plugged into the vertical input jack and everything is

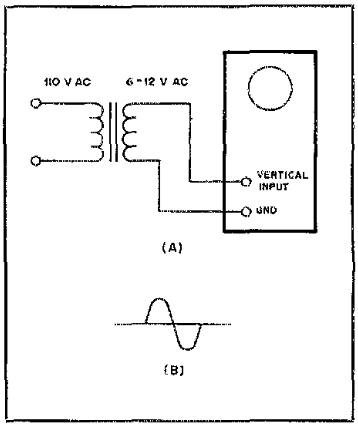


Fig. 1 — At A, test setup for verifying that oscilloscope is functioning normally. At B, simulated display of 1 cycle of a sine wave.

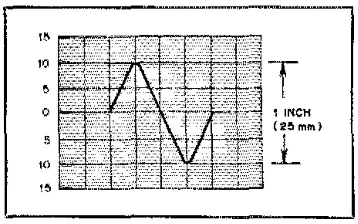


Fig. 2 — Calibrating an oscilloscope with a sine wave having a known pk-pk (peak to peak) value. For instance, the sine wave shown on the display is known to have a pk-pk value of 10 V. Therefore, the scope is calibrated for 10 V per inch.

working well, you will probably see a sine wave on the display (face of the CRT). The test leads act as antennas, and the scope "receives" the 60-Hz signal radiated by the house wiring. When you attach the test probe to a circuit, this image should disappear.

If the scope is not working, you must troubleshoot it. Here, the instruction manual (construction manual, if your scope was a kit) will be invaluable. One of the most likely sources of difficulty in this vintage equipment is tube failure. Test and replace any tubes that seem to be weak, shorted or dead. Clean the switches and potentiometers with electronic contact cleaner. Look for broken wires or damaged components (for example, the charred remains of a power resistor).

Be Cautious!

High voltages (high enough to kill you) can be found inside most scopes. Do not apply line voltage with the case open! Watch for previous repairs that did more harm than good. A friend noticed that the power transformer on his used oscilloscope was mounted on insulators. This was the former owner's way of "fixing" a transformer with an internal short to the core. The transformer core was at a potential several hundred volts above chassis ground!

An even more insidious danger lurks inside the scope cabinet. There is a vacuum inside the CRT. A bump or scratch could cause the envelope to implode, hurling sharp glass fragments in all directions. Protect your eyes: Wear safety glasses!

Let's Play

I do mean *play*. There is nothing serious at this stage. See what happens when ac voltages are fed into the scope. Connect the secondary of a 6- to 12-volt transformer to the vertical input and ground jacks (Fig. 1A). Adjust the controls until you have a display of one cycle of the 60-Hz sine wave (Fig. 1B). Set the VERTICAL ATTENUATION and/or the VERTICAL GAIN to provide a 2-inch (50-mm) high trace. The SYNC SELECTOR should be in the INTERNAL or LINE position. Work with the HORIZONTAL SWEEP and SYNC LOCK controls until you have one cycle standing still in the center of the screen. You can put the trace exactly where you want it with the HORIZONTAL GAIN, HORIZONTAL POSITION and VERTICAL POSITION controls. Advance the HORIZONTAL SWEEP SELECTOR clockwise, step by step, and see what this does to the pattern.

Calibration

If you know the pk-pk output of your transformer under a no-load condition, you can use this information to calibrate your scope (Fig. 2). Don't be misled by the markings on the transformer; the actual no-load voltage will vary considerably from one transformer to the next! If your scope has an input for dc voltages, you can calibrate it with standard zinc-carbon cells. Fresh, *unused* zinc-carbon cells have a no-load voltage of 1.54 V. Four of these in series will give you approximately 6 V, which is as accurate as necessary in this situation. Refer to your instruction manual for the manufacturer's suggested calibration method.

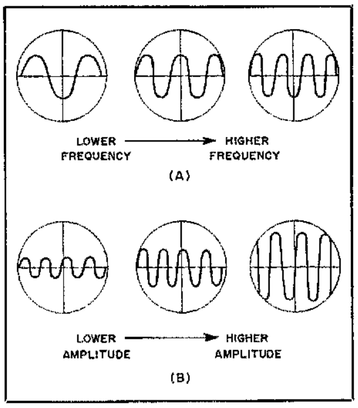


Fig. 3 — At A, representation of the changes in the display as the frequency of the input signal is increased. The amplitude is held constant. At B, the frequency is held constant, and the amplitude of the signal is increased. In both cases the control settings of the oscilloscope are held constant.

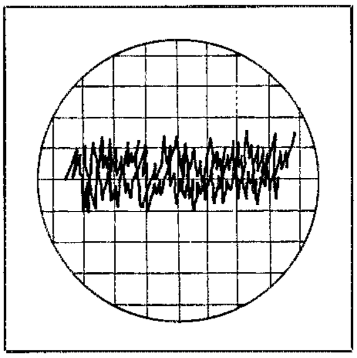


Fig. 4 — Typical complex waveform obtained by coupling oscilloscope to phonograph or other musical source.

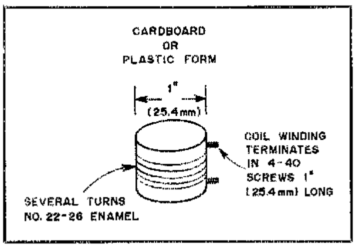


Fig. 5 — Simple rf probe for use with oscilloscope. See text for construction details.

Some of the low-priced oscilloscopes (mine, for example) have no calibration grid on the face of the CRT. I used a china marker pencil to draw my reference marks. The markings can be removed easily should I ever decide to sell it.

Down to Brass Tacks

If you have a variable-frequency audio generator, you can demonstrate the response of the oscilloscope. Connect it to the vertical input jacks. While you are adjusting the generator from a lower to a higher frequency, note the sine wave becoming "tighter" (Fig. 3A). Increase the amplitude of the signal, and watch the height of the trace increase correspondingly (Fig. 3B).

Tune your station receiver to WWV. Connect the test probes to the speaker. You should be able to identify an audio sine wave at 440, 500 or 600 Hz, a pulse as the timing ticks are transmitted and a complex audio pattern during voice announcements. The chart of the WWV broadcast format in the measurements chapter of *The Radio Amateur's Handbook* will help you recognize what you are seeing.

Connect the probes to the speaker of a broadcast-band receiver or phonograph. Before you switch anything on, set the VERTICAL ATTENUATOR for maximum attentuation and the VERTICAL GAIN for minimum gain. Without these precautions, you could damage the scope amplifier by overloading the input. Turn on the device, and adjust the controls. With music playing, you will see rapidly changing complex waveforms similar to those depicted in Fig. 4. Play with the controls, and note the changes obtained in the display.

Accessories

The device detailed in Fig. 5 acts as an rf "pickup" for my scope. It is simply six turns of insulated wire (size not critical) wound on a 1-inch (25-mm) cardboard (or plastic) form. The ends are terminated in 1-inch (25-mm), 4-40 machine screws, which makes connection to the test probes simple. Recently, I used this rf probe to determine if an oscillator under construction was actually oscillating. I knew rf was present when a broad envelope pattern replaced the solid green line on the face of the CRT.

The circuit shown in Fig. 6 is an example of a low-capacitance probe, which is useful in testing high-impedance or high-frequency circuits. The 10-pF capacitor provides frequency compensation and reduces the overall input capacitance. Typically, the capacitor will be a variable one that permits the probe to be adjusted for optimum response. The two resistors

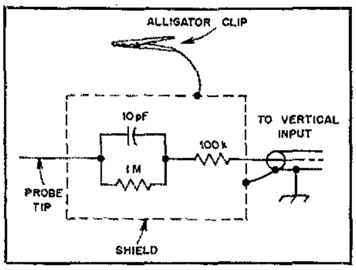


Fig. 6 — Typical low-capacitance probe for use with oscilloscope. The 10-pF disc capacitor can be replaced by a trimmer, permitting the user to adjust precisely the frequency compensation network. The shielded enclosure (broken lines) is insulated from the probe tip and components.

form a voltage-divider network that attenuates the signal by a factor of 10 to 1.

Practical Use

The more familiar you become with your scope, the more uses you will find for it. You can monitor your transmitter for key clicks, IMD products, "flat-topping" and other problems. You can check for ripple on the output of a power supply.

Your oscilloscope will be indispensable for working with digital circuits. Many construction articles give timing charts that show patterns to be expected at specific IC pins. If you have a digital circuit available, probe the various points in the circuit where timing pulses should be found. What do they look like?

The scope can show what happens when a square wave is processed to have a peak on the leading edge (which is required in some circuits). It can illustrate graphically the difference between frequency and duty cycle.

The shortcomings of your older instrument will become apparent in this kind of service. IC switching-circuit frequencies quickly approach the upper limit of the amplifiers in the oscilloscopes. Keeping a steady, single trace on the CRT display will be more difficult than it is with audio sine waves. The most important lesson that you can learn from this is how to get the most out of what is available.

You may be surprised at how much can be done with a "$25 orphan." Of course, you will never know until you try it!

Editor's Note: Oscilloscopes are designed for a specific *bandwidth*. This means that they will respond accurately to ac voltages up to a certain maximum frequency. Most of the older scopes were rated from dc to 3 MHz, while others had a 5-MHz bandwidth, or upper frequency. Beyond the design bandwidth of the instrument, it may be impossible to get a clear waveform. Also, the amount of deflection on the face of the CRT will be less than it would be on a scope that was designed for the particular operating frequency. Modern scopes have bandwidths as great as 1000 MHz.

New Products

SILICONIX 12-V VMOS POWER FETs

☐ It finally happened! Someone developed a 12-V power FET. Heretofore, these excellent components were aimed at the 24-V and higher applications market. This did not make them especially suitable for amateur work, where 11 to 14 V has been the standard during the past decade. The earlier power FETs were certainly ideal for the aircraft market, and were entirely suitable for use in ac-operated equipment. The shortfall was seen by amateurs and the commercial land-mobile market.

There are a number of 12-V FETs available from Siliconix Inc., but this review will treat only two of the low-power components. Information concerning the other transistors in this line can be obtained from the manufacturer.

The DV1202S and DV1205S devices are quite similar except for power rating. The minimum output power for the DV1202S is rated at 2.5 W at 175 MHz. This is specified for an operating voltage of 12.5, a drain current of 250 mA and a driving power (at the gate) of 0.25 W. The maximum device dissipation at a case temperature of 25° C is 10 W. This suggests that in intermittent amateur service it should be possible to obtain up to 5 W of power output without harming the FET. This assumption is based on the premise that excellent heat sinking is used. This would require a perfectly flat heat-sink surface and the use of heat-conducting grease.

The small-signal noise figure for the DV1202S is rated at 7 dB at 175 MHz. Transconductance is 100,000 μ siemens, and the drain efficiency is specified as 60%. Output capacitance is 20 pF, input capacitance is 14 pF and the drain-gate capacitance (C_{rss}) is 2 pF. The DV1202S and DV1205S parts are available in 0.380 SOE flange or C-220 packages.

The DV1205S FET has a 20-W maximum dissipation rating and a transconductance of 200,000 μ siemens. Its noise figure is also listed as 7 dB at 175 MHz for small-signal applications. The output capacitance is 38 pF, the input capacitance is 26 pF and the C_{rss} is 4 pF.

VMOS power FETs are of the enhancement-mode type. This means that forward gate voltage is required to turn them on. The same is not true of most small-signal MOSFETs, which are of the depletion-mode family. VMOS power FETs can be thought of as triode vacuum tubes that are capable of handling power. Apart from their being solid-state components rather than tubes, the major dissimilarity is that the output impedance is low ($V_{DD}^2/2P_o$ ohms). This aids stability and eliminates the need for a neutralizing circuit. Conversely, the input impedance is very high and can be used to advantage when necessary.

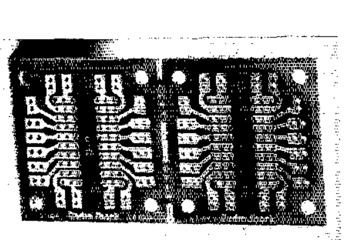
VMOS FETs are relatively immune to damage. They are not subject to thermal runaway and will not self-destruct in the presence of high values of VSWR. They are sensitive, however, to over-voltage (notably spikes and self-oscillation damage) and excessive gate current. Good layout is needed to prevent hf and vhf parasitic oscillations, owing to the high transconductance and upper frequency ratings.

These FETs are well suited to Class A, AB, B and C operation. They have high dynamic range and are excellent in broadband circuits. Price class: DV1202W, 1-24 lot, $8.02 each; DV1205W, 1-24 lot, $11.08 each. The manufacturer is Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054, tel. 408-988-8000. — *Doug DeMaw, W1FB*

RADIO SHACK DUAL IC BOARD

☐ Radio Shack has introduced an Experimenter's Dual IC Board (276-159) to their line of pre-etched, predrilled circuit boards for general applications. Each of these new boards is actually two boards in one; each side of the board provides pads suitable for mounting one 8- to 20-pin DIP IC. Multiple connection points are provided for each lead from the DIPs. Perforated down the middle between the two "sockets," the board can be snapped in two for those applications involving only one IC.

The board is a copper-clad phenolic material; the copper has not been silver plated or tinned. This board should prove to be more than adequate for all but the most demanding projects. Price class is $1.50. — *Peter O'Dell, KB1N*



Hints and Kinks

Conducted By Stuart Leland,* W1JEC

A COMPACT TRANSISTORIZED DIP OSCILLATOR

☐ The dip oscillator I built (Fig. 1) is a cross between the Heath and Kenwood designs. My arrangement is well suited for compact construction and low current drain (10 mA). Compactness results from the use of an LED indicator instead of a meter. Space is also saved by the use of a General Electric no. RT6748 midget variable capacitor (110 pF per section). This capacitor was purchased from Gateway Electronics, 8123 Page Blvd., St. Louis, MO 63130, for only $1. The LED (Radio Shack no. 276-041 or equivalent) is an extremely good indicator. In most cases the LED is completely extinguished at resonance when placed within 1/4 in. of the coils being checked.

Adjust the Trimpot and trimmer capacitor so that all coils perform properly before calibration. My unit has six coils that cover from 3 to 190 MHz. These are constructed from 3/8-in. plastic tubing that was obtained from the plumbing department of a hardware store. Melt the tubing over an RCA type of plug and cement these together with "five-minute epoxy." Two 9-V batteries are required. Although the device will function with one battery, the longevity will be poor. At least eight volts is needed for the dipper to oscillate. This requirement may vary with different transistors. One transistor I used came from a Zenith uhf tuner. The other was a high dc-beta unit that would detect all frequencies, but did not seem critical. Both are silicon npn devices, and may be of the builder's choice. — *Hal Vitrey, WØMSF, St. Louis, Missouri*

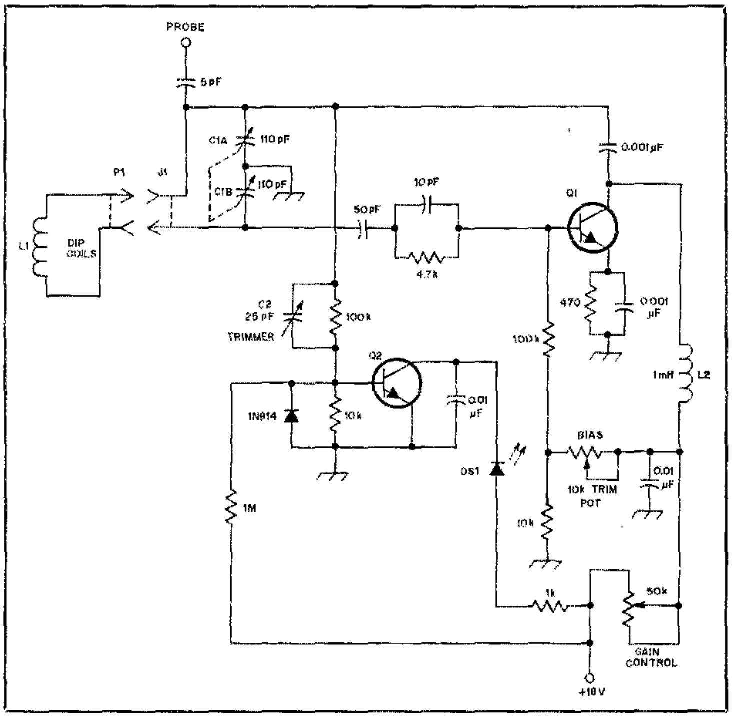


Fig. 1 — The WØMSF transistorized dip-oscillator circuit. Six coils provide coverage from 3 to 190 MHz. Two 9-V batteries furnish the required power. The LED (D1) serves as the dip indicator. Resistance values are in ohms.

C1 — Miniature variable, 110 pF per section. General Electric no. RT6748 or equiv.
C2 — 25-pF trimmer.
DS1 — LED.
J1 — RCA phono jack.
L2 — 1000 µH.
P1 — RCA phono plug.
Q1, Q2 — Silicon npn rf amplifier transistor, 2N3904, ECG-108 or equiv.

Table 1

Coil Information

Freq. (MHz)	*Turns*	*Wire Size*	*µH*	*Notes*
75-190 COIL A	1	no. 12	0.04	Wire spaced out whole length of coil form with starting lead coming straight up through center of coil.
45-92 COIL B	3-1/2	no. 20	0.15	Wire spaced out to fit 1/4" length. Adjust turns spacing for proper inductance before lacquer coating.
22-47 COIL C	9-1/2	no. 20	0.64	Close wound with allowance to spread out to 3/8" length if needed to adjust

Freq. (MHz)	*Turns*	*Wire Size*	*µH*	*Notes*
				inductance before lacquer coating.
11.3-23 COIL D	18-1/2	no. 32	2.6	Close wound, but allow 5/16" space to adjust inductance before lacquer coating.
5.6-11.5 COIL E	45-1/2	no. 32	10.2	Close wound, but allow 5/8" length to adjust before lacquer coating.
2.8-5.8 COIL F	125	no. 36	44	Close wound, but allow 1" for adjusting inductance before lacquer coating.

Plastic portion of coil is 1-1/8" long on all coils but F, which is 1-3/8" long to allow more room for winding. All coils start with lead coming straight up through center of coil. Top of plastic tube is slotted 1/8". Hook wire through this slot, and start winding. End winding at proper length by drilling two holes 1/4" apart. Feed wire in one hole and out the other, and end coil by running this wire straight down and by soldering to outside of RCA plug. Coil adjustment would be less critical by using seven coils, thus having more overlap.

Inches (") × 25.4 = mm.

OPERATION OF THE VE3TIV REPEATER-CONTROL SYSTEM I-D

☐ When our club repeater is timed out, the autocode i-d will operate before the repeater shuts down. In normal operation, the signal from the control board is 0. When the repeater is timed out, this signal becomes a 1. See Fig. 2. It is fed to one of the inputs of a NOR gate, U1A, and its output now becomes 0. This signal goes through a capacitor, and a negative pulse is fed to the start pin on the i-d timer, the output of which now goes positive for seven seconds.

In normal operation the i-d will be transmitted only once every 3 minutes at the end of the transmission in progress; or, if the repeater has not been turned on for at least three minutes, the i-d will come on at the end of the first transmission. For the automatic i-d system to function, all inputs to U2 must be 0. The input from the COS I-D Request is normally 1. When a carrier is received by the repeater, this signal becomes a 0 for a short period of time and then returns to 1. It again becomes 0 when the carrier being received drops out.

The input from U4 pin 10 is normally 0, but when a carrier is received by the repeater the input becomes 1 until the carrier drops out. At that time it returns to 0. Normally, while the timer is counting out the 3 minutes, the input from the i-d timer is normally 1 until the carrier

*Assistant Technical Editor

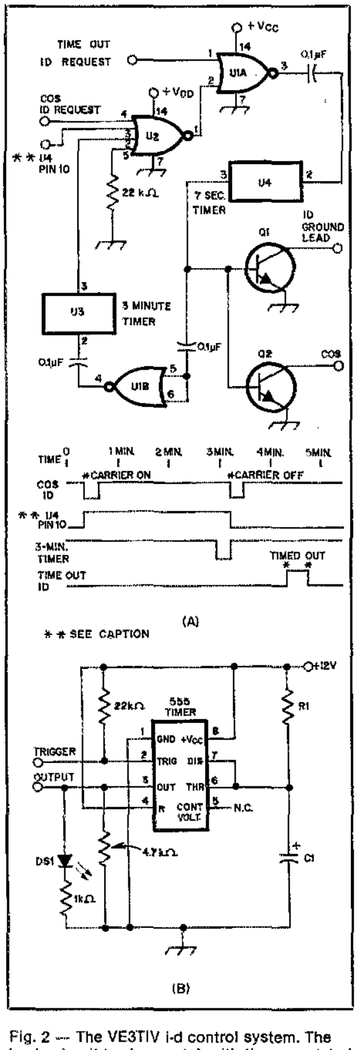


Fig. 2 — The VE3TIV i-d control system. The basic circuit is shown at A with the associated waveform. Details of the timing circuits designed around ICs U3 and U4 (the ubiquitous 555) are shown at B. Unused CMOS gate inputs must be tied together and grounded. **See U4 of diagram on p. 17, March 1979 *QST*.

C1 — 6.8 µF tantalum for the 7-second timer and 10 µF tantalum for the 3-minute timer.

Q1, Q2 — Germanium npn switching transistor, *Radio Shack no. 2001 or equiv.*

R1 — A 39-kΩ resistor coupled with a 400-kΩ potentiometer in series for the seven-second timer. For the 3-minute timer, use a 15-mΩ, fixed-value resistor.

U1 — CMOS quad two-input NOR gate, 4001.

U2 — CMOS dual four-input NOR gate, 4002.

U3, U4 — Timer, 555.

drops out. At the end of 3 minutes, the input drops to 0. The fourth input to U2 is held permanently at 0.

The only times that all four inputs to U2 are 0 are when time-out has occurred after 3 minutes, and when a carrier has just dropped out. The output of U2 will then become 1, and it is fed to one of the inputs of U1A causing the output of U1A to become 0. That turns on the 7-second timer.

At the moment the 7-second timer is turned on, the positive output of the timer is fed through a capacitor to U1B. The output of U1B is then pulsed negative. In turn, this negative pulse is fed through another capacitor to the start pin of the 3-minute timer. This restarts the 3-minute timer causing the output to go to 1. That resets the output of U2 to 0, ready for the next time the i-d is activated. — *Rick Gibson, VE3ASH, Kincardine, Ontario*

SWITCHING 40-METER PHASED VERTICAL ANTENNAS

☐ During one of our QSOs, Dick Evans, VE6XW, of Millet, Alberta, explained the antenna-switching arrangement he has for his 40-meter phased vertical antennas. The method he devised stems from his vocation and expertise as an electrician. He pointed out that his research led him to believe that at least some parts of his design have not been presented by technical writers in Amateur Radio publications.

His system (Fig. 3) provides six end-fire unidirectional selections for 40 meters. It consists of three identical base-loaded vertical radiators. Dick suggests the use of 5/8-wavelength antennas, but points out that 30-foot (9-meter) elements with loading coils are satisfactory. He used a design frequency of 7.100 MHz.

Feed lines W1, W2 and W3, connecting the switch (S1) with the antennas, have identical lengths of 52-ohm coaxial cable. Cables W4, W5 and W6 are each 22 feet, 10 inches (7 m) long. They are neatly coiled indoors. Direction changes are accomplished by a six-position isolated double-pole switch (S1) located at the operating desk. For QRP transmitters, a Radio Shack no. 275-1386 switch is satisfactory; for higher power, a Millen transmitting type of switch (or equivalent) is suggested.

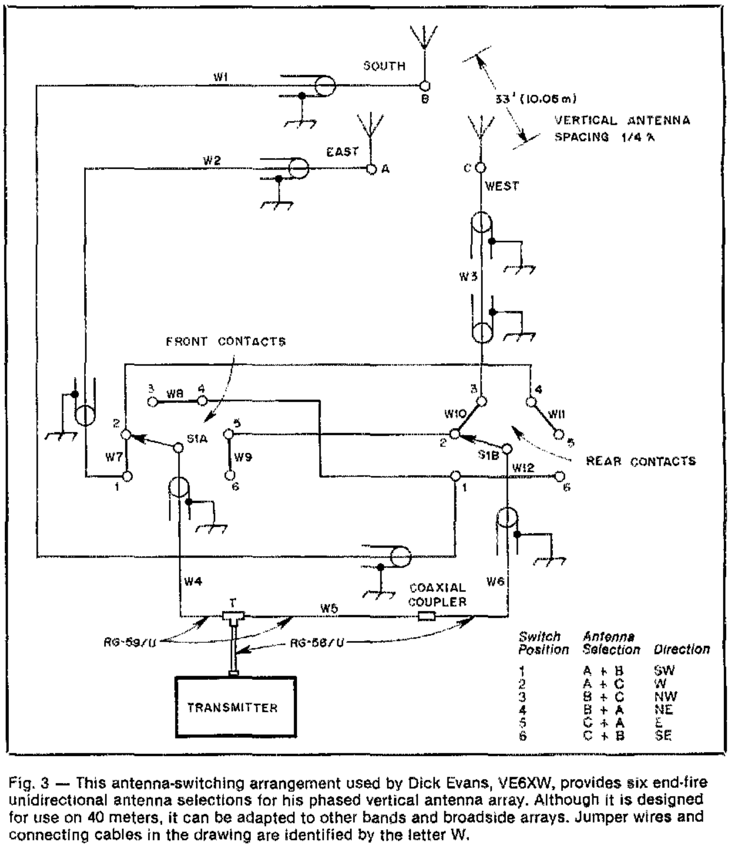
A minimal radial system would consist of four 1/4-wavelengths of wire for each vertical, but 10 to 20 radials per vertical would be better. With this system, excellent DX results can be expected.

Dick has agreed that he would like to share this information with other amateurs. I wish to thank him for letting me present this to *QST*. — *Chuck Coleman, K6ZUR, Santa Rosa, California*

[Editor's Note: For information on Millen equipment, contact Caywood Electronics, 67 Maple Ave., Malden, MA 02148.]

LUBRICATION FOR CRANK-UP TOWERS

☐ After an extended period, the working mechanism of towers tends to become corroded. I have found that a liberal coating of



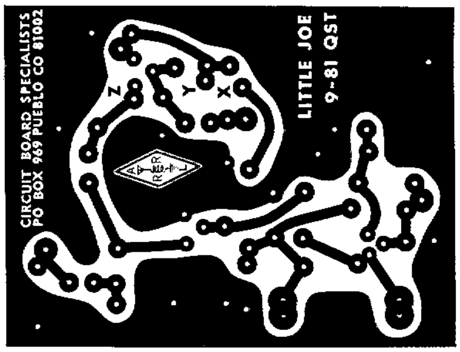
Switch Position	Antenna Selection	Direction
1	A + B	SW
2	A + C	W
3	B + C	NW
4	B + A	NE
5	C + A	E
6	C + B	SE

Fig. 3 — This antenna-switching arrangement used by Dick Evans, VE6XW, provides six end-fire unidirectional antenna selections for his phased vertical antenna array. Although it is designed for use on 40 meters, it can be adapted to other bands and broadside arrays. Jumper wires and connecting cables in the drawing are identified by the letter W.

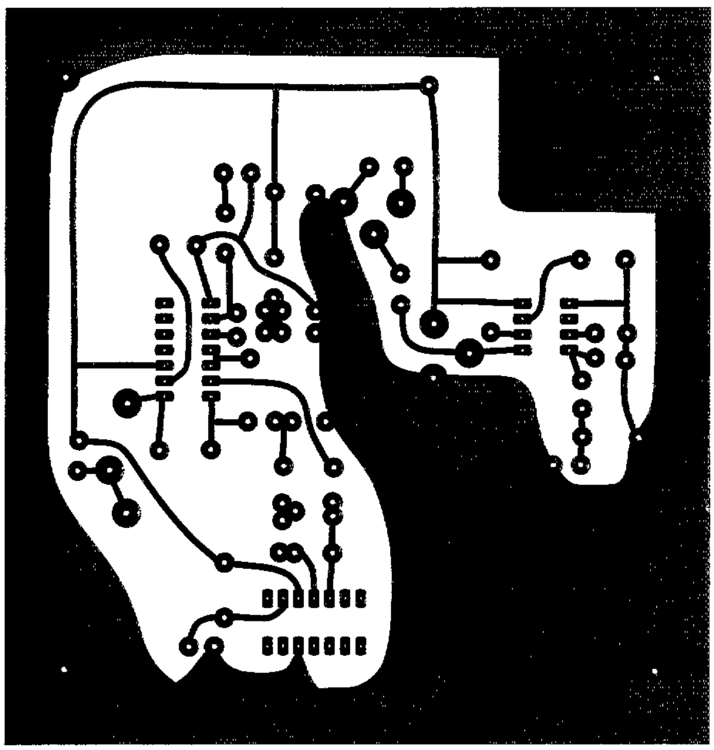
motorcycle chain lube protects and lubricates the winch, pulleys and cables. This lubricant seems to resist extreme weather conditions. Spray all moving surfaces when the tower is down. When you crank the tower up, spray the cable as it is wound onto the winch. — *Steven M. Simons, WA3WAS, Syntonic Technology, North Hills, Pennsylvania*

LUBRICATION FOR SLOW-TURNING ROTATORS

☐ I read in a 1979 issue of *QST* that the Canadian amateurs have used snowmobile grease on their antenna rotators to avoid slow turning in cold weather. I believe I have found something better! After several tests at −12° F, I found that speedometer cable grease maintained its viscosity at low temperatures, while snowmobile grease tended to get thicker. Other amateurs in my area have complained about their slow-moving rotators when the mercury dropped below zero, but my rotator turned as fast and smooth as it does in July's heat. — *Earl P. Anderson, WD9DID, Milwaukee, Wisconsin*



Etching pattern for the Universal QRP Transmitter. Black represents copper. The pattern is shown actual size from the foil side of the board.



Circuit-board etching pattern for the demodulator and modulator. Black represents copper. The pattern is shown at actual size from the foil side of the circuit board.

Product Review

Conducted By Paul K. Pagel,* N1FB

Kenwood TR-7800 2-Meter FM Transceiver

At first glance, one wonders if an FAA license is required to operate Kenwood's new TR-7800 2-meter fm transceiver. After a few minutes of twiddling knobs and pushing buttons, however, it becomes apparent that the TR-7800 design promotes ease and convenience of operation rather than complexity. Many seem to feel that mobile-style fm rigs are going the way of the dinosaur — a solid-state manifestation of Darwinism. Certainly, synthesized "handi-talkies" offer greater utility, right? Sure, "handi-talkies" are the ultimate in portability, but have you seen one that produces a 25-watt punch? Or one that has 15 memory channels and permits scanning the entire band or only the memories? Or one with a priority channel that can be monitored while listening to another frequency and an invert function that allows the operator to monitor the input frequency of a repeater at the touch of a button? I'd like to see an HT that *could* do all these things. No, mobile-style fm rigs will not be the study of paleontologists for quite some time to come!

Installation and Operation at K1CE

The review unit shipped to ARRL Hq. was first installed at my station for base-operation testing. The antenna used was a Cushcraft Ringo Ranger perched at a lofty 75 feet[1] above Talcott Mountain in Connecticut. Several contacts were made using area repeaters and simplex channels. The TR-7800 was put through its paces, and performed well. Every function, every operational nook and cranny was explored during the several-month review period, and all received consistently high marks for reliability.

Audio reports were solicited from amateurs on many *different* repeaters (repeaters vary greatly respective to audio quality) and simplex frequencies. In *all* cases, audio reports received were similar to: "Sounds clean and full," "Takes full advantage of the superior audio quality of fm," and from a young woman "You sound very nice" (I think she meant the rig!).

Mobile Installation and Operation

It's one thing to operate a rig in a warm, stable location such as a ham shack, but quite another to ask it to perform to the same standards in a hostile environment. Could the TR-7800 endure severe cold, bumps, grinds and jolts? To find out, I subjected it to these conditions by installing the unit in my 1972 Volkswagen "bug." If the TR-7800 could survive in my car, it could survive just about anywhere! Installation was simple. A slide-in mobile bracket bolts easily to the underdash. A 5/8-wavelength whip antenna was chosen for the mobile application — a good, standard aerial used by many 2-meter enthusiasts. Again, the rig performed superbly, this time while operating during countless excursions on Connecticut's highways (some say the nation's worst roads). The only difficulty I experienced occurred when driving at night — the keyboard used for frequency entry is difficult to read because it is unlighted. The problem is easily circumvented by programming your set of frequencies into the memories *prior* to departure or while stopped at a rest area; It'll keep you from driving off the road. The digital readouts, however, are bright and easy to read except under conditions of high ambient light, a problem shared by other rigs employing such readouts.

I found on several occasions that the 25 (plus) watts was a boon to establishing reliable communications through distant repeaters. In fact, I used the rig to check into my favorite vhf traffic net, which used a Boston repeater almost 100 miles (160 km) away.

Features and Controls

All of the TR-7800's operating controls are conveniently located on the front panel. The ON/OFF switch is incorporated in the VOL/SQL control. Power output is switchable, HI/LOW. Low power output is adjustable up to 5 watts.[2] The keyboard (4 × 4 matrix) is used to enter operating frequencies, initiate the scanning function, select transmitter offset frequencies and program the memories. The keyboard also operates as a Touch-Tone pad for use with autopatch and other repeater functions. The KEY/M. SEL is a two-position push switch that engages either the keyboard or the memory channel selector for use in selecting the method of frequency call up. The REV switch is used to allow the operator to listen to the input frequency of a repeater without a time-consuming effort. This is a particularly useful feature in that the operator can determine instantly whether or not a transmitting station is within simplex range. A STEP switch determines the steps, 10 kHz or 5 kHz, during automatic scan and frequency selection. The memory-channel selector is used to select the desired memory channel, and the CH indicator displays the channel number.

There are 15 memory channels. Of these, channels 1 through 13 store frequencies with simplex or ± 600-kHz shift. The remaining two channels, 0 and 14, are "odd" split channels for storing transmit and receive frequencies, which are entered individually. Channel 0 is the priority channel. The PRIORITY ALERT switch is used to check the priority 0 channel. When the switch is depressed, the priority channel will be checked at about four-second intervals, regardless of the KEY/M. SEL switch position; a tone sounds when the priority channel is in use. A PRIORITY OPER switch is used to call up the priority 0 channel.

An LED display indicates the operating frequency in four digits: For example, 146.940 MHz is indicated as 6.940. Replacing the traditional S/RF meter is an LED level meter that indicates transmitter output and received signal strength. The greater number of LEDs that are illuminated, the higher the indicated level — this took a little getting used to. But once the rig was in operation for a few days, reading the meter became second nature. In fact, the aesthetics of the display are quite appealing —

[1]meters = feet × 0.3048.

*Assistant Technical Editor

[2]ARRL lab tests showed the TR-7800 "sweeps hot" from the receive to transmit frequency. The microprocessor does not have a transmit-delay circuit.

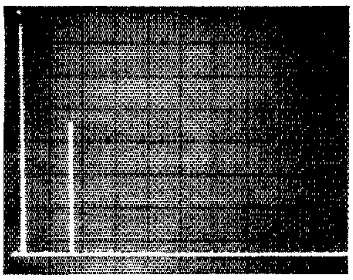


Fig. 1 — Spectral display of the TR-7800 transmitter output. Vertical divisions are each 10 dB; horizontal divisions are each 100 MHz. The fundamental has been reduced in amplitude approximately 33 dB by means of notch cavities; this prevents analyzer overload. Power output is 30 watts at a frequency of 146.52 MHz. A similar test at a power output of 4.4 watts also resulted in a clean spectral display. Tests were performed in the ARRL lab. The TR-7800 complies with current FCC specifications for spectral purity.

Kenwood TR-7800 Serial No. 010149

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 144.000-147.995 MHz.	Readout: 143.900-148.995.
Mode of operation: Fm (F3).	As specified.
Current drain: 0.4 A in receive mode — no input signal; 6 A in HI transmit mode; 2.5 A in LO transmit mode.	Not measured.
Size (HWD): 2-1/2 × 6-7/8 × 8-1/16 in.	
Weight: 4.63 lb.	
Transmitter power output (at 13.8 V, 50-ohm load): HI, 25 watts; LO, 5 watts (adjustable).	HI, 35 watts; LO, 5 watts (adjustable).
Spurious suppression: HI, −60 dB; LO, −53 dB.	HI, −75 dB; LO, −53 dB.
Receiver i-f: 1st i-f, 10.695 MHz; 2nd i-f, 455 kHz.	
Receiver sensitivity: Better than 0.5 μV for 30 dB S/N; better than 0.2 μV for 12 dB SINAD.	0.13 μV/20 dB quieting.
Squelch sensitivity: 0.16 μV (threshold)	0.06 μV.
Audio output (8-ohm load), more than 2 watts.	1.5 watts.
Meter: Red LED.	Red LED, 5/16 in.
Sensitivity (μV/S9): Not specified.	2 μV.

Note: mm = inches × 25.4, kg = pounds × 0.4536.

the meter lends an avionics look to the rig. The TONE switch is for control of a user-supplied tone generator. On the rear panel are the SO-239 antenna connector, dc power input terminal, an external backup power input connection used for retaining memories (for internal memory retention power, four AA NiCad batteries must be user supplied and installed in the battery holder), external speaker jack and final-amplifier heat sink. On the microphone are three switches: The DWN switch steps both the keyboard and the memory frequencies (to the next lower frequency), while the UP switch operates in a similar fashion stepping the frequency or memory channel. The PTT switch also acts to disengage the scan function. Extended frequency coverage is included (143.9 to 148.995 MHz) for those of the "MARSian" persuasion. An AUTOSCAN function allows the operator to scan the entire band or just the preprogrammed memory channels.

The transmitter finals are protected by VSWR sampling circuitry. As reflected power increases (higher SWR), transmitter drive is reduced, thus decreasing input to the final amplifier. This in turn protects the final transistors. The sensitive receiver is a benefit when listening for weak signals.

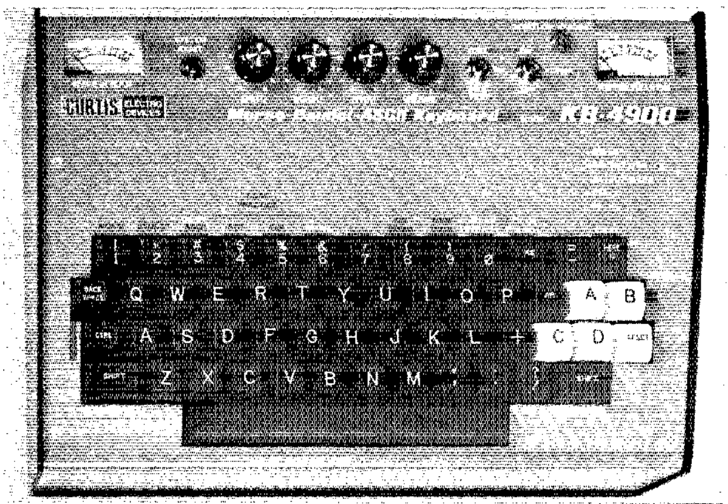
A complete and easy-to-understand instruction booklet describes the TR-7800's operation in detail. The unit itself comes packaged with microphone, mobile mounting bracket, dc power cord, spare fuse, miniature external speaker plug, warranty card and manual. Optional accessories include a matching dc power supply KPS-7, external speaker SP-40 and charger BC-1, which is used as a memory backup power supply when the main power supply is off for extended periods.

I have owned and operated a number of different 2-meter fm transceivers produced by various manufacturers, and I'd recommend the TR-7800 to any amateur looking for a 2-meter rig with more than "bare bones." I think every amateur enjoys a few "bells and whistles" occasionally if only to "keep up with the Joneses." The TR-7800 is a product of Trio-Kenwood Communications, Inc., 1111 West Walnut St., Compton, CA 90220. Price class: $400. — *Richard Palm, K1CE*

CURTIS KB-4900 KEYBOARD KEYER

☐ Some say that an amateur is "cheating" if he or she sends cw by means of a KB (keyboard keyer). Others have been known to say, "I wouldn't be caught dead using a keyboard." This reviewer has made similar statements on a couple of occasions! But, is it a cheating game to use a KB? Definitely not, and here's why. Take, for example, the case of an individual who can copy Morse at, say, 50 wpm, but lacks the dexterity or brain/hand coordination to send *good* (that's the key word here) cw at more than 25 or 30 wpm. The change from a bug or paddle to a KB can remedy the situation almost instantly, allowing for a period of off-the-air familiarization and practice with the new keyboard unit. It isn't necessary to be a touch typist: Many "hunt-and-peck" typists can easily grind out 50-wpm text on a keyboard. If the KB data is buffered (stored), proper spacing is assured, and perfect cw can be possible! The name of the game *should* be "good cw," and by whatever means practical: The cleaner the cw, the easier and more accurately it can be copied. Nothing is more frustrating than trying to copy at moderate or high speeds when the other guy or gal is sending with a "banana-boat swing" (NN GT = CQ), running the characters and sentences together, using excessive weighting or forming the dashes too long with respect to the dots. Cw "butchery" is rampant, even though there is widespread use of keyers and paddles. A keyboard keyer can be used to correct these problems. It must be said, however, that many paddle users can send cw that sounds as good as that from a keyboard!

The Curtis KB-4900 has a multitude of useful "bells and whistles." It provides Morse (5 to 80 wpm), Baudot (45.45 baud/60 wpm) and ASCII (110 baud) output. The buffer and memory will accommodate 256 key strokes with the memory soft-partitioned into four sections. These sections are available to the operator as memory keys (white) A, B, C and D at the lower right of the keyboard. For example, one could program memory A to read CQ CQ CQ de W1AW K. Memory B might contain DE W1AW K for tailending, with QRZ DE W1AW stored in memory C and so on. The memories, plus the built-in incrementing serialization feature (0 to 9999), would enable the amateur to operate an entire cw contest without using



the main part of the keyboard for any function other than inserting the call letters of the station worked. The time saved would be used for logging and "dupe" checking.

Other Features

Morse practice is available from the KB-4900. In practice-mode 1 there are random-length groups of random characters generated and sent in a never-repeating sequence. The desired speed can be chosen by adjusting the speed control. Practice-mode 2 delivers pseudo-random, five-character groups of Morse. These groups are always the same, and answer lists are contained in the owner's manual. The eight lists are available from the keyboard by inserting the numbers 1 through 8 in message memory A. In both modes the operator can insert extra space between the letters by pressing the CTRL key, followed by the S key. Also, the numbers and punctuation can be eliminated in either mode by placing an "N" after the "R" (or numbers 1 through 8) in message memory "A."

A standard paddle or bug type of key can be plugged into the KB-4900 to permit sending *conventionally*, if indeed that is a proper term for it today! Break-in operation is thus available by employing the BUFFER HOLD function of the keyboard.

PTT control is included for transmitter switching in all modes. The PTT release time is 0.5 seconds. Analog controls are provided for sidetone pitch, sidetone volume, weighting and speed. Also, analog meter readout (separate meters) is included for monitoring the Morse speed from 5 to 80 wpm and for observing the amount of data contained in the buffer (0 to 256 key strokes). A buffer-overflow warning light is located adjacent to the buffer meter.

Special prosigns $\overline{AS}$, $\overline{SK}$, $\overline{BT}$, $\overline{AA}$, $\overline{KN}$ and $\overline{KA}$ are included on the KB. Most of the European and commercial prosigns are also provided.

Another feature is a built-in, 24-hour clock that permits transmitting the time in Morse, Baudot or ASCII. In Morse, for example, the output would be 22R18, whereas on ASCII or Baudot it would be 22:18 for the same hour and minutes. This real-time clock is an optional accessory.

Inputs and Outputs

The KB-4900 contains a sidetone oscillator and speaker. The speaker can be used to monitor the output from a receiver by routing it to the audio input jack (8 ohms) of the KB. There is a jack for single- or twin-lever paddles and another for a manual "straight key." These inputs are optically isolated. A 12-volt dc input is available to permit battery connection. This prevents erasure of the memories during interruptions of the power service.

Keyboard outputs are provided for the key line (300 V, 500 mA max., mercury relay), PTT (same ratings) and the loop (same ratings, but optically isolated). There is a TTL TTY output (TTL level, sink or source 5 mA) and a speaker/headphone jack (8 ohms). The 117-volt ac line connects at the rear of the KB by means of a TV "cheater cord."

Some Final Comments

There are many subtle "goodies" associated with this unit, but descriptions are beyond the scope of this review. Additional information is available from the manufacturer.

The reviewer's KB-4900 has been in daily operation from 160 through 10 meters, with dc power input to the transmitter as great as 1 kW from 80 through 10 meters. At no time was there evidence of rf getting into the KB and disturbing the performance. No functional glitches have been observed in the overall performance of the keyboard, and on-the-air signal reports have yielded many compliments about the "perfect cw" generated by the KB-4900 (operator typos excepted, of course!).

An interesting psychological advantage seems available to this reviewer when using a keyboard, and others have reported similar experiences: Seldom-used, long words are much easier to spell on a KB than when sending them with a bug or paddle at the higher speeds. This may result from having the letters be visible to the operator when the word is formed. Poor spellers won't benefit from this phenomenon, however! In summary, the reviewer gives the KB-4900 a four-star rating. — *Doug DeMaw, W1FB*

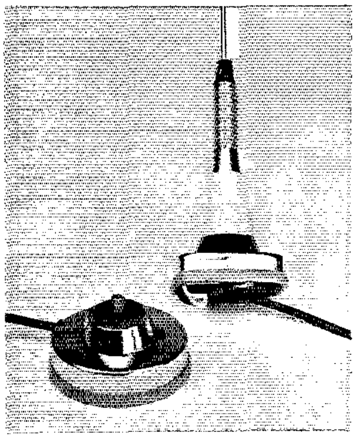
DECIBEL PRODUCTS DB702 2-METER ANTENNA

☐ Another Decibel Products contribution to the array of 2-meter mobile whip antennas is the DB702, a 5/8-wavelength aerial that offers a choice of mounting arrangements. Should you prefer a permanent through-the-roof mount, the DB702E-11 is available. For those not willing to drill holes in their 1937 Bentley, a magnetic mount unit (DB702E-17) or a "no-holes" trunk-lip mount (DB702E-16) may be purchased. The ease with which the magnetic mount antenna can be removed and replaced makes it a good choice if you don't wish to have the antenna vanish under mysterious circumstances!

Antenna assembly is simple: screw the coil, whip and spring onto the mount of your choice. A length of coaxial cable with a PL-259 connector already attached is supplied for use with most contemporary 2-meter rigs.

The antenna was road tested with the "mag" mount and did not detach from the vehicle at highway speeds. It is aesthetically appealing and appears to be ruggedly constructed. An easy-to-read instruction manual and a chart to be used for cutting the whip to size are included. It's good practice to start a bit long and cut off a small piece of the whip at a time until the best SWR is achieved.

The DB702 series is a product of Decibel Products, Inc., P.O. Box 47128, Dallas, TX 75427. Price class: DB702E-11, $45; DB702E-16, $53; DB702E-17, $55. — *Richard Palm, K1CE*



Curtis Electro Devices KB-4900 Keyboard Keyer Serial No. 1026C

Manufacturer's Claimed Specifications

Speed: Morse, 5 through 80 wpm; Baudot, 45.45 baud (60 wpm); ASCII, 110 baud.
Buffer and memory: 256 key strokes.
Keyboard: 54 key alphanumeric plus space bar, punctuation and prosigns $\overline{AA}$, $\overline{KN}$, $\overline{BT}$, $\overline{AR}$, $\overline{AS}$, $\overline{SK}$ and $\overline{KA}$. Also includes European and commercial prosigns. Individually replaceable, gold-inlaid key contacts. Debounced and two-key lockout feature.
Other keying: Manual "straight key" or external paddle (iambic with dot and dash memories).
Size (HWD) and weight: 4-1/2 × 12 × 8-1/2 in., 5.5 lb.
Colors: Light gray panel, black side panels, lettering in white, yellow and red.
Power requirements: 117 V ac at 50-60 Hz or 12 V dc at 500 mA; 234 V ac at 50-60 Hz avail. on order.
Price class: $400.
Manufacturer: Curtis Electro Devices Inc., Box 4090, Mountain View, CA 94040, tel. 415-494-7223.

Note: mm = inches × 25.4; kg = lb × 0.4536.

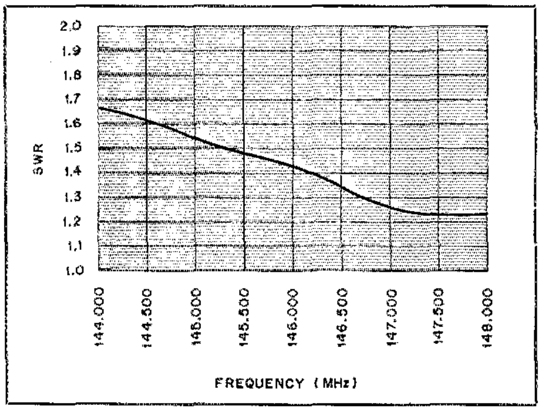


Fig. 2 — SWR curve for the DB702E-17 antenna.

GC ELECTRONICS LIFT-IT TRANSFER SHEETS

☐ Are you one of the many would-be "homebrewers"? Does the absence of a readily available pc board prevent you from undertaking a project you'd otherwise attack with enthusiasm? Sure, the pattern reproductions are nice, but photographing them is a step and expense you don't want to bother with. If only you could produce the required positive or negative from the pattern in the book. . . . Well, now you have no excuse! This easy-to-use method will lift the artwork and will make your pc-board reproductions more convenient and less costly.

One package of the GC Electronics Lift-It Transfer Sheets (catalog no. 22-288) contains two 8-1/2 × 11 inch[1] transfer sheets and one similar size Mylar exposing mask. This is enough material to make a number of boards, depending on their individual sizes.

To lift the pattern from the printed page, simply cut the transfer film to a size slightly larger than the desired pc pattern, peel away the protective backing and apply the film directly to the paper. Take care to place the transfer film correctly the first time because once the film touches the paper, it cannot be lifted — they're bonded for life! I found that it's a good idea to tape the desired pattern or page so that it cannot be moved as the film is being applied. This prevents the pattern from jumping up to meet the film (because of static electricity) as the film is brought closer to the paper.

Once the film is in contact, a smooth, blunt instrument (I used the back of a tablespoon) is used to burnish it in place and to force out any air bubbles from between the paper and film. Then place the pattern/film sandwich in a dish of warm, soapy water for 15 or 20 minutes. This causes the paper to absorb the water and to become crumbly when rubbed between your fingers. Don't use any abrasives — just your fingers. Let the film dry, and apply a piece of the Mylar backing to it. There you have it, a proper pc pattern positive that you can use with either the positive or negative pc board processing methods. Easy, isn't it?

If you'd like to preserve your *QST* copies or other publications and hate to take a pair of scissors to the page or otherwise alter it, you might photocopy the desired artwork. Good "lifts" can be made from photocopy paper. In fact, the density of the resulting positive might be somewhat better than that from the publication page depending on the papers used, photocopier reproduction density and so on.

Lift-It Transfer Sheets are available from your local GC Electronics distributor. If there's no distributor near you, contact GC Electronics, 400 S. Wyman St., Rockford, IL 61101. — *Paul K. Pagel, N1FB*

VOCOM TELESCOPING 5/8-λ ANTENNA FOR 2-METER PORTABLES

☐ "So, what is that? A 5/8-wave antenna for a hand-held?" I asked Sandy when he brought it in for advertising-acceptance examination. He smiled and said that I was correct! Correct, heck: I was being a smart aleck. Wisecracks flew back and forth around the office that day about the absurdity of putting such a large antenna on a hand-held. Then we tested it with an IC-2A. The performance was amazing. We were able to make contacts through repeaters that couldn't even be keyed with the "rubber duck," and we got good signal reports, too! Results of informal tests with various radios were consistent with the initial check.

We do not have facilities for testing and measuring antenna patterns accurately, but we did make a few informal observations about relative field strength. We used a receiver with an S-meter that was connected to a step attenuator through double-shielded cable. A 2-meter "rubber duck" was attached to the input of the attenuator. Another operator with an IC-2A was stationed about 200 yards away. The second operator made three transmissions with the IC2-A: first, with a "rubber duck"; second, a quarter-wavelength whip and third, the VoCom. We observed a 3-dB increase in field strength from the "rubber duck" to the quarter-wavelength whip. We observed a 6-dB increase from the quarter-wavelength whip to the VoCom. That is 9 dB from the "rubber duck" to the VoCom! Keep in mind that these are merely rough comparisons of the antennas. Nevertheless, these measurements are consistent with my on-the-air impressions of the difference in performance. VoCom has made a believer out of a skeptic in my case!

A fundamental rule of the universe is, "There ain't no such thing as a free lunch." Most modern portables are quite small and lightweight. The extra gain of the VoCom has its price — the length of the antenna and, consequently, the convenience of operation. Instead of 6 to 19 inches (152 to 483 mm), the full length of the antenna is 47 inches (1190 mm). This results in a package that can be unwieldy at times. Additionally, in an average room, it may be impossible to stand with the portable near your mouth while the antenna is fully extended. The leverage of the fully extended whip against the base of a female BNC connector (only one model has a male BNC connector) on a radio could be enough to damage the case after prolonged abuse. To some extent, the spring in the base of the VoCom will absorb this pressure. As far as I can tell, these are the only drawbacks to the antenna.

My opinion is that the VoCom antenna can be a useful tool for the 2-meter fm operator. Some care should be exercised in its use. If you happen to be about as graceful as a wounded rhino, and as clumsy as a New Year's Eve reveler, then you should stay with your "rubber duck" for safety's sake. If, however, you are on the fringe area of your favorite repeater, you may want to consider the VoCom. Used selectively and judiciously, this antenna shouldn't harm your radio, while at the same time it will extend the range of your portable. Price class is $25. Additional information may be obtained from VoCom Products Corp., 65 E. Palatine Rd., Suite 111, Prospect Heights, IL 60070. — *Peter O'Dell, KB1N*

MACROTRONICS M8000 RTTY SYSTEM

☐Macrotronics' M8000 is a disc-based RTTY system for the Radio Shack TRS-80 computer. It utilizes fully the capabilities of the disc-driven computer, providing features that the serious RTTY operator requires and desires.

More than 50 commands and subcommands provide versatile system configuration and operation. To configure the system, the user may select ASCII at 110 baud or the Baudot code at 60, 66, 75 or 100 wpm. He or she may vary the rate of transmission to simulate UT-4 operation, choose to ignore returns to conserve the display space on the CRT, vary the carriage width from 15 to 72 characters per line, enter the time and date and enable the automatic 10-minute identifier and select fast, slow or no sync idle (diddles). Other functions include automatic line numbering, line labeling, narrow or wide shift for the cw identifier and the ability to create three canned messages that may be saved on disc.

The operations commands are more numerous. To transfer between the transmit and receive modes, simply press the CLEAR key. Not only will the program change modes, but your ham radio equipment will also be switched between modes. While the system is in the receive mode, the user may be typing a response into the buffer, which is displayed below the received text on the CRT. If the transmitting station asks a question requiring an instant response, the user may stop typing into the buffer, answer the question and resume buffer typing without losing the text previously buffered.

At any time, the user may transmit a "quick brown fox" message, a line of CQs, the time and date, the station identification in RTTY and/or cw and any of the canned messages saved on disc. Disc-based commands include displaying the disc directory, saving and playing back received, previously transmitted or keyboard-created messages and sending and receiving disc files in hex format. A word processor such as Electric Pencil or Scripsit may be used to edit or create M8000 messages on disc. The M8000 also includes an extensive subprogram that allows the user to set up an "electric mailbox" with WRU capabilities.

Performance

The M8000 performed flawlessly during two months of on-the-air testing on both 20 meters and a 2-meter RTTY-bent repeater. Documentation includes a command summary chart and with it at hand, it did not take long to master the numerous commands.

One program quirk involved the use of the IGNORE RETURN command. My line printer (an IDS 440 Paper Tiger) must receive a line return before it will print a line. With IGNORE RETURN enabled, the line printer will not print automatically. To obtain hard copy, the user must disable the IGNORE RETURN function or switch to the transmit mode and send a line return.

Each M8000 sold is personalized with the purchaser's call sign and/or name (48 characters maximum). This serves two objectives — the user's call is included in the program for all station identification functions and personalized software will not likely be stolen.

The minimum hardware requirements for the M8000 are a TRS-80 computer (Model I or III) with 32 k of RAM, one disc drive, TRSDOS 2.3 and a Macrotronics interface (M80, CM80, or TM80) or an RS-232C interface. With some radio equipment, an afsk generator and an RTTY demodulator may be necessary or desirable.

The M8000 package includes one discette containing a personalized copy of the M8000 software, a module that is installed on a Macrotronics interface to make it M8000-compatible and a three-ring binder containing full documentation. The package costs $150 and may be obtained from Macrotronics, Inc., 1125 North Golden State Blvd., Suite G, Turlock, CA 95380. — *Stan Horzepa, WA1LOU.*

[1]mm = inches × 25.4.

Technical Correspondence

Conducted By
Gerald L. Hall,* K1TD

The publishers of QST assume no responsibility for statements made herein by correspondents.

SPREAD SPECTRUM TECHNIQUES

☐ The article on spread spectrum Amateur Radio in November 1980 *QST*[1] was very interesting. Author Paul Rinaldo, W4RI, is to be commended for discussion an extensive subject with such a concise treatment. The essential features and characteristics of spread spectrum were mentioned. However, there are some potential misconceptions.

In the article Rinaldo mentions that spread spectrum signals can be overlaid on top of existing operating frequencies and states, "If this is done with care, the preexisting users wouldn't even detect the presence of the SS overlay." As Rinaldo implies, under the proper circumstances this is completely true. However, if the spread-spectrum transmitter is close to a conventional receiving station, that receiving station will certainly be jammed on all channels in that band! On the converse, when the spread-spectrum station is receiving and the nearby conventional station is transmitting, the reverse will occur: The spread-spectrum station will experience severe bleed-through of the undesired signal. This arises from using limited bandwidth spreading ratios. The equation for jamming rejection is:

$$\text{Jamming rejection} = 10 \log (\text{bandwidth ratio}) \quad \text{(Eq. 1)}$$

where bandwidth ratio is the rf bandwidth divided by the information (audio) bandwidth.

Jamming rejection is the amount of suppression of undesired signals in the spread-spectrum receiver. Eq. 1 also holds true for the degree of covertness (noninterference with conventional receivers) when the spread-spectrum station is transmitting. As can be seen, the amount of bandwidth spreading required for modest rejection is significant: For 30 dB of rejection a 1000:1 spread would be required, and for 40 dB, 10,000:1. A 1000:1 spread of filtered audio is 2.5 to 3 MHz of rf bandwidth, and that only gives 30 dB of dynamic range. But it is common for signal strengths to exceed a dynamic range of 80 dB when considering in-band transmitters within a couple of miles of a receiving station. The author gives typical values of 10 to 100 for spreading ratios. These are clearly inadequate.

The author also states that changing the code allows another private channel. Again, this is completely true under the proper circumstances. Here, there is a better relationship for off-channel rejection:

$$\text{Channel rejection} = 20 \log (\text{bandwidth ratio}) \quad \text{(Eq. 2)}$$

Since this is a 20-dB-per-decade relationship, the channel rejection builds up at a faster rate than jamming rejection. For the same 2.5 MHz, 1000:1 spread spectrum voice signal, 60 dB of off-channel rejection is possible. But that is with a very limited number of codes; with a wider choice, the channel rejection falls short by several decibels.

In addition, the suggestion of spread spectrum for the Amateur Radio Service is not new. J. P. Costas, W2CRR, proposed it back in the 1950s, just when ssb was in its infancy.[2] Costas contributed a circuit, the Costas loop demodulator, which is very valuable to many spread-spectrum systems today. It was designed to demodulate double-sideband suppressed carrier (usually abbreviated dsb) transmissions. Dsb is the simplest spread-spectrum signal, with a spreading ratio of 2. Dsb also has some significant advantages over ssb.[3] The most notable is that the transmitter peak-to-average power requirements for nonsinusoidal modulating signals is much tamer. For example, according to the reference,[4] if a square wave is transmitted with ssb, the peak-to-average power requirement of the transmitter approaches infinity, but for dsb the peak-to-average power requirement is 1:1. For a sine wave, the peak-to-average requirement for both ssb and dsb is 2:1. In the 1950s it was quite difficult to make good ssb transmitters, even compared to the added complexity of the Costas loop demodulator needed for a dsb receiver. Even today this is a significant problem with speech processors being used to help alleviate the wild peak-to-average requirements of nonsinusoidal (voice) modulation. Even with these significant disadvantages, ssb became the standard modulation format. There is a simple reason for ssb winning out over dsb: adjacent-channel rejection. It is easier to increase adjacent-channel rejection to the levels needed (80 dB and greater) with fancy receiver filters than it is to spread the bandwidth of the transmission.

I don't want to sound like a conservative who doesn't want change. Actually I would like to see more experimentation with advanced modulation techniques. It is with the kind of exposure that Rinaldo is giving that this can take place. However, I would not like to see significant misconceptions spoil it by creating distrust between various groups of amateurs. That isn't likely if the fine details are understood in advance. Then the problem becomes (as it is in the military), "Where can enough available spectrum be found for such a service?" Perhaps the answer is at 900 MHz, as suggested by Rinaldo.

Incidentally, the article by J. P. Costas makes very interesting reading. Even though it was published in the IRE literature, it is still readable by persons without a PhD in mathematics, with only a couple of equations per page. Moreover, it reads as if it were written in 1979, rather than 20 years earlier. His comments about congestion and solutions are very perceptive, if not prophetic. Of particular interest are his evaluations of ssb versus spread-spectrum performance in congested conditions. "As the congestion becomes worse it will be impossible to avoid reducing the data rate per circuit. The important point here is that the broad-band philosophy ACCEPTS INTERFERENCE AS A FACT OF LIFE and an attempt is made to do the best that is possible under the circumstances. The narrow-band philosophy essentially denies the existence of interference, since there is an implied assumption that the narrow-band signals can be placed in non-overlapping frequency bands and thereby prevent interference." It is my perception that this philosophy remains prevalent today. — *Ken Wetzel, WA6CAY, 731 Fendrick Circle, Ridgecrest, CA 93555*

[1] P. L. Rinaldo, "Spread Spectrum and the Radio Amateur," *QST*, Nov. 1980, p. 15.

*Associate Technical Editor

[2] J. P. Costas, "Poisson, Shannon, and the Radio Amateur," *Proceedings of the IRE*, Dec. 1959, pp. 2058-2068.

[3] J. P. Costas, "D.S.B. vs. S.S.B.," Technical Correspondence, *QST*, May 1957, p. 42.

[4] *Reference Data For Radio Engineers*, Fifth Ed., p. 21-5.

TELEPHONE INTERCONNECTIONS

☐ August 1977 *QST* Technical Correspondence contains information that I prepared on the subject of telephone interconnection arrangements.[5] The new arrangement described there is designated QKP, shown in Fig. 1. Your readers will most likely not find it possible to obtain the QKP interconnection arrangement at their local telephone stores.

The position of the telephone company on interconnection arrangements includes the following:

1) As the result of "registration" under the FCC rules, Part 68, telephone companies have "frozen" some interconnection arrangements. This means that no new installations will be made of the arrangements that are frozen; existing installations may continue in place.

2) Protective connecting arrangements (PCA) are never sold. The QKP contains a PCA, so it will not be available for sale.

3) Many hams will have to buy some kind of device from a manufacturer who is willing to spend the money to register it.

4) Look for a new offering designated POP, which covers only the voice coupler as used with the QKT arrangement. A telephone

[5] G. Schleicher, "New Telephone Interconnection Arrangements," Technical Correspondence, *QST*, Aug. 1977, p. 42.

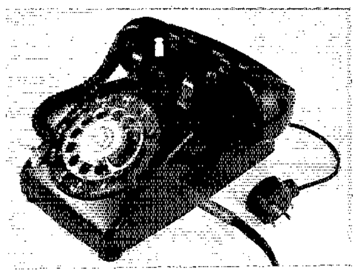


Fig. 1 — The QKP "interconnection" instrument. It contains voice coupler circuitry inside the case, and accepts a standard 1/4-inch plug.

company instrument (priced separately) having an exclusion key must be used with the coupler. The portable QKP is now frozen; it will be available only if some independent maker of telephones decides to market one.

As I see it, the FCC's registration program has made interconnection more difficult for the ham who is not an "appliance operator." — *George Schleicher, W9NLT, 1535 Dartmouth La., Deerfield, IL 60015*

BEVERAGE ANTENNAS FOR AMATEUR COMMUNICATIONS

☐ Questions are often raised about the use of Beverage antennas for 160-m reception. In the mid-1970s, our laboratory carried out an extensive study of Beverage antennas for hf communications, direction finding and over-the-horizon radars. The study included both theoretical and experimental work. In general, there was fair agreement between experiment and theory, and since theory better reveals the design trends because operating parameters can be readily varied, the following remarks are based on theoretical analysis.

1) For frequencies of about 2 MHz, a Beverage antenna has better performance when the ground conductivity beneath it is poor. The calculated gains for an antenna 100 meters long and 1 meter above the ground are −9.3, −12 and −15 dBi for poor, average dry and good ground. At 25 MHz, these gains are −1.3, −0.5 and +1.5 dBi respectively, i.e., the opposite trend with change in conductivity.

2) The gain increases with the length of the antenna. For a frequency of 2 MHz and for an antenna 1 meter above average dry ground, the theoretical gains are −12, −8.5, −7.5 and −7 dBi for antenna lengths of 100, 200, 300 and 400 meters.

3) The gain increases with increases in the height of the antenna above ground, but the change is not large. Again for a frequency of 2 MHz and a 100-meter antenna over average dry ground, the theoretical gains are −12.7, −12, −11 and −10.7 dBi for antenna heights of 0.3, 1, 2 and 3 meters.

4) For a 2-MHz operating frequency and an antenna 100 meters long, 1 meter above the ground, the azimuthal beamwidth is about 77°, the vertical beamwidth is 60° and the take-off angle about 42°.

With this information you can extrapolate to a length to fit your property and estimate the expected (theoretical) gain. However, if you want to cover all azimuths, you will need a rosette of Beverages (comprising at least six), and hence a large amount of land.

The characteristic impedance of the Beverage is about 500 ohms, so the antenna should be terminated at its far end in a resistance of that value, via a resistor and a ground screen. The received signal is taken from the other end through a transformer, with one primary lead connected to ground via another ground screen. The transformer must match the 500-ohm antenna impedance to 50 ohms. — *John S. Belrose, VE2CE, Communications Research Centre, P.O. Box 11490, Station "H," Ottawa, ON K2H 8S2*

INCREASING THE OUTPUT VOLTAGE FROM FIXED-VOLTAGE REGULATORS

☐ Now that you have exposed the poor practice of using diodes to raise the output of

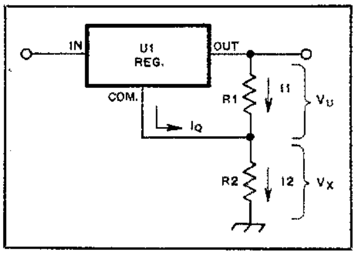


Fig. 2 — Circuit for increasing the voltage output from a fixed-voltage regulator IC.

regulator chips, I think you would do the amateur community an even bigger service by correcting the egregious error printed in May 1981 *QST*.[6]

While observing Fig. 2, note the following analysis:

$$I1 + I_Q = I2 \quad \text{(Eq. 1)}$$

$$V_u = I1 \times R1 \quad \text{(Eq. 2)}$$

$$V_x = I2 \times R2 \quad \text{(Eq. 3)}$$

Therefore, $V_x = (I1 + I_Q) \times R2$. Using the example in the Technical Correspondence letter: $V_u = 12$, $V_x = 1.8$ and $R1 = 560$. Then,

$$I1 = \frac{V_u}{R1} = \frac{12}{560} = 0.0214 \text{ ampere.}$$

Therefore,

$$R2 = \frac{V_x}{I1 + I_Q}$$

The quiescent current, I_Q, for the μA78H12 regulator is 0.010 ampere.[7] From this, $R2 = 1.8/(0.0214 + 0.010) = 57.3$ ohms, as opposed to 84 ohms from calculations presented in the Technical Correspondence letter. This circuit will give close to the desired output, but only because the quiescent current is relatively constant throughout the normal current range of the device. None of these circuits will regulate as well as the device by itself.

As you can see, the error in the method presented in May *QST* will be even worse if someone were to try to raise the device even farther above ground. Incidentally, let me point out that the quiescent current is different for just about every regulator.

Using the practical value of 82 ohms suggested for the 84-ohm resistor, someone is going to end up with about 14.6 volts instead of 13.8; not too bad, but only a small error because of the particular case that was chosen. I feel that the technical editors of *QST* should catch such obvious errors and thus stem the flow of misinformation. — *Ronald J. Whitsel, WA3AXV, 209 Frog Hollow Rd., Churchville, PA 18966*

ADDITIONAL INFORMATION ON AMTOR

☐ I thank *QST* for helping to bring AMTOR to the attention of readers with the publication of my article, "Amtor, an Improved Error-Free RTTY System," in June 1981 *QST*. The introductory comments under the title may be a little misleading, however. For all practical purposes, SITOR, SPECTOR, MICROTOR and AMTOR are *identical*, not merely similar. Contacts can (and have) taken place between equipment operating on AMTOR and any of the others. The fact that all these equipment types meet CCIR recommendation 476 defines them as interworkable.

Ref. 2 of the article, "Amtor, The Easy Way," was printed in RSGB *Radio Communication*, June-July 1980. The *QST* article, page 27, center column, near the top, contains a sentence beginning, "This is done by operator intervention . . ." Unfortunately, this does not reflect the meaning of the original manuscript, which reads, "This can be done by operator intervention to start again as if commencing a new QSO, but the usual procedure is that when both stations have been receiving errors or requests for repeat for 32 blocks, then they both automatically drop back to the synchronization procedure, with the sending station retaining any unsent message in a buffer."

For information, there are, as of May 1981, some 40 amateur stations operational on AMTOR, in eight countries worldwide. At the recent International Amateur Radio Union Region 1 conference, it was recommended that member societies should press for permission to use AMTOR in their countries. — *J. Peter Martinez, G3PLX, 11 Marchwood Ct., Broadsands Dr., Gosport, Hants, England*

[6] P. O'Dell and B. Shriner, "A 5-A Loafer Feedback and Update," Technical Correspondence, May 1981 *QST*, p. 42.

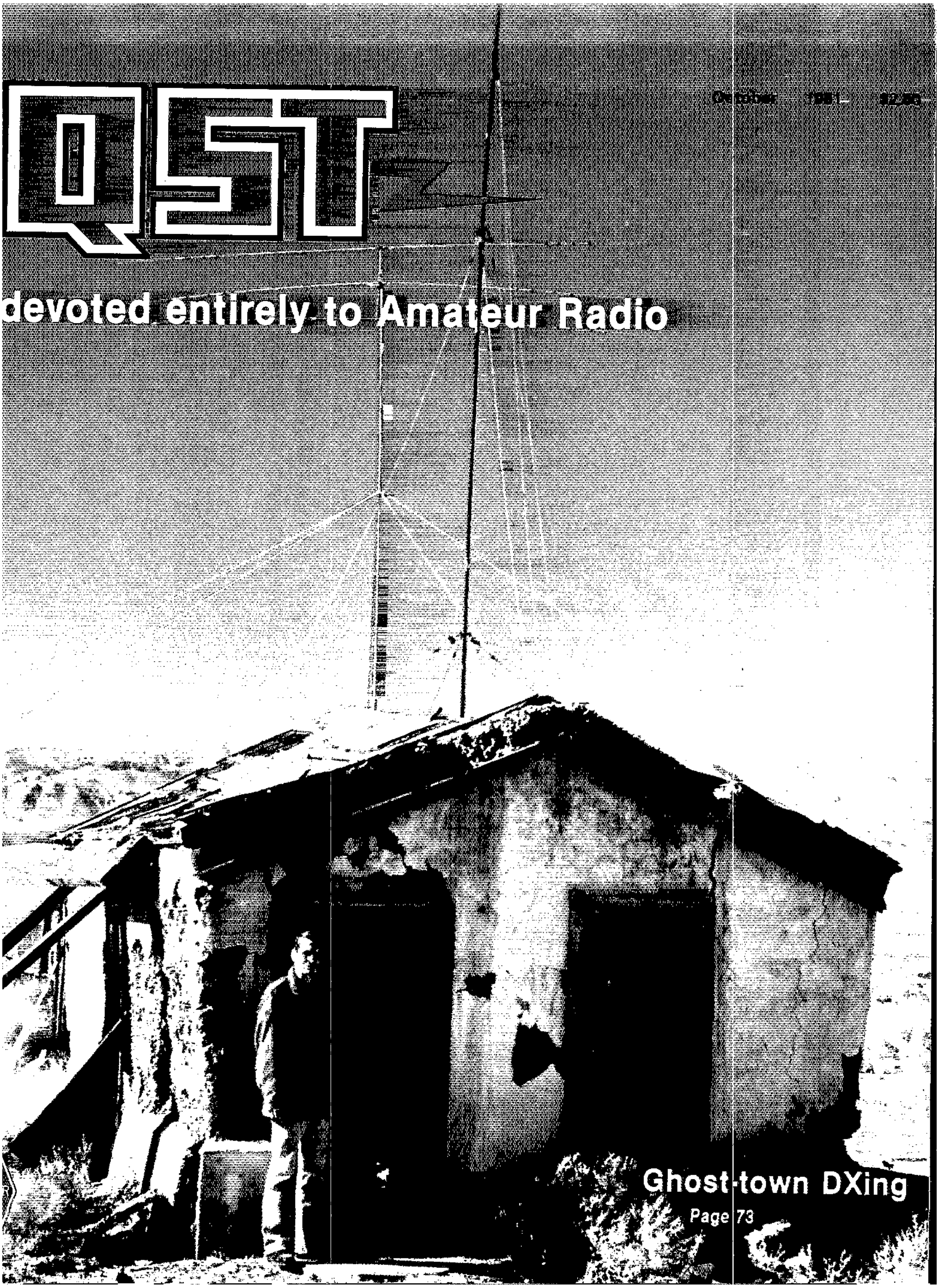
[7] *Fairchild Voltage Regulator Handbook*, 1978 ed.

Feedback

☐ Author Ruh points out a typographical error in "All About Amateur Television," in June 1981 *QST*. The gain figure for the MBM-48 antenna should be 15.5 dB, not 5.5. Ruh also mentions that most U.S. ATV in-band repeaters now use the 4.5-MHz sound subcarrier input/output for normal audio signals, with the on-carrier sound input being reserved for data and other nonvoice signals. Amateurs searching for low-cost hardline for ATV or other uhf applications should contact Sierra Western Electric Cable Co., Box 23872, Oakland, CA 94632, tel. 415-832-3527. (The ARRL and *QST* in no way warrant this offer.)

☐ Colin Dickman, author of "The ZS6U Minishack Special," mentions that the errors in Figs. 1 and 2 of the version of his article appearing in *Radio ZS* were faithfully reproduced when the information was adapted for April 1981 *QST*. The numbers associated with the inductor windings refer to the tap points, not to the number of turns between taps. For example, Fig. 1, p. 32 of the *QST* article, should show a 20-turn coil with taps at 3-1/2, 5-1/4 and 8 turns from the right-hand end. Similarly, Fig. 2 should show a 34-turn coil with intermediate taps. Dickman's current address is 41 Eden Rd., Bramley, 2090 Tvl., Republic of South Africa.

☐ The August 1981 *QST* Product Review column incorrectly listed the Radio Shack DX-302 receiver sensitivity as 0.03 μV for 10 dB S/N. It should have been stated as 0.3 μV.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QST

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THE COVER

After placing Ballarat on the map last year, a group of enthusiastic California hams will do it again. Project Johannesburg will link the old mining town with its namesake in South Africa. Details are on pages 73 and 79. *(photo courtesy WA6NKL)*

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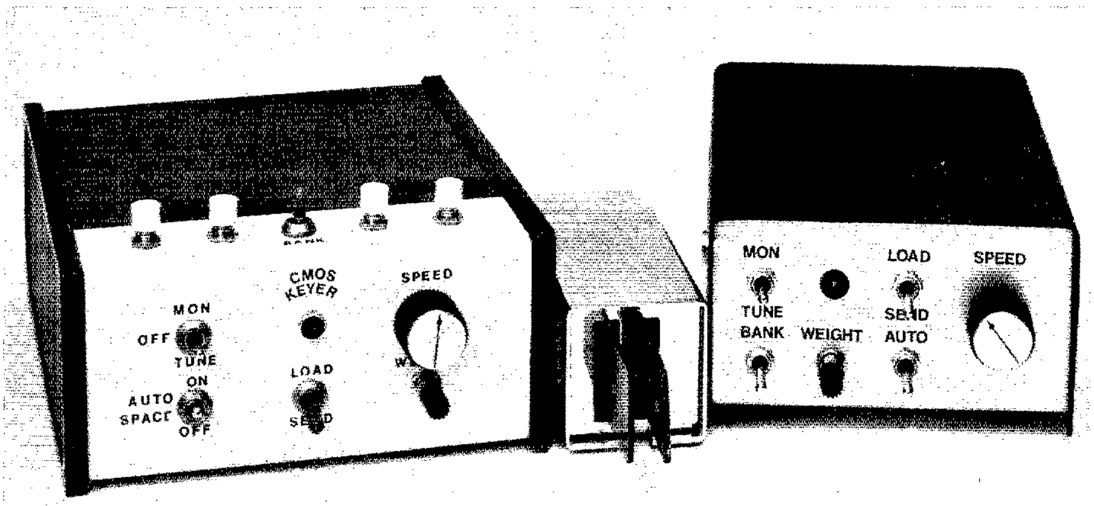
The CMOS Super Keyer



Able to bridge tight pocket books with a single board, this keyer has a features/cost ratio that is hard to beat! It is designed for — and by — cw operators.

By Jeffrey D. Russell,* KC0Q, and Conway A. Southard,** N0II

Why should *you* build this keyer? Well, let's start by listing its prominent features, and see if you can resist its attraction: (1) Compact and inexpensive; (2) Has eight 50-character message memories; (3) Messages are loaded or aborted by paddle operation; (4) Transmitter not keyed during message loading; (5) Any message may be instantly restarted; (6) Includes a message loading indicator; (7) Incorporates iambic operation; (8) Employs both dot and dash memories; (9) Has switch-selectable, auto-character spacing; (10) Uses a gated clock for instantaneous asynchronous starting; (11) Has ultra-low power requirements; (12) Features continuous message retention; (13) Offers very friendly timing circuitry.

Not only will you have a keyer that you will be proud of, but those interested in logic design will find this presentation useful and interesting. Several novel features help to reduce the number of ICs used — only 12 readily available ICs are required. CMOS devices are employed, and with no quiescent current paths the keyer draws only 10 to 15 microamperes in standby. It has no ON/OFF switch! A state transition diagram is also included and, as far as we know, it is the first keyer so presented.

Cost

Certainly this is a factor of primary concern to amateurs. Total IC costs will be about $10, including an approximate cost of $7 for the RAM chip. If your junk box is helpful, a total cost of $20 or $25 can be expected. If you need to buy all the parts,[1] the keyer could cost $60 or so. Not bad in light of today's "smaller" dollar. Double-sided pc boards with plated-through holes are available from either author at a cost of $15 each (plus $1 shipping).[2] These boards measure 3.6 × 4.6 inches (91 × 117 mm).

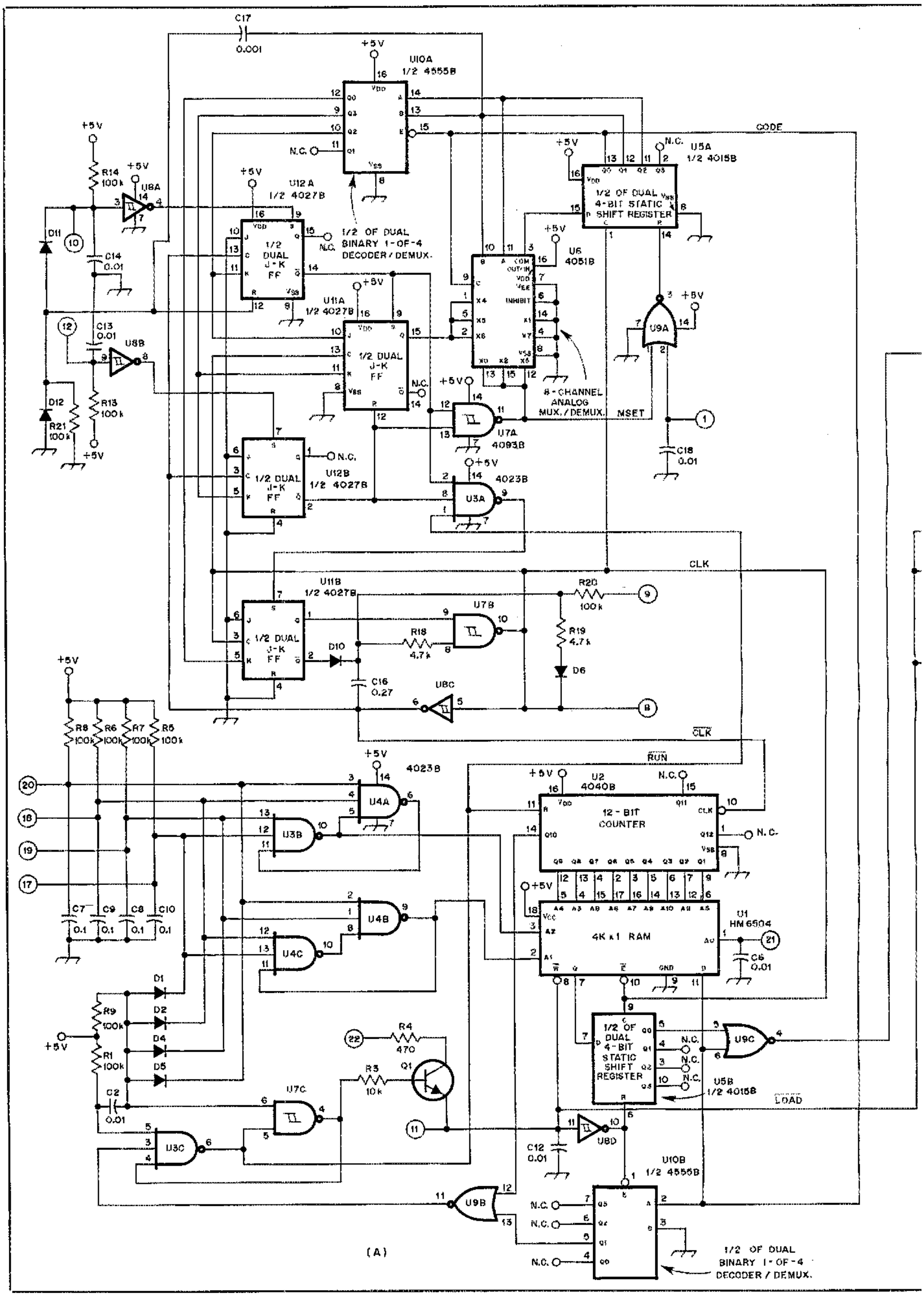
CMOS Design

The advantages of CMOS technology are apparent in this keyer: low cost, ultra-low power requirements, wide logic swings, "down-the-middle" transfer characteristics, high impedance inputs, lots of "fan out" drive capability and good noise immunity, to name a few. The 6504 RAM can store 4096 bits: that's eight messages of 512 bits each, or about 50 characters per message.

This circuit does not depend on how fast one IC is with respect to another. In some designs you are instructed to swap this or that IC if you have a problem, or R-C networks are added to the circuit to reduce "glitches" or race conditions. There are no R-C de-glitchers in this design. The read-in/read-out memory-

*2125 Linmar Dr. NE, Cedar Rapids, IA 52402
**2519 Meadowbrook Dr. SE, Cedar Rapids, IA 52403

[1]Notes appear on page 17.



C17 0.001
U10A 1/2 4555B
1/2 OF DUAL BINARY 1-OF-4 DECODER / DEMUX.
CODE
U5A 1/2 4015B
1/2 OF DUAL 4-BIT STATIC SHIFT REGISTER
U8A
R14 100k
D11
C14 0.01
U12A 1/2 4027B
1/2 DUAL J-K FF
U6 4051B
U11A 1/2 4027B
1/2 DUAL J-K FF
U9A
C13 0.01
U8B
D12
R13 100k
R21 100k
8-CHANNEL ANALOG MUX./DEMUX.
MSET
U7A 4093B
C18 0.01
U12B 1/2 4027B
1/2 DUAL J-K FF
U3A 4023B
CLK
U11B 1/2 4027B
1/2 DUAL J-K FF
R20 100k
U7B
R18 4.7k
R19 4.7k
D10
D6
C16 0.27
U8C
CLK
RUN
R8 100k
R6 100k
R7 100k
R5 100k
U4A 4023B
U3B
U2 4040B
12-BIT COUNTER
C7 0.1
C9 0.1
C8 0.1
C10 0.1
U4B
U4C
U1 HM 6504
4K x 1 RAM
C6 0.01
D1
D2
D4
D5
R9 100k
R1 100k
R4 470
Q1
R3 10k
U5B 1/2 4015B
1/2 OF DUAL 4-BIT STATIC SHIFT REGISTER
U9C
LOAD
U7C
C2 0.01
U3C
C12 0.01
U8D
U10B 1/2 4555B
U9B
1/2 OF DUAL BINARY 1-OF-4 DECODER / DEMUX.

(A)

address transitions are logically synchronized, and all transition states are provided for.

Functional Keyer Description

There are four basic areas of the keyer: The ASYNCHRONOUS paddle logic and oscillator, SYNCHRONOUS (state machine) section, MEMORY AND MEMORY CONTROL, and the WEIGHTING, OUTPUT and SIDETONE section (discussed under Wiring Options). We'll examine them one at a time.

Asynchronous Module

Almost all modern keyer designs have dot and dash memories, as does this one. However, many designs don't allow the full time between elements to get off the dash or dot paddle before another element is loaded. The result, for those keyers, is that you may have difficulty with extraneous elements (usually dots) creating, for example, an R for an A or an I for an E. This keyer design allows you the full interelement time to release the paddles, and a special dot reload circuit makes squeeze timing even less critical — it is a super-easy keyer to use.

The ASYNCHRONOUS module derives its name from the fact that paddle manipulation by the operator can be, and usually is, quite irregular and not in phase with any internal keyer clock. Refer to Fig. 1. U8A and U8B are inverters that isolate the dot and dash paddles. U12A and U12B comprise the dot and dash memory FFs (flip-flops). These FFs are set by the action of the paddles and are reset (as described later) by the state module or the SYNCHRONOUS section. U11A is the iambic FF that allows the keyer to provide alternate dots and dashes when both paddles are closed. (Iambic operation seems to be the design preferred by most

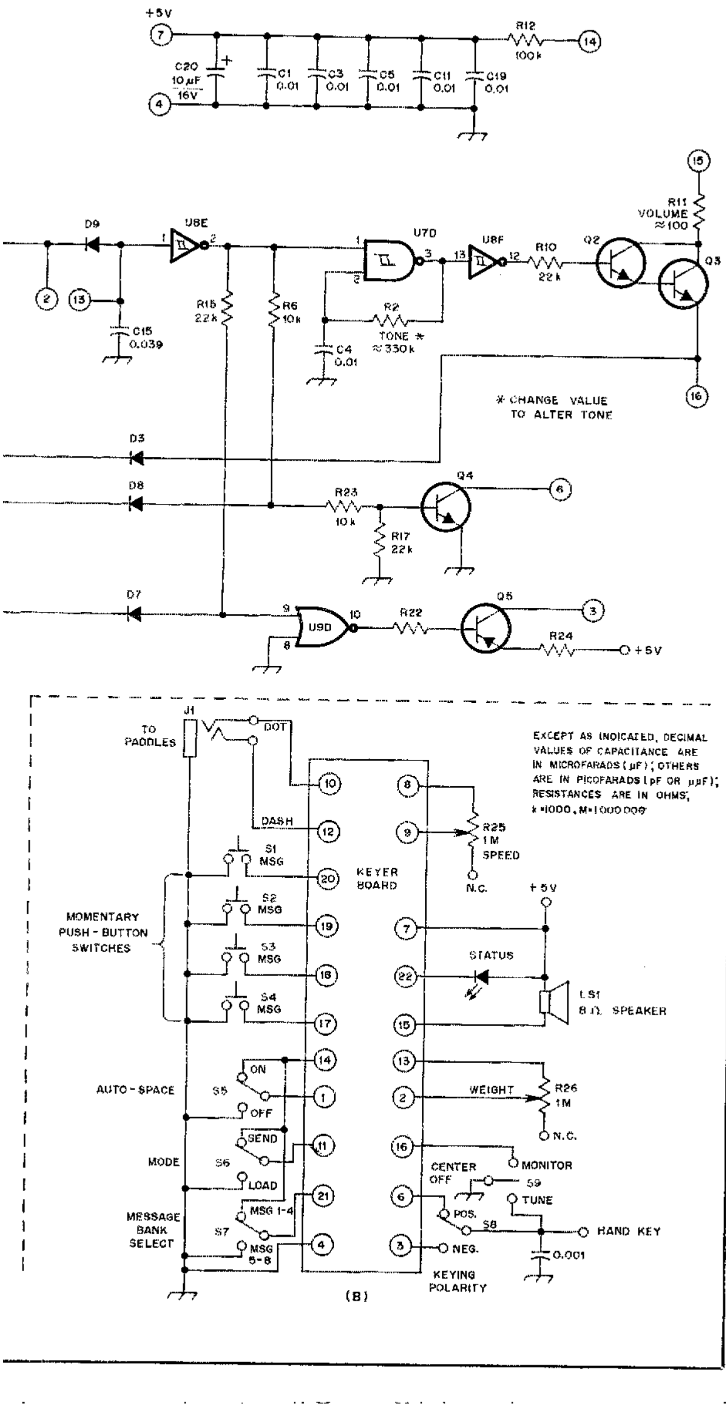


Fig. 1 — Schematic diagram of the keyer. One-eighth- or 1/4-watt carbon resistors should be used. Simplification of the keyer by elimination of features and by component selection is discussed in the text. The circled leads at A correspond to the board edge connector pads shown at B. With the exception of C15, C16 and C20, all capacitors are disc ceramic, 50-V units.
C15 — Mylar, 0.039 µF, 50 V.
C16 — Mylar, 0.27 µF, 50 V.
C20 — Electrolytic or tantalum, 10 µF, 16 V.
D1-D12, incl. — Silicon, fast-switching diode, 100 PIV, 75 mA, 4 ns, 1N4454, 1N914, 1N4148 or equiv.
Q1-Q3, incl. — Npn silicon low power, general-purpose amplifier, 500 mW, 2N2222 or equiv.
Q4, Q5 — See text.
U1 — CMOS 4k × 1 RAM, Harris HM6504-9.
U2 — CMOS 12-bit counter, 4040B.
U3, U4 — CMOS triple 3-input NAND gate, 4023B.
U5 — CMOS dual shift register, 4015B.
U6 — CMOS 8-to-1 multiplexer, 4051B.
U7 — CMOS quad Schmitt NAND gate, 4093B.
U8 — CMOS hex Schmitt inverter, 40106B, MC14584B.
U9 — CMOS quad 2-input NOR gate, 4001B.
U10 — CMOS dual 2-to-4 decoder, 4555B.
U11, U12 — CMOS dual J-K FF, 4027B.

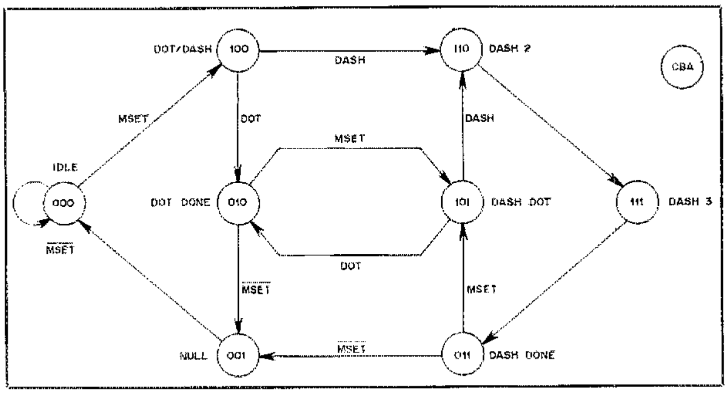


Fig. 2 — State transition diagram of the keyer. Dot = not dash, dash = current output of the iambic FF, MSET = 1 if either the dot or dash memory is set. At the completion of a dot, state 010 (dot done) is always entered. After dash completion, state 011 (dash done) is always entered. A mark is begun in either state 100 or 101. The clock produces short negative-going pulses, and all state transitions occur on the positive-going clock edge. An attempt is made to reset the dot memory on the negative clock pulse edge during the end of state 010 and to reset the dash memory on the negative clock edge during the end of state 011. Setting of the iambic FF to dash on the transition from state 010 to 101 and resetting to dot on transition from 011 to 101 is sought. If the dot reload timing change described in the text is used, a special dot reset pulse is generated at state 110, which tries to reset the dot FF.

Table 1

Edge Connector Signals

Pad Number	*Signal*
1	AUTO-SPACE
2	WEIGHT (1)
3	Negative keying output
4	Ground
5	Spare
6	Positive keying output
7	+5 V
8	SPEED (1)
9	SPEED (2)
10	Dot paddle input
11	LOAD switch
12	Dash paddle input
13	WEIGHT (2)
14	Positive high for pull-ups
15	Speaker
16	MONITOR switch
17	Message button 4
18	Message button 3
19	Message button 2
20	Message button 1
21	MESSAGE BANK SELECT switch
22	STATUS LED

operators.) FF U11B is set to turn on the gated oscillator and keeps the oscillator running until it is stopped intentionally.

The oscillator, U7B and U8C, is gated so that a character can start immediately when you close a paddle. Some designs with gated clocks have a first cycle that is not the same length as the succeeding ones. This problem may be solved by using a continuously running clock, but creates another problem: A character may be initiated only at some undetermined time after paddle closure, depending on where the oscillator may be in the cycle at the time. The oscillator in this keyer is gated, and, when stopped, its output (CLK) is high. Further, the duty cycle is purposely set with a very short negative pulse and a long positive pulse that eliminates the "first-cycle" syndrome. This is crucial to the overall operation of the keyer. D10 serves as a precharge path for the oscillator; it ensures that the oscillator returns quickly to the idle state at the end of the keying cycle.

The dot and dash FFs are set by the paddles, and their outputs are combined in gate U7A. U7A output is the signal called MSET (Memory SET) on the state transition diagram and is a 1 if either or both FFs are set. The MSET signal is an input to the state module. The output of iambic FF U11A is called DOT/DASH and will be a 1 for a dash or a 0 for a dot. The J-K FF used at 11A must have a defined state when both SET and RESET are active — not all FFs are acceptable here.

Dot and dash FFs U12A and U12B are reset by the CLK-NOT (the negative going edge of CLK) on leaving state 010 for a dot or 011 for a dash. These same signals are used to toggle the iambic FF, too.

Clock FF U11B is turned on by a dot paddle closure, a dash paddle closure or a RUN-NOT signal from the memory section. This FF is reset by a high on the K input, which occurs only at state 000, when the keyer has arrived at the idle condition. The oscillator (U7B/U8C) normally does not have a linear speed characteristic, but this is relieved by using a SPEED potentiometer with an inverse log taper. A regular log (audio) taper potentiometer may be used here, but should be wired to increase speed with a counterclockwise rotation of the control.

Synchronous Module

This is the heart of the keyer logic. A state transition diagram (shown in Fig. 2) will aid in explaining the sequencing of the keyer. Basically, the circuit operates as a clocked-state machine with eight states. These states are identified in binary code (CBA), and the circle nodes on the diagram are the binary description of the states. States are identified out of a shift register, which is always shifting to the right. For example, the state 000 is the idle state and when either paddle is closed, the state shifts right and a 1 is shifted into the first position (C) — hence the state 100. Keep in mind that whenever the C position is a 1, the keyer will be outputting a MARK. So on closure of either paddle, the keyer sequences to state 100, and a MARK is output.

On the next clock tick, the keyer can move to state 010 or 110, depending on which desired element (dot or dash) is being keyed. Note that the state is shifted right, and a dash will cause a 1 to shift into the register for state 110, or a not-dash (dot) will cause a 0 to produce a state 010.

In general, a state machine must have sufficient memory to determine its past history (to know what state it is in) that, when mixed with input signals (called qualifiers), will exactly determine the next state. The state history for this unit is kept in a 4-bit shift register, U5A. U5A is clocked (shifted right) by CLK, and the left-most bit is loaded into the D input from U6. The state of the keyer is determined by Q0, Q1 and Q2, and these outputs are the CBA node identifiers in the state diagram. The fourth bit of that shift register is ignored, as only three bits are needed to define the eight states of the keyer.

Assume the keyer is in state 000, and a clock pulse occurs. The signal at U6 input X0 (pin 13) will be output at pin 3 and will become the first bit shifted into the register. Since the clock pulse must occur because of a paddle closure, MSET at pin 13 will be a 1, and the shift register is now set at 100.

Because of this action, the keyer will go to state 100 from 000 with any paddle closure. However, the next state will either be 010 or 110 depending on the DASH input (refer to the state diagram in Fig. 1). Which inputs to U6 are coupled to the shift register are determined by the current state of the keyer and these inputs.

A single dot closure of the paddle produces the following states: 000 (idle), 100 (send dot/MARK), 010 (dot done), 001 (null) and back to 000 (idle). A dot in state 100 is sent, and then the keyer inserts three space elements — the AUTO-SPACE feature.

To produce a single dash, the states are: 000 (idle), 100 (send dash/MARK), 110 (send second MARK), 111 (send a third MARK), 011 (dash done), 001 (null) and 000 (idle) again. A dash is three elements long, followed by three spaces for AUTO-SPACING.

The dot-done (010) and dash-done (011) states test for the MSET line and controls the sequence and alternating requirements for iambic operation. MSET indicates that *either* the dot or dash memories have been loaded. The signals DOT and DASH just indicate whether the dot or dash memories have been set.

The state outputs of U5A are fed to U10A, an output decoder. U10A produces an output at pin 12 for state 000, which is used to attempt a reset of FF U11B and to turn off the clock. For state 010, an output at pin 10 attempts to reset the dot FF and/or toggle the iambic FF U11A. An output at pin 9 for state 011 attempts to reset the dash FF and/or toggle the iambic FF.

U9A supplies a reset signal to the shift register U5A. With the AUTO-SPACE on, a reset is never applied. With AUTO-SPACE off, a low on MSET will cause U5A to reset and return immediately to the idle state. This can only occur at dot-done (010) or dash-done (011) if no paddle is closed; the state module will be short circuited to idle through those two states. All other valid states will have an MSET signal except dot-done or dash-done. AUTO-SPACE OFF prevents the keyer from cycling through the three nulls.

Message Memory and Control

The inclusion of message memory is almost a requirement for cw operation. Therefore, message memory was designed as an integral element of the total design. This circuit includes the RAM (U1), a sequence counter (U2) and some control circuitry — a "which button has been pushed" latch and decoder (U4A, U3B, U4B and U4C), a cross-coupled FF and message-initiate circuit (U7C, U3C), U5B, U10B, and a couple of gates.

U4A/U3B and U4B/U4C are cross-coupled R-S FFs. Pushing a memory button will set these FFs into one of four states, and the outputs are directed to two address lines of the RAM. One address line from the RAM goes to the BANK SELECT switch, which accounts for three of the 12 address lines. The other nine lines come from the counter, which can then count up to 512 bits (about 50 characters) per message.

The tenth line out of the counter is used as an end-of-buffer signal, which resets FF U7C/U3C; this FF is a message-in-progress FF. Decoder U10B is wired so that if the LOAD/SEND switch is in the SEND position and a code element from the keyer arrives on the CODE line, U10B Q1 output will stop the memory. U9B ORS the stop conditions so that the messages terminate by counting up to 512 or when a paddle has been closed. FF U7C/U3C is set through the diode bank (D1, D2, D4, D5) if any button is pushed.

C2 has a special function. If the memory is already running, RUN-NOT will be low, and a pushed button actually forces FF U7C/U3C to a temporary one-shot condition. This provides a pulsed high on the RUN-NOT line and resets the counter to zero. Without this capacitor, restarting a message from the beginning would be impossible.

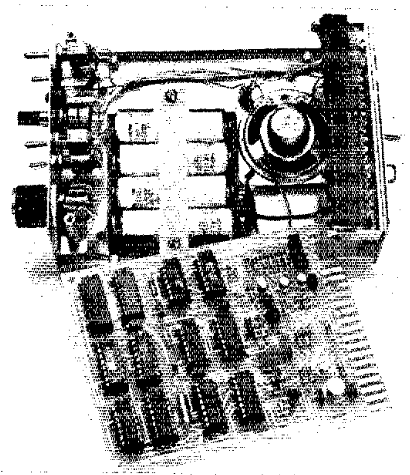
U5B has a unique function, too. It's clocked by the CLK line, which is the same signal that is used to enable the RAM. The rising edge of CLK loads U5B with the data read from memory and holds it for the whole cycle. This way, the RAM can return to standby, and any glitches that might occur in the output, as the address lines are changing, are effectively masked. The counter is incremented by the CLK-NOT signal and is therefore positioned and ready for the next read cycle.

Construction

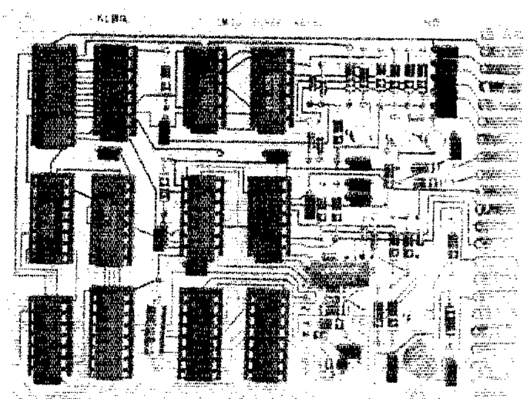
Point-to-point or wire-wrap methods can be used to construct the keyer, but a printed-circuit board is available. With the board, use sockets for the ICs and solder the components to the board while using a low-wattage soldering iron, employing a minimum of heat and solder. The board is laid out with the ICs all oriented in the same direction and with component numbers assigned for easy identification. There are leads between IC pins on the component side of the board, to reduce the physical size of the board. Be careful not to create solder bridges.

This board is designed for use with a standard 22-pin edge connector or solder pads for interconnection to off-board components. Two mounting holes are provided opposite the edge connector. If the edge connector is not used, a third mounting hole can be drilled between pads 4 (ground) and 5 (spare).

It is recommended that you remove the solder flux from the pc board after mounting the components. Radio Shack rosin flux remover (64-2324) is readily available for this purpose. CMOS has



An inside view of the KCØQ keyer. A 10-position switch and associated fixed-value resistors are used for the SPEED control. The 22-pin edge connector is secured to the rear panel by means of a homemade hinged bracket, allowing easy removal of the pc board.



A closeup of the component side of the double-sided pc board. All ICs are oriented in the same direction — a nice touch! If the use of an edge connector is not desired, interconnections may be made by use of holes already drilled at the inside edges of the edge connector pads.

high-impedance inputs. While new, dry solder flux is a good insulator, moisture and other contaminants may create problems later.

Wiring Options

Speed Control: Keyer speed increases as the resistance of R25 decreases. For best operational linearity, the SPEED potentiometer should be an inverse-log taper unit. If counterclockwise rotation of the control is acceptable when increasing speed, a log taper potentiometer will suffice. An alternative to using a potentiometer is the use of a multiposition rotary switch and selected fixed resistance values. Eight or 10 rates of speed are often adequate for normal operation. The resistor values must be chosen experimentally, because the speed is determined by the value of resistance used for R20, R25 and the value of C16; C16 may have a value different from the one marked.

Weight Control: Control of weighting is accomplished by means of D9, C15 and R26. A log taper potentiometer is recommended in order to obtain a finer degree of control at the low-resistance end of the range (as might be used at high keying speeds). The maximum amount of weighting obtainable is determined by C15; the value may be changed to suit your preference. If a weighting control is not desired, eliminate R26, C15 and D9, and install a jumper in place of D9.

Auto-Space Select: S5 may be eliminated if switch selection of the AUTO-SPACE feature is not desired. To disable AUTO-SPACE, don't use C18; install a jumper instead. To enable AUTO-SPACE continuously, disregard C18 and install a jumper between edge connector pads 1 and 14.

Message Bank Select: To limit the number of messages to a bank of four, leave out S7 and C6. Install a jumper in place of C6.

Monitor On While Loading: D3 provides a path to turn on the internal monitor automatically while loading messages. If this is not desired, eliminate D3.

Output Inhibit During Loading: D7 and D8 serve to inhibit keying output when the MODE switch (S6) is in the LOAD position. These diodes may be omitted to delete that function.

Monitor Tone and Volume: The monitor audio frequency can be adjusted by changing the value of R2. Decrease the value of R2 to increase the frequency. If you do not need the monitor, you may exclude LS1, R2, R10, R11, C4, Q2 and Q3, and install a jumper in place of C4.

Dot Reload Timing Change: The dot-memory timing can be altered if desired. D11, D12, C17 and R21 delay setting of the dot FF for one baud during the sending of a dash. In the iambic mode, this allows the operator a bit more time to release the dot lever before the dot memory FF is reloaded. If you wish to delete that function, remove the aforementioned components and install a jumper in place of R21 or D12.

Output Keying: Most applications do not require positive and negative keying outputs. Either one may be disabled. For negative keying output only, eliminate S8, D8, R16, R17, R23 and Q4. If positive keying only is desired, omit S8, D7, R15, R22, R24 and Q5, and install a jumper in place of R15.

In the positive keying line, R16, R23 and R17 have been chosen to accommodate a wide range of keying circuits. Q4 must be selected to handle the keying circuit voltage and current requirements demanded by the transmitter.

Negative Keying Considerations

If negative keying lines are encountered, use the following procedure. Measure the key-up voltage and key-down current of the transmitter keying line. Select a transistor (Q5) that will handle the voltage present (with some margin of safety) and determine the beta of the transistor. Then calculate the values of R22 and R24 using the following formulas:

$$R22 = \frac{0.3 \times \text{beta (Q5)}}{I} \qquad \text{(Eq. 1)}$$

$$R24 = \frac{3.5}{I} \qquad \text{(Eq. 2)}$$

where

I = key-down current in amperes.

With some values of R22 and R24, the negative keying line can actually be pulled above ground potential by a small amount. Most transmitters can handle this positive voltage with ease. If you wish, a protection diode may be added between board pad 3 and ground. This will limit the voltage to one diode drop. Orient the diode with the anode at pad 3 and the cathode to ground.

Troubleshooting

Barring construction problems, bad components or early component failure, few problems (if any) should develop during the life of the unit. An oscilloscope is a useful fault-finding aid, but an analog voltmeter will suffice in many instances. With the analog meter, use the lowest SPEED setting and turn the WEIGHT control off. Higher SPEED control settings are more desirable when using an oscilloscope.

Pay careful attention to which section of the keyer is inoperative. For example, if an output code is present at pin 2 of the edge connector, don't examine the state machine while troubleshooting a monitor problem. If you have troubles in the memory section, check to see that clock pulses are appearing at U1 pin 10, U5B pin 9, and so on. The RAM WRITE line (pin 8) should be high or low depending on the setting of the LOAD/SEND switch. FF U3C/U7C should be set (U3C pin 6 low) when any message button is pushed, and the memory address lines at U1 pins 2 and 3 should indicate which button has been pushed. Otherwise, examine U4A, U3B, U4B and U4C for difficulties.

Remember, most problems are caused by improper construction or faulty components. If sockets have been used for the ICs, substituting and/or swapping ICs may help in locating the difficulty. Constructing the unit so that you can get to both sides of the board readily will make debugging much easier.

Operational Considerations

When power is first applied to the keyer, a continuous mark may be sent. This occurs because the current memory state contains a mark. Place the MODE switch in the LOAD position and depress one of the message buttons to clear the condition. It is recommended that *all* message buffers be cleared initially by setting the SPEED control to maximum and loading spaces into each buffer position.

Message Organization

The 6504 CMOS memory IC has 4096 bit positions that can be used to store data. Because each character requires approximately 10 bits, there is room for about 400 characters. This memory is organized as eight messages of approximately 50 characters each. Instead of using eight message switches, there are four push-button switches and one MESSAGE BANK SELECT switch, S7. (One husband and wife team actually uses the BANK switch to separate his/her messages!)

Loading Messages

Position S7 to select the desired message bank. Place the MODE switch in the LOAD position and start entering data from the paddles after pressing the appropriate message button. The STATUS LED will stay on until the memory is full. It is essential that you allow the keyer to continue loading until the LED extinguishes, even if you are not inputting data. On occasion, you may have a message that is too long for the buffer, in which case you will lose part of the message. It is also possible to leave a mark in the very last buffer location, which will condition the keyer to send a continuous mark if that message is played to the end. The latter condition is rarely encountered, but indicates a message that is a trifle long; it should be re-entered. Note: During loading, the internal clock is running continuously, and the message entered will have long character/word spacing if that is the way it was entered.

Message Playback

To output a loaded message, ensure the

MODE switch is in the SEND position and press the appropriate message push-button. Message output will continue until one of the following conditions occurs: the message buffer empties, a paddle closure occurs, or the same or another message push-button is pressed. Any message may be replayed instantly.

Power-Supply Considerations

Battery operation is recommended for this keyer because it provides continuous memory retention. You'll never need to reload the memories until a change is desired, a feature highly valued by most cw operators. While some operators have used four series-connected alkaline or zinc-carbon batteries, a better choice is a similar combination of NiCads. Using 450 mAh (milliampere-hour) cells, the keyer should operate for many months. The NiCads should be recharged when the voltage drops to about 4.5, or once every six months, whichever comes first.

If ac operation is contemplated, the voltage presented to the keyer should be approximately 5, plus or minus 0.5 volt. The ripple content of the supply should be low. Note that because this keyer draws so little current during standby (10 μA or so), series-connected Zener regulators are difficult to use.

Other Controls

The TUNE/MONITOR/OFF switch (S9) allows the transmitter to be keyed continuously when placed in the TUNE position and selects operation with or without the internal monitor. Operating with the monitor enabled will demand more power from the batteries. Most operators prefer to use the transmitter sidetone instead.

When the AUTO-SPACE feature is enabled, the keyer will perform precision spacing for you. The end result will be more uniform cw.

The WEIGHT control increases the on-to-off time ratio of the generated characters as the control is advanced in a clockwise direction. In the fully counterclockwise position, 50% weighting is provided. The final setting of this control will depend on the keying circuit time constants of the transmitter used and on personal tastes.

Speed Determination

The method used to determine the operational speed of the keyer is based on the fact that the buffers are exactly 512 bauds in length. Here's how it's done. Locate an empty buffer (or one you wish to empty) and press the pushbutton while it is in the LOAD mode. Count the number of seconds it takes until the STATUS LED extinguishes and divide that number into the constant 614.4. That will provide you with the exact speed (in wpm) of the keyer.

Acknowledgments

The authors gratefully acknowledge the efforts of Tom Lindgren (WØWP) and Glenn Thorne (KDØQ) in developing the initial version of the pc board, Joe Gentle (NØBB) for critical evaluation of the keyer "feel," which led to improving it, Russ Lenth (AEØR) for suggesting the addition of D3, and the many hams who have built their own units and expressed satisfaction. We hope you'll join that happy group!

Notes

[1]Parts and kits may be obtained from The Partstore, 999 44th St., Marion, IA 52302. Harris HM6504-9 RAMs are also available from your nearest Schweber Electronics distributor. The HM6504-9 has a specified standby current drain of 10 μA (maximum), with 0.1 μA being typical. An HM6504-5 is specified at 500 μA (maximum) and should probably be avoided if battery operation is contemplated.

[2]A comprehensive instruction manual accompanies each bare board or keyer kit. The manual is available separately for $3 postpaid. Please include an s.a.s.e. when requesting information. The ARRL and *QST* in no way warrant this offer.

Strays

TA PROFILES

☐ RFI/TVI headaches? Yes, indeed! Many radio amateurs are confronted with this annoying situation. For this reason, we are pleased to have ARRL Technical Advisor Harold R. Richman, W4CIZ, join our official family. His area of TA expertise is RFI/TVI.

A member of the ARRL since 1931, Hal received his first Amateur Radio license in 1930 and now holds an Extra Class license. He also has Commercial Radiotelephone, First Class and Radiotelegraph Second Class licenses. Active on the high-frequency and 144-MHz bands from his station in Annandale, Virginia, Hal has held appointments as Emergency Coordinator and Official Phone and Relay Stations. He has presented numerous papers on RFI and TVI correction at club meetings, seminars and technical symposiums, and has had many articles published on this subject in *QST* (see May 1981 *QST*) and other journals. He compiled and edited the WTVIC TVI Aids posters and pamphlets for publication.

TA Hal, W4CIZ (right), proud recipient of the ARRL Roanoke Division Service Award, presented by Vic Clark, W4KFC.

W4CIZ is a member of the ARRL RFI Task Group, North Virginia Chapter QCWA, OTC, Vienna Wireless Association and is a Life/Senior member of the IEEE, now serving as director of Northern Virginia Section and as advertising manager for the *NOVA Bulletin.*

Before retiring in 1974, Hal served as Engineer in Charge of the 24th District Office of the FCC, active in inspections, examinations, enforcement, investigative and other responsibilities of a field officer. He was the recipient of three efficiency awards granted by the FCC: a Sustained Superior Accomplishment award, a Superior Accomplishment award and a Special Acts and Services award. Hal holds a Cinematographer rating in the Washington Society of Cinematographers, and he now serves as Director/Historian. He is also active in the American Theatre Organ Society, and has memberships in the National Capital Trolley Museum and the Yogie Magic Club of Baltimore. — *Marian Anderson, WB1FSB*

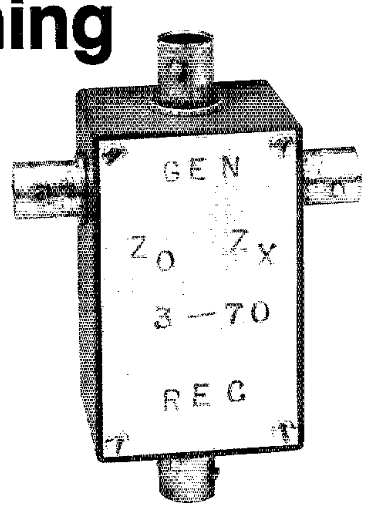
HOW-TOs FOR K2BSA/4 QSL

☐ For those of you who contacted K2BSA/4 and wish to receive the commemorative QSL card, send your card and an s.a.s.e. to: K2BSA/4, c/o ARRL, 225 Main St., Newington, CT 06111. And, introduce a local Scout to Amateur Radio. — *Steve Place, WB1EYI*

I would like to get in touch with . . .

☐ Travel agents interested in forming a net. Art Lyon, KC4OM, P. O. Box 353, Ocala, FL 32678.

A Reflection-Coefficient Bridge — Impedance-Matching Measurements the Easy Way



Need to measure the VSWR of your antenna system? How about the loss in your feed line, or the input VSWR of that new 2-meter preamp? The RCB will do it!

By Jack Priedigkeit,* W6ZGN

The reflection-coefficient bridge is basically a Wheatstone bridge that has been adapted for rf use. Unlike the Wheatstone bridge, however, the component values in the reflection-coefficient bridge are fixed: The unbalance voltage is used as a measure of the reflection coefficient of the unknown impedance. See the Appendix for a detailed analysis.

A reflection-coefficient bridge is easier to construct than is a good VSWR meter of comparable accuracy. It has excellent low-power sensitivity and, as will be discussed later, can be used for matching impedances and coaxial cable lengths. It is also handy for measuring coaxial-cable attenuation. Reflection coefficient can be expressed as a return loss in decibels, or related to an equivalent VSWR.[1]

This instrument uses a radio receiver for the bridge detector, enabling it to operate at power levels of −60 dBm or less. This minimizes QRM when you are performing antenna measurements and makes it possible to measure very sensitive circuits, such as the input to a receiver, or a balanced mixer. This low power level also allows you to measure an antenna system, including harmonic filters, at frequencies outside the amateur bands when pursuing RFI problems.

Construction

As shown in Fig. 1, the reflection-coefficient bridge consists of four resistor arms that are similar to those of the Wheatstone bridge. Instead of using a galvanometer to detect the bridge unbalance, however, an rf balun is employed to connect the rf unbalance voltage to a sensitive radio receiver. The balun is necessary because the unbalance voltage is not referenced to ground, but rather to the opposite arms of the bridge.

Fig. 2 shows a reflection-coefficient bridge built by the author. It is housed in a 2-1/2 × 1-1/8 × 1-3/8 inch (mm = in. × 25.4) diecast aluminum box (Pomona Electronics, Inc., Model 2417). The four UG-1094/U BNC connectors are located for electrical symmetry and minimum lead length. The bridge resistors, R1 through R4, are 51.1-Ω, 1/2-watt, 1% tolerance units, while R5 is a 100-Ω, 1/2-watt, 5% tolerance component.[2] R1, R2 and R5 are soldered directly to the terminals of the BNC connectors marked GEN, Z_O and Z_X. R3 and R4 are mounted in type UG-88/U BNC connectors and are used as rf terminations for the bridge connectors marked Z_O and Z_X.[3] The reason for this type of construction will be apparent when the testing and use of the bridge is discussed.

The rf balun for a 3- to 70-MHz bridge that can also be used in the 2-meter band consists of a bifilar winding on a stack of four Amidon T44-1 powdered-iron toroidal cores. Two no. 30 enameled wires are twisted together, about 10 turns per inch, and 30 turns of the twisted pair are wound on the stack of cores. Take care to ensure that adjacent turns do not overlap, and leave a gap between the start and finish of the winding.

Testing the Bridge

The performance of the reflection-coefficient bridge can be evaluated with a sensitive radio receiver and a signal generator that has a calibrated output level. One figure of merit for the bridge is the null depth that can be achieved when the bridge is balanced. This is measured easily by first placing an open circuit at Z_X, to unbalance the bridge, and by terminating Z_O with R3. Adjust the signal-generator output to establish a reference level on the S meter of the receiver for the open-circuit reflection coefficient of 1.0 (or 100% reflection). Now terminate Z_X with R4, and increase the signal-generator output to bring the S-meter reading up to the reference level for 100% reflection. The decibel increase in signal-generator level is the null depth. Fig. 3 is a plot of the null depth as a function of frequency. The null depth represents the maximum return loss and minimum reflection coefficient that can be measured with the bridge. As is shown, the null depth is 30 dB or more from 3 to 70 MHz and is also good across the 2-meter band.

The measured accuracy is typically better than ±1 dB for a return loss up to 15 dB, better than ±2 dB for a return loss between 15 and 25 dB, and better than ±5 dB for a return loss of 25 dB or more.

[1]Notes appear on page 20.

*441 Sherwood Way, Menlo Park, CA 94025

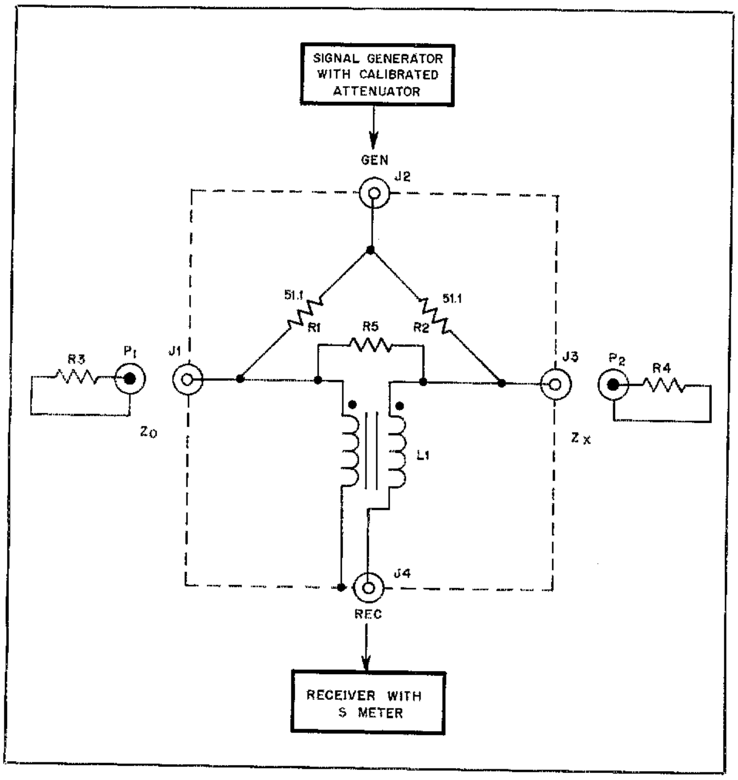


Fig. 1 — Schematic diagram of the reflection-coefficient bridge. The coaxial connectors are single-hole mounting BNC jacks (UG-1094/U or equiv.).

R1, R2 — 51.1 Ω, 1/2 watt, ± 1% carbon.
R3, R4 — 51.1, 1/2 watt, ± 1% carbon mounted in UG-88/U connector.
R5 — 100 Ω, 1/2 watt, ± 5% carbon.
L1 — 30 bifilar turns of no. 30 enamel on four T44-1 cores (see text).

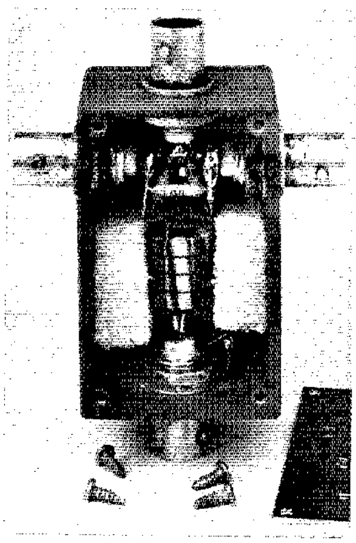


Fig. 2 — Parts placement, as shown in this RCB constructed by the author, should be planned for minimum lead length and maximum symmetry of the bridge components.

The return-loss accuracy was verified with a 1-dB step attenuator and a shorted coaxial connector.[4] The attenuator, with the output shorted, was connected to Z_x, and the return loss measured as a function of the attenuator setting. The return loss is twice the attenuator setting.

A second figure of merit for this bridge is the ratio of the unbalanced voltage for open- and short-circuit conditions at Z_x with Z_0 terminated. Both open and short circuits have a reflection coefficient of 1.0. Thus, the S-meter reading should not change when Z_x is open or shorted. The open-short circuit ratio can be measured by noting the decibel increase or decrease in the signal-generator level necessary to return the S meter to the reference level. The open-short circuit ratio depends on the detector (receiver) impedance connected between the two arms of the bridge, and in this case should be 50 Ω to achieve an open-short circuit ratio of 1.0.[5] The measured open-short circuit ratio, without R5 of Fig. 1, was found to vary a little less than ± 1 dB over the 3- to 70-MHz frequency range. The addition of R5 reduced this variation to less than ± 0.3 dB.

Use of the Reflection-Coefficient Bridge

The bridge can be used to calculate both the VSWR and the return loss of an unknown impedance connected to the Z_x port. Return loss is the ratio of the incident power to the reflected power and is expressed in decibels. A voltage reflection coefficient of 1.0 (100% reflection) corresponds to a 0-dB return loss (i.e., the returned power is the same as the incident power, or no loss). A reflection coefficient of 0.1 corresponds to a return loss of 20 dB. Table 1 shows the relationship between reflection coefficient, return loss and VSWR.

The bridge, with Z_0 terminated, can be used to measure the reflection coefficient of any impedance connected to the Z_x port. The procedure is first to open circuit Z_x to establish a reference level on the S meter for 100% reflection. Second, connect the unknown impedance to Z_x, and increase the signal-generator level to bring the S-meter reading back to the reference point. The decibel increase in signal-generator output is the return loss of the unknown impedance. The reflection coefficient and equivalent VSWR, referred to 50 Ω, may be found from Table 1.

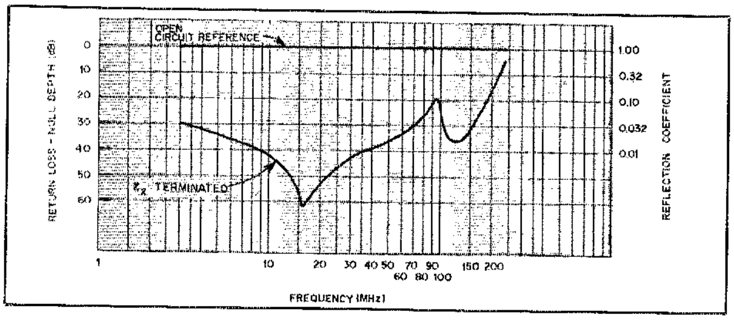


Fig. 3 — The null depth versus frequency characteristics of the reflection-coefficient bridge constructed by the author. The top line of the graph is the 100% reflection reference level. The lower line is the indicated return loss (or reflection coefficient) when Z_0 and Z_x are both terminated in 50 Ω.

Table 1

Reflection Coefficient and VSWR Versus Return Loss

Reflection Coefficient	*VSWR*	*Return Loss, dB*
1.00	∞	0
0.89	17.4	1
0.79	8.7	2
0.71	5.9	3
0.62	4.4	4
0.57	3.6	5
0.50	3.0	6
0.44	2.6	7
0.39	2.3	8
0.35	2.1	9
0.32	1.92	10
0.28	1.78	11
0.25	1.67	12
0.22	1.58	13
0.20	1.50	14
0.18	1.43	15
0.16	1.38	16
0.14	1.33	17
0.13	1.30	18
0.11	1.25	19
0.10	1.22	20
0.079	1.17	22
0.063	1.13	24
0.050	1.11	26
0.040	1.08	28
0.032	1.06	30
0.025	1.05	32
0.020	1.04	34
0.016	1.03	36
0.013	1.03	38
0.010	1.02	40

An antenna or the tap on a tuned coil connected to Z_x may be matched to a 50-Ω line by simply adjusting the antenna or the tap and coil tuning for minimum S-meter reading. The VSWR can be found by measuring the return loss as described in the foregoing text.

The reflection-coefficient bridge can also be used to match impedances at other than the 50-Ω level. In this case, the reference impedance (resistor, capacitor, coil or network) is connected to Z_o. The impedance to be matched is connected to Z_x and is adjusted for minimum S-meter reading. Note that the bridge does not measure the reflection coefficient under these conditions.

The above procedure can also be used to match lengths of coaxial cable. The reference cable is connected to Z_o. The cable to be matched is connected to Z_x and is then trimmed for minimum S-meter reading. *CAUTION — The phase of the reflection coefficient repeats every wavelength on the transmission line.* Be sure that after the cables have been matched, the physical lengths do not differ by one wavelength. The difference in cable length caused by the addition of one UG-914/U adapter to one of two 25-foot RG-58/U cables can easily be detected at vhf when the bridge is near balance.

Cable attenuation can be calculated from the return loss of a length of cable that is shorted or open at the far end. For this measurement, connect the cable to Z_x and terminate Z_o. As an example, the return loss of a length of RG-58/U cable was measured as 4.2 dB. Since the reflected signal has traveled twice the length of the cable, the one-way attenuation is 2.1 dB. The physical length of the cable was 39 feet. The attenuation per 100 feet is 2.1 dB × (100/39) or 5.4 dB. This is a neat way to estimate the loss of an antenna feed cable of unknown length. Simply disconnect or short the antenna, and measure the return loss in the ham shack. This can be done at low power and with minimum QRM.

Final Comments

Except for the effects of cable loss, the reflection coefficient, return loss and VSWR do not change with cable length. Thus, the length of cable connecting the bridge and the unknown impedance is not critical. However, cable attenuation will always reduce the reflection coefficient, reduce the VSWR and increase the return loss. Long lengths of lossy cable are to be avoided because they will make the unknown impedance appear to be more nearly matched.

Occasionally, measurements of coaxial cable made with the reflection-coefficient bridge may not be consistent with the operator's casual concept of the situation. For example, three unequal lengths of RG-58/U cable, each with RG-88/U connectors on both ends, were connected in series using two RG-914/U adapters. The return loss, measured at 146 MHz for each of the six possible series combinations of these cables, was found to range from 9.5 dB to 12.0 dB. This appears to be inconsistent, since the length of the cable is constant. However, note that the Z_o of each of the three cables can be 50 ±2.5 and that there are eight BNC connectors in the system. Consider also that the reflection coefficient seen by the bridge is the vector sum of the reflections from each impedance mismatch in the system. Since the phase of each reflection coefficient depends on the cable length to the reflection point, the resulting reflection coefficient seen by the bridge will change as the unequal lengths of cable are interchanged. From Table 1 it can be seen that a change in the magnitude of the reflection coefficient of only 0.08 will account for the 2.5-dB spread in the return loss observed. Thus a word of caution — use one length of cable, and keep the number of connectors to a minimum when measuring coaxial cable attenuation.

Appendix

Neglecting stray capacitance and lead inductance, the reflection-coefficient bridge shown in Fig. 1 can be drawn as shown in Fig. 4. The unbalance voltage, e_o, is the difference between the voltage developed across R3 and R4. When R4 is

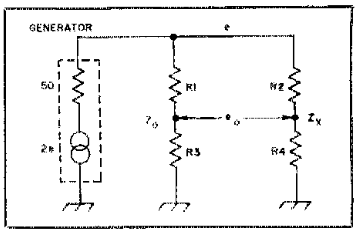


Fig. 4 — Circuit of the RCB, which has been drawn to show the significant electrical features discussed in the text.

replaced by the unknown impedance Z_x, this voltage is:

$$e_o = e\left[\frac{Z_x}{R2 + Z_x} - \frac{R3}{R1 + R3}\right] \quad \text{(Eq. 1)}$$

If R1 = R3 and R2 = Z_o:

$$e_o = \frac{e}{2}\left[\frac{2Z_x}{Z_o + Z_x} - 1\right] =$$

$$\frac{e}{2}\left[\frac{Z_x - Z_o}{Z_x + Z_o}\right] \quad \text{(Eq. 2)}$$

The definition of the reflection coefficient ρ is:[6]

$$\rho = \frac{Z_x - Z_o}{Z_x + Z_o} \quad \text{(Eq. 3)}$$

The bridge receiver responds to the magnitude of the unbalance voltage, e_o; thus the S-meter reading is proportional to the magnitude of the reflection coefficient, $|\rho|$.

The VSWR can be calculated from the expression:[7]

$$\text{VSWR} = \frac{1 + |\rho|}{1 - |\rho|} \quad \text{(Eq. 4)}$$

and the return loss, RL, is defined as:[8]

$$\text{RL} = 20\log_{10}\left|\frac{Z_x + Z_o}{Z_x - Z_o}\right| = -20\log_{10}|\rho| \quad \text{(Eq.5)}$$

Notes

[1]Editor's Note: The reflection-coefficient bridge is also known as the return-loss bridge. Additional information about the construction and use of the return-loss bridge can be found in recent editions of *The Radio Amateur's Handbook* and in *Solid State Design for the Radio Amateur*. Both are available from ARRL.

[2]50.0-Ω resistors are preferred, since this is a standard coaxial-cable impedance. However, 51.1 Ω is within the 5% manufacturing tolerance of most coaxial cables.

[3]Commercially made 50-Ω terminations, such as Texscan Model TF-50 or equiv., may also be used.

[4]Hewlett-Packard Model 355A or equiv.

[5]Editor's Note: The open-short circuit ratio also depends on the generator output impedance. See W. Hayward and D. DeMaw, *Solid State Design for the Radio Amateur* (Newington: The American Radio Relay League, Inc., 1977), p. 154.

[6]*Reference Data for Radio Engineers* (Indianapolis: H. W. Sams & Co.), 22-6.

[7]See note 6, p. 22-7.

[8]See note 6, p. 30-2.

A BASIC Approach to Calculating Cascaded Intercept Points and Noise Figure

This circuit-design information you won't want to miss. The computer program offered here makes things easier, too!

By William Sabin,* WØIYH

With cascaded stages of a signal-processing system, it is often important to know the distortion products generated by an equal-amplitude, two-tone input signal at each point in the chain. Refer to the example in Fig. 1. In one situation, the individual distortion sources to the *right* of point X are referred coherently to point X, producing a composite *input* intercept.[1] As well, distortion sources to the *left* of X produce a composite *output* intercept at X. The distortion products of interest are usually third-order, but second-order product information is often needed, too. Another item of interest is the composite noise figure, looking to the right from point X.

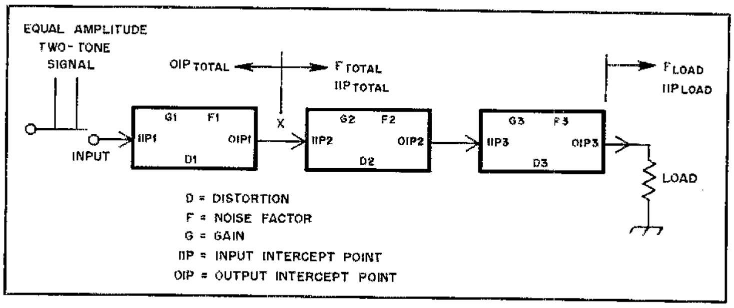


Fig. 1 — A typical signal-processing chain.

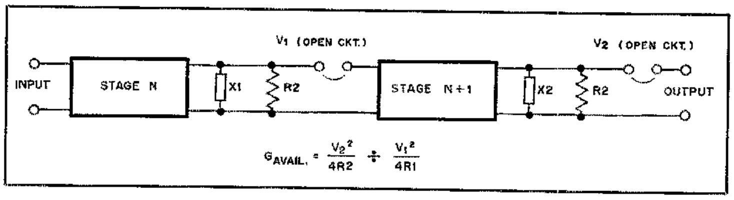


Fig. 2 — Factors involved in the determination of available power gain are discussed in the text. Only the real part of the output impedance (R1, R2) is involved.

In addition to the distortion and noise generated by the individual stages, blocks or circuit elements, the ultimate load may be noisy and produce distortion, or it may be completely passive. Some of the blocks may also be passive, in which case their available power gains (decibels) are negative, their noise figures (dB) are equal in magnitude to the gain values and the production of distortion is absent. Other elements, such as diode mixers, have negative gain (loss) and noise figures nearly equal to the gain value, but they produce distortion. Here, any stage that produces distortion is considered to be an *active* stage.

The distortion specification for an individual block may be given in dBm as an input intercept point (IIP) or an output intercept point (OIP). All gain values are specified in terms of available power gain, as explained in Fig. 2. The determination of available power gain can be tricky in practice, because it involves the measurement or calculation of open-circuit output voltage and the real part of the output impedance. (Consult other references for further information regarding these techniques.)[2,3,4] Available gain also needs to be known for cascaded noise-figure measurements. So the usefulness of the techniques described here depends on the ability to make the gain, noise figure and input/output intercept measurements for each stage. Also, circuit elements having

[1]Notes appear on page 24.

*Rockwell International, Collins Telecommunications Product Div., Cedar Rapids, IA 52498

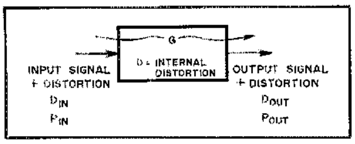


Fig. 3 — An active stage in a signal path contributes to the overall distortion at the output of the stage, as shown here.

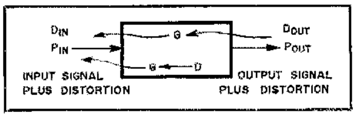


Fig. 4 — Determining the input intercept of a stage is done by working backward from the output to the input. Signal and distortion from the following stages and distortion from this stage are referred to the stage input.

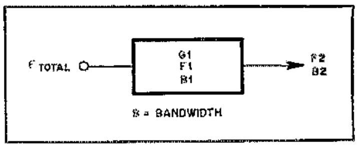


Fig. 5 — The discussed noise figure is that value measured at the signal input port. Bandwidth of each stage must be considered.

intercepts that are sensitive to signal level must be dealt with carefully,[3] ensuring that the measurements are made at the expected signal level.

Analysis of the Method

Shown in Fig. 3 is a circuit element with an input power (P_{in}) and output power (P_{out}) that generates within itself a distortion power, D. The input signal is also contaminated with distortion (D_{in}) from previous stages. These distortion components combine at the output in ways that are sometimes difficult to predict. They can add or subtract partially or be unrelated. The correlation factor (C) is a measure of this relatedness.

Output distortion is given by:

$$D_{out} = D_{in}G + 2C\sqrt{D_{in}GD} + D \qquad \text{(Eq. 1)}$$

Table 1

Intercept Point and Noise Figure Program

```
0010 HOME
0020 REM INTERCEPT AND NOISE FIGURE PROGRAM "INTRCP"
0030 REM W. SABIN  SEP.,1980
0040 DIM F(21),I1(21),O1(21),G(20),CF(21)
0050 DIM I2(20),O2(20),P(21),D(21),C(20),BR(20)
0060 PRINT "CASCADE IP(3) OR IP(2)"
0070 PRINT "CASCADE NOISE FIGURE"
0080 INPUT "NUMBER OF STAGES=";N
0090 PRINT "TYPE 1 IF LOAD PASSIVE,2 IF ACTIVE"
0100 INPUT E: IF E=2 GO TO 140
0110 LET CF(N+1)=0:I1(N+1)=500
0120 PRINT "PASSIVE LOAD"
0130 GOTO 160
0140 INPUT "N.F.(DB) OF LOAD";CF(N+1)
0150 INPUT "I.P. (DBM) OF LOAD";I1(N+1)
0160 PRINT "TYPE 3 FOR THIRD ORDER I.P."
0170 PRINT "TYPE 2 FOR SECOND ORDER I.P."
0180 INPUT X
0190 LET P(N+1)=30
0200 FOR I=N TO 1 STEP -1
0210 PRINT : PRINT"STAGE NUMBER ";I
0220 PRINT "TYPE 1 IF STAGE IS ACTIVE"
0230 PRINT "TYPE 2 IF STAGE IS PASSIVE"
0240 INPUT K
0250 ON K GO TO 320,260
0260 INPUT "INSERTION LOSS (DB)";G(I)
0270 INPUT "BANDWIDTH RATIO=";BR(I)
0280 IF BR(I)<1 THEN BR(I)=1
0290 LET I1(I)=500:O1(I)=500:C(I)=1
0300 LET F(I)=G(I):G(I)=-G(I)
0310 GOTO 490
0320 INPUT "AVAILABLE GAIN(DB)";G(I)
0330 INPUT "STAGE NOISE FIG.";F(I)
0340 INPUT "BANDWIDTH RATIO=";BR(I)
0350 IF BR(I)<1 THEN BR(I)=1
0360 PRINT "TYPE 1 IF INPUT I.P. IS SPECIFIED"
0370 PRINT "TYPE 2 IF OUTPUT I.P. IS SPECIFIED"
0380 INPUT Y
0390 ON Y GO TO 450,400
0400 INPUT "OUTPUT I.P.(DBM) ";O1(I)
0410 LET I1(I)=O1(I)-G(I)
0420 PRINT "INPUT I.P.=";I1(I)
0430 INPUT "CORRELATION FACTOR";C(I)
0440 GOTO 490
0450 INPUT "INPUT I.P.(DBM)";I1(I)
0460 LET O1(I)=I1(I)+G(I)
0470 PRINT "OUTPUT I.P.=";O1(I)
0480 INPUT "CORRELATION FACTOR";C(I)
0490 LET P(I)=P(I+1)-G(I)
0500 IF X=3 THEN D(I)=3*P(I)-2*I1(I)
0510 IF X=2 THEN D(I)=2*P(I)-I1(I)
0520 LET D(I)=.001*10^(D(I)/10)
0530 LET U=10^(F(I)/10)
0540 LET V=10^(CF(I+1)/10)
0550 LET V=V*BR(I)
0560 LET W=10^(G(I)/10)
0570 LET CF(I)=U+(V-1)/W
0580 IF CF(I)<1E-37 THENCF(I)=1E-37
0590 LET CF(I)=4.3429*LOG(CF(I))
0600 NEXT I
0610 IF X=3 THEN D(N+1)=3*P(N+1)-2*I1(N+1)
0620 IF X=2 THEN D(N+1)=2*P(N+1)-I1(N+1)
0630 LET D(N+1)=.001*10^(D(N+1)/10)
0640 FOR I=N TO 1 STEP-1
0650 LET B=D(I+1)/(10^(G(I)/10))
0660 LET D(I)=D(I)+2*C(I)*SQR(D(I))*SQR(B)+B
0670 NEXT I
0680 PRINT "INTERCEPTS,N.F."
0690 PRINT "STAGE          INPUT I.P.          N.F."
0700 PRINT
0710 FOR I =1 TO N
0720 IF D(I)<1E-37 THEN D(I)=1E-37
0730 LET D(I)=4.3429*LOG(D(I)/.001)
0740 IF X=3 THEN I2(I)=1.5*P(I)-.5*D(I)
0750 IF X=2 THEN I2(I)=2*P(I)-D(I)
0760 NEXT I
0770 FOR I=1 TO N
0780 LET I2(I)=INT(I2(I)*100+.5)/100
0790 LET CF(I)=INT(CF(I)*100+.5)/100
0800 PRINT I,I2(I),CF(I)
0810 NEXT I
0820 PRINT :PRINT
0830 PRINT "TYPE X TO CONTINUE"
0840 GET A$
0850 PRINT "STAGE","OUTPUT I.P.":PRINT
0860 LET D(1)=-500
0870 FOR I=2 TO N+1
0880 IF X=3 THEN D(I)=3*P(I)-2*O1(I-1)
0890 IF X=2 THEN D(I)=2*P(I)-O1(I-1)
0900 LET D(I)=.001*10^(D(I)/10)
0910 LET D(I-1)=.001*10^(D(I-1)/10)
0920 LET B=D(I-1)*10^(G(I-1)/10)
0930 LET D(I)=D(I)+2*C(I)*SQR(D(I))*SQR(B)+B
0940 IF D(I)<1E-37 THEN D(I)=1E-37
0950 LET D(I)=4.3429*LOG(D(I)/.001)
0960 IF X=3 THEN O2(I)=1.5*P(I)-.5*D(I)
0970 IF X=2 THEN O2(I)=2*P(I)-D(I)
0980 IF D(I-1)<1E-37 THEN D(I-1)=1E-37
0990 LET D(I-1)=4.3429*LOG(D(I-1)/.001)
1000 LET O2(I)=INT(O2(I)*100+.5)/100
1010 PRINT I-1,O2(I)
1020 NEXT I
1030 END
```

where the powers are given in watts per tone (not dBm per tone).

The circuit element of Fig. 3 has an internal output intercept point (OIP). For third-order products:

$$OIP^3\,(dBm) = 1.5\,P_{out}\,(dBm) - 0.5D\,(dBm) \qquad (Eq.\ 2)$$

For second-order products:

$$OIP^2\,(dBm) = 2\,P_{out}\,(dBm) - D\,(dBm) \qquad (Eq.\ 3)$$

Also, there is a composite intercept point that combines internal distortion and fed-through distortion (Figs. 1 and 3):

$$OIP^3_{total}\,(dBm) = 1.5\,P_{out}\,(dBm) - 0.5D_{out}\,(dBm) \qquad (Eq.\ 4)$$

$$OIP^2_{total}\,(dBm) = 2\,P_{out}\,(dBm) - D_{out}\,(dBm) \qquad (Eq.\ 5)$$

Starting with a distortionless generator, the signal power and the accumulated distortion power are calculated stage by stage. At each stage a composite output intercept point is calculated, using equations 1 through 5, and the signal and distortion levels from the previous stage as inputs.

Similar to the method shown in Fig. 3, one can start at the output of a stage and work backward, as shown in Fig. 4. Here, the distortion generated in stages to the right is referred (reflected) to the input by dividing it by the stage gain, G. The internal distortion of the stage itself is also reflected. By proceeding stage by stage and by working toward the generator, all of the internal distortions are lumped together coherently. Net distortion at the input of each stage is used to compute the input intercept point at that input, using Eq. 4 and 5. The output load can have an input intercept point, too, and the program allows this to be considered.

Noise factor is calculated using the equation:

$$F_{total} = F1 + \frac{F2 - 1}{G1} \qquad (Eq.\ 6)$$

where F is the noise factor and G is the available power gain, neither being expressed in decibels. An example is shown in Fig. 5. The program applies Eq. 6 recursively, starting at the load (which may have a noise figure) and working backward, one stage at a time. Sometimes, the noise bandwidth (B) increases as the signal moves to the right (B2 > B1). In this case, Eq. 6 becomes:

$$F_{total} = F1 + \frac{F2(B2/B1) - 1}{G1} \qquad (Eq.\ 7)$$

In this discussion, noise figure refers to the value that is measured at the signal input port using a noise generator.

The bandwidth ratio for each stage is requested by the program. This value is the bandwidth of the stage under examination, N, divided into the narrowest bandwidth that occurs after stage N. If that ratio is less than one, the program assigns the correct value of one. To ignore this feature, input all ones.

Discussion of the Program

The program shown in Table 1 is written for the Apple II computer with Applesoft. An example problem involving a four-stage circuit is given in Fig. 6 to demonstrate how the program works. Table 2 lists the program output for the example; the large output intercept point (OIP) for stage one (204) should be ignored. The load at the output is assumed to have a 3-dB noise figure and a 30-dBm input intercept point (IIP). (An output power of 30 dBm is assigned in line 190). Any stage that generates distortion is an active stage, even though it may not be active in the usual sense. A correlation factor, C (I) is assigned for each stage and is usually given a value of +1 for a worst-case analysis. The intercept point for each stage may be known either as an input or output intercept, and the program prompts the designer for this information.

Each input power level, the internal distortion generated in each stage, composite distortion and the input or output intercept points are calculated working right to left or left to right. Cumulative noise figure is also calculated using the output load noise figure and the gain and noise figure values for each stage. A maximum of 20 stages can be analyzed with the dimensioning given.

Note that this analysis assumes that the two equal test tones are completely inside the passband of any filters in the signal path. We are looking at in-band performance. In reality, the tones may be on the skirts of the passband and therefore not equal in amplitude. This program does not cover that situation, which will be discussed later.

Improving the Design

Suppose that the results listed in Table 2 that were obtained from the example circuit are not satisfactory. How might the design be improved? By an assumptive and iterative process, it is possible to improve the in-band performance or to arrive at economic trade-offs. If we assume the rf amplifier has a noise figure of 6 dB and an IIP of 25 dBm, a composite noise figure of 9.4 dB and an IIP of 13.7 dBm results. Therefore, the time spent improving the noise figure was worthwhile, but the IIP was not affected very much. Next, let the load noise figure be 6 dB instead of 3 dB. The overall noise figure (NF) increases to 9.8 dB, so the time spent getting a 3-dB noise figure at the output was probably not worthwhile. This improvement process can proceed up to the point where measurement accuracy and values of improvement reach a practical limit.

Table 2

Program Output

```
CASCADE IP (3) OR IP (2)
CASCADE NOISE FIGURE
NUMBER OF STAGES = ? 4
TYPE 1 IF LOAD PASSIVE; 2 IF ACTIVE
? 2
N.F. (DB) OF LOAD ? 3
I.P. (DBM) OF LOAD ? 20
TYPE 3 FOR THIRD ORDER I.P.
TYPE 2 FOR SECOND ORDER I.P.
? 3
STAGE NUMBER 4
TYPE 1 IF STAGE ACTIVE
TYPE 2 IF STAGE PASSIVE
? 2
INSERTION LOSS (DB) ? 6
BANDWIDTH RATIO ? 1
STAGE NUMBER 3
TYPE 1 IF STAGE ACTIVE
TYPE 2 IF STAGE PASSIVE
? 1
AVAILABLE GAIN (DB) ? - 7
STAGE NOISE FIGURE ? 7.5
TYPE 1 IF INPUT I.P. IS SPECIFIED
TYPE 2 IF OUTPUT I.P. IS SPECIFIED
? 2
OUTPUT I.P. (DBM) ? 28
INPUT I.P. (DBM) = 35
CORRELATION FACTOR ? 1
BANDWIDTH RATIO ? 1
STAGE NUMBER 2
TYPE 1 IF STAGE ACTIVE
TYPE 2 IF STAGE PASSIVE
? 1
AVAILABLE GAIN (DB) ? 20
STAGE NOISE FIGURE ? 8
TYPE 1 IF INPUT I.P. IS SPECIFIED
TYPE 2 IF OUTPUT I.P. IS SPECIFIED
? 1
INPUT I.P. (DBM) ? 20
OUTPUT I.P. (DBM) = 40
CORRELATION FACTOR ? 1
BANDWIDTH RATIO ? 1
STAGE NUMBER 1
TYPE 1 IF STAGE ACTIVE
TYPE 2 IF STAGE PASSIVE
? 2
INSERTION LOSS (DB) ? 3
BANDWIDTH RATIO ? 1
```

STAGE	INPUT I.P.	N.F.
1	13.37	11.26
2	10.37	8.26
3	30.88	16.07
4	36	9

TYPE X TO CONTINUE

STAGE	OUTPUT I.P.
1	204.5
2	40
3	26.81
4	20.81

Precautions

The Applesoft-equipped Apple II will produce an error when trying to find the log of a number smaller than about 10^{-37}. This can vary with different machines. Program lines 580, 720 and 940 contain the necessary remedial steps. Also, if output data is presented to the screen, it may scroll off the top and be partially lost. Such action is prevented by program lines 830 and 840; different machines may

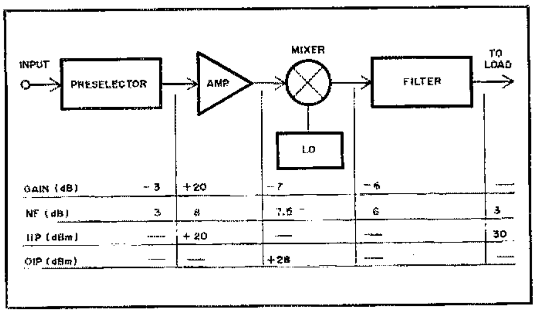


Fig. 6 — A design example. These data are entered into the computer. The corresponding results are given in Table 1.

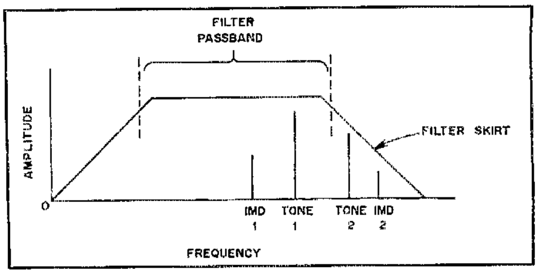


Fig. 7 — A filter response curve showing tone 2 and IMD 2 out of the passband of the filter. The skirt attenuation may be compensated for to calculate correctly the amplitude of the in-band IMD product as described in the text.

require a different procedure.

Unequal Tones

As shown in Fig. 7, one tone and one IMD product are on the skirt of the filter passband, while the other tone and IMD product are inside the passband. The in-band IMD product generated by each stage after the filter will be reduced 1 dB for each dB of skirt attenuation for both the second- and third-order IMD products. When calculating the intercept point, this information can be used in the following manner: Let the third-order (second-order) IIP or OIP of each individual stage after the filter (as well as the IIP of the output load) be rated 1 dBm higher for each 2 dB (1 dB) of skirt-tone attenuation. This is fictitious, of course, but nevertheless the effect of the skirt attenuation is correctly accounted for in calculating the amplitude of the in-band IMD product. Composite input intercept points for locations to the left of the filter involved will have the correct values. The partially-out-of-band problem is fairly important in practice, and is worth the extra effort to calculate. Quite often, gain distribution and filter shape-factor changes can produce worthwhile improvements.

Dynamic Range

Some designers like to use the dynamic-range concept. For more information about this subject, refer to Hayward's article.[6] The input noise figure and input intercept point can be used to make this calculation, if the bandwidth is specified.

Notes

[1]W. Hayward and D. DeMaw, *Solid State Design For the Radio Amateur* (Newington: American Radio Relay League, Inc., 1977), ch. 6.
[2]R. F. Shea, *Amplifier Handbook* (New York: McGraw-Hill, 1969), ch. 24.
[3]J. G. Linville and J. F. Gibbons, *Transistors and Active Circuits* (New York: McGraw-Hill, 1961), chs. 10 and 12.
[4]H. Goldberg, "Some Notes On Noise Figure," *Proceedings of I.R.E.*, Oct. 1948.
[5]E. W. Pappenfus et al., *Single Sideband Principles and Circuits* (New York: McGraw-Hill, 1964), ch. 12.
[6]W. Hayward, "Defining and Measuring Receiver Dynamic Range," *QST*, July 1975.

New Products

TRI-EX TOWER CORPORATION ROTATING TOWER

☐ Looking to "get there fustest with the mostest"? If so, this late release by the Tri-Ex Tower Corporation ought to attract your attention! The RT-120(37) is a 120-ft (37-m) guyed, *rotating tower*. According to the manufacturer, though this tower is usually turned by means of an internal, base-mounted rotator, it may be easily turned by hand. The rotating mechanism uses no exposed chain drives or gears, which could be a safety hazard to people who may enter the tower area.

Ball-bearing type guy-attachment rings are set at the 30, 70 and 110-ft (9, 21, and 34-m) levels. The rotating tower allows antennas to be mounted on the sides of the tower and yet permits them to be turned to any desired direction. A mast may also be inserted at the top of the tower to provide support for additional antennas, which could then be rotated independently of the tower rotation and the side-mounted antennas.

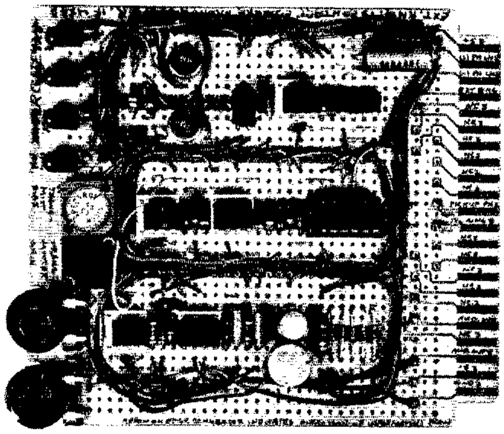
If this doesn't prove to be the "ticket" to snag that long-sought-for DX station, I can't imagine what you'd do next! For further information, contact Tri-Ex Tower Corp., 7182 Rasmussen Ave., Visalia, CA 93291. — *Paul K. Pagel, N1FB*

SILICONIX FET DESIGN KIT

☐ Siliconix is offering a new FET designer's kit that consists of a copy of *Designing With Field-Effect Transistors.* Written by Siliconix personnel and published by McGraw-Hill in February 1981, this book has a retail value of $24.50. It covers the theory and practical applications of FETs and a brief introduction to power MOSFETs; a copy of the *Siliconix FET Design Catalog*, published in July 1981, that includes data sheets and application notes for their entire FET product line; 10 sample FETs — N-channel, P-channel, amplifiers, switches, amplifier/switch combinations, low-leakage FETs and high-frequency FETs and design tips on how to use them.

This kit, which has a retail value of $42.50, is being offered for $28 through the end of 1981. To order, send your check and request to: Siliconix Inc., P.O. Box 4777, Santa Clara, CA 95054. — *Paul K. Pagel, N1FB*

Phone-Line Interface — Do it Solid-State Style



Go modern! Build this compact, active-circuit interface module for connecting the phone line to your repeater. This device is also excellent for standard phone patching at home.

By Scott Mazar,* WBØOOD, and Noel J. Petit,** WBØBGI

How about a solid-state, phone-line interface for repeater or phone-patch use? Our repeater at the University of Minnesota (WØYC/R) required a phone line for repeater control and autopatch. We found that traditional phone interfaces were too bulky to be used in the small cabinet that contains our repeater. Thus, we designed an active electronic interface unit that is superior to most and fits on a single 4 × 5-in. (mm = in. × 25.4) circuit board.

The basic telephone company requirements for interface equipment are given in Table 1. The telephone company requires that phone lines be isolated from voltages in the user's system; this is to prevent unwanted noise and voltages on their equipment. Therefore, any equipment connected to the phone line must be dc isolated. Isolation normally requires transformers and relays in a phone interface circuit. In our unit the transformers and relays are replaced by solid-state optical isolators: Each traditional isolation device is traded for a small six-pin IC.

Fig. 1 contains the schematic diagram of the Monsanto MCT-2 Optoisolator. Internally, the optoisolator is an infrared emitting diode that illuminates an infrared-sensitive phototransistor. The diode is similar to the light-emitting diode (LED) in calculators, except that this diode emits long-wavelength photons (heat) rather than visible light. This is a simple and reliable device that completely isolates the input diode from the phototransistor. Only light couples the input to the output of the optoisolator.

Table 1

Frequency Range	*Voice-Energy Levels*
DC	0.5 mA
Voice Range (300 to 3000 Hz)	−3 dBm*
2450 to 2750 Hz	Should be minimized if long-distance calls are to be made.
3995 to 4005 Hz	18 dB below voice level
4.0 to 10.0 kHz	−16 dBm
10.0 to 25.0 kHz	−24 dBm
25.0 to 40.0 kHz	−36 dBm
above 40.0 kHz	−50 dBm

*dBm is relative to 1 mW across 600 ohms.

Loop Signals

On Hook — minimum 30 kΩ, line to line.
Off Hook — maximum 200 Ω, line to line.

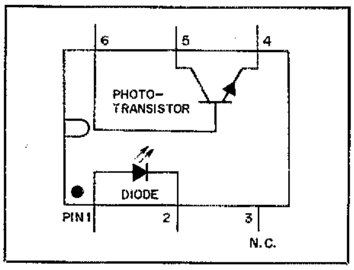


Fig. 1 — Circuit of the Monsanto MCT-2 optoisolator. An etched and drilled circuit board is available from the authors.

Circuit Operation

The circuit in Fig. 2 has three basic sections: ring/connect, transmit and receive. The ring-detector circuit indicates whether the phone line is ringing. This signal is a distorted sinusoidal waveform at about 20 Hz and 90 to 200 volts, peak-to-peak. The detector consists of optoisolator 1 (U4) and the associated rectifier. The ringing waveform passes through C1 (used to block the dc on the phone line) and is rectified by the diode bridge (D1 through D4). Direct current passes through light-emitting diode 1 (DS1), to indicate ring voltage on the line, and the diode of U4, for external electrical sensing. The bridge rectifier is necessary because the LED and diode of U4 cannot withstand reverse voltages in excess of about 3 before they break down; thus the full-wave rectifier ensures that reverse voltage is not applied to these diodes. A half-wave rectifier would not work in place of the bridge rectifier because C1 would charge fully within the first few cycles and remain charged long after the ringing stopped, rendering the detector useless.

When the diode of U4 turns on, the

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associated photo-transistor conducts, discharging C2, bringing the inputs to TTL inverters U1A and U1B low. These inverters electrically indicate the presence of a ring signal on the phone line. The combination of R2 and C2 on the inputs of the inverters provides a long time constant for the ring signal. DS3 on the output of U1B visually confirms the electrical ring signal. The output of U1A is the digital ring signal sent to the external equipment.

The disconnected phone line is normally provided with 45 volts of dc. When the phone is picked up (that is, connected) the dc resistance drops from greater than 30 kΩ to less than 200 Ω. This allows about 20 mA of direct current to flow through the phone line. The interface connection is accomplished by applying a high logic level to the "pick up the phone" input, energizing the diodes of U5, U6 and DS4. The LED visually confirms the input signal. U5 and U6 are connected in series to prevent breakdown of the phototransistors when the ring voltage is present (typical $BV_{CER} \approx 100$ V for one transistor). The optoisolator transistors then conduct, causing Q1 to conduct. This turns on Q2, which then has about 20 mA flowing through it. This connects the phone interface to the telephone system.

Audio Receiver

The second basic section of the interface is the audio receiver. U7 conducts most of the line current through its diode, lighting it to a constant brilliancy. Audio from the telephone system is the modula-

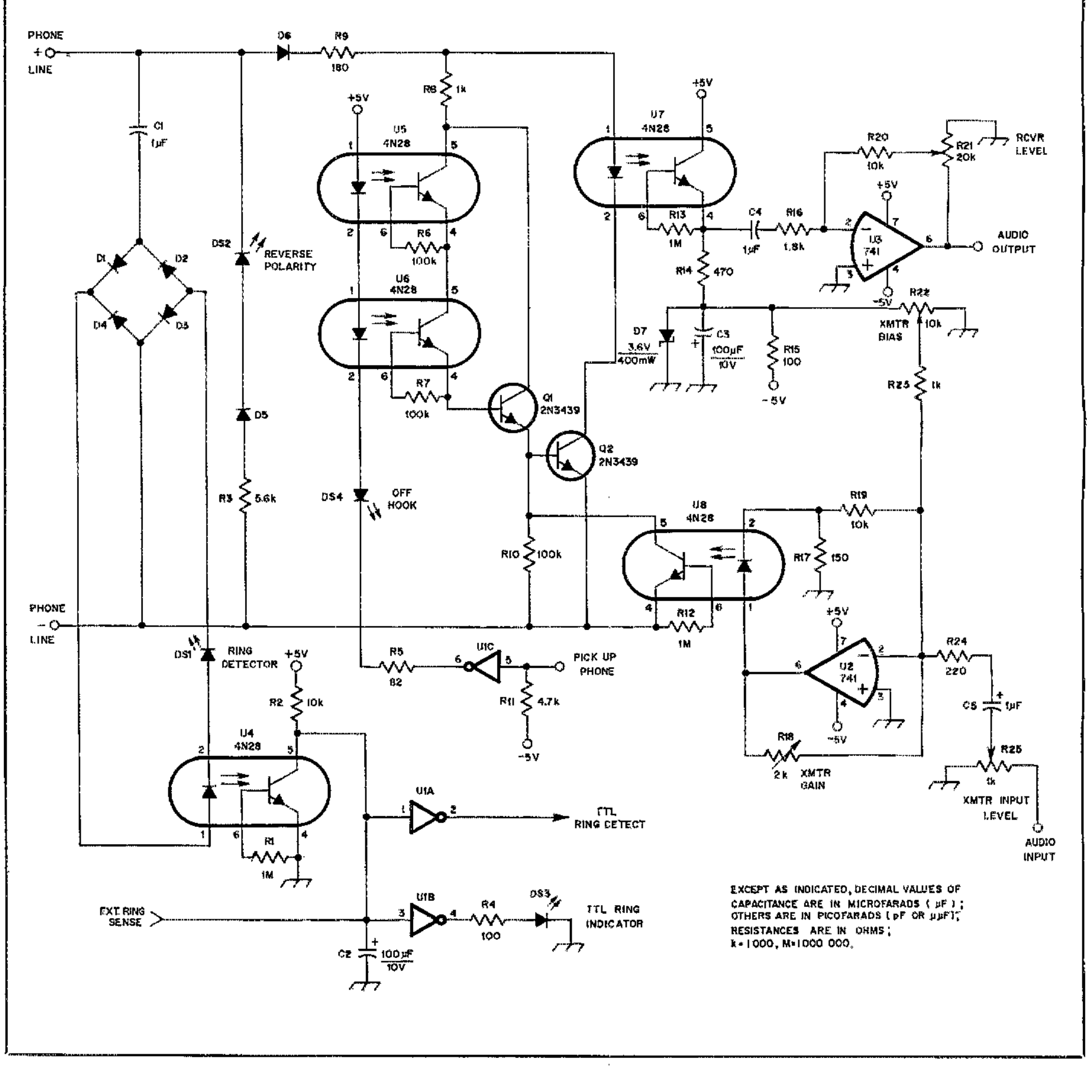


Fig. 2 — Schematic diagram of the phone-line interface circuit. Fixed-value resistors are 1/4-watt metal film or carbon types. Variable resistors are 1/4-watt trimmer units. C1, C4 and C5 are metalized polyester capacitors. C2 and C3 are electrolytic, 10 V or greater. DS1-DS4, incl., are red 10-mA LEDs. U4-U8, incl., are Monsanto MCT2 (4N28) optoisolators. U1 is a 7404 hex inverter.

tion of the dc loop current. This modulates the intensity of the infrared emission from the diode of U7. This, in turn, modulates the collector current of the phototransistor, and this current modulation is then amplified to a useful level by means of op amp U3. Note that no electrical contact is made to the phone line: All coupling is done with light. U3 amplifies the signal to provide a standard 0-dBm audio signal to the repeater. R20 sets the received-audio level, which depends upon the particular phone line being used.

Audio Transmitter

The final section is the audio transmitter. To inject audio back into the phone line, the loop current is modulated by the audio from the repeater. Since Q2 is in series with the 20-mA current loop, perturbing its base current (by shunting some of this base current to ground through the U8 phototransistor) will modulate the loop current. The collector current of Q2 is proportional to the transistor base current. The circuit driving the diode of U8 is a constant-current source to ensure linear transmission of the audio. Typically, the voltage variation at the phone line terminals is less than 0.5, peak-to-peak, for transmitted and received audio. This low level is insufficient to trigger the ring-detection circuit, which requires about 3 volts to fire.

Other Features

The circuit has two additional noteworthy features. The reverse polarity LED is to inform you that the line is connected to the wrong polarity (this LED may also light during ringing). Also, the diode and capacitor regulator (D7 and C3) isolate the hash on the −5 volt dc supply to provide a noise-free signal to the input of U2 and U3. This is especially important if the negative supply is used for other computer components.

Construction Notes

As shown in the title page photograph, the prototype interface is constructed on a single 4- × 5-in. perforated circuit board, using point-to-point wiring. All connections to external circuits are made through the 22-pin edge connector. Component placement is not critical. The LEDs are lined up along the front edge of the circuit board for easy viewing. The control signals are all at standard TTL levels, but can be interfaced to any digital circuit. In the WØYC repeater, the pick-up and ring-detect signals connect to the C port of an Intel 8255 parallel peripheral interface (PPI), which is controlled by an 8080-based microcomputer. Thus, the phone-interface signals can be sensed and controlled with simple microprocessor input and output instructions.

In our case, long distance calls cannot be made from the repeater phone line. Hence, we need not filter the 2600-Hz disconnect tone (see Table 1). Additionally, the receiver filters audio frequencies above 3000 Hz, so no filters are needed in the interface unit. Other systems may require additional filtering to meet phone company specifications.

Adjustment

Once constructed, the circuit should be tested on the phone line to be used in the final application, since the impedance and audio levels of various phone lines differ somewhat. The ring-detect, pick up-the-phone and reverse-polarity indicator sections require no adjustment, but they should be checked before proceeding to the adjustment of the audio levels.

Connect the interface receiver audio output to the audio input of the radio transmitter, apply a pick-up phone signal and use the dial tone to set the proper level into the transmitter. Next, connect the radio receiver to the interface transmitter audio input connection. Hang up the interface (remove the pick-up signal), and dial the phone line from another phone. Apply the pick-up signal, and set the interface input level to 0 dBm. Check the audio level on the phone line, and adjust the transmitter gain and bias until clear, loud audio is heard, with about 20 mA of loop current; the two adjustments will interact. Once the interface transmitter is adjusted, recheck the audio reproduction of the receiver. Its output level may have changed if the magnitude of the loop current has changed.

Conclusion

This interface is currently in use on the WØYC repeater. The microprocessor control system checks the ring-detect output each quarter second. If a ring signal is sensed, the repeater branches to a subroutine that allows external control of the computer. A signal from the repeater receiver initiates the autopatch function. The computer picks up the phone and passes the dial signals and voice audio to the phone interface during the autopatch.

There are other applications for this interface. The circuit can be used as a phone patch for hf rigs. Similarly, it could provide the connection of a microcomputer system to the phone line, with the addition of a serial-data modulator/demodulator (modem).

The optoisolator can provide a compact, simple replacement for bulky transformers and relays; and as in this application, optoisolators are ideal links between computer-based control systems and the outside world.

Strays

HAPPY ENDING FOR STUDENTS

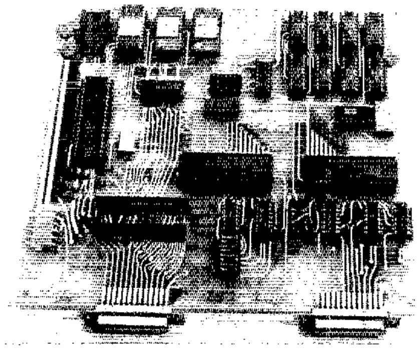
☐ In September 1980, the New York City school system accepted my proposal to teach an Amateur Radio course as a regular part of the Junior High School curriculum. The course was a success, and 120 students were learning about ham radio as part of their everyday program, just like science and math . . . until May 20. On that day our gear was stolen, effectively putting us all off the air. Not ones to give up easily, the students contacted hams they had worked and local clubs to collect money for another station. Thanks to the generosity of these individuals and clubs, my students at JHS 22 and I will be back on the air this fall. — *Joseph J. Fairclough, WB2JKJ*

HAND-KEY SENDING RECORD

☐ Harry A. Turner, W9YZE, of Alton, Illinois, appears to own the legitimate hand-key code-sending record. Listed in the *Guiness Book of World Records,* W9YZE sent 175 characters per minute (35 words per minute), the top speed Army machines at that time could send back. This was accomplished with a hand key in November 1942 at the U.S. Army Signal Corps School at Camp Crowder, Missouri. Still pounding brass, Harry has been at it for over 65 years! — *Egyptian Radio Club, Granite City, Illinois*

Fore! Shown working some of the many contacts made during their special-event operation at the 40th Bing Crosby Pro-Am golf tournament are (l-r) W6OII, N6ALS and N6LLR. The sporting event captured the imagination of the Naval Postgraduate School (Monterey, California) ARC, who overcame natural and legal obstacles to get on the air. *(photo courtesy Bill Webb, WD6COR)*

The Making of an Amateur Packet-Radio Network



U.S. and Canadian Radio Amateurs are experimenting with packet radio. Plans are underway for an amateur packet-switched network to be built over the next few years.

By David W. Borden,* K8MMO, and Paul L. Rinaldo,** W4RI

October 16, 1981, is the date set for the ARRL conference on Amateur Radio Computer Networking at the National Bureau of Standards, Gaithersburg, Maryland.[1] This will be the setting for a get-together by North American radio amateurs who are eager to build a packet-switched network.

Store-and-forward packet-switching techniques date back to a 1964 study by the RAND Corporation. The term "packet" was coined in 1965 by D. W. Davies of the British National Physical Laboratory. In that year, the U.S. Advanced Research Projects Agency (DARPA) started working on time-sharing concepts that would lead to the activation of ARPANET in 1969. Since then, a whole new science of packet communications technology has matured, and numerous government and commercial packet-switched networks have emerged. This history and an excellent treatment of packet technology is covered in a recent book edited by Kuo.[2]

Amateur Radio packet experimentation got its start in Canada on September 15, 1978, when the Department of Communications (DOC) announced rules for the Amateur Digital Radio Operator's Certificate.[3] The DOC also established regulations for packet-radio transmissions and designated certain vhf and uhf subbands for packet emission. This kicked off packet activity in Ottawa, Montreal, Vancouver and elsewhere.

In 1975, the availability of microprocessors and inexpensive microcomputer kits gave personal computing a big send-off. Because ASCII was not at that time permitted in the ham bands, the choices for data communications were to convert to Baudot or to use the telephone lines. Couple this with the fact that many computerists do not have ham licenses, and you can see why telephone data communications became popular. In 1978, the Computerized Bulletin Board System (CBBS) was developed by Christensen and Suess.[4] There are now around 200 active CBBS systems in the U.S. and Canada. This picture was changed by FCC action, effective March 17, 1980, that legalized ASCII over the U.S. ham bands. This set in motion some experimentation with serial (start-stop) transmission of ASCII; i.e., just hook up the computer to your ham radio equipment through a modem, and let 'er rip! As only a short time passed, it became clear that packet transmission of ASCII offered some advantages. So, a handful of U.S. experimenters set out to catch up with the 18-month lead enjoyed by their Canadian counterparts.

Pardon Me, But . . .

What is a packet? A packet is a group of ASCII characters (information) surrounded by control signals and error-detection features. The control signals help recognize the presence of a packet and tell any intervening switching equipment where the packet should be sent. The error-detection feature works so well as virtually to guarantee that bad information will not be observed by the destination station. Table 1 illustrates a typical packet.

As may be seen, a packet is similar to a message format. In fact, it's a lot shorter than the average Amateur Radio or MARS message. Besides carrying smaller payload, the header and trailer components are designed to be read by computer, not by human operators. The computer, in this case, can be either a home computer programmed to perform this function or a packet controller — a single-purpose microcomputer board dedicated

Table 1

Format for a Typical Packet

Time →

SYNC	FLAG	ADR	CTL	DATA	FCS	FLAG

← *Direction of BIT Transmission*

SYNC — First packet in a group of packets contains 16 bits of alternating zeros and ones.
FLAG — 8 bits, always 01111110 (7E hex).
ADR — Address of the sending station, either assigned dynamically by the Station Node at sign-on or hard-coded into the Terminal Interface Program (8 bits).
CTL — 8 bits containing control information for handling the packet.
DATA — From 0 (supervisory packet) to 255 bytes of data in ASCII.
FCS — Frame Check Sequence — 16 bits, computed by the sending station and checked by the receiving station.
FLAG — 8 bits, always 01111110 (7E hex).

[1]Notes appear on page 30.
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to this task. There are advantages to the packet-controller board approach, such as (a) taking advantage of packet-controller chips on the market, (b) keeping the hardware costs low by not tying up the personal computer and (c) avoiding the necessity of generating new software for every type of computer as changes are made.

Following this philosophy, a typical vhf Amateur Radio packet station would look like that in Fig. 1. The terminal in this case could be either a cathode-ray tube (CRT) or printer and could operate in either ASCII or Baudot code. The Terminal Node Controller (TNC) of the type designed by Doug Lockhart, VE7APU, can be programmed by means of programmable read-only memories (PROMs) to handle serial or parallel communication with a wide variety of terminals, including computers. The other side of the TNC manages the line — sending and receiving packets in High-Level Data Link Control (HDLC) format.

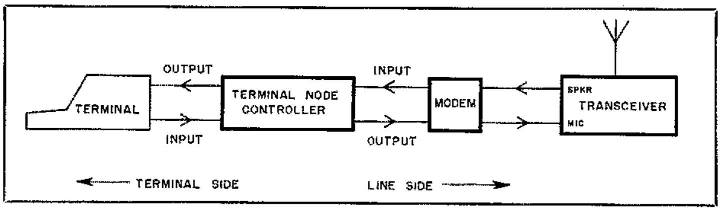

Fig. 1 — Block diagram showing a typical vhf packet-radio station. The arrows indicate the direction of data flow.

Example Packet Transmissions

Assume that the source station wishes to send a two-page message to a destination station using packets. The transmission might be broken up into 48 packets, each containing the address of the source and destination, an information (data) field containing a part of the total message and a frame check sequence (FCS) for error detection. The source station would enter his message into a computer terminal attached to a Terminal Node Controller. The TNC would accept the message as input, break it up into packets, send the packets over the transmission medium (radio, in this case) and receive an acknowledgment of correct reception from the destination station for each packet sent. The destination station would also employ a TNC to receive the packets, acknowledge correctly received packets (ASCII ACK) or request retransmission of any bad packets (ASCII NAK or negative acknowledgment). Bad packets are detected using the FCS. An FCS is appended to each packet by the transmitting station. The receiving station computes what the FCS should be and compares that with the FCS supplied with the packet. If the two agree, the chances are very great that the packet is error free. If the two answers disagree, the destination station knows that the packet is bad and requests retransmission of that packet only.

We have yet to observe the benefits of packet radio. First, a channel can be utilized by a number of users through a time-sharing arrangement known as time-division multiplexing. These different conversations can take place on the same channel, apparently at the same time. In fact, each pair of users believes that the channel is theirs exclusively. Unless a station deliberately tells its TNC to monitor everything on the channel, the station will recognize only those transmissions meant for it.

You might ask, "What happens when two users transmit at the same instant?" In ham radio, it's QRM. In packet terminology, it is called a "collision." There are all sorts of so-called contention schemes to avoid collisions, but they happen even in the best packet networks. In this case, the TNC performs a carrier-sense check (to see if anyone is using the channel). Just to reduce the possibility of two TNC boards hearing nothing and bursting packets at exactly the same time, a variable time delay is built in. Because the time delay at each TNC (user) is changing, repeated collisions between the same pair of users should not occur.

Local Repeaters

In packet terminology, Local Area Network (LAN) is used to designate a number of terminals within a small geographical area that are able to talk to one another through a common channel. That may be coaxial cable or radio. It is difficult for some people to feel comfortable with the term "packet repeater," because this type of repeater may be quite different from the usual ham 2-meter fm variety. Because local area network packet repeaters are still highly experimental, those now operating or in the construction stage in the U.S. and Canada represent different approaches. As examples of two implementations of local area networks using the same Vancouver TNC boards and HDLC protocol, let us look briefly at San Francisco and Washington, DC.

The KA6M/R local area network packet repeater was activated on December 10, 1980.[3] It is a single-frequency repeater that accepts packets, performs an error check on them and retransmits them when the packets contain no errors. The repeater itself uses a Z-80 microprocessor driving a custom-built board containing a Western Digital 1933 HDLC chip. Bell 202 1200-baud modems are used both at the repeater and by members of the net. Individual stations are using Vancouver TNC boards.

The WD4IWG/R repeater is a straightforward 2-meter fm voice repeater, which is also used by local AMRAD (Amateur Radio Research and Development Corp.) members for data communications. So, what comes in is repeated on the output frequency at the same time. This approach has the advantages of (1) using an existing repeater and (2) being able to sense the repeater output for presence of carrier before transmitting, avoiding collisions when the other station cannot be heard directly. Like those local networks in Vancouver, San Francisco and Hamilton, Ontario, the Washington, DC group is using the Vancouver TNC boards.

The local area network packet repeater scene is continuing to evolve with new compromises between doing it "right" and making do with what is available.

The Wider Network

The eventual goal is to tie these and many other local areas together to form a larger packet network. The focus, at the moment, is on interconnecting the various groups in Canada and the U.S. We are using the acronym AMNET to designate this wider network, which may go much beyond North America. Basic approaches, and possibly some tentative standards, for this network are the topic of the October 16 conference in Gaithersburg, Maryland.

There is general agreement that the bulk of the network traffic will be handled by the vhf or uhf packet repeaters deployed across North America. The spread of these repeaters could be as rapid as seen in past years with fm repeaters, but that depends upon enthusiasm and agreement of how to proceed. One view, perhaps the prevailing one, is that the intercity packet repeaters should be separate from the local area network packet repeaters. Also, it seems that the place for them is 220 MHz, and that they should operate at high signaling rates in the range of 1200 to 48,000 bits per second. The idea is to have the speed as high as practical in order to ensure that there is sufficient capacity to handle all intercity traffic. The higher speeds, however, require both wider bandwidths and greater power. So, the trade-offs are being studied. The lower speed (1200) would be necessary if, for some reason, we are unable to obtain an FCC rules change or waiver.

There is also a preference for the use of satellites for the long-haul circuits needed to "leapfrog" the vhf/uhf terrestrial network. Data communications channels are

A Glossary of Packet-Radio Terms

Address — Element(s) of a packet frame that identify the source and/or destination stations by means of an agreed bit pattern.

CCITT — Consultative Committee for International Telegraph and Telephone, a part of the International Telecommunication Union (ITU).

CSMA — Carrier sense multiple access, a contention scheme in which stations listen for the presence of a carrier on the channel before sending a packet.

HDLC — High-Level Data Link Control, a packet transmission protocol developed by the International Standards Organization (ISO). It was derived from IBM's Synchronous Data Link Control (SDLC).

Flow control — The method used to regulate the rate of data exchange between the end users of the packet network in order to prevent system overloading. In general, the input is slowed down or stopped until the network handles the previous input.

Packet — (CCITT definition) A group of binary digits, including data and call control signals, that is switched as a composite whole. The data, call control signals and possibly error-control information are arranged in a specific format.

Packet switching — (CCITT definition) The transmission of data by means of addressed packets, whereby a transmission channel is occupied for the duration of transmission of the packet only. The channel is then available for use by packets being transferred between different data terminal equipment.

Protocol — A format and set of procedures for achieving communications.

Protocol layering — The International Standards Organization (ISO) has divided protocols into seven layers, from the lowest through the highest levels, as follows: Physical, Link, Network, Transport, Session, Presentation and Application. RS-232-C is an example of a Physical level protocol, HDLC a Link level.

Routing — A sequence of passing packets through various store-and-forward packet switches in a network to the desired destination.

Terminal Node — As used by the Vancouver Amateur Digital Communications Group, a user station in the packet network consisting of a Terminal Node Controller board, a data terminal (or computer), a modem and radio equipment.

assigned to AMSAT Phase III and later satellites in the planning stages. Hank Magnuski, KA6M, is the chairman for the AMSAT International Computer Network (AMICON) system architecture design group.

High-frequency (hf) packet circuits will be needed to fill in the gaps while the satellite capability is still not operational. Also, some hf capability should be maintained as a back-up system. An experimental hf packet circuit is being tested between AMRAD (WD4IWG) in Washington and ARRL (W1AW) in Newington to determine both equipment and software requirements for an operational circuit. Hf propagation restricts practical speeds to the general range of 75 to 600 baud, although 300 baud is the top speed presently permitted by FCC rules. The speeds of 300, 600 and 1200 baud are possible over ionospheric paths within the limitations of multipath distortion. Generally speaking, a radio signal that is operating on the maximum usable frequency (muf) has only one path, thus no multipath. However, lower frequencies (than the muf) can follow several paths within the same ionospheric layer, and suffer multipath distortion at higher speeds. This is a complex effect that varies by path distance and operating frequency, relative to the muf. The worst circuit distances for multipath are the shortest ones, e.g., under 300 miles — that between Newington and Washington. The best path distance is around 1000 to 1600 miles.

Getting Started

First, you need to do some reading. In addition to the references at the end of this article, you will find a number of books and magazine articles in many technical libraries. More to the point, you may wish to join one or all three of the following Amateur Radio groups that regularly publish newsletters with substantial packet information:

1) Amateur Radio Research and Development Corp. (AMRAD), monthly *AMRAD Newsletter* ($12). Gerald Adkins, N4GA, 1206 Livingston St. North, Arlington, VA 22205.

2) Vancouver Amateur Digital Communications Group (VADCG), *The Packet* ($10). Don Oliver, VE7AOG, 818 Rondeau St., Coquitlam, BC V3J 5Z3.

3) Hamilton and Area Packet Network (HAPN), *I-Frame de VE3PKT* ($10). Stu Beal, VE3MWM, 2391 Arnold Cres., Burlington, ON L7P 4J2.

If you decide to start with the Vancouver TNC board, you can order them from VE7AOG. The price is $30 for a bare board and all documentation. You will need to populate it with integrated circuits, resistors, capacitors and the switches required. You then plug in PROM chips containing the appropriate program and begin communicating. The total cost of the TNC is about $250 when you add up the costs of the board and parts.

Next, you will need a Bell 202 modem. These may be available as surplus at hamfests, but several manufacturers are now making them at affordable prices. If you contemplate only hf operation, your existing RTTY modem (AFSK keyer/demodulator) may be used at the slower speeds of 75 and 150 baud, possibly with some modification.

Some Cautious Conclusions

Amateur packet radio experimental activity is well under way. Local area networks have been set up in a number of places in Canada and the U.S. Network standards and protocols are beginning to take shape.

You can get involved by starting a local area network with just two (or more) hams within range of each other. One or more of the groups mentioned in this article can help you get started. QST

Notes

[1] "Call for Papers on Packet Radio and Computer Networking," *QST*, July 1981, p. 32.

[2] Kuo, *Protocol & Techniques for Data Communication Networks* (Englewood Cliffs, NJ: Prentice-Hall, 1981).

[3] R. Hesler, "Canadian Newsfronts: DOC Creates New Amateur License Class," *QST*, Dec. 1978, p. 61.

[4] Christensen and Suess, "Hobbyist Computerized Bulletin Board," *Byte*, Nov. 1978, p. 150.

[5] H. Magnuski and P. O'Dell, "First Packet Repeater Operational in U.S.," *QST*, April 1981, p. 27.

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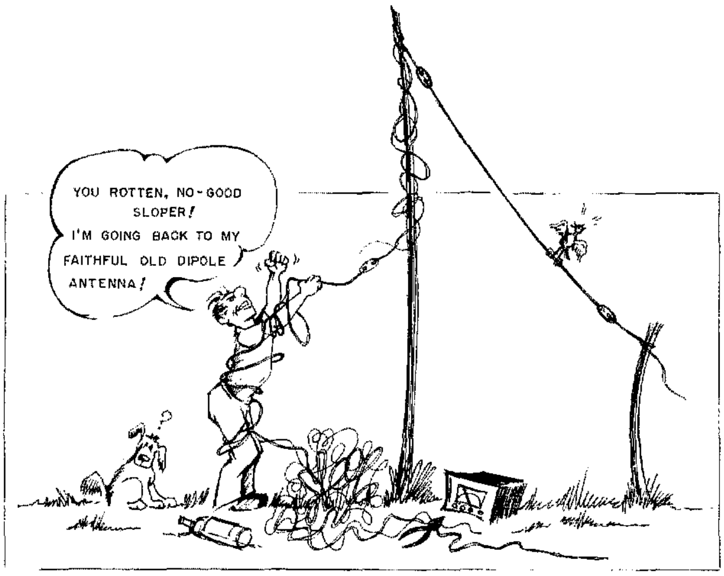
More Thoughts on the "Confounded" Half-Sloper

Half-sloper antennas don't function well for some amateurs, but others laud the performance. If you've tried them and experienced problems, these practical observations will be of interest.

By Doug DeMaw,* W1FB



"I read the *QST* articles[1] on half-slopers, built one, then found out it was no good!" We've actually received a couple of letters to this effect at Hq. But we've also had correspondence that said, "Thanks for publishing the half-sloper data. I erected one and have picked up 22 new countries on 80 meters with it!" Conflicting reports about performance have trickled in for many months, so we decided to do some testing that might reveal what had gone wrong with those slopers that performed poorly. A number of interesting observations were made, and numerous experiments were conducted at W1FB. This article will outline some of the more significant aspects of the tests that were conducted over an eight-month period.

What is a Half-Sloper?

The half-sloper is known also as the quarter-wave sloper. It differs from a full-sloper mainly by being half as long. The full-sloper is a half-wave dipole fed at the center with coaxial cable. Conversely, a half-sloper consists of a quarter-wavelength wire conductor, which is operated *in combination with* the metal mast or tower that supports it. Indeed, the tower is an electrical part of the sloper, which means that the height of the support and whatever else is attached to it play a significant role in antenna adjustment and performance (more on that later). The half-sloper is fed with 50-ohm coaxial cable at the point of attachment to the tower, as shown in Fig. 1. The center conductor of the cable connects to the slope wire, and the shield braid is attached to the tower leg or the mast. An enclosed angle of approximately 45° is used between the tower and the slope wire.

Half-Sloper Virtues

Inverted-V, full-sloper and half-sloper antennas require but one supporting structure. That's a plus factor. Unlike the full-sloper, the quarter-wave version has the current part of the antenna high above ground (desirable). The feed line can be taped to a tower leg, thereby preventing it from dangling across the property, as would be the case when using a full-sloper.

The half-sloper exhibits directivity (not gain) in the direction of the slope. This can be useful for favoring a particular DX region. In all tests at W1FB the sloper was a quieter antenna than the 55-foot (m = ft × 0.3048) vertical against which it was compared. That is, it was less responsive during receive periods to man-made and atmospheric noise than was the vertical.

Misconceptions

In reading our mail concerning the sometimes dismal performance of half-slopers, we have found that a misunderstanding of basic antenna principles caused much of the difficulty. Some amateurs used a tree or wooden mast to support the antenna. In such cases there was no place to connect the coax-cable braid, so it was left unattached at the feed point! The half-sloper requires a grounded metal mast or tower as a support, since the support is an electrical part of the system. In the most general of terms we can equate the sloper and tower to the two legs of an inverted-V dipole. The current and voltage distribution are not the same, however.

Others said that the VSWR was high, no matter how much pruning of the wire length was done. We'll address this matter

[1]See D. Atchley, W1CF, "Putting the Quarter-Wave Sloper to Work on 160," *QST*, July 1979; J. Belrose, VE2CV (ARRL TA), "The Half-Sloper — Successful Deployment is an Enigma," *QST*, May 1980; and D. DeMaw, W1FB, "Additional Notes on the Half-Sloper," *QST*, July 1979.

*Senior *QST* Technical Editor

later in the text. Some said that an SWR of 1:1 was easily obtained, but the antenna was very ineffective compared to a horizontal dipole at modest height above ground. It turned out that the tower in those examples was merely set in concrete without an effective ground system. The operators didn't think an earth ground was essential for this style of antenna.

Initial Investigations

The letters suggesting "black magic" concerning half-slopers arrived as winter was setting in on the East Coast. This ruled out any comprehensive outdoor evaluation of various half-sloper configurations. The practical solution seemed to be in scaling the W1FB tower, triband Yagi and sloper to 144 MHz. This would permit reasonable indoor tests during the bad-weather months. Then, the full-scale tests could be based on 2-meter results when spring arrived. Fig. 2 shows the setup used on 144 MHz to learn which factors affected the tune-up and performance of the antenna in question. Copper tubing was substituted for the Rohn-25 tower. Brazing rod was used to make the scaled-down hf Yagi, and sheet aluminum was extended 1/4 wavelength beyond the base of the short tower to simulate the buried radial system at W1FB, which consists of only 16 wires that range in length from 60 to 110 feet in rather swampy ground. No. 28 enameled wire was employed as the half-sloper wire. The scaling was not precise, but it was close enough to optimum, thereby yielding satisfactory results. A diode type of field-strength meter (calibrated in decibels) provided the instrumentation needed for pattern checks. The SWR was monitored by means of a Bird wattmeter. A Kenwood TS-700 all-mode 2-meter transceiver served as a signal source and was used in the receive mode to observe relative directivity of the half-sloper system while monitoring various repeaters in the area.

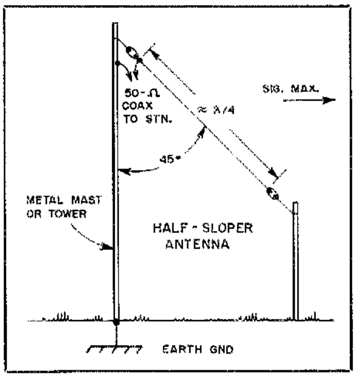


Fig. 1 — Basic half-sloper antenna attached to a metal supporting structure. The feed point is at the top of the wire. Coaxial cable is used for the transmission line, with the center conductor made common to the slope wire. The shield braid is connected to the mast or tower leg. The mast or tower must be grounded at the base. A buried radial system is preferred.

This technique is within the technical and financial means of any amateur, and is highly recommended for scaling one's tower, guy wires and beams when evaluating shunt-fed towers, slopers and other antennas that in some way depend on the tower.

Test Results

It was not too great a surprise to learn that the data gathered on 2 meters was repeatable at scale, with an accuracy of approximately 10%, the following spring. Similar results were obtained during earlier scaling tests of 80- and 160-meter shunt-fed towers. The system at that time was scaled to 10 meters. W1VD performed similar tests of his 80-foot tower (scaling to 28 MHz), and had results at scale that were accurate within 10%.

These are the significant factors that affect the SWR of a half-sloper.

1) *Height of attachment point on the tower.* The best results were had when this point was approximately 1/4 wavelength above ground.

2) *Enclosed angle of the tower/wire combination.* Varying the angle had a marked effect on the SWR, irrespective of the height of the attachment point.

3) *Other conductors connected to the tower.* The triband Yagi had a large effect on the SWR: Removing it changed the SWR from 1:1 to 4:1, indicating that the beam was related electrically to the overall system. Guy wires and other sloping antennas had a similar effect. An array (4)

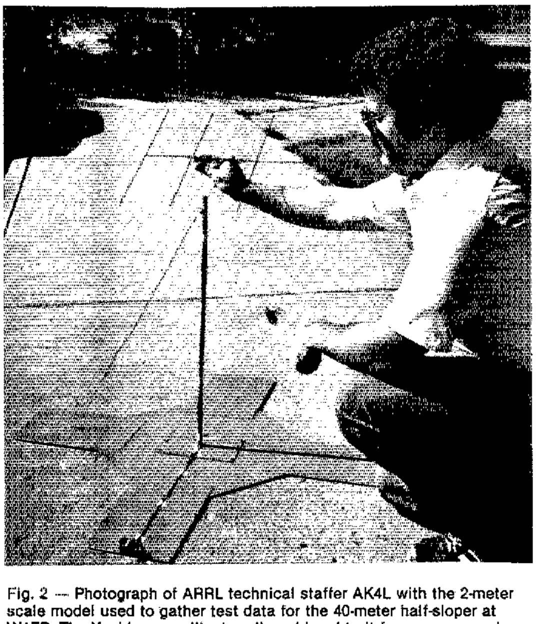


Fig. 2 — Photograph of ARRL technical staffer AK4L with the 2-meter scale model used to gather test data for the 40-meter half-sloper at W1FB. The Yagi has an alligator clip soldered to it for easy removal during tests. Aluminum sheeting serves as a ground system (see text).

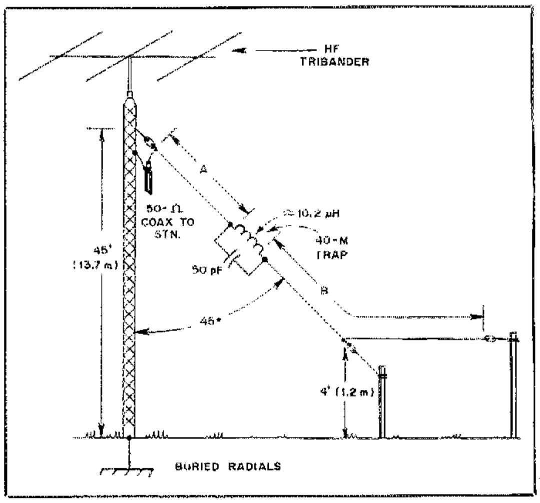


Fig. 3 — Practical circuit for the W1FB 40/80-meter, coax-fed half-sloper antenna. Owing to insufficient tower height, the lower part of the 80-meter extension is bent and routed horizontal to the ground. The feed line should be taped to a tower leg (likewise with rotator cable and other feed lines) at regular intervals, then routed to ground level. This will decouple the cables and prevent unwanted rf energy from entering the shack. The cables can be laid on the ground and brought to the shack, or they can be buried in the soil.

of half-slopers for the same band (spaced at 90° increments) made it impossible to obtain an SWR of less than 5:1 with any given sloper. This interaction was severe with only two half-slopers on the tower. Guy wires had to be broken up at nonresonant intervals and had to be insulated from the tower to eliminate SWR problems and preserve the radiation pattern of the antenna.

4) *Ground system under the tower.* The quality of the ground system (buried radials, on-ground radials or ground rods) affects not only the SWR, but also the effectiveness of the half-sloper. Removal of one half the aluminum-sheet ground system at 2 meters changed the SWR and reduced the field strength off the slope of the antenna.

An SWR of 1:1 could be obtained under most of the foregoing conditions by varying the height of the attachment point and the enclosed angle of the antenna. In all of the tests it was learned that the half-sloper needed to be slightly longer than the computed length obtained from l(feet) = 234/f(MHz). The antenna is not resonant at the operating frequency. Rather, the length is varied until the feed point exhibits a 50-ohm characteristic.

All scaling was done for a 40-meter sloper system. Extrapolation of the bandwidth from 2 meters to 40 meters indicated that the 40-meter bandwidth between the 2:1 SWR points would be approximately 150 kHz. Later tests at scale confirmed that number. As a matter of casual interest, the 2-meter half-sloper turned out to be a very effective fm/repeater antenna. From inside the W1FB QTH (antenna 4 feet above ground level) it was possible to access repeaters as far away as 40 miles when orienting the sloper toward the repeater. Power output from the TS-700 was 10 watts.

The directivity of the antenna produces a lobe that is approximately 5 dB stronger than the points along the otherwise omnidirectional pattern of the antenna. The radiated wave is essentially vertical in polarization.

A Practical Half-Sloper

Following verification of the scale-model tests in February of 1981, and after many local and DX contacts were made on 40 meters, a two-band version of the half-sloper was tested. It was designed for use on 80 and 40 meters by using a 40-meter trap in the slope wire. The system is illustrated in Fig. 3. The length of the wire A is the same as for a 40-meter single-band half-sloper. Wire sections A and B constitute the 80-meter half-sloper, with the 40-meter trap becoming part of the system. Owing to the loading effect of the trap, sections A and B combined are somewhat shorter than would be the case of a single-band 80-meter half-sloper. There was insufficient tower height at W1FB to permit a continuous slope of the wire. Therefore, the last 10 feet of the wire was run off at an angle, as shown in Fig. 3.

To permit operation at 1 kW, the trap contains a section of large-diameter Miniductor stock. A surplus ARC-5 50-pF vacuum capacitor was chosen for the trap capacitor. Transmitting ceramic capacitors can be substituted for the trap capacitor specified, but will change value when large changes in outdoor temperature occur. This effect will be noticed especially in regions where severe winters are common. The trap should have a high Q and can be tuned with a dip meter for the center of the chosen operating range before installation. Do not put the vacuum capacitor inside the coil because the metal parts of the capacitor will detune the trap and lower the Q significantly.

A compromise was made when selecting the attachment point of the antenna on the tower. It is somewhat higher than 1/4 wavelength at 7.025 MHz to permit ample height for the overall wire in the two-band format.

The SWR on 40 meters is 1.3:1 at 7025 kHz. Owing to the bent format on 80 meters, plus the less-than-prescribed height of the attachment point, a low value of SWR was not attainable. The best SWR turned out to be 2:1 at 3510 kHz. Line losses are of no consequence at 80 meters, since only 60 feet of RG-8/U is used in the system. The SB-221 amplifier loaded into the system just fine, despite the 2:1 SWR. Phone-band operation is possible by using a Transmatch (at the transmitter) for either band.

Some Precautions

The continuity of the tower sections is important to good performance, since the tower is part of the antenna system. Similarly, the tower-to-mast continuity should be ensured. This can be achieved by placing short lengths of shield braid across the joints between tower sections. A long, flexible conductor can be used between the mast and tower to provide continuity in that part of the system. If intermittents are present (especially when there is a breeze), the SWR will ramp up and down in an alarming manner! Some operators have solved the problem by merely running a continuous length of heavy conductor from the mast to the base of the tower.

On-the-Air Results

A shunt-feed arm was attached to the tower to permit using it as an 80-meter vertical. The tower was resonant at 3.8 MHz with the tribander atop it, so getting a match to 50 ohms was not difficult. The tower was rigged in this manner to permit comparisons between it and the 80-meter half-sloper during DX QSOs. A coax switch was used at the operating position to facilitate fast comparisons. It should be acknowledged that there is significant interaction between the half-sloper and tower. In an ideal situation the two antenna should be well separated from one another. Despite this condition, however, some interesting results were obtained in the spring of 1981.

During a 1-1/2 month period of casual DX chasing, 72 countries were worked by W1FB with the two antennas. The sloper was arranged for maximum directivity to the south because of property limitations. It showed a consistent 8- to 10-dB advantage over the vertical out to approximately 1500 miles in all directions. It was similarly superior to the vertical when working stations in the West Indies and South America. During QSOs with European stations, the sloper and vertical were often neck and neck, but the vertical was predominantly 5 to 6 dB better than the sloper. Had the wire been sloped to the northeast, the sloper would probably have equaled the vertical in performance, and may have exceeded it on occasion.

Since the half-sloper was the quieter of the two antennas, it often provided an advantage in weak-signal reception, even though the received signals were not as strong as when using the vertical.

Recommendations and Summary

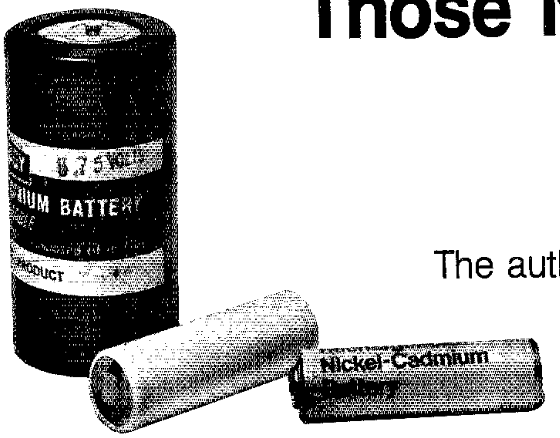
Some amateurs have reported success when using an 80-meter half-sloper on 160 meters. This was done by placing a loading coil and capacitance hat at the lower end of the wire. An 80-meter trap was inserted between the end of the wire and the loading coil. This same technique might be applied to the antenna of Fig. 3 to make it a three-band half-sloper.

The operator should make an effort to install a ground-radial system when using a half-sloper. A practical rule of thumb is to put as much wire in the ground as possible, but not to worry if an elaborate, classical ground system isn't practical. During tune-up, experiment with the attachment point and the enclosed angle of the antenna. If an SWR of 1:1 can't be obtained, don't worry about it. The system will provide good results as long as the transmitter will load into it. If it doesn't, use a Transmatch at the rig.

A multiband sloper can be erected by using open-wire or TV-style 300-ohm line. This was tried at W1FB by cutting the slope wire for 40 meters and by using a Transmatch in the shack. Excellent results were had from 40 through 10 meters, with the sloper at times providing reports as good as those obtained with the tribander out to 1000 miles or more. The 40-meter version with tuned feeders also did a pretty good job on 80 meters.

If you have tried this antenna and found out it was "no good," perhaps you didn't experiment enough. We hope this article will give you some hints toward making your half-sloper do a proper job for you! QST

Those NiCad Batteries and How to Charge Them!



The author explains the nature of NiCad batteries. He also shows how to charge them sensibly with a home-built charger that works better than store-bought units.

By David W. Potter,* W2GZD

Nickel cadmium batteries (NiCads) are remarkable devices! They have been in use for more than 50 years. They can be used and recharged hundreds of times. The internal resistance of NiCad batteries is low and remains low until the end of the discharge cycle, and the output voltage remains fairly constant during the discharge period. Typical voltage is 1.3 for a freshly charged cell. It decreases to about one volt at the end of the discharge cycle. If the discharge continues, the output voltage falls rapidly from this point. Higher-voltage batteries or power packs are realized by connecting one or more cells in series.

Sealed cylindrical cells and batteries that are most commonly found in Amateur Radio equipment are made something like a capacitor. Thin, sintered electrodes of sheet nickel hydroxide and cadmium hydroxide are isolated from each other by a porous separator sheet. A limited amount of potassium hydroxide serves as the electrolyte. The three sheets and the electrolyte are rolled together, then placed in the cylindrical steel case. An insulating seal ring separates the positive cover from the negative case.

The chemical reaction of the nickel cadmium cell is:

$$Cd + 2NiOOH + 2H_2O \underset{\text{Charged}}{\overset{\text{Discharged}}{\rightleftharpoons}} Cd(OH)_2 + 2Ni(OH)_2 \quad \text{(Eq. 1)}$$

Notice that the reaction can go in either direction. If current from a charging source flows in the proper direction, it will drive the reaction backward toward the charge direction and in effect will recharge the electrodes. What is not clear from the equation, though, is that during the final part of a charge cycle, and during periods of overcharge, NiCads generate gas. Oxygen is generated at the nickel (positive) electrode and hydrogen is generated at the cadmium (negative) electrode as each reaches full charge. If the charging rate is about 1 C (defined later) the pressure and temperature inside a cell will soar at full charge, and the cell will be damaged or destroyed. Since the cells are sealed, the pressure must not become excessive. The cells have vents that will release pressure when it exceeds 150 to 300 psi, but such venting shortens the life of a cell. The manufacturers avoid the generation of hydrogen gas by making the positive electrode smaller than the negative one, so that the positive electrode becomes fully charged first. Oxygen is generated at this positive electrode at full charge, but this gas can migrate back to the negative electrode, with which it reacts, preventing the negative electrode from charging further. This also prevents it from becoming fully charged and producing hydrogen. The NiCad cell can be overcharged indefinitely then, without being damaged, owing to this protective mechanism (well, in theory, anyway).

Another interesting fact about the NiCad that makes it different from other types of batteries is that the terminal voltage is at maximum around 75° F (24° C). The voltage decreases as the temperature goes above or below that temperature. Similarly, the internal resistance is smallest at 75° F, and it increases as the temperature goes above or below that temperature. Because of this characteristic and for other reasons, a NiCad should be operated inside of the temperature range of 32° F to 105° F (0 to 40° C).

Cell Capacity

The capacity (C) of a NiCad cell is stated in ampere hours or in milliampere hours. A 500-milliampere/hour cell has a C equal to 500. It means, for example, that you may discharge the cell at a 50-mA rate for 10 hours, or at a 500-mA rate for one hour, but the capacity decreases with increasing discharge rates. The term C has another meaning. It can define the charging or discharging current. A 1-C discharge rate means a discharge current of 500 mA for a battery rated at 500 mA/hours, while a 0.1-C charging rate implies a charging current of 50 mA (0.1 × 500). Hence, C defines a certain milliampere/hour capacity, or a charging or discharging current based on that milliampere/hour rating.

Charging Characteristics

Now that the basic theory of NiCad cells has been reviewed, how can the cell be recharged sensibly so that we can approach a thousand or so recharge cycles? First, the charging rate must be limited to 0.1 C. As the charging rate exceeds 0.1 C, the oxygen generated as the cell nears full charge does not diffuse and react quickly enough at the negative electrode. The internal pressure will build up, and damage will take place. A 0.1-C charging rate implies a 10-hour charging time (0.1 C × 10 = 1 C), but the battery is not 100% efficient. It is necessary to put in 140 to 160%

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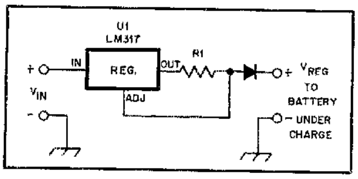


Fig. 1 — Circuit for a simple constant-current battery charger. The series diode can be a 1-A, 50-PRV silicon rectifier. U1 is a three-terminal regulator.

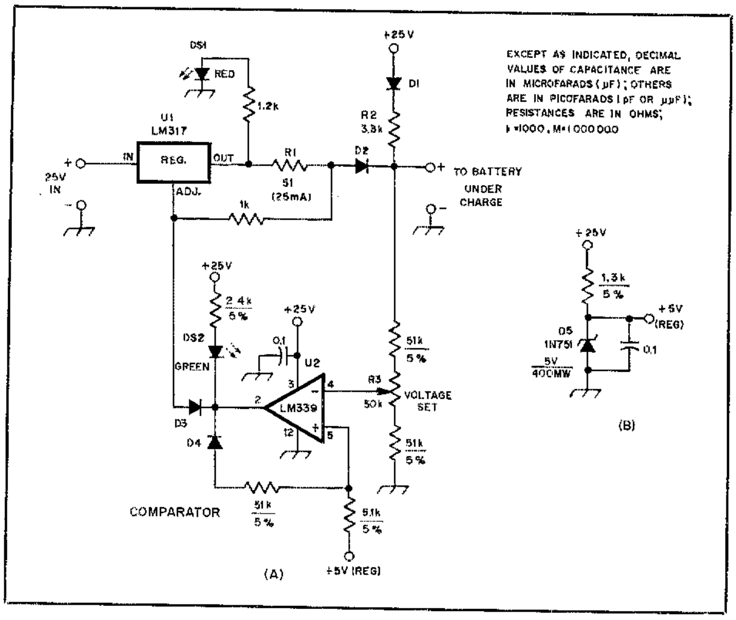


Fig. 2 — Schematic diagram of a constant-current charger with an automatic shut-down feature. R3 is adjusted to provide the maximum desired battery voltage. The capacitors are disc ceramic or Mylar. D1-D4, inclusive, are 1-A, 50-PRV silicon rectifiers. DS1 and DS2 are LEDs (see text). R3 is a linear-taper, wire-wound control. See text for details of the circuit at B.

of the charge. Now you can see where the familiar 14- to 16-hour charging time comes from. It is typical for completely charging the NiCad battery.

A battery consists of two or more cells in series. Because no two cells have exactly the same capacity, one cell will become discharged before the rest. When this happens, the weak cell will be *reverse-polarized* by the remaining cells. When this happens, oxygen will be generated at the cadmium electrode and hydrogen at the nickel electrode. Not only will the gas pressure soar, but the internal resistance will increase, and heating will take place. Manufacturers have introduced clever schemes to suppress this generation of gas in the reverse-voltage case, but the protection is effective up to discharge rates of only 0.1 C. Since the discharge rate may be in excess of 0.1 C, you should stop discharging a NiCad battery when the potential drops below 1 volt per cell. Some battery-powered amateur gear has low-voltage indicators. Cease operation when that condition is observed.

NiCad batteries can supply large pulse and dc discharge currents because of their low internal resistance. The inquisitive reader might wonder why a cell may be discharged at rates of several C safely, yet charging them at those rates can be destructive. The reason is related to the gas and heat that is generated at or near the full-charge condition, as we discovered. Quick chargers do exist, but special NiCads are used. The "quick chargers" generally measure the temperature of the cell or battery. As the temperature climbs (near the end of the charge), a temperature sensor turns the charger off or reduces the charging rate to a "trickle" charge. Such chargers and special batteries are not commonly found in Amateur Radio equipment.

Chargers for the NiCad Battery

If you enjoy building electronic circuits, you can save some money and end up with a better charger than many that you can buy! A charger can be built for a few dollars, plus some components that you probably have in your shack. A simple charger, using a constant current that is equal to 0.1 C, can be realized by using an LM317, which is a three-terminal, adjustable (positive) voltage regulator. The circuit in Fig. 1 is for a constant-current charger. The regulator is available in several types of cases. Pick your favorite. The input potential should be at least 5 to 6 volts greater than the desired maximum output voltage, and it may be up to 40 volts greater. Therefore, you have a broad range of input dc voltages with which to work. The greater the voltage difference between the input and output, the greater will be the dissipation in the regulator. The charging current in milliamperes is given by:

$$\text{mA} = \frac{1200}{R1} \qquad \text{(Eq. 2)}$$

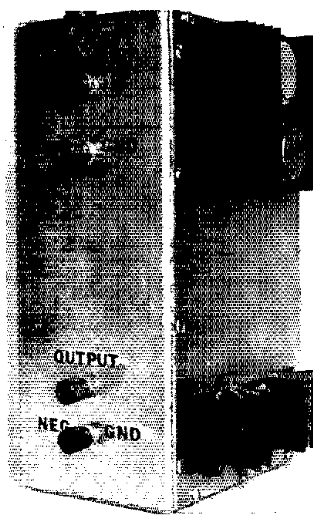
If your battery is rated at 250 mA/hr, set the current for a 25-mA charging rate. Similarly, you would set a 45-mA charging rate for a 450-mA/hr battery. These 0.1-C charging rates will require 14 to 16 hours to recharge a fully discharged battery. Overcharging should not damage them with this rate. The series diode in the schematic diagram disconnects the battery from the charger in the event that the charger is turned off, or if there is a power failure.

You can add a simple feature (Fig. 2B) that shuts down the charger when the terminal voltage of the battery reaches some fixed value. A trickle charge equal to 0.01 C to 0.03 C is supplied by resistor R2. This is the recommended "float" or leveling charging rate. The voltage comparator circuit employs 0.4 volt of hysteresis so that if the battery voltage should fall 0.8 volt below the set point, the full 0.1-C charging rate will be reinstated until the voltage reaches the desired level. A red LED (DS1) indicates that the unit is charging; the green LED indicator (DS2) shows that the battery has reached the desired (fully charged) condition. These LEDs serve only as indicators, and one or both can be eliminated.

The voltage comparator that I used is an LM339. This version has four comparators in a 14-pin DIP format, which is useful because my charger has the capability to charge several batteries independently at the same time. Just add as many constant-current regulators as you need; one LM339 will control four regulators.

All of my batteries have terminals on the bottom; they do not have connectors. I have fashioned battery supports from wood, and they have screws in the base that contact the battery terminals if the battery is inserted correctly in the blocks. A table-top charger to hold and charge an HT and spare batteries can be made with a scrap of 2- × 4-inch (51 × 102-mm) lumber and a pine board. You can decide how to connect the charger to your battery. Now go to it! Charge sensibly!

Polarity Inverter



Impossible to run a negative-ground-only rig in a positive-ground vehicle? It can be done! Here's one way.

By Gary Laurence,* WB7NAE, Dustin Laurence,* KA7FIU and Rodney Reitan,** WB7VTS

We had a unique problem: Most vehicles have negative ground electrical systems, but our motor home (a converted 1954 Greyhound bus) has a *positive* ground system! Most radio equipment these days is designed for negative ground systems. We considered changing the bus generator, regulator and wiring, but the cost was prohibitive. So we isolated the negative-ground from the positive-ground chassis for some of the circuits.

The challenge came when we decided to install a 2-meter fm rig in the bus! It would have been simple enough to isolate the radio from the bus chassis, but not so for the antenna. Besides, we were determined to use the "expansive acreage" of the roof as a ground plane for our antenna. With those constraints in mind, the possibility of damage from an accidental short outweighed the relative ease of isolating the equipment from ground. We searched for another solution.

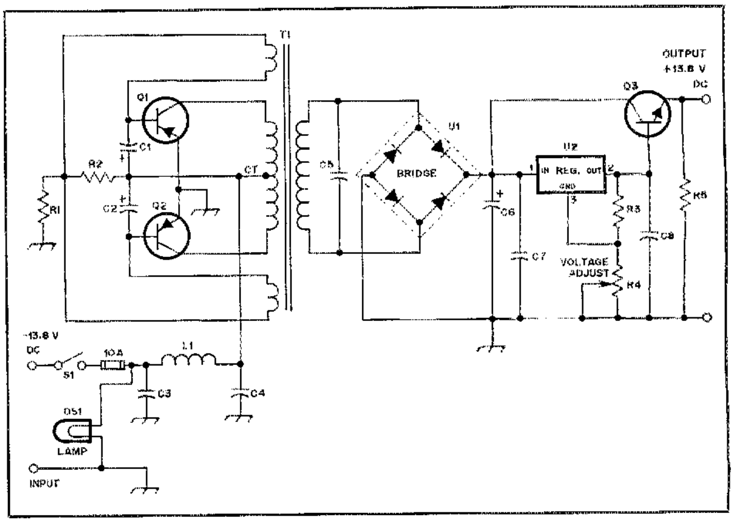


Fig. 1 — Schematic diagram of polarity inverter. Refer to text for a discussion of component types and values, which are not critical. Layout and construction techniques are not critical either.

C1, C2 — 25 μF, 150 V electrolytic.
C6 — 5000 μF, 50 V electrolytic.
DS1 — 12-V lamp, Radio Shack 272-332 or similar.
L1 — See text.
Q1, Q2 — Silicon pnp audio power bipolar transistor, 100 W, GE-4 or equiv.
Q3 — Silicon npn audio power bipolar transistor, 115 W, REN-130, Radio Shack 276-2041 or equiv.
R3 — 470 Ω, 1 W carbon composition.
R4 — 2-kΩ, 1-W potentiometer (linear taper).
S1 — Spst, 10-A toggle switch.
T1 — See text.
U1 — Monolithic bridge rectifier, 25 A, 50 PIV, Radio Shack 276-2285 or equiv.

The Answer

A polarity inverter seemed like the obvious answer. A basic circuit was decided upon. The problem was in locating a 1:1 transformer of adequate current rating for T1 of Fig. 1. We thought of winding the transformer on a large toroid, but soon abandoned that idea because we could not locate a large enough toroid, so we decided to use the core of an old TV transformer. The primary of T1 consists of 40 turns of no. 10 enameled wire, center tapped, while the feedback windings contain five turns each of no. 30 enameled wire. The secondary has 40 turns of no. 10 enameled wire also (no. 14 enameled wire should be more than adequate for both the primary and the secondary).

A regulator circuit was added as a safety feature. We used a 1-A, 12-V monolithic regulator chip (type 7812) for U2. R3 and R4 set the output voltage slightly above the rating of the chip. This results in a drop in dc output voltage from 13.8 to 13.4 when current consumption rises from approximately 700 mA (receive) to 4 A (high-power transmit). Better

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regulation might be had by substituting an adjustable regulator chip and circuit (such as the LM-317) for the 7812. However, for our use the performance of the 7812 circuit is adequate. Q1, Q2 and Q3 are mounted on heat sinks.

Filtering

The input filter of Fig. 1 (C3, L1 and C4) prevents noise from the bus electrical system from being coupled into the inverter. Component values are not critical. In our case, C3 and C4 are 0.47-μF, 200-V dc capacitors, but larger-value capacitors should work. We recommend maintaining the somewhat-high voltage rating to prevent damage caused by voltage spikes. Our L1 carries Motorola part number 24A4/2536-0. If you do not have something comparable in your junk box, you can "roll your own" by winding at least 20 turns of no. 10 enameled wire on a 3/4-in. (19-mm) form. If the output of your inverter contains a "whine" component, increase the number of turns of L1 or increase the capacitance of C3 and C4.

R1 is a 2-Ω, 25-W wire-wound resistor. You may want to substitute five 10-Ω, 5-W wire-wound resistors in parallel, because of ease of procurement. R2 is a 75-Ω, 10-W wire-wound resistor. C5 is a 0.047-μF, 50-V dc nonpolarized capacitor. C7 and C8 are 0.22-μF, 200-V dc capacitors. The value is not critical, and the voltage rating is probably higher than necessary. But, again, we relied on the contents of our junk boxes. These two capacitors should be located quite close to the regulator chip. R5 is a 1200-Ω, 2-W carbon resistor: The value is not critical.

Operation

The operation of the circuit is similar to an astable multivibrator, with the inductance of the primary windings controlling the frequency of oscillation — the greater the core mass, the lower the frequency. The TV transformer that we used provided an output frequency of about 100 Hz.

If the power supply fails to oscillate when first turned on, reverse the direction of the feedback windings on the base terminals of Q1 and Q2. It is easier to determine the proper connection by trial and error than by doing the "mental gymnastics" necessary to wire it correctly the first time. If it is backwards initially, no harm will result when power is applied: The circuit simply will not oscillate. If your transformer gets hot while operating, it is a sign that the core is not of adequate size. If the voltage "sags" under heavy load, the wire used on the primary and secondary of T1 is probably too small.

On-the-air operation indicates that there is no hum or objectionable whine on the output signal of the radio. Besides, we've got our super ground plane, and there is no danger of shorting the rig to ground!

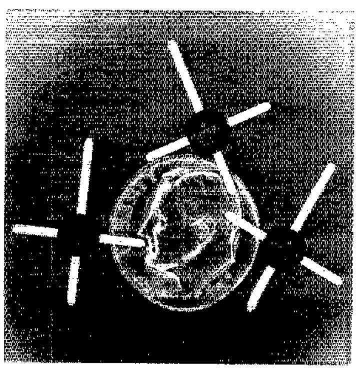
New Products

NEW MOTOROLA SEMICONDUCTOR

☐ The slogan is "Performance up, cost down," in new low-power rf transistors, as noted in some recent Motorola promotional literature that describes the MRF559 0.5-watt bipolar transistor, which has a recommended operating range of 250 MHz to 1.5 GHz. Effective emitter ballasting (protection against hot-spotting) is ensured by the current techniques in geometry, processing and packaging. This type of design in overlay transistors improves the operating linearity and enhances the reliability of the device. The metalization of the semiconductor "sandwich" uses Nichrome, titanium, tungsten and gold to eliminate the corrosion malady that is referred to in the industry as "purple plague." This is said to improve the transistor longevity by a factor of 10.

The MRF559 is contained in a Macro-X plastic package, rather than in the more familiar TO-39 case. Four 10-mil- (0.25 mm-) thick, silver-plated copper leads extend at 90-degree increments from the case, and aid cooling of the semiconductor junction.

The new transistor has large signal characterization at 470 and 870 MHz for mobile/hand-held fm operation. It should work well at vhf and uhf through 1296 MHz in amateur applications. Its ratings at 870 MHz are: P_o = 0.5 W; gain = 8 dB (min); eff. = 50%; V_{cc} = 12; 1-dB compression greater than +20 dBm (typ). The f_T is rated at 3 GHz and the noise figure at 1 GHz is 4 dB [I_c = 40 mA (3 dB at 500 MHz)]. P_D is 2 watts at a case temperature of 50° C. Price class: $1.80 in 100 to 999 lots. Available from Motorola distributors or the factory in Phoenix, Arizona 85036. Phone Tom Bishop at 602-244-6394 for additional information. — *Doug DeMaw, W1FB*



CURTIS ELECTRO DEVICES, INC. 8044M CMOS KEYER IC

☐ The number of this particular IC may be familiar to you. An 8044M IC forms the core of the Curtis EK-480M keyer, which was described in the June 1980 *QST* Product Review column, and earlier versions (the 8043 and 8044) have been appearing in *The Radio Amateur's Handbook* since 1977. As you might suspect, the "M" suffix denotes a change. This change is an *addition to* and not an *alteration of* the 8044IC.

An 8044 is a 16-pin IC, while the 8044M is an 18-pin device. By connecting a 100-μA meter and a few components to the added pins, the operator of a completed 8044M keyer can read the keyer speed directly from the meter. According to the manufacturer, the speed indication is accurate and stable for a speed range of from 6 to 50 wpm using the components recommended in the specification sheet accompanying the IC.

Why the emphasis on addition to and not alteration of the 8044? Neatly, Curtis has arranged the package so that the 8044 and 8044M are compatible despite the 2-pin difference in package size! So, if you already have an 8044 keyer and don't wish to "start from scratch" again, you can plug the 8044M into the existing 16-pin socket, allowing pins 9 and 10 to hang over the end of the socket. Attachment of the speed-meter components may then be made directly to the overhanging pins. Or the 8044 can replace the 8044M simply by leaving the two end-pin connections open and sacrificing the speed-meter circuitry. How about that!

If you're planning to construct a compact, multifeature keyer, investigate the possibility of using this IC. With it, you'll have self-completing dots, dashes and spaces; iambic operation; dot and dash memories; weight control; sidetone; a TUNE and straight key input; selectable speed range; and a keying output level sufficient to drive a keying transistor. Because it is a CMOS device, the 8044M draws a minimum of current during a standby (50 μA at 5 V dc). Key-down current is approximately 30 mA, with most of that being required for the sidetone output and drive for the output transistor.

In quantities of one to nine, price classes are: 8044M IC only, $20; 8044-3 (IC, pc board, socket), $30; 8044M-4 (limited kit), $60. These items and further information may be obtained from Curtis Electro Devices, Inc., Box 4090, Mountain View, CA 94040. — *Paul K. Pagel, N1FB*

BEGINNER'S BENCH

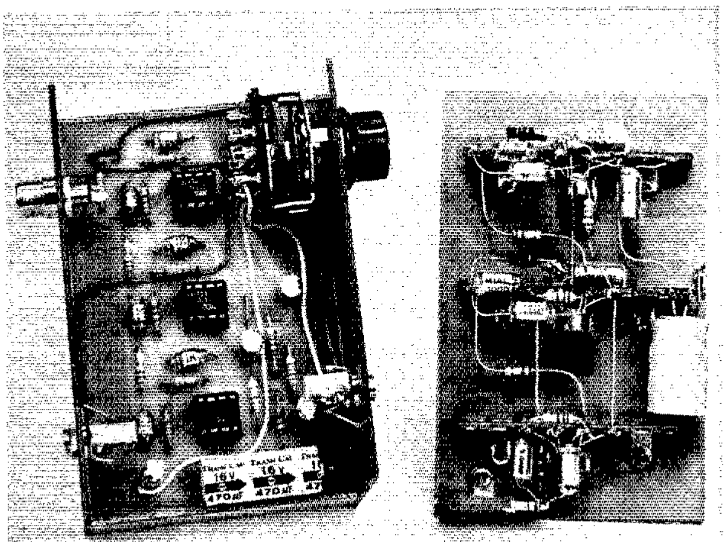
Beating Rotten QRM — CW Filtering for the Beginner

Sorting out those cw signals in a crowded band can drive an inexperienced operator to distraction. Providing cw selectivity for the receiver will help. Here's how.

By Doug DeMaw,* W1FB

What's this? You can't operate in the 40- and 80-meter Novice bands because there are too many signals, and you can't sort them out? Perhaps your ham receiver isn't tailored to handle QRM (interference) effectively. Some simple cures may be in order if that receiver just isn't "chopping it" on cw.

But first let's consider the human factor in separating signals that are close to one another in the ham bands. It has been said, and rightfully so, that the human brain and ears form the most effective filter one can utilize. Unfortunately, most of us started out in our prelicense months by learning the Morse with a code-practice oscillator. There wasn't any QRM to spoil our concentration, and we listened to a single pitch (note). When that license finally arrived and we went on the air (gulp) for the first time, things weren't a bit like they used to be! The cw notes sounded quite different in the receiver, and many notes of different pitches



KIT VERSION ARRL PROTOTYPE

*Senior *QST* Technical Editor

(audio frequencies) were blending together like a pot of stew. Sure, we could sift a loud one out of the mayhem and perhaps even copy it perfectly, but the weaker signals couldn't be pulled out of the confusing mess because the other signals tended to degrade our concentration. That wonderful ear/brain filter wasn't broken in yet, so it wasn't of much use to us. If we add that to the usual jitters experienced by a new amateur, we may feel like "cashing in our chips" in favor of tennis or some other pastime.

The fact of the matter is that the human filter doesn't become really effective until the cw operator has spent many weeks on the air. He or she must develop the ability to concentrate solely on a single pitch in order to filter out the unwanted beat notes. So what does the poor beginner do to aid reception while that built-in filter is developing its potential? The rapid solution is to employ electrical filtering of some type, and that is the topic of this month's beginner's article.

I-F Filters

There are a number of receiver filters that we might elect to use in reducing the effects of QRM when operating in the cw mode. First, and perhaps best, is the i-f (intermediate-frequency) filter that we can install immediately after the receiver mixer stage. It has a center frequency that is the same as the receiver i-f. Hence, if the receiver has a 9-MHz i-f, the center frequency of our filter must be 9 MHz. Most modern receivers and transceivers come equipped with an i-f filter, but the stock filter is too wide in response for most cw work and is intended mainly for ssb reception. Many receivers and transceivers have blank positions on the circuit boards to add one or more additional i-f filters, and these are sold as accessories. Each has a different bandwidth for use with a different mode of reception — cw, a-m (amplitude modulation), fm, radioteletype and so on. Generally, these filters are in the $50+ price class, but the benefits obtained from having the proper filter for a specified operating mode are well worth the expense when we consider, for example, that a $50 filter for an $800 rig represents only 0.065 the total cost of the equipment! We can extrapolate the cost of a $50 filter to 13-1/2 cents per day for 12 months of use. A cup of coffee costs *more* than that nowadays!

Filter Bandwidth and Shape Factor

When selecting an i-f filter for cw reception we are interested in the center frequency (f_c) nose selectivity (−6 dB points on the filter response curve) and the skirt selectivity (−60 dB points on the lower portion of the response curve). Other factors of interest to designers are the insertion loss (signal loss in decibels through the filter), ripple (flatness of the response across the top of the response curve) and the characteristic impedance of the filter, expressed in ohms. We won't cloud the issue by discussing all of the characteristics of an i-f filter. A detailed discussion of filters can be found in other ARRL literature.[1] We will concern ourselves here with the filter bandwidths (BW) and the filter shape factors. Fig. 1 illustrates how a filter passband would appear on a spectrum analyzer during the testing of a particular filter. In this example we find a −6 dB bandwidth of 500 Hz (0.5 kHz) and a −60 dB bandwidth of 4 kHz. The shape factor is the ratio of the two bandwidths, which in this case is 8:1. The smaller the ratio the better the i-f selectivity of the receiver and hence the greater rejection of signals adjacent to the one we're interested in copying. The more resonators or filter poles we use, up to a practical limit, the better the skirt selectivity and the more spectacular the shape factor. In a crystal filter the poles are the crystals, as seen in the ladder filter of Fig. 2. A 4-pole filter is illustrated. Typical crystal i-f filters have from one to as many as eight poles. Mechanical filters contain resonator discs, which are the selective elements for that kind of filter.

Why is the shape factor important? Well, consider the example in Fig. 3, which has a better response for cw reception than does the example in Fig. 1. The sides of the curve are much steeper for the 8-pole filter of Fig. 3. Imagine that you are listening to a cw signal that is tuned in at center frequency (f_c). A strong signal is present 750 Hz lower in frequency (8999.25 kHz on the curve). That signal will be 45 dB weaker than if it were tuned to f_c on the curve, by virtue of the *attenuation characteristics* of the filter. Now, imagine the same signal combination while using the filter represented in Fig. 1. The unwanted signal would be only 23 dB down on the curve. Hence, the wider the skirt of a filter, the more pronounced the QRM from the interfering signal. An ideal filter would have perfectly straight sides (rectangular response), but this is not attainable with the present state of the art.

We can have good results when using 500-Hz bandwidth cw filters, but some operators like even more i-f selectivity. They install 250-Hz filters in their receivers to help improve the copy when QRM is heavy. The ssb filters that come with most transceivers and receivers have 6-dB bandwidths from 2.0 up to 2.4 kHz. Therefore, no matter how steep the sides of the response curve for an ssb filter, the relatively flat part at the top of Fig. 1 will accommodate all of the signals between f_c and either limit on the nose of the curve with no more than 6 dB of attenuation. The wider filters are mandatory for ssb reception in order to provide ample fidelity of the reproduced human voice. If we

¹Notes appear on page 42.

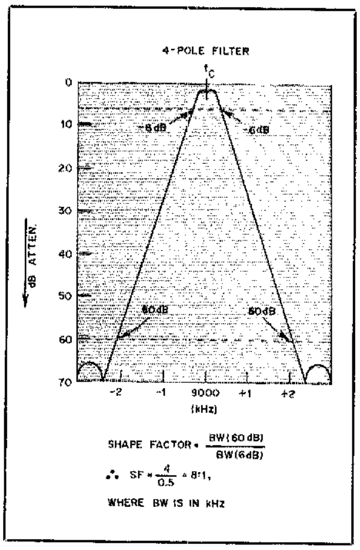


Fig. 1 — Representation of a filter response in terms of bandwidth and selectivity. The filter shape factor is determined by the relationship between the nose and skirt characteristics in decibels, as measured at the −6 and −60 dB points on the curve (see text).

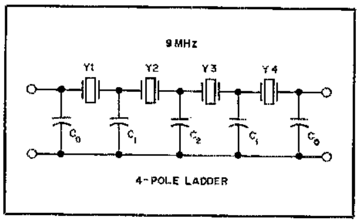


Fig. 2 — Circuit of a 4-pole ladder filter that uses crystals as the selective elements. The capacitors are chosen in accordance with the operating frequency and terminating resistance of the filter. (See J. Hardcastle, G3JIB, "Some Experiments with High-Frequency Ladder Crystal Filters," *QST*, Dec. 1978.)

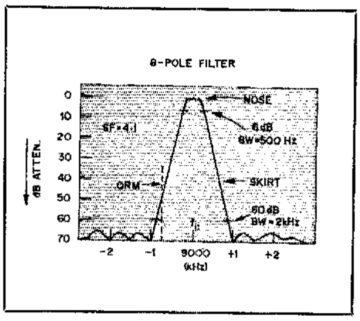


Fig. 3 — A response curve that might be obtained when testing an 8-pole crystal filter for cw reception. Compare the skirt selectivity of this filter with that shown in Fig. 1 for a 4-pole filter.

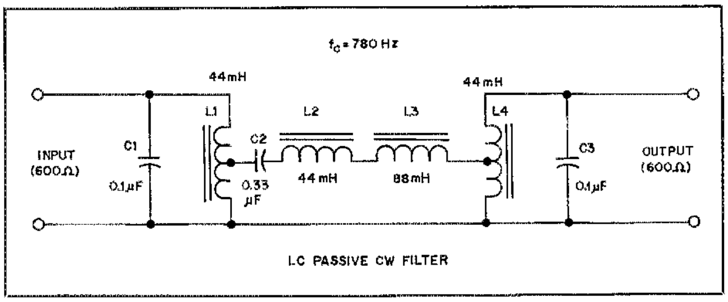


Fig. 4 — Circuit of a passive LC filter for cw reception. Surplus telephone toroids are used for the inductors (see *QST* Ham Ads for suppliers of these toroids).

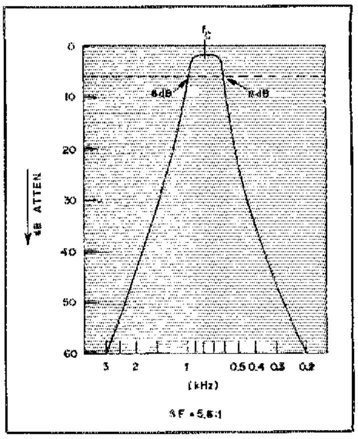


Fig. 5 — Typical response curve for the filter of Fig. 4.

were to tune in an ssb signal with a narrow cw filter, the audio would be restricted to such a narrow band of frequencies that we would be unable to understand what the operator was saying.

What About Audio Filters?

There seems to be a glut of R-C (resistance-capacitance) active audio filters on the market today. Some have fixed values of Q (selectivity) and frequency, while others contain provisions for varying the Q and the peak frequency. Still others enable us to notch out interfering cw signals that are near in frequency to the one of interest. Some R-C filters are switchable to facilitate band-pass, low-pass and high-pass responses, which makes them more flexible for multimode operation (cw, ssb, a-m and RTTY). But, let's concern ourselves here with R-C active filters that exhibit a band-pass response similar to those shown in Figs. 1 and 3. The principal difference between the i-f filters and audio filters is the operating frequency. There are some distinct advantages in using i-f filtering over audio filtering, but audio filters offer some plus factors, too.

Audio filters are inexpensive to build and to get operating. We need only a small handful of parts to build a practical filter: A couple of op amps, a few 5% resistors and some polystyrene capacitors will do the job. An audio filter can simply be plugged into the headphone jack of the receiver, and it's ready to use. Furthermore, the audio filter will greatly reduce the wide-band noise that is generated in the receiver i-f and audio circuits. This improves the *overall* signal-to-noise ratio of our receiver.

Many of the commercially made R-C active audio filters contain amplifiers that enable us to connect loudspeakers to the filter output, while others have only enough audio-output power to operate headphones. Most of the fancier commercial units cost more than a narrow-bandwidth i-f filter does, but they have the advantage of being usable with any receiver. Also, these filters provide variable selectivity, variable frequency and two or three response modes. So, the investment can be a worthwhile, lifetime one.

As we add poles (filter sections) to an audio filter, we improve the shape factor, as is true of all types of filters. Generally, two to four poles of audio filtering are used by amateurs to obtain good cw selectivity, although many more poles can be used by skilled designers. One amateur reported building a super cw filter that contained 100 op amps! Such a design is anything but casual!

Actually, there are two popular types of audio filters in use by amateurs. The remaining kind is called a *passive* filter. It contains high-Q inductors (coils — toroids or pot cores) and high-Q capacitors. An example of this style of filter is given in Fig. 4. Surplus telephone toroid coils are used for the inductances (L1-L4). Standard-value Mylar capacitors can be used at C1, C2 and C3. The filter needs a 600-Ω termination to provide the proper response, which is shown by the curve in Fig. 5. This filter was designed by D. C. Rife, WA2PGA, and was described in *QST* (Technical Correspondence) for May 1972. It requires an 8- to 600-ohm audio transformer between the receiver speaker jack and the filter input. Headphones of the 600-ohm variety can be connected to the filter output, or a second matching transformer may be obtained for stepping down from 600 ohms to a pair of 8-ohm hi-fi phones.

The term "passive" means that no operating voltage is required to make the circuit function. On the other hand, "active" devices require an operating voltage. Generally speaking, if we use a passive audio filter we will lose some signal through it (insertion loss, expressed in decibels), but the active audio filter will yield unity gain, or an actual gain in decibels. Unity gain means that we will have no loss or no gain. How much loss (passive) and the amount of gain (active) will depend on the particular design of the filter and how well it is terminated in terms of the characteristic impedance of the filter (600 ohms for the circuit of Fig. 4, for example).

Either style of filter will "launder" the audio heard in the phones or speaker. This is especially useful to us if we have unwanted hum on the audio-output line from the receiver. The usual 60- or 120-Hz hum will be greatly attenuated by a well-designed band-pass type of cw filter.

A Practical R-C Active Filter

We can build a fixed-frequency R-C active cw filter at low cost by duplicating the circuit in Fig. 6. Three inexpensive 741 op amps are used in the three-pole filter. A center frequency of 750 Hz has been chosen as a compromise value for most commercial receivers. The filter is used between the phone/speaker jack of the receiver and a pair of headphones.

Best performance will result when the polystyrene or Mylar capacitors are matched in value. If a capacitance meter is available, select six 0.001-μF capacitors that are close in value to (above or below) the marked value. If the set is not exactly on the mark at 0.001 μF, that will be okay. The capacitors should be within 5% of the value in Fig. 6 if a matched set can't be obtained. Performance will still be good over a ±5% spread. Resistors R1 to R9, inclusive, should be 5% types. The more closely matched the capacitors and resistors are to the prescribed values, the narrower the nose of the response curve.

Construction and Operation

We can build this filter with point-to-point wiring on a piece of perf board, or we can use a pc board (Fig. 7).[2] Some may wish to assemble the circuit on a universal IC breadboard, such as those that are sold at Radio Shack stores. The

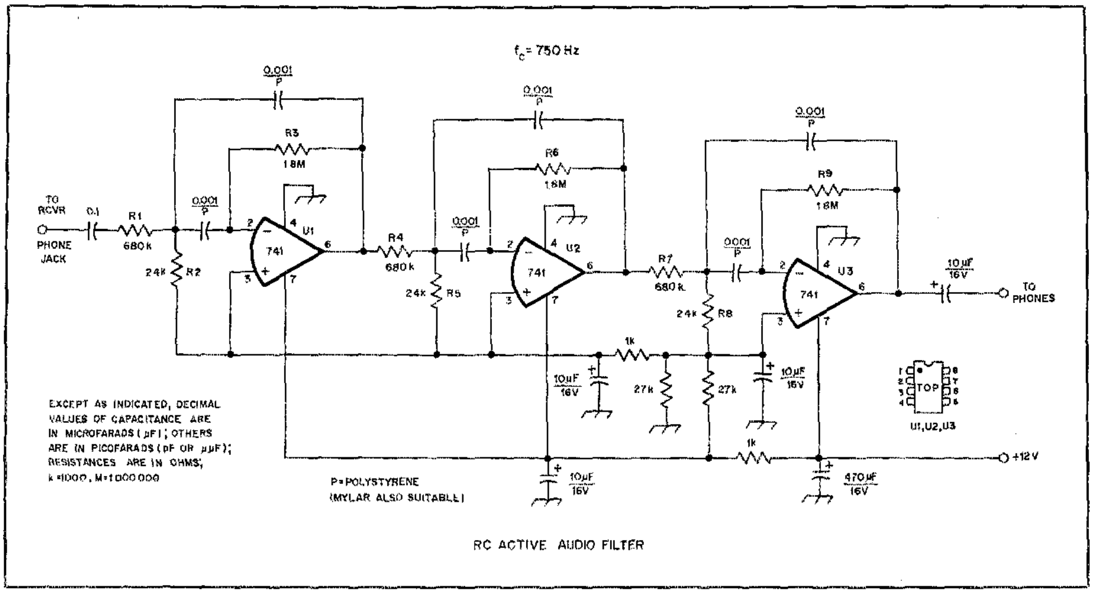


Fig. 6 — Schematic diagram for a practical 3-section R-C active audio filter that uses type 741 op amps as the active elements. See the text for details concerning the choice of capacitors and resistors in the frequency-determining part of the circuit. Resistors are 1/4- or 1/2-watt composition types. Polarized capacitors are tantalum or electrolytic.

important consideration is to lay out the ICs and their associated components in a straight line. This will help to ensure input/output isolation to reduce leakage around the filter. It will also enhance stability. All component leads should be kept as short as possible.

Although a 12-volt dc supply is specified, the filter will operate satisfactorily from a 9-volt transistor-radio battery. If you have a tube type of receiver, chances are that you can obtain sufficient operating voltage for the filter from the cathode of the audio-output tube. Generally, between 6 and 8 volts of clean dc is developed across the cathode resistor of the output tube.

When using the filter, control the headphone audio level at the receiver in the normal manner. Too high an audio level will result in distortion, so be conservative for best results.

Tune in the desired cw signal for peak response (maximum loudness) as heard in the headphones. The response at peak frequency (750 Hz) will be fairly sharp, so tune slowly. It is a good practice to rock the tuning dial back and forth over the signal slowly, observing the point of maximum loudness. After a little experience with the filter it will become a simple matter to tune in a cw signal properly on the first pass across it.

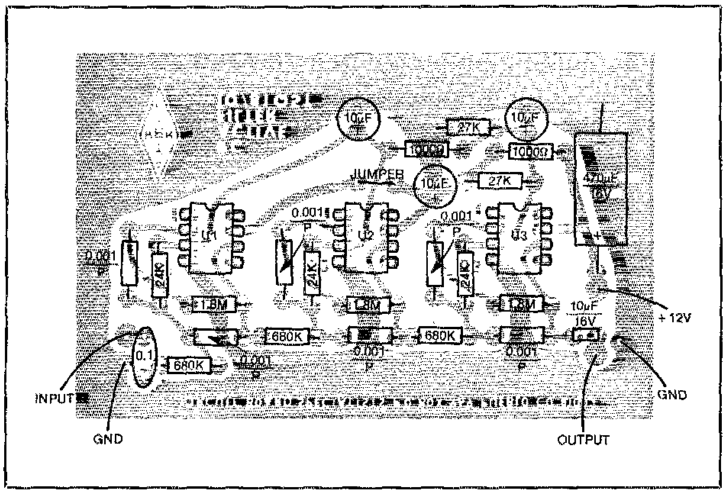
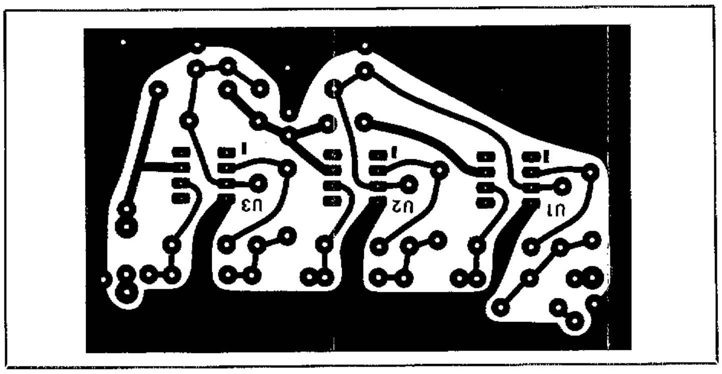


Fig. 7 — Parts-placement guide for the R-C active audio filter. View is from the component side of the board.

Summary

The choice between i-f and audio filtering is ours to make. How we approach the QRM problem on cw will depend on the amount of money we are willing to spend for selectivity, whether or not a narrow cw filter is available as an accessory for the rig we're using, and what our operating objectives are. If an audio type of filter is desired, we have the choice of buying one of the many commercial versions that appear in *QST* ads, or we can build the filter of Fig. 6. We may want to go further and employ a cw-bandwidth i-f filter plus an R-C active audio filter. This has been a highly desirable operating technique at W1FB for a number of years because it not only provides a high degree of QRM rejection, but also launders the audio out-



Scale pattern of the audio-filter board, as viewed from the foil side.

put of the receiver by reducing wide-band noise and hum. Both filters are on line at all times, even when loud signals are being copied.

If you haven't been using selective cw filters, perhaps it's time you did. The signal-laden 80- and 40-meter Novice bands will become fresh vistas if you can reduce the rotten QRM that spoils reception on those bands during night-time operation.

Notes

[1] W. Hayward, W7ZOI, and D. DeMaw, W1FB, *Solid State Design for the Radio Amateur*, (Newington: American Radio Relay League, Inc.). Also, see the receiving chapter of *The Radio Amateur's Handbook*.

[2] Circuit boards, negatives and parts kits are available from Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002.

Strays

DEBUNKING THE MYTH ABOUT SATELLITE WAC

□ Heavily populated areas of the continent have been resigned to the impossibility of working all continents with satellites because East Coast hams have no satellite communications paths to Oceania and Asia, and West Coast amateurs have none to Africa and Europe. Careful calculations will show, however, that portions of the Midwest can indeed program and expect to work all continents via OSCARs 7 and 8.

The area of mid-America where amateurs can work all continents is shown on the map, which has an odd bullet shape that is the result of parameters indicating coincidence of AOS (acquisition of signal) and LOS (loss of signal) at the very extremes of the desired ranges. Calculations were based on norms and should be considered theoretical. Experience has shown, however, that AOS occasionally is earlier than what is calculated, and LOS occurs more often later than what is calculated. This affords a greater "window" in that given direction. Another variable to consider is the local topography, which can also add or subtract time from the "window."

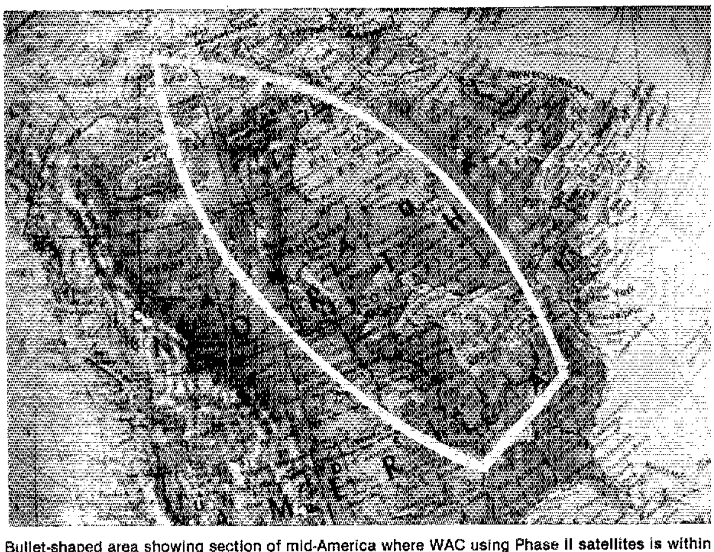
The western edge of the bullet-shaped area is dictated by the maximum range possible from a known satellite user in Africa, and begins at the junction of the states of Missouri, Arkansas and Tennessee. It then travels generally to the northwest just to the east of Kansas City, through Omaha, Council Bluffs, Sioux Falls and the International Peace Gardens on the North Dakota and Manitoba border. It then travels diagonally across Saskatchewan.

The southern edge of this area responds to the maximum range from a known Asian satellite user located at Cape Chelyuskin (104° east longitude and 78° north latitude). It begins again at the junction of Missouri, Arkansas and Tennessee, moving eastward past just north of Nashville to Cumberland Gap National Forest.

The eastern edge of this area is the maximum range possible from Hawaii, the only Oceania area that can be considered at this time; it is again taken from a known Hawaiian satellite user. Starting at Cumberland Gap National Forest and traveling generally northward, the line goes just to the west of Charleston and Wheeling (West Virginia), Buffalo, and to the east of North Bay (Ontario).

The most northerly point is the apex of the eastern and western borders that meet at 75° north latitude. This is just west of the magnetic North Pole at 118° west longitude, north of Victoria Island.

Satellite communicators operating from within these "possibility" boundaries are in an excellent position to earn WAC, with endorsement, via Phase II satellites. The only additional ingredients necessary are for the operator to have a sharp pencil and to pay attention to details, especially time and timing. But with careful work and diligent application of the knowledge available to us, be assured that "it can be done." — *Nick J. Laub, WØCA, Sarasota, Florida*



Bullet-shaped area showing section of mid-America where WAC using Phase II satellites is within the definite range of possibilities. *(photo courtesy WØCA)*

Conducted By Stuart Leland,* W1JEC

TS-830S FINAL-AMPLIFIER CURRENT MONITORING

□ The reason for monitoring individual tube currents of paralleled tube final amplifiers is to ensure that one tube is not loafing and the other doing all the work. Parallel-tube final amplifiers should have near equal (within 10%) currents flowing through them at all times. All the transceivers I've owned have not provided a means of ensuring this was happening. The manufacturer simply specified that the tubes should be balanced and connected in parallel, and provided a means for monitoring the *total* cathode current drawn by both tubes. The TS-830S is no exception. After many months of hard use, I noticed the power output of the rig had decreased, and cathode current readings (I_p on the meter) led me to believe one of the tubes was "goofing off." Investigation proved this to be true and prompted me to alter the cathode current monitoring circuit.

Remove the top and bottom covers of the transceiver, the final-amplifier cage cover and the two final-amplifier tubes. Turn the rig upside down. Remove the blue wire to the pin labeled DRV (driver input), and also remove the seven screws securing the final-amplifier pc board to the stand-offs. Invert the board; locate R4, R5, R6 and J2. Using a low-wattage iron (25 W) and wicking material, remove those components.

On the foil side of the board, solder R4 and R5 between V2 pin 2 foil and the ground foil. (One resistor lead may be placed into the hole previously occupied by J2.) Solder a length of wire to V2 pin 4 and another wire to the V1 pin 1 foil at the hole vacated by R6. Solder the short end of R6 to the IPM ("plate" current meter) foil. Replace the final-amplifier pc board, securing it with six screws; do not replace the screw near the J1/L2/R8 foil yet. Resolder the blue wire to the DRV pin. Mount a small, four-lug (three-isolated, one ground) terminal strip to the pc board at the mounting hole near the J1/L2/R8 foil; use a lockwasher beneath the screw head.

Wire the circuit as shown in Fig. 1. S1 is a miniature spdt toggle switch (Radio Shack 275-613) mounted in one of the pre-punched 1/4-in. (mm = in. × 25.4) holes on the rear panel. Route the wires from the terminal strip across the rear of the chassis and up through the clearance hole behind the PLL unit board. Use of two or three tie wraps will make the installation of the wires neat in appearance. Before replacing the covers, make certain you know which position of the switch is used for which tube, and label the switch. You'll now be able to spot easily any imbalance between the tubes and to take corrective measures early. — *Paul K. Pagel, N1FB, ARRL Hq.*

*Assistant Technical Editor

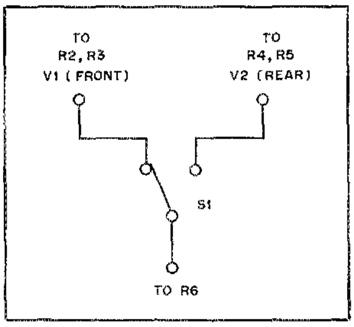


Fig. 1 — Current in each final-amplifier tube of the Kenwood TS-830S can be monitored by installing the switching arrangement shown here. Paul K. Pagel, N1FB, *QST* New Products editor, suggested this modification. It permits the operator to observe any tube imbalance.

ELECTRONIC AIDS FOR BLIND TECHNICIANS

□ Two electronic circuits are presented for use by blind technicians. One (Fig. 2A) is a type of voltage-controlled oscillator (VCO) that converts a slowly varying signal voltage to a proportional frequency change. This proportional frequency change is then amplified and fed to a miniature loudspeaker. For example, a 0- to 5-volt signal variation is converted to a proportional frequency change from 200 to 2000 Hz. The other electronic circuit (Fig. 2B) converts a slowly varying signal voltage to a proportional amplitude change of a single-frequency tone. This single-frequency tone is then amplified and fed to the loudspeaker. Call this a voltage-controlled amplitude circuit (VCA).

Both of these circuits are suitable for various instruments that drive X-Y or strip-chart recorders. The amplitude changes of the recorders are thus converted to an audible frequency change if the VCO is used, or to an audible amplitude change if the VCA is employed. Both of these devices were tested with an NMR Spectrometer, an instrument for determining structure in liquids and soluble chemical compounds.

The heart of the VCO is the 566 function generator, which is itself a VCO. It gives, however, an output frequency at pin 3 that is inversely proportional to its input voltage from pin 5 to ground. In order to make the output frequency of the 566 directly proportional to the input signal voltage, the 741 immediately preceding the 566 is connected as a summing amplifier. It has two imputs, namely the output from the first 741 (the buffered version of the input signal V_{in}) and −5 volts. Thus, as V_{in} varies from 0 to +5 volts, the voltage into the 566 at pin 5 varies from +4 volts to 0. Hence, the frequency of the output voltage at pin 3 of the 566 varies from 200 to 2000 Hz. The 7400 gate can be used to drive the speaker because its input voltage from the 566 varies between +5 volts and ground.

The +5-volt and the −5-volt supplies must be regulated so that the frequency of the signal does not waiver for a fixed value of input signal voltage. A 7805 and an LM320T provide the needed voltage regulation.

In the VCA circuit, the 555 timer is con-

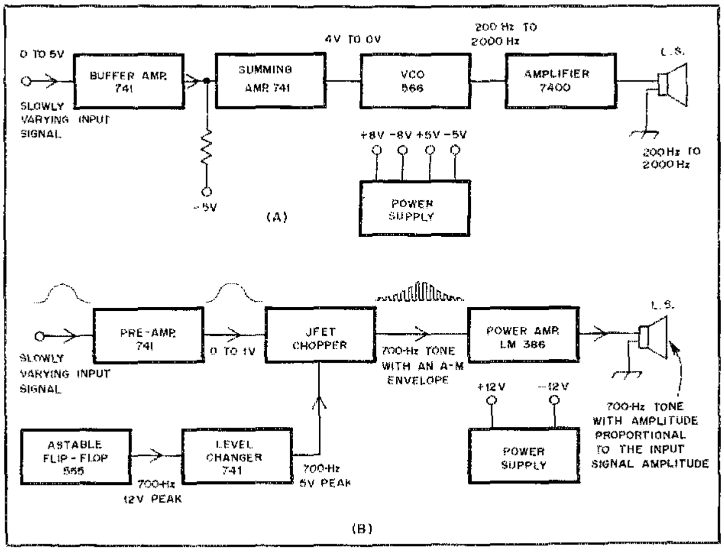


Fig. 2 — Dr. William S. Wagner, AA4WW, of the Physical Science Department at Northern Kentucky University, designed two electronic aids for blind technicians. These are shown in block diagram form. The complete diagrams are available from the ARRL for $1. Enclose an s.a.s.e.

nected in the astable mode, allowing it to run free as a multivibrator. With the particular component values shown, it produces a 700-Hz, square-wave voltage with a peak value of 12 volts. The 741 operational amplifier immediately following the 555 changes the output level of the 555 circuit to a 0- to −5-volt, 700-Hz square wave. This square wave is applied to the gate of the JFET in order to turn it on and off. The JFET thus acts as a chopper to allow the chopped version of V_{in} to reach the 386 power amplifier. The signal into the channel of the JFET must be in the range of 0 to 1 volt. The 5-kΩ potentiometer and the plug-in feedback resistor in the input circuit to the 741 allow for this condition to be satisfied. Both power supplies are regulated. The 7812 must have a heat sink because it supplies power to the 386 power amplifier. — *Dr. William S. Wagner, AA4WW, Physical Science Dept., Northern Kentucky University, Highland Heights, Kentucky*

MINIATURE KEYING CIRCUIT FITS INSIDE PHONE JACK

☐ How simple a keying circuit can be is illustrated by Fig. 3. Moreover, it can be mounted in a 1/4-in. in-line phone jack. The parts consist of two 0.01-µF capacitors, a transistor and one resistor. These are mounted on the terminal end of a 1/4-in. in-line phone receptacle. With the receptacle cover in place, the components are protected. The arrangement shown in the drawing was for use with an ICOM 551, but may be applied to other transmitting equipment.

Construction consists of cutting an audio cable equipped with a miniature plug (Radio Shack no. 42-2434 or equiv.) to a desired length. Connect a 1/4-in. in-line receptacle to the cable end that is opposite the miniature plug. Remember to slide the Bakelite cover of the receptacle back toward the miniature plug before connecting the cable to the receptacle. Mount the 2N3904, capacitors and resistors on the in-line receptacle terminals using the diagram for guidance. Screw the cover in place, and the circuit is ready to operate. The necessary operating voltage is generally available at the key jack of the transmitter and at the output of an electronic keyer. — *Jay Rusgrove, W1VD, QST Technical Consultant*

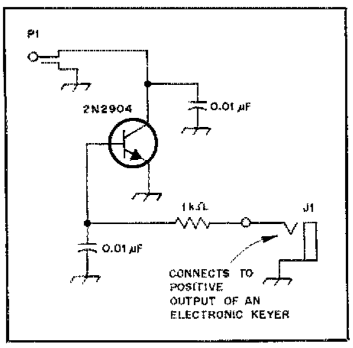


Fig. 3 — If you want an ultra-simple keying circuit that will fit inside an in-line phone-plug receptacle, here it is. You may just want to try this idea for the fun of it. Jay Rusgrove, W1VD, explains in the text how it is made.

USING A CUSHCRAFT BALUN WITH A MOSLEY TRIBANDER

☐ When I moved to a new location, I decided to rework my Mosley triband antenna, which had been in use for 12 years. The balun I had been using needed to be replaced. In seeking a replacement I found that many baluns are for use with wire antenna systems, but are not easily adapted to beam use. My search ended while helping a friend install a Cushcraft ATB-34 triband beam antenna. I found that the Cushcraft antenna is furnished with a balun that is suited to my needs. This unit is designed for the 10-, 15- and 20-meter bands rather than 80 through 10 meters. Although the mounting hardware that comes with the unit is for a tubular-boom installation, I adapted it easily to the driven element of my Mosley beam antenna. Fig. 4 shows how the installation was accomplished. — *Don Klesick, WA2VVW, Savannah, Georgia*

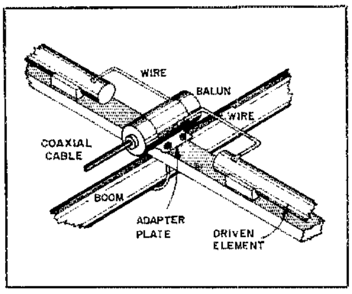


Fig. 4 — Don Klesick, WA2VVW, installed a Cushcraft balun on his Mosley triband antenna using the arrangement shown here. The adapter plate of the balun is modified to fit the bolts on the Mosley antenna.

HEAT CONTROL FOR SOLDERING IRON

☐ Precise heat control of a soldering iron can be obtained economically by use of a standard dimmer switch. Controllable heat permits safer work on delicate components. With plug-in irons, the controlled heat prevents burning of the tip coating (essential to good soldering). Better heat control with less triggering is obtained for gun types of irons. Satisfactory soldering on light work can be done between 70 and 90 volts, depending on type and size of iron.

The dimmer switch shown in Fig. 5 is a typical SCR, 600-watt unit used in lighting circuits. It is designed for use only on incandescent lighting, but works safely on any resistive load within its wattage rating. I have used the dimmer successfully on a 1/4-in. drill motor, taking care to lock the motor switch closed and to always start and stop the drill at the zero position of the knob.

I've placed the dimmer switch and a ground-type, split-circuit, duplex-plug receptacle on the cover plate of a 4-in. outlet box. The receptacle is split by removing the thin bar connecting the upper and lower terminals on the "hot" side of the receptacle. A connection for the source is made to the upper plug (observing hot and neutral polarities). The dimmer switch is wired between the hot side of the source and the hot terminal of the lower plug. Safe wiring practice calls for grounding the box and receptacle through a power cord or cable with a built-in grounding conductor (or grounding a separate wire to a good ground).

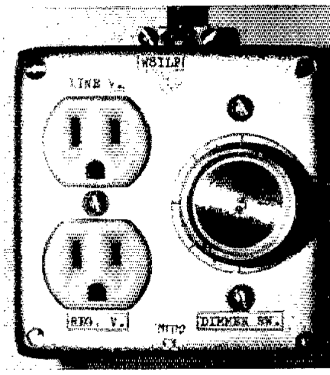


Fig. 5 — A 600-watt light-dimmer switch is mounted in the outlet box shown in this photograph. It offers a convenient means for controlling the voltage to a soldering iron. The author, Gerhard Lampinen, W8ILP, has also used the dimmer to control a 1/4-in. electric drill.

The dimmer switch has an internal ON/OFF switch that is operated by pushing the knob. Rotating the knob varies the voltage. The segmented dial plate shown was installed to facilitate positioning the knob, which bears a mark on its edge. The maximum dimmer voltage under load is always several volts lower than the line voltage. — *Gerhard Lampinen, W8ILP, Rochester, Michigan*

COUNTERACTING SALT-WATER CORROSION ON AN ANTENNA

☐ My doublet antenna for 80 through 10 meters is located only 100 ft (m = ft × 0.3048) from the ocean. As a result it gradually became "victimized" by corrosion. After the antenna had been in use for four years, I replaced the cadmium-plated hardware with stainless-steel equivalents, using silicone grease on the nut and bolt threads. I was not familiar, however, with the galvanic action that takes place between aluminum clamps and copper wire, especially when exposed to salt air. Corrosion on aluminum causes the surface to become very resistive. This deterioration built up over the next three years to the point where at times the SWR reached as high as 4:1. With help and advice from a friend (WB4KGY) the antenna was dropped, and the fault discovered. The corroded aluminum parts were cleaned, burnished and reassembled with the help of NOALOX, a conductive anticorrosive compound for protecting aluminum-to-aluminum or aluminum-to-copper fittings and wire connections. I suggest that when installing an antenna having aluminum and copper connections, an application of NOALOX be made to the connecting points. The stainless-steel hardware, mentioned here, has served the purpose well. — *Otto Freytag, K4QFM, Riviera Beach, Florida*

[Editor's Note: NOALOX is made by Ideal. Penetrox, another anticorrosive product, is manufactured by Burndy. They are available at many electrical supply stores. Both are distributed by General Electric Supply Co.]

OPTIMIZING FILTER USE IN THE TEN-TEC OMNI-B

☐ The Omni-B uses the first stage of its eight-pole cw active audio filter as a selectable filter for ssb reception. This stage has a center frequency of 750 Hz and a 3-dB bandwidth of 450 Hz. One would expect such a filter to distort the voice signals somewhat, but at the same time to reduce QRM from adjacent stations. I find that it is more effective at the former than the latter.

There is very little information-bearing sound power within a band of frequencies centered at 750 Hz in the human voice.[1] The Omni voice filter is, therefore, peaked at the wrong frequency, with the result that, in addition to distorting the desired signal, it also attenuated the signal relative to some types of interference.

These effects can be minimized simply by tuning the Omni notch filter to 750 Hz. Natural-sounding voice, with clarity and crispness, can be had by carefully tuning the notch across the voice filter passband until the desired signal sounds best. In addition to shaping the filter response for a more voice-like characteristic, the filter is made more effective by the addition of this new stopband.

This technique should be applicable to the Ten-Tec Delta and possibly to other rigs that have notch filters as well as outboard audio filters. — *Gary Myers, K9CZB, Naperville, Illinois*

[1] R. W. Harris and J. F. Cleveland, "A Baseband Communication System," *QST*, Nov. 1978, pp. 11-18.

TS-520S SWITCHABLE BROAD/NARROW CW FILTERS

☐ The addition of a switch to allow selection of the cw or ssb filter during cw operation will make a significant improvement in the operating convenience of the TS-520S. This change is simple and so unobtrusive that it looks like original equipment. The switch operates only in the cw mode and has no effect on USB or LSB mode switch positions.

Obtain a miniature spdt toggle switch, such as Radio Shack 275-662 or equivalent. After making careful note of the position of all knobs and the tuning dial, take them off by loosening the respective set screws. Remove the hex nut holding the transparent meter and dial window, and then take out the window. Both the top and bottom of the cabinet are to be removed next. Check behind the panel just above the phone jack and to the left of the microphone socket. There will be an empty area with a few wires crisscrossing. Move them out of the way. Now, stuff a small rag in the area to catch drill chips. Through the front panels, very carefully drill a 1/8-in. pilot hole, centered 7/8 in. above and 1/8 in. to the right of the center line of the phone plug. Before drilling, check your rig and visualize how the switch will be positioned. Once drilled, the hole is *forever!*

Next, remove the top and bottom edge flathead screws holding the front panel. Also remove the front decorative panel. Enlarge the 1/8-in. hole in the main chassis to accept the switch shank. Deburr the edges. A good idea is to poke something hard behind the panel when you drill so that the drill does not blast through and damage something. Continue by carefully enlarging the hole in the front decorative panel. I used a 1/4-in. drill. It provided sufficient clearance for my miniature switch. Drill carefully, as the panel is die cast and brittle. I darkened the inside rim of the hole with black ink so that it would not shine.

Solder three lengths of small-diameter insulated wire to the switch terminals, and twist them together. Install the switch on the panel, and snake the wires up through the openings and across the filter area. Unsolder the brown filter wire (see page 35 of the TS-520S owner's manual), and connect it to the lead to the common switch terminal. Tape the junction. Then solder one of the two remaining switch leads to the soldering post beside the cw filter marked CW and the other lead to the ssb post between the two filters. I wired mine so that with the switch "up," the brown lead is connected to the cw filter.

Make sure all of the metal chips are removed. Then, replace (in order) the outside panel, plastic meter/dial window and nut, knobs, dial and the cabinet top and bottom. Check to make sure the screws are tight and the dials are positioned correctly. Be careful while you work, keeping track of each operation. You will find that this is an easy change to incorporate and that the switchable filters are a real convenience.

I have not had the opportunity to check the TS-820, but as the mechanical arrangement and circuit diagram are much the same as for the TS-520S, the filter-switch addition may be applicable. You might remove the bottom cover of your TS-820 and see if there is sufficient room. — *R. M. Stevens, W1SUZ, Winsted, Connecticut*

IMPROVING HIGH-PASS FILTER CONNECTION ON TV SET

☐ The reception on channel 17 was degraded noticeably after I installed a Drake TV-300 HP filter on a neighbor's TV set. Connecting the filter after the vhf-uhf splitter (Fig. 6) cured the problem. In this case, the uhf tuner had very good rejection of signals below 54 MHz and did not require further filtering.

The signals from my 6-meter transmitter apparently were entering the TV set through the vhf tuner and were reaching the i-f amplifier. Shielding in the TV receiver did not seem adequate.

If you install a high-pass filter to reduce TVI, and your transmitter is known to be clean but you cannot eliminate the interference, check the splitter, if there is one. I found that one of these splitters had an open inductor that resulted in the TV-300 filter failing to provide the expected 40-dB rejection. The etched inductor had been trimmed too closely, chopping off a turn. Ohmmeter readings for the splitter are shown in Fig. 6. — *Bruce Randall, WD4JQV, Alpharetta, Georgia*

THOUGHTS ON CALIBRATING AN ELECTRONIC KEYER WITH A POCKET CALCULATOR

☐ Jim Pitts, KE4Y, explained in Hints and Kinks, *QST*, May 1980, how to use a pocket calculator to calibrate an electronic keyer. His idea is really neat, especially for being so simple. Instead of punching 1 + 1 before starting the keyer, I suggest that you punch 0 + 1. Then the first pulse from the keyer will produce "1" on the calculator rather than "2." Following this, the code speed can be read directly from the number of dashes counted in a five-second interval. This involves a small approximation (yielding about a half wpm error at 13 wpm) but this approach is much quicker to use.

On my calculator, I disconnected the external dc power jack and rewired it in parallel with the " = " key contacts. This counter input can handle pulse rates of up to 900 per minute. — *Tim Wulling, WB0JZX, Roseville, Minnesota*

☐ A simpler way of calibrating an electronic keyer by means of a pocket calculator than that suggested by Jim Pitts, KE4Y, is to punch 0.04 + 0.04 instead of punching 1 + 1. After 60 seconds, the speed rate can be read directly from the display. Alternatively, you may punch 0.08 + 0.08 and reduce the operating time of the keyer to exactly 30 seconds. The results will be more or less the same. — *Jesús A Géliga-Torres, KP4DIN, Aquadilla, Puerto Rico*

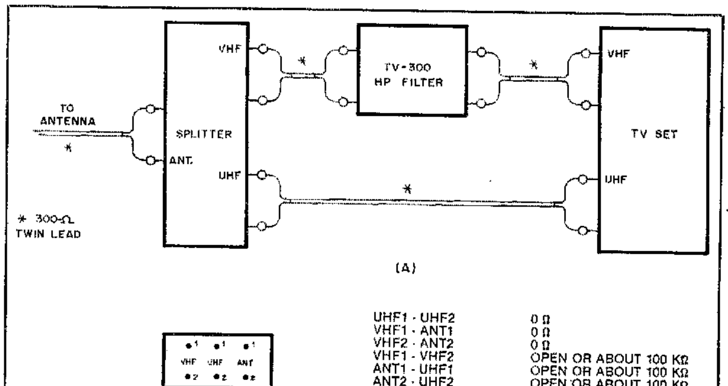


Fig. 6 — When signals from WD4JQV's 6-meter transmitter disrupted a neighbor's channel-17 reception, a high-pass filter placed between the antenna splitter and the TV set cured the problem. The filter was not effective when placed in the line to the antenna. Ohmmeter readings at the terminals of the splitter are shown.

Product Review

Conducted By Paul K. Pagel,* N1FB

Yaesu FT-480R 2-Meter Multimode Transceiver

This is one of a new breed of multimode 2-meter transceivers from Japan. It covers the entire 144-MHz amateur band (and then some) and operates on fm, upper and lower sideband, and cw. A versatile radio, the '480R is equally convenient to use in your automobile or at your home station.

Frequency Control

The FT-480R operating frequency is determined by a microprocessor-controlled PLL circuit composed of three PLL oscillators, each consisting of a reference crystal oscillator, a programmable divider, a prescaler and a phase comparator. The circuit develops local signal voltages for the receiver and transmitter stages using a synthesis scheme that produces 10-Hz steps. A 4-bit CPU controls the PLL circuitry. This CPU halts transmission and prevents spurious radiation if any VCO is unlocked. A seven-digit fluorescent-blue readout displays the operating frequency.

Aside from the main tuning knob, 13 of the controls are related to frequency selection. The STEP switch controls the 10-Hz, 100-Hz or 1-kHz increments on ssb and cw, and 1-kHz, 20-kHz or 100-kHz increments on fm. The CLAR switch provides a function similar to RIT. When the CLARifier switch is depressed, the operator can use the main tuning knob to move the receive frequency ± 10 kHz from that indicated by the readout without changing the transmit frequency. The VFO A/B TXA control allows split operation using the two built-in VFOs, receiving on VFO B and transmitting on VFO A. This is especially useful for operating strange splits on fm. Normal +600-kHz or −600-kHz repeater splits and simplex operation are controlled by the RPT switch on the bottom panel of the FT-480R. The F-SET switch on the front panel eliminates the fractional frequencies that might occur if one switches from the low end of the band to the fm portion of the band. For example, if you are operating on 144.213 MHz and wish to QSY to 146.52, you may go up frequency in 100-kHz steps (MODE switch at FM) until you reach 146.513 MHz. Then, press the F-SET switch, and the transceiver operating frequency becomes 146.500 MHz. From there you move in 20-kHz steps to 146.520 MHz.

One of the nicer features is the frequency memory. If you have several favorite repeater frequencies you use often, you can program them into the memory and call them up with the ease of a crystal-controlled radio. The MEMORY control, ganged along with the STEP switch, allows the operator to choose among any four frequencies in memory. To load a frequency, simply set the MEMORY switch to one of the four positions, dial up the desired frequency using the main tuning dial and touch the M (memory) button. When calling up any of the memory channels, touch the MR (memory recall) button, which transfers frequency control from the main dial to the MEMORY switch. To return frequency control to the main dial, simply press the DIL (dial) button. If you want to retain the frequencies stored in memory after turning off the FT-480R, activate the BU (backup) switch on the rear apron, and the memory will continue to operate as long as dc power is connected to the POWER jack.

A scanning feature is built into the '480R. With the MEMORY switch in the MS position, the rig will scan all four memory channels. Push buttons on the microphone allow the operator to activate and stop the scan function. In addition, these push buttons allow the operator to scan up and down the entire 2-meter band in increments selected by the STEP control. With the mode switch in the FM position, you can use the SCAN switch on the bottom panel to have the rig stop scanning on either the first open or first busy channel it comes to. With the SCAN switch in the MAN position and the MEMORY switch in the MS position, you can switch through the memory channels at your discretion using the push buttons on the microphone. If you are operating from the main tuning dial and want to keep tabs on one of the frequencies in memory, the PRI (priority) switch allows you to scan one of the memory channels every five seconds. If the priority channel is in use or clear (your choice using the SCAN switch), the rig will automatically go to the memory channel.

In addition to displaying the operating frequency, one digit of the main readout also indicates which memory channel is in use. In the priority mode, the character P is displayed. An LED display in the upper left-hand corner of the front panel serves as an S meter on receive and as a relative power output indicator on transmit. LEDs indicate when the rig is transmitting and when the clarifier is activated. The BUSY/MOD indicator has a dual function; on receive, it lights when the channel is occupied, and during fm transmissions it indicates modulation.

Other Features

The transmitter section is rated at 30-watts input. A HI/LOW switch on the front panel allows operator selection of high- or low-power output. An indicator near the S meter lights when the rig is in the low-power position. The final transistors are VSWR protected; the higher the reflected power, the lower the output power.

Yaesu also recognizes that not all repeaters are carrier access. The T-CALL switch closes the PTT line and transmits an 1800-Hz tone for accessing repeaters. The CALL button on the microphone performs the same function. The TONE-IN connector on the rear apron provides easy access for the optional FTS-64 tone encoder, which synthesizes 32 PL or tone-burst frequencies. Other rear-apron jacks include antenna (SO-239), 1/8-inch (mm = in. × 25.4) key, external speaker and power connections.

The SAT switch, located on the bottom panel is used for OSCAR work. This switch allows the operator to move the transmit frequency

*Assistant Technical Editor

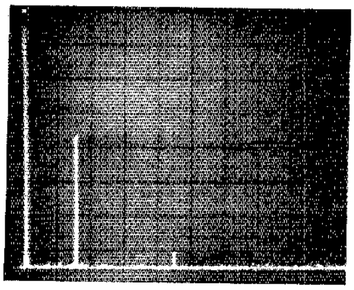


Fig. 1 — Spectral display of the FT-480R. Vertical divisions are each 10 dB; horizontal divisions are each 100 MHz. The fundamental has been reduced in amplitude approximately 36 dB by means of notch cavities; this prevents analyzer overload. Power output is 10 watts at a frequency of 146 MHz. The third harmonic is visible approximately 70 dB below peak fundamental output. Tests were performed in the ARRL lab. The FT-480R complies with current FCC specifications for spectral purity.

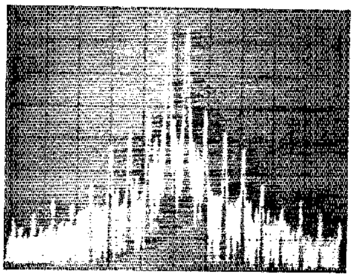


Fig. 2 — Spectral display of the FT-480R output during two-tone IMD test. Third-order products are 32 dB below PEP, and the fifth order products are 37 dB down. Vertical divisions are each 10 dB; horizontal divisions are each 2 kHz. The transceiver was being operated at rated 15-watts PEP output on the 2-meter band.

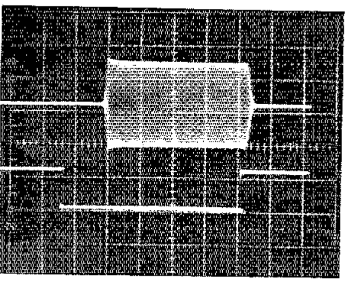


Fig. 3 — Cw keying waveform of the FT-480R. Horizontal divisions are each 5 ms. The upper trace is the output of the transceiver; lower trace is the actual key closure. There is a delay of approximately 6.5 ms between key down and actual output. This waveform will produce key clicks.

(while transmitting) to compensate for Doppler effect. This control should be left in the OFF position during normal operation because neither the VFO A/B TXA nor the CLAR function operates when the SAT switch is activated.

There's also a built-in noise blanker, activated by the front panel NB switch. This noise blanker was reasonably effective against airborne pulse-type noises.

Installation and Operation

Compact size makes the '480R a natural for mobile installation. Yaesu provides a universal mounting bracket that slides into guide rails on the sides of the transceiver, making it easy to take the rig in and out of the car. Power connections can be made at the fuse panel or the battery. Since I couldn't find a convenient access hole to the engine compartment, I used the accessory connection on my fuse panel. A 5/8-wavelength whip antenna completed my installation.

Mobile operation with the unit was a little difficult until I got used to the positions and functions of the controls. A few days of use solved this problem. When driving, I found it especially useful to program a few frequencies into memory and then to use the push buttons on the microphone to select among them. This feature made mobile operation much easier.

For home installation, Yaesu provides a wire mounting stand that supports the front of the transceiver. This stand performs two functions. It provides easier viewing of the front panel, and it allows audio to escape from the speaker located on the bottom panel. The manual recommends use of a 5-A, 13.8-V/dc power source. We measured the current consumption at 3 A in the ARRL lab, and my 4-A supply ran the radio for extended periods with no problem. I used beam antennas for both fm and ssb/cw operation from home.

Fm operation with the transceiver was a dream once I became familiar with the controls. The receiver is sensitive, the audio clean and the squelch smooth. I experienced no interference problems, even in areas with a repeater on every pair. All transmit audio reports I received indicated that the transmitted signal was clean and that my voice sounded natural. My only complaint is the intermediate 20-kHz fm channel steps. Often I found the 1-kHz steps too slow for easy frequency selection, so I switched to the 20-kHz steps and tuned right past my intended target. Yaesu says that the 20-kHz position may be converted to 5-kHz stepping through a simple modification. With a little practice, I found I could dial up even the strangest repeater splits with ease.

Being used to an hf transceiver with outboard transverter for the vhf ssb and cw operation, I was a little skeptical of the FT-480R because of its compact size. A few hours of operation convinced me that the rig is indeed capable of good performance on these modes. The 13 watts of output was enough to enjoy many local ssb contacts as well as a few with stations in the Philadelphia and Washington, DC, areas when band conditions were right. I consistently got good signal reports, with no evidence of splatter or distortion. Semi-break-in and a sidetone are provided for cw operation.

Receiver sensitivity was adequate for all but the weakest-signal contacts. As with most multimode vhf transceivers, a good outboard preamp is a valuable asset. On cw, the absence of a narrow filter sometimes caused problems, especially during times of crowded band conditions. Another annoyance in times of heavy activity was the excessively long agc release time.

I used the '480R during the ARRL VHF Sweepstakes contest with good results. The receiver held up even with several local stations running the full legal power limit. I was able to hear most of the stations that were on, and the transmitter easily drove a homemade amplifier that uses a pair of 4CX250B tubes.

I enjoyed using the FT-480R. The performance exceeded my needs, and I appreciated the convenience of having everything in one compact box. It was nice to be able to listen to 2-meter ssb without having to wire up the transverter. I would recommend this transceiver to anyone looking for a multimode 2-meter rig.

Station accessories available include the FP-80 power supply, FTS-64 tone encoder and AD-1 antenna coupler. Price class: $530. Manufacturer: Yaesu Electronics Corp., 6851 Walthall Way, Paramount, CA 90723. — *Mark Wilson, AA2Z*

Yaesu FT-480R Transceiver Serial No. OHO20232

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: 143.500-148.500 MHz.	As specified.
Modes of operation: Fm, ssb and cw.	As specified.
Readout: Digital, 7-digit, fluorescent-blue digital display.	0.25-inch-high digits.
Resolution: 100 Hz.	As specified.
kHz/turn of knob: Not specified.	Ssb/cw: 0.5, 5, 50. fm: 50, 1000, 5000.
RIT range: ± 10 kHz.	As specified.
S-meter sensitivity (μV/S9): Not specified.	1.7.
Receiver sensitivity: Ssb, cw — 0.5 μV for 20-dB S/N; fm — 0.35 μV for 20-dB quieting.	Ssb, cw — 0.2 μV for 10-dB S+N/N; fm — 0.3 μV for 20-dB quieting. Noise floor (MDS) dBm: −133. Blocking DR (dB): 104. Two-tone, 3rd-order IMD DR (dB): 79.
Audio power output (8-ohm load): 2.0 watts at 10% THD.	1.02 watts at 10% THD.
Current consumption: Receive, dc 0.5 A; transmit, dc 3.0 A.	As specified.
Transmitter rf output: Fm/cw, 10 watts/1 watt; ssb, 10 watts.	Fm/cw, 13 watts/3 watts; ssb, 13 watts.
Spurious emission: At least −60 dB (ssb).	−70 dB.
Carrier suppression: Better than 40 dB.	As specified.
Third-order IMD: Not specified.	32 dB below PEP.
Size (HWD): 2.4 × 7.2 × 9.5 inches.	
Weight: 6.5 lb.	
Color: Two-tone gray.	

KENWOOD TR-7850 2-METER FM TRANSCEIVER

☐ This unit is a big brother to the TR-7800.[1] Front panel layout and operational features are exactly the same on both units, except the TR-7850 has an additional 6 dB of power output.

Operation with the '7850 in different environments proved to be flawless. At my home in Newington, Connecticut, I was able to work through many repeaters, some up to 75 miles away, using the high-power mode and a 1/4-wavelength ground plane up 40 feet and fed with 75 feet of RG-58/U. Coverage during mobile operation was exceptional. This area is very hilly, and holding a repeater for any distance is difficult. With 50 watts available, the range of coverage increased dramatically.

Power consumption in the high-power mode is 8 A. The power cord is heavy gauge and should be connected directly to the battery or fuse box to prevent excess voltage drop.

Observations

Kenwood has done a good job in the human engineering department with this rig. Although the front panel is quite small, people with large hands should have no trouble operating the controls. Perhaps the addition of tactile feedback (such as a "beep" upon key closure) on the keyboard would be useful for mobile operation so the operator would know when the key was hit without looking at the display.

For those who spend many hours on the highways or who live far from a repeater, the high power and versatility of the TR-7850 would be a great asset. The TR-7850 is distributed by Trio-Kenwood, 1111 West Walnut St., Compton, CA 90220, and is available from dealers throughout the U.S. and Canada. Price class: $450. — *Gerry Hull, AK4L*

[1]"Kenwood TR-7800 2-Meter FM Transceiver," Product Review, *QST*, Sept. 1981, p. 46.

Kenwood TR-7850 Serial No. 1110120

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 144.000-147.995 MHz	143.900-148.995 MHz.
Power requirements: 0.4 A receive, 9 A high-power transmit at 13.8 V.	0.4 A receive, 3 A low-power, 8 A high-power transmit.
Power output: Hi, 40 W minimum.	High, 50 W.
Low, 1 to 15 W, depending on frequency.	Low, 144.000—3 W, 145.000—6 W, 146.000—9 W, 147.000—12 W, 148.000—15 W.
Harmonic and spurious outputs: Not specified.	More than 70 dB down (see spectral photo).
Receiver sensitivity: Better than 0.5 μV for 30-dB S/N.	0.21 μV for 20-dB S + N/N.
Squelch threshold: Not specified.	0.15 μV.
S-meter sensitivity: Not specified.	S1 = 1.1 μV, S9 = 6 μV, 20 dB/S9 = 7.4 μV.
Audio output: More than 2 W across 8 Ω at 10% distortion.	1.8 W at 8 Ω.
Frequency display: 4, 1/2-in. red LEDs.	
Size: 6-7/8 × 1-1/2 × 8-5/8 in.	As specified.
Weight: 4.84 lb.	As specified.

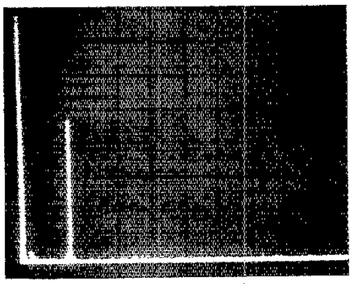
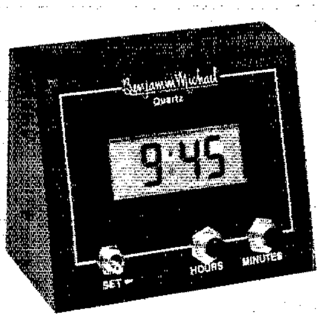


Fig. 4 — Spectral display of the TR-7850. Vertical divisions are each 10 dB; horizontal divisions are each 100 MHz. The fundamental has been reduced in amplitude approximately 33 dB by means of notch cavities; this prevents analyzer overload. Power output is 50 watts at a frequency of 146.94 MHz. Tests were performed in the ARRL lab. The TR-7850 complies with current FCC specifications for spectral purity.

BENJAMIN MICHAEL INDUSTRIES MODEL 173B STATION CLOCK

☐ Digital station clocks, especially those with readout in UTC, are as handy a station accessory as any ham could desire. The BMI 173B is a relative newcomer deserving attention: It is simple, functional and accurate.

The 173B has a black plastic case with a slanting faceplate for viewing ease. An LCD readout with highly visible 1/2-inch-high digits is provided; a flashing colon indicates the seconds with the 24-hour display. If you'd rather have an A.M. and P.M. indication, you can order the 12-hour version.



The clock face is uncluttered — a toggle switch for stopping the count and two momentary-contact push buttons for setting the hours and minutes. WWV synchronization is easy. Turn the SET switch on, and the clock seconds reset to zero and the display stops. Set the HOURS and MINUTES, then snap off the SET switch on the WWV tone. The clock has remained accurate within four seconds per month since I've had it, well within the 30-seconds-per-month maximum error claimed by BMI. One 1.5-V penlight cell powers the clock for about one year, according to the manufacturer. The clock module has outputs for an alarm and various other functions. Wiring details are available from BMI. A pleasing standard feature on the 173B is a backlight for the display actuated as long as the HOURS button is depressed; the backlight feature may be wired separately if a larger battery is used to power the clock.

Several versions of the 173B are available in addition to the 12- and 24-hour models discussed here. A panel-mount unit is designed for those who wish to add a flush-mounted clock to their operating-position console. Dual-display versions may be obtained for simultaneous local and UTC timekeeping. These models range in price from $32.95 for the 12- or 24-hour panel-mount clocks, to $124.95 for the dual-display Presentation Model housed in a walnut enclosure. They're available from Benjamin-Michael Industries, 65 East Palatine Rd., Prospect Heights, IL 60070. — *Sandy Gerli, AC1Y*

KLM 144-148-13 LB ANTENNA

☐ The 13 LB (13 elements, long boom) will perform with low VSWR across the entire 2-meter band. It can be mounted horizontally or vertically and can be stacked in two- and four-bay arrays.

Assembly instructions, assembly pictorial, dimension sheet and parts list are easy to read and the assembly pictorial mechanical drawing detail is excellent, showing the driven element and coax balun feedpoint connections. No problems were encountered during assembly, each step was explained very well. The ready-made RG-144/U 4:1 coaxial balun aided assembly. Making the connections simply involved slipping the balun terminals over the driven element and ground post studs, adding lockwashers and nuts, and tightening them. All electrical hardware is stainless steel.

Operating with this antenna at 40 feet[2] using 80 watts and a low-noise receiving preamplifier was all that was needed to work aurora with contacts from Nova Scotia to West Virginia and Indiana to Michigan from south central Connecticut. A total of 19 states and two Canadian provinces have been worked terrestrially. Five new states were added from west of the Mississippi as far away as South Dakota during an intense sporadic Es opening in July 1980. Distances of 150 to 200 miles are common communication ranges with this antenna and 80-watt power level during non-enhanced conditions. Long-range fm work is possible by rotating the antenna elements to the vertical position. Loosening the boom to mast clamp is all that is required, but for best results in the vertical position the manufacturer suggests using a hardwood, fiberglass or other non-conducting material for the mast.

Hundreds of OSCAR satellite contacts were made using this antenna for transmission and reception. When transmitting on 145 MHz, uplinks at elevation angles of 30° or less, 10 watts was sufficient to operate through the OSCAR 7 and 8 satellites on modes A and J. At elevation angles of over 30° an 80-watt amplifier was needed for good results. Receiving mode B on 145 MHz was good on the

[2]ft × 0.3048 = m, in × 25.4 = mm, mi × 1.609 = km, lb × 0.454 = kg.

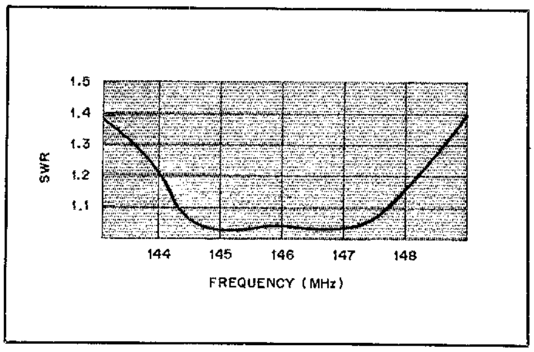


Fig. 5 — SWR curve for the KLM 144-148-13LB.

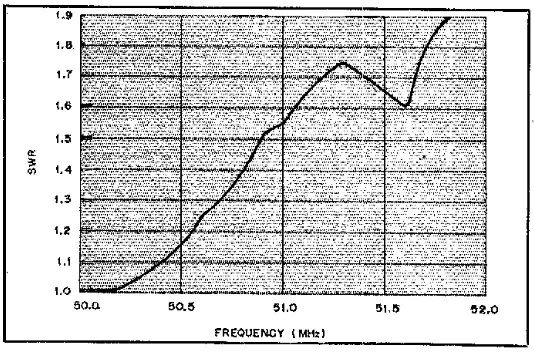


Fig. 6 — SWR curve for the KLM 50-7LD 6-meter Yagi.

KLM 144-148-13 LB Antenna

Manufacturer's Specifications

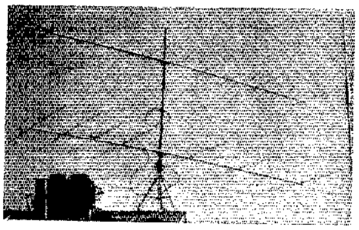
Frequency coverage: 144 to 148 MHz.
Number of elements: 13.
Power rating: 1 kW. (KLM 144-148-100N balun is recommended for powers greater than 1 kW.)
Weight: 9 lb.
Boom length: 21.8 feet.
Boom diameter: 1.5 inches.
Mounting: 4 × 8 inch plate for 2-inch mast to 1.5 inch boom.
Feed line required: 50 ohms unbalanced.
Feedpoint impedance: 200 ohms balanced, 4:1 balun supplied.
Longest element: 40 inches.
Shortest element: 31 inches.
Spacing dimensions: 2 bay, 13 to 15 feet between antennas. 4 bay, 14 to 16 feet between bays.
Manufacturer: KLM Electronics, Inc., 17025 Laurel Rd., Morgan Hill, CA 95037.
Price class: $90.

horizon, but there was too much fading at the higher angles. It is recommended that for maximum communications effectiveness through the OSCAR satellites, azimuth and elevation tracking antennas with switchable polarization be used.

Beamwidth and gain were noted when conducting front-to-side and front-to-back checks. This antenna is very directional and the received signals drop off sharply on a medium-strength distant signal, within about 15° of rotation. Most unwanted stations could be nulled out and this was very helpful during the ARRL VHF Sweepstakes. During the January SS event, 74 QSOs were made in 14 ARRL sections totaling 10 states, in eight and a half hours of operating time.

The most impressive feature of this antenna is the uniform VSWR across the entire 2-meter band. This is realized by the KLM design of dual, split, high-impedance driven elements and a low-loss balun matching system. One driven element is cut for a higher frequency, the other cut for a lower frequency.

With a 21.8 foot boom length and 13 elements, this is a ideal size beam for terrestrial and moonbounce communication. After one year of operating using this "long-boomer" my conclusions are that the KLM 144-148-13 LB will meet all expectations of performance and endurance that the most discriminating amateur could expect. — *Bernie Glassmeyer, W9KDR*



The KLM 144-148-13LB is mounted above the 50-7LD at W9KDR.

KLM 50-7LD 6-METER ANTENNA

☐ Erecting a 50-7LD — seven elements on a 20-foot[1] boom optimized for 50.1 MHz — says you're quite serious about a respectable signal on 6 meters. The LD stands for "light duty" and the manufacturer recommends use only in milder climates where extremely high winds and ice loading are not a problem. The review antenna has survived the Connecticut south-central coast weather for over a year. The only wind-created problem encountered occurred because the wrong element mounting blocks were supplied and a few of the elements broke off. A call to the factory revealed all of the seven blocks had to be changed. The bad blocks were brittle and could be broken by applying pressure at the end of the element. The new blocks could not be broken by hitting them with a sledge hammer while holding the blocks in a vise!

Wind loading is reduced by using a 1-1/2 inch boom and 3/8 inch elements, which keeps the weight at 12 pounds. This makes the antenna ideal for a moonbounce array if four 50-7LDs are stacked on an "H" frame. KLM will provide stacking information, but does not supply "H" frame or power dividers for 50 MHz.

Antenna assembly was delayed because the instruction sheets were missing and the coaxial balun sent was a 1:1 type instead of the 4:1 needed. Like all KLM antenna assembly instructions they are detailed, and with the use of good mechanical drawings the assembly is made easy.

Reviewing this antenna during the peak of solar cycle 21 added to the excitement of 6-meter operation — it's been my favorite band for many years. I've worked a number of new countries and states in the last year using this antenna and 200 watts' input power, with the antenna mounted at a height of 30 feet. A total of 21 countries and 47 states (needing only Montana, Wyoming and Utah for WAS) have been worked since putting up this antenna. Sporadic-E, F2, aurora, ground wave and scatter were all used with good success. One way to improve communication effectiveness is the addition of a bit more power. For this reason an old HT-33B was converted recently to 6 meters. This addition resulted in a 2 to 3 S unit increase in received signal reports.

Probably the most important aspect of using a beam having more than 3 or 4 elements on 6 meters, other than the additional gain, is the ability to null out unwanted signals. This can be used to advantage, especially during periods of high activity. The 50-7LD performed well in this respect, but still exhibited a 15 to 20° beamwidth when peaking a received signal. Some periods of intense sporadic-E or F2 propagation with backscatter disallow any specifications regarding antenna performance and leave one undecided as to which way to turn the antenna, but that's part of the fun of operating 6 meters!

Most often, when the step up from makeshift or small 2- or 3-element antennas is made, one realizes that a new operating dimension exists, taking you from occasional sporadic-E contacts to ground wave, scatter and aurora communications that exist every year regardless of the solar cycle. If you are contemplating operation on 6 meters or want a little more enjoyment, try a long-boom Yagi and see if you don't agree that it's the way to go on 6 meters! — *Bernie Glassmeyer, W9KDR*

[1]ft × 0.3048 = m, in. × 25.4 = mm, lb × 0.454 = kg, ft^2 × 0.093 = m^2

KLM 50-7LD 6-Meter Antenna

Manufacturer's Specifications

Frequency coverage: 50 to 51 MHz.
Number of elements: 7.
Power rating: 4 kW PEP.
Weight: 12 lb.
Boom length: 20 feet.
Boom diameter: 1.5 inches.
Mounting: 4 × 8-inch plate for 2-inch mast to 1.5-inch boom.
Feed line required: 50 ohms unbalanced.
Feedpoint impedance: 200 ohms balanced; 4:1 balun supplied.
Longest element: 122 inches.
Shortest element: 100 inches.
Wind area: 2 sq. feet.
Manufacturer: KLM Electronics, Inc., 17025 Laurel Rd., Morgan Hill, CA 95037.
Price class: $120.

Technical Correspondence

Conducted By
Gerald L. Hall,* K1TD

The publishers of QST assume no responsibility for statements made herein by correspondents.

LINEAR-READING RF WATTMETERS

☐ Kroenert's article, "What Your Wattmeter Really Reads,"[1] naturally raises the questions of how to make a wattmeter and what to do with it then. This note gives some guidance on the first question, and leaves the second open.

Taking a "forward and reflected power" bridge, Fig. 1, we find that the dc output voltages are the phasor sums of samples A and B (including -B) and a term combined with the cosine of the angle between rf current and voltage.[2] Sample A is proportional to rf voltage, and sample B is proportional to rf load current. The combined term, AB cos C, is directly proportional to rf power accepted by the load. Therefore we can "measure" power by isolating this term.

If we start with the conventional bridge and its two dc outputs, E_f and E_r, we can square them and subtract E_r^2 from E_f^2 (Fig. 2). The voltmeter, V, can then be calibrated linearly in watts.

$$E_f = \sqrt{A^2 + B^2 + 2AB\cos C} \qquad \text{(Eq. 1)}$$

$$E_r = \sqrt{A^2 + B^2 - 2AB\cos C} \qquad \text{(Eq. 2)}$$

where

C = the phase angle between A and B or between rf voltage and rf current

From this,

$$E_f^2 - E_r^2 = 4AB\cos C \qquad \text{(Eq. 3)}$$

Note that for the special case of A = B and C = 0 that $E_r = 0$, the indication that the SWR is now 1:1.

Unfortunately this approach (brute force) takes a bridge, five integrated circuits and six zeroing potentiometers to obtain an indication linearly in rf watts. An MC1494L and MC1456G may be used in each squarer (see Motorola's data sheet on the MC1594L/MC1494L), and an operational amplifier such as the 741 may be used to make the subtraction.

A bit more finesse can be used by building the calculation into the rf bridge if you are willing to start from scratch. See Fig. 3. The bridge can be used to drive a doubly balanced ring mixer. The mixer has two outputs, one of which is shorted at twice the radio frequency by the capacitor marked C, and the other is proportional to AB cos C, the power term. As this second output is at dc, a dc voltmeter can be calibrated linearly in watts.

[1]J. T. Kroenert, "What Your Wattmeter Really Reads," *QST*, Feb. 1981, p. 26.

[2]The basic equations for this type of bridge are shown in Geiser's paper, "The Impedance-Match Indicator," *QST*, July 1980, p. 11. Appropriate changes must be made to account for the signal splitting of Figs. 1 and 3.

*Associate Technical Editor

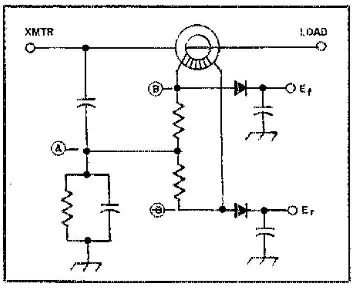


Fig. 1 — A phase-compensated form of the common "directional wattmeter" SWR bridge circuit. Dc output voltages are proportional to E_f and E_r in Eqs. 1 and 2.

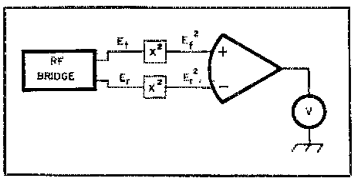


Fig. 2 — IC processing of outputs of the common bridge to give voltmeter readings at V proportional to rf power. Power supplies are also needed.

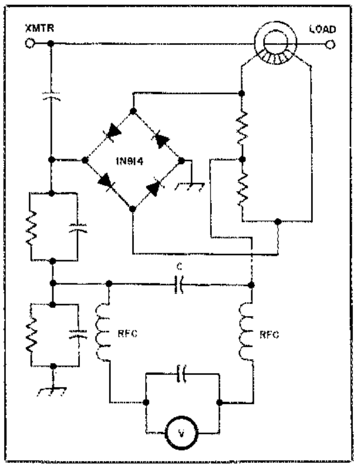


Fig. 3 — Splitting the bridge to drive a ring-modulator detector directly gives a dc voltage proportional to the rf power.

Any measurement scheme has errors. The bridges shown pay a bit more attention to phase angle than some of the more common commercial models.[3] At low A and B values the detector diodes become nonlinear. There is always some frequency effect, and linear ICs aren't always linear. — *David T. Geiser, WA2ANU, ARRL TA, RD 2, Box 787, Snowden Hill Rd., New Hartford, NY 13413*

References

Bruene, W. B., "An Inside Picture of Directional Wattmeters," *QST*, April 1959, p. 24.

Edwards, J. "Wattmeters," *Ham Radio Horizons*, Aug. 1980, p. 15.

TURNS RATIO VS. IMPEDANCE RATIO

☐ I would like to call attention to an ambiguity in Doug DeMaw's article, "Simple Gain Antennas for the Beginner" (August 1981 *QST*, p. 32). The 2-element beam he describes has a driven impedance of approximately 25 ohms. He shows a number of ways to match this impedance to either 50- or 75-ohm coaxial cable. One method involves the use of a toroidal broadband 2:1 matching transformer.

The 2:1 implies a turns ratio, and since the impedance ratio is the square of the turns ratio, this would result in a 4:1 impedance ratio. The 25-ohm antenna impedance would be stepped up to 100 ohms and if fed with 50-ohm coax cable, the SWR would be 2:1, thus negating the attempt at impedance matching. What is required is an impedance ratio of 2:1 or a turns ratio of $\sqrt{2:1}$ or 1.41:1, and this was not made clear. — *Robert J. Ruplenas, W1DDO, 90 Sawyer Ave., Dorchester, MA 02125*

PIN DIODE SWITCHING

☐ In the article on PIN diode switches,[4] I noticed that there was a rather large difference between the measured isolation of the switch and the theoretical prediction of 55 dB for a single-section unit. To get to the bottom of the problem I derived an approximate formula for this type of PIN diode switch for the general case of N sections. At the same time I modeled the circuit on a digital computer using a program called Compact, written by Compact Engineering, which is used widely in the microwave industry. My approximation formula for high isolation agrees very closely with Compact. The isolation for this type of switch is given as:

$$\text{Isolation} \triangleq -10\log\frac{P_{rx}}{P_{tx}} \qquad \text{(Eq. 4)}$$

[3]"An Amateur's Guide to Wattmeters," *Ham Radio Horizons*, Aug. 1980, p. 12.

[4]Ridpath, "T-R Switching With PIN Diodes," *QST*, March 1981, p. 19. Also see Feedback, April 1981 *QST*, p. 53.

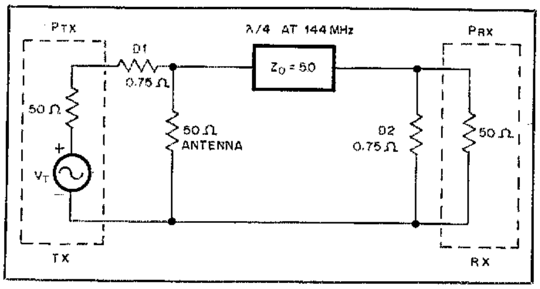


Fig. 4 — Single-section PIN diode switch for a 50-ohm system. Resistor symbols identified as D1 and D2 represent forward-biased PIN diodes. The rectangle represents a length of transmission line.

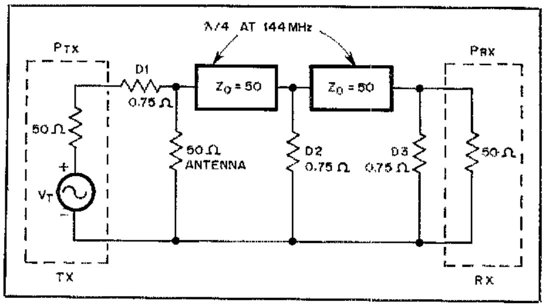


Fig. 5 — A two-section PIN diode switch. The resistances of forward-biased PIN diodes are represented as D1, D2 and D3.

where

P_{rx} = input power at the receiver

P_{tx} = available power from the transmitter

$$ISO = 20\,N \log \frac{Z_o}{R_d} \qquad \text{(Eq. 5)}$$

where

Z_o is the transmission line characteristic impedance

R_d is the PIN diode resistance (0.075 ohm in this case)

N is the number of sections

For example, if N = 1 (two diodes used) then ISO = 36.48 dB, which agrees with the experiment but differs with the presented theory of 55 dB. (See Fig. 4.) Similarly, if one uses three diodes (see Fig. 5), then the isolation from Eq. 5 is given as 72.9 dB. As you can see, the effect of cascading sections is much greater than 10 dB, as claimed.

I think that the article is a very important one, but is quite misleading for the amateur who is trying to make these switches. For a single-section switch the theoretical limit on isolation is 36.74 dB, which means that for a 100-W (50-dBm) transmitter the receiver will have a 13.26-dBm signal at its input. This will be too much for many receivers. For the two-section switch the receiver power level is only −23.22 dBm.

This type of switching may be used for frequencies other than those at 2 meters. I obtained a computer printout from the Compact program for the frequency range of 130 to 150 MHz, but the output can also be interpreted as 13 to 15 MHz. This information shows that the switch is quite good over the whole of the 20-m band. For example, the return loss at 13 MHz is 23 dB, which is the worst case between 13 and 15 MHz. I think a fair design goal of 33 dB isolation for a single-section switch and 66 dB for a two-section switch is practical at 14 MHz, and about 2 dB less for 144 MHz. PIN diode switching is a very interesting area for amateurs who are working with digitally controlled rigs. — *David Conn, VE3LAO, 47 Barnes Cres., Nepean, ON K2H 7C1*

FINDING A PAD

☐ If a variable capacitor is to tune a given frequency range, the inductance and padding capacitance must be found. Having had enough of the tail-chasing that normally ensues, I decided to meet this problem head on. I solved for the required pad as follows:

From the formula for resonance of an LC circuit,

$$\frac{C_{max}}{C_{min}} = \left(\frac{f_{max}}{f_{min}}\right)^2 = K^2 \qquad \text{(Eq. 6)}$$

Let the maximum and minimum values of the variable capacitor be C2 and C1, respectively. Let the residual circuit capacitance be Cx. Then,

$$C_{max} = Cp + C2 + Cx, \text{ and} \qquad \text{(Eq. 7)}$$

$$C_{min} = Cp + C1 + Cx \qquad \text{(Eq. 8)}$$

where Cp is the fixed padding capacitor. Substituting,

$$\frac{Cp + C2 + Cx}{Cp + C1 + Cx} = K^2, \text{ from which} \qquad \text{(Eq. 9)}$$

$$Cp = \frac{C2 + Cx - K^2 (C1 + Cx)}{K^2 - 1} \qquad \text{(Eq. 10)}$$

Note that K cannot exceed $\sqrt{\dfrac{C2 + Cx}{C1 + Cx}}$

The required inductance is

$$L = \frac{1}{4\pi^2 f_{min}^2 (Cp + C2 + Cx)} \qquad \text{(Eq. 11)}$$

Cx may be neglected in Eqs. 10 and 11 if it is much less than C1. — *Frank W. Noble, W3MT, 10004 Belhaven Rd., Bethesda, MD 20034*

FM TERMINOLOGY

☐ With regard to the Technical Correspondence letter by Thurston, W4PPB,[3] and the article by Hyder, W7IV,[4] there still remains confusion between deviation ratio and modulation index. They are closely related and yet different. Both express the ratio of carrier deviation to the frequency causing that deviation. Deviation ratio is the maximum carrier deviation (100% modulation) divided by the maximum modulating frequency. This is a constant for a given fm system. In narrow-band fm the maximum deviation is 5 kHz, and the maximum audio frequency is 3 kHz, giving a deviation ratio of 1.67. Regardless of any set of operating conditions, the deviation ratio for nbfm remains 1.67.

Modulation index, on the other hand, describes a set of operating conditions. Modulation index, β, is the carrier deviation under those operating conditions divided by the frequency of the audio tone that causes that deviation. This is obviously a variable; it can range from 0 to 16.7 for nbfm, assuming 300 Hz as the lowest modulating frequency. Both examples assume a single-frequency modulating tone. — *C. L. "Chuck" Hutchinson, K8CH, ARRL Hq.*

[3] J. N. Thurston, "Fine Points on Modulation Systems," Technical Correspondence, *QST*, May 1981, p. 42.

[4] H. R. Hyder, "Phase Versus Frequency Modulation," *QST*, July 1981, p. 33.

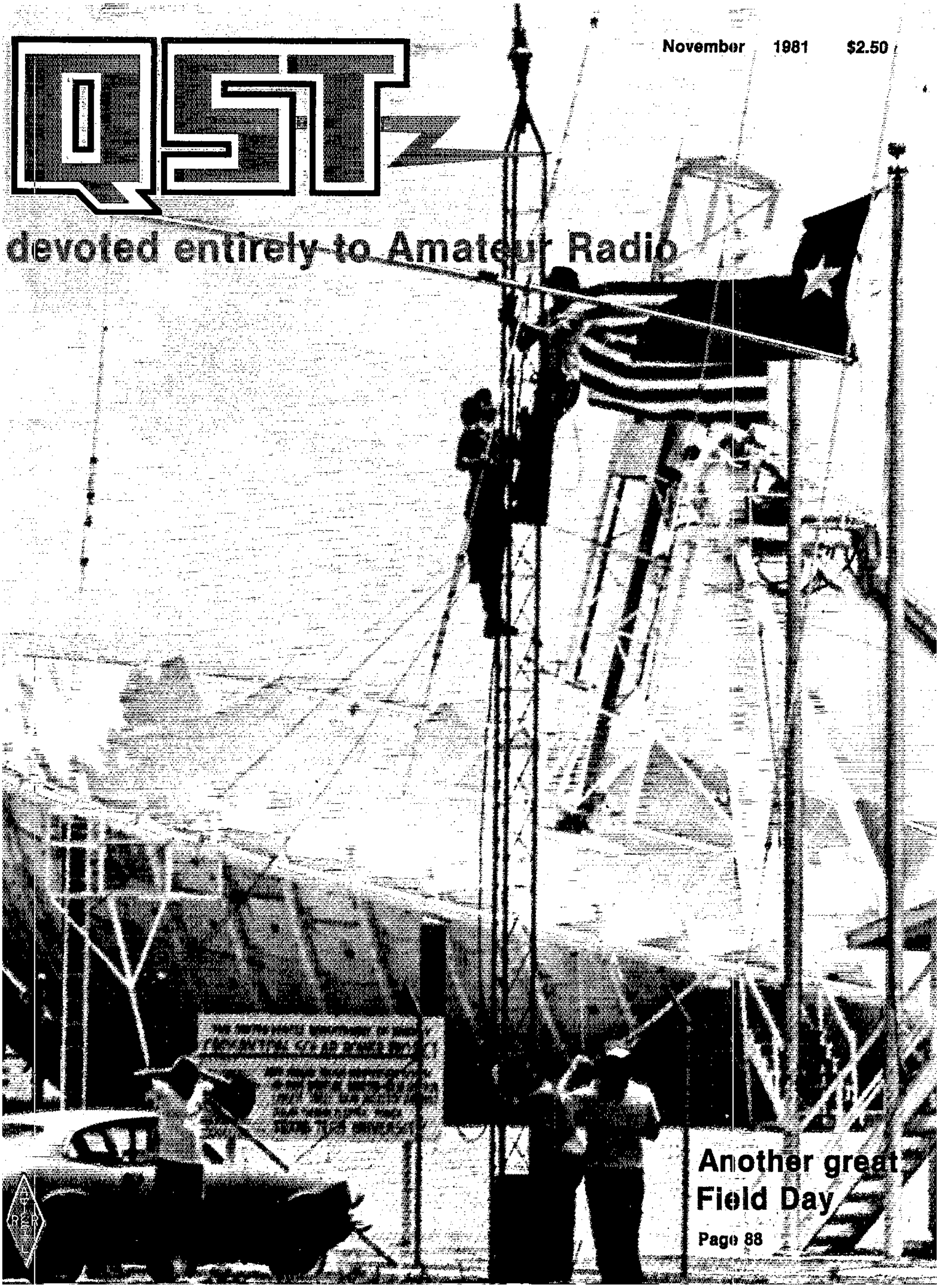
Feedback

☐ Harry Hyder, W7IV, author of "Phase Versus Frequency Modulation," July 1981 *QST*, mentions that he made a small error in the third from the last paragraph on p. 34, in a statement about fm broadcast stations pre-emphasizing audio frequencies above 1 kHz at the rate of 6 dB per octave. Harry mentions that, in fact, the pre-emphasis/de-emphasis curves only approach 6 dB per octave, as do all single R-C networks. The FCC actually specifies these curves in terms of a time constant of 75 microseconds, he states.

☐ In "Modifications for the Plessey IC Receiver," Technical Correspondence, June 1981 *QST*, p. 40, the sixth and seventh lines should read, "These remarks were based on the performance of a receiver that I tested in the ARRL lab."

☐ Dan Sanderson, KM5T, tells us that a couple of errors crept into his July 1981 *QST* article, "The Burglar Alarm that Resets Automatically," p. 28. The collector and emitter are reversed in the bottom views of the TO-92 packages in Fig. 1. As a result, Fig. 3 shows Q1, Q2 and Q3 mounted backward. The trace going from U1, pin 2, to ground should be removed (leave the 10-kΩ resistor connected to pin 2). Dan also advises that it may be necessary to install a capacitor (approximately 50 μF) across the alarm leads to prevent interference from transients if the builder plans to use a high-current alarm (e.g., a large bell).

☐ In "The New Frontier," September *QST*, p. 76, Fig. 1 should have noted that all elements should be 0.2 in. wide.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THE COVER

This 65-foot solar collector dish furnished power for the Field Day operations of the Texas Tech University Amateur Radio Club. See page 94 for the details. *(photo courtesy KC5W)*

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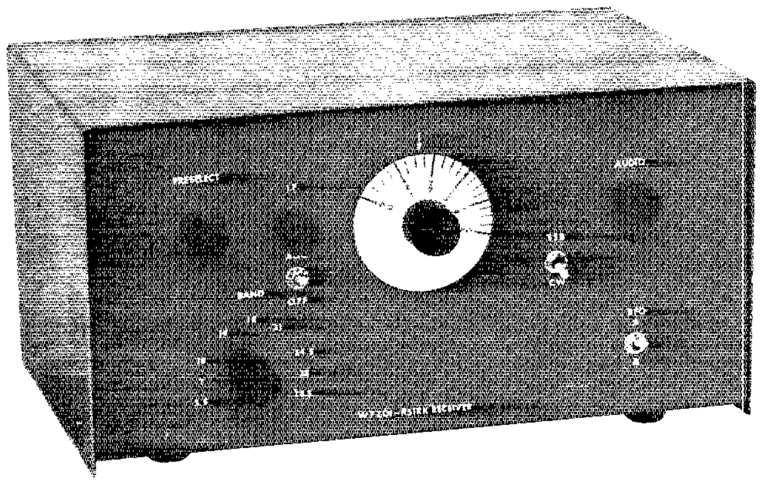
A Progressive Communications Receiver

Try your hand at building a good receiver! This two-step approach combines construction simplicity with performance that equals or exceeds that of many commercial units. You'll be proud to say, "I built it myself!"

By Wes Hayward,* W7ZOI and John Lawson,** K5IRK



The word "progressive" has a multiplicity of meanings. When applied to a receiver construction project it might imply that the work *progresses* from a simple beginning to something more elaborate. The receiver user, however, would assume that a *progressive* receiver is modern in design, having progressed with the state of the amateur art.

Both meanings apply to the receiver described here. The initial project results in a simple, but well-performing direct-conversion (D-C) receiver. Phase two adds circuits to provide an 80-meter superheterodyne. Multiband coverage is then provided for on an as-needed basis by the addition of carefully designed crystal-controlled converters. Virtually all of the components used for the D-C receiver are contained in the final version.

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**126 Buttercup Ln., Lake Jackson, TX 77566

saving time and money.

We should emphasize that although simple, this receiver is not a toy. The final superheterodyne features excellent stability, selectivity (consistent with the filter used), adequate sensitivity and a dynamic range that rivals or exceeds that of many commercial equivalents. The major compromise is the utilization of dual conversion on the higher bands. This penalty is small, for the gain distribution has been controlled carefully through proper design. Achieving good performance in simple equipment is not something that just happens — it must be *designed*. The reader is urged to review the thoughts on this subject presented by Roy Lewallen, W7EL.[1]

Some prospective builders may have little interest in a simple D-C receiver. Step-by-step construction of a D-C version is not shown here. However, bypassing that part of the project and proceeding directly to the final "superhet" design is *strongly* discouraged, especially if the builder lacks construction experience. The two-step method of construction facilitates later debugging and adjustment.

Simplicity and ease of duplication were considered paramount in the design. Readily available components are used throughout; alternatives are suggested where appropriate. Circuits are insensitive to the transistor type, thereby allowing component-substitution freedom.

A variety of construction methods may be used. Some builders may wish to etch their own circuit boards.[2] This is not meant to imply that etched boards are necessary or even desired. All of the circuit was initially breadboarded using "ugly" methods;[3] while not as professional in appearance, performance is vir-

[1]Notes appear on page 21.

tually identical. Where a performance difference could be detected, the ugly breadboards proved superior, usually a result of improved grounding. An added virtue of the ugly boards is that they are built in less than half the time required to lay out, etch, drill and construct the etched versions. Also, an "ugly board" is altered easily allowing a builder to incorporate design changes.

Ugly boards are built using scraps of unetched circuit-board material, which serve as the ground foil. Components are supported by those parts that are attached to the ground foil. Additional support may be provided with suitable tie points. Large-value resistors can serve this purpose well, especially in rf circuits where impedance levels are generally low.

The Progressive System

The system will be described in block-diagram form before we proceed with circuit details. This shows what the final result can be and aids in module interconnection. Fig. 1 is the block diagram of an 80-meter D-C receiver. The preselector filter is followed by the product detector and audio amplifier module. A doubly balanced diode-ring mixer serves as the detector. Four audio stages provide sufficient output to drive low-impedance headphones. An optional R-C active filter is shown. The remaining circuit section is the VFO.

A three-band superheterodyne version of the receiver is presented in Fig. 2. With the band switch in the 80-meter position, incoming signals are applied first to the preselector filter. This is the same one used in the D-C receiver. The preselector output is routed to a mixer module. This board contains a diode-ring mixer and a bipolar transistor i-f amplifier. Output of the mixer module is fed to the i-f amplifier board, which contains the crystal filter and a simple i-f derived agc system.

The i-f amplifier drives the detector/audio board used originally in the D-C receiver. Except for a couple of resistor value changes, the audio amplifier is unaltered. Detector injection voltage is provided by a crystal-controlled BFO. Use of two BFOs provides convenient sideband selection.

The 80-meter mixer is driven by the same VFO that was used in the D-C receiver. Some capacitors have been changed to move the output frequency of 3.5 to 4 MHz up to 5 to 5.5 MHz.

Multiband reception is provided by a crystal-controlled conversion process. While the receiver shown in Fig. 2 has only three bands, the band coverage and means of switching are flexible. The converter filter section *may* contain an optional rf amplifier (recommended only for the higher bands). A separate preselector filter is required for each band to be covered. The filter section is followed by a mixer module that feeds the 80-meter part of the receiver. Only one mixer module is used in the converter section. Mixer LO injection is provided by a group of crystal-controlled oscillators. One oscillator is required for each band.

There is considerable board commonality in the superhet. All of the converter filters have identical layouts; the converter mixer module is identical to that used in the 80-meter receiver. The crystal oscillators used for the BFOs and converters are identical.

80-Meter Preselector Filter

This filter (Fig. 3) consists of two cascaded sections. The first section is a 7-pole high-pass filter (3-MHz cutoff) composed of the components located between the two 650-pF capacitors. It is used to suppress spurious responses from mf broadcast signals.

The second filter section is unusual. While basically a low-pass type, it was designed for a very pronounced peak, resulting in a sharp, bandpass-like response. A front-panel mounted PRESELECTOR control is required. A 365-pF broadcast band replacement type of capacitor is used. If it is located remotely from the rest of the filter, a short length of small-diameter coaxial cable (RG-174/U) may be used for interconnection. A filter tuning range of 3 to 4 MHz may be useful for some applications to be discussed later. Data is provided for this variation.

Some builders may wish to construct a receiver without the front panel PRESELECTOR control. In that case, we suggest a 9-pole low-pass filter be designed for a 1-dB ripple (Chebyshev response) and a cutoff frequency of 4.1 MHz. This can be cascaded with the 7-pole high-pass filter of Fig. 3.

Detector-Audio Section

Shown in Fig. 4 is the backbone of the D-C receiver — the product detector and audio amplifiers. For ease of construction and component procurement, no ICs have been used. Although discrete-component detectors were used in early versions of the receiver, the Mini-Circuits Labs SBL-1 doubly balanced mixer was finally chosen. Not only does it offer excellent performance in D-C receiver applications, but the improved balance helps to eliminate problems caused by the agc system of the superhet being activated by BFO leakage. Other commercial mixers or homemade equivalents will also work well.

Detector output is fed to a diplexer network consisting of RFC1 and the related components. This network ensures that the detector is terminated properly at all frequencies from audio to vhf, providing optimum dynamic range in D-C receiver applications. Additional information about product detectors for D-C receivers is presented in *Solid-State Design for the Radio Amateur*[4] and in the paper by Lewallen.[5] We have borrowed liberally from his work in much of this design.

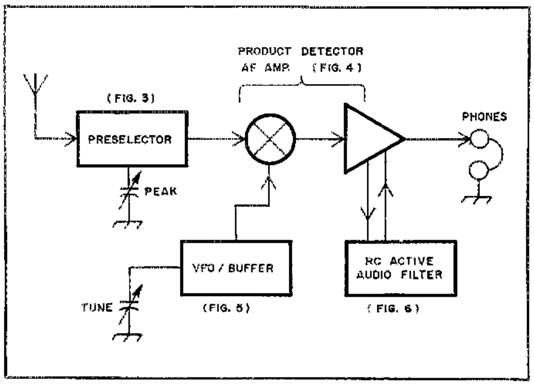
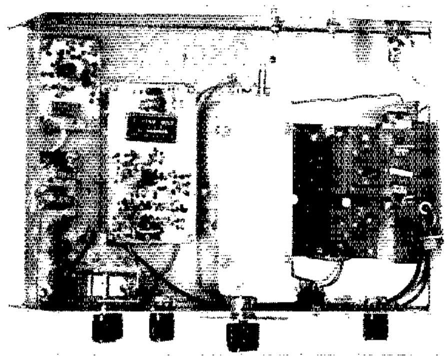


Fig. 1 — Block diagram of an 80-meter direct-conversion receiver. The receiver may be constructed for use on other bands.



An inside, top view of the Progressive Receiver. The unit shown in the photos was constructed by John Lawson, K5IRK. *(photos by Roger Hayward, KA7EXM)*

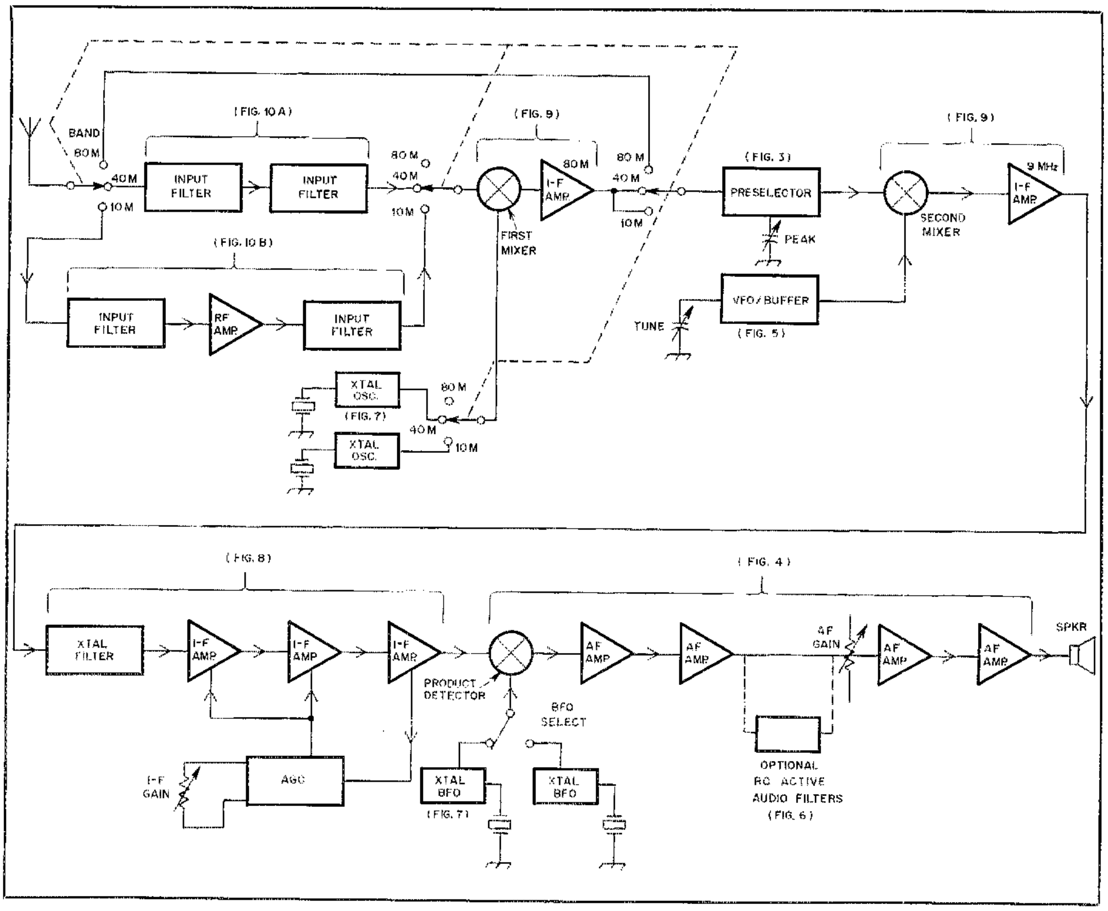


Fig. 2 — Superheterodyne receiver block diagram. As shown, the receiver covers three bands: 80, 40 and 10 meters. All bands from 80 through 10 meters (including the WARC frequencies) may be added to the basic receiver at the builder's discretion. Refer to the text for details.

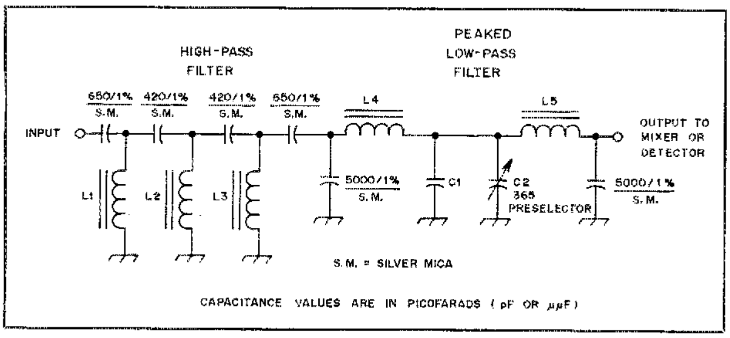


Fig. 3 — The 80-meter preselector filter. A high-pass filter is used at the input; a peaked low-pass filter comprises the output section. Nearest value 5% silver-mica capacitors may be substituted for the 1% units shown.

C1 — 560-pF silver-mica capacitor for 3.5- through 4-MHz coverage, 250-pF silver-mica unit for 3- through 4-MHz coverage (see text).
C2 — Broadcast replacement type of variable capacitor, 365 pF or more.
L1, L3 — 21 turns no. 22 enameled wire on T50-2 core.
L2 — 20 turns no. 22 enameled wire on T50-2 core.
L4, L5 — 30 turns no. 22 enameled wire on T68-2 core for 3.5- through 4-MHz coverage; 45 turns no. 24 enameled wire on T68-2 core for 3- through 4-MHz coverage.

First audio amplifier Q1 is connected in a common-base configuration to terminate properly the diode-ring detector. It is biased to an emitter current of about 0.5 mA to present an input resistance of 50 ohms. Q2 is a direct-coupled pnp amplifier that functions as the second audio stage. The receiver may be muted by shorting the collector of Q2 to ground. This is accomplished by applying a positive potential of a few volts to the muting input to saturate Q5. The output of Q2 is fed to an AUDIO GAIN control on the front panel. If the optional R-C active filter is used, it is inserted in series with the output of Q2.

Q3 is a common-emitter amplifier. Q4 is an emitter follower. Q4 has an emitter-current bias of about 30 mA to provide enough audio output to drive low-impedance (4- to 16-ohm) headphones. Two series-connected, 75-ohm, 1/4-watt emitter resistors are used to provide sufficient power dissipation and to ensure

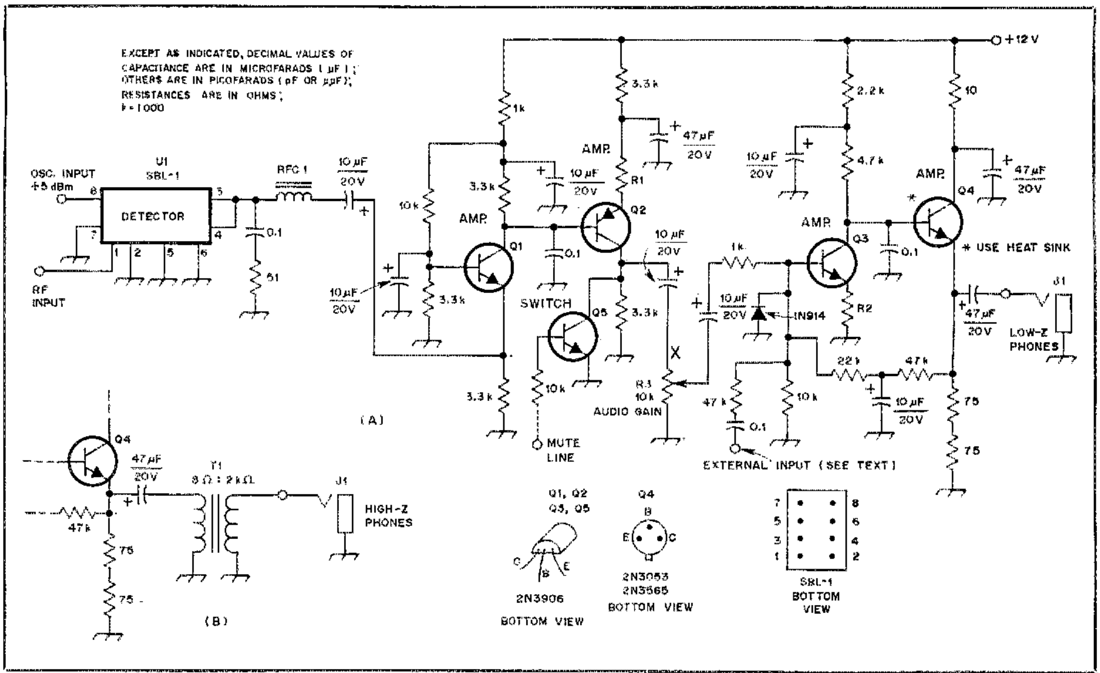


Fig. 4 — Schematic diagram of the product detector and audio-amplifier section is shown at A. The circuit at B may be added if high-impedance headphones are used. When the recommended optional audio filters are employed, they are inserted at the point marked X. All resistors are 1/4-watt composition or metal film types. Pin 1 of the SBL-1 is beneath the MCL marking on the top of the case.

Q1, Q3 — Silicon npn low-noise bipolar transistor 2N3565 or equiv.
Q2 — Silicon pnp general-purpose bipolar transistor, 2N3906 or equiv.
Q4 — Silicon npn bipolar transistor, 2N3053 or equiv., with small heat sink.
Q5 — Silicon npn general-purpose bipolar transistor, 2N3904, 2N2222, 2N3565 or equiv.
R1, R2 — 10 Ω for direct-conversion receiver, 220 Ω for superheterodyne version.
R3 — 10-kΩ audio-taper potentiometer.
RFC1 — 20 turns no. 28 enameled wire on FT37-43 core.
T1 — Reverse-connected miniature audio-output transformer, 8 Ω to 2 kΩ.
U1 — Doubly balanced diode-ring mixer, Mini-Circuits Laboratory SBL-1 or equiv. (see text). The SBL-1 may be obtained from Mini-Circuits Laboratory, 2625 East 14th St., Brooklyn, NY 11235.

reliability. A small heat sink is used on Q4. If low-impedance headphones are used, they should be the inexpensive types. Those designed for high-fidelity applications are usually too inefficient for use in this circuit. Should you wish to use high-impedance headphones, the circuit of Fig. 4B should be employed to achieve the required voltage amplification.

Two resistors in the audio system (R1 and R2) must be changed when the board is used in the superhet version. This is because higher audio gain is needed in the D-C receiver. An auxiliary input is provided in the audio-amplifier section. This is intended for cw sidetone signal injection.

The VFO

A general-purpose VFO is shown in Fig. 5. It will function well at frequencies in the 2.5- to 10-MHz range. Only the capacitors need to be changed to alter the tuning range.

Q6 is employed in a JFET Hartley circuit that has the virtues of simplicity and good stability. Recent work by Lewallen[6] has optimized this oscillator for thermal stability. Best stability results if a toroid core of the SF type (Amidon −6 code)[7] is used for the inductor. This material has a +50 ppm/C° temperature coefficient — much better than the usual slug-tuned inductor. All fixed-value capacitors should be NPO ceramic units. They have the lowest temperature coefficient of any of the readily available types. Use of silver-mica and polystyrene capacitors should be avoided. The latter exhibit a temperature coefficient of −150, ±50 ppm/C° and are not recommended. Their popularity in VFO applications results from frequent use with slug-tuned inductors, which often have temperature coefficients of about +150 ppm/C°.

The resonator (tuned circuit) should be lightly loaded by the FET. This is ensured by keeping the gate-coupling capacitor as small in value as possible. If the specified 2.7-pF NPØ ceramic unit cannot be found, a small air-variable of similar capacitance may be substituted.

Excellent VFO stability is obtained easily if these precautions are followed. Oscillators operating at 5 or 7 MHz have exhibited a typical warm-up drift of less than 200 Hz over a period of about 10 minutes. Afterward, the VFO does not move more than 10 or 20 Hz in a five-minute period, assuming the ambient temperature is reasonably constant. This data is not the result of a single measurement. Literally dozens of these oscillators have been built, all producing predictable results.

Capacitor values for the circuit of Fig. 5 may be taken from Table 1 if a 365-pF variable is used for C6, the MAIN TUNING capacitor. Considerable flexibility exists, and the equations in the appendix may be used to calculate the values for C3, C4 and C5 if another type of variable capacitor is used for C6. The Table 1

Table 1

VFO Capacitor Values For Different Operating Frequencies

Frequency Range (MHz)	*C3 (pF)*	*C4 (pF)*	*C5 (pF)*
3.5 to 3.8	281	200	120
3.5 to 4.0	290	200	40
3.0 to 4.0	305	1000	18
5.0 to 5.5	126	100	82
5.0 to 6.0	66	200	120
7.0 to 7.2	60	50	200

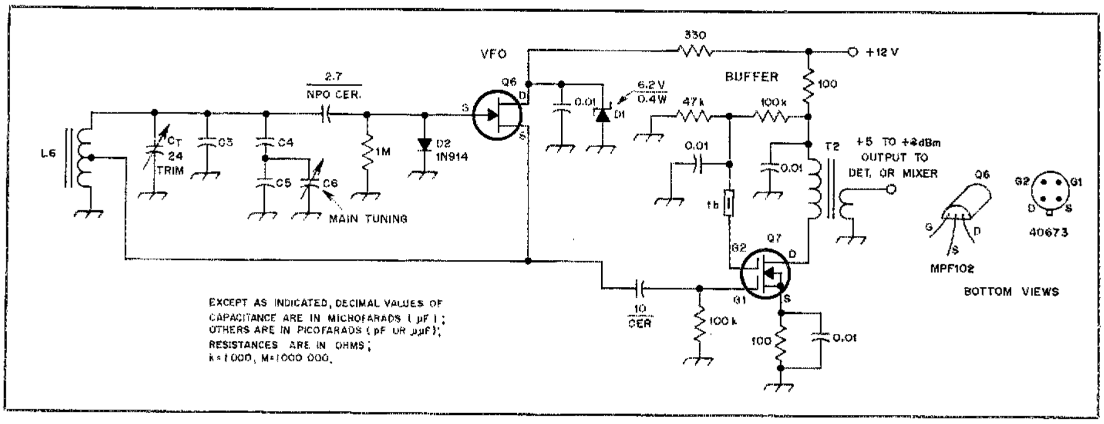


Fig. 5 — VFO schematic diagram. This circuit performs well at frequencies between and including 2.5 and 10 MHz. Refer to the text, Table 1 and the Appendix for component selection information. Resistors are 1/4-watt, 5% composition or metal film types. All fixed-value capacitors are disc-ceramic types.

C3-C5, incl. — NPØ ceramic. See Table 2 and Appendix.
C6 — Air variable capacitor, 100 pF or more total capacitance variation.
L6 — Approximately 4.9 μH, 35 turns no. 28 enameled wire on T50-6 core, tapped at 8 turns from ground end.
Q6 — Silicon n-channel high-frequency JFET, MPF-102, 2N4416, TIS-88, 2SK19GR or equiv.
Q7 — Silicon n-channel dual-gate rf-amplifier MOSFET, 40673, 3N140, 3N211, 3SK40 or equiv.
T2 — Ferrite transformer, 18-turn primary, 5-turn secondary, no. 28 enameled wire on FT37-43 core.

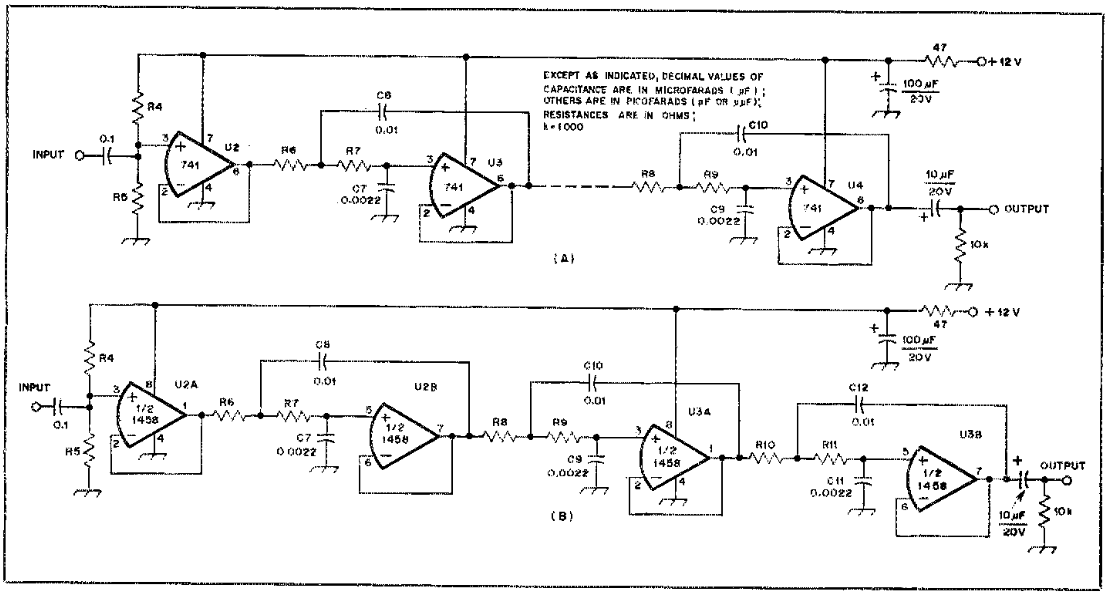


Fig. 6 — An optional R-C active audio filter. At A, a 4-pole, low-pass filter using 741 (single-section) op amps is shown. The circuit at B employs two 1458 (dual-section) op amps and provides six poles of low-pass filtering; more poles are recommended for improved performance. Other types of op amps may be substituted, but use caution as pin numbers may differ. Resistors are 1/4-watt, 5% composition or metal film types.

C7, C9, C11 — 0.0022 μF ceramic or polystyrene, 10% or better tolerance.
C8, C10, C12 — 0.01 μF ceramic or polystyrene, 10% or better tolerance.
R4-R11, incl. — 33 kΩ, 5% for cw filter, 15 kΩ for ssb filter.
U2-U4, incl. — See caption.

value for C3 includes the capacitance of the trimmer, C_T.

A dual-gate MOSFET is used for the buffer amplifier, Q7. The circuit is conventional except for the use of a broadband output transformer. Good isolation is provided, and the power output is ample for driving a diode-ring mixer or detector. Power values of +5 to +8 dBm have been measured, using a 50-ohm load. A ferrite bead is placed directly on gate 2 of Q7. While we attempt to design without "Band-Aids of anticipation," this one is worthwhile; it introduces loss, which will stop uhf oscillations.

Mechanical construction is important in a VFO. Any of the available reduction drives are suitable for the direct-conversion model of this receiver. Additional bandspread is desirable for superhet applications. A Jackson Brothers dual-speed drive, type 4511/DRF,[8] was used in the K5IRK receiver, and it is adequate. The receiver built at W7ZOI contains a surplus capacitor and drive unit from a BC-455.[9]

Optional R-C Audio Active Filter

Additional selectivity may be desired for either phase of the project. The R-C active filter shown in Fig. 6 is designed to fulfill this need. The filter has a single pole of high-pass filtering followed by a series of low-pass poles. The cutoff frequency is about 1 kHz for cw and 2 kHz for ssb. Filter bandwidth is selected by a proper choice of the resistor values. More filter sections may be added for improved skirt selectivity. The Q of the individual low-pass sections may be increased if a narrower bandwidth is desired. While the filter is shown with operational amplifiers as the active elements, discrete transistors are also suitable.[10]

The performance of the D-C receiver is excellent. Detailed measurements have not been done on this unit, but Lewallen has done some while using a similar circuit.[11] Good D-C receivers display a quality of exceptional "cleanliness" and "presence", and this one is no exception. Indeed, the effect is perhaps more pronounced because of improved audio fidelity.

Crystal Oscillators

The circuit shown in Fig. 7A is used for all of the crystal oscillators in the receiver. One or two will serve as the BFO. Additional units are required for each band to be covered by means of the crystal-controlled converters. Though the circuit may appear to be strange (something of a "trick" circuit), this is not the case. If the diagram is redrawn with the ground point placed at the transistor base, it becomes clear that this is nothing more than a Hartley oscillator with the crystal in series with the feedback tap from the coil.

A capacitor in series with the crystal permits adjusting the oscillator to the operating frequency. This is vital only for the oscillators used for the BFOs. This capacitor may be eliminated (using a jumper wire) in those modules used for converter application. C12 is tuned for maximum output and reliable oscillator starting. The +12-volt operating bias is applied through the resonator output link for ease of band switching. Power is supplied to any single oscillator, as shown in Fig. 7B. The method used for sideband and band selection is shown in Fig. 7C. Only the oscillator in use has power applied to it.

These crystal oscillators will deliver an output power of about +10 dBm. This is more than enough to drive the detector or mixer. The circuits are adjusted easily as long as they are terminated properly — they are best adjusted with the mixer or detector attached. If experimentation is done with the circuits for other than their intended application, they should be ac coupled to a 50-ohm load.

One crystal type, a KVG XF-903,[12] will function well for all 9-MHz BFO applications. Two crystals can be used in separate BFO units, or a single BFO can be mounted near the receiver front panel, with an operator-adjusted variable capacitor used for the BFO control.

A list of oscillator frequencies and component values appears in Table 2. Use of the 3.3-MHz oscillator frequency will convert the 7- through 7.3-MHz band to the 3.7- through 4-MHz tuning range. The virtue of this scheme is that all bands will

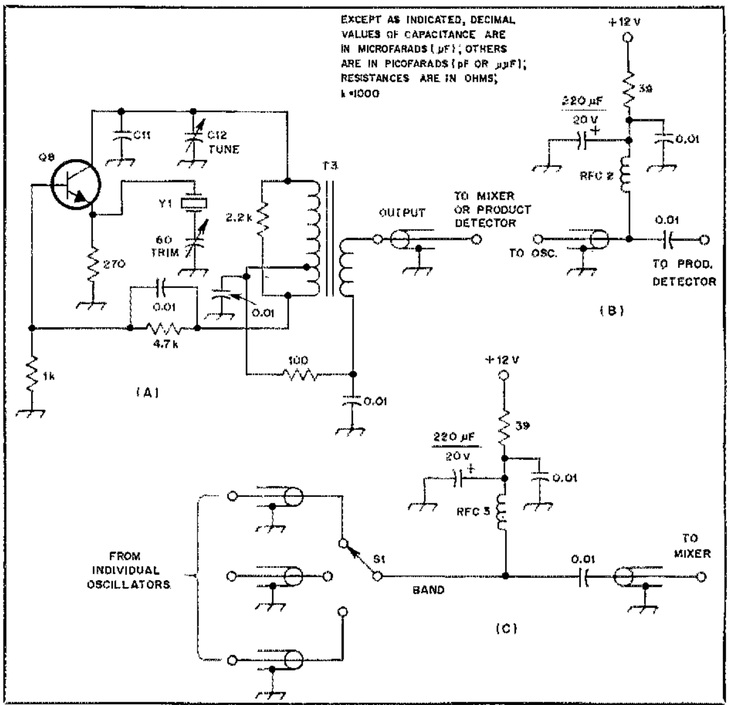


Fig. 7 — At A, the crystal oscillator schematic diagram. This module is duplicated a number of times in the receiver. It is used for the BFO as well as for the individual conversion oscillators. Refer to the text for circuit details. Component information is given in Table 2 and the parts list. Resistors are 1/4-watt composition or metal film types, 5% tolerance. B and C show the methods used to couple the oscillator output to the product detector and mixer circuits, respectively.

C11 — Silver-mica or ceramic capacitor; see Table 2.
C12 — Mica compression or similar trimmer capacitor; see Table 1.
Q8 — Silicon npn general-purpose bipolar transistor, 2N3904, 2N2222 or equiv.
RFC2, RFC3 — Approximately 20 turns no. 28 enameled wire on FT37-43 core.
S1 — Part of band switch or sideband-selector switch; see text.
T3 — Wound with no. 28 enameled wire; see Table 2.
Y1 — Series-resonant crystal for use at required frequency shown in Table 2. For 9-MHz BFO applications, the KVG XF-903 is suitable for lsb or usb.

Table 2

Crystal Oscillator Component Selection

Y1 (MHz)	Frequency (meters)	C11 (pF)	C12 (pF)	Core type	T3 Primary turns	Tap turns	Secondary turns
3.3	40	100	90	T68-2	65	13	10
6.5	30	100	60	T50-6	35	7	6
9	BFO	56	60	T50-6	35	7	6
10.5	20	56	60	T50-6	30	7	6
11	20/40	22	60	T50-6	30	7	6
14.5	17	33	60	T50-6	23	5	4
17.5	15	33	60	T50-6	23	5	4
20.5	12	none	60	T50-6	20	4	4
24.5	10/15	none	60	T50-6	20	4	4
32	10	none	60	T50-6	15	3	3

Note: No. 28 enameled wire is used for T3 windings.

then tune in the same direction, a subjective detail of consequence to some. Forty-meter reception may be achieved by using an oscillator frequency of 11 MHz. But the tuning direction will be opposite that on 80 meters. The latter method is used by the writers.

Many converter-construction options are available. You can build the basic 80-meter receiver to tune the wider range of 3 to 4 MHz. Then, all five bands from 80 to 10 meters may be received using only two crystal oscillators (11 and 25 MHz). This scheme would be ideal for the economy-minded builder. Data for this approach is presented for the construction of the VFO and 80-meter preselector.

I-F Amplifier

An important part of any superheterodyne receiver is the i-f section. A 9-MHz i-f is used in this receiver (Fig. 8). Selectivity is provided by a crystal filter of the builder's choice. This circuit accepts

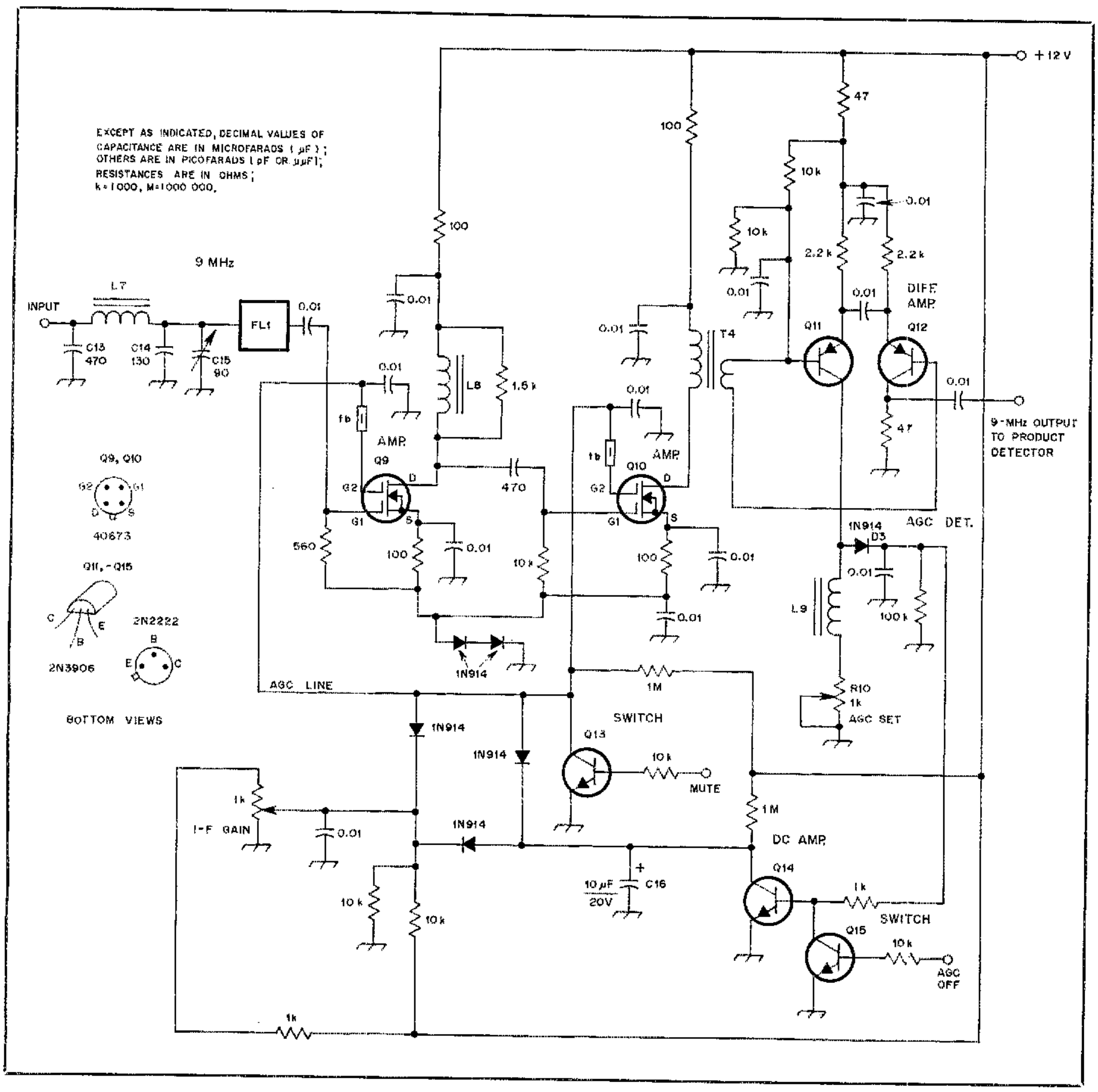
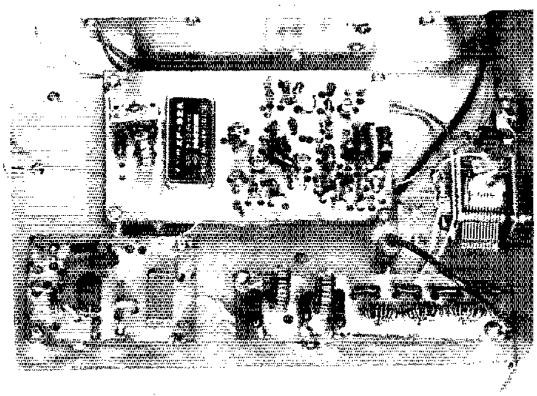
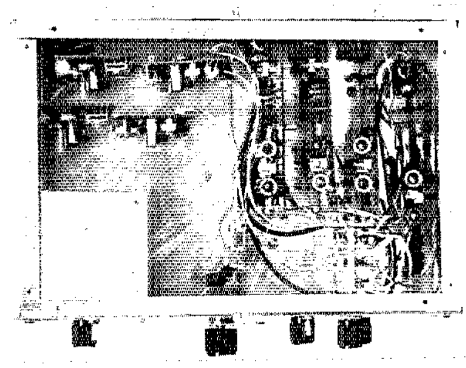


Fig. 8 — Schematic diagram of the 9-MHz i-f amplifier. All fixed-value resistors are 1/4-watt, 5% carbon or metal film types. The adjustment of R10 is discussed in the text.

C15 — 90-pF mica compression trimmer.
FL1 — 9-MHz crystal filter, 500-Ω input/output impedance; for ssb, KVG type XF-9B or Yaesu XF-92A; for cw, KVG type XF-9M, XF-9NB or Yaesu type XF-90C. KVG filters may be obtained from Spectrum International, Inc., P.O. Box 1084, Concord, MA 01742. Yaesu filters may be obtained from Yaesu Electronics Corp., P.O. Box 498, Paramount, CA 90723.
L7 — 23 turns no. 22 enameled wire on T50-6 core.
L8, L9 — 15 turns no. 28 enameled wire on FT37-43 core.
Q9, Q10 — Silicon n-channel dual-gate rf-amplifier MOSFET, 40673, 3N211, 2SK40 or equiv.
Q11, Q12 — Silicon pnp general-purpose bipolar transistor, 2N3906 or equiv.
Q13-Q15, incl. — Silicon npn general-purpose bipolar transistor, 2N3904, 2N2222 or equiv.
R10 — 1-k, pc-mount, linear-taper potentiometer.
T4 — Ferrite transformer, 15 primary turns and 3 secondary turns of no. 28 enameled wire on an FT37-43 core.



In this close-up photo, the 80-meter preselector and 2nd mixer module may be seen in the foreground. The 9-MHz i-f board is in the center, and a portion of the VFO enclosure is at the top of the photo.



At the lower left, a pc-board enclosure houses the BFO circuitry. Immediately above the BFO four crystal oscillator modules may be seen. Four input filter boards are arranged behind the BAND switch. The two input-filter boards at the extreme right are without rf amplifier components. Another mixer module is at the lower center of the chassis.

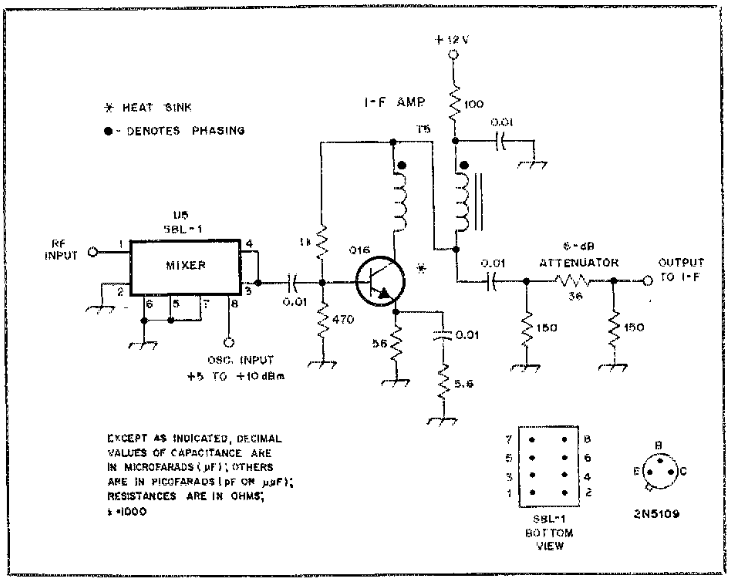


Fig. 9 — Mixer-module schematic diagram. Two of these units are required when constructing the superheterodyne version of the receiver. One module is used as a first mixer stage for input signal frequencies of 40 through 10 meters, with an output at 80 meters. The other module (the second mixer stage) converts 80-meter input signals to the 9-MHz i-f. All resistors are 1/4-watt, 5% composition or metal film types.

Q16 — Silicon npn CATV amplifier (f_T = 500 MHz or greater) bipolar transistor, type 2N5109, 2N3866, 2SC1252, 2SC1365 or equiv. A small heat sink should be used on Q16.

T5 — Broadband ferrite transformer, 10 bifilar turns no. 28 enameled wire on FT37-43 core.

U5 — Doubly balanced diode-ring mixer, Mini-Circuits Laboratory SBL-1 or equiv.

filters requiring 500-ohm terminations. A pi-network input circuit transforms the 50-ohm source impedance of the mixer module to the 500-Ω load required by the filter. The filter output is terminated in a 560-ohm resistor. An unusual feature of the i-f system is the lack of tuned circuits other than the pi network. All transformers are ferrite types that are designed for broadband performance.

A majority of the i-f gain is provided by two dual-gate MOSFETs, Q9 and Q10. The bias on these stages is raised by placing a pair of silicon diodes in the source lead. This extends the gain control range as the gate 2 bias is altered.

The last i-f stage is a differential pair of transistors, Q11 and Q12. Output is available from each of the collectors. The output of Q12 is routed to the product detector by means of small-diameter coaxial cable, while Q11 output is fed to the agc detector, D3. A voltage appears at the base of Q14 when high-amplitude signals are present. C16, the timing capacitor, is then discharged. To reduce i-f stage gain, this voltage change is coupled to the agc line by means of a diode. R10, the AGC SET, is adjusted for a dc voltage of 0.4 to 0.5 at the base of Q14. This adjustment should be made with the agc system activated and with no signals present. The potential on the agc line will then be about 6 volts with manual I-F GAIN set at maximum. A high-impedance (10 megohms or greater) voltmeter should be used for any agc-line measurements.

Two transistor switches are contained in the i-f strip. Q15 defeats the agc when a positive voltage is applied to the AGC OFF line. Q13 is attached directly to the agc line. A positive input voltage to that switch shorts the agc line to ground to mute the receiver. The agc line diodes allow muting to occur quickly without discharging C16. The i-f strip returns quickly to full gain after muting periods.

Agc response is more than adequate, with minimal overshoot. Recovery time is relatively independent of the signal level. By decreasing the value of C16 or its associated 1-megohm resistor, the recovery time may be shortened.

Mixer

Fig. 9 is the schematic diagram of the 80-meter mixer. A Mini-Circuits Lab SBL-1 or similar unit may be used. Again, homemade mixers will also work well. A suitable substitute can be built from a pair of Amidon FT37-43 toroid cores and four hot-carrier diodes.

Q16, a 9-MHz i-f amplifier, follows the mixer. This is one of the more critical stages of the receiver. It must have a low noise figure, for it will determine the receiver sensitivity. Intermodulation distortion must be low, and the input and output impedances need to be 50 ohms. A bipolar transistor with negative feedback is used to establish the gain and required impedance levels. The stage is biased to draw a moderately high current. This ensures low distortion. A 6-dB pad at the output preserves the impedances at the input and output of the amplifier.

Transistor type *is* critical for Q16 because it should be one with a high gain-bandwidth product (f_T) — at least 500 MHz. Amplifier gain, minus the loss in the pad, is about 16 dB. The mixer has a conversion loss of about 6 dB, leaving a net gain of 10 dB. The amplifier output intercept is approximately +30 dBm. Careful measurements have shown that a diplexer network is not required between the mixer and this amplifier.

Assuming the VFO frequency has been changed to cover 5 to 5.5 MHz, the receiver is now ready for operation on 80 meters. A few circuits requiring alignment are adjusted for maximum output. Homebuilt instrumentation[13] is adequate for use during alignment. It was used by the writers. The adjustments may also be performed "by ear," listening to incoming signals with the agc defeated.

Crystal-Controlled Converters

To receive other bands of interest, suitable converters can be added to the basic receiver. Net gain through the converters is kept low to preserve the overall receiver dynamic range. An additional mixer module, identical to that used in the 80-meter front end, is needed. Each band to be added will require a band-pass preselector filter and a crystal oscillator. You may wish to include an rf amplifier on the higher frequency bands; none is required for the 40-meter band.

Fig. 10 shows two versions of the input filter. That at A is without the optional rf-amplifier stage, while that at B shows a filter with the rf amplifier. The same board layout is used for both versions; a wire jumper (W) between points X and Y is used when the amplifier is omitted.

Consider first the option without the rf amplifier stage. There are two filter circuits shown that may be separated at points X-Y. The input filter (to the left of the X) is a five-pole low-pass type. Use of this filter section was necessary to eliminate spurious responses resulting from strong TV and fm broadcast station signals. This problem results from the tendency of diode-ring mixers toward harmonic mixing. The second filter (to the right of point Y) provides the major portion of the front-end selectivity. It is a double-tuned circuit composed of L12, L13 and the related capacitors. These filters were designed for a Butterworth response, but may be shifted to a Chebyshev response with a slight increase in the value of C22. The filters were designed while using the equations presented in Appendix 2 of reference 4.

A variable capacitor (C22) is used as the coupling element between the resonators. This was done in the interest of component selection. Small, nonstandard capacitance values are often difficult to obtain, whereas a 1- to 5-pF variable trimmer is common. The proper capacitance setting for C22 may be taken from Table 3.

Use a signal generator to align the filters. If one is not available, a crystal calibrator may be used. Terminate the filter input with a 50-ohm resistor. C22 is set initially near minimum capacitance, and the receiver is tuned to the band center. C23 and C25 are adjusted to provide a peak response. The capacitance of C22 is then increased, and C23 and C25 are repeaked. Filter bandwidth is estimated by tuning toward the band edges, repeating the alignment procedure until the desired bandwidth is realized.

A dual-gate MOSFET is used for the rf amplifier in the version shown in Fig. 10B, along with a modified input low-pass filter. This modification produces a pi network that transforms the 50-ohm filter

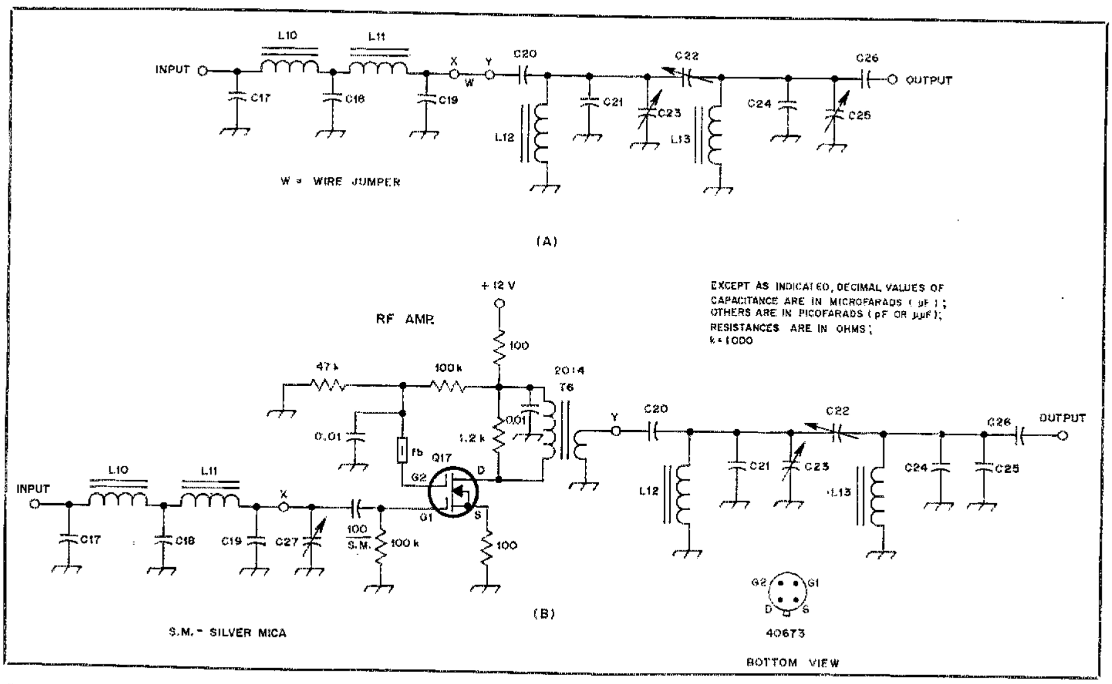


Fig. 10 — Input filter/amplifier circuitry. The same pc board pattern is used for the circuits of A and B. At A, a jumper wire is used when no rf amplifier (as shown at B) is employed. The circuit at B is recommended for operation at frequencies above 40 meters. Resistors are 1/4-watt, 5% composition or metal film types. Refer to the parts list and Table 3 for component descriptions.

Q17 — Silicon n-channel dual-gate rf-amplifier MOSFET, 40673, 3N211, 3SK40 or equiv.

T6 — Ferrite transformer, 20-turn primary, 4-turn secondary, no. 28 enameled wire on FT37-43 core.

Table 3

Input Filter Components

Without rf amplifier:

Frequency (MHz)	C17 C19 (pF)	C18 (pF)	L10* L11 (turns)	C20 C26 (pF)	C21 C24 (pF)	C23 C25 (pF)	C22 (turns)	L12* L13 (turns)
7.1	430	860	17	42	50	180	4.6	25
10.1	300	600	13	32	50	180	4.1	17
14.2	220	430	12	20	—	180	2.3	17
18.2	180	360	10	22	50	180	3.9	10
21.2	150	300	10	18	—	180	3.0	10
24.2	130	270	9	14	—	180	2.1	10
28.5	110	220	8	12	—	180	1.6	10

With rf amplifier:

Frequency (MHz)	C17 (pF)	C18 (pF)	C19 (pF)	C27 (pF)	L10* (turns)	L11* (turns)
10.1	300	680	33	50	13	29
14.2	220	500	22	50	12	25
18.2	180	390	—	50	10	22
21.2	150	330	—	50	10	20
24.2	130	300	—	50	9	19
28.5	110	250	—	50	8	17

Note: Other filter parts identical to that without rf amplifier.
*All inductors wound with no. 22 enameled wire on T50-6 cores.

Table 4

Performance Summary

Circuit	Rf amp.	Bandwidth (Hz)	NF (dB)	IP_{in} (dBm)	MDS (dBm)	DR (dB)
Single conv.*	no	500	16	+18	−131	99
Single conv.	no	2500	16	+18	−124	94
Single conv.	yes	500	5	+2	−142	96
Single conv.	yes	2500	5	+2	−135	92
Dual conv.	no	500	18	+12	−129	94
Dual conv.*	no	2500	18	+12	−122	89
Dual conv.	yes	500	6	−2	−141	92
Dual conv.*	yes	2500	6	−2	−134	88

Rf amplifier assumed to have a 3-dB noise figure, a 15-dB gain and a +22-dBm output intercept. Circuits marked (*) are measured cases. All measurements done at 14 MHz.

impedance up to about 2000 ohms, with a Q of 10, to provide a near optimum driving impedance for the amplifier. The amplifier output circuit uses a broadband ferrite transformer to present a 50-ohm output impedance to the following double-tuned circuit. This ensures a proper termination. This two-pole input preselector filter is aligned as previously described, then the pi network section is adjusted, peaking the response by means of C27 at the band center.

The amplifier uses no source-bypass capacitor. During evaluation it was found that the gain of the rf amplifier was excessive when such a bypass was included, resulting in degraded receiver dynamic range. Removal of the capacitor dropped the gain from 25 to 15 dB with little change in the distortion characteristics; noise figure was still low enough.

Thoughts, Hints and Results

A number of construction details have been left to the discretion of the builder — band switching, the power supply and an enclosure. Band switching is not critical, because all switched points are low impedance. A multiwafer rotary switch would serve nicely. Something as mundane as a group of slide switches will work just as well. Small-diameter coaxial cable, such as RG-174/U, should be used for all signal lines. Some builders may wish to include an auxiliary audio power amplifier for speaker operation. Suitable circuits have been described in *QST*.

Other refinements could be included: an S meter (using a simple high-impedance voltmeter circuit attached to the agc line), a crystal calibrator or a digital readout. The constructor looking toward the future may want to include the WARC bands. Calculated data for these bands is provided, although the writers have yet to build these circuits.

Just as the receiver can be refined and made more elaborate, simplification is also possible. For example, a converter may be used with the original D-C receiver. Or, a simple superhet may be built by eliminating the i-f amplifier. A crystal filter mounted on a board with a pair of impedance-matching, 50-ohm pi networks could be inserted between a mixer module and the detector. This could be refined by placing a single i-f stage after the filter. A single-conversion receiver for 14 MHz may be built by replacing the 80-meter preselector with one for 20 meters and by choosing the appropriate VFO frequency. There is no need to include bands that you are not interested in. Use of an ssb filter, with provisions for selecting sidebands, is not warranted for the devoted cw enthusiast.

System measurements were performed on constructed receivers at various stages of development. The data is summarized in Table 4. Measured data is extended with calculations to give the prospective builder some feel for the performance to be expected.[14] Measurements and calculations generally agreed within 1 dB.

Table 4 reveals no surprises. The nature of the trade-off between single and dual conversion is well illustrated, as is the effect of adding an rf amplifier stage. That system showing the greatest dynamic range is the single-conversion design without the rf amplifier. It should be emphasized that the data in Table 4 pertains to the modules described. Changes in gain, noise figure or intercept of any stage will change the results.

The dual-conversion systems are about 5 dB "weaker" than the single-conversion ones — a typical situation. It should be understood that this observation applies only to dual-conversion systems with a wide bandwidth, first i-f section. Modern systems that use a crystal filter at the first i-f will display performance much the same as that of a single-conversion receiver, even if they use many conversions. Still, traditional dual conversion seems to be a reasonable compromise if the overall gain distribution is well controlled.

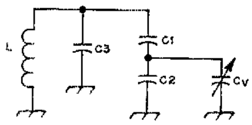
No gain compression was measurable in a single-conversion model without an rf amplifier stage while using an input signal level of −10 dBm. The VFO phase noise was measured to be −152 dBc/Hz at a spacing of 10 kHz. While the writers have access to laboratory-quality instrumentation, all of the evaluations were done with home-built test equipment. This was done to emphasize that a reasonable receiver *can* be built and evaluated without the need for exotic instruments.

The results quoted represent performance that rivals or exceeds that of most commercial equipment available to the amateur. These receivers are pleasing to use, offering a clean, crisp sound that is not always found in the commercial equivalents. Of great significance is that the receiver should be easily duplicated, with a cost well under that of a similar "appliance."

The writers gratefully acknowledge the interest and ideas of many friends. We would especially like to thank Roy Lewallen, W7EL, for all of the data he has shared with us during the two-year period devoted to this project.

Appendix

Calculation of capacitor values for a VFO using an arbitrary capacitor.



In the following equations, the inductance (L) is expressed in henrys, capacitance (C) in farads and frequency (f) in hertz. Follow the sequence of equations as shown. f_b and f_u represent the lower and upper frequency limits to be tuned. C_v is the *range* of the variable capacitor.

$$\omega_b = 2\pi f_b$$

$$\omega_u = 2\pi f_u$$

$$C_b = \frac{1}{\omega_b{}^2 L}$$

$$C_u = \frac{1}{\omega_u{}^2 L}$$

$$\Delta C = C_b - C_u \qquad \text{(Eq. 1)}$$

Pick a value for C1 and C_v. Then let:

$$x = 2C1 + C_v$$

$$y = C1C_v + C1^2\left(1 - \frac{C_v}{\Delta C}\right) \qquad \text{(Eq. 2)}$$

Then, C2 and C3 are given by:

$$C2 = 1/2\left(-x + \sqrt{x^2 - 4y}\right)$$

$$C3 = C_v - \left(\frac{1}{C1} + \frac{1}{C2}\right)^{-1} \qquad \text{(Eq. 3)}$$

Example:

$L = 3\mu H$, $f_b = 7$ MHz and $f_u = 7.2$ MHz.

Then $C_b = 172.3 \times 10^{-12}$ F
$C_u = 162.8 \times 10^{-12}$ F.

Choose C1 = 50 pF and $C_v = 355$ pF (variation in a 365-pF variable capacitor).

Then, $x = 455 \times 10^{-12}$,
$y = -73.76 \times 10^{-21}$, yielding
$C2 = 126.8 \times 10^{-12}$ F and
$C3 = 127.02 \times 10^{-12}$ F.

Notes

[1] R. Lewallen, "An Optimized QRP Transceiver," *QST*, Aug. 1980, p. 14.
[2] Etched circuit boards and many of the required parts are available from Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002. Pc templates and parts overlays are available from the ARRL for $2 and an s.a.s.e.
[3] R. Hayward and W. Hayward, "The Ugly Weekender," *QST*, Aug. 1981, p. 18.
[4] W. Hayward and D. DeMaw, *Solid-State Design for the Radio Amateur* (Newington: American Radio Relay League, 1977).
[5] See note 1.
[6] See note 1.
[7] Toroid cores used in these receivers are available from Amidon Associates, 12033 Otsego St., North Hollywood, CA 91607.
[8] See note 2.
[9] Fair Radio Sales, P.O. Box 1105, Lima, OH 45805.
[10] See note 4.
[11] See note 1.
[12] Spectrum International, P.O. Box 1084, Concord, MA 01742.
[13] See note 4.
[14] The noise factor formula for two cascaded stages is given in Chapter 6 of reference 4. Also presented are the relationships between intercepts, noise figure and dynamic range. The output and input intercepts of a given stage differ only by the stage gain. Intercepts may be combined for a cascade by noting that the output intercept of one stage adds to the input intercept of the following one in exactly the same way that resistors in parallel combine so long as the intercepts are presented in milliwatts rather than in dBm. This relationship assumes that the third-order intermodulation distortion is coherent. (This relationship is derived in Hayward's *Introduction to Radio Frequency Design*, Prentice-Hall, Englewood Cliffs, NJ 07632, to be published early in 1982. Also see B. P. Gross, "Calculating the Cascade Intercept Point of Communications Receivers," *Ham Radio*, Aug. 1980, and W. Sabin, "A BASIC Approach to Calculating Cascaded Intercept Points and Noise Figure," *QST*, Oct. 1981.)

Strays

"Thanks for the memories . . ." might better have been sung, "Thanks for jogging the public's memory circuits," as Jim Dudley, W5HYW, presented an award to comedian Bob Hope in appreciation of his efforts in promoting Amateur Radio. A plaque, outlined by Hope's famous profile, was given by the Port Arthur (Texas) ARC on the occasion of the Bum Phillips Celebrity Golf Tournament. Amateur Radio fraternities from Jefferson and Orange Counties, Texas, served as the communications arm of the event. *(photo by WB5YIF)*

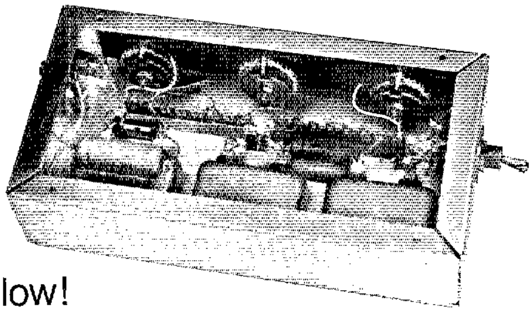
APPLICATIONS FOR GENERAL MANAGER, ARRL

The present General Manager of the League is retiring in the spring of 1982, and the Board of Directors seeks a qualified replacement. Those wishing to submit their applications for this challenging post should do so prior to January 1, 1982. Send your resumes and any supporting data to Ray Wangler, W5EDZ, Chairman of the ARRL Management & Finance Committee, 642 Beryl Dr., San Antonio, TX 78213.

The General Manager, ARRL, is charged with managing and directing League operations under policies established by the Board of Directors. He employs and oversees the operations of a staff of 115, ensuring that they maintain professional standards. He maintains sound financial policies and procedures, involving an annual budget of six million dollars. He assists the president in representing the League with national and international government agencies and other Amateur Radio organizations, and serves as secretary of the International Amateur Radio Union. He is responsible for developing effective programs for the growth of the Amateur Radio population and of League membership, which currently stands at over 150,000. He is responsible for initiating plans, programs and policies for the advancement of Amateur Radio which are presented to the Board for approval. He must monitor all aspects of the Amateur Radio Service in order to advise and counsel the Board. He also serves as the Editor of *QST*.

A demonstrated knowledge of management skills, a wide-ranging interest in and knowledge of Amateur Radio and ARRL, and evidence of leadership will be in your favor.

New Selectivity for Old Receivers



Razor-sharp selectivity aids in sorting out those signals when the band is crowded. The performance of this filter provides a difficult act to follow!

By Frank Noble,* W3MT

Most old, tube-type receivers have a passband that is far too wide for modern cw reception. Some have drifting oscillators and sloppy tuning (backlash); for these there is little hope. But, if the receiver is frequency stable and has good tuning, the performance can be improved greatly with a narrow band-pass filter in the audio-output circuit. The filter described here is inexpensive and crude, but *very* sharp and unconditionally stable. The owner must be willing to make a simple modification to the receiver when using it.

If the loudspeaker is disconnected, the output transformer becomes an audio choke that passes dc, but has a fairly high impedance at audio frequencies. Now, let's install the simple R-C network shown in Fig. 1. It produces a high-level (up to 175 V) source that measures 5-kΩ internal impedance, typically. The 470-kΩ resistor has no audio function; it simply charges the coupling capacitor so the output will not shock the operator or harm the filter.

The filter (Fig. 2) consists of three telephone toroids tuned to the same frequency and top coupled by means of large-value resistors. This arrangement has a single sharp-resonance peak, a bandwidth as narrow as can be used with moderate-speed cw and good skirt selectivity. The circuit has been designed so that all three resonant circuits have the same Q; this was done to achieve the best possible skirt selectivity for a given bandwidth. The performance approximates that of a cascaded set of three isolated tuned circuits, each having a Q of 14.3, as shown in Fig. 3.[1] (The response is approximately symmetrical with respect to the resonant frequency.) It will be observed that the skirt selectivity improves as the number of tuned circuits increases. Unfortunately, the attenuation also increases with the number of tuned circuits so that three is the maximum practical number unless additional amplification is used.

Tuning Procedure

For a filter this sharp it is vital to tune all LC circuits to exactly the *same* frequency. (The absolute frequency is inconsequential.) To do this, the following procedure is recommended. With reference to Fig. 4, the oscilloscope indicates the phase angle of LC. At exact resonance, the phase angle is zero, as indicated by a line slanting upward to the right. Find which LC network resonates at the lowest frequency. Leaving the oscillator set at this frequency, remove this network and install another. Add capacitance until the line is restored on the oscilloscope. Repeat for the third LC network. Then recheck all LC assemblies to

*10004 Belhaven Rd., Bethesda, MD 20817

[1]Notes appear on page 23.

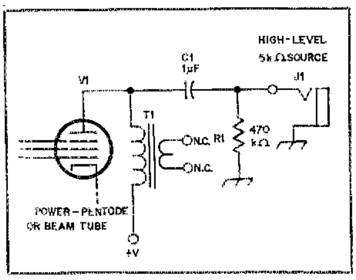


Fig. 1 — Receiver modification to drive the filter. The 1-µF capacitor should be rated at 600 V and may be a paper or film type. J1 is a single-circuit, nonshorting phone jack. R1 is 1/2 watt, carbon composition.

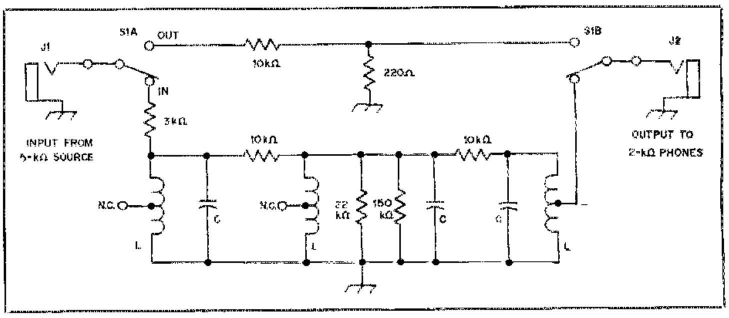


Fig. 2 — Schematic diagram of the narrow band-pass filter. C is rated at 1 µF at 400 V and may be paper or film. J1 and J2 are single-circuit, nonshorting phone jacks. Each toroid (L) is 44 mH. The resistors are 1/2 watt, carbon composition. S1 is a dpdt toggle switch.

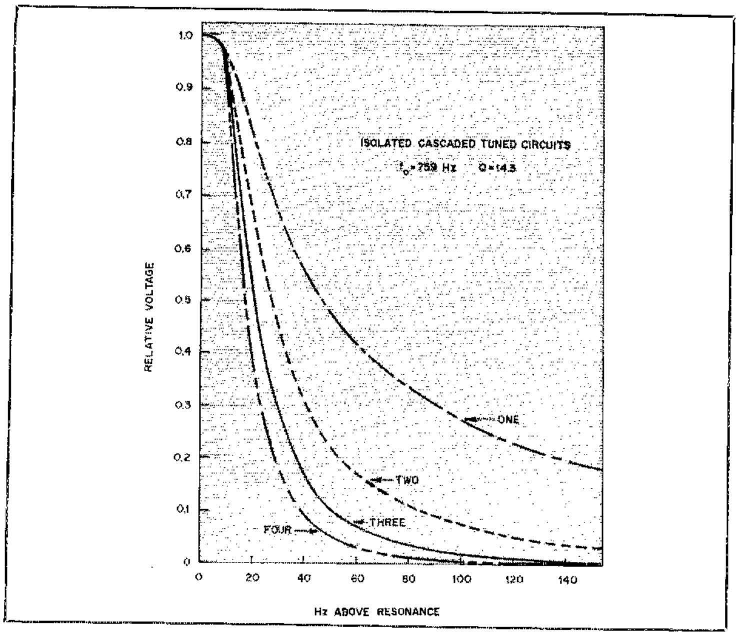


Fig. 3 — Frequency response of cascaded resonant circuits. The sharpness becomes greater as the number of circuits is increased from one to four.

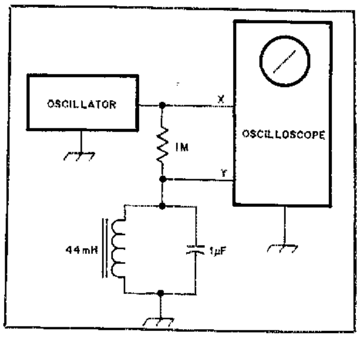


Fig. 4 — Arrangement for setting tuned circuits on frequency. The procedure, described in the text, is to tune the oscillator for a slanted line on the oscilloscope ($f_o \approx$ 759 Hz). Resistance is in ohms.

be sure the oscillator has not drifted. When all three produce the desired "scope" line, they are on the same frequency, with a high order of accuracy.

The circuit may be wired now and put to use. Note that 2-kΩ phones are specified. Phones having another impedance should be matched to 2 kΩ, preferably with a transformer, to minimize loss.

Since the toroids have no external field (self-shielding), by reciprocity, they will pick up no external fields; hence shielding is not necessary. Any enclosure (or none) will be quite satisfactory. The layout is entirely noncritical.

Theory

At resonance, a parallel LC circuit looks like a resistance

$$R_O = Q_O\sqrt{\frac{L}{C}} \qquad \text{(Eq. 1)}$$

For the 44-mH toroid resonated with a 1-μF capacitor, the unloaded Q_O measures 35, so for this case R_O = 7342 ohms. The loaded Q is $R_p\omega C$, where R_p is the parallel value of R_O and the net resistive shunt imposed by the external circuit. If we were to connect the 2-kΩ phones directly across the coil, R_p would become 1572 ohms, and the Q would drop to

$$\frac{35 \times 1572}{7342} = 7.494 \qquad \text{(Eq. 2)}$$

corresponding to a bandwidth of 101 Hz, as determined by

$$B = \frac{f_o}{Q} = \frac{759}{7.494} \qquad \text{(Eq. 3)}$$

The additional loading imposed by the signal circuit would lower the Q further, making the bandwidth still greater. To prevent this, we connect the phones to the center tap, so that they reflect 8 kΩ across the coil. This shunt will reduce Q_O by less than half, which is far more reasonable. The output impedance now looks like a resistance on the order of 3828 ohms. The coupling resistor should be of a large value compared to 3828 ohms to prevent excessive reduction of the Q and to provide the isolation between resonators required to obtain selectivity. On the other hand, too much resistance will make the attenuation excessive. We arbitrarily assign the value 10 kΩ. Recall that all resonators are to have the same Q. Referring to Fig. 2, to simplify matters, we make the center section symmetrical by using two 10-kΩ coupling resistors. Now, whatever shunting is done on the center coil for Q adjustment will result in equal loading effects on the other two coils. If all Q values are to be the same, we must start by making the loading the same on the input and output coils. This means the input coil must see 8 kΩ looking back at the source; since the source impedance is 5 kΩ, we use the 3-kΩ series resistor to satisfy this requirement. The procedure to find the shunt for the center coil is too lengthy to present here. It turns out to be about 19 kΩ and is provided by the parallel resistors. The Q factor mandated by the calculation is 14.3. Fig. 3 shows that the 6-dB (or 0.5 relative voltage) bandwidth is 40 Hz.

When the filter is switched out, the resistive attenuator sets the level to equal the peak output level of the filter. If the filter is not terminated in 2 kΩ, the Q factors will not be identical, and the skirt selectivity will be degraded.

Results

The minimum bandwidth required to copy 25-wpm cw under good conditions is given as 60 Hz;[2] no conditions on the filter shape factor are given. Although the details are beyond this writer's ken, it is generally accepted that ringing is related to the way the filter rolls off. Even with 40-Hz bandwidth this filter does not ring objectionably; the writer has been able to copy 40-wpm cw through average QRM and noise. The greatest practical problem is keeping the signal in the slot. This is inevitable if you want just one signal.

A word on low gain: If the receiver gain is low (or the phones are insensitive), the three-coil filter may have too much loss. The best solution is to correct the receiver deficiency, resorting to additional amplifiers if necessary. An easier solution is to eliminate the center coil, then top couple the input coil to the output coil through a 10-kΩ resistor. This will result in degraded skirt selectivity, as shown in Fig. 3. However, the writer has used several filters of this type, and the performance was still good. The filter-out attenuator will need to be changed so the level does not shift greatly when the switch is thrown. A good start would be to replace the 220-ohm resistor in Fig. 2 with an 820-ohm resistor. QST

Notes

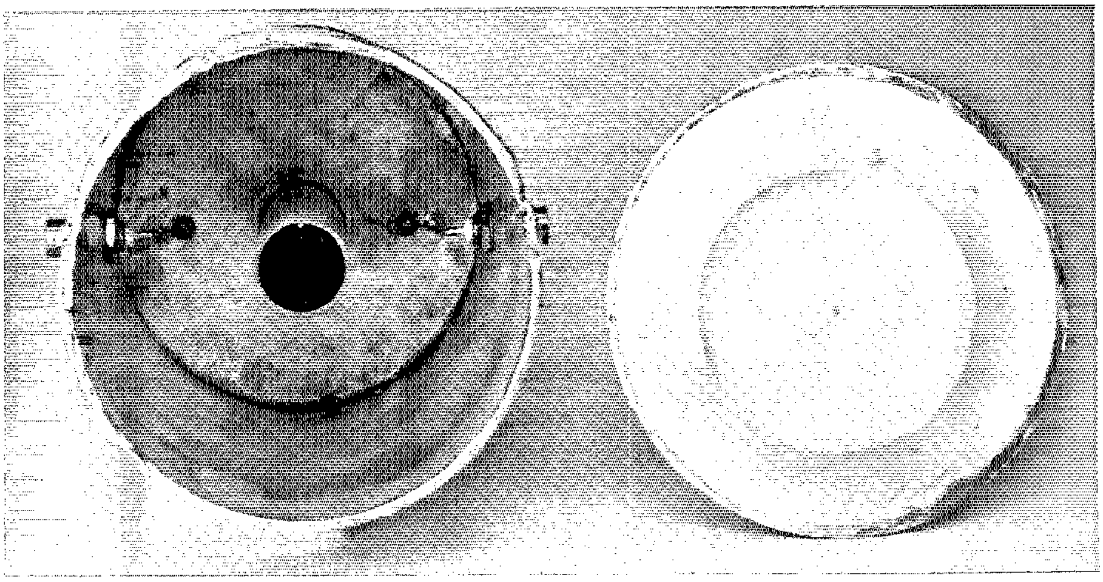
[1]Adapted from the Universal Resonance Curve presented in Terman, *Electronic and Radio Engineering* (New York: McGraw-Hill, 1955), p. 48.

[2]*Reference Data for Radio Engineers*, 3rd ed. (New York: International Telephone and Telegraph Corp.), p. 18.

Simple, Inexpensive Plating Methods for VHF and UHF

Have you noted degraded vhf or uhf circuit performance after a few months' use? The cure may be easier than you think.

By Robert D. Shriner,* WAØUZO



Some vhf and uhf circuit failures can be traced to oxidation of components, circuit-board foils, grounds and other conducting surfaces. Unprotected copper surfaces often fall victim to this naturally occurring process. As operating frequency increases, skin effect (the tendency for rf currents to flow nearer to the surface of a conductor) becomes more pronounced. Oxides that are of no consequence at audio or hf suddenly take on villainous significance! I have discovered a few situations where oxides had formed de facto semiconductors.

Remedies

I suppose that the best solution is to use components with pure gold leads but that is impractical. Pure silver is another expensive option. Electroplating systems offer the best industry compromise in terms of performance and cost, but the plating equipment may be too expensive for the home-construction enthusiast. Immersion plating techniques, however, when done carefully, can provide a workable alternative for the individual builder. The drawback is that the coat of plating material is thin and can be removed easily with light scratching.

Immersion silver plating on copper is, in my opinion, the easiest plating operation for the home-construction devotee. A similar process can be used to plate copper onto steel or iron with a hydrated copper sulphate (sold by drug stores under the name "blue vitrol"). Once this operation is complete, silver can be plated on the copper coating. Aluminum can be plated, but the process requires a skill level beyond that of the novice plater.

Surface Considerations

The surface to be plated must be thoroughly clean. To test for cleanliness, pour on a little water. If the water spreads evenly without beading or breaking, the surface is clean enough. If it beads or breaks, additional cleaning is called for. Muriatic acid, a diluted solution of hydrochloric acid, may be used to cleanse the surface. I suggest that you use a solution of no greater strength than 10%. As with all other chemicals mentioned in this article, *please use caution* and follow the directions on the containers. Once the surface has been polished with fine steel wool, use rubber gloves and small balls of cotton to apply the acid cleaner. After

Photo: Internal view of a 220-MHz cavity. Although somewhat discolored, the silver-plated conductors have been in service for several years without degraded performance.

*Box 969, Pueblo, CO 81002

light rubbing, rinse the material under cold running water to remove any traces of the acid. Set it aside to dry and make absolutely sure that nothing comes in contact with the surface to be plated after it has been cleaned.

Probably the least expensive silver-plating solution is discarded "fixing solution" used in developing black-and-white photographic film. You can probably obtain this from a local photographic studio or from businesses doing X-ray work. Some fixing solutions make better plating agents than others. You may have to try different sources before you find one that will work satisfactorily. Or if you choose, you may purchase a silver-plating solution from a chemical supply house.

Make sure that your hands are clean and avoid touching the surface that is to be plated. Pour a small amount of the plating solution into two containers. Use a steel-wool pad dipped in the first container to polish lightly the surface to be plated. This will further clean the surface and leave a bit of the plating on the material. Immerse the material in the second container or use a cotton swab to spread the solution evenly over the surface. You should now have a uniform layer of silver on the copper. Thoroughly wash the surface to remove all traces of the plating solution by holding the plated surface under running water for several minutes. Next, carefully dry the surface with a soft cotton cloth. Do not allow any sharp object to come into contact with the newly plated surface. The silver plating is thin and not very durable if left exposed. However, the layer is adequate for surfaces not subjected to handling. Don't worry if the plating discolors, because silver changes into silver oxide, which is a good conductor at vhf and uhf. Do not try to protect the plated surface by spraying it with paint or lacquer: This will destroy the effectiveness. Once the surface is plated, do not touch it with your fingers, because the body oils left behind in the fingerprint will destroy the plating. This will degrade the performance at vhf or uhf.

Really, the only question left is whether a particular surface should be plated. Why risk finding out later that you should have plated it initially? I've never enjoyed taking a piece of equipment apart to fix something that was not done right in the first place. To paraphrase a popular advertisement, "you can plate it now or you can plate it later." The choice is yours.

[Editor's Note: There is a general belief that the Q of a silver-plated inductor or conductor is higher than that of a plain-copper conductor. This appears to be true at vhf and higher, but in the hf range and lower (owing to greater "skin-effect" penetration) there was no discernible difference in the unloaded-Q readings obtained with a specified coil during ARRL lab tests. However, even an hf-band inductor looks nicer when silver plated, and is less prone to severe oxidation than an equivalent inductor made from bare copper wire or tubing.]

New Products

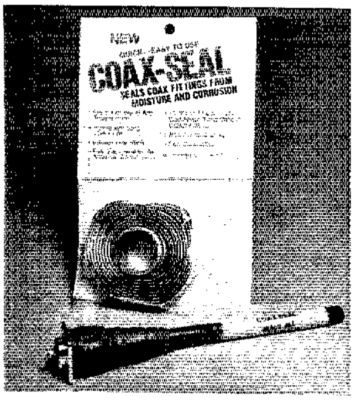
UNIVERSAL ELECTRONICS, INC. COAX-SEAL

☐ Any Amateur Radio operator who has to contend with outdoor antenna and feed-line connections (and that includes most of us) faces the problem of effectively sealing those connections from the elements. Many of us, I'm sure, have tried a number of sticky, messy and malodorous concoctions in an effort to ensure the integrity of the transmission line/antenna system. The degree of success obtained varies, and the search for the "right" sealing material continues. Perhaps your search has now ended.

Coax-Seal is a pliable, rubber-based plastic material that is easy to use and appears to be "just what the doctor ordered." It is supplied in 1/8-in. (mm = in. × 25.4) thick by 1/2-in. wide rolls, having a removable backing paper. Each roll is 60 in. long, supplying enough material to cover approximately five or six coaxial connector/cable assemblies. The green, tacky material may be hand-molded over fittings of any size or shape and adheres well to the coaxial cable outer vinyl jacket. The manufacturer claims flexibility, though not tested in the ARRL lab, will be maintained over a temperature range of −25° to 350° F (−4° to 177° C).

Tom Harrington, president of the company, says that Coax-Seal has been used commercially for eight years. It was first developed for microwave and TV system use. The material will not stain paint and is nontoxic and noncorrosive. It is meant to be applied to clean, dry surfaces at ambient temperatures between 50° and 90° F (10° and 32° C).

Members of the ARRL staff who had an opportunity to use samples of the material all reported that its application and sealing qualities are favorable. Exterior surfaces covered with Coax-Seal were clean and unaffected by the weather

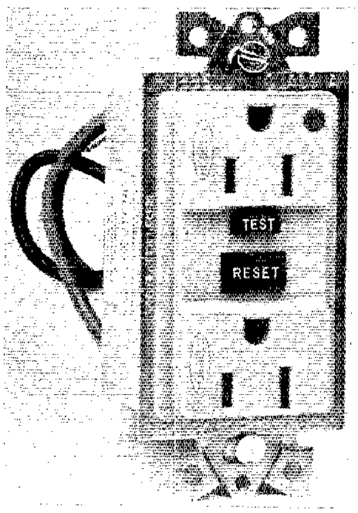


when uncovered months later.

Coax-Seal is available from Universal Electronics, Inc., 1280 Aida Dr., Reynoldsburg, OH 43068. Price class for the 60-in. roll is $2; 50-ft rolls are also available. — *Paul K. Pagel, N1FB*

HUBBELL GROUND FAULT INTERRUPTER RECEPTACLES

☐ The Hubbell Corporation has recently announced the addition of ground fault interrupter receptacles (GFIR) to their product line. Designed to replace standard 3-wire ac receptacles, the GFIRs provide safety by opening the line circuit in the presence of line-to-ground electrical shock hazards if the leakage level exceeds the unit trip level of 4 to 6 mA. This type of hazard may develop in faulty tools or appliances, or from defective insulation in line and extension cords.



Hubbell receptacles are available in either specification or hospital grade, 15 or 20 A/120 V units and in five different colors: brown, ivory, red, gray or white. All units feature external indication of ground fault, as well as front-mounted test and reset buttons. In addition, a feed-through feature allows the GFIR to provide shock-hazard protection for standard receptacles located downstream on the ac line. Installation is simple, for the units are engineered to fit in any standard 2-1/2-inch box. No additional spacers are needed.

Additional information and pricing are available from your local distributor or the Wiring Device Division, Harvey Hubbell, Inc., State St. and Bostwick Ave., Bridgeport, CT 06602. — *Dennis J. Lusis, W1LJ*

Compact Multiband Antenna Without Traps

Looking for an inexpensive, easy-to-build, portable antenna to use with your tube-type transmitter? This first cousin of the G5RV may be the aerial of your dreams.

By Taft Nicholson,* W5ANB/AAR6AG

Do you need an antenna for portable operation? I do! My preference is for making things as simple as possible. I don't like traps and matching units. The antenna shown in Fig. 1 has no traps, needs no matching unit for the 10-, 20- and 40-meter bands (when used with vacuum-tube PAs), is lightweight and installs easily. What more could you ask for?

Construction

Construction is simple. Cut two lengths of stranded copper wire (such as Radio Shack 278-1292) to 44 feet, 2 inches each (m = ft × 0.3048). Attach 36 feet, 8 inches of 300-ohm twin lead as shown in Fig. 1. Coaxial cable attaches to the other end of the twin lead at the points marked A and B in the diagram. I wound 7 feet, 2 inches of RG-58/U coaxial cable into an rf choke to minimize problems with rf flowing on the outside of the coaxial cable. This length of cable in the choke evolved from an attempt to match the antenna to the transmitter for operation on 15 meters.

Alternatively, you could use open-wire feeders in place of the twin lead. If you choose that method, you will need to make the section 42 feet, 6 inches long. Or you could attach the twin lead or open-wire conductors to a matching unit. When using a matching unit, there is no particular merit in the lengths given in the diagram.

SWR

The SWR of the antenna is less than 3:1 on 10, 20 and 40 meters. I have no difficulty loading transmitters with tube-type PAs (e.g., Galaxy V, Swan 350 or Drake T4X). This antenna will work with some transmitters on 15 meters, but tuning is quite critical.

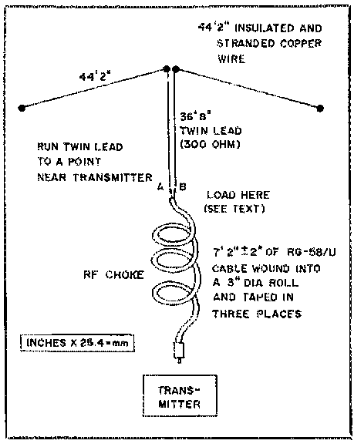


Fig. 1 — Diagram of the compact multiband antenna. For 80-meter operation the loading coil is inserted at points A and B. Banana plugs and jacks may be added here to facilitate insertion and removal of the loading coil.

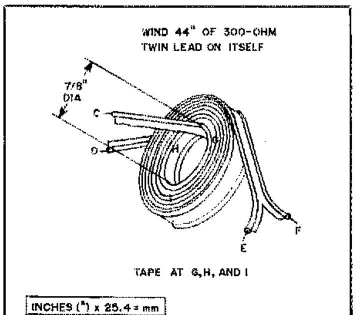


Fig. 2 — Loading coil for 3500-3750 kHz operation. Points E and F on the coil are connected to the coaxial cable. Points C and D are connected to the twin lead.

However, 80-meter operation is a problem. I have not been able to obtain full output power with these transmitters on frequencies below 3.750 MHz. The SWR measures between 5:1 and 8:1 for the lower part of the band. I constructed a loading coil to go between the choke and the twin lead (Fig. 2). The coil consists of 44 inches of twin lead wound on a 7/8-inch diameter form (my left thumb). Once the coil was wound, I removed it from my thumb and used electrical tape to secure it. For 80-meter operation, attach ends C and D to the choke and ends E and F to the twin lead. Remove the coil for operation on the other bands. Banana plugs and sockets can be used to facilitate the insertion and removal of the coil.

Installation

The antenna should be as high as practical. I've had satisfactory results with the center of the antenna only 25 feet above ground, with the ends tied to fences or other convenient supports. Telescoping TV mast sections make a good support if nothing else is available. The legs of the antenna serve as two of the guy wires. One or two additional guy supports should be added (nonconducting material such as nylon rope is best).

This compact multiband antenna works satisfactorily on all bands from 20 through 80, and 10, meters. It has no traps and requires no matching unit when used with tube-type equipment. I have used it for portable operation in and out of the country. It is easy to pack, carry and erect. Perhaps you might want to try one. I think you'll like it! A brief discussion of the theory of operation follows in the appendix.

[Editor's Note: A description of the G5RV appears in the RSGB *Radio Communications Handbook*. Gray described it in the June 1977 issue of *Ham Radio Horizons*. A similar design was depicted in the Collins Radio manuals of the 1930s.]

*2304 Willow Dr., Alamogordo, NM 88310.

Appendix

This multiband antenna evolves from two connected transmission lines with critical length and ratios of surge impedances. The system is self resonant at a fundamental frequency and at most of the even harmonics and several of the odd harmonics. The first five are 2nd, 4th, 5th, 7th and 8th.

Consider the transmission lines in Fig. 3.

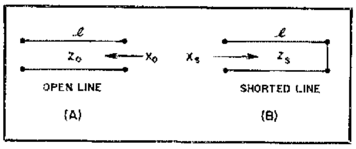


Fig. 3 — Two identical lengths of transmission line. Looking into the lines, the opposite ends are open and shorted at A and B, respectively.

The two lines are of equal length, "ℓ" and different surge impedances, Z_o and Z_s.

Looking into the lines:

$$X_o = \frac{Z_o}{\tan(2\pi\ell/\lambda)} \text{ and } X_s = Z_s \tan(2\pi\ell/\lambda)$$

where

λ = wavelength

X_o = reactance looking into open line

X_s = reactance looking into shorted line

From the theory of resonant circuits, we know if we connect the lines the system will be resonant at all frequencies where $\bar{X}_o = \bar{X}_s$, provided the two reactances are of equal value and opposite signs. The open and shorted line provide this condition except at some harmonics.

Joining the lines as depicted in Fig. 4 we find that

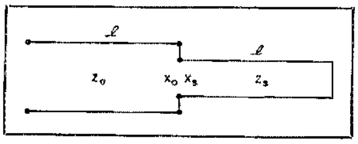


Fig. 4 — The two transmission lines from Fig. 3 are joined to form one line.

$$\frac{Z_o}{\tan(2\pi\ell/\lambda)} = Z_s \tan(2\pi\ell/\lambda)$$

$$\frac{Z_o}{Z_s} = \tan^2(2\pi\ell/\lambda) = \tan^2(360°\ell/\lambda)$$

If the angle $2\pi\ell/\lambda$ is made 60°, then the amplitude of the tangent at 120° or second harmonic will be the same. This will be true for 240° (4th harmonic) and 300° (5th harmonic). Similarly, these harmonic responses will continue at discrete angles above 360°, e.g., 7th, 8th, 10th, 11th, 13th, 14th and so on. The signs of the tangents wash out when squared.

The angle $2\pi\ell/\lambda$ becomes 60° by making $\ell = \lambda/6$ (1/6 of a wavelength) at the fundamental frequency.

$$\frac{Z_o}{Z_s} = \tan^2(360° \times 1/6)$$

$$= \tan^2 60° = (1.73)^2 = 3$$

Therefore $Z_o = 3Z_s$. This equation makes practical the multiband antenna because Z_o can represent the antenna proper and Z_s can represent the resonant feeder.

Z_o for the antenna may be computed from formulas in radio engineering handbooks or text books. For a piece of wire above the earth and parallel to it as shown in Fig. 5C

$$\frac{Z_o}{2} = 138 \log \frac{4h}{d}$$

For no. 12 wire, d = 0.08081 in.

Let h = 20 feet or 240 in.

$$\frac{Z_o}{2} = 138 \times \log\left(\frac{960}{0.08081}\right)$$

$$138 \log(11879) = 562 \text{ ohms}$$

This value is not critical. One can use 300-ohm twin lead or 400-ohm open line with good results. The harmonics will be displaced somewhat, but with variable tuning of the transmitter the system can be brought on frequency.

If the wire size had been no. 18,

$$\frac{Z_o}{2} = 605 \text{ ohms}$$

If we use no. 12 wire, then we would have 562 ohms on one side and + 562 ohms on the other side.

$$Z_o = \frac{Z}{2} + \frac{Z}{2} = 1124 \text{ ohms}$$

From the formula $\frac{Z_o}{Z_s} = 3$

$$Z_s = \frac{Z_o}{3} = \frac{1124}{3} = 374.6 \text{ ohms}$$

The above indicates that $Z_o/2$ varies with antenna height, wire size and configuration. The function is logarithmic and a lot can be done to the antenna before Z_o changes very much. The inverted V works well; just use the $Z_o/2$ formula for a horizontal wire and let h be the average height of the inverted V. A formula for surge impedance can be worked out for most any configuration, including a vertical. If the reader is interested in feeding a vertical antenna, he is referred to LaPort,[1] which has the fundamental information for finding surge impedance or characteristic impedance of antennas.

The system could be used for a single-ended antenna fed with a balanced transmission line with a balun at each end. Another possibility for a vertical is the use of a two-wire, grounded, open transmission line, as discussed in LaPort's book. The ground system would be critical.

When experimenting with these multiband lines, it is convenient to have some "stock" numbers to apply to the lines (see Fig. 6). One-sixth of a wavelength is one-third of a half wavelength. A convenient length for a half wave on 80 meters is 135 feet. One-third of that is 45 feet or $\lambda/6$ for 80 meters. One-sixth of a wavelength on 40 meters is 22-1/2 feet. When you are designing an antenna, these lengths need to be multiplied by the propagation constant of the line. After construction and testing, the dimensions can be pruned for end effect, etc.

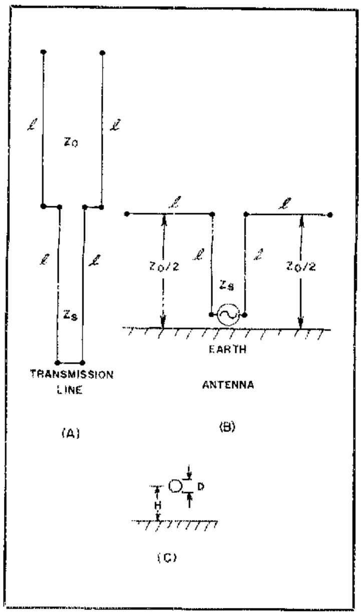


Fig. 5 — At A and B, the open portion of the transmission line evolves into the flat-top portion of the antenna. At C, diagram illustrating the formula for calculating Z_o for the antenna.

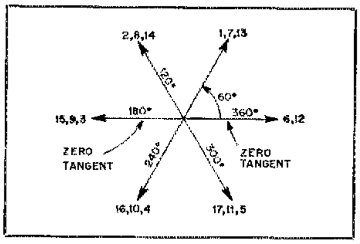


Fig. 6 — Angular position chart useful for determining "stock numbers" to apply to the chart.

When operated as a transmision line, the system as described may have application in end-feeding half-wave antennas, especially two half waves in phase. The system transforms a high impedance to a low impedance as a quarter-wave line will; however, it will do this at several even harmonics, in contrast to the quarter-wave line that is only responsive to odd quarter wavelengths.

The author wishes to thank Walt Maxwell, W2DU, for his detailed analysis of the theory section of this article. Further information about this antenna is available from the author. Please enclose a self-addressed, stamped envelope with your request.

Notes

[1]E. LaPort, Radio Antenna Engineering (New York: McGraw-Hill Book Co., 1952).

[2]See note 1.

Auto-start and Anti-space for the State-of-the-Art TU

Warm up that soldering iron and add these welcome features to that new terminal unit. They may be just what you've been waiting for.

By Robert Witmer,* W3RW

The terminal unit (TU) in December 1980 *QST* is a fine example of the simplicity of sophisticated electronic equipment designed and built with special-function ICs.[1,2] I built only the receive portion of the circuit and use it with a model 15 printer to monitor activity on a local 2-meter fm RTTY repeater. This demodulator is a "natural" for this type of service because of the noise-free nature of 2-meter fm operation. Described here is the circuit I added to the original demodulator to incorporate auto-start and anti-space. The parts needed should be easy to find and are inexpensive.

What is Auto-start?

The function of auto-start (also called automatic printer control) is to energize the RTTY printer only when an RTTY signal is present. Auto-start is almost essential if you want to monitor RTTY signals with an unattended printer — unless you don't mind the noise and power consumption of perhaps all but the newest printers when they are left on all of the time. If you don't want or need printer control, you can use the relay contacts to control an audio cassette recorder, which will record the received audio signal for later playback through the demodulator and printer.

The RTTY signal identification function has often been implemented with circuitry that samples the MARK and SPACE channels. It turns on the printer only when a signal with a duty cycle in excess of 75% has been sensed.,[3,4] Most cw and voice signals have a lower duty cycle. The 2-meter fm RTTY repeater I monitor performs this screening process for me as the repeating process ignores other modes of transmission and involves regeneration of the RTTY signal. The MARK (lock) detector output of the XR-2211 (pin 5) also performs a type of signal identification; this output will be used with the auto-start function. With the signal screening process completed, the only other desirable features to incorporate are turn-on and turn-off delays and anti-space circuitry. The delays minimize printer cycling when the repeater is keyed up by a "kerchunker" or between a series of transmissions. Anti-space circuitry keeps the printer in a MARK-hold condition during an absence of signal and when the motor control relay is timing out.

Adding Auto-start

The auto-start circuit of Fig. 2 consists of a modified 555 timer circuit employing U1, with the timer output driving a relay-driver transistor, Q2. The relay contacts control the application of 117 V ac to the RTTY printer motor. (An extra set of contacts could be used to open the loop supply to minimize power dissipation when the system is awaiting a valid signal.)

R1, R2, D1 and C1 form the input turn-on time delay part of the circuit and connect to the lock-detect output of the XR-2211 demodulator. This output goes low only when a signal within the lock range of the IC is present. Since this output is normally high, D1 provides a quick charge path for C1 when no signal is present, which keeps pin 2 of U1 high. When a signal is present, the lock-detect output goes low and provides a discharge path for C1 through R2, creating a turn-on delay of approximately five to seven seconds. U1 is triggered on the negative-going edge of an input pulse caused by the discharge of C1. When triggered, U1 starts a timing cycle with the output at pin 3 going high until the timing cycle is completed. The internal voltage comparator of U1 resets, completing the timing cycle, when the voltage on C3, charged through R4, reaches the trip point.

Without Q1, U1 would go through a timing cycle on the low input from C1 (discharged) and then reset — even if a low continued to be present. The function of Q1 is to keep C3 from charging and to prevent the timing cycle of U1 from being completed until the XR-2211 output goes high, indicating a loss of signal. Q1 provides a discharge path to ground for C3 as long as pin 2 of U1 is low. When pin 2 goes high, Q1 is turned off, C3 is allowed to charge and U1 completes the timing cycle, turning off the drive to Q2. The time delays can be varied by changing the values of R2/C1 for the turn-on delay and of R4/C3 for the turn-off delay.

Control Relay

I use a 12-volt dc, dpdt, 110-ohm coil relay with 10-A rated contacts for K1. Fig. 2 indicates the parts for R5 and Q2. Other relays can be accommodated by supplying the required dc operating voltage for the relay, choosing the correct transistor for Q2 and the proper value for R5. Q2 acts as a ground-return switch for the relay. It should be chosen to have a collector-to-emitter breakdown voltage (V_{CEO}) at least twice that of the relay supply voltage. A current-handling capability of at least several times that required by the relay coil should be ensured. In any case, do not forget D2; it protects Q2 from the high-voltage transients generated by the relay coil during switching. R5 should be chosen to provide a base current for Q2 at least equal to the relay current divided by the dc current gain of Q2. Being a little on the high side never hurts in switching applications like this, provided you don't ex-

[1]Notes appear on page 30.

*79 Blaine Ave., Leola, PA 17540

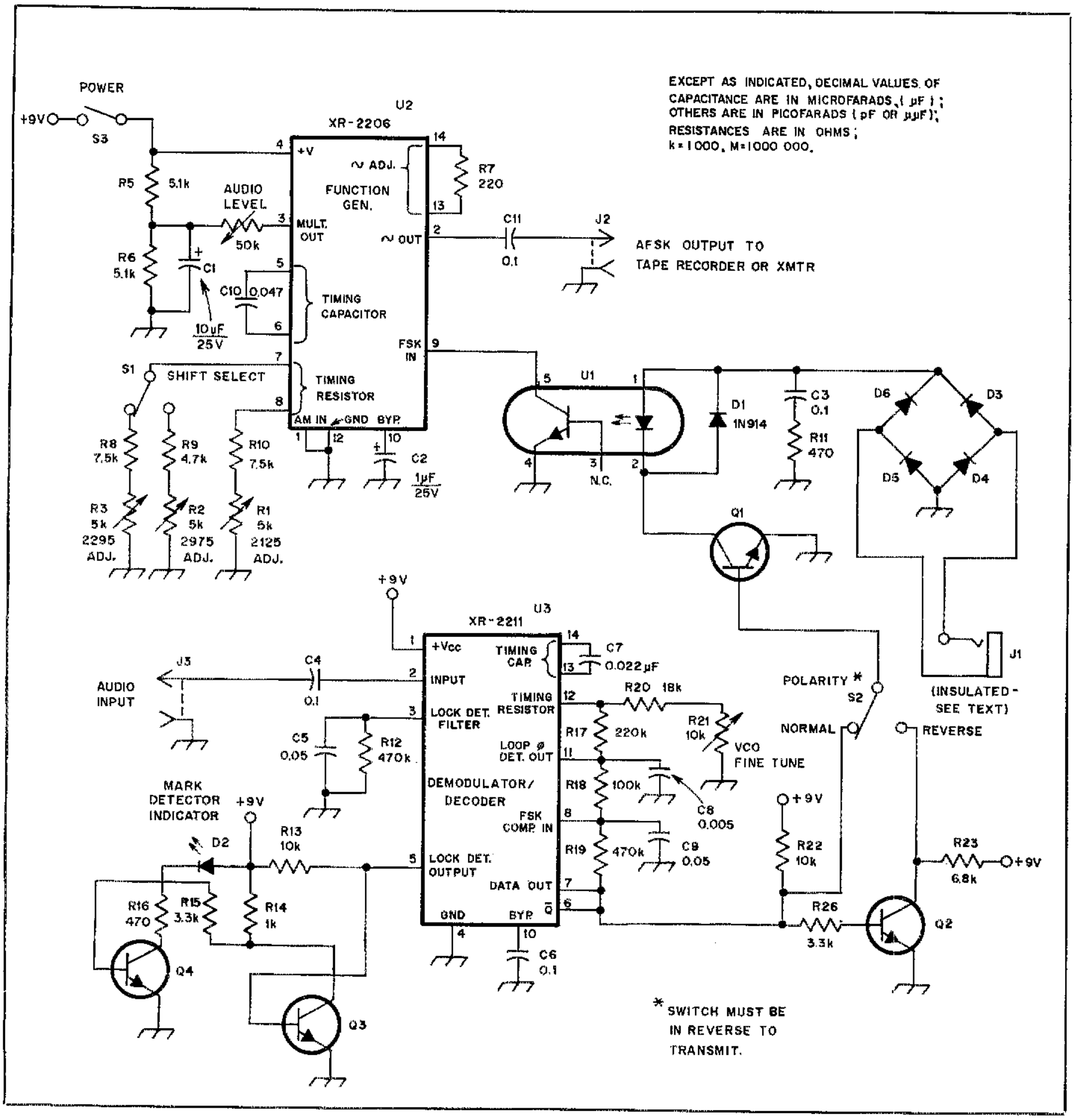


Fig. 1 — Diagram of the State-of-the-Art TU that was described in December 1980 *QST*. The diagram includes the correct value for C8 and connection data for R14. C3 should have a 400-V rating if a 150-V loop supply is used.

ceed the maximum base current limit.[5]

Anti-space

R8, R9, D3 and Q4 form the anti-space circuit. When the correct signal is not present, pin 5 of U1 (Fig. 1) is high. This turns on Q4, which supplies current through R9 and D3 to the base of the loop-keying transistor, keeping the printer in a MARK condition when no signal is present. Without this circuit the loop opens with a loss of signal, and the resulting chatter from the printer can be annoying. A 1N914 diode must be added to the original circuit of Fig. 1 between the NORMAL/REVERSE switch (S2) and the base of the loop-keying transistor. This diode and D3 connect directly to the base of the loop-keying transistor, as shown in Fig. 3.

Construction

Both the demodulator and auto-start circuits were constructed originally on perf board because of the simplicity of the receive-only circuitry. Another system is being built with Radio Shack IC prototyping pc boards. Two types are available, bearing part numbers 276-159 and 276-151. The use of these inexpensive boards is a great help during construction; the end product will have a more professional look than that obtainable with most perf boards.

I utilize a different MARK (lock) detector indicator circuit (shown in Fig. 2), which consists of R6, Q3, R7 and DS1. Those wishing to duplicate this circuit can disconnect the components from pin 5 of the XR-2211 IC and connect that pin

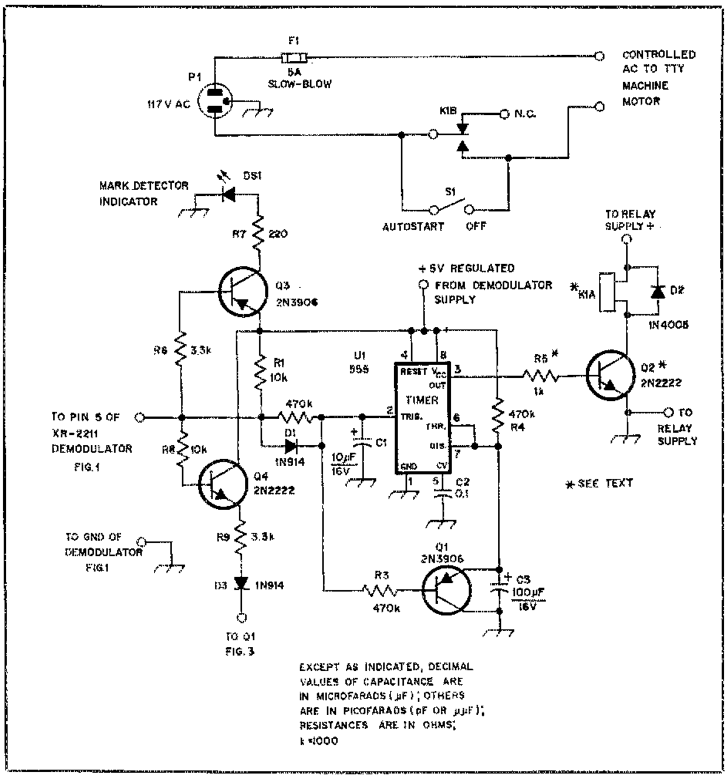


Fig. 2 — Auto-start, anti-space and mark-detector indicator circuit additions for the TU. The selection of K1 and Q2 is discussed in the text. All resistors are 1/4 watt, 5 or 10% tolerance units. Capacitors with polarity indicated may be electrolytic or tantalum types.

directly to the point shown in Fig. 2.

Supply Voltages

For my demodulator and auto-start circuits, I chose to use a 5-volt supply. A 12-volt, 450-mA battery eliminator (wall transformer) with a 5-volt regulator IC is employed. Changes required to the original demodulator circuit of Fig. 1 for operation with a 5-volt supply are the use of a 5.1-kΩ resistor for R22, a 3.3-kΩ resistor at R23 and a 1.8-kΩ resistor for R26. Since I did not use the transmit portion of the TU, I replaced the optoisolator diode of the original circuit with a 1N4005 diode. Note that both the demodulator and auto-start circuits should be operated at the same supply voltage. The afsk generating part of the TU can continue to be operated at 9 volts, since the opto-

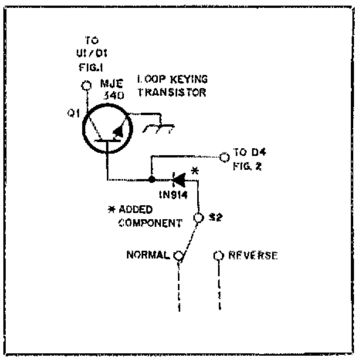


Fig. 3 — A diode must be added in the original circuit to incorporate the anti-space circuit.

isolator provides the necessary isolation.

Operation

When the demodulator/auto-start circuit is first powered up, the timer starts a complete timing cycle, and the motor control relay is energized. I find this to be a useful check of the auto-start function (not a problem). If desired, a switch can be placed in parallel with the relay contacts to provide a means of manual auto-start on/off control (S1 of Fig. 2).

The modifications and additions described here are easy to perform. Try them — it won't take you long to enjoy the improved operating conveniences.

Notes

[1]M. J. Di Julio, "A State-of-the-Art Terminal Unit for RTTY, *QST*, Dec. 1980, p. 20. Also, Feedback, *QST*, Feb. 1981, p. 46 and March 1981, p. 51; and Hints and Kinks, *QST*, July 1981, p. 45.
[2]"XR-2211 FSK Demodulator/Tone Decoder," *Phase-Locked Loop Data Book*, EXAR Integrated Systems, Inc., 750 Palomar Ave., Sunnyvale, CA 94088.
[3]I. M. Hoff, "The Mainline ST-3 RTTY Demodulator," *QST*, April 1970, p. 11.
[4]I. M. Hoff, "The Mainline ST-6 RTTY Demodulator," *Ham Radio*, Jan. 1971, p. 6.
[5]W. Hayward and D. DeMaw, *Solid State Design for the Radio Amateur* (Newington: The American Radio Relay League, 1977).

Strays

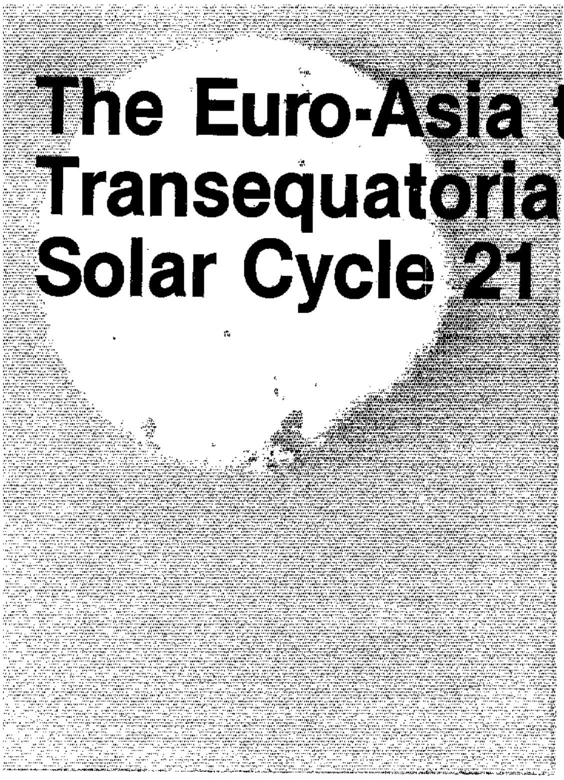
EXPERIMENTAL RADIO NET

☐ The communications subsection of the Long Island chapter of IEEE and the Long Island Amateur Radio Club will initiate an experimental radio net whose purpose will be to disseminate information about trends in the communications and electronics industry. Originating from Plainview, New York, the net should be accessible throughout Long Island and southern Connecticut. The net will operate on an output frequency of 147.375 MHz, and the target date for start up is November 11, at 8:30 P.M. Thereafter, it will operate on the second Wednesday of each month, directed by Ed Piller, W2KPQ. Interested Amateur Radio operators are being sought who can originate speakers and help with administrative details. Contact W2KPQ days at tel. 516-349-2484, other times at 516-938-5661.

I would like to get in touch with . . .

☐ anyone with a circuit diagram for an Eico Signal Generator Model 315. Bill O'Hara, W7TOJ, 3126 SE 36, Portland, OR 97202.

☐ amateurs who are board sailors to exchange information and discuss advancements in the sport of wind surfing. Jerry Swalling, WA7ZTT, 8525 Naketa Beach Rd., Mukilteo, WA 98275.



The Euro-Asia to Africa VHF Transequatorial Circuit During Solar Cycle 21

Part 1: "VHFers" have long suspected that Transequatorial Propagation would support 2-meter contacts over great distances. In 1978 that suspicion became reality. This is a two-part report on research conducted since then.

By Ray Cracknell,* ZE2JV, Fred Anderson,** ZS6PW and Costas Fimerelis,*** SV1DH

The current world long-distance record for a 144-MHz two-way QSO via the ionosphere, a distance of 4475 miles (kilometers = mi × 1.6093), is held by SV1AB and ZS6LW. The longest distance over which 144-MHz signals have been heard and recorded is from ZS3B in Luderitz (26°38′ S, 15°10′ E) to I4EAT in Faenza (44°17′ N, 11°48′ E), a great circle distance of 4930 miles.

Transequatorial Propagation

Countries bordering on the Mediterranean in Europe and Asia, as well as the coastal strip of North Africa, are ideally situated to enjoy optimum vhf and uhf transequatorial propagation (TE) into a belt of Africa stretching from somewhere north of Zambesi to the Orange River (approximately 15-30° S). Following is an account of the use made of these opportunities by a group of amateurs in Cyprus, Greece, South Africa and Zimbabwe during the high solar activity of Solar Cycle 21.

Twenty-two years ago, during solar cycle 19, amateurs in these areas explored the possibilities of TE at 50 and 70 MHz[1] with encouragement from The ARRL Propagation Research Project.[2] When solar-cycle 21 promised to produce peaks of solar activity almost as high as those experienced in solar-cycle 19, and propagation at 144 MHz was found possible,[3] old friends of the Africa circuit[4] got together with several new ones to take up the investigation again.

As the basic method of investigation, we monitored continuous transmissions from ZE2JV in Salisbury, Zimbabwe, on 29, 144 and 432 MHz; ZS6DN, near Pretoria, South Africa, on 28 and 144 MHz; and ZS6PW, in the suburbs of Pretoria, on 28, 50 and 144 MHz. Stations 5B4WR, 5B4AZ and 5B4HY in Limassol, Cyprus, and SV1DH and SV1AB in Athens, Greece, were on the monitoring end. We resumed propagation time measurements with much improved techniques. We successfully obtained Doppler-shift measurements between ZS6PW and SV1DH at 144 MHz. We looked at angles of arrival and again found they vary considerably. The characteristics of the signals, especially the flutter-fading and frequency spreading, were compared at various frequencies.

The Experiments

Our experiments this time concentrated on the 144-MHz band, but not exclusively. Communications at 432 MHz over the 3750-mile circuits proved to be possible, and we made detailed observations of the 10- and 6-meter transmissions and propagation times as well as those for 4 meters. As a result we were able to say, without fear of contradiction, that propagation on all these frequencies did indeed occur across the equator via the ionosphere. At times, particularly at night in years of high solar activity, the tropical ionosphere is capable of supporting propagation between optimum areas over a wide band of frequencies including the whole of the vhf and the lower portion of the uhf spectrum.

*13 Rowland Square, P.O. Belvedere, Salisbury, Zimbabwe
**101 van Niekerk St., Meyerspark 0184, near Pretoria, South Africa
***23 Ellanou St., Athens 817, Greece

[1]Notes appear on page 36.

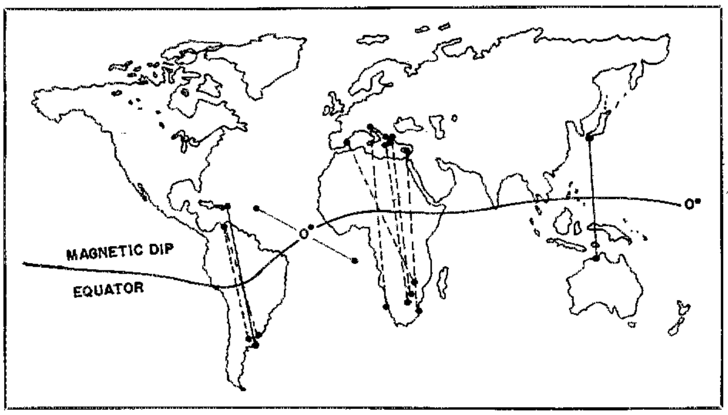


Fig. 1 — TE paths worked by amateurs on 144 MHz, showing the symmetrical distribution of stations with respect to the magnetic dip equator drawn on a map of magnetic inclination or dip, published by the U.S. Defense Mapping Agency Hydrographic Center.

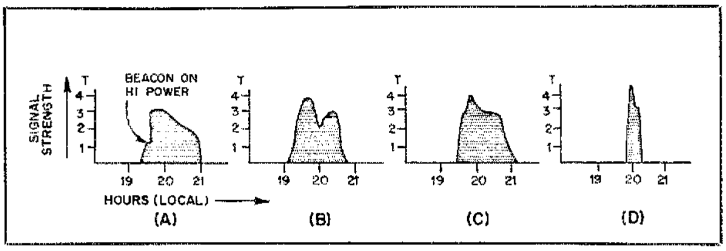


Fig. 2 — Typical signal strengths and duration of openings on 144 MHz: at A, ZE2JV at 5B4WR October 10, 1978; at B, ZE2JV at 5B4WR March 14, 1979; at C, ZE2JV at SV1DH March 25, 1980; and at D, ZS6DN at SV1DH March 25, 1980.

We found that as the signal frequency increased, the zones became more restricted to those equidistant from and perpendicular to the magnetic dip equator (Fig. 1). The duration of openings tended to be shorter and closer to 8 P.M. local time. We also found that the rate of flutter-fading and the degree of frequency spreading, both of which tend to characterize pure TE signals, likewise increased with signal frequency.

At lower frequencies (below 70 MHz) two-hop F-layer and F-type TE, which are supported by the high-density belts of the ionosphere forming on each side of the magnetic dip equator, may provide very strong signals during the afternoon and early evening. Later at night and sometimes in the early morning as well, only the weak and watery type of propagation we call pure TE was likely to be operative on frequencies of 50 MHz and above. In this two-part series we concentrate on pure TE, describe our experiments, detail the results achieved, and discuss modern theories and research relevant to the tropical ionosphere.

The Early Contacts

The initial contacts on 144 MHz occurred later over the African circuit than over Central/South American circuits. The strong signals reported by YV5ZZ[3] were not at any time in evidence. The first signals received in Cyprus by 5B4AZ from ZE2JV on April 8, 1978, and then by 5B4WR, SV1AB and SV1DH, were very weak, diffuse and difficult to copy because of rapid flutter-fading and frequency spreading. We were excited and thrilled because these QSOs arose, not from a chance hearing, but from careful preparation, and only after weeks of unsuccessful monitoring. Conditions improved thereafter, but the excitement died down, only to be revived by the appearance later in 1978 of ZS6DN's 144-MHz signal in Athens, and of ZE2JV's 432-MHz transmission in Athens and Cyprus in March and May 1979.

The geographical distribution of the TE paths worked by amateurs on 144 MHz is illustrated (Fig. 1) on a map of magnetic inclination, as published by the U.S. Defense Agency. TE paths are all between stations spaced more or less at equal distances from the magnetic dip equator and on paths that cross it at right angles. The greatest deviation experienced at 144 MHz is EA6FB on the Island of Ibiza, hearing ZE2JV's signal and ZD8DT on Ascension Island hearing KP4EOR.

Reliability and Seasonal Variation

After the excitement of the first QSOs, stations in Cyprus and Athens concentrated on monitoring beacon transmissions and plotting the daily and seasonal variations in reliability. SV1DH had spent 2500 hours monitoring by the end of December 1980. A comparable effort was maintained in Cyprus. Because of the low signal strengths encountered, the wide frequency spectrum to be covered and the number of stations to be monitored, mechanical means were not feasible. The combined efforts of our stations represent the only known systematic investigation so far made of the TE phenomenon above 100 MHz.

We first conducted tests on a 24-hour basis. Although some short, early-morning openings were recorded, no other daytime signals were heard. It soon became apparent that at 144 MHz the most significant openings were confined to a period of a little over two hours after the setting of the sun on the ionosphere. 5B4WR plotted graphs of every evening reception of ZE2JV's signals from April 1978 to December 1979. The results of two good evenings (October 10, 1978, and March 14, 1979) are illustrated in Fig. 2, together with SV1DH's reception of ZE2JV and ZS6DN on March 25, 1980. The Salisbury-to-Cyprus path proved to be the most reliable and provided, by a small margin, the strongest signals. It is remarkable that the South African stations were heard rarely in Cyprus, and when they were, they were very weak.

The monthly reliability of occurrence of propagation at 144 MHz over three circuits (Pretoria-Athens, Salisbury-Athens and Salisbury-Limassol) is illustrated in Fig. 3 for the period from March 1978 to December 1980. The three monthly running means are illustrated in Fig. 4. From these, the seasonal dependence, with maxima shortly after the equinoxes and minima at the summer and winter solstices, is clearly apparent. These results can be compared with the smoothed monthly value of solar flux and the average monthly values of geomagnetic activity that are illustrated in Fig. 5.

Complex Relationship

The relationship is complex. In general, it may be said that the high level of ionization that results from high solar flux is essential for TE at 144 MHz, and that magnetic disturbances disrupt it. However, when the solar flux is below about 180, and as the seasons near the summer and winter solstices, ionization is pushed high enough only for propagation at 144 MHz to occur in the period immediately following a solar outburst and before the arrival of the associated disrupting magnetic disturbance. Hence, prior to mid-1979, the reliability curves tend to follow the geomagnetic activity curve. After that time, when the magnetic index decreased, the curves follow the solar-flux curves much more closely. These conclusions are confirmed when our results and solar data are compared on a daily basis.

Signal strengths at 144 MHz were generally low. At SV1DH the strongest signal received via 144-MHz TE was from ZS6DN. This produced 0.6 microvolt across the 50-ohm input to the receiver. It represents a propagation loss of 43 dB, relative to free-space attenuation over a comparable propagation distance. Signals from ZE2JV were weaker, but lasted longer with a minimum propagation loss of 47 dB compared with free space. The strongest signals were received over the Salisbury-Cyprus (ZE2JV and 5B4WR) circuit with a minimum propagation loss of 40 dB, relative to free space being recorded.

Receivers

A good receiver with a front-end noise figure of 2 dB or less is essential for TE work at 144 MHz. As with other modes of ionospheric propagation, the noise level rises when the band opens; efforts to reduce the noise figure below 2 dB may not pay off. Above that figure many openings may be missed. Variable selectivity is desirable, but when the signal is broad because of frequency spreading, narrowing the selectivity excessively is not helpful.

Weak signals, received with flutter-fading, frequency spreading and poor notes caused by the propagation medium, are not suitable for RST code reporting. We reported with a simple T code in which T1 stood for signal present and

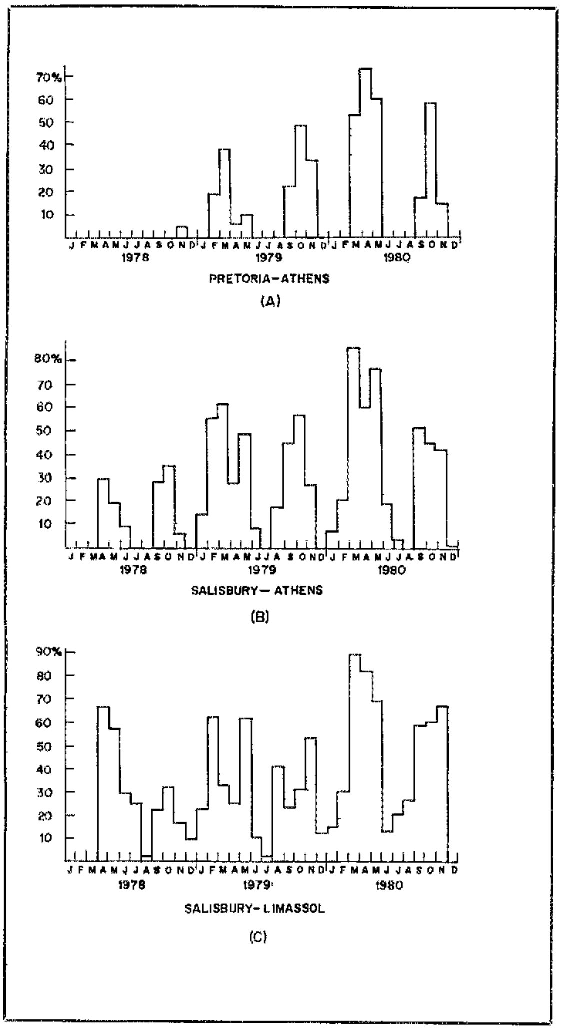


Fig. 3 — Reliability of occurrence of 144-MHz signals: at A, Pretoria-Athens; at B, Salisbury-Athens; and at C, Salisbury-Limassol.

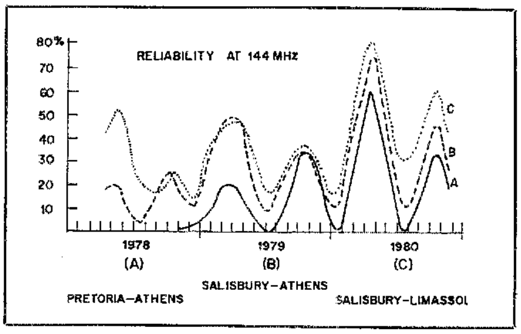


Fig. 4 — Smoothed reliability of occurrence curves for three circuits.

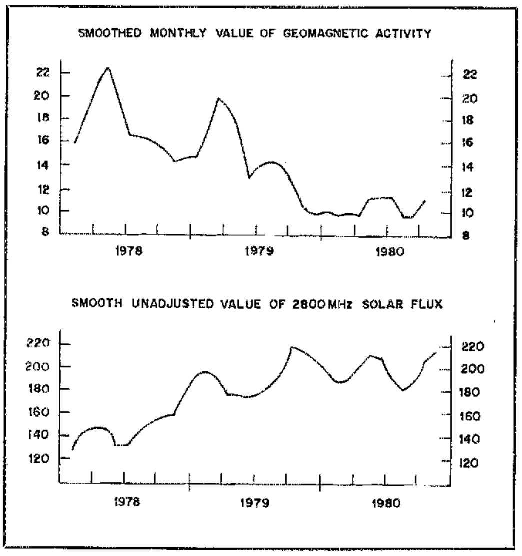


Fig. 5 — Smoothed monthly value of 2800-MHz solar flux and average monthly value of geomagnetic activity based on data extracted from the solar Geophysical Reports published by the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, USA.

recognizable, T2 for signal copied 50%, and T3 for signal copied 100%. For initial and record-breaking QSOs, we employed the RST code. Reports such as 317F (the report given by ZE2JV to 5B4WR on the first TE 144-MHz QSO over the Africa circuit) seemed to be a poor reward for the effort involved.

Transmitters

Under the best conditions, low-power transmitters (10 to 50 watts output) have been heard across the TE circuit. A power of at least 100 watts into a well-matched antenna proved necessary for comprehensive TE work. The effect of increasing power from the 40-watt, 24-hour beacon to 200 watts for the evening test period is illustrated in Fig. 2A. This resulted in a jump from a T1 (just recognizable) to a T3 (fully readable) signal. Below the 100-watt level the duration of openings is considerably reduced. Above that level, increased power improves the received signal proportionately without extending the length of openings to any appreciable extent.

Crystal oscillators, although quite satisfactory for working QSOs, present drift problems. Stabilization against a frequency standard is necessary when sophisticated measurements are attempted.

Cw (A1) was used for most transmissions, although ZE2JV used fsk (F1) to avoid TVI problems. Fsk has the advantage that casual listeners are less likely to tune through an F1 signal without hearing it. Against this, many operators find it difficult to copy, and more heat has to be dissipated in the PA than when using A1. Two-hundred watts of output on fsk was about as much as ZE2JV's Johnson Thunderbolt (two 4CX250Bs) could manage when running continuously in hot weather. ZS6DN used 100 watts (A1) into a high-gain antenna system on an excellent site. ZS6PW transmitted 150 watts, also on A1.

Between call signs, pulses were applied to these transmitters and used extensively for time-delay measurements. These pulses were in fact a series of dots. It would have been of great advantage to use pulses with much higher peak power, but this was not permissible because of licensing restrictions.

Antennas

We have avoided the term erp (effective radiated power) when discussing power. When working a mode of propagation involving multipath, off-line transmission and variable vertical angles, obtaining the optimum cone of radiation is difficult. Clearly, sharpening the beam directivity below the optimum will not increase the *effective* radiated power. This may even cause the signal to be lost.

An efficiently coupled antenna system is, however, essential for successful TE work. Time spent in optimizing a beam for maximum forward gain usually will be rewarded amply. The aim has to be the maximum transfer of power into or from space. Deficiencies in this respect cannot be compensated for by adding more elements to an array, once the optimum condition has been reached.

Many stations with large stacked beams were unable to work TE. We conducted tests at 432 MHz from ZE5JJ, a well-known moonbounce station, using 1 kW of rf into a 20-ft (meters = feet × 0.3048) parabolic dish, which could be aimed right down to the horizon. The installation produced signals in Athens that were no better, if as good, as ZE2JV's 40-watt one into a pair of horizontally spaced 8-element quagis. Stations farther out from the magnetic dip equator will likely have an ionospheric target low on the horizon. They will seldom be far off a direct great circle line from station to station. They may well benefit from big stacked arrays. ZS6DN used an array of four 16-element Yagis. ZS3B and I4EAT also used big arrays very successfully. Closer in, however, in Cyprus, Athens and Zimbabwe, single Yagis of 10 to 16 elements seem to provide the most reliable results at 144 MHz.

The Transponder System

The first TE propagation time measurements were devised some 21 years ago to prove or disprove a suggestion by Professor Obayashi[6] that TE signals traveled through field-aligned ducts outside the ionosphere. The method used was to transmit a series of dots on cw (A1) to the far end of the TE circuit, where a receiver in the cw mode produced a train of audio pulses. These audio pulses were then applied as modulation and transmitted back to the originating station. The returned pulses and a sample of the original outgoing pulses were displayed on an oscilloscope. Time markers were also applied. This represented the time taken by the signal to cover the distance between stations twice, plus equipment delays. The latter were found readily by repeating the experiment between stations that were a short, known distance apart and that used similar equipment.

Crude as it was, this method demonstrated that TE propagation times were slightly longer than normal two-hop F-layer propagation time. They were never long enough to indicate that any extraordinary path outside the ionosphere was being followed by either the 28- or 50-MHz signals.

The Relative Time Delay System

The suggestion that propagation at 144 MHz was an entirely new mode of propagation led to renewed interest in propagation times. Different modes would be associated with different time delays over the circuit. A transponder system would not be satisfactory because of the poor signal-to-noise ratio, flutter-fading and

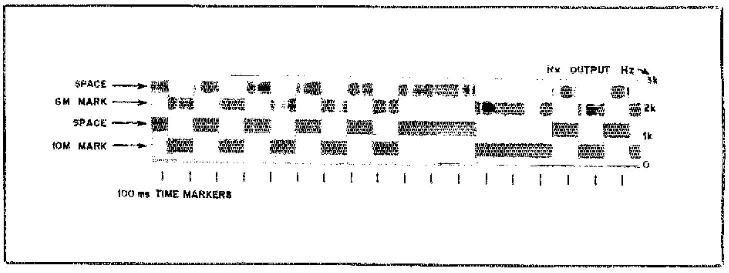


Fig. 6 — Spectrogram of simultaneous 28- and 50-MHz transmissions from 5B4CY in Limassol, Cyprus, as received by ZS6PW in Pretoria, South Africa.

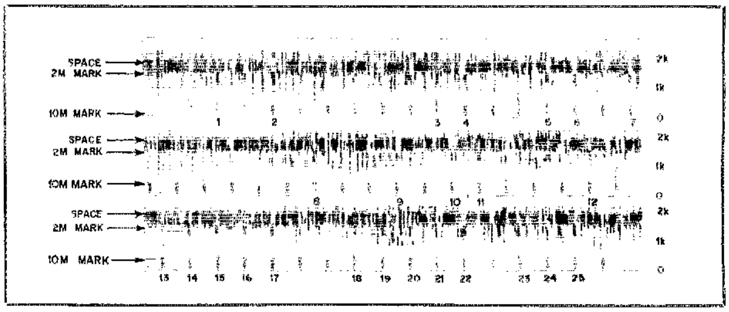


Fig. 7 — Spectogram of simultaneous fsk pulses on 28 and 144 MHz as received by SV1DH in Athens from ZE2JV in Salisbury.

frequency spreading experienced on 2 meters. Also, we knew from the original tests that multipath propagation takes place on 10 meters, the band that would have had to be used for the retransmission back to the originating station. The resulting oscilloscope display would have been completely unintelligible.

The interest lay, however, in determining whether signals on one band had traveled over a longer or shorter path than those on another band. The measurement of *relative* propagation times would provide the required information.

We therefore conducted a series of tests in which the call sign 5B4CY was keyed simultaneously on the Cyprus 28- and 50-MHz beacons. The ZE2JV beacons were arranged to transmit call sign and pulses simultaneously on 28 and 144 MHz. At the receiving end of the TE circuit we adjusted two receivers, operating in the cw mode, to produce different audio notes, which were summed and recorded on tape. We subsequently analyzed the tape recordings on a sonograph. This is a device that provides a running display of the audio spectrum over several seconds.

Some results of these tests are shown in Figs. 6 and 7. In Fig. 6, the "5B" of the call sign 5B4CY is shown as received simultaneously on 50.498 and 28.220 MHz by ZS6PW. It can be seen that any difference in the time of arrival of the transitions from mark to space, or vice versa, is less than the resolution of the system — some 2 milliseconds in this case. Band conditions at the time were typical for evening propagation with slight, slow fading on 10 meters and moderate flutter-fading on 6 meters. Note the excellent signal-to-noise ratio presented in Fig. 6.

Fig. 7 shows a series of pulses that were received simultaneously by SV1DH from ZE2JV on 144.160 and 29.266 MHz. Band conditions were typical, with slight QSB on 10 meters and severe flutter-fading on 2 meters. Owing to the poor signal-to-noise ratio, not all the 2-meter pulses are visible. The best 25 have been marked, and none appear to occur at times that are not coincident with those at which the 10-meter pulses were received.

Although this system showed that there were no significant differences in the propagation times on 10, 6 and 2 meters, its limitations are fundamental. It is cumbersome and places great demands on the operator to adjust two receivers to produce the optimum audio notes. Furthermore, the bandpass of the analyzing filter has to be narrow to resolve the limited frequency shift of the F1 signals. This severely limits the time resolution. There is, of course, no measurement of the actual time taken by either signal.

A System for Measuring Absolute Propagation Times

Consider the transequatorial circuit involved, the probable virtual height of the ionosphere and the propagation modes that could be in operation. A little geometry plus a few simplifying assumptions lead to Fig. 8. The range of values to be expected for the propagation time over the Pretoria-to-Athens circuit for the two normal propagation modes would be some 2 or 3 milliseconds. Hence, a system providing a time resolution of 0.1 millisecond would be very useful in estimating the propagation parameters involved. The 2-ms resolution of the previous systems only indicated broad trends.

These considerations, as well as the drawbacks to the relative time measurements mentioned above, led to the decision to set up an entirely new one-way measuring system, based on Universal Coordinated Time (UTC). UTC was available with great accuracy at both ends of the Pretoria-to-Athens circuit. In Pretoria at ZS6PW, it is only a short ground-wave path to the vhf transmitter of ZUO, the South African equivalent of WWV. In Athens at SV1DH, UTC was available from the Lampedusa station of the Mediterranean Loran C navigation system operating on 100 kHz. Over both these paths the propagation times are constant and can be calculated with great accuracy.

The system used is based on the transmission by ZS6PW of pulses having the same repetition period as the Mediterranean Loran C eight-pulse groups, namely 79.9 ms. The first pulse of each group as received by SV1DH from Lampedusa triggers a two-channel oscilloscope. In the oscillogram reproduced in Fig. 9, the last

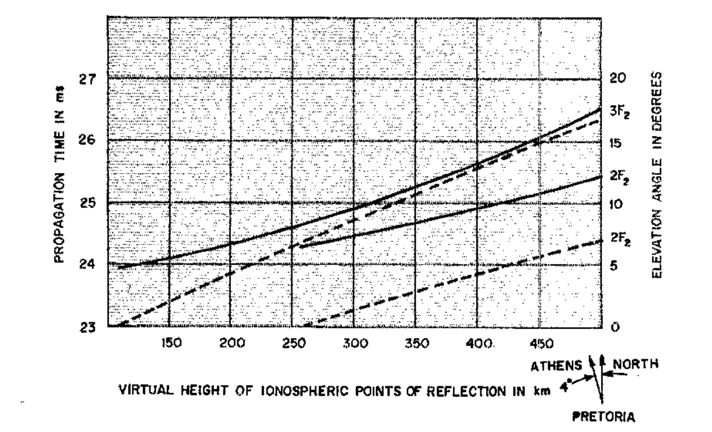


Fig. 8 — Propagation time and angles of arrival of normal multi-hop, F_2-layer propagation between Pretoria, South Africa, and Athens, Greece.

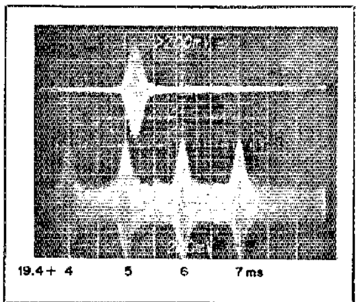


Fig. 9 — Oscillogram of propagation delay photographed by SV1DH, displaying a pulse received from ZS6PW on 28.270 MHz on the upper trace, and Loran C timing pulses on the lower trace. The actual delay is 19.4 plus the 5.2 milliseconds read from the oscillogram.

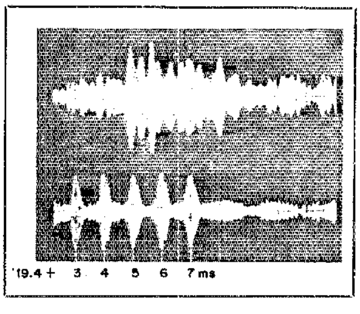


Fig. 10 — Multipath propagation from ZS6PW on 28.270 MHz photographed by SV1DH. There are 10 received pulses from the one transmitted pulse, with time delays from 24.3 to 27.5 milliseconds.

four of the set of eight pulses, which are spaced by 1 millisecond, are displayed on the bottom trace, while a pulse received from ZS6PW is shown on the top trace. From the very convenient Loran C markers the time of arrival can be read off once all delays have been accounted for. These are the offsets from UTC of both pulse systems and the transit time from Lampedusa to Athens. Inherent delays in receivers used for these two signals cancel, provided they have similar band-pass filters and time measurements are taken at corresponding points on the two pulse envelopes, such as at the peaks in Fig. 9. In our system a total of 19.4 ms has to be added, so that the 5.2-ms delay shown in Fig. 9 represents a propagation time between Pretoria and Athens of 24.6 ms. Keeping in mind the distance, time of day and operating frequency, a delay of 24.6 ms is a realistic figure. Propagation was probably by two hops, with the virtual height of the F layer at 210 miles.

Fig. 9 represents almost ideal propagation on 10 meters. The signal-to-noise ratio was very good, the pulse shape well preserved and no multipath propagation could be detected. By way of contrast Fig. 10 shows extreme multipath propagation with numerous pulses arriving between 24.3 and 27.5 ms for every pulse transmitted by ZS6PW. The signal-to-noise ratio is much poorer than in Fig. 9.

Examples of the received pulses are illustrated in Fig. 11 for which much wider (1.8 ms) pulses were used to improve the chances of detection on 2 meters. Fig. 11A shows elongation of a 10-meter pulse to 3.9 ms, its beginning occurring at 24.9 ms. This is an example of severe multipath propagation. Fig. 11B shows a relatively undistorted 6-meter pulse received under typical F-type TE conditions; the propagation time can be read as 25.1 ms. By way of contrast, Figs. 11C and 11D show how typical pure TE propagation causes severe elongation on 6 meters, but rather less on 2 meters. The propagation times were 25.0 and 25.8 ms, respectively.

In February 1980, ZS6PW commenced transmitting these Loran-synchronized pulses simultaneously on the 10-, 6- and 2-meter bands. SV1DH made routine measurements of the propagation time under various propagation conditions.

Of main interest was the measurement of propagation times when the three transmissions of ZS6PW could be heard simultaneously by SV1DH. This normally occurred within the period 7:30 to 8:30 P.M. local time. During the 1980 March and September equinoxes there were 10 evenings when all of these signals were strong enough to make such measurements possible. Their combined results are listed in Table 1. In the case of multiple or elongated pulses the propagation time was logged as the time indicated by the first-arriving peak.

There are significant differences in propagation times at the three frequencies, with a slightly longer time being taken at higher frequencies. The differences are within the limits of error possible in the relative propagation-time tests. The absolute time system, like the transponder system, indicates different modes of propagation are operative on the lower frequencies.

At 28 MHz, measurements were taken during the day as well as during the evening. The dominant mode (the first to arrive) was almost certainly two-hop F-layer propagation. It is occasionally present at 50 MHz and never present at 144 MHz.

At 50 MHz, the dominant mode is likely to be F-type TE, which exhibits a slightly longer propagation time than two-hop F layer. As two-hop F-layer and pure TE are also operative at times on 50 MHz, this frequency shows the greatest variation in propagation time.

At 144 MHz, the only mode that has been observed is pure TE. Even so, there remained considerable variability, and this is a matter of great interest.

In the concluding Part 2 of this article, we will discuss Doppler-shift measurements, backscatter observations, angles of arrival, patterns of fading and the support mechanism. We also include an appendix explaining our propagation time measuring system.

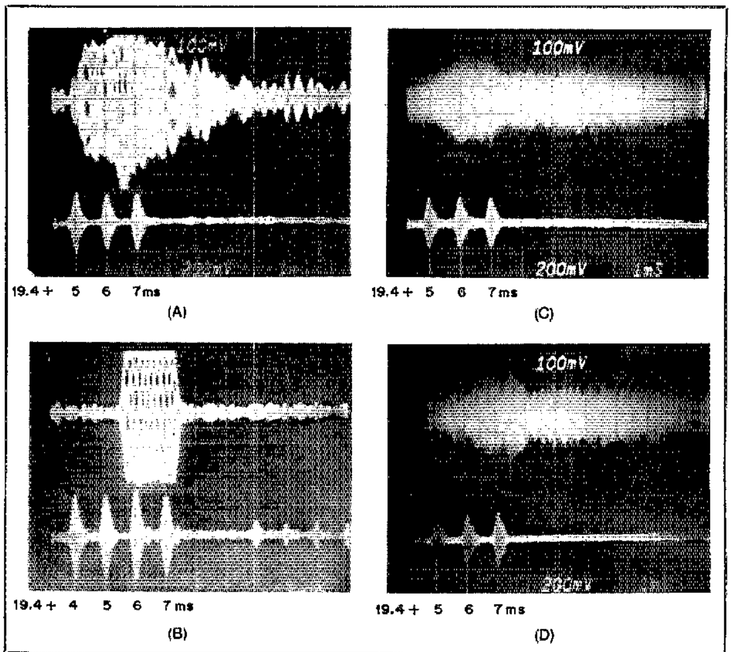


Fig. 11 — Recordings of propagation time between Pretoria and Athens. Pulse width in all cases = 1.8 ms: at A, an elongated pulse on 10 meters (24.8 ms); at B, an undistorted 50-MHz pulse (25.1 ms); at C, pure TE on 50 MHz at 8 P.M. March 18, 1980 (25.0 ms); at D, TE on 144 MHz at 7:45 P.M. on the same evening (25.8 ms).

Table 1

Variations in Propagation Time by Band

Frequency	*Avg. Propagation Time*	*Standard Deviation*
28.270 MHz	24.6 ms	0.2 ms
50.029 MHz	25.2 ms	0.3 ms
144.90 MHz	26.0 ms	0.2 ms

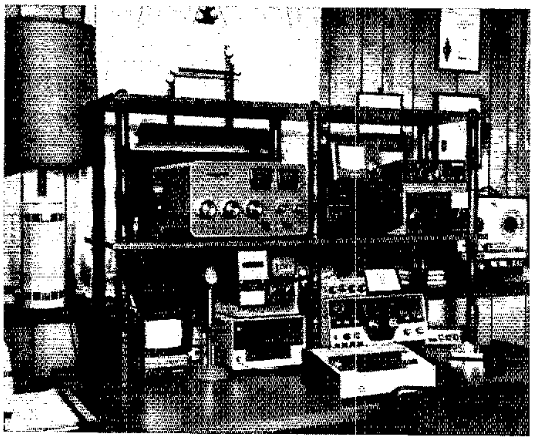
Propagation time recorded between ZS6PW in Pretoria and SV1DH in Athens using the 10-, 6- and 2-meter amateur bands.

[Editor's Note: The references cited in this article provide excellent background information. Reference 5 is particularly germane and should be readily available to most readers.]

Notes

[1]Cracknell, R. G., "The Transequatorial Propagation of VHF Signals," *QST*, Dec. 1959, pp. 11-17.
[2]Southworth, M. P., "A Look Back and Ahead at P.R.P.," *QST*, June 1959, p. 48.
[3]Mueller, E., Letter in *Dubus*, No. 4, 1978, Berlin.
[4]Tilton, E. P., "TE Propagation — VHF Discovery Extraordinary," *QST*, April 1963.
[5]Reisert, J. and Pfeffer, G., "A Newly Discovered Mode of VHF Propagation," *QST*, Oct. 1978, pp. 11-14.
[6]Obayashi, T., "A Possibility of Long Distance HF Propagation Along the Exospheric Field Aligned Ionization," *Journal of the Radio Research Labs.*, 6, 1959, p. 603.

BEGINNER'S BENCH



That First Ham Station — How to Choose It and Set It Up

Station equipment, layout and hookup for the beginner can be perplexing! The major considerations are cost, convenience and safety. Here are some tips.

By Doug DeMaw,* W1FB

I've walked into a number of beginner's amateur stations and found myself gasping in horror at what I saw! In one fellow's shack I observed a 600-volt, 300-mA power supply sitting open (and operating) on the floor just ahead of his feet. Various "hot" terminals were fully exposed while his 3-year-old son played on the radio-room floor! On another occasion I dropped in to visit a young Novice and saw her operating with a 250-watt amplifier her father had helped her build. The entire circuit was assembled on an open chassis that was only 12 inches from her J-38 cw key! Again, high voltage was lethally near the operator as she keyed merrily away. In both examples the operators didn't think the danger was significant, because they stated, in effect, "I won't get a shock. I know the voltage is there and am used to being careful!"

But, safety is not the only consideration in our amateur stations. There is the matter of operator convenience and operating ease. We need to organize our equipment by placing the various pieces in strategic spots on the table, shelves or both (more on this later). Then there is the question of reliability, which rules out haywire hookups between the units of amateur gear, and between the station and the antenna.

A final and vital consideration is the threat of television interference (TVI) and radio-frequency interference (RFI) to a-m radios, fm receivers and hi-fi equipment. There is much we can do in the amateur station to eliminate or greatly reduce interference problems in our neighborhoods. This should be an important objective for all radio amateurs, regardless of license class.

Station Components

One of the biggest "nail biters" faced by the new ham is how to decide ***which*** and ***how much*** amateur equipment is necessary to get on the air and have effective communications. We might compare this to any newly discovered hobby, such as photography or archery. Human nature often drives us toward more equipment than we need, or in the direction of gear that is more sophisticated than that which we presently own! But, it is better to learn the fundamentals of Amateur Radio with simple but effective equipment. In the process we will avoid unnecessary expense. Let's go down the list and consider each item.

1) *Separate transmitter/receiver combination:* Frequently, this can be an economic means to an end if used equipment is purchased. For cw operation we might consider a second-hand E. F. Johnson Viking I or II transmitter, or a Viking Ranger I or II. The latter has a built-in VFO (variable-frequency oscillator), but an outboard VFO is needed with the Viking I or II units. Most of these rigs sell used for under $100 (see *QST* Ham Ads). The Viking I and II rigs deliver about 100 watts of rf output power, while the Ranger is in the 50-watt class. The disadvantage in using separate transmitters and receivers is that there are more controls to adjust when changing frequency. Also, the older equipment is somewhat bulky compared to present-day ham gear that uses solid-state devices.

2) *Transceivers:* A good, used hf-band transceiver will cost more than the older "separates," but part of the reason is that the transmitter and receiver are contained in a single box and may be complete with power supply. Some of the earlier units worthy of consideration are the R. L. Drake TR3 and TR4 transceivers. A used

*ARRL Senior Technical Editor

Swan 500C would be suitable, as would the Heath HW-100 or HW-101 transceivers (all use tubes and require outboard power supplies). Used transceivers like these can be purchased (with power supply) in a price bracket of $275 to $500 as a rule. The older Kenwood TS-520 and Yaesu FT-101 transceivers are worth considering also, as they have built-in power supplies. The advantage of the transceiver is that a single frequency-adjusting control and readout dial are used for the combined transmitter/receiver main tuning. Also, transceivers are easy to transport and set up for portable work, because the "works" (except for the key, microphone and antenna) are in one package.

3) *Separate Receiver:* If our choice is to be a separate transmitter and receiver pair, the used market can be searched for a low-price receiver (again, see *QST* Ham Ads). Some pretty good older receivers can be purchased for less than $100 these days. They may not look like works of art by present-day aesthetic standards, but they will do the job nicely for a beginner. Receivers such as the Hallicrafters SX-71, National HRO-50T1 and HRO-60, Collins 75A1/75A2, Hammarlund HQ-180 and Heath SB-300 are suggested. Some amateurs like to have a separate receiver for use with a transceiver. This permits split-band operation (receiving on a different frequency from the transmit frequency) without disturbing the setting of the transceiver main-tuning dial. All of the receivers mentioned here are tube-type units.

4) *New Equipment:* Most of the new amateur apparatus on the market is compact, has solid-state circuitry and is capable of better overall performance than older, used gear can provide. That isn't to say that old gear is unsatisfactory. Rather, it implies that many operating aids and frills found in new amateur equipment won't be available in the older gear. It would be inappropriate to recommend any item of new equipment in this article, but be prepared to pay as much as $1500 for a brand new transceiver these days! *QST* product reviews and ads contain prices and descriptions for current amateur products.

5) *Homemade Equipment:* To buy or to build? *That* is the question! Most beginners feel that their lack of experience as hams puts them at a disadvantage when it comes to assembling that first cw station. But, if you have a background in electronics, don't pass up the chance to build your own transmitter and receiver. There is a special feeling of pride and accomplishment that comes with building and operating homemade gear. There are many good circuits in *The ARRL Radio Amateur's Handbook*, *Understanding Amateur Radio* and *Solid State Design for the Radio Amateur*. The sometimes-negative factor concerning the use of home-built amateur equipment is *cost*. If all of the parts must be bought new, they may be costly and difficult to acquire — the cost of a given project might be greater than when buying comparable new or used gear!

6) *Antennas and Accessories:* Some serious "head scratching" will often accompany the beginner's decision to buy or avoid purchasing certain accessory items for the amateur station, and choosing that first antenna. Fortunately, not many accessory items are required for effective operation, although many of them serve as useful operating conveniences. Some suggestions about beginner's antennas were published earlier this year in *QST*.[1] So, let's skip the question of antennas and address those other items that we may or may not need in our first station.

a) *SWR indicator* — This device is handy for adjusting an antenna for the lowest attainable SWR when the antenna is first erected. Thereafter, it serves only as a monitor to keep tabs on the condition of the antenna system. If a Transmatch is used with a multiband wire antenna, an SWR indicator is essential for ensuring that the Transmatch is adjusted for an SWR of 1:1 in the band of interest. If a multiband trap or single-band 50-ohm antenna is used, however, an SWR meter should not be necessary.

b) *Transmatch* (antenna tuner, antenna coupler): A plethora of these devices exist on the commercial amateur market today, and a newcomer can easily get the false impression that it is impossible to operate without a Transmatch. If our station antennas present an SWR of less than, say, 2:1 in a 50-ohm system, we can forget about Transmatches. But, if we elect to use an end-fed wire or center-fed dipole for multiband operation (assuming that antenna traps aren't used), a Transmatch becomes a necessary tool. The Transmatch in that instance would be used to provide a matched condition between the antenna or its feed line and the transmitter. Some Transmatches (depending upon the circuit used) will attenuate harmonic emissions from the transmitter, thereby aiding in the reduction of TVI and other forms of interference. A manufactured Transmatch will sell for $75 to $1500, depending on its power capability and operating features. A homemade unit is easy to build and shouldn't cost more than $50 if surplus parts are used. Check the radio flea markets for inexpensive components.

c) *Keys, keyers and paddles* — There's a certain mystique connected with using a hand or straight key. If we have reasonable rhythm in our souls, we should be able to send good cw up to 20 wpm with a straight key. A new key can be purchased for less than $6, and a surplus one (military J-38) costs even less. A paddle (for use with an electronic keyer) can, on the other hand, cost as much as $50. Keyers are great for sending good, fast cw, but are only as good as the commands sent by the operator. Some of the most dreadful cw heard on the amateur bands today is being sent by means of poorly operated electronic keyers. Keyers vary in price from a few dollars to more than $200. Our best economic approach is to start out with a straight key.

The foregoing discussion is intended to draw a line between what's really needed in our first station, as opposed to the collection of unnecessary apparatus that some beginners end up with after spending absurd sums of money. The new, more-expensive equipment can come later (and it surely will!), after we've learned the fundamentals of operating and have gained knowledge and experience. Used ham gear can often be resold without losing a red cent, and sometimes we can actually sell it for more than we paid! Conversely, brand new equipment (like automobiles) loses its face value the moment we move it out of the store.

Laying out the Station

This part of our new adventure is anything but casual if we are to have a station that is safe and convenient to use. An awkward layout, or one that is too cramped, can cause operator fatigue in short order. The equipment needs to be placed strategically, and there should be plenty of room on the table or desk for our arms, pencils, paper and even a coffee cup!

Those of us who have basements are prone to setting up "studio B" in that part of the house, while others opt for a "studio A" (attic) location. A basement or first-floor ham shack is the best choice (assuming that the basement is dry and clean) because the distance to an earth ground is usually short (desirable). Also, a basement or first-floor spot is cooler than an attic in the summer and warmer than an attic in the winter. An effective earth ground is imperative in the interest of safety, reducing interference and keeping unwanted rf voltages off our radio equipment.

Assuming that we've chosen a clean, well-lighted site for the ham shack, what can we use for an operating table? Well, many amateurs buy used wooden office desks (the larger the better) at auction sales or through newspaper ads. A desk of this type provides plenty of surface area and has numerous drawers in which to store our station supplies (QSL cards, jumper cables, scratch pads and so on).

A good alternative to a desk is a pair of used, two-drawer file cabinets and a blank interior door from the lumber yard. I used this type of operating table during my first 20 years as a ham, and it was excellent. A file cabinet was placed two feet in from

[1] D. DeMaw, W1FB, "Which Antenna to Use?" *QST*, May 1981, p. 26.

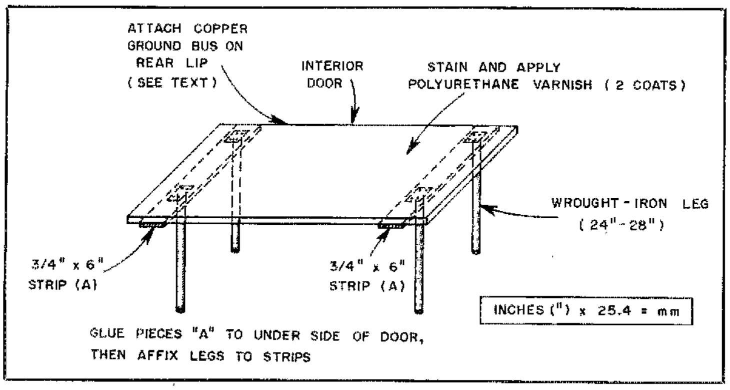


Fig. 1 — A blank interior door can be used to make a ham-shack table. File cabinets are suitable to support the table top, or wrought-iron legs can be attached as shown. See the text for information about wooden strips "A."

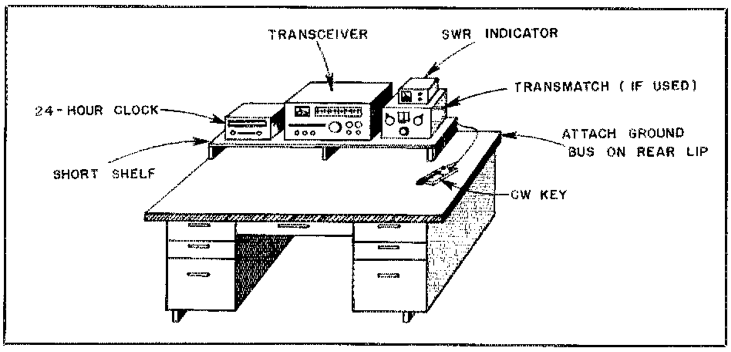


Fig. 2 — Suggested layout for a simple station that uses an office desk. The cw key is situated for minimum arm fatigue (see text).

each end of the door, and the door served as the desk top. Two coats of clear lacquer were applied to the surface of the door (after it was stained an oak color), thereby providing a smooth surface that could be cleaned easily. If file cabinets are too expensive or hard to find, we can use four wrought-iron legs to support the door. If this is done it will be wise to affix two pieces of 3/4 × 6-inch (mm = 25.4 × inches) pine board to the bottom of the door. This will ensure proper anchoring of the iron legs (see Fig. 1). Most interior doors are hollow and have thin sections of veneer for the outer surfaces. Therefore, sections "A" of Fig. 1 are necessary to ensure secure attachment of the iron legs.

Still another excellent operating platform is a used library table. Not only is this type of furniture rugged, it's large! Many library tables have one or more drawers in the front, providing storage space for paper, pencils, a logbook and what have you.

Placing the Equipment on the Table

Most transmitters, receivers and transceivers generate internal heat. Therefore, we should be careful to avoid blocking the vent holes in the cabinets by stacking one piece of gear atop another. Always allow room for the passage of air around the equipment.

The cw key should be far enough away from the front of the desk to permit the sending arm to lie flat on the desk top from elbow to finger tips. Most operators prefer to locate the key at an angle of 20 to 30 degrees from a line that is perpendicular to the front edge of the desk or table. These suggestions will greatly reduce arm tension, and will help ensure good cw sending.

Our receiver or transceiver should be located so that its digital or analog frequency-readout dial is approximately in line with our eyes. It can be lower if the equipment has an upward-tilt feature (inclination bar or front legs that are longer than the rear ones). Ideally, the main-tuning knob should be at a height above the table top that permits tuning while the arm is resting comfortably on the surface of the desk. Also, we should push the transceiver far enough back on the desk to prevent bumping the tuning knob accidentally (it does happen!) while we're transmitting. Fig. 2 illustrates how a modest ham station could be set up for operating ease and convenience.

Electrical Considerations

Safety first! Let's be certain to have an effective earth ground routed to the station. How do we accomplish this? It isn't too difficult with respect to ac and dc, but the task becomes a bit sticky when dealing with rf energy from the transmitter. I like to use as many grounds as I can locate, bonding them together electrically and bringing the connection point to the operating position. For example, my rig is located near the baseboard heat strip in my family room. Copper plumbing was used in my home when it was built 11 years ago, and all of the joints are soldered. So, even though I'm using a hot-water line (not recommended with older iron plumbing because of poor joints) for a ground, it is an effective one. I also use a 6-foot copper ground rod, which is driven into the soil just outside the ham-shack window. Additionally, I use the 16 buried radials I employ as a ground system for my 80-meter vertical.

Our lead wires from the various ground points to the shack should be a short as possible. Large-diameter conductors, such as the shield braid from RG-8/U coax cable, or wide strips of flashing copper, are recommended. The large conductor area and short lengths will aid in reducing unwanted inductances, which impede the passage of rf (radio-frequency) currents, thereby improving the quality of the ground system at rf. The leads between the common ground point in the shack and the various pieces of station gear should be similarly short and large in cross-sectional area.

I like to run a 1-inch-wide strip of flashing copper the length of my desk, behind the equipment. This serves nicely as a ground bus to which the cabinets of the gear are connected. A length of no. 8 copper wire would serve our needs equally well. All ac-operated equipment should be grounded to prevent shock hazard. This also helps prevent rf energy from wandering to areas in the shack where it is not wanted. Obtaining an effective ground system from a second floor or higher is nearly impossible. Fair warning!

In the interest of safety, all points that carry ac, dc or rf voltages should be accidental-contact free. That is, we should have cabinets around all of our equipment that contains dangerous levels of voltage. Frayed or brittle ac power cords should be replaced with new ones as soon as the condition is noted.

As a convenience and additional safety precaution, we should use an ac multiple-outlet strip at the operating position. It is unsightly and dangerous to use a single

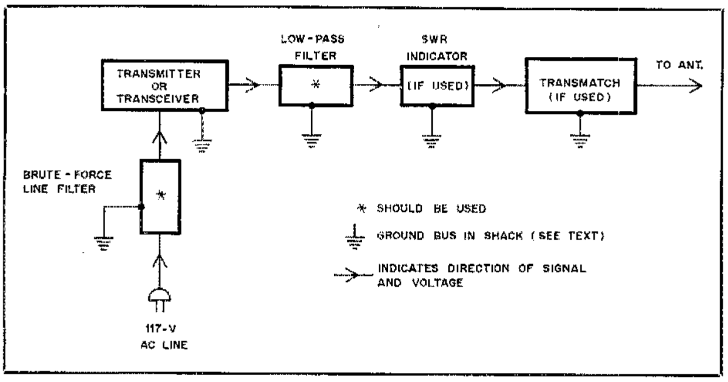


Fig. 3 — Block diagram that shows where to install a brute-force ac-line filter and a transmitter low-pass filter to reduce interference. Additional information is given in the text.

wall outlet for several pieces of gear, especially when it becomes necessary to stack two or more cube taps (3-way sockets) in the wall outlet. Most outlet strips can be screwed to the rear of our tables or desks to avoid an unattractive jungle of cords and plugs. All electrical connections should be tight and solid. The splices in wires and ground leads will be the most durable and effective when they are soldered. A few wire twists and a gob of electrical tape is not a prescribed technique (likewise with the joints in our antenna systems)!

TV and Radio Interference

There are two things that every ham shack should have: a brute-force ac-line filter and a transmitter low-pass filter. Both of these items are described in *The ARRL Radio Amateur's Handbook* and *Radio Frequency Interference* (an ARRL book). Each filter is easy and inexpensive to build — even by beginners.

The brute-force line filter is used between the transmitter power supply and the ac outlet in the wall, as shown in block-diagram form (Fig. 3). The case of the filter needs to be grounded, and it should be placed as close to the transmitter cabinet as possible, thereby preventing the ac cord from radiating rf energy before it enters the filter. This type of filter keeps rf energy out of the power line — an aid to the reduction of TVI and RFI.

The low-pass filter passes all rf energy up to approximately 40 MHz when used with a high-frequency (3.5 to 29 MHz) transmitter. Harmonic frequencies that fall into the TV and fm channels are greatly attenuated by the filter, preventing them from being radiated by the amateur antenna and feed line. This filter should be well grounded and mounted at the rf-output jack of the transmitter. Other techniques for curing and preventing TVI and RFI are detailed in *Radio Frequency Interference*. Low-pass filters can be purchased as manufactured units (see *QST* ads). Line and low-pass filters are listed in the J. W. Miller catalog (19070 Reyes Ave., Compton, CA 90224).

Loose or poorly soldered joints in the feed line and antenna system can also cause TVI and RFI. Make sure that all coax connectors are well soldered and screwed securely to their mating receptacles. Solder all antenna joints carefully to prevent rectifying connections (they generate harmonic energy and cause interference).

Closing Comments

Questions about that first station will come to your mind. We can't cover all possibilities in a single article. But, most of the details you need to know are provided in the League's book, *Understanding Amateur Radio* (sort of a junior *Handbook*). If all else fails, send your question to the ARRL Technical Information Specialist. Be sure to include a stamped, self-addressed return envelope.

Technical descriptions of the older amateur equipment you may want to buy on the used-gear market can be found in back issues of *QST*. Perhaps you have a neighbor or friend who will let you browse through his or her copies. Your public library may have a complete file of *QST*s, so check there also.

The name of our Amateur Radio game is, in part — fun! So let's make it safe as well as enjoyable by setting up that first station in a logical and orderly manner. I hope the suggestions in this article will reduce your head scratching to minor proportions. Good luck!

Reference

DeMaw, D., W1FB. "Simple Gain Antennas for the Beginner." *QST*, Aug. 1981.

Strays

TA PROFILE

☐ Putting up a new antenna? Need advice? I'm sure many of us would agree the answer is, definitely, "Yes!" Because of this, we were pleased when ARRL Technical Advisor Edward L. Kane, W6ONT, joined our official family in 1979. Ed is one of TA experts on design, development, testing, and analysis of antennas and antenna systems.

First licensed in 1956 as WN3GJU, Ed now has his Extra Class license. His primary interests in Amateur Radio are cw QSOs, building equipment and antennas. He also enjoys doing antenna measurements.

Residing in Cypress, California, Ed is a senior engineer for the Douglas Aircraft Company. He received his BSEE degree from Pennsylvania State University and his MSEE degree from California State University at Long Beach. He is a member of the ARRL, the Antenna Measurement Techniques Association, IEEE (with memberships in the Antennas and Propagation Society), and the Aerospace and Electronic Systems Group.

Although Ed spends a great deal of his leisure time in continuing his education, he does find time to enjoy sailing, sailboat racing, woodworking and teaching Celestial Navigation for the U.S. Power Squadrons. — *Marian Anderson, WB1FSB*

Meet ARRL Antenna TA Ed, W6ONT.

I would like to get in touch with . . .

☐ anyone interested in forming a computer-to-computer communications net. David J. Hait, WB2CRM, University of Pennsylvania ARC, Moore School of Engineering (Moore School Library), Philadelphia, PA 19104.

Product Review

Conducted By Paul K. Pagel,* N1FB

The Daiwa CNA-1001 Automatic Antenna Tuner

The antenna tuner or Transmatch has become a staple accessory in many ham shacks. Until recently, little has been done in Amateur Radio to automate the actual tuning process, but now the amateur operator can rely on electronic means for setting the tuner controls on the band of his or her choice. Daiwa's CNA-1001 represents an interesting new form of electronic Transmatch operation.

Theory of Operation

The CNA-1001 is comprised of an internal directional coupler and associated VSWR meter, the matching network, and the sensing circuitry that controls motorized tuning capacitors used in the matching network. Metering is accomplished with the Daiwa cross-needle design, which allows simultaneous observation of forward and reflected power and VSWR, the latter corresponding to the intersection of the meter needles. The sensing circuit samples the rectified rf voltage induced within the directional coupler. This voltage, whenever the VSWR is higher than 1.5 to 1, closes a solid-state switch that completes a 12-volt line to the capacitor drive motor. The motor is turned off when the VSWR drops below 1.5 to 1, and the switching circuitry is cut off.

A pi-network circuit is used. It incorporates an 8-position tapped inductance that is controlled manually from the front panel. Additional series capacitance is provided at the tuner output. The 250-pF parallel and series capacitors at the network output that make up the automatic feature of the CNA-1001 are motor driven. Smaller, 30-pF variables are wired in parallel with the motor-driven units; these are set manually from the front panel and are designed to touch up the match once the capacitor drive motor shuts off. The motorized capacitors are geared together in a 30:1 ratio, the series capacitor turning at the faster rate (such gearing appears to be a clever means of eliminating the need for separate drive motors). This arrangement permits the network to "scan" the mismatched condition until a proper match is obtained.

Method of Operation

The instructions provided with the CNA-1001 are brief, but adequate. It is hoped that future models of the tuner will be accompanied with a typeset manual that includes some discussion of the theory of operation — information that is missing in the typewritten instructions provided to this reviewer.

There are seven controls that must be preset before automatic operation may be commenced: The BAND and ANTENNA are selected — the user has the choice of either two antenna inputs on the rear apron, or an internal 10-watt dummy load for testing purposes. The two FINE TUNING controls on the front panel are set to midscale; the meter RANGE is set to read the 20-watt scale. A 200-watt scale is provided, but the tuner will not operate if that level is selected. The CONTROL INPUT LEVEL switch on the rear apron is set for either 1, 5 or 10 watts, sensitivity. The range selected determines the maximum power the sensing circuit may handle. The TUNER control, set ON, places the tuning network on line with the transmitter on transceiver while the OFF position provides a handy bypass should the user wish to take the tuner out of the transmision line. Power may then be applied up to the CONTROL INPUT level selected. An average of 15 to 30 seconds has been required to reach a matched condition from the time the OPERATE switch is depressed,

Daiwa CNA-1001 Automatic Antenna Tuner Serial No. D08023

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 3.5-30 MHz, WARC bands included.	As specified.
Input/output impedance: 50 ohms.	
Meter scale: Fwd/ref 5:1.	
Meter range: Forward, 20/200 watts; reflected, 4/40 watts.	
SWR detection: 5 watts, min.	As specified for visible reading.
Power rating: 500 watts, PEP.	250 watts dc input.
Insertion loss: Not specified.	0.4 dB at 28 MHz.
Input power for automatic operation: 1-12 watts.	As specified.
Impedance matching range: 3.5 MHz, 15-250 ohms; 7-30 MHz, 10-250 ohms.	As specified
Automatic operation time frame: 45 seconds, maximum.	15 to 30 seconds.
Power requirement: 13.8 V dc at 0.2 A	As specified.
Dimensions HWD: 3-5/8 × 7-7/8 × 9-5/8 inches	
Weight: 8 lb.	
Cabinet materials: Steel and brushed aluminum.	
Color: Blue-gray.	
Output terminals: 2 antennas (SO-239 connectors) plus internal 10-watt dummy load.	As specified.

Note: mm = inches × 25.4, kg = pounds × 0.4536.

*Assistant Technical Editor

enabling the automatic operation. In several months of use at AC1Y, I have been able to approximate 5:1 conditions to check the matching range. In all cases, tuning has been accomplished in well under the 45 seconds maximum specified by the manufacturer. The claimed impedance-matching range of the Transmatch is between 15 and 250 ohms at 3.5 MHz, and between 10 and 250 ohms on the 7- to 28-MHz bands. Inductance settings for the new WARC bands at 10, 18 and 24 MHz are included in addition to the currently available ham bands. The 5:1 matching capability makes the CNA-1001 able to follow "QSYs" of some magnitude. This allows ease of operation and is especially useful with broadband, solid-state transceivers.

Operating Impressions

It would appear that much time is spent in presetting the CNA-1001 controls before use, making the name Automatic Antenna Tuner seem a misnomer. Once the sequence of operation is mastered, however, there is no time wasted in putting the unit through its paces. At AC1Y, where dipoles are used on 80 and 75 meters, the CNA-1001 has allowed me to QSY up and down, band edge to edge, with relative ease. The tuner requires a 13.8-volt, 0.2-A supply to power the sensing circuit and the capacitor drive motor, so any small power supply will suffice. In fact, the tuner would be a "natural" during portable battery operation for emergencies or, for instance, Field Day. Since the CNA-1001 is designed for use with unbalanced line only, it would be intriguing to use it for mobile hf operations.

The relative complexity of presetting the controls, however, would tend to make it a distraction while driving, despite its convenience. All controls are clearly marked. The only inconvenience is the location of the CONTROL INPUT LEVEL switch on the rear apron. Inattention to the proper setting of this control could lead to damage to the sensing circuit. It's possible to neglect the switch considering that it's not immediately visible. The switch should really be located on the front panel to afford maximum operator convenience.

All in all, the Daiwa CNA-1001 represents a convenient package. Its use definitely takes some of the drudgery away from operating a Transmatch under normal circumstances. No more hairline tweaking of capacitors; the automatic tuning feature sets up the tuner in little time and has provided better than a 1.5 to 1 match consistently, with little or no use of the FINE TUNING controls. The Daiwa CNA-1001 is imported and distributed by J. W. Miller Division, Bell Industries, 19070 Reyes Ave., Compton, CA 90224. Price class: $370. — *Sandy Gerli, AC1Y*

JAPAN RADIO COMPANY MODEL NRD-515 ALL-WAVE RECEIVER

☐ The NRD-515 is a high-performance communications receiver covering the range of 100 kHz to 30 MHz. Receiver features include digital PLL frequency control, an up-conversion heterodyning scheme and high dynamic range.

Tuning is accomplished by means of an optical interrupter dial coupled to the MHz control switch. The dial tuning rate is 10 kHz per revolution in 100-Hz steps. A momentary switch labeled UP/DOWN is used for changing frequency rapidly. The MHz portion of the operating frequency can be selected by the MHz control or by the main tuning dial. An optional memory unit, included with the review receiver, will store 24 spot frequencies in the receiver tuning range. The bandwidth switch has four positions (two of these being 6 kHz and 2.3 kHz) that are the standard filter bandwidths for the stock receiver. Optional filters in the review model provide cw bandwidths of 600 and 300 Hz. Other useful features are PASSBAND TUNING, DELTA-F (same as RIT), built-in 10- and 20-dB rf attenuators, noise blanker, selectable agc speed, and an adjustable BFO pitch when in the cw mode. Operating modes include a-m, upper and lower sideband, cw, and RTTY.

The heterodyning scheme in the receiver differs from most in that it uses a 70-MHz first i-f. Use of such a high first i-f ensures excellent image rejection. Frequency synthesis in the '515 is done in two stages. One loop controls the first i-f local oscillator frequency; the other sets the VFO frequency. This dual-loop system helps to eliminate many of the spurious responses found on many single-loop systems.

Operation

On-the-air operation with the receiver was a delight. The digital tuning took some getting

JRC Model NRD-515 Receiver Serial No. BR20156

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*	
Frequency coverage: 100 kHz-30 MHz.	As specified.	
Modes of operation: Ssb/a-m/cw/RTTY.	As specified.	
Frequency display: Six 7-segment LEDs.	Red, 0.5 inch.	
Resolution: 100 Hz.	As specified.	
kHz/turn of knob: 10.	As specified.	
Backlash: Not specified.	Nil.	
Agc auto/manual selection: Not specified.	Selection of slow, fast or manual.	
Receiver attenuator: 0-10-20 dB.	As specified.	
S-meter sensitivity (μV/S9): Not specified.	80 M—44 μV; 40 M—44 μV; 20 M—25 μV; 15 M—50 μV; 10 M—50 μV.	
Receiver sensitivity: Less than 0.5 μV from 1.6 to 30 MHz.	80 M	20 M
Noise floor (MDS) dBm:	− 136	− 136
Blocking DR (dB):	136	136
Two-tone, third-order IMD DR (dB):	90	94
Audio power output (8-ohm load): 1 W (4 ohms).	1 W.	
Audio quality: Not specified.	Excellent.	
Power requirements: 117/220/240 Vac, 50/60 Hz, 50 W.	As specified.	
Frequency stability: Less than 50 Hz/hour after warmup.	75 Hz from cold start to *one hour later*.	
Size (HWD): 5.5 × 13.4 × 11.8 in.		
Weight: 16.5 lb.		
Color: Black and gray.		

Note: mm = inches × 25.4, kg = pounds × 0.4536.

used to (it results in somewhat "musical" audio). I was skeptical of the performance of a receiver using a digital synthesizer because some other synthesized receivers we tested have had spurious responses throughout the tuning range. Our review receiver was remarkably clean throughout its tuning range. The only objectional spurious signals were found at the extreme low end, just below the 100 kHz lower limit of coverage. Strong-signal performance of the receiver is the best this reviewer has seen in any communications receiver. Observed performance was confirmed by tests done in the ARRL lab. The noise blanker was effective in blanking both ac-line and ignition noise, although when the blanker is on, the dynamic range of the receiver is reduced somewhat. Agc action is smooth, with no popping or lockup noted. Only once during the review period did I observe front-end overloading. A 160-meter dipole was connected to the receiver, and the presence of a 10-kW a-m broadcast station less than 3 miles[1] away was evident throughout the passband. With the 20-dB attenuator switched in, the overload problems disappeared, and the sensitivity was adequate for 160-meter operation. During a "multi-multi" contest operation, the '515 was used as a spotting receiver on 14 MHz and performed very well in the presence of five 1-kW transmitters.

Those amateurs interested in shortwave listening will appreciate the digital display and 6-kHz bandwidth position. A-m sounded quite realistic for such a narrow bandwidth. The af amplifier chain is very clean.

An interesting use for the memory unit is to place the various WWV frequencies into the memory and then quickly check them to see how the F2 layer MUF is changing. Also, net and DX pileups can be stored for future recall.

Shortly after acquiring the receiver I found an urge to open the covers and see what was "lurking" inside. The physical layout of the receiver is exceptionally clean. All pc boards are silk screened, clearly making service or adjustment an easy task. The optional filters mount on a pc edge card connector that I thought would degrade the ultimate attenuation of the filters, but this is not the case!

Observations

The manual for the receiver is quite comprehensive in operation procedures and theory of design explanations, although the English translation used in the manual in quite awkward, making some reading difficult. The NRD-515 represents state-of-the-art performance in communications receivers. JRC has shown that a digitally synthesized receiver can compare in performance to the best analog systems. The receiver is designed to be mated with the NSD-505 amateur transmitter, but may be used with any transmitter with a slight loss in versatility. Gilfer Associates, the U.S. importer of the NRD-515, supplies the receiver in two configurations. One of these is aimed at the shortwave-listener market and is equipped with i-f filters having bandwidths of 6.0, 3.0, 2.3 and 0.6 kHz. The other option replaces 3.0-kHz filter with a sharp 300-Hz filter for amateur and commercial uses. Gilfer's address is P.O. Box 239, Park Ridge, NJ 07656. Price class: $1490; memory unit, $290; optional 300-Hz filter, $70. — *Gerry Hull, VE1CER*

[1]km = miles × 1.609.

HEATH VF-7401 2-METER TRANSCEIVER

☐ My first thought on seeing the new Heath 2-meter digital scanning transceiver (VF-7401) was "Gee, that's pretty." (A preassembled rig was in the lab for advertising acceptance.) And pretty it is! It is not the traditional Heath green that I expected.

After opening the box, the first thing that must be done is to update the instruction manual. There are some additional paragraphs supplied to expand the original instructions, new diagrams and some pages to paste over others. The instruction book is well done; Heath does a magnificent job of preparing easy-to-follow instructions. Components are carefully numbered and labeled. Although this is not a beginner's kit, anyone with an interest and some kit-building background should be able to complete this project within 50 to 70 hours. Heath (and others) makes kits that are simpler, have fewer parts and are easier to assemble than this one. This one is not difficult, but takes some time — and patience!

Assembly

What's next? There are six circuit boards to assemble: readout, VCO, power amplifier, receiver, synthesizer and transmitter. These boards range in complexity from the readout board (which has three digital-display chips) to the transmitter and receiver boards, which are both rather intricate. I assembled the optional Micoder II microphone that includes a Touch-Tone pad. The builder has the option of wiring the Micoder to use an internal 9-V battery or to extract power from the rig. I chose the "power-from-the-rig" route.

I've learned (in my Heathkit assembling experiences) never to open a package unless the manual says "OPEN PACKAGE." The problems you could run into. . . . I use egg cartons to hold all the parts while the kit is being assembled, count out different values of resistors and capacitors, sort them, and store them in separate containers. The VF-7401 is a "four-carton kit." Of course, if you run into the built-in problems I have (a three-year old who wants to "help"), you might want to choose some other method!

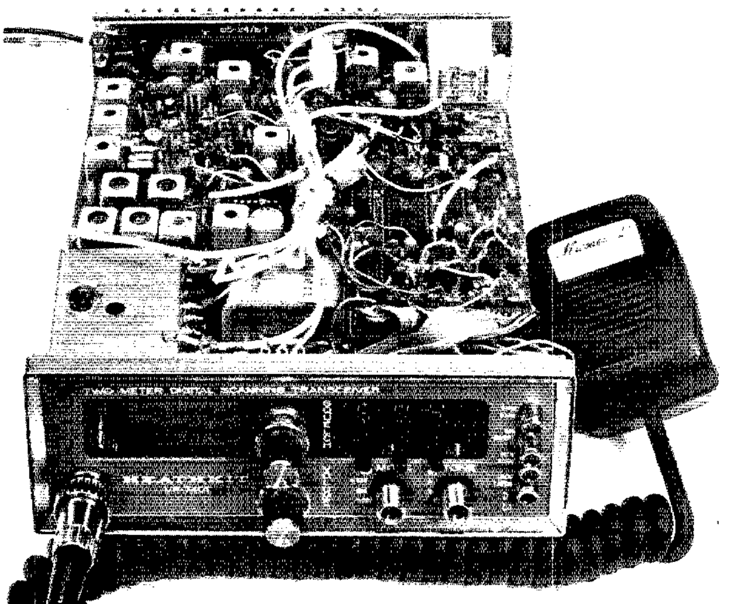
Heath provides very explicit soldering instructions, which is one of the prime factors in assembling any kit. I know what a good solder connection looks like. I know how the iron feels when holding some solder next to a connection along with a tip but . . . the one thing I couldn't understand was why the solder wasn't melting the way it should while I was assembling the VCO board. Afterward, I mentioned the problem to my husband, Pete. He wanted to know why I hadn't said something earlier. The iron was "on the fritz" — a burned out element! I had been using too little heat to melt the solder, but more than enough heat to cause component problems!

Alignment

I started through the alignment routine just like it said in the book. One of the coils didn't tune properly, and the meter readings weren't right. After "playing" for a week, we sent the rig back to the factory. It was back in a few days — fixed, aligned and ready to go. My soldering iron difficulty and one unsoldered connection had caused the problems we encountered.

Technical Description

The VCO is the heart of the transceiver. It



Heath VF-7401 2-Meter FM Transceiver Serial No. 0008

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: Any 4-MHz segment from 143.5 MHz to 148.5 MHz (within transmitter/receiver specifications; total coverage 140.000 MHz to 149.995 MHz).	As specified.
Mode of operation: Fm.	As specified.
Readout: Digital; 3-digit, LED (red) display.	3/8-inch digits.
S-meter sensitivity: Not specified.	2 μV/full-scale reading.
Receiver sensitivity: 0.5 μV/12 dB SINAD.	0.55 μV/20-dB quieting.
Squelch threshold: 0.3 μV or less.	Less than 0.1 μV.
Internally generated spurious signals: Below 1 μV equivalent.	As specified (none detected).
Audio output: 1.5 watts at less than 10% THD.	As specified.
Transmitter rf-power output: At least 15 watts, adjustable.	As specified.
Current consumption: 750 mA maximum, receive; 4 A maximum, transmit at 13.8 V dc.	700 mA maximum, receive; 3.2 A maximum, transmit at 13.8 V dc.
Size (HWD): 2-3/4 × 7-1/4 × 10-1/4 inches.	
Weight: 5 pounds.	
Color: Black/gray.	

Note: mm = inches × 25.4, kg = pounds × 0.4536.

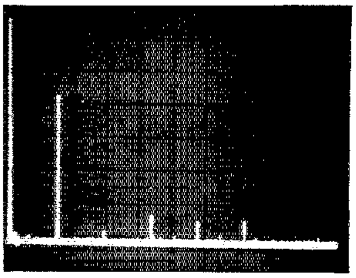


Fig. 2 — Spectral display of the VF-7401. Vertical divisions are each 19 dB; horizontal divisions are each 100 MHz. Output power is 15 W at a frequency of 146.94 MHz. The fundamental has been reduced in amplitude approximately 28 dB by means of notch cavities; this prevents analyzer overload. All spurious signals are at least 63 dB below peak fundamental output.

provides proper frequencies for transmitter and receiver injection. The incoming signal passes through a double-tuned circuit to an rf-amplifier stage where it is mixed with the sixth harmonic of the VCO. Low-sided injection is employed. The resultant 10.7-MHz signal passes through an 8-pole crystal band-pass filter and is amplified. A 10.245-MHz signal is mixed to produce the 455-kHz i-f. A monolithic quadrature-detector IC demodulates the signal and feeds the recovered audio to the audio-amplifier stage. The receiver has a noise-squelch system, which provides excellent squelch action. A green LED indicates an unsquelched condition. The associated voltage is also used to control the scanning functions.

On transmit, the audio passes from the high-impedance microphone through an amplifier stage and a preemphasis network that improves the signal-to-noise ratio. The pre-emphasized audio passes through another amplifier stage and a clipper stage that limits the deviation. A deviation-limit control is used to adjust the deviation level. An astable multivibrator generates the Continuous Tone Coded Squelch System (CTCSS) tones that are used to access some repeater systems. Audio voltage from the microphone and the tone generator is applied to the VCO, which produces the fm signal. The signal is tripled, doubled, amplified and applied to the power amplifier for final amplification to the 15-watt level. Output power is sampled and fed to the meter to give an indication of the output power level. Adequate filtering is provided to ensure that the output signal is clean.

Several safety features are built in. A diode provides reverse-polarity protection. High VSWR will not damage the transceiver. An out-of-lock detection circuit will cause the transmitter to be inhibited if the PLL looses lock. Scanning will cease automatically if the PTT line is keyed during scan.

Operation

The microphone is a high-impedance type. All operating controls are located on the front panels, including a meter that shows relative transmitted and received signal levels. A three-digit, red LED display shows the receive frequency (for instance, with the receiver set at 146.88 MHz, the display will show 688). The transmit frequency is not shown. The knobs on the VOLUME control (on/off switch) and SQUELCH control have a "good feel" and are large enough to be adjusted comfortably.

The mode switch contains four operating positions: −600, SIM (simplex), +600 and AUX (auxiliary). The AUX position is provided for an alternate (e.g., MARS, CAP and so on) frequency split. Owners may contact the Heath technical consultant department for information about wiring the transceiver for other desired offsets. One frequency pair (of interest to me) is 143.99/148.01 MHz, used by Army MARS repeaters. I found Heath's instructions for modifying the wiring very easy to follow.

The TONE switch permits the user to choose among three standard CTCSS (or PL in general amateur parlance) tones or no tone. CTCSS is in use by more and more repeaters these days. Heath should be commended for providing this as "standard."

The DIM/BRIGHT switch makes the display readable in bright light without "blinding" you at night. This feature is useful to the mobile operator. Three black push-button switches mounted beneath the corresponding digit are used to select the 1-MHz, 100-kHz and 10-kHz digits of the desired receive frequency. Touch the switch, and the display will scan up frequency until pressure is released.

When the MAN/SCAN switch is in, the transceiver operates in the manual mode. Any frequency may be selected by pushing any combination of the frequency-selector switches located below the LED display. When the MAN/SCAN switch is out, the transceiver scans upward continuously in the 10-kHz steps for the full range of a 1-MHz segment. At the "top" of the segment, it jumps back to the "bottom" of that same segment; e.g., 146.99 is followed by 146.00.

The LOCK/LATCH switch permits selection between two types of scanning action. With lock engaged, the VF-7401 scans until a signal opens the squelch. The receiver remains on this frequency until the LOCK switch is released. If LATCH is selected, the unit scans until a signal opens the squelch. The transceiver stays on this frequency until the signal disappears and the squelch closes. After an additional few seconds delay with the squelch closed, the VF-7401 resumes scanning.

One other feature that is most useful is the "power-up" function. Without this function, the VF-7401 could "come up on" any frequency between 140.00 and 149.99 MHz each time it is turned on. With this circuit operating, the VF-7401 always "powers up" on the same frequency. The user chooses this frequency by selecting and properly attaching wires on the synthesizer board. The Heath manual contains detailed information for setting the chosen frequency.

Operating Report

I use the VF-7401 fixed and mobile. Four adhesive-backed rubber feet were installed on the bottom of the radio case to prevent marring supporting surfaces. Heath provides a gimbal bracket that can be used to mount the transceiver under the dash of an automobile. The gimbal bracket comes with four predrilled mounting holes and matching self-tapping screws. The lip under our dash is large enough to mate with only two of the screws. I used a small hand drill to form two pilot holes for mounting the bracket. Thus far, the two screws are holding the bracket firmly in place, with no evidence of problems. The gimbal bracket may also be used as a supporting stand if mobile operation is not contemplated. In that case, Heath recommends that four adhesive-backed rubber feet be attached to the gimbal bracket.

A large screw is welded to each side of the case of the VF-7401. The screws slide into slots in the bracket when mounting. One-inch cork washers prevent the bracket from marring the side of the VF-7401 case. The transceiver is held firmly in place by means of two 1-1/4-inch thumbnuts. The first time I mounted the VF-7401 in our car, I did not tighten the thumbnuts sufficiently. The radio "swiveled" when we hit bumps in the road — we were traveling in New York and Heaven knows that New York has a lot of bumps in the road! After that first experience I remembered to tighten the nuts firmly when installing the radio in the bracket. No further problems were noticed. This system makes it quite convenient to remove or install the radio when desired.

I have not encountered any problems when using the rig either mobile or as a base station. The scanner function is great while driving. Right now, the rig is set up in the dining room instead of the shack. I told you it was pretty. — *Sally O'Dell, KB1O*

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

SSB OVERDRIVE INDICATOR

□ The lead photo, Fig. 1 and the diagram in Fig. 2 show an ssb overdrive indicator that I built. It was inspired by the March 1981 *QST* article, "A Peak-Reading Bar-Graph Meter for SSB Transmitters," by Eric Kirchner, VE3CTP.

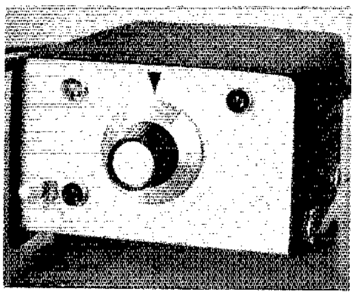
Conventional panel instruments are simply incapable of telling you what is happening in the ssb mode. With this device, if things are normal, the green LED on the left winks at you as you speak. But if you overdrive the transmitter, the red LED (DS2) on the right flashes as if to say, "Lower your voice or turn the microphone gain down; you are distorting and splattering!" The circuit is simple, and the components are easily obtainable and inexpensive. Most of them would be in any junk box worthy of its name. It's an easy weekend project! I find it quite useful at my station.

An rf voltage sample is taken from the transmission line by means of a rear panel SO-239 connector with an M-358 T fitting attached. The variable voltage divider, rectifier and filter are essentially the same as described by Kirchner. The green LED (DS1) will be illuminated whenever an appreciable voltage is present. The unijunction transistor (UJT) is biased by the 9-V battery. Conduction between E and B_1 starts when the dc voltage at E rises to a critical level, around 3 V. When this occurs, the red LED, DS2, is illuminated.

Setting the indicator is easy. Flip the switch on, illuminating the pilot LED (DS3). The potentiometer should be in the zero position (fully counterclockwise). Tune the rig in the cw mode, following the usual procedure. Send a series of dots while advancing the potentiometer to the point where the red LED just starts flashing. Switch the rig to the ssb mode. To maintain a good average power level, I adjust the microphone gain so that I see an occasional red flash on an exceptionally high voice peak. The resulting minimal distortion should not be objectionable.

Conduction through the UJT starts abruptly and decisively when the potential rises to the critical 3 V. As the voltage drops below the critical level, however, the UJT does not stop conducting in the same abrupt way. The voltage must drop to 2.8 before conduction finally stops. This latching effect is the reason the potentiometer should be set while sending a series of dots rather than with the rig key-down. This effect is of no concern when the rig is in the ssb mode, as voice peaks are of short duration and unlatching happens naturally. — *Joe Kennicott, W4OVO, Lexington, Tennessee*

*Assistant Technical Editor



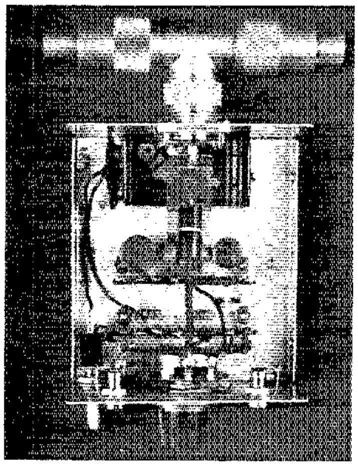


Fig. 1 — This photograph shows the tidy arrangement of the W4OVO ssb overdrive indicator components. A coaxial cable T placed in the transmission line brings a sample of the rf to the indicator. A 9-V battery that energizes the unit is mounted conveniently just below the coaxial connector at the rear of the enclosure.

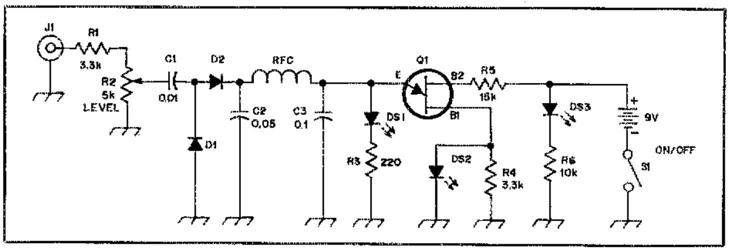


Fig. 2 — The simple circuit for the W4OVO overdrive indicator. Most parts may be found in a well-stocked junk box or may be obtained at electronic supply stores, such as Radio Shack.

C1 — 0.01 μF disc, 500 V.
C2 — 0.05 μF disc, 50 V.
C3 — 0.1 μF disc, 50 V.
D1, D2 — 1N914 or equiv. switching diode.
DS1 — T-1-3/4 LED, green.
DS2 — T-1-3/4 LED, red.
DS3 — LED, pilot, color optional.
Q1 — Unijunction transistor, 2N2646 or equiv.
R1 — 3300 Ω, 2 W.
R2 — Linear potentiometer, 5 kΩ.
R3 — 220 Ω, 1/4 W.
R4 — 3300 Ω, 1/4 W.
R5 — 15 kΩ, 1/4 W.
R6 — 10 kΩ, 1/4 W.
RFC — 1 mH.

CORRECTING INTERMITTENT DISPLAY ON TS-830S

□ After several months of perfect operation, my TS-830S exhibited an intermittently erroneous and fluctuating digital display over a portion of the VFO range. The improper display frequency was always lower than that indicated on the analog dial. This occurred regardless of the band selected. When my remote VFO-230 memory was used to "read" and then "write" the internal VFO frequency, the remote VFO display agreed with the main analog dial. Also, the audio of the received frequencies agreed when comparing the two VFOs. The internal display also read correctly and would not fluctuate when the remote VFO was selected.

The problem was traced to low VFO output (which measured 150 mV in my case). This was sufficient to operate the rig, but marginal for driving the counter. The output level of the VFO should be 200 mV, which is set by adjusting VFO capacitor TC2. Access is gained to this capacitor by removing the four allen-head screws from the corners of the VFO and then sliding the VFO forward. Refer to the TS-830S service manual for suitable measurement points and test-equipment recommendations. — *Steve Lawrence, WB6RSE, Los Angeles, California*

TEMPORARY TIE WRAPPING

□ Most common plastic and nylon tie-wrapping devices use corrugations or teeth on one side of the band. When threaded correctly through the locking device, a ratchet prevents the band from being withdrawn. Each time I would install a wrap, thinking I was through, it wasn't long before I thought of another wire that should also be harnessed, or perhaps I would decide to reroute a wire another way to make it shorter or to correct circuit instability. I often ended up wasting several wraps because they had to be cut needlessly.

Temporary tie wrapping can be a big help until things are really nailed down and the project finished. To use them without permanently locking the straps in place, thread the strap through the locking device with the smooth side toward the ratchet. In this way, the ratchet still provides sufficient friction to hold the wrap in place, but does not interfere with unwrapping a wire that must be changed or when the wrap must be moved elsewhere. When the project is complete, the wraps can be redone so that the ratchets engage, and the lid can be put on before another brainstorm occurs. — *Robert G. Weaton, W5XW/VP1XW/XE2XW, San Antonio, Texas*

CUTTING CIRCUIT-BOARD MATERIAL

☐ Use a plastic cutter to cut circuit-board material. Scribe a deep line on each side of the circuit board. This will provide a clean break. The tool can also be used to make the ARRL universal board in a few minutes. I use a Fletcher no. HPC-22 to do the work. This tool is available at hardware stores. — *Richard B. Stevens, W1QWJ, Ashuelot, New Hampshire*

USING AN EXTERNAL AMPLIFIER WITH THE FT-707

☐ I read Doug DeMaw's review of the Yaesu FT-707 transceiver in June 1981 *QST*. Being a proud owner of one of those rigs, I was especially interested in his comments about the equipment not having a direct control line for activating an external amplifier. Such a provision does exist, but not in the conventional format. That is, there is no internal relay or solid-state switch that is intended for triggering a linear amplifier. There is, however, a +12-V connection available at pin 6 of accessory socket J7. See Fig. 3. When the transmitter is keyed, +12-V dc appears on pin 6. This can be used as a control voltage for an external 12-V dc relay, thereby providing the actuating mechanism for an outboard amplifier.

Another tip concerns the use of an external VFO. For those who aren't aware of this interesting condition, I want to mention that when a VFO is plugged into the appropriate J6 socket, the internal VFO becomes inoperative. Switching diodes remove the operating voltage from the built-in VFO when an external one is plugged into J6. — *Jesse Conn, W7SOD, Seattle, Washington*

FT-301 KEY CLICKS SOLVED

☐ Your March 1980 Hints and Kinks article concerning improved keying for the FT-7B inspired me to do something about the keying for my FT-301 (a second cousin to the FT-7B). A nearby ham reported that I was wiping out his reception with key clicks. His oscilloscope observations indicated that my FT-301 had almost instantaneous rise time and a decay time of 10 ms. Also, the rig had always keyed lightly. I reasoned that if I were to reduce the total overall resistance to the base of Q106 and reproportion resistors R135 and R136, I could improve the keying wave form, aside from making the keying a little heavier. See Fig. 4.

The replacement resistors came from my junk box, but they did the job. It was unnecessary to change C127. My neighbor tells me that the wave-form rise and decay times are about 5 ms. He now enjoys copying DX within 1 kHz of my signals while I run a string of continuous dots through my 1/2-kW linear amplifier and beam my TA-33 directly at his QTH. My solution may help other FT-301 owners. — *Jack L. West, W6VD, Sacramento, California*

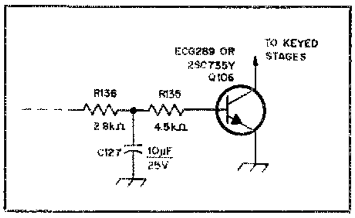


Fig. 4 — A key-click problem concerning the FT-301 at W6VD was cured by reducing the overall resistance to the base of Q106. The values shown above were substituted for the original values. This change resulted in rise and decay times of 5 ms.

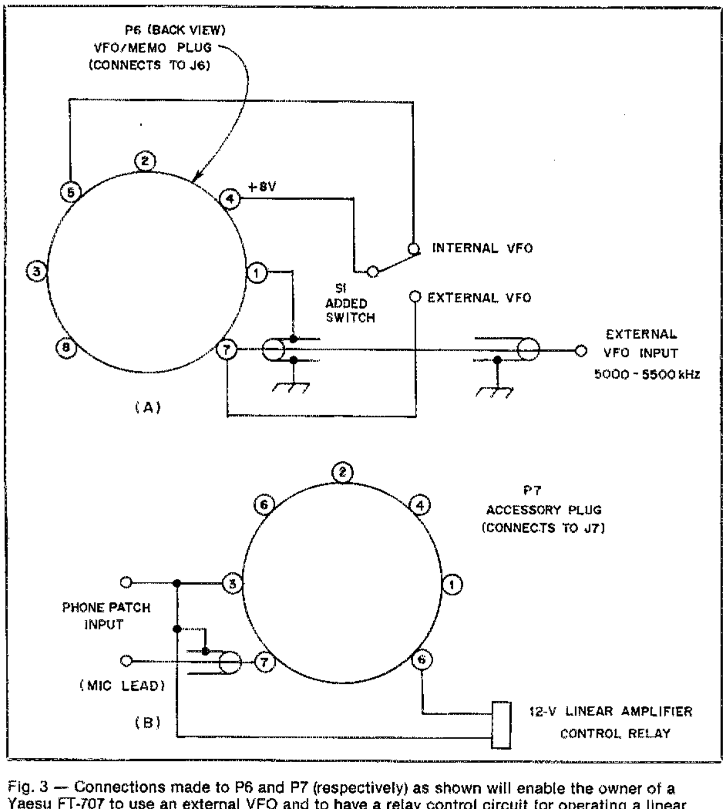


Fig. 3 — Connections made to P6 and P7 (respectively) as shown will enable the owner of a Yaesu FT-707 to use an external VFO and to have a relay control circuit for operating a linear amplifier with the '707.

AN OLD TIMER'S WAY OF PROTECTING MOBILE RELAYS

☐ Old voltage regulator boxes make excellent relay enclosures for mobile applications. The boxes are weather-tight, are easy to mount, and usually have a hole or two in the bottom for bringing leads in or out of the box. Discarded voltage regulators can probably be obtained at local garages. — *Rathbun B. Griffin, W1VON, Granby, Connecticut*

TRANSISTOR REPLACES RELAY IN LITTLE JIMMY KEYER

☐ I built the Little Jimmy Keyer, described by Richard Rose in September 1979 *QST*. After being unable to make it operate (no smoke evident!), I gave my problem to Al Davis, WA2URT. He found an insufficient current in the power supply (I tried a 9-V battery). In the process he replaced the reed relay with a transistor, making the whole unit solid-state. The changes in the circuit are shown in Fig. 5. — *Harvey Horn, WB2NMN, Stony Brook, New York*

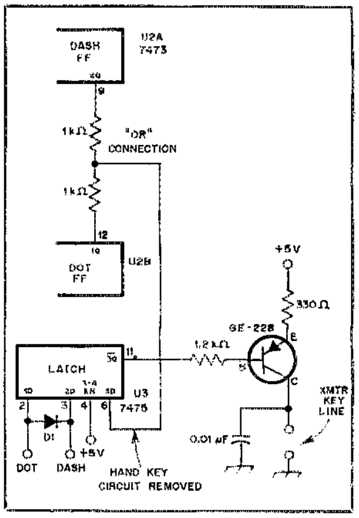


Fig. 5 — The Little Jimmy Keyer, described in September 1979 *QST*, becomes all solid-state with the modification shown that eliminates the reed relay of the original circuit. With this configuration 3Q̄ and 3D provide a simple buffer. The GE-228 is wired for grid-block keying.

Technical Correspondence

Conducted By
Gerald L. Hall,* K1TD

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WAVE TRAPS WITH THREE COMPONENTS

☐ Wave traps are simple circuits used to obtain a low impedance at resonance, Fig. 1A, or a high impedance at anti-resonance (parallel resonance), Fig. 1B. These circuits are effective, but (sometimes unfortunately) they show definite reactive impedances at all other frequencies.

By definition, a wave trap opposes signals near one frequency (or wavelength) while not hindering some other signals. The addition of a single capacitor or inductor will provide a trap that is resonant at one frequency and anti-resonant at another. See Fig. 2. Resonance occurs below the anti-resonant frequency in the circuit with the added capacitor (Fig. 2A), and above the anti-resonant frequency using the added inductor (Fig. 2B).

The general design procedure (Fig. 2C) is to select values for X and X1 to give resonance.

*Associate Technical Editor

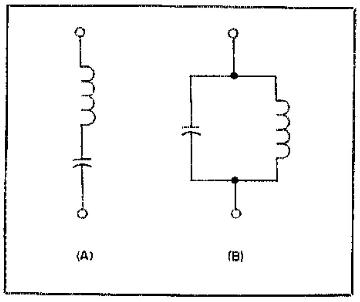


Fig. 1 — At A, a resonant wave trap to be shunted across a high-impedance source. At B, an anti-resonant (parallel resonant) wave trap to be used in series with a low-impedance load.

Scale these values to the anti-resonant frequency and add. Select X2 to have the negative of this value at anti-resonance. For example, to design a wave trap that is resonant at 4 MHz and anti-resonant at 8 MHz, Fig. 2A is applicable:

Let C1 = 1000 pF
X1 = −40 ohms at 4 MHz, −20 ohms at 8 MHz
X = 40 ohms at 4 MHz, 80 ohms at 8 MHz
X2 = −(80 − 20) = −60 ohms at 8 MHz

From this:
C2 = 333 pF and L = 1.6 μH

As another example, Fig. 2B applies for a wave trap that is resonant at 8 MHz and anti-resonant at 4 MHz:

Let X = −80 ohms at 8 MHz, −160 ohms at 4 MHz
X1 = 80 ohms at 8 MHz, 40 ohms at 4 MHz
X2 = −(40 − 160) = 120 ohms at 4 MHz
In this example C = 250 pF, L1 = 1.6 μH and L2 = 4.8 μH.

There is a small inaccuracy in the estimation of anti-resonance. This tends to vanish as the inductor Q rises toward 100. Depending on the application, some care must be taken in the selection of the initial values of X and X1 to obtain the desired results with practical values of Q. — *David T. Geiser, WA2ANU, ARRL TA, RR 2, Box 787, Snowden Hill Rd., New Hartford, NY 13413*

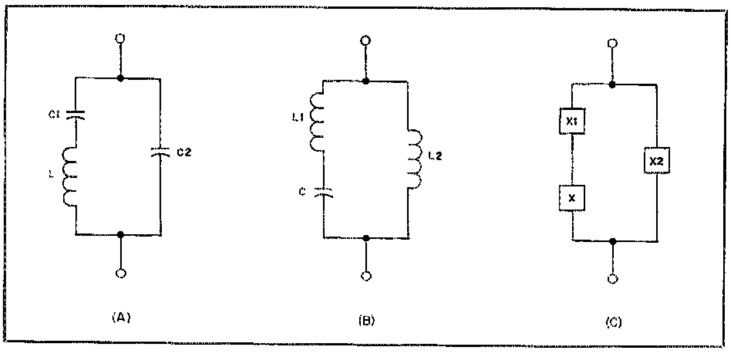


Fig. 2 — A circuit with anti-resonance below the resonant frequency is shown at A. At B, a circuit with anti-resonance above the resonant frequency. At C is the generic circuit used in design calculations. The relative positions of the components as drawn in C are the same as in A or B, whichever is applicable. The use of high-Q components is assumed.

WAVE REFLECTIONS IN ATTENUATORS, FILTERS AND MATCHING NETWORKS

☐ Network-type filters and attenuators have one thing in common — they both attenuate energy. However, this is just about the extent of their similarity; they operate on quite different principles and should not be confused with one another. Network-type filters attenuate harmonic and/or subharmonic energy.

Network-type attenuators usually comprise resistive elements to absorb and dissipate power equally at *all* frequencies. See Fig. 3 as an example of this type of network. The elements are well matched to the system impedance so as not to reflect any power back to the source. Filters, on the other hand, comprise low-loss reactive elements so as to absorb or dissipate a minimum of power, thereby conserving power at the frequencies to be passed through the filter. (An ideal filter would have lossless elements and thus dissipate no power.) The reactive elements in the filter are arranged so that it is well matched for minimum reflection at the pass frequencies, but mismatched for maximum reflection at all frequencies to be rejected. The rejection is accomplished by selectively reflecting back to the source all the power appearing at the unwanted frequencies, where, on return, the reflected power causes the source to be mismatched to the line at *only* the unwanted frequencies. This selective mismatch prevents the source from delivering further power at the unwanted frequencies. Thus, attenuators attenuate all frequencies by absorption and dissipation, while filters attenuate only the *unwanted* frequencies by *selective reflection.*

The primary purpose of the matching network is to couple circuits that have different impedance levels, such as a power source and a load, so that the source will make its maximum power available to the load at the fundamental frequency. Low-loss reactive elements, as in the filter, are used to perform the matching function.[1] See Figs. 4 and 5. The distributed elements of transmission-line transformer and stub configurations may be used instead of lumped reactances, but the principles are the same.

The elements of the network are arranged so that when the network is terminated in a resistance, R, equal to the optimum load impedance of the source, Zc, the network will produce a mismatch at the fundamental frequency that is *complementary* to the mismatch that would arise if the source and the load were connected together directly without the matching network. Complementary mismatches pro-

[1]G. Grammer, "Simplified Design of Impedance-Matching Networks," in three parts, *QST* for March, April and May, 1957.

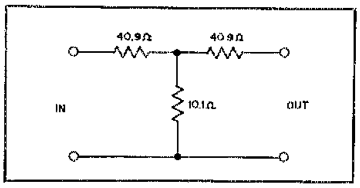


Fig. 3 — A network type of attenuator. The values indicated provide 20 dB of attenuation in a 50-Ω system. When terminated in 50 Ω, the input impedance of the network is 50 + j0, and the output energy is attenuated by 20 dB from that at the input no matter what the input frequency, assuming the resistors have no reactance. Networks such as this may also be designed for unequal input and output impedances.

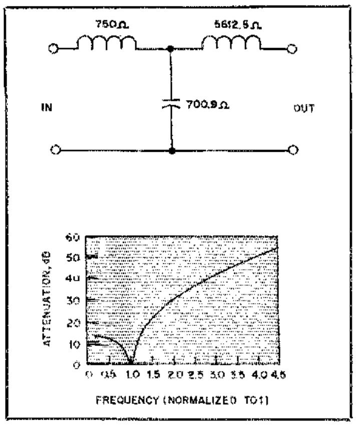


Fig. 4 — A T-network matching circuit of L and C elements, and a curve showing its attenuation versus frequency. The component reactances shown here provide a match for a 5000-Ω load to a 50-Ω source, with an unloaded input-section Q of 15. The attenuation curve is calculated for a 5000-Ω load of pure resistance at all frequencies, but the impedance of loads such as antenna systems are seldom if ever constant across such a frequency range. The input impedance versus frequency for the fixed 5000-Ω load is presented in Table 1. By changing the Q and component reactances in the circuit, many other combinations will provide the same 5000- to 50-Ω match, but the attenuation curve will assume a different shape.

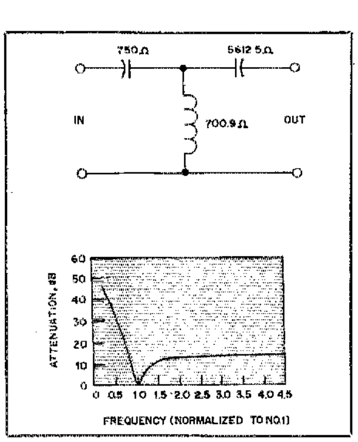


Fig. 5 — Another T-network matching circuit of L and C elements and its attenuation curve. The circuit is identical to that of Fig. 4 except that inductances have replaced capacitances and vice versa; the reactance values remain the same for similar locations in the circuit. This network, too, will match a 5000-Ω load to a 50-Ω source. The input impedance versus frequency for a fixed 5000-Ω load is given in Table 2.

duce complementary reflections, each mismatch producing a reflected voltage (and current) that is equal in magnitude, but of opposite phase, to that produced by the other.

When the matching network is inserted between the source and load of different impedances, complementary mismatches are produced, one between the source and the network, and its complement between the network and the load. The reflected voltages (and currents) of equal magnitude and opposite phase resulting from the mismatches combine in the network to produce a resultant voltage (and current) of zero phase relative to the voltage (and current) of the source wave. Thus the resultants of the reflected voltages and currents add in phase to those of the source wave. These in-phase additions to the source wave have the effect of re-reflecting the reflected voltages and currents into the forward direction, resulting in the cancellation of all rearward-traveling waves. Thus a 1:1 conjugate match is formed, and since the source now has its desired or optimum impedance for a load, it makes its maximum power available to the actual load of different impedance. Keep in mind that the "load" now seen by the source is the combination of the actual Zc-mismatched load and the matching network. Although it may seem difficult to appreciate that an additional mismatch is deliberately introduced to obtain a match (such as with a stub on a line), the mismatches described above must exist as Zc mismatches to produce the controlled complementary reflections that are required to develop the conjugate match. However, no power is lost from the reflections, and, except for the small I^2R and E^2/R losses in the low-loss elements of the matching network, the maximum available source power is transferred to the Zc-mismatched, but conjugate-matched, load.

As stated earlier, the principles of network and stub matching are identical. To emphasize the general concept that all conjugate matching is achieved by canceling one mismatch reflection with another, a few words concerning stub matching will be helpful. In stub matching, the stub introduces the deliberate mismatch, and thereby produces the complementary reflections that accomplish the conjugate match on the line. The stub is of the correct length and impedance to produce amplitudes of reflected voltage and current equal to those reflected by the load mismatch. The stub is placed on the line where the voltages (and currents) reflected by the load mismatch are of opposite phase to those produced by the stub. The line is thus matched (no reflections) between the stub point and the source. By comparison, the network generates the same complementary-mismatch reflection as the stub, and simultaneously adjusts the effective electrical distance from the mismatched load, so that its complementary reflection is placed at the same electrical position on the line as a correctly placed stub.

Turning now to the harmonic rejection capability of matching networks, the key to the rejection is *mismatch.* As we know, the percentage of power the source will make available to a load is proportional to the quality of the impedance match to the load. Conversely, and crucial to harmonic rejection, the amount of power the source will *withhold*, relative to its maximum available power at a given frequency (such as a harmonic), is proportional to the impedance mismatch at that frequency. Single-frequency matching networks are designed to provide only *one* complementary mismatch, compensating for the load mismatch appearing at the fundamental frequency. Thus, the beauty of the network is that it inherently fails to provide complementary mismatches to compensate for the mismatches presented by the load at the harmonic frequencies. Consequently, as in the filters described earlier, the source remains mismatched at the undesired subharmonic and/or harmonic frequencies, and delivers reduced power at these frequencies in the amount that the degree of match (or mismatch) dictates. Tables 1 and 2 indicate this effect by showing the input impedances for the networks of Figs. 4 and 5, respectively, for a range of frequencies and a fixed load. Only at the fundamental does a match occur.

The most common amateur usage of a matching network is the so-called antenna

Table 1

Frequency Vs. Network Input Impedance for the Circuit of Fig. 4

A fixed load of 5000 Ω and lossless circuit elements are assumed for all frequencies. The frequency is normalized to 1 for the fundamental.

Frequency	*Input Z, Ohms*
0.4	1.8 − j1589.6
0.6	8.4 − j814.4
0.8	23.6 − j346.4
1.0	50.0 + j0.0
1.2	89.1 + j284.4
1.4	140.9 + j530.8
1.6	204.9 + j750.4
1.8	279.8 + j948.8
2.0	364.3 + j1129.1
2.2	456.9 + j1293.3
2.4	556.3 + j1442.7
2.6	661.2 + j1578.3
2.8	770.2 + j1701.1
3.0	882.3 + j1811.7
3.2	996.5 + j1911.0
3.4	1111.9 + j1999.6
3.6	1227.6 + j2078.1
3.8	1343.1 + j2147.3
4.0	1457.6 + j2207.8
4.2	1570.8 + j2260.2
4.4	1682.1 + j2305.1
4.6	1791.2 + j2343.1
4.8	1897.9 + j2374.8
5.0	2001.9 + j2400.8
5.2	2103.0 + j2421.4
5.4	2201.2 + j2437.2

Table 2

Frequency Vs. Network Input Impedance for the Circuit of Fig. 5

A fixed load of 5000 Ω and lossless circuit elements are assumed for all frequencies. The frequency is normalized to 1 for the fundamental.

Frequency	*Input Z, Ohms*
0.4	608.1 − j1512.1
0.6	228.7 − j818.7
0.8	100.8 − j349.0
1.0	50.0 + j0.0
1.2	27.1 + j282.5
1.4	15.8 + j526.1
1.6	9.8 + j745.2
1.8	6.4 + j948.3
2.0	4.3 + j1140.2
2.2	3.0 + j1324.2
2.4	2.1 + j1502.3
2.6	1.6 + j1675.9
2.8	1.2 + j1846.0
3.0	0.9 + j2013.4
3.2	0.7 + j2178.5
3.4	0.6 + j2341.8
3.6	0.4 + j2503.5
3.8	0.4 + j2664.0
4.0	0.3 + j2823.5
4.2	0.2 + j2982.0
4.4	0.2 + j3139.7
4.6	0.2 + j3296.8
4.8	0.1 + j3453.2
5.0	0.1 + j3609.1
5.2	0.1 + j3764.6
5.4	0.1 + j3919.7

tuner. [*QST* uses the word Transmatch to denote any such circuit. — Ed.] The network increases operating flexbility by providing the conjugate match to compensate for the mismatch between the feed line and the antenna that arises when a coax-fed antenna is operated off resonance or when the antenna is fed with open-wire line. In these cases the load terminating the matching network is the impedance appearing at the input terminals of the feed line. As we know, when the antenna impedance is mismatched to the Zc impedance of the feed line, reflections from the mismatch cause the line input impedance to change from its resistive characteristic value Zc (usually 50 or 75 ohms) to some new complex value determined by the antenna impedance and the length of the feed line.[2] It is this new line-input impedance (which changes as we change frequency) that we match to the source with the Transmatch at only the fundamental frequency.

Obviously the antenna presents a drastically different impedance to the feed line at harmonic frequencies compared with that of the fundamental, and consequently the imput impedances to the feed line are vastly different at the harmonic frequencies than what the matching network sees as a load at the fundamental frequency. These load-impedance changes with frequency, as well as the effects described earlier in the paragraph on filter principles, create reflections from the uncompensated mismatches at the harmonic frequencies that are responsible for the harmonic rejection of the matching network.

There are many arrangements and configurations of reactance elements that can be used equally well to generate a complementary mismatch for obtaining a conjugate match. However, there are vast differences among these various configurations concerning the severity of their *noncomplementary* mismatches that are required to reject harmonics and other unwanted frequencies. Figs. 4 and 5 illustrate this simply. Note that both circuits are T networks having identical reactance values in similar positions of the circuits; only the type of reactance differs, capacitive vs. inductive. Both circuits will match a 5000-Ω load to a 50-Ω line at the fundamental frequency. The circuit of Fig. 4 is commonly called a high-pass configuration, and that of Fig. 5 a low-pass configuration. Either circuit may attenuate frequencies both lower and higher than the fundamental, however, as shown by the frequency-response curves. Of course, since the frequencies of the harmonic energy are higher than the fundamental, a matching network of the low-pass configuration would be the most desirable, a circuit with series inductance and shunt capacitance arms.

For a more detailed explanation of the role played by reflections in the science of impedance matching and harmonic rejection, may I refer you to two of my previous *QST* articles.[3,4]

As a parting thought concerning the operational adjustment of Transmatches, the amateur should be aware of the trade-off between optimum efficiency (minimum power lost in the network) and optimum harmonic rejection. There are usually several settings of the network that will yield a 50-Ω impedance at the Transmatch. As far as the transmitter is concerned, all such settings are equivalent — the same as if you were feeding a 50-Ω dummy load. However, the 50-Ω input obtained with the lowest loaded Q has the optimum efficiency. At the other extreme, the 50-Ω inputs obtained with the higher loaded Qs offer increased rejection of unwanted frequencies, but with some increase in insertion loss. In either case, the loss is usually small and is well worth the improved operating flexibility afforded by the Transmatch. In the circuits of Figs. 4 and 5, higher Qs are obtained with greater reactances in the series-input arms (lower input capacitance in Fig. 4, higher input inductance in Fig. 5).

In conclusion I would further point out that those Transmatch settings that yield a 50-Ω input impedance do not mean the *SWR* is 1:1. It means only that a 1:1 SWR would exist on a 50-ohm line preceding the Transmatch. You have not "brought the SWR down" on the antenna feed line by adjusting the matching network; you simply have a 50-Ω impedance looking into the input. — *Walt Maxwell, W2DU, ARRL TA, 243 N. Cranor Ave., DeLand, FL 32720*

TRAP ANTENNAS

☐ Probably the simplest coax-fed multiband antenna we amateurs use is one with traps. For purposes of this discussion a trap vertical and a trap dipole, both shown in Fig. 6, can be considered as essentially the same type of antenna. (The vertical antenna operates against an identical image portion in the earth, which might be thought of as the "missing" half of a dipole.) The feed-point impedance of the vertical is approximately half that of its horizontal counterpart, but disregarding earth losses and the possibility of current flowing outside the shield of the coax in the dipole case, the two are otherwise electrically identical.

Even though a trap-antenna arrangement is a simple one, an explanation of how a trap antenna works eludes most of us. For some designs we find traps that are resonated in our amateur bands, and for others (especially commercially made antennas) we find the traps are resonant far outside any amateur band. Can both work?

A trap in an antenna system can perform either of two functions, depending on whether or not it is resonant at the operating frequency. A familiar case is where the trap *is* resonant. For the moment, let us assume that dimension A in Fig. 6 is 33 feet (10 meters) and that each L/C combination is resonant in the 40-meter band. Because of its resonance, the trap presents a high impedance at that point in the antenna system. The electrical effect on 40 meters is that the trap behaves as an insulator. It serves to divorce the outside ends, the B sections, from the antenna. The result is easy to visualize — we have an antenna system that is resonant in the 40-meter band. Each 33-ft section (labeled A in the drawing) represents a quarter wave, and the trap behaves as an insulator. We therefore have a full-size 40-meter antenna.

The second function of a trap, obtained when the frequency of operation is *not* the resonant frequency of the trap, is one of electrical loading. If the operating frequency is below that of trap resonance, the trap behaves as an inductor; if above, as a capacitor. Inductive loading will electrically lengthen the antenna, and capacitive loading will electrically shorten the antenna.

Let's carry our assumption a bit further and try using the antenna we just considered on 80 meters. With the traps resonant in the 40-meter band, they will behave as inductors when operation takes place on 80 meters, electrically lengthening the antenna. This means that the total length of sections A and B (plus the length of the inductor) may be something less than a physical quarter wavelength for resonance on 80 meters. Thus, we have a two-band antenna that is shorter than full size on the lower frequency band. The total antenna length (or height) needed for resonance in the 80-meter band will depend on the L/C ratio of the trap elements.

The key to trap operation off resonance is its L/C ratio, the ratio of the value of L to the value of C. At resonance, however, within practical limitations the L/C ratio is immaterial as far as electrical operation goes. For example, in the antenna we've been discussing, it would make no difference for 40-meter operation whether the inductor were 1 μH and the capacitor were 500 pF (the reactances would be just below 45 ohms at 7.1 MHz), or whether the inductor were 5 μH and the capacitor 100 pF (reactances of approximately 224 ohms at 7.1 MHz). But the choice of these values will make a significant difference in the antenna size for resonance at 80 meters. In the

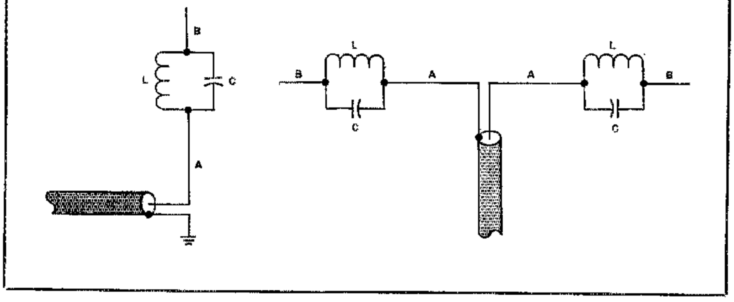


Fig. 6 — A trap vertical and a trap dipole antenna. Either type may be fed with 50-ohm coaxial line. Depending on the L/C ratio of the trap elements and the lengths chosen for dimensions A and B, the traps may be resonant either in an amateur band or at a frequency far removed from an amateur band for proper two-band antenna operation.

[2] M. W. Maxwell, "Another Look at Reflections," Part 7, *QST*, Aug. 1976. See pages 16 through 19.

[3] M. W. Maxwell, "Another Look at Reflections," Part III, QST, Aug. 1973. See Fig. 4, p. 39.

[4] M. W. Maxwell, "Another Look at Reflections," Part IV, *QST*, Oct. 1973, p. 22.

first case, where the L/C ratio is 2000, the necessary length of section B of the antenna for resonance at 3.75 MHz would be approximately 28.25 ft (m = ft × 0.3048). In the second case, where the L/C ratio is 50,000, this length need be only 24.0 ft, a difference of more than 15%.

The above example concerns a two-band antenna with trap resonance at one of the two frequencies of operation. On each of the two bands, the vertical (or half of the dipole) operates as an electrical quarter wave. However, the same band coverage can be obtained with a trap resonant at, say, 5 MHz, a frequency quite removed from either amateur band. With proper selection of the L/C ratio and the dimensions for A and B, the trap will act to shorten the antenna electrically at 40 meters and lengthen it electrically at 80 meters. Thus, an antenna that is intermediate in physical length between being full size on 80 meters and full size on 40 meters can cover both bands, even though the trap is not resonant at either frequency. Again, the antenna operates with electrical quarter-wave sections.

Additional traps may be added in an antenna section to cover three or more bands. Or a judicious choice of dimensions and the L/C ratio may permit operation on three or more bands with just one trap (a pair of identical traps in the dipole). Design information for two-band trap antennas has appeared in *QST*,[1] but the calculations for the more complicated multiband designs are beyond the means of most amateurs.

Lest the significance of information in a previous statement become lost, let me rewind it and play it back again: ***If the operating frequency is below that of trap resonance, the trap behaves as an inductor; if above, as a capacitor.*** Now we all know that inductive reactance is directly proportional to frequency, and capacitive reactance is inversely proportional. Let's now choose trap L and C components, which each have a reactance of 20 ohms at 40 meters. When we shift operation to the 80-meter band, the inductive reactance becomes 10 ohms, and the capacitive reactance becomes 40 ohms, right? Right! How can the trap become inductive at 80 meters with a higher capacitive reactance? Doesn't the extra capacitive reactance make the antenna electrically shorter yet? Fortunately, the answer to this last question is no. You see, the inductor and the capacitor are connected in parallel *with each other,* but the *series equivalent* of this parallel combination is what affects the electrical operation of the antenna. The series equivalent of unlike reactances in parallel may be determined from the equation

$$Z = \frac{-jX_L X_C}{X_L - X_C}$$

where j indicates a reactive impedance component, rather than resistive. A positive result indicates inductive reactance, and a negative result indicates capacitive. In this 80-meter case, with 40 ohms of capacitive reactance and 10 ohms of inductive, the equivalent series reactance is 13.3 ohms inductive. At 20 meters, where X_L = 40 ohms and X_C = 10 ohms, the result is 13.3 ohms capacitive. At 40-meter resonance, X_L equals X_C, and the theoretical series equivalent is infinity, the insulator effect. — *Gerald L. Hall, K1TD, ARRL Hq.*

[1]W. Hayward, "Designing Trap Antennas," Technical Correspondence, *QST*, Aug. 1976, p. 38.

Feedback

☐ N1ATB points out correctly that there is an error in the truth table in Fig. 8 for "The NOR Gate Break-in" from May 1980 *QST.* The R and S at the upper left of the table should be transposed.

☐ In "A Basic Approach to Calculating Cascaded Intercept Points and Noise Figure," October 1981 *QST*, Eq. 1, the radical sign was extended too far to the right. The + D portion of the equation does not belong under the radical sign.

☐ In "A Universal MOSFET I-F Amplifier," August 1981 *QST*, the source resistor for Q1 of Fig. 1 should be 2200 ohms rather than 220 ohms.

☐ Thanks to the sharp eyes of W. H. Bollinger of Pittsburgh, Pennsylvania, we point out that the 470-μF capacitor in Fig. 5 of "Experimenting for the Beginner," September 1981 *QST*, should be connected to terminal "Y" rather than terminal "X." When connected to "X," it will degrade the keying wave shape during operation on 160 through 15 meters.

☐ W2DQA mentions an error in the pc-board pattern for "The L Meter," January 1981 *QST*, Fig. 2. The drain and source leads for Q1 and Q2 need to be transposed in accordance with the leads of the MPF102s.

☐ The schematic diagram in Lewallen's "An Ash-Proof Keyer Paddle — Something New for CW Operators!" (Fig. 1, p. 31 of August 1981 *QST*), contains two errors. U7A should be labeled U1A, and the unidentified output pin of U2B is pin 7. Also, the correct replacement number for U1 is ECG4093B, and not ECG4082B (listed incorrectly in the Sylvania master replacement guide).

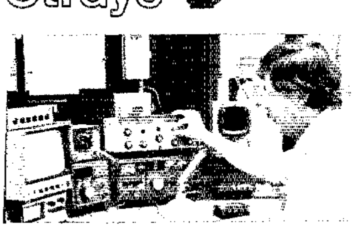
☐ Wayne Sandford, Jr., K3EQ, author of "A Modest 45-Foot DX Vertical for 160, 80, 40 and 30 Meters," September 1981 *QST*, advises that the ground-loss reference in the first column on p. 30 should be 2 dB on 80 meters, rather than 2 dB on 40 meters.

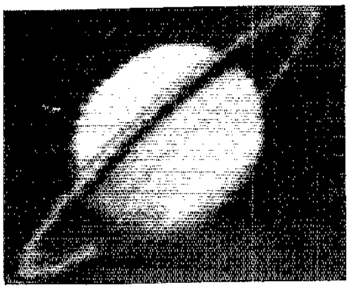
☐ Bob Heil, K9EID, of Marissa, Illinois, calls attention to a misnomer in his article, "Experience 10-Meter FM Operation," in August 1981 *QST*. The third paragraph makes reference to a system that allows the operator to access a 10-meter fm station with a 2-meter signal. He called this a "remote base." It should have been called a "cross-band repeater," because it is a part of the WD9GOE repeater system. The difference is one of semantics. Unfortunately, stated one way it is legal; the other way, it is not.

☐ The Preformed Line Products Company has informed us that GUY-GRIP® is a registered trademark of that company. In the July article "The Ups and Downs of Towers," we failed to note this fact. The correct reference for this product is GUY-GRIP® dead-end.

☐ As described in the Stray on UoSAT, Amateur Radio's newest satellite (this issue, page 105), the beacon antennas will have left-hand circular polarization. "The New Frontier" (October *QST*, page 78) stated that right-hand circular polarization would be used.

Strays





Bernard Glassmeyer, W9KDR, ARRL OSCAR Program Manager, adjusts Hq. lab station W1INF for peak reception of last month's SSTV pictures from the Voyager II Flyby of Saturn. Amateur Radio was used to retransmit the photos worldwide from the Jet Propulsion Laboratory in Pasadena, California. At right is one of the computer-enhanced pictures, including a view of the mysterious spindle shapes in some of Saturn's rings. *(photos courtesy Andrew Tripp)*

BEARING AND DISTANCE PROGRAM

☐ I've trimmed down a TI Programmable 59 Calculator program to determine the true bearing and distance (in kilometers, miles or nautical miles) to a distant station so that the program can also be used on the TI 58. My program, which uses Morse code prompts and entry instructions, is based on the "Direction and Distance by Trigonometry" article in the *ARRL Antenna Book.* I'll send a copy of the program to anyone who will send me an s.a.s.e. The program is written for my /4X QTH, but I'll send a copy of a program with proper coordinates to anyone sending me their coordinates and a blank mag card along with an s.a.s.e. Geary G. Blankenship, KA2MBS, c/o Negev Airbase Constructors, Group: Communications, APO New York, NY 09674.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THE COVER

A crisp winter's day at OH6NU/OH6NM, Jyvaskayla, Finland. Wherever you may be, why not prepare to join in the host of operating activities described on pages 93, 94, 101 and 102.

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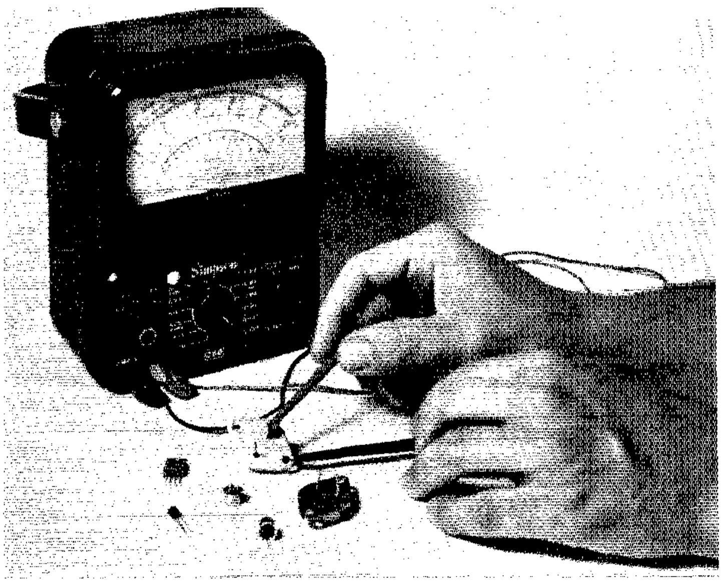


Some Basics for Equipment Servicing

Part 1: Costly repairs to amateur equipment can often be avoided if we do our own repair work. Knowing the nature of semiconductors is a vital means to that end.

By Doug DeMaw,* W1FB

"Gosh, I sure wish the ARRL would have a series of articles on how to fix ham gear at home!" Have we heard or read that comment at Hq.? You bet we have! Our dereliction has not been intentional. Rather, we wondered how such a series might be structured to provide an effective set of practical guidelines. With all of the brands and models of commercial gear in use today, where would we start? The answer seemed to be elusive until we reasoned that a *general treatment* of the basic troubleshooting procedures for solid-state circuits should be entirely applicable to most amateur equipment.

Servicing Commercial Gear

It can be perplexing to peer into the cabinet of today's factory-built equipment. Our eyes are greeted by countless circuit-board modules, most of which stand on end in inaccessible areas of the gear. It's logical to ponder, "How in the world can I check these circuits, and where shall I start?" Rule number 1 should be to purchase the factory service manual for the equipment we own. Rule number 2 calls for buying circuit-board extender cards or cables from the manufacturer. If they aren't available, things will get pretty "sticky" when servicing is necessary. The factory manual provides detailed data on the individual modules in our rigs, X-ray views (sometimes) of the pc boards, lists of typical failures and the causes, and alignment procedures. Extender cables, on the other hand, permit us to extract the suspected module and test it with signal and operating voltage applied. This is important when attempting to locate a faulty voltage or component.

The standard operating manual that comes with most amateur equipment is fairly deficient with respect to servicing information, but the circuit diagrams may be adequate for much of the troubleshooting work. It is practical in some instances to make our own extender cables, provided we can obtain mating sockets for the plug-in pc-board modules. This approach should not be overlooked as an economy measure.

Basic Test Equipment

We need not own a research lab in order to repair our own gear (although at times it might help!). Most of the common failures can be resolved through the use of a high-impedance VOM (VTVM or FET VM).[1] An oscilloscope is a very useful tool, but it will be of little use in signal tracing and analysis unless it responds well to the frequency of the circuit under investigation. We are concerned in this case with the *bandwidth* of the scope. If the instrument has, say, a 30-MHz bandwidth, it should be accurate up to that frequency, and it should be able to yield an accurate waveform display up to 30 MHz. But, if harmonic or spurious energy is present very far above 30 MHz, it won't appear on the waveform being investigated. Ideally, we would have a scope with a 250- or 500-MHz bandwidth for our amateur repair work. Some of the older Tektronix and Hewlett-Packard vacuum-tube scopes can be purchased used at reasonable prices. Check the big radio flea markets for bargains in used test equipment.

A signal generator is recommended if signal tracing and alignment work is to be done. Again, we should keep an eye out for bargains at flea markets. WW II URM signal generators are excellent, as are

*Senior ARRL Technical Editor

[1]Notes appear on page 14.

General Radio Model-80 signal generators. (Numerous inexpensive items of homemade test equipment are described in the League book, *Solid State Design for the Radio Amateur,* chapter 7.)

A homemade or commercial rf power meter and a 50-ohm dummy load should be a part of our repair-shop bill of goods. A solder-sucker tool and a low-wattage pencil type of soldering iron are also standard items. A high-intensity desk lamp and magnifying glass will always be useful, too.

Diode Testing

We can determine the general condition of germanium and silicon diodes by means of an ohmmeter. One end of the suspected diode must be unsoldered from the circuit board to isolate it from other components. If this is not done, transistors or resistors that are attached to the immediate circuit of the diode can cause false resistance readings.

Diodes can be tested for forward and back resistance as shown in Fig. 1. Silicon diodes will show a forward resistance between 200 and 300 ohms (R × 100 scale) and a back resistance of 100 to 1000 megohms, typically (R × 1-megohm scale). Germanium diodes will show a forward resistance of roughly 200 to 400 ohms, with a back resistance of 100 k to 1 megohm. These two readings are obtained with either type of diode by simply reversing the leads of the VOM and changing the VOM multiplier scale. This procedure is useful when selecting matched diodes from a group of diodes. They should be matched as closely as possible for the forward-resistance characteristic.

If no resistance reading is obtained, the diode junction is open. Conversely, if a low-resistance reading is obtained in both directions, the diode is shorted.

Zener Diodes

Zener diodes can be tested for forward and back resistance in the same manner as the diodes we just discussed. But, we are concerned also with the regulation characteristics of our Zener diodes. This parameter can be checked by using the setup shown in Fig. 2. A low current, variable voltage dc power supply is required. The Zener diode under test (D1) is connected across the test leads of a dc voltmeter, as shown. A 1-W, 180-ohm limiting resistor (R1) will suffice for diodes with ratings up to 18 volts. Assume we are checking a 9.1-V Zener diode in Fig. 2. We will set the dc voltmeter to the 15-volt scale. Next, we will vary the power-supply voltage from zero to a point where the voltage across D1 does not increase. This will be the regulation zone of D1. The reading should not increase significantly when the power-supply voltage is raised further. If we are unable to observe a voltage-stabilization point at or near the specified regulation characteristic of the diode, the component can be considered defective. Always be certain to connect the positive lead from the power supply (via R1) to the *cathode* of the Zener diode, as shown in Fig. 2. This will be the banded end of the diode. This technique is useful for learning the "zener" value of unmarked Zener diodes, such as those obtained as surplus.

Bipolar Transistors

Most failures involving bipolar transistors are caused by faulty associated components, voltage surges or transients that subject the transistors to unsafe voltage or current. In a proper environment the transistor should be capable of outlasting its owner. Therefore, if we locate a defective transistor we should search for the "culprit" that caused the untimely demise. It would be highly speculative simply to pop a replacement transistor into the circuit board!

Although there are a number of simple (and not so simple) transistor testers available, some basic home-workshop checks can reveal the most common faults in these devices. Specifically, we can test them for opens, shorts and high leakage. It is possible to check the transistors for approximate current gain as well.

Junction Testing

Let's think of the bipolar transistor as two diodes (p-n junctions), as in Fig. 3. Malfunction generally results from one of the diodes being damaged (open or shorted). Incorrect operation may result also from excessive leakage (reverse current). If a junction is open, chances are that the failure was caused by excessive current. A shorted junction is most often caused by perforation brought on by voltage spikes that rise beyond the safe rating of the transistor. These conditions serve as clues to the cause of the failure.

Observation of the junction condition can be made if we use an ohmmeter, as shown in Fig. 3. We can check the forward resistance of the junctions in the manner indicated. The ohmmeter polarity is set for testing an npn type of transistor. The positive and negative meter leads must be reversed when checking a pnp device. The method is otherwise the same as that shown in Fig. 3. A normal resistance reading should be 300 to 600 ohms, depending on the transistor under test (TUT). High resistance readings indicate an open junction.

We can test the junctions for shorts by reversing the ohmmeter leads and switching the meter to a higher resistance scale. This is shown in Fig. 4. This reverse-resistance reading is taken with the ohmmeter switched to the R × 10 k scale. The meter places a reverse bias on the junctions in this hookup. Low- to medium-power transistors (npn) should indicate a reading of 800 kΩ to as much as several megohms. A typical range for germanium

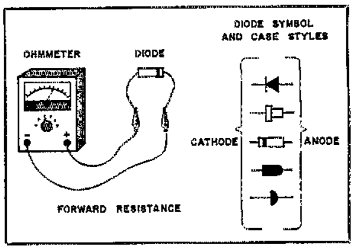


Fig. 1 — Method for checking the condition of small-signal and rectifier diodes with an ohmmeter.

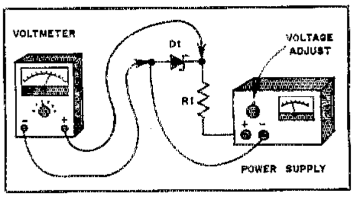


Fig. 2 — Zener diodes can be tested by using a variable dc power supply and a voltmeter.

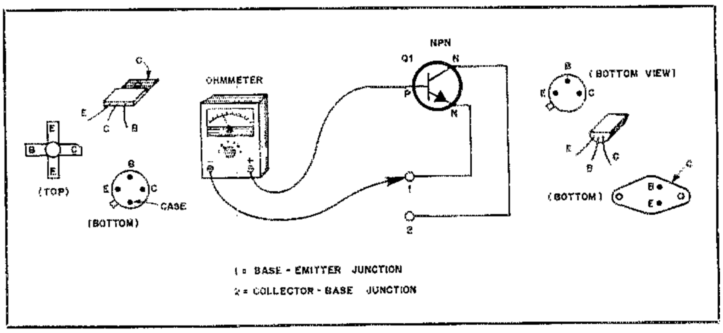


Fig. 3 — Technique for checking the forward resistance of a bipolar transistor. Shorts and opens can be detected in this manner.

transistors is 500 kΩ to 1.5 megohm. High-power transistors have much larger junctions. Therefore, the reverse readings will be lower than for small-signal transistors. Typical readings will be on the order of 50 kΩ or greater. This test indicates the leakage (large) trait of the transistor. We need only reverse the meter leads from the polarity shown in Fig. 4 when testing pnp transistors. It is important that we note the following: The resistance readings we obtain are relative at best, since an ohmmeter can respond accurately only to linear resistances. The readings we obtain will differ with various brands of instruments. Similarly, they will be different if we use meter scales other than R × 100 and R × 10 k. If there is doubt concerning the reliability of our measurements, we can obtain a set of typical readings first by testing an equivalent transistor of known quality (new) and by using the readings as a standard when testing suspected transistors.

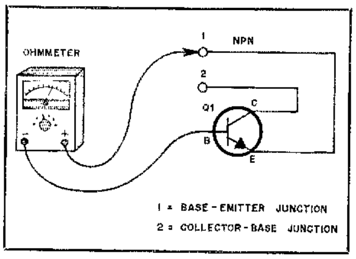


Fig. 4 — Reverse junction resistance of a bipolar transistor can be tested in this fashion.

Direct-Current Measurements

A more precise method of measuring leakage can be accomplished by using a dc-voltage source and a 100-μA dc meter (see Fig. 5). Most low- and medium-power pnp (germanium) transistors will exhibit collector-base (I_{cbo}) and emitter-base (I_{ebo}) leakage currents on the order of 15 μA maximum at approximately 25° C. High-power transistors will have leakage amounts of 90 μA or greater. Silicon npn transistors have much lower leakage — usually less than a microampere. Excessive leakage in any transistor indicates that excessive heat or overloading has taken place. Since ambient temperature (which affects the junction temperature) has a marked effect on the leakage readings we should double the expected leakage current for each 10° C increase in temperature. Pnp transistors can be checked by reversing the battery and meter polarity from that of Fig. 5.

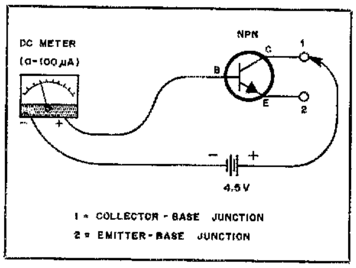


Fig. 5 — Transistor leakage can be investigated with a voltage source and a microammeter, as shown.

Testing for Current Gain (Beta)

The dc beta is the ratio of the collector current to the base current. Hence, if a base current of 1 mA were flowing, and the resultant collector current became 70 mA, the beta would be 70. A check of the manufacturer's specifications would indicate whether or not the transistor was exhibiting a beta within the published boundaries. A typical beta spread might be, say, 30 to 100 for a given transistor, owing to nonuniformity of performance characteristics for a specified transistor type from a particular manufacturing batch. In other words, if we picked up 10 type 2N2222A transistors, it would be unlikely that any two would have identical beta traits.

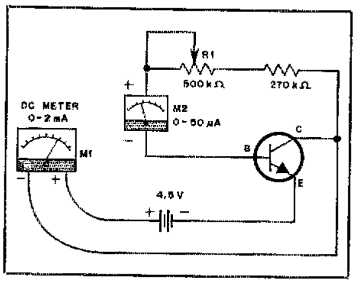


Fig. 6 — Test set-up for determining the dc beta of a transistor.

Ac beta is a parameter of interest to us in signal-amplification circuits. This is a bit more difficult to measure accurately with simple methods. But, we can make the reasonable assumption that if the dc beta is within the specified range, the ac beta will be all right too.

A simple technique for measuring the dc beta of a transistor is illustrated in Fig. 6. R1 is set for a base current of 10 μA. Then the collector current is noted on M1. From this we can determine the dc beta from I_c/I_b with both currents expressed in μA. Therefore, if we had 10 μA of base current and 0.75 mA of collector current, the beta would be 750/10 = 75. By reversing the meter and battery polarities in Fig. 6 we can check the dc beta of pnp transistors.

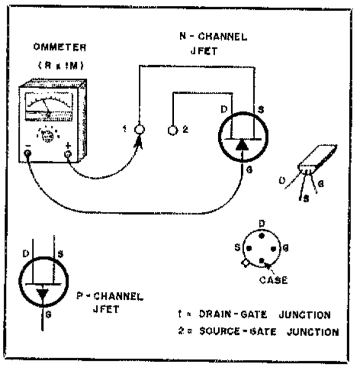


Fig. 7 — System for checking the forward and reverse resistance of a junction FET.

Junction Field-Effect Transistors (FETs)

N-channel JFETs can be checked for opens or shorts if we use the method shown in Fig. 7. With the ohmmeter negative lead hooked to the gate, check positions 1 and 2 with the positive meter lead. If the FET is good, the resistance reading (R × 1 megohm scale) will be several megohms, possibly as high as 1000. If we connect the positive meter lead to the gate and check from source to gate, and drain to gate, we should obtain a resistance reading (R × 100 scale) of 500 to 1000 ohms, typically. P-channel JFETs can be tested by reversing the polarity of the meter leads and performing the same tests. Low-resistance readings indicate high leakage or shorts. Infinite readings in reverse resistance indicate an open junction.

Dual-Gate MOSFETs

It becomes a bit more difficult to test metal-oxide-silicon FETs (MOSFETs), since the gates are insulated from the drain and source of the transistor by a thin, fragile layer of oxide insulating material. If the gates are not protected internally (Zener diodes from the gates to the source) even the static charge on our fingers can destroy the gate insulation. MOSFETs with Zener-protected gates can be damaged easily by voltage peaks greater than about 6 volts, so it is best to handle them with more care than we might give to JFETs or bipolar transistors.

Owing to the gates being insulated from the drain and source, we cannot make forward and reverse measurements with an ohmmeter. An alternative test method is to plug them into a simple crystal oscillator of the type presented in Fig. 8. Rf energy from the oscillator drain is rectified by a diode doubler (D1 and D2), and the resultant dc is monitored at M1. If the MOSFET is defective there will be no meter deflection. A transistor socket can be placed on the test fixture to permit easy connection of the device to be checked. *Warning:* Make sure that S1 is in the OFF mode before plugging Q1 into the tester; likewise when removing Q1.

Y1 can be any fundamental crystal in the hf range, but the circuit constants in

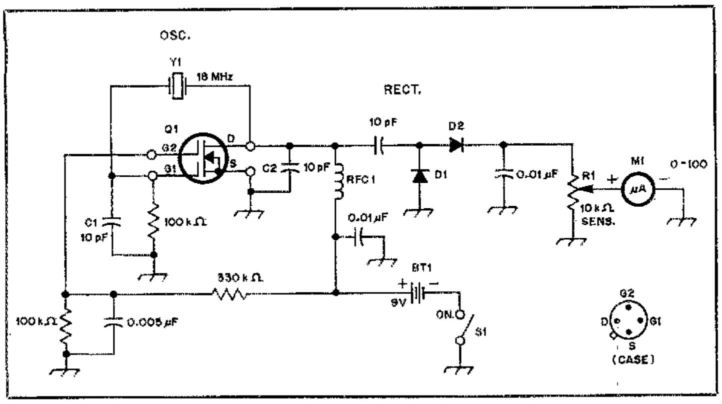


Fig. 8 — Practical circuit for testing a MOSFET (see text). All capacitors are disc ceramic, 10 V or greater. BT1 can be a 9-V transistor-radio battery. D1 and D2 are small-signal germanium diodes (1N34A or equiv.). M1 may be a 50- or 100-µA dc meter. R1 is a linear-taper composition control, and RFC1 can be a miniature rf choke (500 µH to 2.5 mH suitable).
S1 — Spst slide or toggle switch.
Y1 — High-frequency, fundamental-cut crystal, any frequency (see text).

Fig. 8 are for use from 15 to 21 MHz. If crystals for lower frequencies are used it may be necessary to increase the value of feedback capacitors C1 or C2, or both. A similar tester that accommodates bipolar transistors, JFETs and MOSFETs, inclusive of a polarity-reversing switch, appears in the measurements chapter of the *Handbook* (past several editions). A simple go-no-go type of MOSFET tester is shown in an RCA publication.[2] *Caution:* Before performing any of the tests that require the use of a VOM, make certain that a positive potential does, in fact, exist at the positive output jack! Some VOMs and VTVMs exhibit a negative potential at the positive jack, and a positive potential at the negative or ground jack. The condition of your instrument can be checked by attaching a second voltmeter in parallel with the output leads of the first meter. A forward needle deflection on the second voltmeter will indicate which jack of the first instrument is positive. Use that lead as the positive one for all of the tests that require a VOM.

What About ICs?

It would be a difficult, if not impossible, undertaking to determine the condition of an integrated circuit (IC) by simple means. We have such a wide variety of ICs to deal with that it seems almost incomprehensible. Things are complicated further by the myriad pin-out arrangements and case styles. We wouldn't even find it convenient to build a functional tester of the type in Fig. 8, because each type of IC would require a special functional-test circuit. The most practical option before us is to localize the malfunction and make a strong assumption that the IC in that part of the circuit has caused the equipment failure. Removing the suspected IC and substituting a new one will provide the answer. Voltage checks (ac and dc, as applicable) at the pins of the ICs may offer clues concerning the IC performance, but generally will not yield conclusive results.

Summary Remarks

This installment on servicing can best be thought of as "openers" for the game of home-workshop repair. Subsequent treatment of amateur servicing techniques will deal with voltage measurements (typical voltages at the semiconductor terminals), isolating the problem area, signal tracing and waveform analysis. Meanwhile, you should be able to apply the principles discussed in Part 1 to locate minor faults and make easy repairs.

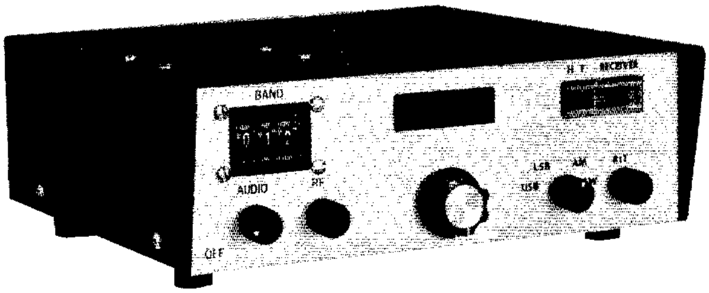
Notes

[1] An inexpensive homemade FET VOM is described (pc board pattern included) in recent editions of *The ARRL Radio Amateur's Handbook*, measurements chapter. The next installment of Beginner's Bench will describe the construction of a high-impedance voltmeter and an rf probe.
[2] *RCA Solid-State Servicing* (TSG-1673A), ch. 7, p. 260.

SEASON'S GREETINGS FROM THE HAMS AT ARRL/IARU HQ.
(Listed in alphabetical order of call sign)

Joel Kleinman	N1BKE
Richard Palm	K1CE
Jeannie DeMaw	W1CKK
Laird Campbell	W1CUT
George Grammer	W1DF
Elizabeth H. Karpiej	KA1DTU
Joan Merritt	KA1DTV
Byron Goodman	W1DX
Maureen Thompson	KA1DYZ
Stephen C. Place	WB1EYI
Paul K. Pagel	N1FB
Doug DeMaw	W1FB
Hal Steinman	K1FHN
Marian Anderson	WB1FSB
Marge Tenney	WB1FSN
John Nelson	W1GNC
Bill Webb	WB1GOO
Bob Atkins	KA1GT
Ed Tilton	W1HDQ
Jim Clary	WB9IHH
Jean Peacor	K1IJV
Stuart B. Leland	W1JEC
Brian Downey	WA1KSF
Dennis Lusis	W1LJ
Stan Horzepa	WA1LOU
Peter O'Dell	KB1N
Sally H. O'Dell	KB1O
Mike Kaczynski	W1OD
Bruce Kampe	WA1POI
George Woodward	W1RN
Ed Kalin	K1RT
Richard L. Baldwin	W1RU
Lee Aurick	W1SE
Gerald L. Hall	K1TD
Perry F. Williams	W1UED
George Collins	KC1V
Arline Bender	WA1VMC
Bill Jennings	K1WJ
Chuck Bender	W1WPR
Bob Halprin	K1XA
John Lindholm	W1XX
Sandy Gerli	AC1Y
Ellen White	W1YL/4
David Sumner	K1ZZ
Steve Pink	KF1Y
Carol L. Colvin	AJ2I
Mark J. Wilson	AA2Z
Don Search	W3AZD
W. Dale Clift	WA3NLO
Larry Wolfgang	WA3VIL
William A. Tynan	W3XO
Gerry Hull	AK4L/VE1CER
Paul Rinaldo	W4RI
John Troster	W6ISQ
Chuck Chadwick	K8AXL/ WB8MOB
Chuck Hutchinson	K8CH
Bernard D. Glassmeyer	W9KDR
Harry MacLean	VE3GRO
Maxim Memorial Station	W1AW
ARRL Hq. Station	W1INF

A Modern Upconverting General-Coverage Receiver



Why limit yourself to those slivers of spectrum called the amateur bands? Build this upconverting, synthesized receiver and hear what the rest of the world sounds like!

By Albert D. Helfrick,* K2BLA

Once the mainstay of communications receivers, the general-coverage receiver has until recently been missing from the new-equipment scene. Some modern receivers are suited only for casual shortwave broadcast listening, while others are designed for serious users. The better-quality receivers naturally carry appropriately higher price tags. One thing that has still been sorely lacking is an article describing a good do-it-yourself construction project for a general-coverage receiver.

This article describes an upconverting, synthesized, digital readout, general-coverage receiver. This is not a project intended for the newcomer or the faint of heart. It is a thoroughly modern communications receiver, requiring construction ability and a knowledge of communications receivers. On the other hand, those with the necessary experience will find the project interesting and rewarding.

Although the size and performance of upconverting receivers is impressive, most designs, such as the one described by Rohde,[1] require parts that are difficult to obtain and quite expensive. Most notable among these are the shaft encoder and the first i-f filter. I was determined to design a small, high-performance receiver that could be built by the amateur from readily available parts. This receiver evolved from two earlier designs. The first upconverting receiver I built was a fully synthesized 100-kHz to 20-MHz receiver made primarily for broadcast reception. The channels were 10 kHz apart, and thumbwheel switches were used for frequency selection. The only other control on the receiver was a volume control. It was a single-conversion affair with a 21.4-MHz i-f. The purpose of that design was to allow me to gain experience with the upconverting scheme before making any further design efforts. Although the receiver functions well for its intended purpose, the design was never published. The second cut was a versatile receiver with a BFO, product detector, three degrees of selectivity and digital readout. This unit was designed to be a communications receiver and has been serving that end for some time.[2] While this unit can be built from readily available parts, it is large and relatively complicated in design. What was desired for attempt number three was a small, portable, upconverting receiver with wide dynamic range and digital readout. The receiver described here meets these requirements in a 3 × 8 × 8-inch (mm = in. × 25.4) package.

Circuitry

Fig. 1 shows the block diagram of the receiver. The input signal passes through a low-pass filter that removes the 90- to 120-MHz image band. This filter must be relatively flat for constant receiver sensitivity across the entire hf band. Also, it should have 80 dB or more attenuation at 90 MHz and about 60 dB or more at 45 MHz, the first i-f. A small compromise between flatness and attenuation was made, and a 1-dB ripple filter was used. The first mixer is an active type from Plessey Semiconductors. This device was thoroughly evaluated by the author and by Collins and DeMaw.[3] Although there are higher performance active mixers, the Plessey SL-6440 is suitable for all but most the demanding applications. The 100-kHz to 30-MHz input spectrum is converted to the first i-f of 45 MHz by mixing with a 45.1- to 75-MHz local oscillator signal from the synthesizer. The first i-f filter has a 13-kHz bandwidth and was made for use in commercial uhf fm receivers. This device is very small and

[1]Notes appear on page 22.

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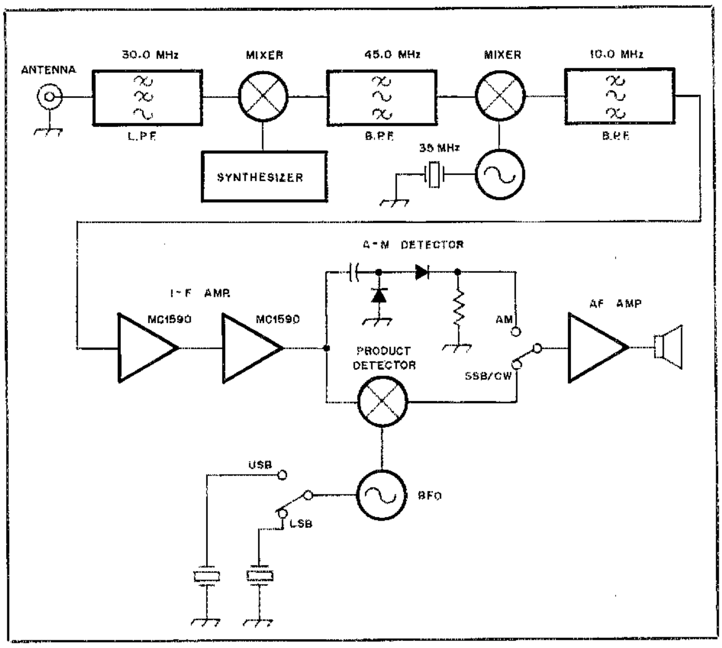


Fig. 1 — Block diagram showing the major functional units of the synthesized general-coverage receiver.

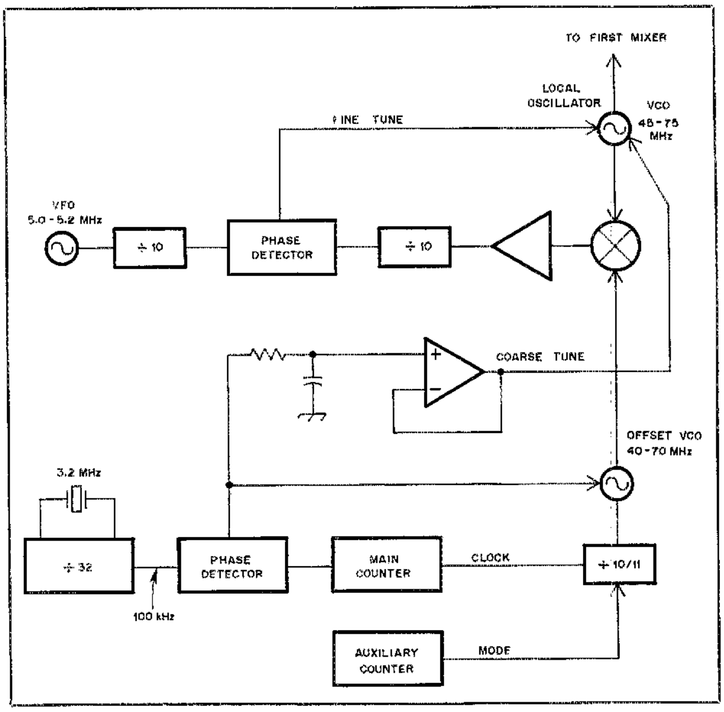


Fig. 2 — The synthesizer, shown here in block form, uses a dual-loop system. The main and auxiliary counters are programmed by the thumbwheel switches located on the front panel. Fine tuning is provided by the varactor-tuned VFO.

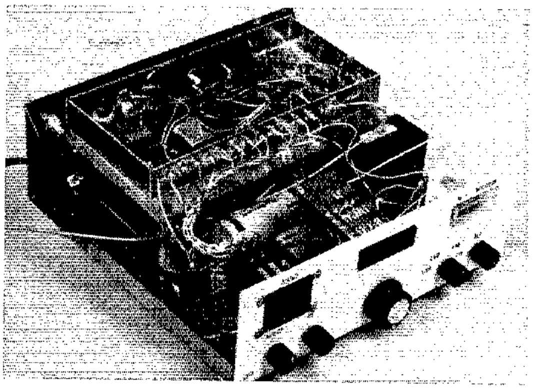
relatively inexpensive. Since it is used in high-volume applications, the price is expected to drop considerably when it has been designed into equipment. The second mixer is also a Plessey '6440. The signal from the first i-f is converted by this mixer to the second i-f of 10 MHz. Since passband tuning is not contemplated, a simple crystal oscillator is sufficient for the second local oscillator. The output of the second mixer passes through the second i-f filter, which provides the operating selectivity of the receiver.

Although a considerable amount of gain is available from the active mixers, it is not desirable to use the maximum obtainable gain. If a large input signal is present, the mixers are capable of producing enough output power to damage the crystal filters. The manufacturer suggests that the power input to the filters be kept below 10 mW. This limit is assured by operating the mixer at a low supply voltage, so that even when the mixer is in saturation the power to the filter is below 10 mW. The combined gain of the two mixers is about 20 dB. This implies that when the input level is 20 dB below 10 mW, or 100 μW, the second mixer is in saturation. For greater input signal levels there would be severe distortion and intermodulation. This situation occurs only when the input signal is within the first i-f filter passband; thus a large input signal is only a problem when it is very close to the frequency to which the receiver is tuned. To prevent intermodulation for frequencies close to the desired frequency, the first-mixer gain has been kept to a minimum. Total first-mixer gain, including the losses of the input low-pass filter and the first i-f filter, is about 6 dB. The remaining 14 dB of gain is obtained in the second mixer.

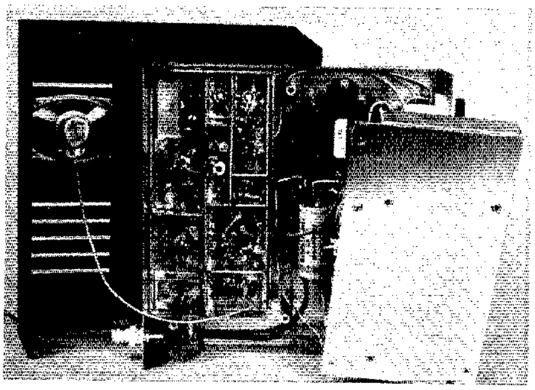
The output of the second mixer feeds the 10.0-MHz crystal filter. An odd i-f of 10.0 MHz was chosen because of filter availability. To use another i-f, such as 9.0 or 10.7 MHz, only the frequency of the second local-oscillator crystal, and the BFO crystals, need be changed. Changing the second i-f will have no effect on receiver performance.

The i-f amplifier uses two high-gain ICs and is heavily loaded with resistors for maximum stability. Most upconverting designs have very little gain between the antenna input and the second i-f amplifier. Typically, two balanced diode mixers are used, each with a loss of 6 or 7 dB compared with the combined gain of nearly 20 dB in this design. The difference is about 32 to 34 dB. Often an i-f amplifier is included at the first i-f, but even with the amplifier, the differential gain between the usual upconverting receiver and this design is considerable. Because of this, not as much gain is required at the second i-f.

However, there is no mixer agc capability, and the i-f amplifiers are called upon



Interior view of the receiver. The synthesizer box, with the cover removed, is situated at the top. The power supply and frequency counter are located near the front of the cabinet.



The compartmented circuit-board box containing the rest of the receiver can be seen with the synthesizer removed. The receiver cabinet measures 3 × 8 × 8 inches.

to supply all of the agc action. Only about 50 dB of gain is required of the amplifiers, but the entire 100-dB agc capability of the ICs is used.

The i-f amplifier feeds two detectors simultaneously: a two diode voltage doubler for a-m and a product detector for ssb and cw. The diodes used in the a-m detector are Schottky types, with fixed dc bias for maximum sensitivity and effective agc operation.

In addition to being the a-m detector, the Schottky diode voltage doubler serves as the agc rectifier. Temperature compensation is achieved by using two similar Schottky diodes, biased with the same current, as a voltage reference for the agc amplifier. It would be difficult to achieve the desired temperature stability without this biasing.

The product detector is a commercial doubly balanced diode-ring mixer. The BFO is a crystal-controlled oscillator with diode-switched crystals. Because the i-f amplifier does not have the large amount of gain often found in receivers using passive mixers, it is not difficult to prevent the BFO from entering the i-f amplifier and causing problems with the agc system.

Audio gain, sufficient to drive a small, self-contained loudspeaker, is provided by a single IC amplifier. It is capable of about 1 watt of output.

The Dual-Loop Synthesizer

The key to good upconverting receiver performance is the synthesizer design. A synthesizer is required to provide a 45- to 75-MHz local oscillator signal of high stability and low noise. In addition, a method of frequency readout must be provided that has at least 100-Hz resolution. The synthesizer in this receiver uses a partially synthesized dual-loop system. Band switching is accomplished with a conventional phase-locked loop, while fine tuning is done with a VFO. The internal frequencies of the synthesizer are chosen so that a conventional frequency counter can be used for frequency readout.

Refer to the block diagram in Fig. 2. The offset phase-locked loop operates in 100-kHz steps from 40.0 to 69.9 MHz and is programmed from the thumbwheel switches. A setting of 40.0 MHz corresponds to 00.0 MHz on the band switch, and 69.9 MHz corresponds to 29.9 MHz on the band switch. The tuning voltage generated by the offset PLL is buffered, filtered and fed to one of two varactor diodes in the local oscillator VCO. The local-oscillator and offset VCOs are designed so that the nominal local-oscillator frequency is about 5.1 MHz above the offset VCO. Both VCOs feed a mixer that has the output tuned to 5.1 MHz. This difference frequency is divided by 10 and fed to a phase detector. A VFO operating from 5.0 to 5.2 MHz is also divided by 10 and fed to the same phase detector. If a phase detector that had a 5-MHz capability were used, both divide-by-10 circuits could be eliminated. Very few integrated circuit phase detectors are capable of reliable operation at 5 MHz. Reducing the frequencies by a factor of 10 allows a popular and reliable phase detector to be used. The output of the phase detector is filtered and fed to a second varactor diode in the local-oscillator VCO to close the loop. The fine-tune loop maintains the frequency difference between the two VCOs exactly equal to the frequency of the front panel tuned VFO.

There are several important characteristics of this synthesizer that make it suitable for a high-frequency receiver. First, all of the phase-locked loop reference frequencies are high. The offset loop has a reference of 100 kHz, and the main loop has a reference of 500 to 520 kHz. When the reference frequency is this high, it is not difficult to filter out the reference sidebands while removing phase noise from the VCO. Second, the VCOs have a switched capacitor to reduce the required tuning range of the VCO. It is possible to generate both the 45- to 75-MHz and 40- to 70-MHz signals without switching VCO capacitors, but the amount of noise at the low-frequency end, where the tuning sensitivity is high, would be excessive. It would also be difficult to achieve tracking.

The 5.0- to 5.2-MHz VFO is varactor tuned from the front panel by a 10-turn potentiometer. Frequency stability at 5 MHz is not difficult to obtain, but varactor tuning is not as stable as a capacitor-tuned VFO or a PTO. An N150 temperature-compensating ceramic capacitor is used to reduce the temperature drift to acceptable limits. Since the tuning range is only 200 kHz, the degradation in stability is not troublesome. The tuning rate is about 220 kHz for 10 turns or 22-kHz per turn, which is ideal for amateur use.

Anyone experienced with receiver design will suspect that this receiver has spurious response problems resulting from the nice even numbers used as i-fs and in the synthesizer. The first i-f is 45.0 MHz, and the second i-f is 10.0 MHz. The VCO covers 5.00 MHz, and the offset oscillator covers the range from 40.00 MHz to 70.00 MHz. The round numbers were chosen, with full knowledge of the potential for spurious response, to allow for a simple tuning and frequency-readout system. To reduce the spurious responses to a low level, the synthesizer parts are divided and shielded very carefully. Some spurious responses remain, and it is doubtful that any receiver built to this design can be completely free from such responses. It is doubtful that any general-coverage receiver can be *totally* free from spurious responses. There is one spurious signal that will be present in any receiver of this design, regardless of construction.

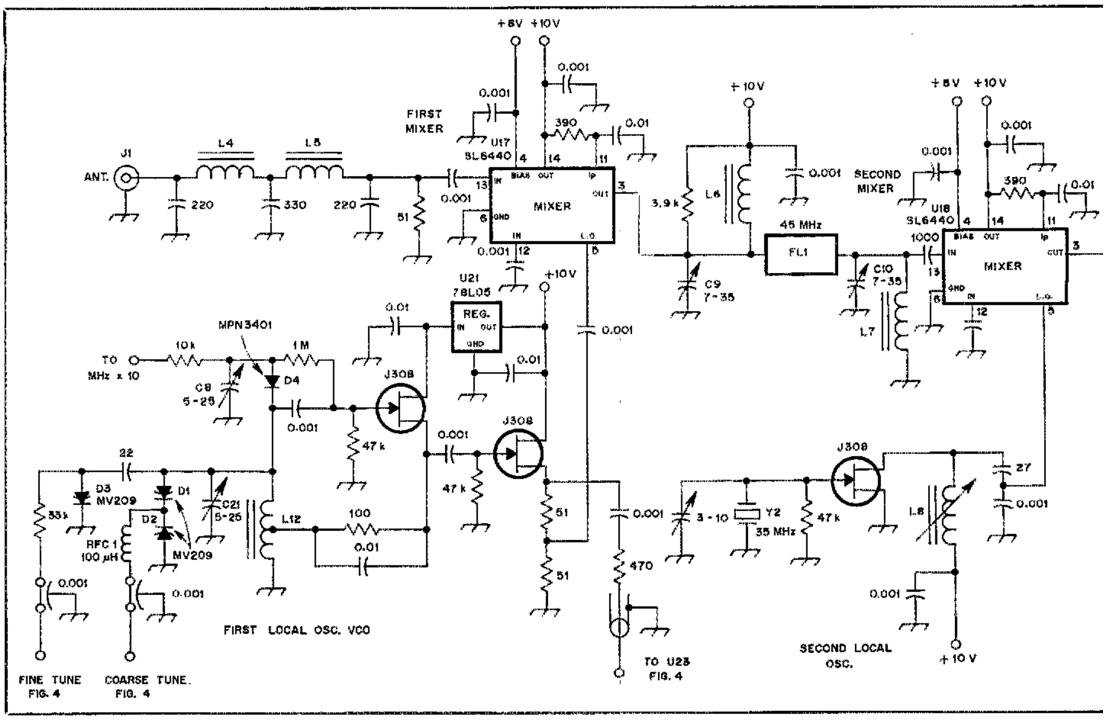


Fig. 3 — Schematic diagram of the general-coverage receiver. Numbered components not given in the parts list are for text reference only.

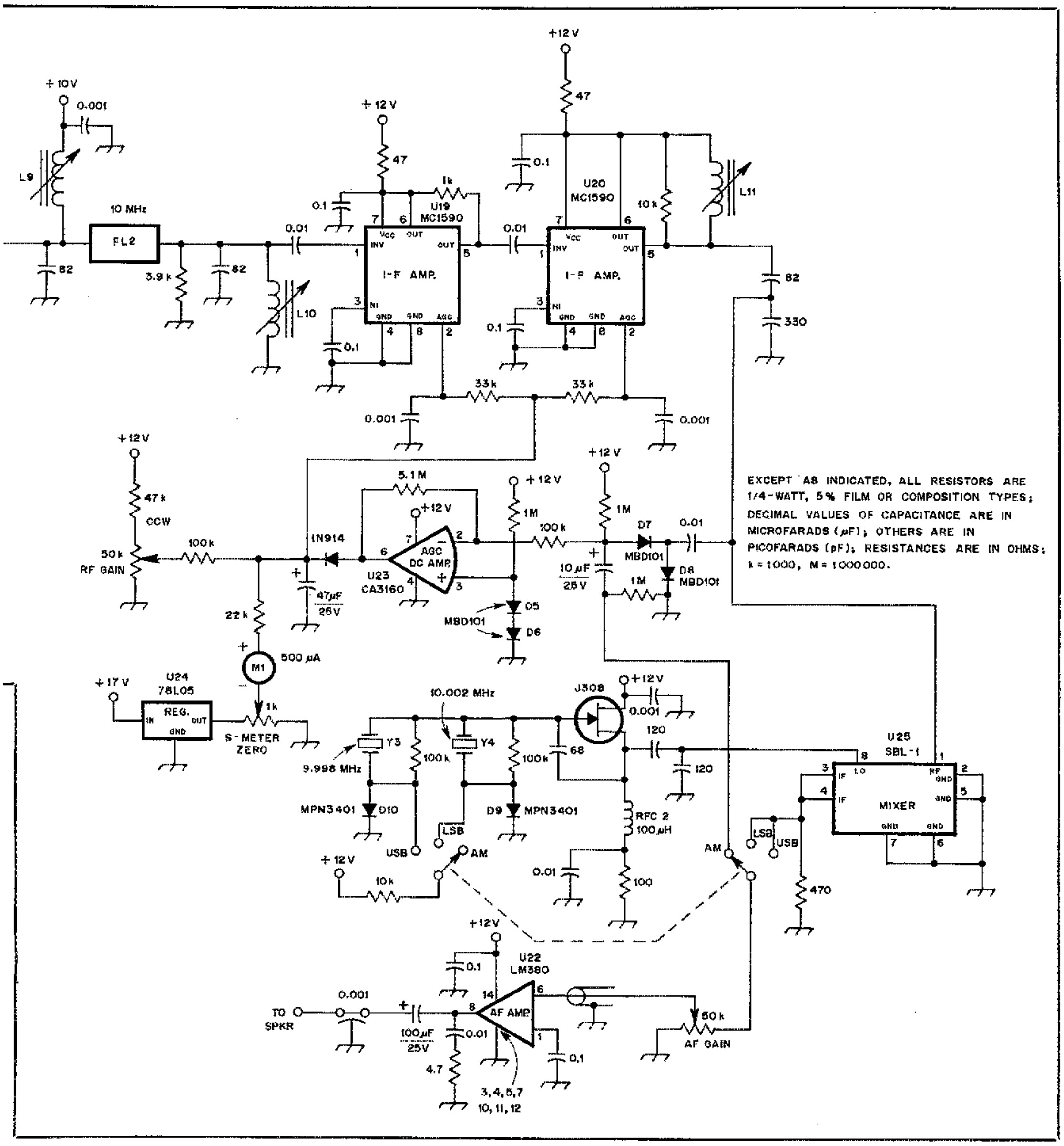
D1-D3, incl. — Motorola MV209 voltage variable capacitance diode, 26 to 32 pF.
D4, D9, D10 — Motorola MPN3401 PIN switching diode.
D5-D8, incl. — Motorola MBD101 hot-carrier diode.
FL1 — 45.0-MHz crystal filter, 13-kHz bandwidth. Piezo Technology Inc. model 2833A or equiv.
FL2 — 10.0-MHz crystal filter, 2.5-kHz bandwidth.
L4, L5 — 13 turns of no. 30 enameled wire on a T16-10 toroid core.
L6, L7 — 16 turns of no. 28 enameled wire on a T30-10 toroid core.
L8 — 1.0-µH slug-tuned inductor.
L9-L11, incl. — 3.0-µH slug-tuned inductor.
L12 — 11 turns of no. 28 enameled wire, tapped 2 turns from ground, on a T37-2 toroid core.
U17, U18 — Plessey SL6440 doubly balanced mixer IC.
U19, U20 — Motorola MC1590 i-f amplifier IC.
U21, U24 — Fairchild µA78L05 three-terminal voltage regulator, 5 volts at 100 mA.
U22 — National LM380 af amplifier, 1-watt IC.
U23 — RCA CA3160 op amp IC.
U25 — Doubly balanced diode-ring mixer. Mini-Circuits SBL-1 or equiv.

When the band switch is set to 5.0 MHz, the offset VCO is operating at exactly 45.0 MHz, which is the first i-f. Even though good shielding can reduce this level to a few microvolts of equivalent signal, the VCO produces a beat with every signal tuned in that range. The solution to this problem is simple: When tuning signals in the 5-MHz range, use the 4.9 MHz bandswitch positions. The 200-kHz range of the VFO allows continuous tuning through 5 MHz.

It may appear that a simple solution to the spurious signal at 5 MHz would be to change the offset synthesizer to operate 5 MHz above, rather than 5 MHz below, the local oscillator. In this case the offset VCO would cover the range of 50 to 80 MHz and not pass through 45 MHz. The VFO frequency would be the offset VCO frequency minus the local oscillator frequency, and the receiver would tune in the direction opposite the VFO. The frequency readout derived from the VFO would have to be changed to account for this difference. An up/down counter could be used for the 5-MHz frequency display. The counter would be preset to 5000 and counted down. However, this would preclude the use of an LSI frequency counter and would require at least 10 additional ICs.

The design and construction of the two VCOs used in the synthesizer are very important if the receiver is to function reliably. First, the noise levels of the VCOs must be very low. The total noise contribution of the local oscillator will be the sum of the noise of both VCOs plus any noise contributed by the programmable divider and phase detector. Each VCO uses a high-Q toroid tank with minimal loading as well as a low operating voltage (supplied by individual 5-V regulators). Adequate buffering is used between the VCO and the dual-modulus prescaler. This prevents noise and sidebands from being generated by the prescaler. Only one stage of buffering is needed between the local oscillator VCO and the two mixers it drives. This is because the first receiver mixer has an inherent isolation, and the synthesizer mixer is fed from a large resistive divider. A fixed-value capacitor is switched across the VCO tank for receive frequencies below 10 MHz. This corresponds to 55 MHz at the local oscillator VCO, and 50 MHz at the offset VCO. To maintain frequency tracking, identical tank components, varactors, coils, wire sizes and FETs are used in the two VCOs.

The synthesizer mixer is fed by both VCOs. The offset VCO, providing about 200 mV, is used as the high-level signal, while the local-oscillator VCO is used as the low-level signal at about 30 mV. The mixer output circuit is tuned to 5.1 MHz and loaded to produce a wide-band tank. An FET amplifier provides the necessary gain for driving the TTL divide-by-10 IC. It is the mixer output circuit that requires the frequencies of the VCOs to track. If the VCOs should differ by more than about 7 MHz or less than 4 MHz for any reason, the output of the amplifier will not be sufficient to drive the divide-by-10 circuit, and the loop will not lock up. If the frequency is too low, because the VCOs are too close in frequency, the absence of output pulses from the counter



will appear to the phase detector as zero frequency.

The fine-tune loop will then go to the highest tuning voltage. This is the correct direction to restore the loop to operation. Providing the VCOs are not extremely misaligned, the high tuning voltage of the fine-tune loop will cause the VCOs to move more than 4 MHz apart, and the system will acquire lock. However, if the frequencies are separated by more than 7 MHz, the pulses to the phase detector will also cease. The phase detector will again interpret this as zero frequency and change the tuning voltage on the fine-tune loop to its highest value. This is the wrong direction and will only aggravate the situation. The loop will become latched-up and never return to operation. This situation can occur on a transient basis when changing bands.

To prevent latch-up during band changes, an out-of-lock detector is included. It reduces the fine-tune voltage to about half the maximum value when an out-of-lock condition occurs in the fine-tune loop. The reduction occurs for only a short period of time to prevent latch-up from occurring when the loop is out-of-lock because the VCOs are too close in frequency.

Constructing the Receiver

The receiver is built in two shielded boxes constructed from double-sided pc board. Although not the prettiest way to build electronic circuits, the flexibility to add shielding as needed is a must for a receiver of this type. Feedthrough capacitors are used liberally whenever a low-frequency signal or power passes into the shielded box. The larger bypass

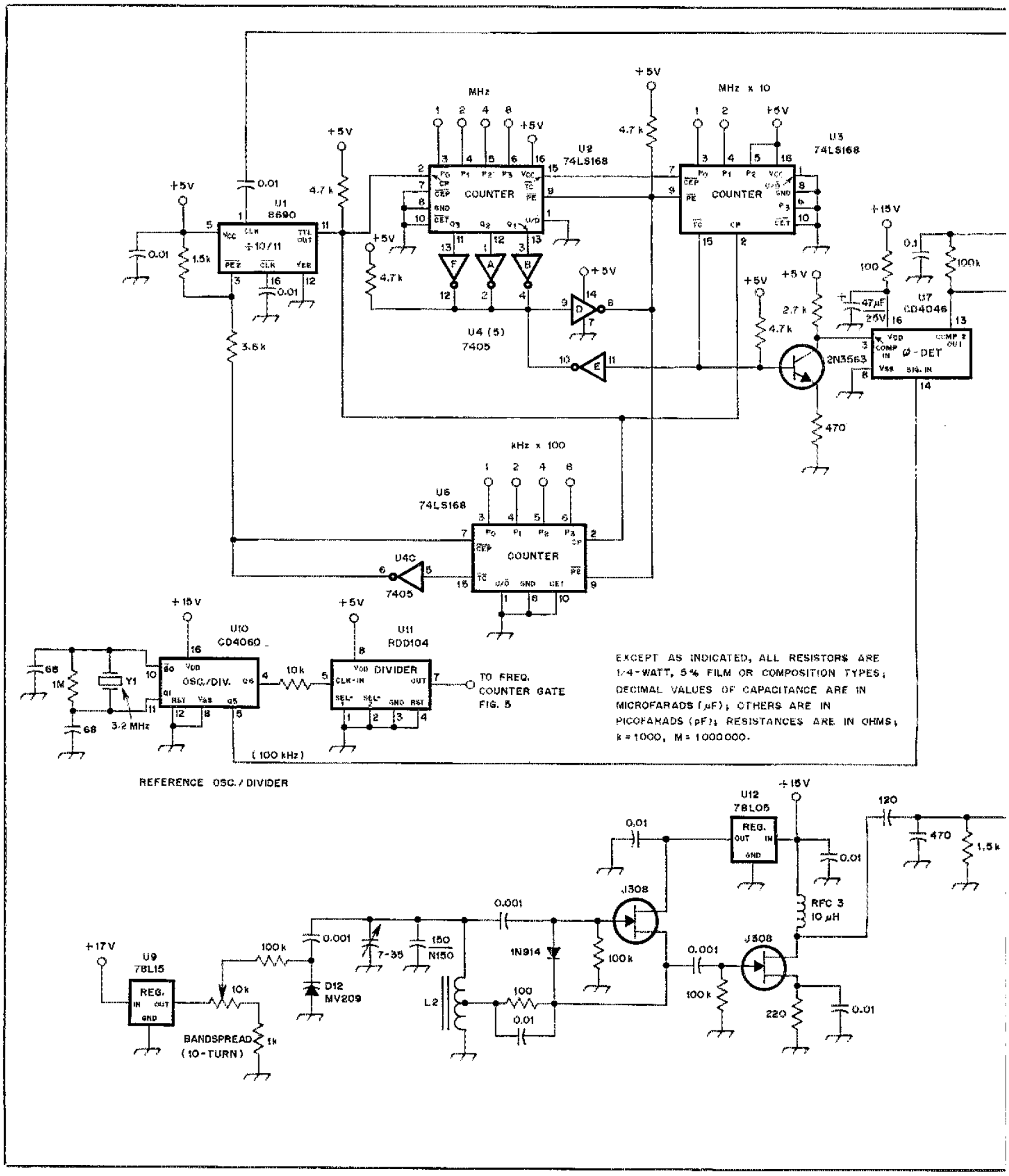
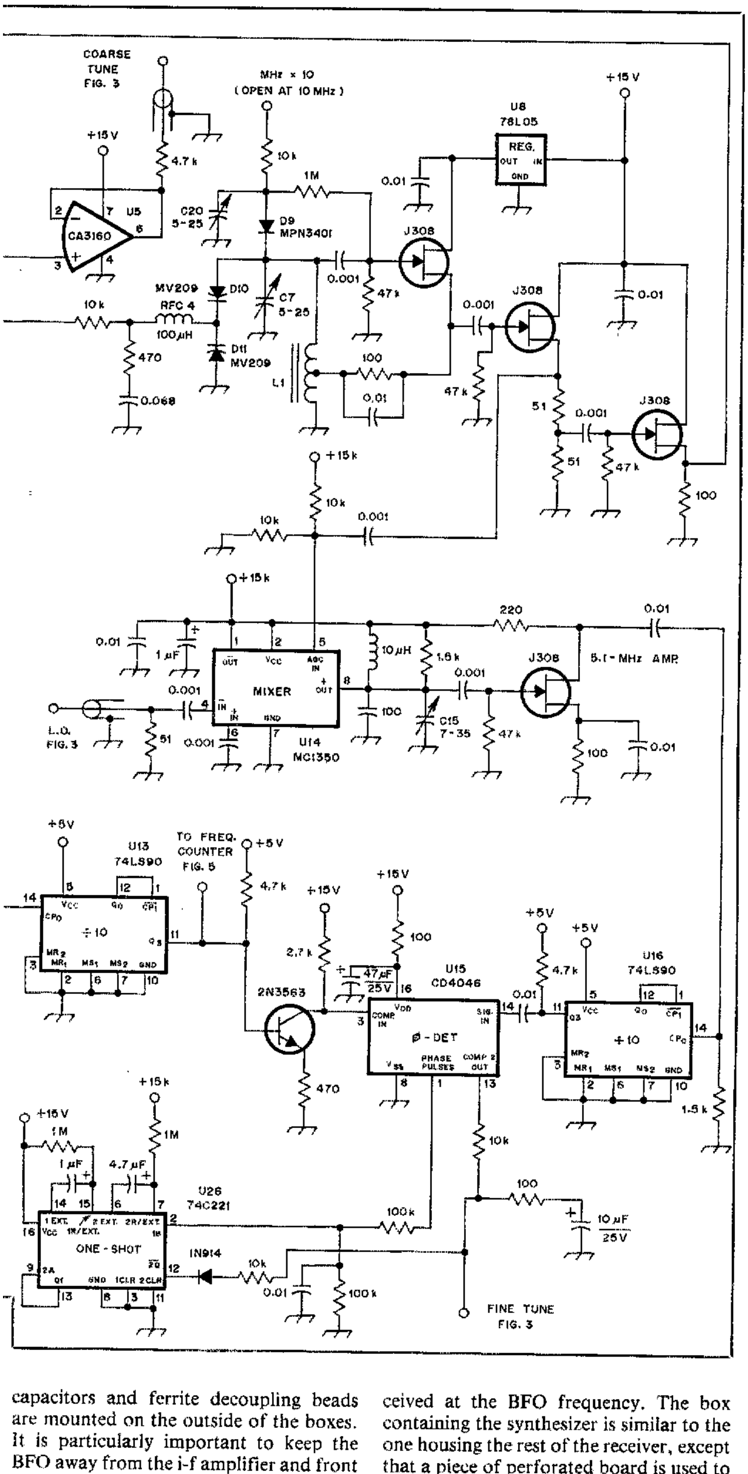


Fig. 4 — Schematic diagram of the synthesizer section of the general-coverage receiver. Numbered components not given in the parts list are for text reference only.

D9 — Motorola MPN3401 PIN switching diode.
D10-D12, incl. — Motorola MV209 voltage variable capacitance diode, 26 to 32 pF.
L1 — 12 turns of no. 28 enameled wire, tapped at 3 turns from ground, on a T37-2 toroid core.
L2 — 41 turns of no. 28 enameled wire on a T50-6 toroid core.
U1 — Plessey SP8690B low-power, programmable divide-by-10/11 IC.
U2, U3, U6 — 74LS168 low-power Schottky TTL presettable up/down counter.
U4 — 7405 TTL hex inverter with open-collector output.
U5 — RCA CA3160 op amp IC.
U7, U15 — CD4046B CMOS micropower phase-locked loop IC.
U8, U12 — Fairchild µA78L05 three-terminal voltage regulator, 5 volts at 100 mA.
U13, U16 — 74LS90 low-power Schottky TTL decade counter IC.
U10 — CD4060B 14-stage binary counter and oscillator IC.
U11 — RDD104 CMOS selectable decade divider. LSI Computer Systems Inc. (two CD4518s connected to divide-by-10,000 can be used to replace the RDD104).
U14 — Motorola MC1350P i-f amplifier IC.
U26 — 74C221 CMOS dual monostable multivibrator IC.



capacitors and ferrite decoupling beads are mounted on the outside of the boxes. It is particularly important to keep the BFO away from the i-f amplifier and front end. If the isolation between these areas is insufficient, either the agc system will be affected or a healthy signal will be received at the BFO frequency. The box containing the synthesizer is similar to the one housing the rest of the receiver, except that a piece of perforated board is used to mount the digital circuit inside the enclosure. The programming wires to the thumbwheel switches are routed through feedthrough capacitors. The VCOs for the offset and local oscillators are made with very short leads and rigid connections.

A 3 × 8 × 8-inch cabinet houses the receiver, including an ac power supply. Although the small size suggests portability, no special considerations were given to low power consumption. The active mixers, LED frequency-counter readouts, illuminated thumbwheel switches and S meter all consume fairly large amounts of power. The power supply uses several regulators, spread throughout the receiver, to provide isolated sources of power; this too is inefficient. The power requirement is 18 volts at about 750 mA. This requirement is beyond a self-contained battery, but not a mobile installation. I plan to construct a regulated 12-volt to 18-volt inverter, using a high-frequency transistor supply for mobile applications.

The complete receiver is easy to check and tune if the proper test equipment is available. First checks can be made with only the receiver section functioning. The synthesizer will be made operational after the receiver section has been aligned. First, monitor the gate voltage of the 35-MHz crystal oscillator with a high-impedance voltmeter, and adjust L8 for maximum negative voltage. While monitoring with a frequency counter, tune the first local oscillator to 45 MHz by connecting an external variable power supply to the coarse-tune input. At this point, using the a-m detector, a strong signal from the first local oscillator should be received. This should occur with about 2 volts on the VCO control line. If necessary, adjust C8 for a frequency of 45 MHz at 2 volts. Feed a signal, less than 10 MHz in frequency, to the receiver input. Tune it in using the variable tuning voltage from the external power supply. Tune C9, C10, L9, L10 and L11 for maximum S-meter indication. L9 and L10 should then be retuned for best filter response. Switch the receiver from a-m to usb and lsb to check the operation of the BFO.

Now the synthesizer should be connected. If all is operating correctly, the control voltage at the offset VCO should change as the band switch is changed. Adjust C7 for a control voltage of 12 at a band-switch position of 29.9 MHz. Adjust C20 for a control voltage of 12 at 9.9 MHz. Set the tuning control for a VFO frequency of 5.1 MHz (100.0 on the counter) and use a scope to observe the waveform at the drain of the 5.1-MHz amplifier. Set the band switch to 10.0 MHz, and carefully tune C15 for maximum amplitude response.

Observe the dc level at the output of the fine-tune phase detector, and adjust C21 for approximately 7.5 volts. While measuring the dc level of the fine-tune phase detector, change the band switch in 1-MHz steps to 29 MHz. If the voltage

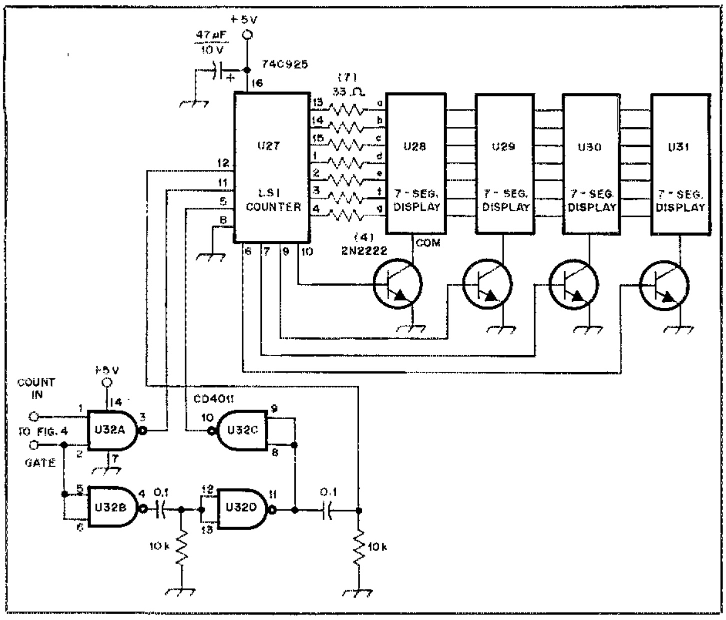


Fig. 5 — Schematic diagram of the frequency readout circuitry. All resistors are 1/4-watt, 5% carbon film or composition type units.
U27 — 74C925 CMOS 4-digit counter with 7-segment output drivers.
U28-U31, incl. — Common-dathode 7-segment LED displays.
U32 — CD4011 CMOS quad two-input NAND gate IC.

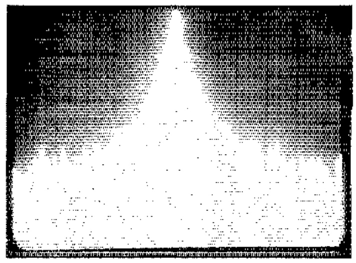


Fig. 6 — Spectrum-analyzer display of the synthesized local-oscillator output. The analyzer bandwidth is 5 Hz, and the scan width is 20 Hz per division. Each vertical division is 10 dB. The measurement of LO noise is limited by the noise generated within the analyzer (see text).

goes lower than 1 volt, or higher than 14 volts, readjust C21 until it stays within these limits. Repeat this procedure for 00.0 MHz and 9.0 MHz, using C22.

Performance Evaluation

It is difficult to evaluate a high-performance receiver without the proper test equipment. Fortunately, two calibrated signal generators were available in the author's shop for intermodulation measurements during the development of the receiver. A spectrum analyzer was borrowed for making synthesizer evaluations.

The first step in the receiver evaluation is to terminate the receiver with a 50-Ω load and listen for spurious signals. The expected spurious signals were present, including the constant "birdie" when the band switch is in the 5.0-MHz position. It would be a time-consuming job to test all 300 of the band-switch positions, so a few selected positions, especially those corresponding to amateur bands, were tested. Several spurious signals were heard, but the vast majority of them were too weak to move the S meter, which will deflect on a 1-µV signal. The atmospheric noise will be stronger than most of these signals when an antenna is attached to the receiver. There were a few other spurious signals that were greater than 1 µV in level. They appeared to emanate from the synthesizer. It is possible that additional ferrite beads and bypassing could eliminate these unwanted responses.

A laboratory grade spectrum analyzer was used to evaluate the local oscillator for spectral purity. Because the performance expected of the local oscillator exceeds the capability of the spectrum analyzer local oscillator, the receiver local oscillator should appear as good as a crystal oscillator would to the analyzer. The first look at the local oscillator showed a pair of 60-Hz sidebands about 40 dB down from the carrier. The receiver was operated from a separate regulated power supply, and the 60-Hz sidebands disappeared. Ground loops from the filter capacitors or magnetic-field modulation of the synthesizer were responsible for the sidebands. Either way, the problem can be solved by moving the power transformer, rectifier diodes and filter capacitors out of the receiver case to an external box. In addition to the 60-Hz sidebands, there was a wideband noise spectrum that extended several hundred hertz from the carrier and was 60 dB down. Disconnecting the frequency counter eliminated the noise. Since the counter was not shielded, I feel that enclosing it will eliminate this wideband noise. Fig. 6 shows the spectrum-analyzer display of the local oscillator when the receiver is operated from an external dc supply and the frequency counter is disabled. The display shown is practically identical to that obtained from this spectrum analyzer and a crystal oscillator. What is shown is the noise of the spectrum analyzer; the receiver local oscillator is better than what is shown. The noise level is about 70 dB below the carrier at 100 Hz from the carrier frequency. This would translate to about −76 dB at 1000 Hz.

Judging sensitivity "by ear" indicates that a 0.1-µV signal is just discernible. This corresponds exactly to the theoretical value. The required input level is 0.5 µV for a 10-dB signal plus noise-to-noise ratio.

Two signal generators were connected to the input of the receiver through step attenuators. Since the attenuators were simply "Teed" together at the receiver input, each attenuator looked into a load of about 25 Ω. A correction was made to the signal levels to account for this mismatch. When two input signals were applied, separated by 10 kHz, and each at a level of −27 dBm, a third-order intermodulation product could be heard. According to the calibrated S meter, the IMD product was equivalent to an input signal of roughly 0.5 µV, or about the sensitivity limit of the receiver. This corresponds to a third-order intercept of about +17 dBm and a two-tone dynamic range of 94 dB.

The third-order products decrease when the two input signals are separated by more than 20 kHz. This is because only one of the two signals can pass through the first i-f filter and generate IMD in the second mixer. The gain of the first mixer is 6 dB, which implies that the third-order intercept is +17 dBm when the intermodulation is generated in the second mixer. The intercept should be about +29 dBm when generated only in the first mixer. This figure agrees with the measurements made and with the manufacturer's specifications.

Notes

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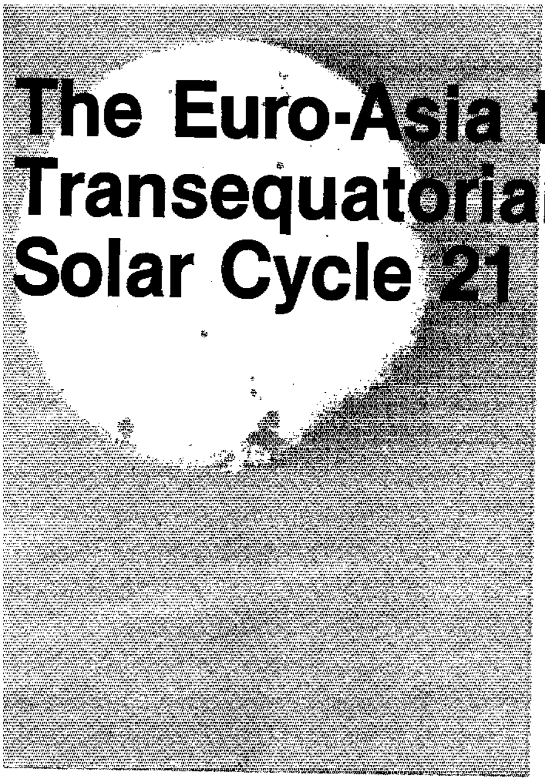

The Euro-Asia to Africa VHF Transequatorial Circuit During Solar Cycle 21

Part 2: Five-thousand-mile 2-meter circuits explained? Do the theories fit the observations? Where do we go from here?

By Ray Cracknell,* ZE2JV, Fred Anderson,** ZS6PW, and Costas Fimerelis,*** SV1DH

Part I of this article appeared in November 1981 *QST*. In that installment we provided the fundamental details of the propagation experiments and defined the kinds of equipment that were used in the tests. This installment concludes the discussion of the work done by the authors.

Doppler-Shift Measurements

Variations in the time taken for a signal to travel from the transmitter to the receiver indicate changes in the propagation medium. A mobile medium will produce changes in the frequency of the received signal, increasing it as the path shortens (a positive shift) or lowering it as the path lengthens (a negative shift). These changes, known as Doppler shifts, were measured by ZS6PW and SV1DH on 144 MHz. Both stations had access to laboratory frequency counters of sufficient accuracy to determine the frequency of transmission and reception to within 10 Hz. They took frequent readings throughout several openings and reported them to each other via a 28-MHz ssb link.

The results varied in a random as well as in a systematic manner. Results of two evenings, when conditions were good enough for measurements to be made throughout the duration of the openings on 144 MHz, are illustrated in Fig. 12. Measurements made on other evenings are shown as dots, and they indicate random variations. Nevertheless, there seems to be a systematic variation where the Doppler shift starts slightly negative and swings to a small positive shift. Then it becomes progressively more negative with a shift of up to 200 Hz at the end of an opening.

The average shift recorded was about 100 Hz negative. This confirmed reports from Cyprus, Zimbabwe and South Africa of a downward Doppler shift on back-scattered signals received simultaneously with a weak ground-wave or tropospheric signal at 144 MHz. It would appear that these systematic, random, short-term Doppler shifts are characteristic of TE on 144 MHz over the Euro-Asia to Africa circuit.

Back-scatter Observations

Although 144-MHz back-scatter reports are rare, available evidence points to a rising or retreating region of the ionosphere from which back scatter on 144 MHz occurs. This is consistent with the observed Doppler shift on such signals. Nowhere along the circuit are the 144-MHz signals observed to return to the earth with sufficient strength to scatter from there and to produce a detectable signal level back at the transmitting site.

By contrast, ZS6PW has observed ground back scatter of 50-MHz signals transmitted from his vicinity at times when multihop F-layer propagation was open to Europe. The regularity of back scatter on 28 MHz is remarkable. In these cases Doppler shift is not present, indicating that ionospheric height is relatively constant.

ZE2JV and ZS6PW, who are separated

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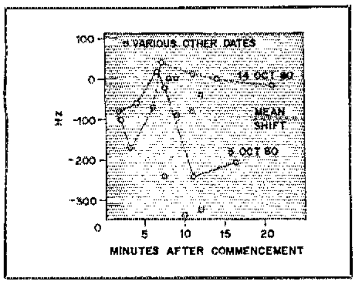

Fig. 12 — Doppler-shift measurements on 144.9 MHz between ZS6PW in Pretoria and SV1DH in Athens.

by 600 miles (km = mi × 1.6093), have a back-scatter QSO almost every day of the year on ssb on 28,988 kHz at 5 P.M. local time. Their respective 10-meter beacons can be heard at each other's location from early morning until late at night, sometimes outlasting all other signals on the 10-meter band.

Surprisingly, it has been shown conclusively that this back scatter on 28 MHz comes mostly (and perhaps exclusively) from the ground and not, as might be expected, from the ionosphere. ZS6PW observed the pulses from the ZS6DN beacon located eight miles away, and measured the time delay between the ground-wave and back-scatter signals. He found a delay that varied between 16 and 20 milliseconds. This is equivalent to reflection from a distance of 1500-1900 miles, a typical one-hop F-layer range at 28 MHz. At such a distance the ionosphere is wholly below the radio horizon and can not act as the source of back scatter. These results were confirmed by beam-rotation tests between ZS6PW and ZE2JV.

The experiment showed that optimum back scatter was obtained from two areas equidistant from the two stations and within the range indicated. This system is illustrated in Fig. 13. Of the two, the area to the northwest is much more reliable, because it is near the high density area of the tropical ionosphere. Backscatter also comes from the north. The 600-mile difference in distance means that the area best illuminated by ZE2JV's signals does not coincide with the area best seen by ZS6PW's receiver. This leads to weaker and sometimes distorted ssb signals.

Angles of Arrival

Tests between Salisbury and Cyprus during the International Geophysical Year (IGY) revealed that at 50 MHz, Yagi beams tend to lose their directivity in a random manner. The loss of directivity was related to the southward spread of TE signal toward the southern end of Africa. Elevation tests conducted by SV1AB on

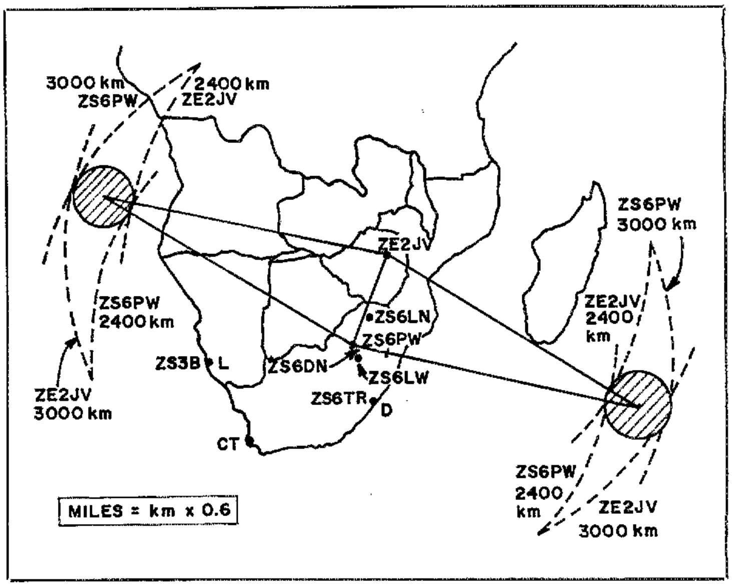

Fig. 13 — Map of Southern Africa showing the locations of ZS6PW and ZE2JV and the optimum areas for back scatter between them on 10 meters. The locations of other 2-meter stations heard in the Mediterranean area are also shown.

ZE2JV's 2-meter signals indicated similar random variations. The best signals were received sometimes with a nine-element Yagi elevated at 20 degrees and at others with it horizontal. Reports from 5B4WR indicate occasional preference for a beam heading 15 degrees to the west of the great circle bearing on 144 MHz. ZS6PW and SV1DH conducted tests on 6 meters at times of multipath propagation, as illustrated in Fig. 10 (see Part 1, November *QST*). These showed that turning beams to a more westerly bearing accentuated the longer-delayed pulses.

In these tests the propagation time of the first arriving pulse on 6 meters decreased steadily from about 8:30 P.M. to 9:30 P.M. local time. It disappeared when the delay became 24.3 ms. Fig. 8 (see Part 1, November *QST*) shows that the elevation angle of the wave was then 0 degrees. This means that the ionosphere at the distance concerned had then just dropped below the horizon for $2F_2$ propagation.

Nobody as yet has been able to follow a moving ionospheric target through the course of an opening on 144 MHz. Also, no one has reported a preference for a beam heading to the east of the great circle path. When an opening occurs on 144 MHz, there is an area of the ionosphere that becomes receptive to TE signals. Doppler shifts confirm that it is mobile. Beam tests indicate that the ionosphere target gets smaller with greater distance from the magnetic dip equator. At the limit of the TE range (approximately 2500 miles from the dip equator) it presents a point target on the horizon.

Patterns of Fading and Frequency Spreading

TE signals have a characteristic sound often reported as being similar to signals reflected from aurora. The flutter-fading frequently present on late evening 28- and 50-MHz signals often appears to chop the signal to the extent that Morse signals may become unintelligible. From 70 to 144 MHz the flutter becomes increasingly rapid, giving the signal a raw, ac-sounding note. When frequency spreading is in evidence the signal becomes broad. At times no beat note can be obtained with the receiver BFO. Such a signal only makes an increase in the noise produced by the receiver, with perhaps an accompanying change in the quality of the noise. The signal is, therefore, rather difficult to detect by ear, especially when it is weak.

An assessment of the degree of frequency spreading is largely subjective. The spreading on 2-meter signals is believed to be as much as several hundred Hz. On occasion it is often less than this amount. Figs. 14, 15 and 16, which are sonograms of received signals, illustrate the various fading patterns. They give some indication of the degrees of frequency spreading that are encountered on the 10-, 6- and 2-meter bands over the southern Africa to Mediterranean TE circuit.

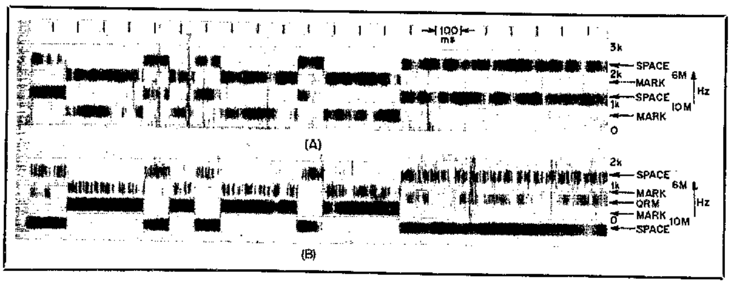

Fig. 14 — Sonograms of fsk signals on 10 and 6 meters from 5B4CY as received by ZS6PW showing (A) moderate amplitude flutter on both frequencies, and (B) a clear signal on 10 meters and severe flutter on 6 meters.

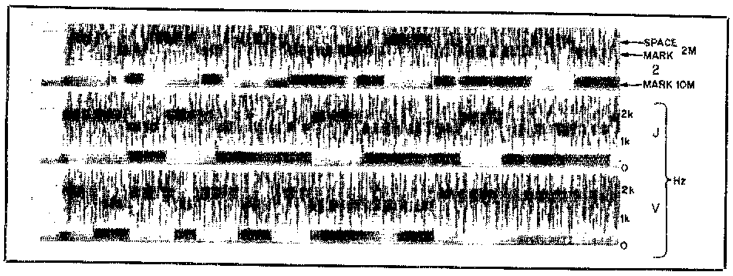

Fig. 15 — A sonogram of simultaneous fsk signals on 10 and 2 meters as received by SV1DH from ZE2JV showing slight flutter on 10 meters and severe flutter on 2 meters. The frequency spreading on 2 meters is not sufficient to make differentiation of the mark and space possible.

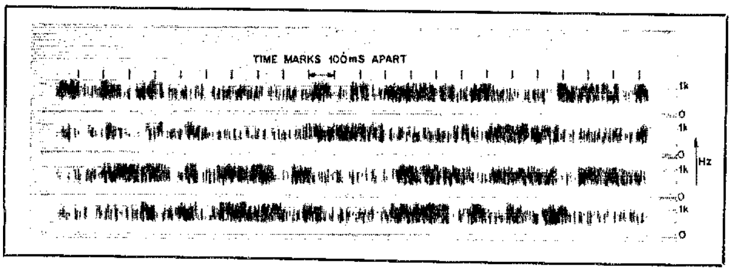

Fig. 16 — A sonogram of an A1 (cw) signal from ZS6DN as received at SV1DH. This signal produced no audible tone with the receiver BFO and was readable only as changes in the noise. It reads, bottom left to top right, FB Costas F.........

Under the best conditions, communication by ssb is marginally possible. A completely clear ssb signal has not yet been heard over the Africa TE circuit at 144 MHz. The rate of flutter and the degree of frequency spreading depend on the frequency of the signal. Variations in the quality of the signal, and the degree of fading and spreading, seem to be random. They do not correlate with loss of beam directivity. Strangely enough, sharpening the beam width does not reduce the degree of flutter and spread.

The Supporting Ionospheric Mechanism

TE is a mode that was not readily explainable by the knowledge of the tropical ionosphere available at the time of its discovery. This invited many unsubstantiated theories and explanations from academic, professional and amateur sources. These can be classified as theories of scattering from one or two areas, theories of tilts and gradients, and theories of ducting under, through or outside the ionosphere.

In 1960, ZE2JV[7] claimed to have isolated three distinct modes of propagation operative between 28 and 70 MHz from Salisbury to Cyprus. These were two-hop F-layer, F-type TE and pure TE. He distinguished them by the characteristics of the signals, their propagation delays and times of occurrence. Two-hop F-layer and F-type TE were described as supported by the high density (HD) zones. HD zones tend to form some 10 to 15 degrees on either side of the magnetic dip equator from about midday. They persist until late at night.

[7]Notes appear on page 27.

Two-hop F layer ($2F_2$) up to frequencies well above 50 MHz supported circuits between Salisbury and Cyprus. Frequently chordal-hop F-type TE replaced $2F_2$ through the afternoon and early evening. Vhf signals "see" the HD zones as lenses; only half the bending is required for a chordal hop. Frequencies up to a maximum of 90 MHz could be propagated by this means. This mode depends on the horizontal density gradients on the equator side of the HD areas. It is sometimes referred to as "afternoon" or "early evening" type TE and sometimes as the FF mode. The mechanism and seasonal variations are generally thought to be understood and accepted. At that time many investigators thought TE resulted from the rise, breakup and descent of the tropical F region. After ionosphere sunset, "blobs" of ionization persisting in the HD areas scattered and deflected signals.

This late-night or pure TE was the first to be observed. Reports of "scatter" QSOs, back scatter and flutter-fading on transequatorial paths go back to the early 1930s. The name "TE scatter propagation" appeared in Amateur Radio literature until well into the 1960s. By that time, F-type TE became of importance because of the wonderful conditions it afforded on 50 MHz. It is a nuisance as a source of interference on the lower TV channels for four or five years out of every 11-year solar cycle. The strength of F-type TE signals is sometimes greater than the free-space signal strength over a comparable distance. This made the term "scatter" inappropriate, so it was dropped.

During solar cycle 21, pure TE has come back into prominence with record-breaking QSOs on 144 MHz. The possibility of repeating them on 432 MHz becomes apparent. No complete and totally satisfactory theory has yet been advanced. Many theorists tend to oversimplify down to a model that is related to mathematical analysis. This provides explanations for some, but not all, the phenomena that we observed. We have nevertheless consistently maintained that only a much greater knowledge of the morphology of the tropical ionosphere can provide the answers we seek. Without that knowledge, we are, to a large extent, guessing.

Some Recent Research and Proposals

Those who are interested in a

theoretical approach to an intriguing propagation problem will find much of interest in the 50-MHz radar research of Woodman and La Hoz at Jicamarca.[8] They report "plumes" and "bubbles" of ionization depletions rising up to a height of 600 miles over the magnetic dip equator. This phenomenon gives rise to prolific 50-MHz backscatter echoes. Rastogi[9] has worked for many years on the tropical spread-F phenomenon. A critical frequency at vertical incidence is no longer apparent on vertical sounders, and diffused returns result. It seems to have a close association with TE regarding times of occurrence. It is present in that part of the ionosphere through which TE is propagated, namely up to 20 degrees either side of the magnetic dip equator.

Aarons and his coworkers[10] describe the dynamics of equatorial irregularity patch formation and decay. They postulate the formation of huge bridge-like structures, 1250 miles in length and a few hundred miles wide. These structures straddle the magnetic dip equator at right angles and align themselves along the magnetic field of the earth. These patches develop toward the west after the setting sun. Once formed, they break off and drift eastward with velocities ranging from 300 to 600 feet per second. They have a life of up to two and a half hours. Heron[11] used a mathematical model to explain the possibility of the depletion bubbles described by Woodman and La Hoz. He suggests they form ducts through the ionosphere, following the lines of the earth's magnetic field, and straddle the dip equator with "cones of acceptance" at each end. This allows for off-line propagation into gigantic natural waveguides. Woodman and La Hoz reported the easterly drift of the background ionosphere, which Aarons also observed. Heron uses this to explain Doppler shifts similar to those we observed. His concept of ducting is illustrated in Fig. 17, with the permission of the author.

Also writing in 1979, ZE2JV and 5B4WR[12] proposed a multiplicity of similar, but smaller, field-aligned ducts in a mobile and turbulent plasma. Small-scale irregularities in the lower levels of the F region also cause spread F. The effect is that of frosted glass. Some of the signal bounces and bends into the ducts, which are changing constantly.

In 1980 Tsunoda[13] published confirmation that the ducts exist. They pass right through the tropical-F region and align along the magnetic field of the earth. Radar on 155.5 MHz from the Pacific island of Kwajalein (magnetic dip latitude 4.3° N) showed depletions within these ducts of as much as 90% and greater than 750 miles in length. They are present in the nighttime tropical ionosphere.

Discussion

Large transequatorial bridges of high-density irregularities, their growth, and subsequent drift and decay is to some extent supported by our observations of multipath propagation and Doppler-shift measurements. Several of these irregularity patches could be reached simultaneously. Aaron suggests that "several patches could be melded together." From this we can visualize various propagation paths, each with its own propagation time and Doppler shift. When the signals from the differing routes are combined, the resultant signal could carry the frequency-dependent rate of fading and the frequency spreading that characterize TE.

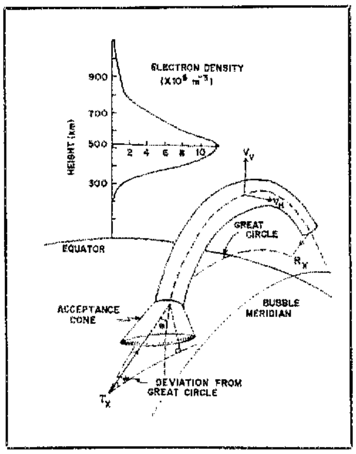

Fig. 17 — The supporting mechanism for TE as suggested by M. L. Heron of James Cook University, Townsville, Australia *(reproduced by permission of the author)*.

Although Heron discusses one discrete waveguide, he does not preclude the presence of several such structures. It is perhaps significant that workers in Australia and Africa came independently to the conclusion that only ducting, and not scattering, could account for the very wide band of frequencies propagated by pure TE. It seems that Aaron's findings and Heron's theoretical proposals could be combined to provide a plausible explanation. Both omit spread-F phenomena, and neither could explain the chopping and pulse-splitting action of flutter-fading. To explain these phenomena we envisage ducts that open and close as smaller-scale irregularities and bubbles shift and realign themselves within the larger structures.

Another interesting phenomenon not explained is that on many evenings around 7:30 P.M. local time, signals arriving by F-type TE on 50 MHz fade down or disappear, to be replaced soon afterward by pure TE signals. However, pure TE signals do not obey the usual rules, whereby lower frequencies appear first. Two meters often opens before the return of the 50-MHz signals, which may be delayed up to an hour. The effect is presumably caused by the size of the ducts, the scattering irregularities or the greater penetrative power of higher frequencies. Whenever 144-MHz signals appear, however, pure TE also seems to be operative on lower frequencies later at night. The general rule of a hierarchial fade-out probably holds good although our observations on 432 MHz were too few to confirm this. Fifty- and 28-MHz signals last far too late into the night to be observed regularly.

There are also two major points of disagreement between our observations and the theories we have discussed.

1) The beam heading preference is toward the west rather than the east. Aarons and Heron proposed an easterly drift of the propagating medium. This should lead to a positive frequency shift when it approaches the direct line between stations, and a negative shift as it drifts away to the east. The average Doppler shift was observed to be about 100 Hz negative. This should lead to a preference for a beam heading to the east of the direct line. The opposite was in fact observed. Whenever a preference was noted, it was always to the west, as it would be if the propagating medium were retreating after the setting sun.

2) F-type TE has a longer propagation time than normal two-hop F-layer propagation.

This observation was first noted in 1960; the transponder propagation times reported then were confirmed by recent studies. A simple FF or chordal hop should take a similar or slightly shorter propagation time than two-hop F layer, according to its ray geometry. This is certainly not so, and the propagation times for F-type TE and pure TE are very similar. The question of whether both follow a very similar path has to be considered, but at present current theories can not explain this observation.

Conclusion

High density ionized zones exist 10 to 15 degrees north and south of the magnetic dip equator. These zones account for excellent transequatorial propagation in the 6- and 10-meter bands. Amateurs recently discovered that the ionosphere will support communications at 144 MHz, and at times, up to 432 MHz. These circuits can open between stations located up to 5000 miles apart. The stations must be spaced approximately equidistant from the dip equator, and the line joining them must be perpendicular to the equator. Amateurs situated in optimum areas have a unique opportunity to engage in pioneer research. We have the chance to investigate and to prove or disprove many interesting theories. Such opportunities are rare in radio today.

Our observations and experiments

provide many clues into the nature of this propagation. The final explanation must await the findings of basic research into the morphology of the nighttime tropical ionosphere. This will require resources far greater than those we employed. Ingenuity notwithstanding, the resources required may be beyond the limits of most amateurs. Time will tell.

APPENDIX

ZS6PW's pulses were derived from a 100-kHz oscillator locked to the 100-kHz modulation carried by the 'ZUO vhf link. This 100-kHz signal is of very high stability and is derived from a cesium frequency standard.

Dividing 100 kHz by 7990 gives pulses that are the required 79.9 ms apart. Their timing relative to UTC is set by starting the divider at the correct instant with reference to the UTC second, which is also obtained from 'ZUO.

The basic time interval of the Mediterranean Loran C system is 79.9 ms, and that of the UTC system is 1 second. It follows that 10,000 Loran C periods take precisely 799 seconds. Consequently, every 10,000th Loran C period coincides precisely with every 799th UTC second. Such moments (13 minutes, 19 seconds apart) are called "Times of Coincidence" (TOC).

The Lampedusa data, including tables of TOC, were kindly supplied by the U.S. Naval Observatory in Washington, DC.

Although the distance from Lampedusa to Pretoria is over 4400 miles, the 100-kHz signal can usually be received late at night, and this enabled the accuracy of ZS6PW's timing system to be checked by measuring the time of arrival of the Lampedusa pulse groups in Pretoria. The calculated and measured propagation times were found to correspond within 20 microseconds on most evenings. The application of this system is discussed in Part I. QST

Notes

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[9] R. G. Rastogi, "Seasonal Variations on Equatorial Spread F in the American and Indian Zones," *Jnl. Geophysical Research* 85, A2, Feb. 1980, pp. 722-726.

[10] J. Aarons, J. P. Mullen, H. E. Whiting and E. M. Mackenzie, "The Dynamics of Equatorial Patch Formation, Motion and Decay," *Jnl. Geophysical Research* 85, A1, Jan. 1980, pp. 139-149.

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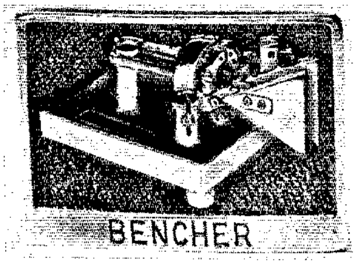
New Products

BENCHER BELT BUCKLE FOR CW OPERATORS

☐ There's always "something new under the sun," but who'd ever expect a belt buckle that was designed specifically for radio amateurs? "Seeing is believing," if I may borrow another cliche. An unsolicited parcel arrived on my desk from Bencher, Inc., and upon opening it I was pleasantly astonished to perceive a bright, rugged belt buckle that exhibited the very paddle I use in the home station, a Bencher.

The paddle on the buckle is raised to give a three-dimensional format. A check of the weight (no pun meant!) indicated that the buckle tipped the scale at approximately 4-1/2 oz (140 g), which makes it substantially heavier than any of the numerous buckles I have collected in recent years.

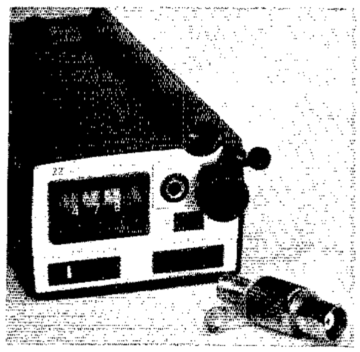


When I wrote an acknowledgment letter to Bob Locher, W9KNI, of Bencher, I said in a jocular fashion, "Not only is the big buckle beautiful, but it would be excellent for street fighting!" Bob came back with, "Cw operators are gentle people. They don't engage in street fighting." At any rate, it is a pretty object, and is done in a high-gloss, yellow-bronze motif. It seems like just the thing to wear to hamfests, conventions and club meetings. If you wear it where hams aren't present, you'll be asked some interesting questions about what that "funny emblem represents"!

The price is $7.95, plus $1 for shipping and handling, from Bencher, Inc., 333 West Lake St., Chicago, IL 60606, tel. 312-263-1808. — *Doug DeMaw, W1FB*

ANTENNA ADAPTER FOR TEMPO "S" PORTABLE TRANSCEIVERS

☐ Henry Radio is manufacturing and selling an antenna adapter for the Tempo "S" series synthesized portable transceivers. It converts the 5/16-32 threaded antenna jack to a standard BNC type. This permits the user to connect RG-58/U coaxial cable directly to the S1, S2, S4 or S5 without fear of damage to the radio. The adapter is sturdier and less susceptible to damage than is the built-in miniature phone jack used for external antenna connection. Ground connection is made by means of an indented lug that rests against the grounded portion of the antenna jack. Tempo owners who frequently use external antennas will find this adapter useful. Price class is $10. For further information, contact: Henry Radio, 2050 S. Bundy Dr., Los Angeles, CA 90025. — *Peter O'Dell, KB1N* QST



Antenna adapter for the "S" series synthesized portable transceivers. The threaded portion makes contact with the center conductor while the lug provides the ground connection.

Build a Gossamer Quad

Can the wire loops of a quad antenna survive without being supported by several hundred pounds of tower, mast, boom, spiders and spreaders? Sure! A seven-pound "gossamer quad" will sway in the wind, but it won't break.

By R. F. Thompson,* W3ODJ, ZF2CD

Gossamer antennas may become popular alternatives to the massive tower/mast/boom structures usually associated with beam antennas for the 10-, 15- and 20-meter bands. Rapidly rising costs of metal towers have caused some radio amateurs to look for other ways of supporting beam antennas at effective heights. Since the weight of a beam antenna is a principal factor, ways of making the antenna lighter are to be considered. The minimal weight of the gossamer places this antenna in the foreground in this respect. The essential parts of a two-element monoband quad are the two copper-wire loops that weigh less than 2 pounds (kg = lb × 0.4536). Conventional use of several hundred pounds of "passive" metal to support a few pounds of "active" copper seems absurd.

This article describes the evolution and construction of a two-element gossamer quad that began as a vacation exercise and has since developed into the main 20-meter antenna at W3ODJ. Presently, the antenna is made of copper wire, four wooden poles and a fiberglass pole. Two trees and a pair of nylon ropes elevate the antenna 50 ft (meters = feet × 0.3048) in the air. Another pair of ropes provides a means for steering the antenna around the compass. Although the total weight of the antenna is less than 10 lb, it has survived all weather to date, including winds reported to exceed 50 mi/h. It can be fabricated to fit into a ski case for easy transport.

Gossamer Evolution

Over the years, many radio amateurs have put up dipole antennas between trees, hoisting simple rigging into or over tall trees by throwing weighted lines, casting with rod and reel or launching a light leader line with bow and arrow.[1] Gossamer design begins with the observation that the same light rigging supporting a dipole can support one or more additional dipoles as well. If the dipoles are kept parallel and spaced properly, then a fixed-direction wire Yagi beam can be made. A recent example of a three-element gossamer Yagi is the "Ten Dollar Disposable 15-Meter Beam," described by Bruce Burnham, C6ADN, in November 1980 *QST*.[2] He supported his Yagi between two trees by means of two ropes. Two lengths of PVC tubing kept the three wire elements properly spaced and parallel. His gossamer beam survived Hurricane David with only minor damage.

Considered as a mechanical structure, a

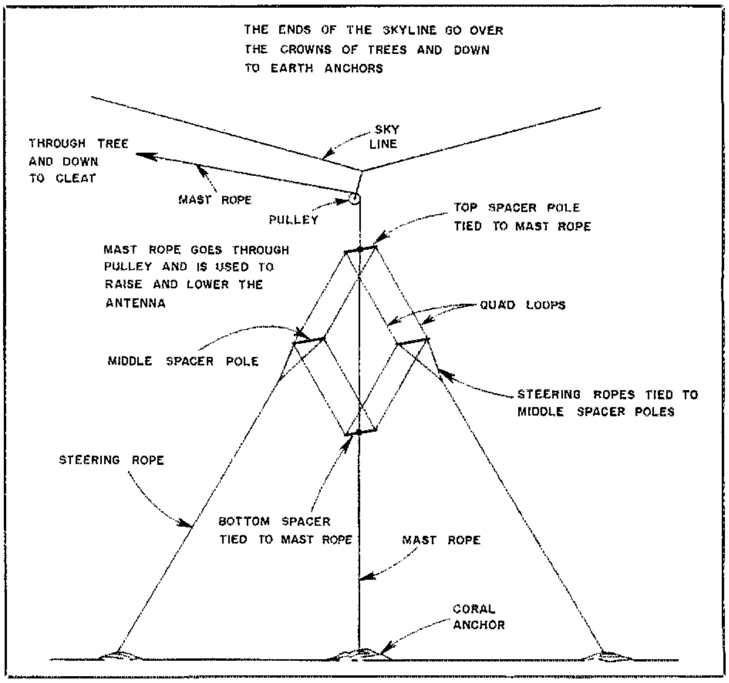


Fig. 1 — The two-element, 20-meter Cayman quad. Quad loops are pulled out into a diamond shape by the steering lines. The spacer poles are 9 feet long. The distance between opposite spacers (not critical) is 25 feet. See text for loop dimensions. Feed point for the driven element is at the bottom. A quarter-wave, 75-ohm matching section (not shown) is used.

[1]Notes on page 31.

*Rte. 7, Box 31, Waldorf, MD 20601

dipole antenna rigged between two trees is a suspension wire holding up several pounds of coaxial cable. Replace the dipole wire with rope and the center insulator with a pulley and you have a "sky line" and "sky hook" that can hold up the several pound weight of a gossamer quad antenna. The quad hangs like a pendulum from the pulley. A pendulum is naturally stable; displace it from equilibrium and gravity restores it to equilibrium. Conventional quads are supported by a tower that, to some degree, acts as an inverted pendulum. An inverted pendulum is unstable; displace it from equilibrium and gravity pulls it down. Towers must be massive to overcome the instability. By simply replacing the massive tower with a thin mast-rope, the gossamer quad gains natural stability, construction is simplified and the expense of owning a quad is greatly reduced.

Since the antenna is supported from above, tension in the wire loops can support light spacer poles that separate the loops and keep them parallel. Thus, the loops are both mechanical and electrical elements in the gossamer quad. The top and bottom spacer poles are tied to the mast rope, which extends upward through the pulley for hoisting the antenna to the sky line.

Prototype — The Cayman Quad

In June 1980, Paul Schmid (W4HET, ZF2BN) and I made a vacation DXpedition to Grand Cayman Island. Our Cayman QTH provided tall trees and a wide clearing, just right for gossamer experiments. One end of a 40-meter dipole was rigged by nylon rope stretching 50 ft across a clearing to a pine tree. A pulley at the midpoint of that sky line was the sky hook for a 20-meter gossamer quad.

On the flight to Cayman, I took eight quarter-inch diameter wooden rods as carry-on luggage, all taped together rather like a poor man's walking stick. Pairs of these sticks joined by 1-ft lengths of snug-fitting PVC tubing were used as 9-ft spacers between two quad loops. All the PVC tubing, wire, coils of rope and coaxial cable had been packed with clothing in a suitcase. The sides of the loops were pulled into a diamond shape by light ropes sloping down to the ground and held in place with large sand-filled conch shells and shards of coral. (See Fig. 1.) The first time the antenna was pulled up to the sky line, it was obvious that the top spacer would not support the antenna. As a replacement, two mop handles obtained from a local supermarket were spliced together with filament tape and placed in the antenna. The completed array included 1.75 pounds of copper wire, plus approximately 5 pounds of rope, PVC tubing and sticks. The entire quad weighed less than a pair of heavy-duty spiders used in conventional quads.

There are two noteworthy features of this Cayman design. The Cayman quad can be rotated by picking up the conch and coral and then walking in a circle. Furthermore, the entire antenna can be assembled on the ground and pulled up to the sky line by the mast rope that passes through the pulley. Any part of the antenna can be lowered rapidly to shoulder height for adjustment or repair.

On the ground, the assembled Cayman quad looked like a great fragile tangle. Winds gusting from the sea delayed the first hoisting, but that delay later seemed unnecessary because once the antenna was pulled up to the sky line, the quad withstood winds the likes of which are seldom experienced in Maryland. The dynamic stability (ability to withstand strong winds) of the Cayman quad was impressive. Neither the copper wire nor the 9-foot sticks had significant wind resistance.

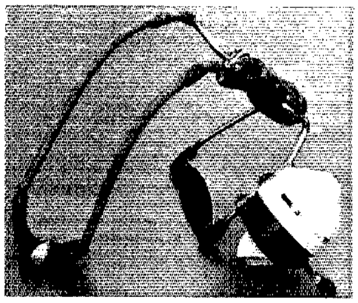
The bottoms of the loops were only 6 feet above the sand, but the quad was a great performer. Paul was working numerous European stations when the quad was ready for the first test. We therefore aimed the antenna at Europe, a move that enabled us to compare it with a vertical antenna located on the beach. When switching rapidly between the two antennas, received signals from Europe were at least two S units stronger on the quad.

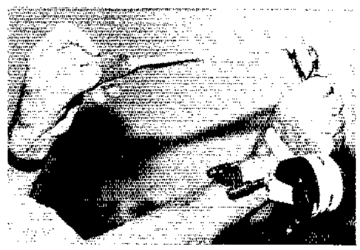
This was the first 20-meter beam I had ever used. It gave such great performance for so little money and effort that I decided to try it at home. I left the disposable walking-stick spacers on Cayman, repacked the wire and ropes, and hand carried the large conch shells on the flight home (they make great gifts!).

Gossamer Construction

Back home, the Cayman quad was installed between two oak trees at a height of 50 ft. The sky line was launched by taping light monofilament nylon fishing line (15-lb test) to an arrow that was then shot over the tree crowns by means of an archery bow. This light leader line in turn served to pull the ends of the 1/4-in. nylon sky line over the crowns and down to the earth anchors.[3] Another nylon rope goes through the pulley that is attached to the sky line. From the pulley this rope extends vertically down to become the "mast rope" on which the antenna is constructed. The other end of this rope passes over the nearest tree, and then down to a cleat. This end of the rope is used to pull the antenna up or lower it. If the hoisting end of the mast rope is returned straight down from the pulley, the vertical load on the sky line is doubled, and the additional sky-line sag would cause an unnecessary loss of antenna height.

The antenna is so easy to raise or lower that several design changes resulted in the antenna's becoming a remotely controlled rotating quad. Now, the top spacer is a





Small hose clamps are used to attach a casting reel to the wrist bracket of a slingshot. Monofilament nylon line tied to a 1-ounce (0.8 g) sinker is easily shot over any tree. The line can be rewound for repeated shots, and it is used to pull a heavier line over the tree when a suitable path through the tree is found.

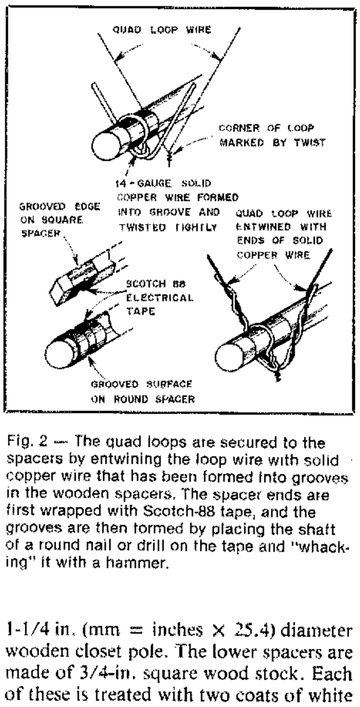


Fig. 2 — The quad loops are secured to the spacers by entwining the loop wire with solid copper wire that has been formed into grooves in the wooden spacers. The spacer ends are first wrapped with Scotch-88 tape, and the grooves are then formed by placing the shaft of a round nail or drill on the tape and "whacking" it with a hammer.

1-1/4 in. (mm = inches × 25.4) diameter wooden closet pole. The lower spacers are made of 3/4-in. square wood stock. Each of these is treated with two coats of white latex paint. Insulators for attaching the quad loops were formed by wrapping Scotch-88 electrical tape around the ends of the spacers (Fig. 2). A groove was formed in the wood beneath the tape by placing a nail lengthwise (not the point) on the tape and striking the side of the nail with a hammer. A short length of no. 14 solid copper wire was formed into the groove and twisted tightly, leaving the free ends 3 or 4 inches beyond the twist. During construction, the quad loops were fastened to the spacers by twisting these free ends around the loop wire.

At first, the steering lines were anchored by bricks on a large steering circle, but several backyard obstacles prevented 360° rotation. A smaller circle without obstacles could be used if the steering lines did not have to pull the loops into a diamond shape. Therefore, one major addition to the Cayman design is a 27-ft spreader (Fig. 3), which pushes the two middle spacers to opposite corners of the diamond. This pole consists of two telescoping fiberglass poles that extend from 6 to 16 ft. These weigh only 1.25 lb each. Skylane Products Co.[4] filled our order for them. Aluminum angle stock and hose clamps are used to join the poles end-to-end. The telescoping sections are extended and clamped for a combined length of 27 ft.

Both middle spacers are strapped to wood blocks drilled for snug passage of a short length of copper water pipe having one capped end (Fig. 4). Hose clamps fix the position of the block on the pipe. The spacers are mounted on the spreader by slipping the copper tubes over the ends of the spreader pole. This spreader and the top and bottom spacers can be tied to double bowlines in the mast rope. If you are not too familiar with double bowlines, ask a Boy Scout or Girl Scout, check a Scout manual or seek the aid of a mountain climber. Practical information on ropes and knots may also be found in books on mountaineering. Knowledge of knot tying and ropes can be most useful in constructing a gossamer and other antennas.[5] With the spreader pole in place, the steering lines can be brought to opposite points on a 13-ft-diameter circle on the ground. The steering procedure becomes much easier by tying the steering lines to the ends of a pole and pinning the center of the pole with a cinder block. Then the steering procedure is simply a matter of removing the block, rotating the pole and replacing the block.

Recent improvements include the placement of a vertical cedar pole under the center of the antenna, installation of a rotator atop the pole and putting a 13-ft steering pole on an 18-in. wooden mast attached to the rotator. A small length of PVC tubing is strapped to the short mast. The mast rope is passed through this tubing and is wrapped around the cleat on the cedar post to immobilize the pendulum. Light ropes are attached from the center of the bottom spacer out to the ends of the steering pole, and from the rotator mast out to the ends of the bottom spacer.

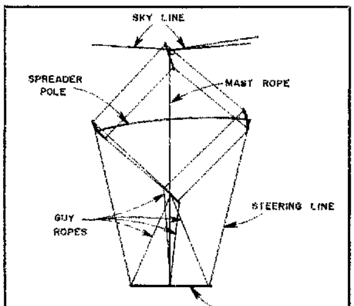


Fig. 3 — The gossamer quad is a slightly modified Cayman quad. Less steering room is needed if a spreader pole is added to push the loops into a diamond shape. The steering lines can be tied to a steering pole anchored on the ground or attached to a rotator. Guy ropes between the bottom spacer and steering pole steady the diamond in strong winds.

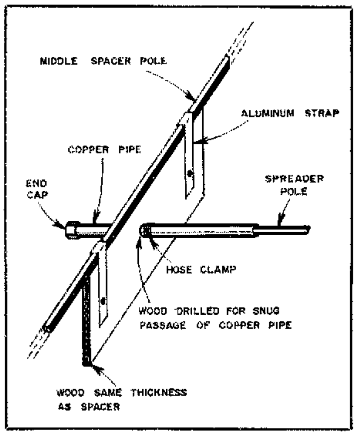


Fig. 4 — A spreader/spacer bracket is strapped to each middle spacer pole and slipped over the ends of the spreader pole. A hose clamp limits the motion of the board on the pipe.

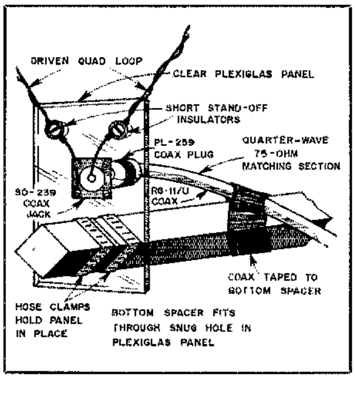


Fig. 5 — The coaxial-cable feed-point fixture is made of clear Plexiglas and slips onto the bottom spacer.

These four guy lines steady the lower part of the antenna and help maintain the diamond shape in strong winds. Although the steering pole for this antenna is 14 ft above ground, any height above heads and clotheslines would be satisfactory.

Cutting, Shaping and Feeding Loops

Quad dimensions are not very critical.[6] The loops are cut to length and spaced for f = 14 MHz according to published formulas.[7]

Length of one side of driven radiator: 250/f = 17.86 ft.

Length of one side of closed reflector: 258/f = 18.43 ft.

Spacing between loops: 118/f = 8.43 ft.

The loop wires are twisted to mark the four corners. (See Fig. 2). When the loops are formed into a diamond with square corners, the horizontal and vertical diagonals are close to 25 ft long. The spreader pole has to be 27 ft long to overcome spreader-pole droop and to allow for the spreader-spacer brackets. But again, this is not critical. In fact, the quad might have more gain if the vertical diagonal is longer than the horizontal diagonal (side lengths same as above). Loop gain depends on the separation between current maxima. These occur at the top and bottom corners when a diamond loop is fed at the bottom corner. Folke Rasvall, SM5AGM, has been told by his computer that a one-wavelength diamond with equal diagonals ought to have 1-dB gain relative to a half-wave dipole[8] (the corresponding element in a Yagi beam antenna). But if the vertical diagonal is made three times longer than the horizontal diagonal, so that the loop looks like a thin ARRL emblem, then the loop ought to have about 1.7-dB gain. The trade-off is more gain at the expense of reduced bandwidth and lower input impedance. The spreader pole on a 3 to 1 diamond would be only about 12 ft long, and the feed point would be 35 ft below the top spacer.

A quarter-wave section of 75-ohm coaxial cable was carefully pruned to 14 MHz using a grid-dip meter. This matching section is inserted between the 50-ohm feed line and the feed point at the bottom corner of the radiator loop. (See Fig. 5.) Minimum SWR ocurs below 14 MHz. The loops could be shortened to improve the SWR profile over the 20-meter band. What the transmitter "sees" is a standing-wave ratio of 1.4 to 1 at 14 MHz, and 1.9 to 1 at 14.35 MHz. No attempt has been made to optimize the quad for gain or front-to-back ratio, but when it is aimed correctly the received signals are usually two S units stronger on the quad than on either a vertical or a dipole.

Trees and Ropes

One ice storm lowered the quad two feet, the height loss resulting from drooping tree crowns and a sagging sky line. But, because the mast rope and guy lines are rigged for rapid adjustment, the antenna can be trimmed in a few minutes for prevailing conditions. The mast rope is wrapped around the cleat on the cedar post. Clothesline tighteners having spring-loaded cam wedges are used to adjust the guy lines.

Trees "eat" rope. Prolonged abrasions from rough tree bark can eventually sever the rope. To minimize wear, ropes should be routed for the least contact with the tree. The abrasion problem can be reduced by choosing suitable rope. A given amount of abrasion weakens a thin rope relatively more than a thicker rope. Good manila rope loses more strength to abrasion than does good nylon rope, but some inferior nylon ropes have poor abrasion resistance.[9] Several hundred feet of 1/8-in utility nylon takes little space in a suitcase and is probably adequate for a temporary expedition installation. For a permanent antenna, however, a good choice is 1/4-in. Mountain Climbing Goldline, an economical, high-quality nylon rope of three-strand, hard-lay construction, which (as this is written) costs about 15 cents per foot. It is sold by Recreational Equipment, Inc., Seattle, WA 98188.

Recently, Alan Hack, WA5VLX, suggested that the best way to get an antenna into a tree is to use a slingshot and casting reel combination such as developed by Robert Cowan, K5QIN.[10] In rerouting the mast rope I found that method definitely superior to using a bow and arrow. A one-ounce sinker painted yellow makes highly visible ammunition for the sling shot. Load the reel with fluorescent monofilament nylon, and the path through the tree is easier to see.

Comments

The gossamer quad is not a rigid structure. It bends against a strong wind rather like the venerable oaks that support the sky line. The steering is soft, and the antenna yaws at sudden gusts. No doubt there exist locations subjected to frequent gales where gossamer antennas often might be useless, but in Waldorf, Maryland, the author's quad has remained 100% usable in all weather experienced to date.

Some local ordinances against having beam antennas might not apply to a gossamer quad since there is no "unsightly" tower, and no mast or boom. One thin sky line below the tree line is less conspicuous than a dark swath of telephone or power lines, and a light-colored sky line is virtually invisible in many aspects of daylight. It is usually difficult to see the loop wires. Often the spacer poles seem to float magically in the air.

The quad will reward all efforts to rig it as high above ground as possible, but it does not have to be very high to outperform dipole and vertical antennas. Any radio amateur who can get a dipole 40 ft or more in the air can rig a sky line in its place. If there is a suitable clearing under the sky line, a two-element gossamer quad can replace the dipole and provide noticeably better results.

Acknowledgment

Paul Schmid (W4HET, ZF2BN), helped reactivate W3ODJ after many years. His enthusiasm for operating on Cayman convinced the author to join in the fun. Paul also encouraged the writing of this article. Thanks, Paul! QST

Notes

[1] *The ARRL Antenna Book* (Newington, CT: ARRL, 1976).
[2] B. Burnham, "A 15-Meter Beam for $10," *QST*, Nov. 1980.
[3] See Note 1.
[4] Skylane Products, 406 Bon Aire Ave., Temple Terrace, FL, 33617.
[5] W. Wheelock, *Ropes, Knots and Slings for Climbers* (La Siesta Press, 1967). Available from Recreational Equipment, Inc., Box C-88125, Seattle, WA 98188. Price in 1980: about $2.
[6] See Note 1.
[7] W. Orr, *All About Cubical Quad Antennas* (Wilton, CT: Radio Publications, Inc.).
[8] F. Rasvall, "The Gain of the Quad," *Radio Communication*, Aug. 1980, p. 784.
[9] H. Manning (Editor), *Mountaineering*, 2nd ed. (Seattle: The Mountaineers, 1967).
[10] A. Hack, "The Best Way to Get an Antenna into a Tree," *Ham Radio*, March 1981, p. 84.

Strays

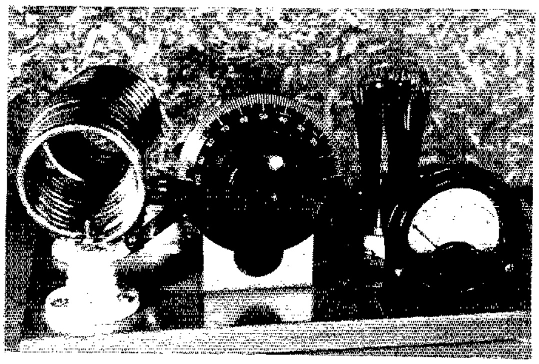
I would like to get in touch with . . .

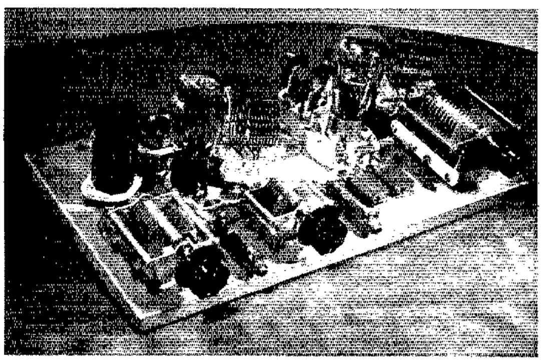
☐ anyone who has a collection or file of troubleshooting and maintenance information about the Heath SB-303 receiver and the Heath SB-401 transmitter. I will pay reproduction and postage costs. John Carter, KT6R, 412 Jamaica Way, Bakersfield, CA 93308.

☐ amateurs with a knowledge of and interest in the old WRL Galaxy V transceivers and accessories. Mike Flowers, KA3FJD, 1022 Woodland Way, Hagerstown, MD 21740.

☐ amateurs with information about the HW 12-22-32 Triband conversion made by Dynalab. Jim Fyles, WBØCZI, 820 El Paso Blvd., Denver, CO 80221.

☐ hams who are also teachers of electricity, electronics or industrial arts courses, to start an 80-meter net to discuss new projects. John Nenning, Industrial Arts, W. D. High School-Beckman Annex, Dyersville, IA 52240.





Gary Legel, N6TO, built these replicas of his first transmitters, a 59 Tri-Tet crystal oscillator and 301 amplifier (left), and the more modern Hartley 210 (right). Interest in nostalgic equipment is rising, and rigs such as these are cropping up with greater frequency. *(photos courtesy N6TO)*

Build this Extended, Expanded Collinear Array

Liven up the "Lazy H" and put it on its feet. Have a ball with this broadband beam for 2 meters.

By Walter W. Schmidt,* W2EA

I had a problem! For more than 25 years I have been operating in the vhf bands, first on a-m and later using cw and ssb. Horizontal Yagi antennas had worked fine until two developments combined to limit their usefulness: I began using fm repeaters, and I became a member of New Jersey Army MARS. I needed a vertically polarized antenna. It would have to be broadband, as Army MARS repeaters have their inputs on 148.010 MHz and their outputs on 143.990 MHz. My antenna would need fairly high gain; I live in southern New Jersey about 6 miles[1] southeast of Philadelphia, and wanted to use a MARS repeater in the northern part of the state. That repeater is 72 miles away in mountainous terrain with the antenna only 30 feet[2] above the ground.

I considered a multielement Yagi, but quickly discarded that idea because of the narrow bandwidth. Antenna designer E. M. Brown, W2PAU, former vhf editor of *CQ*, suggested several antennas that might do the job. They were the W8JK array, coaxial sleeve dipoles with reflectors and directors, and the "Lazy H."

My research indicated that the "Lazy H" would meet my requirements, and I could build it using only hand tools. The basic design is found in *The ARRL Antenna Book.*[3] It is an array consisting of two pairs of collinear half-wavelength elements; all of the elements are driven in phase. To provide vertical polarization the H would not be "lazy," of course; the four driven elements would be mounted vertically.

Design Details

Maximum gain is obtained with a pair of collinear elements when they are spaced at 0.625 λ. That is the spacing between the sides of the "Unlazy H." Brown suggested a way to get a bit more gain, and the *Antenna Book* confirmed it. All I had to do was extend the length of the collinear elements (sides of the H).[4] Each side of the H would now be composed of two elements 0.64 λ long instead of 0.5 λ. That resulted in one additional decibel of gain (3-dB gain over a dipole) for each pair of elements. Two 0.64-λ elements driven in phase form the extended double Zepp. Based on that information, I decided to build my antenna design around a vertical or "Unlazy H." The sides would be a pair of extended double Zepps, and they would have a spacing of 0.625 λ between them.

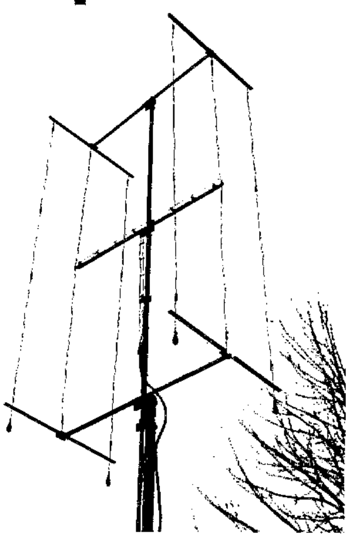


Fig. 2 — The extended, expanded collinear array in place. The wire elements terminate in insulators made of 3/8-inch Teflon rod. Monofilament fishing line is used for vertical spacing between parasitic elements. Four 8-ounce fishing sinkers are used to provide even tension on the parasitic elements.

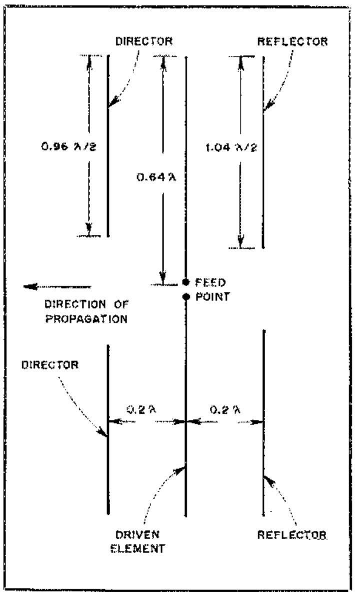


Fig. 1 — A drawing of half the antenna. The extended double Zepp may be thought of as two end-fed driven elements. When a parasitic reflector and director are added to each of these, a 12-element array is the result . . . and the results are good.

A *QST* article by Reisert[5] confirmed that this was the basis for an effective antenna. He described an extended, expanded collinear antenna array with optimum-gain spacing between collinear element pairs. That is essentially what I have made. It should be noted that with collinear elements of 0.64 λ, the spacing between current maximum points on the pair is about 0.78 λ. (This is an extended double Zepp.) The increased spacing (from 0.5 λ) is the reason for the increased gain.

I decided to increase the gain further by adding parasitic elements to each of the four driven elements. To do this, I cut four directors for the high-frequency end of the 4-MHz-wide band and four reflectors for the low-frequency end. The spacing between the parasitic and driven elements was set for 0.2 λ at 146.0 MHz. This gave me a 12-element, unidirectional array. See Fig. 1.

Construction Technique

Fig. 2 shows how the antenna was

[1]Notes appear on page 33.

*709 E. Graisbury Ave., Haddonfield, NJ 08033

actually built. A wooden center-support pole was employed to minimize the effects on the antenna pattern. I wrapped the pole with fiberglass tape and coated it with resin to seal it against the weather. Two aluminum support frames were constructed and mounted to the center pole. The wire elements, made of no. 16 AWG Formvar wire, run between these frames. Insulators for the array are fabricated from 0.375-inch-diameter Teflon rod.[6] The rod is cut into 24 pieces, each 2 inches long. These are then drilled 0.25 inch from the ends.

The 1/2-inch loop formed at the end of an element, when it is passed through an insulator and soldered, will act as a capacitive hat. I used my dip meter to determine how great a loading effect the loop has. Adding the loops at the element ends shortens the length by 3 inches for resonance at 146 MHz. I used the multiplication factor of 0.64/0.50 to calculate the element length for the extended double Zepp. This gave me a dimension of 47 inches.

I wanted the reflectors to be 4% longer than a half wavelength at 144 MHz. That meant they would resonate at 138.25 MHz. Once again the dip meter provided the answer. The wire, including loops, is 38.5 inches long. Similarly, the directors were to be 4% shorter than a resonant element at 148 MHz. A bit of math and the dip meter indicated 34.3 inches of wire, with loops, was resonant at 154.0 MHz.

Open-wire line is used to feed the driven elements. It and the matching stub are constructed using no. 16 AWG wire — the same kind used for the elements. Teflon rod of 0.25-inch diameter was used for the line insulators. I cut and drilled them to provide 1-inch spacing between the conductors. The stub is connected at the center of the feed line. Fig. 3 illustrates how the feed line, matching stub and balun are connected to the driven elements.[7]

Tune-up Procedure and Results

To start, the matching stub was made slightly longer than 0.5 λ. The sliding short and balun were equipped with clips. That allowed the connection points to be moved easily. Next, I tuned up my rig into a dummy load, selecting a seldom-used simplex frequency near the top of the band. (I was interested in the 148.010-MHz repeater input frequency.) I then inserted my vhf wattmeter in the line near the antenna, using a short piece of RG-8/U coaxial cable. A foot switch and a long ac cord allowed me to key the transmitter while near the antenna. The antenna was mounted at a 45-degree angle during adjustment of the array. This directed the signal into space so that ground reflections would not affect tuning. The adjustments were made "cold," but I wanted to take no chances. I wore a pair of cotton work gloves while moving the clips (to prevent rf burns).

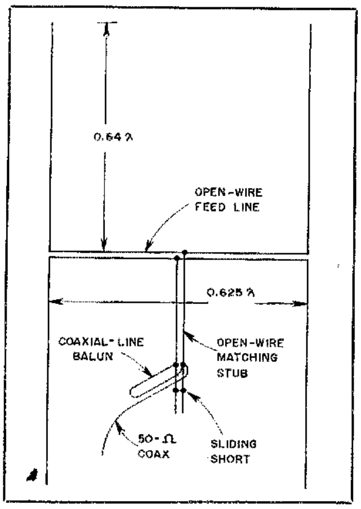


Fig. 3 — A coaxial-line balun and a stub match are used in the feed to the driven elements that form an "Unlazy H" in this vertically polarized array. The parasitic elements are not shown in this drawing.

In general, the position of the sliding short was adjusted to provide maximum output: the balun clips were located to obtain minimum reflected power, as shown on the wattmeter. The two adjustments interact, so it is necessary to adjust them alternately until an optimum match is found. When I had determined the best positions, I removed the clips and soldered the short and the balun to the stub. The wire below the short was cut off.

The antenna is working well. Since the photograph was taken I have installed a rotator and am now able to use the amateur repeaters in the northeastern part of the state. I enjoy reliable access to the MARS repeater in Wilmington, Delaware, but the same cannot be said for the NNJ MARS repeater, because of distance and terrain. When the plans to move that repeater to New Brunswick, New Jersey, are realized I should enjoy reliable communications through it. Initial pattern tests with W2PAU indicated a good front-to-back ratio. I feel that the results are worth the effort expended in the design and construction of this antenna.

Notes

[1]km = mi × 1.6.
[2]m = ft × 0.3048.
[3]*The ARRL Antenna Book*, 13th ed. (Newington: The American Radio Relay League, Inc., 1980), p. 143.
[4]*The ARRL Antenna Book*, p. 137.
[5]J. H. Reisert, "VHF Antenna Arrays for High Performance," *QST*, Dec. 1974, p. 38.
[6]mm = in. × 25.4.
[7]See *The ARRL Antenna Book*, pp. 115 and 229, for information on the balun and stub matching used on this antenna.

Strays

RELAY REMINISCENCES

☐ Sixty years ago, when radio was in its infancy and *QST* was in its fourth year of publication, I became the radio editor of the Hartford *Times*, a job I took to earn money to go to college. My job as radio editor came about as follows:

City Editor — "What do you know about radio?"

Me — "Nothing."

City Editor — "That's fine. Then you won't have any prejudices. You're our radio editor, in addition to your other obligations."

I didn't worry too much about the assignment because there was a radio store and the ARRL Headquarters nearby to whom I could take questions and then print the answers. If a telephone call came into the office, ". . . the radio editor is out, but if you will submit your query in writing, he will be pleased to answer it." (Once in a while I was scrambling because my colleagues double-crossed me by saying that the radio editor was *in*.) After hearing the caller's plight, I used either of two standard ploys. (1) Are your batteries delivering the necessary juice? (2) If your connections are not soldered, that may be your trouble. I always added, "Try this. If it doesn't work give me a diagram of your set, and I'll print an answer."

In 1922 the first national radio show was scheduled to be held in New York City. I wanted to be sent there to cover the show, but my editors didn't think it was worth the expense. Then I had a stroke of genius: the *Times* would cover the radio show by radio. It turned out that K. B. Warner, editor of *QST*, was going to the show, and Hiram Percy Maxim offered to get Mr. Warner's signal from Jersey City on his own set, 1AW.

Around 8:00 of the appointed evening, I went to Mr. Maxim's home to await word from Mr. Warner. Every 15 minutes 1AW called the Jersey City station, but there was never a response. At about 1 A.M., we were discouraged and ready to fold up. Then came a call to us from a ham in Lewiston, Maine. "I've been listening to Jersey City calling you and to you calling him. Apparently there's some weather interference because both of you are coming in loud and clear here. I'll be glad to relay any messages." (Don't forget, this was before the days of voice; it was all done in Morse.)

The venture was a success, and later that day the *Times* proudly printed a 100-word story of the first radio coverage of the first national radio show. And it was all because of a radio relay between two early pioneers of radio, Hiram Percy Maxim and K. B. Warner. — *Victor A. Rapport, Sarasota, Florida*

An Introduction to the Bilateral Transverter

VHF DXing with 100-mW ssb interest you? Get into the act with a "BT" for great fun with "whisper" power!

By Fred Brown,* W6HPH

If your shack is typical, it is equipped with an "all band" (80- through 10-meter) ssb/cw transceiver. Vhf bands, and even 160 meters, can be added to these ubiquitous boxes by means of a *transverter* (Fig. 1A). The transverter up-converts the transceiver rf output to the desired vhf band and also down-converts the received vhf signal to the hf band. Since a common local oscillator is used for the heterodyne process, the receive and transmit frequencies are translated an identical amount, and the transceiver operates just as it would on hf.

Reduced to its barest essentials, the transverter simplifies to nothing more than an oscillator-mixer combination, as in Fig. 1B. If the mixer is of a *bilateral* type, it will handle both the up and down frequency conversions, no antenna switching or changeover relays will be needed.

The principal advantage of such a bilateral transverter (BT) is simplicity, as should be apparent from comparing Figs. 1A and 1B. Of course, a price must be paid for this simplicity: Power output will be very limited, and the receiver noise figure will not be the ultimate. The BT, by itself, will not meet the needs of the demanding vhf DXer. Nevertheless, it is adequate for working the locals and for getting started on a new band. Furthermore, the BT can be upgraded later by adding a power amplifier and/or a receive preamplifier.

System Principles

Theoretically, there is no efficiency or power limitation to the frequency-conversion process. In principle, we could convert as much as 100 watts of hf ssb into nearly 100 watts of vhf ssb with nothing more than a passive mixer. To do this with presently available devices, and with a reasonable local oscillator power level, is not within the current state of the art.

Work DX with four diodes? Here's proof of the pudding. These cards confirm contacts with W6HPH, who was using nothing more than an attic dipole in conjunction with the 50-MHz BT described here.

Probably the most practical form of bilateral mixer is the four-diode, ring-modulator type of doubly balanced mixer originally developed for telephone communication. As with any mixer, sum and difference frequencies in addition to harmonics of the local oscillator are produced. These unwanted mixer products must be removed by a good band-pass filter.

The diode mixers used in the transverters described here operate at an rf output level of 100-mW PEP. To some, this might seem like a QRP level where communication would be impossible, but the author has made solid 3000-mile (km = mi × 1.6) contacts with the 6-meter BT. Usually, range is limited more by the antenna and location than power. Remember, if you are 40 dB over S-9 with a kilowatt, you will still be S-9 with 100 mW. Realistically, 100 mW is a power level suitable for the vhf beginner who is interested mainly in exploring a new band and working the locals or other easy-to-work stations.

As a receiver, the BT will never win any noise-figure contests. The best you will be able to do is about 8 dB worse than the NF of your hf transceiver. Even so, signals as weak as 0.5 microvolt are easily readable. With only 100 mW on transmit, you will always be able to hear more than you can work. Furthermore, one point in favor of the BT as a receiver is its excellent cross-modulation performance. In this department it will surpass any vhf converter.

The 6-Meter BT

Twenty meters was chosen as the i-f for the 6-meter BT because both the 21- and 28-MHz bands would have been too close in frequency to one half of 50 MHz. As can be seen from Fig. 2, four transistors are used to provide 36-MHz injection for the doubly balanced mixer. About 1 watt of rf is developed; any crystal-controlled 36-MHz source that provides this level of power could be ap-

*1169 Los Corderos, Lake San Marcos, CA 92069

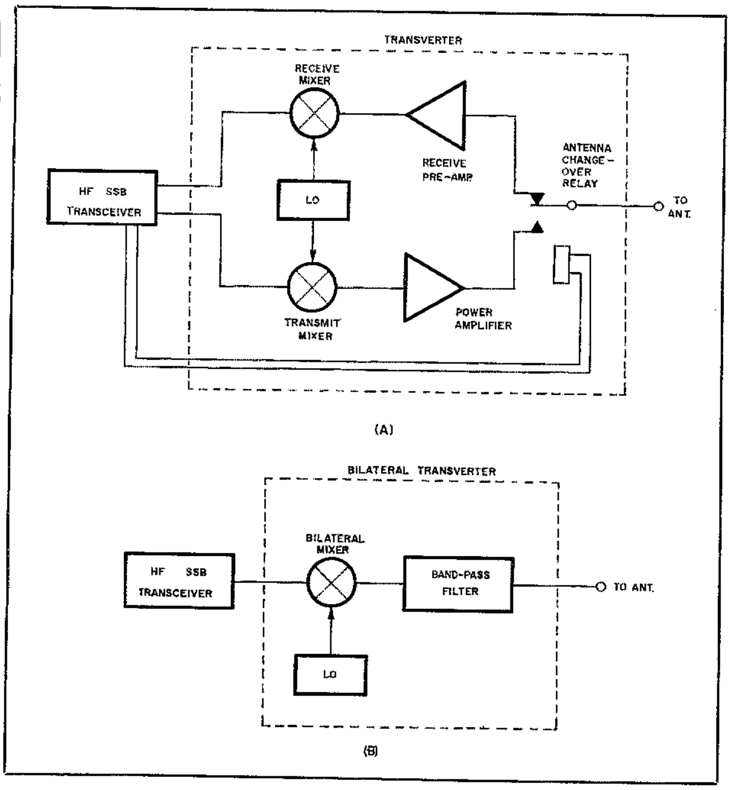
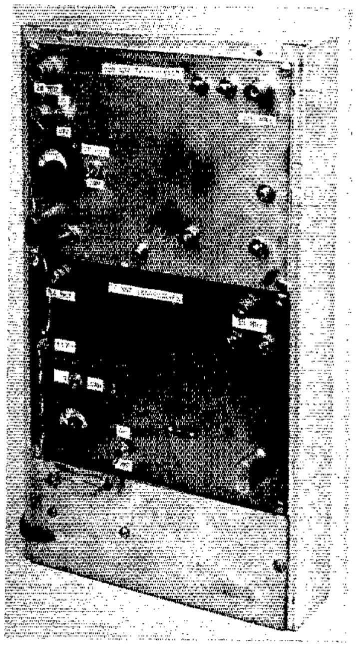


Fig. 1 — The conventional transverter shown at A requires two rf connections to the hf transceiver, plus a push-to-talk control voltage for the antenna changeover relay. The much simpler bilateral transverter at B requires only one connection to the hf transceiver.



The two transverters are shown here "rack" mounted in a 7- × 13- × 2-in. aluminum chassis. Behind the bottom panel is a regulated 12-V power supply. Total shielding is recommended to avoid i-f leakthrough problems. If a nonmetallic box is used, it should be lined with metal foil.

plied. For instance, a reworked CB rig could be substituted for the LO rather than the circuit shown.

The doubly balanced mixer (DBM) is followed by a two-pole filter (L6-C6 and L7-C7), which prevents the unwanted image and harmonic products from reaching the antenna. To some degree, this filter also acts as an antenna coupler, since C6 and C7 can be adjusted to match any impedance that does not depart radically from 50 ohms (resistive).

Any of a large number of transistors could have been chosen for Q1 through Q4. The 2N2222As were used because they are inexpensive and readily available. Q1 is a conventional overtone crystal oscillator. Q2, a buffer/amplifier, drives the parallel combination of Q3 and Q4. The latter two transistors are fitted with small heat sinks. An L-pi network[1] is used between the collectors of Q3/Q4 and the DBM to provide optimum coupling along with good harmonic suppression. A stabilizing network (C4, L5 and R1) performs as a parasitic suppressor for Q3 and Q4. The low L-C ratio tank circuit (C4 and L5) is parallel resonant at 36 MHz and prevents power loss in R1 at this frequency. At all other frequencies, R1 loads Q3 and Q4, thereby preventing parasitics. L5 may be adjusted by squeezing or spreading turns to resonate with C4 at exactly 36 MHz. Resonance should be determined with a dip meter, which in turn has been checked against a frequency counter or calibrated receiver to indicate the precise frequency.

[1] *VHF-UHF Manual*, 1969 edition, RSGB, p. 6.12.

A 0-100 microammeter can be switched to monitor either DBM dc current or rf output voltage. The former is used in tuning up the LO chain, and the latter is used for tuning the DBM and two-pole filter for maximum rf output.

The ring modulator is unusual in that the four diodes are self-biased by the bypassed resistor, R2. As a result, the diodes act as varactors throughout most of the rf cycle, which means the balanced mixer functions partly as a parametric up-converter. This permits a much higher saturated power output than could be attained with a conventional ring modulator.

Unfortunately, like most parametric converters, it is also subject to parasitics. These parametric parasitics can be extinguished by reducing the value of R2, but at the expense of lower saturated output. The value of R2 should be the maximum that will permit completely stable operation.

Construction

Both the 50-MHz and the 220-MHz BTs are constructed on 5- × 6-1/2 inch (mm = in. × 25.4) double-sided circuit boards, the correct size for a standard 5- × 6-1/2- × 1-1/2-inch meter box. Suggested component layouts are shown in Figs. 3 and 5.

Terminal-strip construction was chosen in preference to the more popular printed-circuit technique. There are several reasons, the main one being that all components are maintained close to a conducting ground plane. This is important in vhf work because it avoids the radiation and ground-loop problems of pc boards. In addition, if the board is used as the cover of a conducting box, a completely shielded rig results. Furthermore, terminal-strip or stand-off construction makes circuit alterations easier than would be the case with pc board construction.

Tune-Up

Collector current of Q2 can be observed

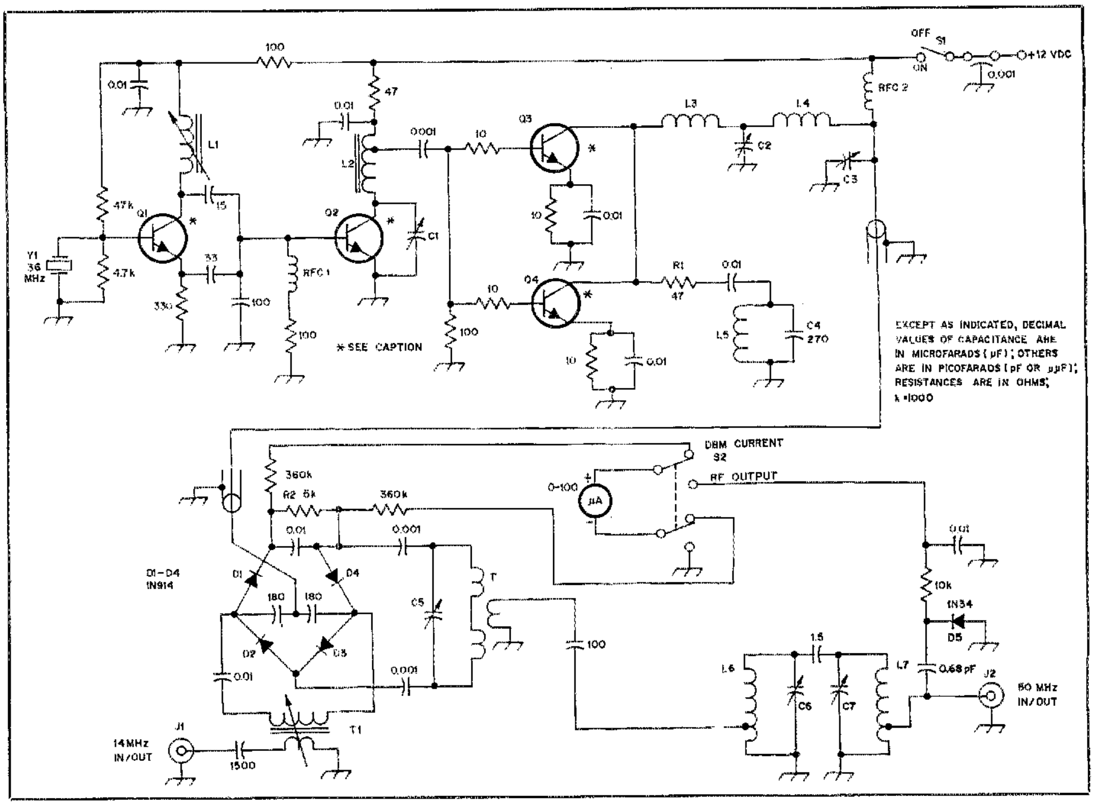


Fig. 2 — Inexpensive 2N2222A transistors may be used in the 6-meter BT. The doubly balanced mixer consists of diodes D1 through D4 coupled to the antenna through a 2-pole filter.

C1 — 2.5-11 pF ceramic trimmer.
C2 — 100-pF APC trimmer or Arco 463.
C3, C5 — 9-180 pF mica trimmer, Arco 463.
C6, C7 — 3-32 pF, E. F. Johnson 160-130.
D1-D4, incl. — Switching diode, 1N914
D5 — Germanium diode, 1N34.
L1 — 11 turns no. 22 enam. copper wire, close wound on 1/4-in. slug-tuned form.
L2 — 9 turns no. 24 enam. copper wire on Amidon T37-2 toroid form, tapped at 3 turns.
L3 — 1.1 µH, 23 turns no. 24 enam. copper wire close wound on 3/16-in. dia form.
L4 — 0.95 µH, 8 turns no. 18 enam. copper wire, 3/8-in. ID, close spaced, air wound.
L5 — 3 turns, no. 14 enam. copper wire, airwound, 3/8 in. ID, 1/2 in. long.
L6, L7 — 11 turns, no. 14, copper wire, 5/8-in. ID, 1-3/8 in. long, air wound. Tap two turns from ground end.
RFC1, RFC2 — 22 µH, J. W. Miller no. 70F225A1 or equiv.
S1 — Spst.
S2 — Dpdt.
T1 — Primary: 5 turns no. 24 hookup wire wound over secondary tape. Secondary: 1.5 µH, 16 turns no. 26 enam. copper wire, close wound on 1/4-in. slug-tuned form and covered with a single layer of vinyl tape.
T — 2-1/2 turns each side of center, no. 18 enam. copper wire on 1/2-in. dia form with 3-turn no. 24 enam. copper wire link. See Fig. 3.

by connecting a voltmeter across the 47-ohm resistor in series with L2. There will be no Q2 collector current unless Q1 is oscillating. L1 should be adjusted to maximize this current. In like manner, the emitter currents of Q3 and Q4 can be checked by measuring the dc voltages across the two 10-ohm emitter resistors. These voltages should be around 0.6 V and should be roughly equal. If unequal, they can be balanced by reducing the value of the 10-ohm base resistor of whichever transistor is drawing the smaller current. C2 and C3 can then be adjusted for maximum DBM diode current as indicated on the microammeter. It should be possible to exceed 60 µA.

With the LO chain functioning properly, the next step is to connect the 14-MHz port to a receiver and to run a moderately strong 50-MHz signal into the antenna

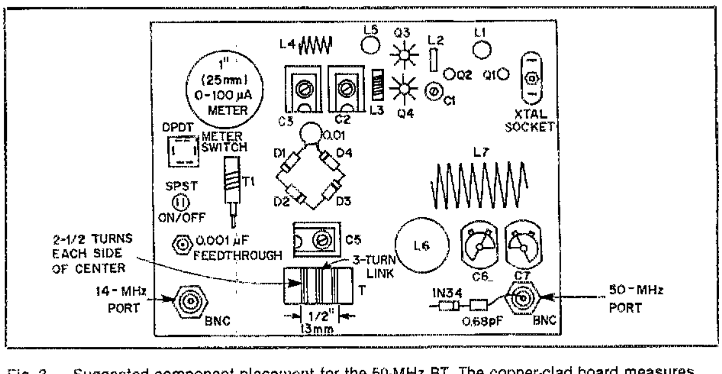


Fig. 3 — Suggested component placement for the 50-MHz BT. The copper-clad board measures 5 × 6-1/2 inches. Only the larger components are shown. Coils are generally oriented to minimize inductive coupling between them. Winding details of L5 are shown. Transistors Q3 and Q4 are fitted with small heat sinks. A short length of miniature coaxial cable can be used to connect C3 to the ring modulator. All other rf leads should be reasonably short and direct.

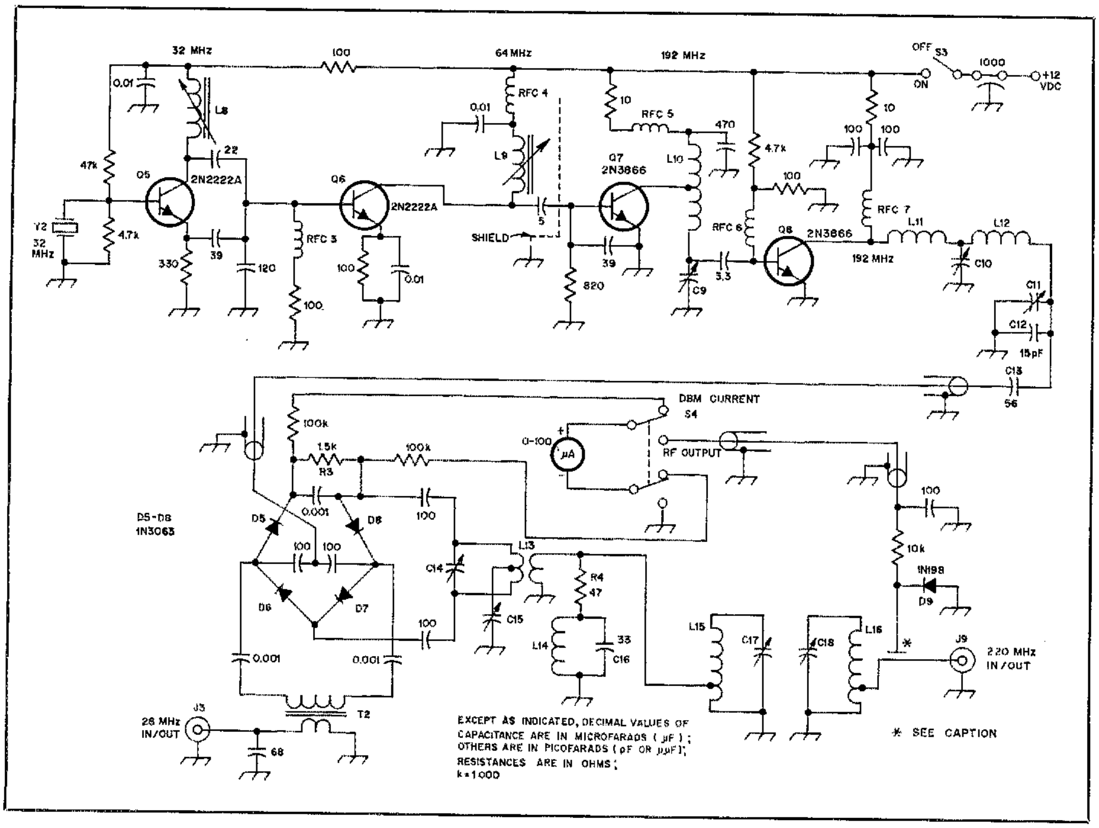


Fig. 4 — The 220-MHz BT is similar to the 50-MHz model but uses a 28-MHz i-f. Input and output impedances are 50 to 75 ohms. The rf pickup (*) for the meter is a short length of insulated wire brought near the center conductor of the coaxial fitting. It is adjusted for half-scale meter deflection when you are running full output into a matched load.

C9, C10, C11 — 2.9 pF, E. F. Johnson 160-104.
C12 — 15 pF disc ceramic.
C13 — 56 pF disc ceramic.
C14, C15 — 4-40 pF, Arco 422.
C17, C18 — 1.5-5 pF, E. F. Johnson 160-102.
D5-D8, incl. — Silicon switching diode, 1N3063.
D9 — Germanium diode, 1N198.
L8 — 10 turns no. 28 enam. copper wire, close wound on 1/4-in. slug-tuned coil form.
L9 — 9 turns no. 28 enameled copper wire, close wound on 0.215-in. dia slug-tuned form.
L10 — 4 turns no. 16, 1/4-in. dia, 5/16 in. long, air wound, center tapped.
L11 — 8 turns, no. 16 copper wire, 3/8-in. ID, 9/16 in. long, air wound.
L12 — 8 turns, no. 16 copper wire, 1/4-in. ID, 9/16 in. long, air wound.
L13 — One turn no. 14 copper wire, 5/8-in. ID, center tapped with a 1-turn, close-coupled link. See Fig. 5.
L14 — One turn no. 18 copper wire, 1/4-in. dia. Resonates with C16 at exactly 221 MHz.
L15, L16 — 5 turns, no. 16 copper wire, 3/8-in. ID, 1/2 in. long, tapped one turn from low end.
RFC3 — 22 μH, J. W. Miller no. 70F225A1 or equiv.
RFC4-RFC7, incl. — 1.5 μH, J. W. Miller no. 4604 or equiv.
S3 — Spst.
S4 — Dpdt.
T2 — Secondary is 5 turns no. 28 enameled copper wire close wound on 0.3-in. dia. by 0.6 in. long powdered-iron slug. Inductance is 0.5 μH. Cover secondary with one layer of vinyl electrical tape, and wind three-turn primary with no. 24 hookup wire over tape.

port. C5, C6, C7 and T1 can then be tuned for maximum S-meter reading.

The equipment is now ready to be connected to an antenna or dummy load and tuned up. First, be sure that the transceiver drive has been reduced to a very low level so that the output is well below 1 watt. Switch the transceiver to cw, and press the key. The DBM current should not rise more than 20%. If it does, the drive should be reduced further. Typically, the required drive will be + 27 dBm. Switch the microammeter to the rf-output position, and again close the key. Tune C5, C6 and C7 for maximum meter readings, repeating the process a few times, since there is some interaction among these adjustments.

Your BT is now ready to go on the air. Normally, the DBM current will kick up 10% or so on voice peaks, but if it goes much higher, that indicates the DBM is overdriven. This will result in flat topping.

The 220-MHz BT

The 220-MHz model has an intermediate frequency of 28 MHz. Many transceivers cover 28 to 30 MHz fully, a range that permits coverage of 220 to 222 MHz if the LO is at 192 MHz. Again, any crystal controlled source that develops 0.25 watt or more at this frequency, such as a reworked Sonobuoy transmitter, could take over as the LO.

The oscillator-multiplier chain, shown in Fig. 4, uses commonplace and inexpensive transistors. Q5 is an overtone crystal oscillator at 32 MHz, and Q6 doubles to 64 MHz. If a 64-MHz crystal is available, one transistor could be eliminated. Q7 is a tripler to 192 MHz. Its output is amplified by Q8, which develops about 0.25 watt of drive for the DBM. An L-Pi network matches the collector impedance of Q8 to 50 ohms, and the rf energy is delivered to the DBM through a short length of miniature 50-ohm coaxial cable.

Details of the DBM layout are shown in Fig. 5. Because of their switching speed, 1N3063 diodes were chosen. Like the 6-meter version, the DBM proved susceptible to parasitics. Rather than sacrifice output by reducing the value of R3, a parasitic suppressor was used on the out-

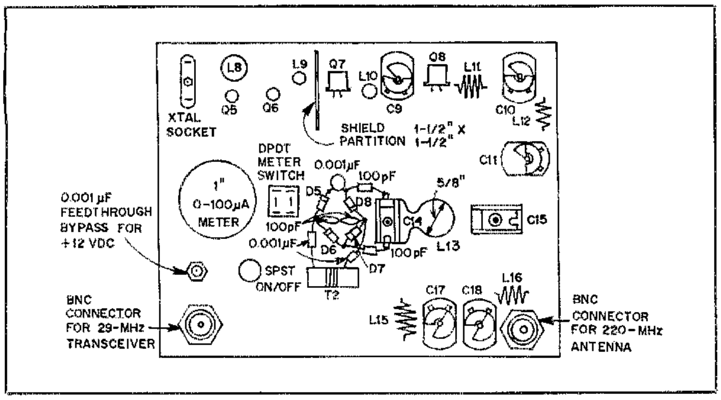


Fig. 5 — Suggested parts placement for the 220-MHz BT. Short lengths of miniature coaxial cable are used for connecting C11 to the DBM and for connecting the link of L13 to the tap on L15. L13 is spaced 1/2 inch above the board. The one-turn link is directly below it and tightly coupled. All rf leads must be short, especially the emitter leads.

Table 1

Measured Collector Currents

Q1 — 4.3 mA	Q5 — 6.7 mA
Q2 — 39 mA	Q6 — 4.2 mA
Q3 — 60 mA	Q7 — 27 mA
Q4 — 60 mA	Q8 — 61 mA

put link. This network consists of R4, C16 and L14. The combination of C16 and L14 forms a low L-C ratio tuned circuit, which must be resonated to precisely 221 MHz. This tuned circuit prevents the desired output from being lost in R4.

The two-pole filter (L15-C17 and L16-C18) ensures that only 220-MHz rf reaches the antenna. In Fig. 4 there is apparently no coupling between these two tank circuits. Each coil is oriented to minimize inductive coupling, but since the two capacitors are mounted adjacent to each other, there is sufficient stray capacitance between the two stators to provide "top coupling." As in the 6-meter transverter, some antenna impedance matching can be accommodated by careful adjustment of C17 and C18.

Tuning

Tune-up procedure is similar to the 50-MHz BT method. There are sampling resistors in series with the collectors of Q5, Q7 and Q8, which permit measurement of collector current if a voltmeter is connected temporarily across the appropriate resistor. Emitter current of Q6 can be checked in the same manner. It will be zero unless Q5 is oscillating. L9 should be adjusted to maximize this current. C8 should be adjusted for maximum collector current of Q7, and C9 for maximum Q8 collector current.

Collector currents should be approximately as shown in Table 1, with everything properly adjusted. C10, C11 and C15 should be adjusted for maximum DBM current as indicated by the microammeter. It should exceed 65 µA.

Rough adjustments of C14, C17 and C18 can be made by feeding a strong 221-MHz signal into the antenna port and tuning for maximum S-meter reading on a 29-MHz receiver.

Switch the transceiver to the cw mode, and begin the tune-up with the drive control turned all the way down, gradually advancing it to a point where the DBM current increases about 10%. Then switch the meter to indicate rf-output voltage. Next, alternately adjust C14, C17 and C18 for maximum meter reading. Repeat the adjustments a few times, since there is some interaction. Approximately +23 dBm of drive power is required. This completes the tune-up.

Results

With the help of the November 1980 6-meter band opening, the author has worked all eight northeastern states and three Canadian provinces. The antenna was nothing more than an attic dipole, 13 feet above ground. Amateur operators at several stations were incredulous that such a good signal could come from four diodes. On 220 MHz, the F2 layer does not provide transcontinental DX; but with a small Yagi, several Los Angeles stations, 75 miles away, have been worked with good reports. QST

[Editor's Note: Both bilateral transverters described in this article meet FCC requirements for spectral purity. Laboratory tests show the most significant spurious emissions for the 50-MHz transverter were 50 dB below the power of the fundamental. For the 220-MHz transverter, the most significant spurious emission was 43 dB down. Spectral analysis of the two-tone tests on these units disclosed that the third-order products for the 50-MHz and 220-MHz transverters were both 30 dB below PEP.]

Strays

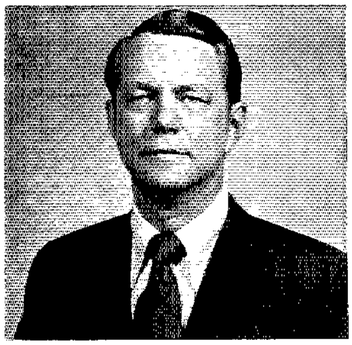
TA PROFILES

☐ We are indeed grateful to have ARRL Technical Advisor Paul L. Rinaldo, W4RI, on our TA team. He is our specialist for computer communications, spread spectrum and technical aids to the handicapped.

Licensed in 1949 as W9IZA Paul received his Extra Class license in 1954, and he also holds a First Class Radiotelephone license, a Second Class Radiotelegraph license and a Ship Radar Endorsement. W4RI has been an active computer enthusiast since 1975.

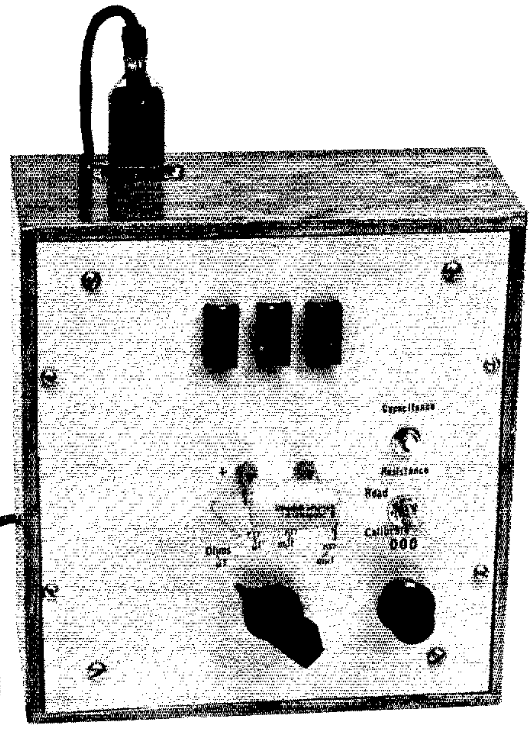
Paul is a Life Member of the ARRL, an author of technical articles published in *QST* and editor of *QEX: The Experimenter's Exchange* (see August 1981 *QST*, p. 48). He has organized five ARRL Technical Symposia and has managed two personal computing shows. A Life Member of AMSAT, a member of AFCEA and IEEE, W4RI is active in vehicular technology and computer societies. He is president and director of the Amateur Radio Research and Development Corporation (AMRAD). Under AMRAD, he is program manager for a two-year grant from the U.S. Department of Education for research in applying personal computers to telecommunications for the deaf.

Residing in McLean, Virginia, Paul is president and founder of Communications Resources, Inc., and has provided consultant services in communications, communications security, electronic countermeasures and business computers. He previously served in various positions with the Federal government as a technical advisor working with foreign countries, as a technical manager and as a communications officer. His experience includes planning, systems development, operations, training, installation and technical writing. — *Marian Anderson, WB1FSB*



TA Paul Rinaldo, W4RI

A Digital Resistance-Capacitance Meter



This item is certain to find use in your shack. Enjoy it twice — when you build it and when you use it!

By W. Conley Smith,* K6DYX

Instead of building just a capacitance meter, why not a combination resistance *and* capacitance meter using the principle on which most capacitance-only meters are based? That is, use the time constant of an RC circuit to gate a reference frequency to a counter and devise things so that the counter will indicate either the value of an unknown resistance or the value of an unknown capacitor. After some experimentation with the versatile 555 timer IC in various modes, a circuit that performs admirably was developed. It reads resistance values to one megohm and capacitance values to 10 μF, with 3-digit resolution. Furthermore, it has a built-in calibrator to ensure confidence in the readings.

Circuitry

The 3-digit display circuit is conventional in design. To minimize jitter, however, only the three most significant figures of a 4-decade counter are used. The "heart" of the circuit of Fig. 1 is U1, a 555 timer in the monostable mode. If pin 5 (the modulation input) of this timer is simply bypassed to ground without the calibrating circuit, the width of the gate pulse from pin 3 is given by $T_g = 1.1$ RC. This is the time required for the capacitor to recharge to 2/3 V_{CC} after a trigger pulse is applied to pin 2. The calibrating circuit will vary this time, effectively increasing or decreasing the gate width.

A 100-kHz reference frequency makes the arithmetic simple. To get, say, 9990 counts through the gate at this frequency requires a gate width of nearly 0.1 second. According to the formula for T_g given previously, and using a 999-ohm resistor, this would require a capacitor of approximately 100 μF, which is too large. A 10-μF capacitor can be used, if the gate is opened 10 times before the latches are opened, to show the total number of 100-kHz pulses that get through. This is accomplished by the triggering oscillator U4, a 555 timer in the astable mode. Driven by this oscillator, U2 triggers U1 and causes the gate of U5D to open 10 times, as counted by U3. After the 10th trigger, U6 opens the latches of the display to register the total number of

*67 Cuesta Vista Dr., Monterey, CA 93940

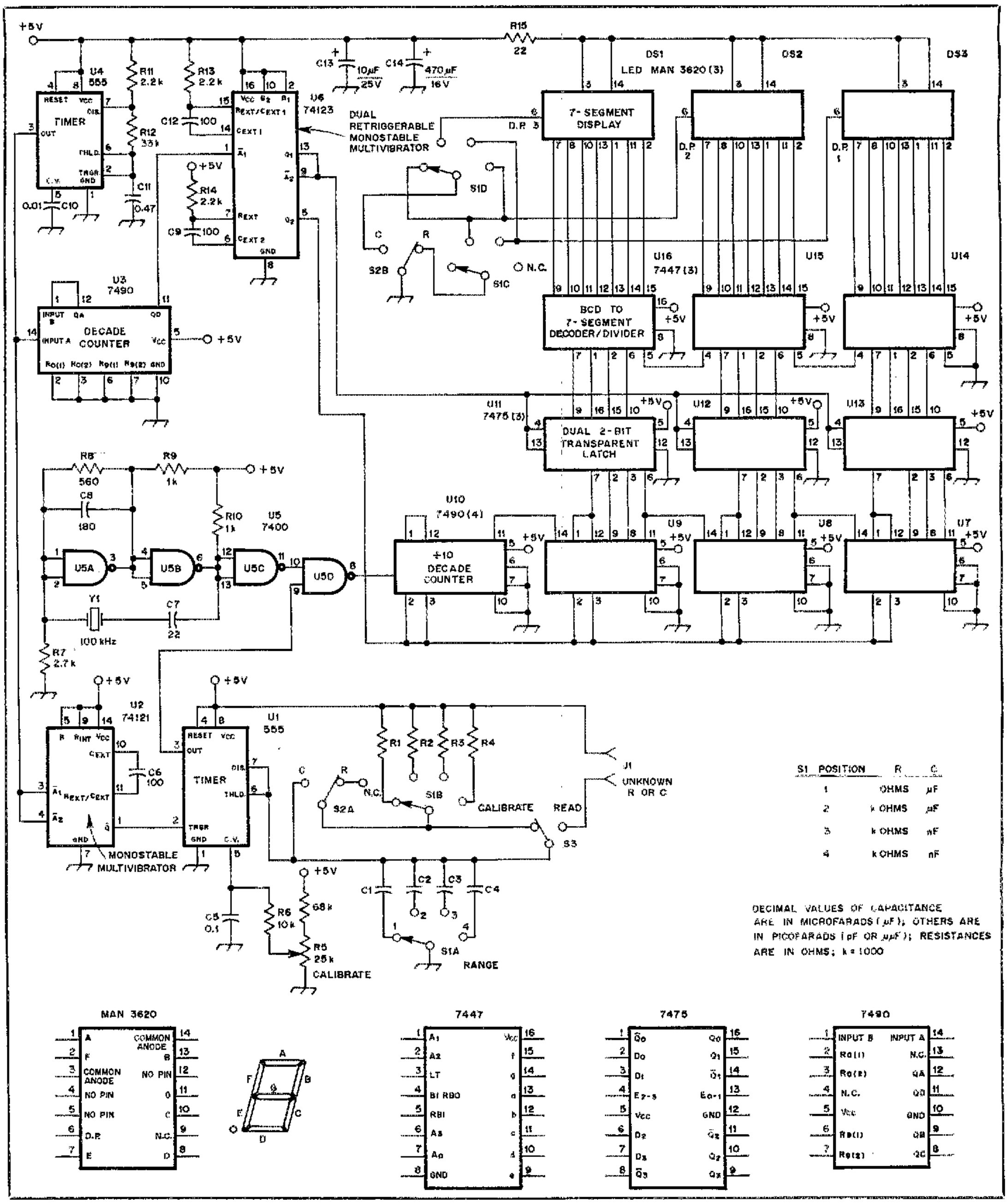


Fig. 1 — Digital resistance-capacitance meter schematic diagram. All resistors are 1/4-watt carbon composition types; capacitors are disc-ceramic 50-volt units unless otherwise specified.

C1 — 10 µF, 1% tolerance (see text).
C2 — 1 µF, 1% tolerance (see text).
C3 — 0.1 µF, 1% tolerance (see text).
C4 — 0.01 µF, 1% tolerance (see text).
DS1-DS3, incl. — Common anode, left-hand decimal point LED display, MAN 3620 or equiv.
J1 — See text.
R1 — 1 kΩ, 1% tolerance.
R2 — 10 kΩ, 1% tolerance.
R3 — 100 kΩ, 1% tolerance.
R4 — 1 MΩ, 1% tolerance.
R5 — 25-kΩ linear-taper potentiometer.
S1 — 4-section, 4-position rotary nonshorting switch.
S2 — Dpdt toggle switch.
S3 — Spdt toggle switch.
U1, U4 — Linear timer 555.
U2 — TTL monostable multivibrator, 74121.
U3, U7-U10, incl. — TTL decade counter 7490.
U5 — TTL quad 2-input NAND gate 7400.
U6 — TTL dual retriggerable monostable multivibrator, 74123.
U11-U13, incl. — TTL dual 2-bit transparent latch 7475.
U14-U16, incl. — TTL BCD to 7-segment decoder/driver 7447.
Y1 — 100-kHz crystal, HC-13/U holder.

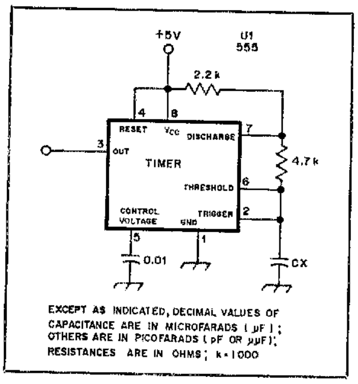


Fig. 2 — Schematic diagram of the test circuit used to select the proper values of capacitance (CX) required for the various meter ranges. Resistors are 1/4-watt carbon types.

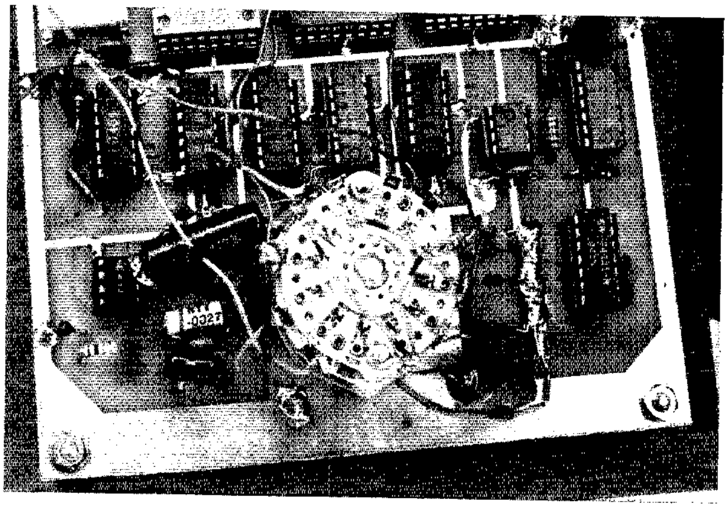


Fig. 3 — Component side of the double-sided board near S1. The board shown is a prototype and differs slightly from the final version.

pulses accumulated. Then the 4-decade counter, U7-U10, is reset. The display is therefore the average of 10 samples of the time constant or, effectively, 10 measures of the unknown.

Accuracy

The ultimate accuracy depends on the precision of the calibrating components.[1] Resistors with 1% tolerance are readily available at modest prices, but precision capacitors are another matter! I solved this problem by making a test circuit, using a 555 timer in the astable mode, as shown in Fig. 2. Other things being constant, the oscillation frequency of this circuit is inversely proportional to the capacitance used. Using a 1% tolerance capacitor of 0.0124 μF, I measured the frequency to be 10,554 Hz. By proportion then, I should get a frequency of 13,087 Hz with a 0.01 μF capacitor (0.0124 × 10,554/0.01). Similarly, frequencies of 1308.7 Hz, 130.87 Hz and 13.087 Hz are expected with capacitors of 0.1 μF, 1.0 μF and 10 μF, respectively. I then assembled single or parallel combinations of capacitors that would yield frequencies within 1% of those determined. In the case of the 10 μF unit, I found it more accurate to match the period of oscillation (76.41 ms). How accurately these capacitors are chosen may be determined easily: With S3 in the CALIBRATE position, it should not be necessary to readjust the calibrating potentiometer when S1 is switched to the different ranges.

You might be tempted to add a fifth measurement position, using a 100-MΩ resistor and a 0.001 μF capacitor in the calibrating circuit. Theoretically, this would allow measurement of capacitors in the range of 100 pF to 999 pF, with 3-digit resolution. The distributed capacitance, however, unavoidably built in with all the switching, is such that the accuracy of the readings is questionable. Therefore, this range has been omitted.

The capacitance measurement ranges of the author's unit shown in the photographs are: 0.01 to 1.99 nF (1 × 10^{-9} farad), 0.1 to 19.9 nF, 0.001 to 0.999 μF and 0.01 to 9.99 μF. These ranges increase in a counterclockwise direction, as may be determined from the panel markings. Resistance measurement ranges are: 1 to 999 ohms, 0.01 to 9.99 kΩ, 0.1 to 99.9 kΩ and 1 to 999 kΩ. These ranges increase in a clockwise direction. Direct measurement of resistance values of less than approximately 300 ohms is not possible. This will be discussed later. No over-range indicator is incorporated in this design; such a feature would require an additional circuit.

Construction

All circuit components except the CALIBRATION control R5, S2, S3 and J1 are mounted on a double-sided pc board.[2] The three 7-segment LED displays are mounted in wire-wrap sockets, which are soldered to the opposite side of the board. The wire-wrap sockets for the readouts stand off from the board at a height that will bring the displays through, or at least flush with, the panel. Holes can be drilled in the pc board for passing connecting wires to the +5-volt bus and panel-mounted components. A close-up view of the area surrounding S1 is shown in Fig. 3.

The board is bolted to the panel by means of 3/4-in. (19-mm) spacers. This allows plenty of clearance for the panel-mounted parts. Ensure the shaft of S1 is long enough to extend through the panel. Since one of the terminals of J1 is at a potential of +5 volts, nonconductive panel material, such as Formica, is recommended. The unit shown in the photographs was built in a cabinet made from scraps of mahogany. Surplus binding posts (unidentifiable) were used for J1, but 5-way binding posts or Fahnstock clips may be substituted.

Adjustment and Use

The device is powered by an external source. Current drain is approximately 400 mA at 5 volts. The 7447 decoders and readouts "hog" most of the current.

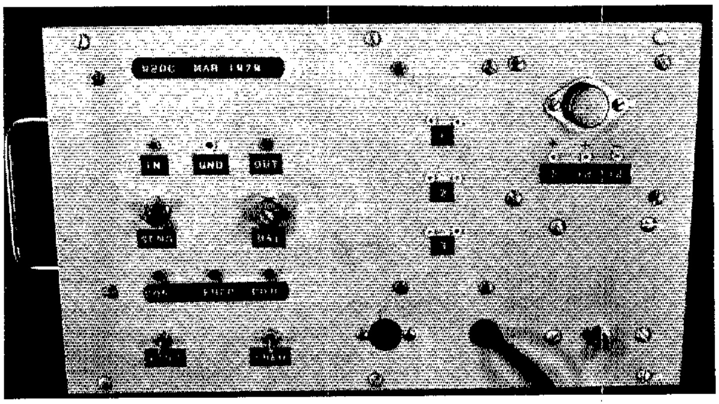
With S3 in the CALIBRATE position, adjust the CALIBRATE potentiometer (R5) until the display shows 000. The count through the gate is then within 0.1% of 10,000, with only the middle three digits being displayed. When S3 is switched to the READ position, the count will change, and the display will indicate the value of the unknown resistor or capacitor connected at J1, depending on the position of S2. For resistances of less than about 300 ohms, U1 will not sink enough current to completely discharge C1, and the reading will be in error. To measure low-value resistors, one should first measure one of several hundred ohms and then make another measurement with the low-value resistance in series. Once you're familiar with the operation of the unit and the range settings, I'm sure you'll find this unit as useful in your shack as it is in mine.

Notes

[1] Measurements performed in the ARRL lab using the author's meter showed a worst-case capacitance measurement accuracy of ±5%. A Data Precision 938 digital capacitance meter was used for comparison measurements. Resistance measurements agreed within ±3% when compared with results obtained using a Fluke 8020A DMM.

[2] Pc-board templates and a parts overlay may be obtained from the ARRL at a cost of $1 and a business-sized s.a.s.e. Boards are not available from the author.

Digital Frequency Filter for Repeater Inputs



Is adjacent-channel splatter keying your repeater? Try this easy-to-build filter that keeps the "garbage" from flying in through your window.

By Bill Fisher,* W2OC

Off-frequency signals can key repeaters, and few users or operators find this desirable. This circuit (Fig. 1) shows a filter that will discriminate between splatter from adjacent channels and an on-frequency carrier. (Originally I intended to call it a "discriminator," but I decided that it would lead to confusion, since that term is used almost exclusively to mean a demodulator where fm receivers are concerned.)

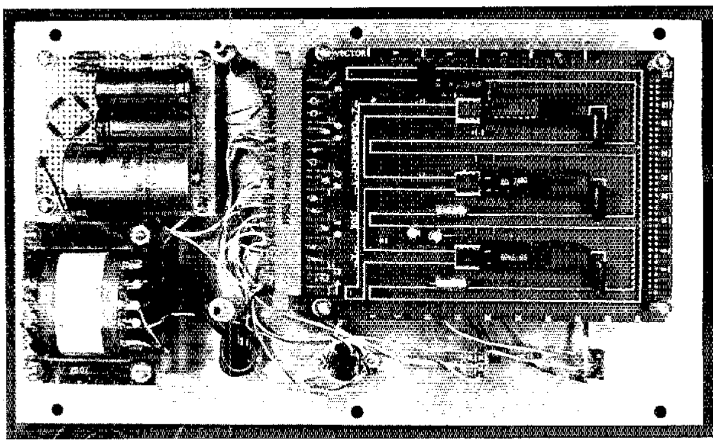
Selectivity is adjustable from a few hundred hertz to several kilohertz. Obtaining an equivalent amount of selectivity with crystal filters would be very difficult and probably more expensive. I designed and installed this circuit at WR2AGI to permit the use of a nonstandard repeater input frequency for a 2-meter satellite receiver.

Heart of the Circuit

The demodulator of the receiver must produce an output voltage that swings positive and negative as the instantaneous frequency varies. The Foster-Seeley discriminator is an example of this kind of demodulator. A coincidence detector is an example of a demodulator that would not work with this circuit.

The input of U6 (test point A) is connected to the output of the receiver discriminator (Fig. 1). The discriminator voltage is then amplified by U6 and fed to the inputs of U4A and U4B, pins 1 and 13 respectively. When the output of U6 is positive and reaches the threshold of U4A (approximately + 1.2 volts), pin 3 will fall abruptly from a high (+ 4 volts) to a low (approximately 0 volts).

Similarly, when the output of U6 is negative and reaches the threshold of U4B (adjusted by balance potentiometer R2 to approximately − 1.2 volts), the state of pin 11 will rise abruptly from a low to a



Inner workings of the Digital Frequency Filter. Straight-forward design permits clean layout. The unit shown has a built-in power supply.

*2 Barnard Rd., Armonk, NY 10504

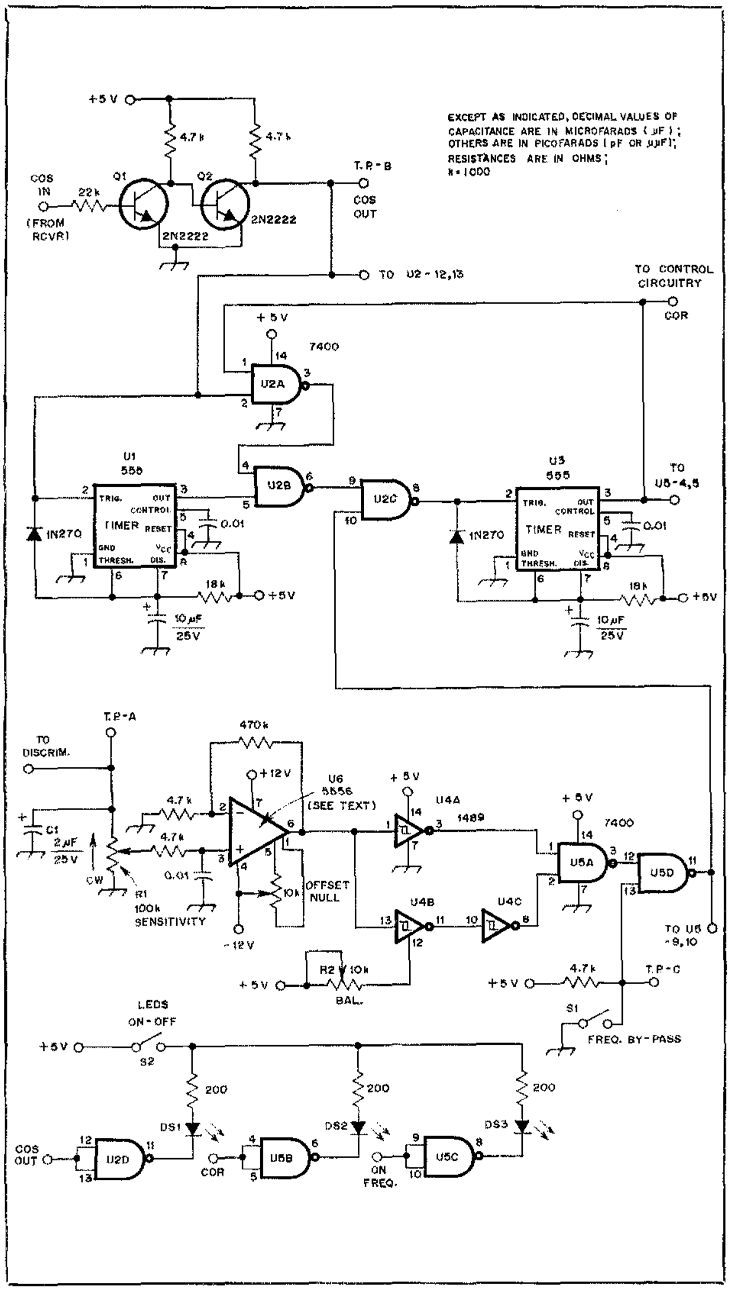


Fig. 1 — Schematic diagram of the digital filter. Fixed-value resistors are 1/4-watt carbon-composition type. Capacitors are disc ceramic, except those with polarity indicated, which are electrolytic. Note: Part numbers in parentheses are Radio Shack.

D1, D2 — Small-signal germanium diode, 60 PIV. 85 mA (276-1123).
DS1-DS3, incl. — LED (276-070, 276-071, 276-072 or equiv.).
Q1, Q2 — Npn silicon, general purpose, 2N2222 or equiv. (276-2009).
R1 — 100-kΩ, pc-mount potentiometer (271-338 or 271-220).
R2 — 10-kΩ, pc-mount potentiometer (271-335 or 271-218).
S1, S2 — Spst switch, type noncritical (275-401, etc.).
U1, U3 — 555 timer IC (276-1723).
U2, U5 — TTL quad 2-input NAND gate (276-1801).
U4 — Quadruple line receiver IC, MC1489, SN75189 or equiv.
U6 — Operational amplifier IC, SN5556, MC1486 or equiv. (See text.)

high. U4C is utilized to invert the output of U4B. U5A then functions effectively as an OR gate, producing a high output on pin 3 if either pin 1 or pin 2 is low. The output of U5A is gated (and inverted) through U5B, which provides an inhibit action, if desired, by grounding pin 13. The end result, assuming pin 13 of U5A is not grounded, is that the condition at pin 11 of U5B will be low whenever the discriminator output indicates an input frequency above or below the desired "frequency window" set by input sensitivity potentiometer R1.

Q1 and Q2 comprise a level translator needed to convert the Carrier Operated Signal (COS) of the GE receiver used at WR2AGI from a level of 0 to 2 V to a level of 0 to 5 V. This part of the circuit may not be needed, or may have to be modified, depending on the particular receiver used. In any case, the signal level at test point B should be 3 to 5 volts positive with carrier input, and approximately 0 volts without carrier input.

U1 is a 555 timer that provides a delay of approximately 200 ms following receipt of a carrier input before checking if the carrier is within the frequency window. This prevents key-ups of the repeater by any instantaneous spikes on the input or by stations off frequency but with occasional on-frequency splatter. U2A and U2B effectively bypass U1 once the carrier-operated relay (COR) signal is activated.

U3 is a similar 555 timer that prevents interruption of the COR signal during brief (less than 200 ms) dropouts of carrier such as might be experienced with a marginal mobile signal. The output of U3 (pin 3), labeled COR, is intended to be used to activate the repeater transmitter via existing control circuitry.

Spare gates of U2 and U5 are used to operate LEDs that show the status of the COS, COR and on-frequency signals. S2 permits turning off the LEDs when they are not needed for test purposes. A manual frequency bypass switch, S1, is provided for local test purposes. With this switch in the open position, test point C can be used, if desired, to control the frequency filter remotely via the repeater control circuitry.

Adjustment Procedure

Turn the SENSITIVITY control, R1, fully counterclockwise (i.e., arm of potentiometer at ground), and adjust offset null control R3 for zero output voltage on pin 6 of U6. Next, connect test point A to the output of the receiver discriminator, and apply a signal to the receiver input. Vary the frequency of the input signal above and below the receiver center frequency while monitoring test point A. You will find that some receivers will show a positive discrimination reading above center frequency while others will show a negative one.

Once you have determined the positive-output direction, offset the frequency of the input signal in that direction by the amount you desire for half the width of the frequency window. For example, if moving below center frequency produces a positive output and you wish the window to be 6 kHz (i.e., ±3 kHz) wide, set the input frequency 3 kHz below center. With this signal on the receiver input, slowly adjust R1 clockwise while monitoring the voltage on pin 3 of U4A. Leave R1 set at the point at which pin 3 of U4A drops abruptly from a high (approximately 4 volts) to a low (approximately 0 volts).

Next set the input signal to 3 kHz on the opposite side of center frequency. Monitor the voltage on pin 11 of U4, and adjust the BALANCE control, R2, to the point at which the state of pin 11 rises abruptly from a low (approximately 0 volts) to a high (approximately 4 volts). This completes the adjustment procedure.

Sensitivity potentiometer R1 controls the width of the frequency window. *Increasing* the sensitivity by rotating R1 clockwise will *decrease* the width of the window. Conversely, decreasing the sensitivity by rotating R1 counterclockwise will increase the width of the window. Balance potentiometer R2 controls the symmetry of the window and can be adjusted with R1 to provide an unsymmetrical window, if desired. In some repeater situations an unsymmetrical frequency window can be advantageous.

C1, the 2 μF (paper) capacitor connected from test point A to ground, was added to correct an anomaly that showed up after initial installation of the unit. We discovered that although an off-frequency (outside the window) signal appearing on the input would not bring up the repeater, the repeater would be keyed up momentarily when that off-frequency signal was removed from the input. The off-frequency indication at pin 10 of U2 was returning to the normal on-frequency indication faster than the COS signal was being removed from pin 9 of U2. The addition of C1 to the input (test point A) slowed the response of the frequency-sensing circuit enough to correct this condition.

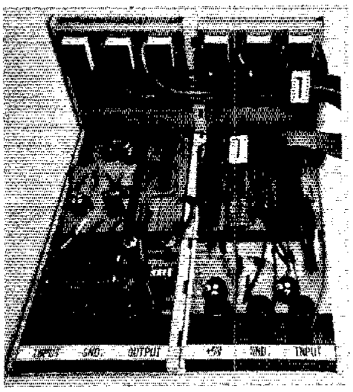
If the 5556 chip used for U6 is not readily available, a 741 or one-half of a 5558 without the offset null adjustment, will serve as a satisfactory substitute. Power requirements are +5 V, +12 V and −12 V (less than 100 mA each).

Our users and control operators are much happier with the performance of the repeater now that we are using this circuit. Virtually all "falsing" has been eliminated. Perhaps this circuit or one similar to it will keep the garbage from coming in your window. I will be glad to answer any questions from readers desiring to use this circuit if they will include an s.a.s.e. with their correspondence.

New Products

A P PRODUCTS INC. HOBBY-BLOX

□ "Hobby-Blox" tends to kindle childhood memories of building houses and forts out of little wooden (yes, I go back *that* far!) or plastic blocks. But that's not what we're talking about here. While Hobby-Blox are made of plastic (acetal copolymer) and are used for building, we're now building electronic circuits — breadboarding, actually.



The Hobby-Blox system is a solderless (just plug in the components and wires), expandable (modules can be added to expand existing projects), compatible (all sizes of DIPs and discrete components are accommodated) and affordable (compare prices) means of assembling breadboards. Modules are color-keyed to aid in identification of their designed function and are cross-indexed with letters and numbers to identify rows and columns rapidly.

If you'd like to sample the wares, two starter packs are offered. A project booklet (one for either discrete-component or IC-circuit construction) accompanies each pack. While components are not included, a listing of every part required to complete the projects described in the respective booklet is provided on the back of the bubble-package card.

Of course, you're not limited to purchasing the starter packs. Individual modules are available to suit your personal needs. The module line-up includes: bus, terminal, discrete component and distribution strips; and LED strip that accommodates six LEDs and includes a common bus for current-limiting resistor termination; horizontal and vertical trays; control, speaker and blank panels; extender clips, binding posts and a battery pack. There are more modules to come, according to the manufacturer.

Interconnections are made using 22-gauge solid hook-up wire. You can make your own leads or purchase a jumper wire kit (p/n 923351), which contains a large assortment of pre-cut and stripped wires of various colors.

Use of a system such as Hobby-Blox should kindle your project-building enthusiasm. Keep 'em hidden from the kids, though, 'cause those colorful modules might disappear! Hobby-Blox are manufactured by A P Products Inc., 9450 Pineneedle Dr., P.O. Box 603, Mentor, OH 44060. You can obtain the name of your nearest dealer by telephoning 800-321-9668. — *Paul K. Pagel, N1FB*

SO-1 UNIVERSAL ANTENNA STANDOFF

□ If you have ever tried to homebrew a standoff for your tower in an effort to side mount a vhf/uhf antenna, then you will be interested in this inexpensive solution. The SO-1 has been in use at W1SE for just about a year, and has supported an AEA Isopole 2-meter, twin 5/8-λ antenna through a variety of New England gales and storms. It is ideally suited for antennas up to and including Ringo Ranger types. The standoff is made of welded and galvanized steel angle, rod and tube, and may be clamped to virtually any pipe or tower. Installation takes only a few minutes with the two stainless-steel hose clamps provided. The SO-1 is manufactured by, and available from, IIX Equipment Ltd., P.O. Box 9, Oak Lawn, IL 60454. Price class: $30, UPS included. — *Lee Aurick, W1SE*

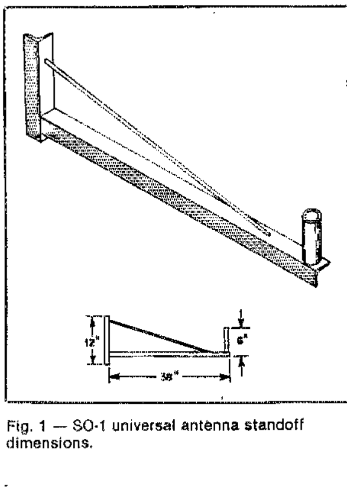


Fig. 1 — SO-1 universal antenna standoff dimensions.

Braille Tactile Transducer — New Freedom for the Sightless

Digital techniques and an ingenious electromechanical device combine to offer greater freedom, flexibility and self-sufficiency to blind radio amateurs.

By Professor G. W. Horn,* I4MK

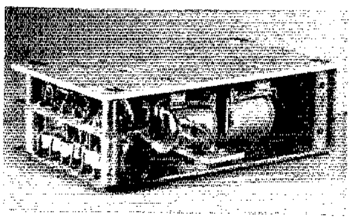
If you were blind, how would you determine the operating frequency of your transmitter? How would you read a voltmeter? Acquiring data in a usable fashion is an obstacle that has plagued the visually impaired operator since the earliest days of wireless. What are some possible solutions?

Variable tone and amplitude oscillators are often used to indicate the status of circuits in an analog manner, but these systems convey information in a relative form only. Digital data can drive voice-synthesizer circuits, but such designs are often cumbersome to use. Various other systems have been developed, each having advantages and drawbacks. Because many blind people read Braille, a readout device that converts electrical pulses to a mechanical Braille format would seem ideal. Until recently, little attention has been paid to designing and building such a device.

*40017 S. Giovanni in Persiceto, Via Pio IX n. 17, Bologna, Italy

Braille is Digital

Braille characters are formed on a six-dot matrix. The presence or absence of a dot at each of the six positions determines the "value" of the character. If we assign a sequence to the six dots, we can process Braille data with standard digital techniques. Translating Braille to and from other digital codes (e.g., ASCII) becomes trivial.

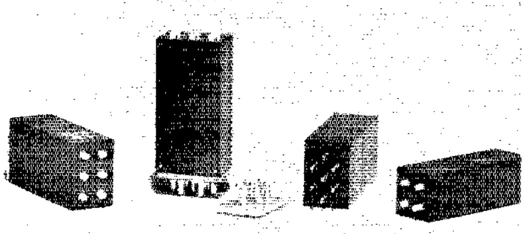


The author's early attempt using relays and cantilevers to produce a Braille transducer. The major drawback is the space required by the relays and cantilevers, which makes it impractical to mount several units side by side.

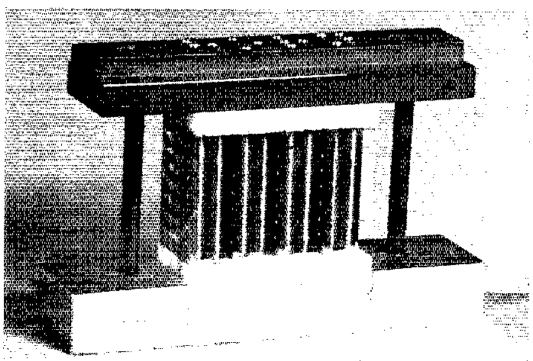
Fig. 1 shows a simple circuit for converting binary-coded-decimal (BCD) data to Braille. The source of the data could be a multimeter or other device. BCD data is not always conveniently accessible; Fig. 2 depicts a circuit that converts 7-segment display data into Braille. Similarly, Baudot or ASCII pulses passed through a series-to-parallel converter could easily be converted to Braille.

The problem, however, lies not in the manipulation of the data, but rather in the readout. Almost all digital-readout devices rely on the user's eyesight. LEDs, LCDs and other digital *displays* are of little use to the blind amateur.

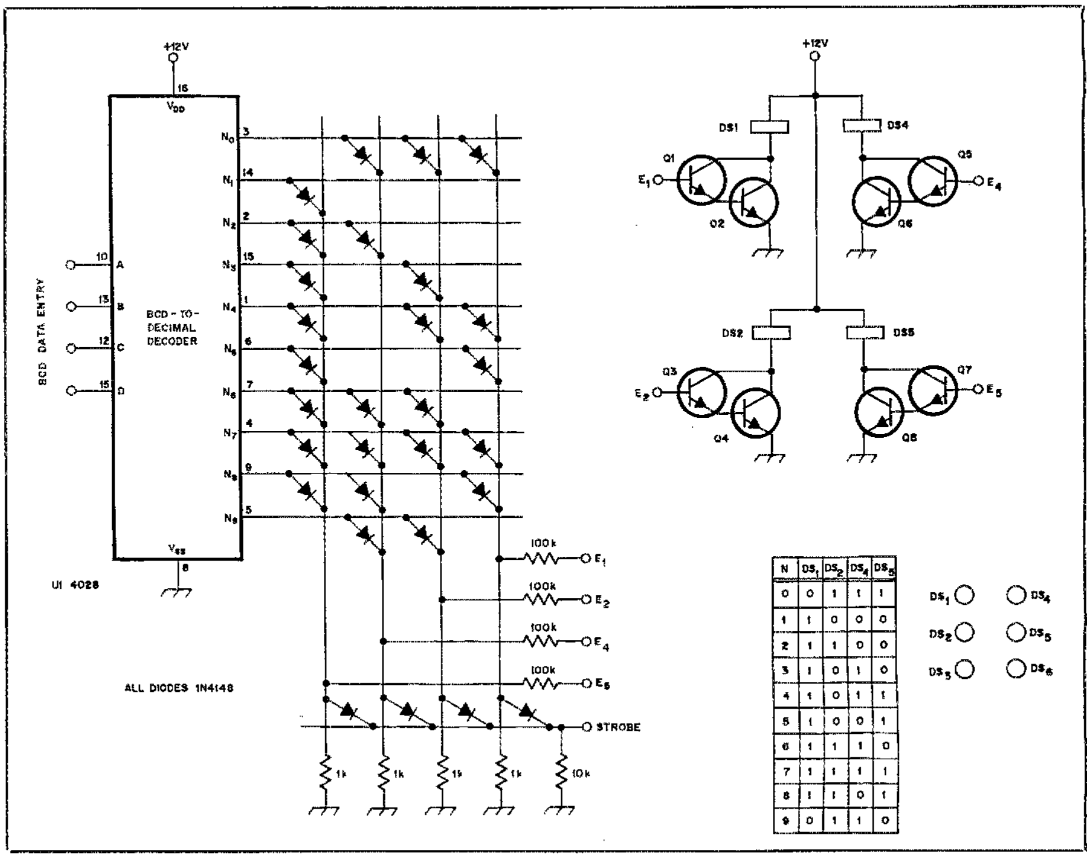
A tactile transducer for Braille consists



Commercially available electromechanical transducers used by the Italian telephone company. The four-dot model on the right is useful for displaying figures only.



Row of four 6-dot, latching-type transducers designed and built by the author. The word displayed on the Braille readout is "HORN" (⠓⠕⠗⠝).



N	DS_1	DS_2	DS_4	DS_5
0	0	1	1	1
1	1	0	0	0
2	1	1	0	0
3	1	0	1	0
4	1	0	1	1
5	1	0	0	1
6	1	1	1	0
7	1	1	1	1
8	1	1	0	1
9	0	1	1	0

Fig. 1 — BCD-to-Braille code converter circuit driving a 4-dot (figures only) nonlatching Braille transducer. The standard Braille matrix and the pattern for figures 0 through 9 are shown also. This is a representative circuit and is not intended as the basis for a construction project.

of six pins arranged according to the standard Braille pattern. The pins are raised from the "no dot" (0) level to the "dot" (1) level corresponding to the logic voltages of the circuit. This is very easy to describe, but it is not so easy to construct.

My first approach was to drive the pins with cantilevers attached to miniature relays. I found it impossible to package the relays in any manner that would permit side-by-side mounting of several characters. (See the accompanying photograph.)

In the meantime the telephone company (Italian) introduced Braille transducers[1] in 4- and 6-dot formats for use by blind operators. Six suction solenoids drive and maintain the pins in their raised position when excited. By putting some of these units side by side, you may assemble a Braille row.

These units suffer from two drawbacks: The dimensions of the matrix are slightly larger than standard Braille, and the pins tend to recede under fingertip pressure. Both of these factors make reading the output difficult.

A Different Approach

Keeping in mind the shortcomings of the other units, we developed a different kind of transducer. The pin is energized by a single coil, and mechanically latches into two stable positions. A positive pulse (10 ms, 80 mA at 10 V) causes the pin to raise to logical 1. A similar negative pulse resets it to the logical 0 (no-dot) position. Because of the mechanical latching mechanism, the pins will not change state without a signal, regardless of fingertip pressure.[2]

The solenoids draw power only during the excitation periods (write/erase). This feature makes muliplexing operation very attractive because it drastically reduces both power dissipation and hardware. Finally, the 6 pins are arranged into a matrix of the exact standard Braille dimensions.

Fig. 3 depicts a circuit used to control this kind of transducer. A row of eight transducers is multiplexed. The two opposite polarities are supplied by an operational amplifier followed by a pair of complementary-symmetry transistors. Since the solenoids are excited by positive as well as negative currents, the design calls for a bidirectional switch that is capable of withstanding the peak current demanded by the unit. If all six pins should be raised or reset at the same time, the current would be 480 mA (6 × 80 mA).

Future Trends

We can construct a row of many Braille characters to allow us to read RTTY or the output of a computer terminal. Serial-to-parallel conversions, in addition to code conversions, would probably be involved in any such endeavor. Multiplexing is an advantageous approach for these

[1]Notes appear on page 47.

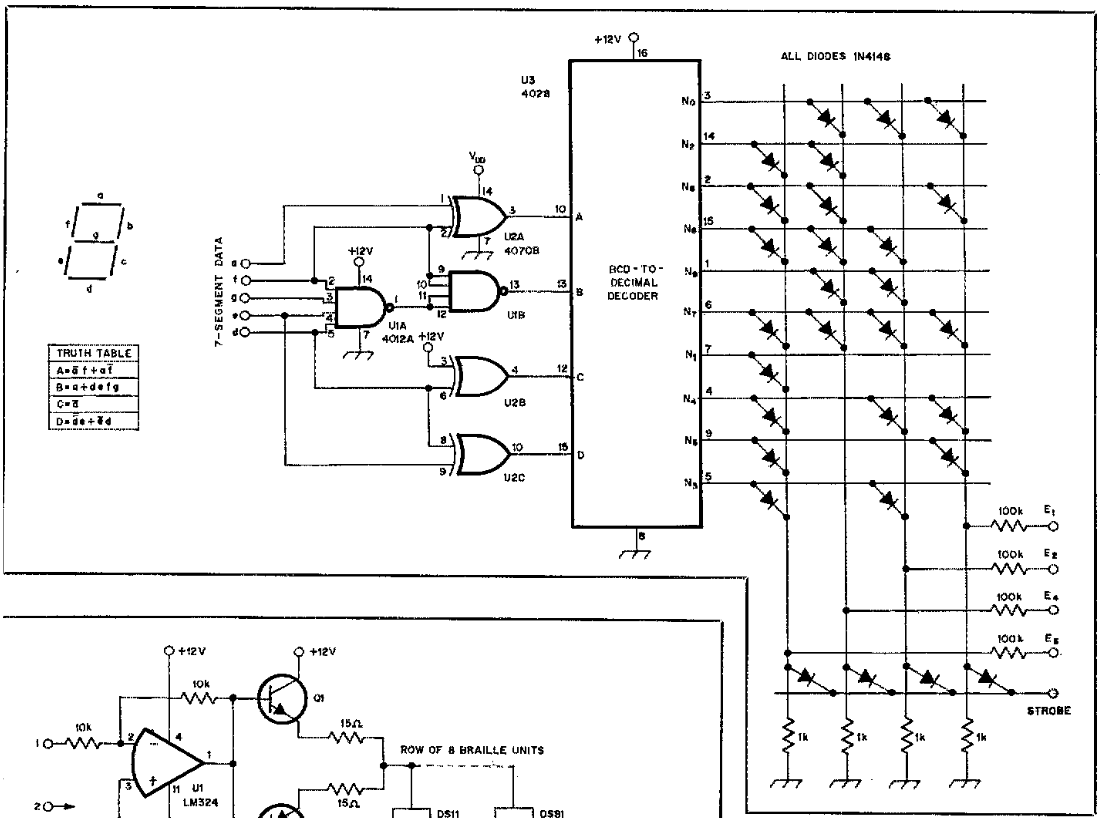


Fig. 2 — Circuit for converting 7-segment display data to Braille code. This representative circuit demonstrates the relative ease with which other forms of digital data can be translated into Braille code.

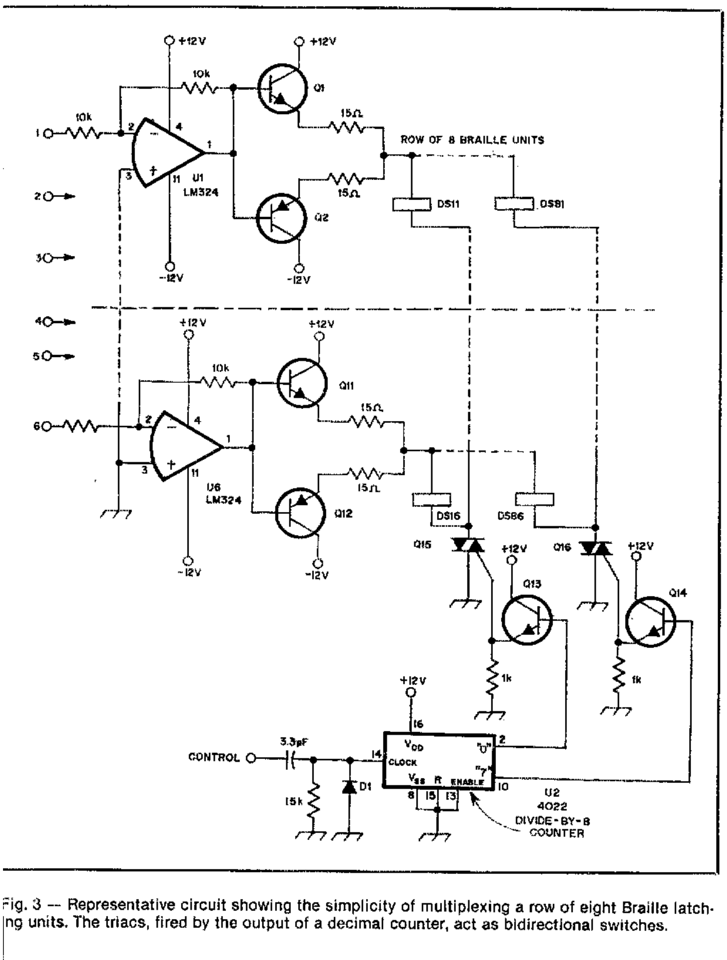


Fig. 3 — Representative circuit showing the simplicity of multiplexing a row of eight Braille latching units. The triacs, fired by the output of a decimal counter, act as bidirectional switches.

projects! Because of the small size, the transducers fit nicely into a small, compact row!

Voice-synthesizer circuitry points toward the possibility of translating the output data of digital instruments into synthetic speech. Still, my preference (I'm blind) is for a "written" Braille text as opposed to spoken letters, words or figures. This is particularly true for electronic readouts. If you were blind, which would you prefer?

Notes

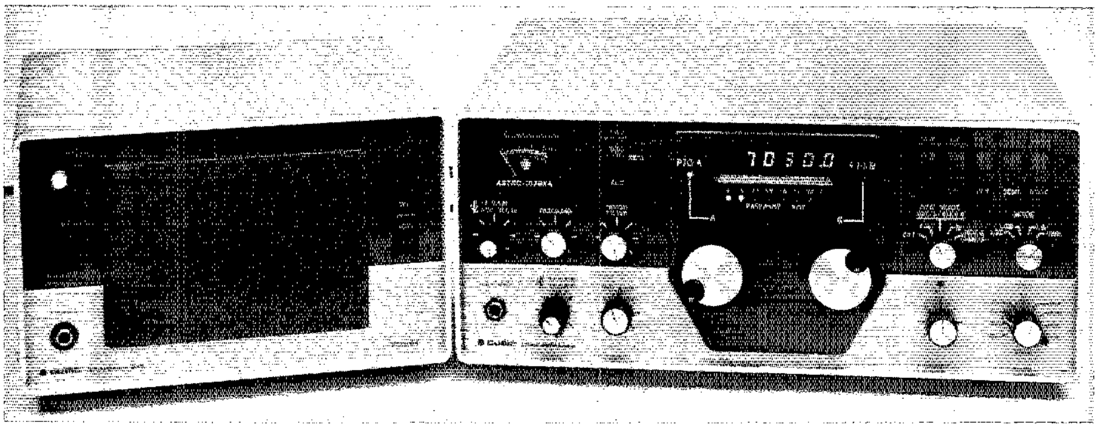
[1]For more information about these units, contact the supplier directly: Coelte Inc., P.O. Box 25, 24032 Calolziocorte, Bergamo, Italy.

[2]Professor Horn has established a licensing agreement with Coelte (see note 1) for the production and distribution in Italy of the latching transducer. He indicates that he would consider licensing the unit for production in the United States. (For more information, contact Professor Horn directly.) He has made available several additional circuit diagrams for use with the transducers. If you would like a copy of these diagrams, please send an s.a.s.e. to the Membership Services Department, ARRL, 225 Main St., Newington, CT 06111.

Product Review

Conducted By Paul K. Pagel,* N1FB

Cubic Astro 102BXA Transceiver



American made? Yes, indeed! The Astro 102BXA (formerly Swan/Astro) is built by a tenured engineering firm, Cubic Corporation, of Oceanside, California. The manufacturer once stated that "75 of our engineers were involved in the design of the Astro." Those who subscribe to the "buy American" doctrine should be pleased with this product.

If your buying urge is stimulated by the presence of dazzling geegaws, this rig may not be for you. But if truly functional and important operating features inspire you, the 102BXA might be what you've been waiting for. It has what the operator needs, and nothing more.

Coverage is from 160 through 10 meters in six bands. This transceiver is completely transistorized (inclusive of ICs and diodes). Twin PTOs are included to provide split-band operation when desired. Other features are variable agc time constant, passband tuning, and separate controls for rf and i-f gain. It also has RIT, selectable break-in delay or full QSK, noise blanker and speech processor. The panel meter indicates forward and reflected power in watts, alc level and the relative strength of incoming signals.

A large red digital display provides readout of the operating frequency to six places, such as 21,025.3 kHz. An eight-level LED string shows the status of the passband tuning from 0.6 to 2.7 kHz. There is also a notch filter that is adjustable from the front panel of the transceiver.

The passband-tuning control sets the i-f bandwidth with either a high-pass or low-pass cutoff. Clockwise rotation of the control attenuates low-frequency audio, while counterclockwise rotation reduces the high-frequency response. The LEDs mentioned earlier indicate the effective audio passband of the receiver. I learned that the control needs to be set for approximately 1.0 kHz or higher when the sharp cw accessory filter (300 Hz) is being used. Otherwise, no cw beat note is heard.

The microphone impedance is specified as 47,000 ohms. A key jack is located on the rear panel of the transceiver, but the PTT line (accessible at the mike jack) can also be used as a keying-control line.

Other connection points on the rear apron of the equipment are EXT RELAY, EXT MODULATION, EXT LO, ANTENNA, GND and EXT SPEAKER. There is a built-in speaker, plus provision for an external one. The EXT MODULATION jack provides an interface for AFSK, and the MIC GAIN control on the front panel is used in that mode to control the level.

The speech-processor action is determined automatically by the setting of the MIC GAIN. There is no separate external adjustment for the processor. Similarly, the noise blanker is factory-adjusted. It has no external threshold control. Carrier-level control during cw operation is provided by the MIC GAIN control.

I am mystified by the presence of a SOFT/HARD keying switch on the transceiver front panel. The keying waveform in the "hard" position is what we at ARRL consider objectionable in terms of clicks (see Fig. 3). The "soft" position yields an excellent waveform, closely approaching the desired 5-ms rise and fall times that result in click-free keying. That panel switch might have been put to better use as a CARRIER LOCK control, which has not been included in the design. This makes tune-up difficult unless the keyer has a "carrier hold" switch.

Other features that aren't present in the Astro 102BXA are a crystal calibrator or WWV band-switch position. Fortunately, the 40-meter coverage is from 7.0 to 7.5 MHz, which permits reception of Canada's CHU time/standard station in some areas of the country.

The internal switching feature for an external amplifier is compatible with the manufacturer's Astro 1200Z and 1500Z amplifiers. Unfortunately, the internal solid-state switching circuit is limited to a maximum of + 200 V and 200 mA. Therefore, most amplifiers of different manufacture can't be switched by the Astro 102BXA — at least not directly. I had to interface the transceiver with my Heath SB-221 by means of an external relay that was actuated by the solid-state switch in the Astro. A 12-V dc relay can be used (low-current coil), and power for it can be borrowed from the + 12-V bus in the transceiver. If an external relay is used, it will negate the use of full QSK since many control relays will not follow the cw speeds that are used by most operators.

I was impressed with the skirt selectivity of the i-f system. The variable passband tuning of the receiver complements the i-f filters to reduce wideband noise and enhance the effective selectivity. In fact, acceptable cw selectivity can be had when using the ssb i-f filter by ad-

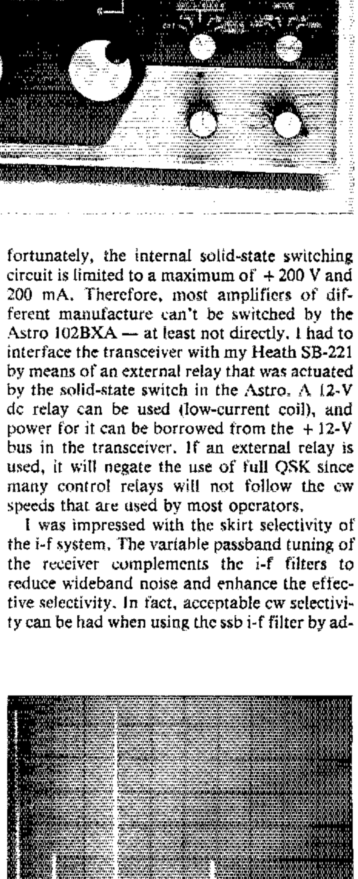


Fig. 1 — Worst-case spectral display of the Cubic Astro 102BXA. Vertical divisions are each 10 dB; horizontal divisions are each 10 MHz. Output power is approximately 100 watts at a frequency of 28 MHz. Spurious emissions are at least 49 dB down from peak fundamental output. The Astro 102BXA complies with current FCC specifications for spectral purity.

*Assistant Technical Editor

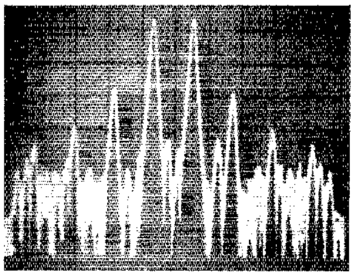


Fig. 2 — Spectral display of the Astro 102BXA output during transmitter two-tone IMD test. Third-order products are 28 dB below PEP, and fifth-order products are 39 dB down. Vertical divisions are each 10 dB; horizontal divisions are each 1 kHz. The transceiver was being operated at rated input power on 14 MHz.

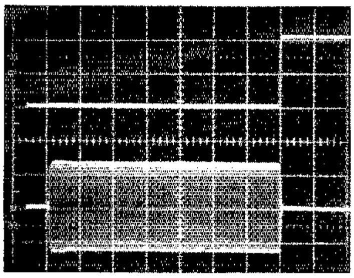


Fig. 3 — Cw keying waveform of the Astro 102 with the selection switch in the "hard" keying position. The upper trace is the actual key closure; lower trace is the rf output envelope. Each horizontal division is 5 ms. This waveform will generate key clicks.

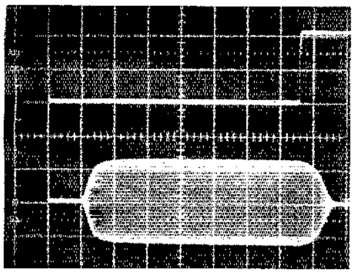


Fig. 4 — Cw keying waveform of the Astro 102 with the selection switch in the "soft" keying position. The upper trace is the actual key closure; lower trace is the rf output envelope. Each horizontal division is 5 ms. This waveform is essentially click-free.

Cubic Astro 102BXA HF Transceiver Serial No. 659

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: 160, 80, 40, 20, 15, 10 meters.	As specified, plus additional coverage above and below each band: 1378-2106 kHz; 3379-4106 kHz; 6879-7606 kHz; 13,878-14,606 kHz; 20,878-21,606 kHz; 27,878-30,106 kHz.
Operating modes: Cw and ssb.	As stated.
Readout: Digital (red LEDs).	
Resolution: 100 Hz.	25 kHz per 360° turn of tuning knob.
Backlash: Not specified.	Nil.
Power requirements: 12-14 volts dc, negative ground, 20-A peak.	As stated.
Transmitter rf power output: 100-W PEP into 50-ohm load at 13.5 V dc.	80/40 m = 125 W; 20/15 m = 108 W; 10 m = 100 W.
Transmitter third-order IMD: Not specified.	Approximately −28 dB (worst case) on 20 m (see photo).
Spurious suppression: 55 dB below peak power.	Approximately 49 dB (worst case), 10 m (see photo).
Harmonic suppression: 45 dB below peak power.	Approximately 50 dB (worst case), 10 m (see photo).
Frequency stability: Not specified.	80 Hz from cold start to one hour later.
Receiver audio output power: Greater than 3 W into a 4-ohm load.	Not measured.
RIT range: Not specified.	±1 kHz.
S-meter sensitivity (μV/S9): Not specified.	160 m = 85; 80 m = 65; 40 m = 55; 20 m = 50; 15 m = 50; 10 m = 75.
Receiver sensitivity: 10 dB S+N/N, 0.35 μV typ.	Receiver dynamics measured with optional 300-Hz crystal filter installed:
Size (HWD): 6-3/8 × 14-1/4 × 13-1/4 in.	
Weight: 23-1/2 lb.	
Color: Not specified.	

	80 m	*20 m*
Noise floor (MDS) dBm:	−125	−129
Blocking DR (dB):	*	*
Two-tone, third-order: IMD DR (dB):	90	84
Third-order input intercept (dBm):	−10	−3

'mm = in. × 25.4, kg = lb × 0.454.

*unmeasured — noise limited.

justing the variable passband control to the counterclockwise end of its range.

Cw offset is 800 Hz. In the sharp cw mode (300-Hz accessory filter installed), the cw filter is operated in series with one of the two 8-pole ssb filters. This greatly reduces wideband noise from the i-f amplifiers and provides an apparent improvement in overall receiver signal-to-noise ratio. During ssb operation the two 8-pole filters are in use. The ssb filters have a bandwidth of 2.4 kHz, and the shape factor is 1.4, referenced to the 6- and 100-dB points on the response curve.

Other Features

The transmitter is rated at 100 watts output for peak ssb and cw. Power output is limited to this level by the alc circuit. Available output power is 100% of this amount with VSWR values up to 1.7:1 at 50 ohms. It drops to 60% when the VSWR is 3:1. During an open or short condition the factor is 25% (equivalent voltage). A built-in VSWR sensor causes the foregoing shutdown power amounts to protect the PA transistors from damage.

Mobile operation is possible from the automotive dc-voltage system. The safe operating range is specified as 10 to 15 volts dc. Apart from the fairly large dimensions of the Astro 102, it is well suited to mobile use because it employs broadband tuning in the receiver and transmitter sections. Only minor adjustments are necessary when changing bands. The receiver is a single-conversion type with a 9-MHz i-f. Five weak birdies were noted in the receiver tuning range.

Those wishing to have full RTTY capability, plus inclusion of the WARC-sanctioned 10-, 18- and 24-MHz amateur bands, may want to consider purchasing the Astro 103BXA transceiver. The 102 and 103 models are otherwise identical. Price class: $1200. Manufactured by Cubic Communications, Inc., 305 Airport Rd., Oceanside, CA 92054. — *Doug DeMaw, W1FB*

KENWOOD TR-9000 MULTIMODE 144-MHz TRANSCEIVER

☐ If you read the survey article in March 1981 *QST*[1] carefully, you may have been surprised to learn how much activity was reported on "vhf/uhf, a-m/cw/ssb." Of the survey respondents active in Amateur Radio, 18% said they averaged at least an hour of such activity per week. For comparison with other vhf/uhf figures, the percentage for fm was 48%, for "other modes" 3% and for satellite communications (where cw and ssb are also used), 2%. Numbers like that make it easy to understand why new vhf transceivers with multimode capability keep popping up in the marketplace. (Less easy to understand is why Japanese manufacturers have totally dominated this particular market, but that's another story.) Not surprisingly, 2 meters has been the most popular band for the vhf multimode rigs, as it has been for fm rigs.

In the past, these multimode transceivers generally could be characterized in two ways: whether they were designed primarily for fm or for ssb, and whether they were designed primarily with fixed station or mobile operation in mind. If a rig is intended mainly for ssb, it will give the operator a "feel" very similar to a conventional high-frequency transceiver; if for fm, it will have the features you have come to look for in a sophisticated fm rig — ease of selection of the most frequently used channels,

[1]D. Sumner, "Survey of Amateur Radio, 1980," *QST*, March 1981, pp. 11-18.

Kenwood TR-9000 Transceiver Serial No. 0121075

Manufacturer's Claimed Specifications	*Measured in ARRL Lab.*
Frequency coverage: 144.0000 to 147.9999 MHz.	143.9000 to 148.9999 MHz.
Modes of operation: Fm, usb, lsb, cw.	As specified.
Frequency readout: Digital; 5-digit, red LED display, 100-Hz resolution.	0.3 inch' digits.
kHz/turn of knob: Not specified.	5 kHz or 500 kHz (cw/ssb); 5, 250 or 500 kHz (fm).
RIT range: ± 1 kHz.	± 2.5 kHz.
S-meter sensitivity: Fm—Full scale occurs at 15 μV; ssb — S9 = 5 μV.	As specified. S9 = 2.5 μV. S9 = 6.5 μV.
Receiver sensitivity: Fm—0.5 μV for 30 dB signal-to-noise;	0.26 μV for 20-dB quieting
ssb — 0.25 μV for 12-dB SINAD.	As specified.
	Noise floor (MDS) dBm: −132
	Blocking DR (dB): 122
	IMD DR (dB): 76
	Third-order input intercept (dBm): −18
Transmitter power output: 10 W.	Fm: 14 W. Ssb: 10 W PEP.

Size: (HWD) 3 × 6-7/8 × 9-3/4 in.
Weight: 5.5 lb.
Manufacturer: Trio-Kenwood Communications, Inc., 1111 West Walnut St., Compton, CA 90220.
Price class: $500.

adjustable output power level, scanning and the like. If the manufacturer expects you to put the rig under the dashboard of your car and leave it there, it will be a lightweight, low-profile package sans ac power supply.

Kenwood was one of the earliest and most successful of the entrants into the vhf multimode fray. The TS-700A was introduced to North America in 1975[3] and was soon followed by the TS-700S[4] and TS-700SP. There was no question but that these rigs were intended primarily for home-station use and that they had been designed with ssb operation in mind.

It is much more difficult to classify Kenwood's current entry, the TR-9000, in the multimode sweepstakes. It appears that Kenwood designers hoped to make the rig be all things to all people. The basic rig is much smaller, and is quite a bit less expensive, than the TS-700 series, and it has features undreamed of just a few years ago. On the other hand, these improvements have not come without a penalty, especially for the operator whose main interest is something other than fm.

Description

The TR-9000 is all solid-state and is rated at 10 watts rf output on fm, cw and ssb (upper or lower sideband). It is designed to operate from a nominal 13.8-V source; an external ac power supply is an option. Other options available include a "system base" for added convenience in fixed-station operation and an external speaker (although the internal speaker, mounted in the bottom of the transceiver case, is entirely adequate unless the bottom of the case is blocked). There is no provision for VOX operation.

Frequency coverage is 143.9000 to 148.9999 MHz, in steps of 100 Hz, 5 kHz or 10 kHz. The step rate is selectable from the front panel (you'll figure out how to do it in the first few minutes you use the rig, but two switches, neither one adequately labeled, are involved, and explaining the maneuver is something else again!). The 100-Hz step rate translates to 5 kHz per revolution of the main tuning knob, which is much too slow for casual tuning around on ssb or cw, but the 10-kHz step rate (5 kHz is not available in the ssb and cw modes) will cause you to miss stations on these two modes.

The frequency control selects the receiver frequency, the transmitter being on the same frequency or 600 kHz higher or lower depending on the position of the TX OFFSET switch. Five memories are provided, one for operation with any split (e.g., something other than 600 kHz). A useful feature on many fm rigs is the ability to swap the receiver and transmitter frequencies at the flick of a switch to permit monitoring of a repeater input or to make it easy to use "inverted" repeaters; this is not a feature of the TR-9000. Rapid switching from fm to ssb, or between frequencies that are not programmed into memory, is facilitated on this Kenwood rig by a pushbutton that shifts the VFO between two independently selected settings.

The main tuning knob is not the only way to select the operating frequency. Two push buttons on top of the hand-held microphone are used to move the frequency up or down one step at a time, or more rapidly if a button is held down for a couple of seconds. A "beep" will be heard each time a button is depressed, which may be annoying under some circumstances. Unfortunately, in mobile operation the "beep" may be the only indication you have of your operating frequency, because the red LED frequency display is unreadable in bright sunlight.

An interesting feature of the TR-9000 is its scanning capability. The normal method of operation is to put the transceiver in the fm mode and to let it scan up in frequency to the first busy channel. It takes about 90 seconds to scan its entire range in 5-kHz steps. Narrower limits cannot be set; you must scan the entire range. The memories cannot be scanned. On ssb/cw there is no provision for stopping automatically on a busy frequency, and because it takes so long to scan in 100-Hz steps, you are more likely to use a special feature that permits the scanning of a 10-kHz segment than to scan the whole band. This feature lets you scan between, for example, 144.190 and 144.200 MHz, but not between 144.195 and 144.205 MHz; the limits must be integral multiples of 10 kHz.

Other features of interest include an rf gain control, noise blanker, receiver incremental tuning, combination signal strength and relative power output meter, and rear-panel jacks for a tone pad and back-up power supply (to retain memory when the main power is disconnected).

[3] "Kenwood TS-700A 2-Meter Transceiver," Product Review, *QST*, March 1976, p. 38.
[4] "Trio-Kenwood TS-700S 2-Meter Transceiver," Product Review, *QST*, Feb. 1978, p. 31.

All on-the-air reports received during the testing period were complimentary. On receive, the time constants in the agc circuit switch automatically from slow, for ssb, to fast, for cw; the recovery time on ssb is slower than many operators would prefer. While it's difficult to quantify, the "feel" of the controls and the ruggedness of the physical package give the impression that the rig should provide years of trouble-free operation.

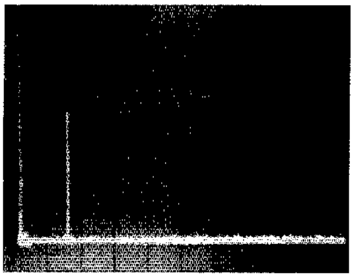


Fig. 5 — Spectral display of the Kenwood TR-9000. Vertical divisions are each 10 dB; horizontal divisions are each 100 MHz. Output power is approximately 10 watts at a frequency of 146 MHz. The fundamental has been reduced in amplitude approximately 32 dB by means of notch cavities; this prevents analyzer overload. The TR-9000 complies with current FCC specifications for spectral purity.

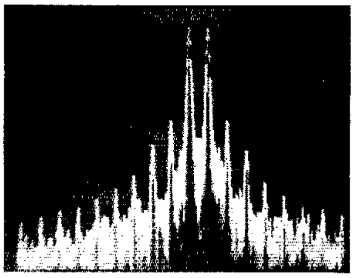


Fig. 6 — Spectral display of the TR-9000 output during transmitter two-tone IMD test. Third-order products are approximately 33 dB below PEP, and fifth-order products are 43 dB down. Vertical divisions are each 10 dB; horizontal divisions are each 2 kHz. The transceiver was being operated at 10 watts of PEP output on 146 MHz.

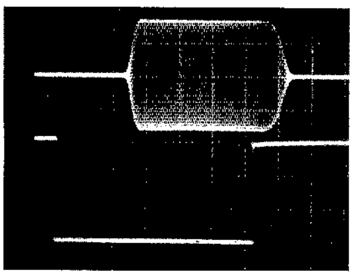


Fig. 7 — Cw keying waveform of the TR-9000. The lower trace is the actual key closure; upper trace is the rf output envelope. Each horizontal division is 5 ms.

Summary

If you're interested primarily in fm but would also like to have ssb and cw capability in a box no larger than most single-mode rigs, you will want to give serious consideration to the TR-9000. On the other hand, if you're interested mostly in OSCAR or in the low end of the band, you're likely to be disappointed at what has been left out of the box in the interests of compactness and economy. — *David Sumner, K1ZZ*

CUSHCRAFT 20-4CD SKYWALKER 20-METER MONOBAND YAGI ANTENNA

☐ Regardless of attempts to improve the triband Yagi, monobanders are still accepted as "the way to go" for top performance. Cushcraft's most recent offering in this category is the new Skywalker line of computer-designed 3- and 4-element Yagis. The 20-4CD tops the line, providing 4 elements wide-spaced on a 32-foot, 8-inch boom. As expected, the Skywalker is quite a large antenna; it weighs 55 pounds and has a wind surface area of 8.1 square feet. The longest element is 36 feet, 1 inch, and the turning radius is 23 feet, 8 inches. Because of its massiveness, it is recommended that the Skywalker be mounted only on towers of considerable loading capacity, and that a heavy-duty rotator and braking system be used as well.

Construction

The 20-4CD is shipped in two boxes. All small parts are neatly packaged in plastic bags, making a check of the contents quite painless. The materials used are all first quality — 6063-T832 aluminum for the elements and boom, with cadmium-plated hardware used throughout. Element clamps are stainless steel, excluding the worm gear, leaving some potential for corrosion after extended periods in harsh-weather areas.

Construction is quite simple using Cushcraft's method of assembly. All elements and boom sections are premeasured and marked at the factory. All one must do for assembly is slide matching pieces together up to the proper mark, then tighten the clamps. Just to make sure, the element lengths were checked with a tape measure and found to be exactly as specified.

The 20-4CD Skywalker is fed with 50-ohm coaxial cable through a gamma match, which Cushcraft refers to as its "Reddimatch." Adjustment is carried out with the aid of an SWR indicator or wattmeter. A single aluminum slider is moved to achieve the best possible match. The adjustment must be carried out with the antenna elevated above ground level. Even though this is a full-sized antenna, construction time was only four hours.

Testing

Following assembly, the antenna was installed atop a 60-foot self-supporting tower. During installation, the Yagi had to be moved from a horizontal position to a vertical one, and considerable flexing was noticed in the boom. Cushcraft has chosen to use small-diameter tubing for the boom to keep weight and wind loading to a minimum. While the vast majority of antennas this size have 3-inch O.D. booms, the Skywalker has 2-1/8 inch O.D. tubing for the boom. Although the antenna has held up to summer thunderstorms, heavy winter icing and high winds may leave a small mechanical safety factor. It should be noted that the boom *is* strengthened by the use of two struts that join it to the mast above. This is standard procedure on long booms; however, it is not a good substitute for larger diameter aluminum tubing. The additional strength offered by a 3-inch boom overrides the disadvantages of added weight and windloading in this antenna class.

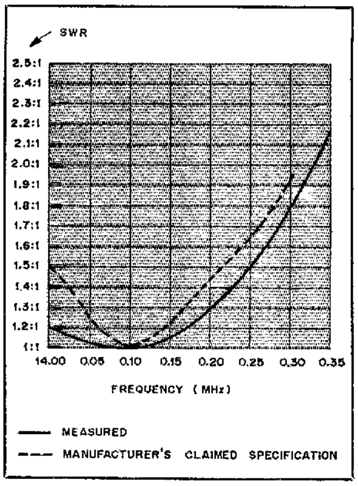


Fig. 8 — SWR curve of the Cushcraft 20-4CD.

An initial test was gratifying. Reflected energy was within manufacturer's specifications in the cw band for which the antenna was set. (The antenna may also be optimized for the low or high end of the phone band.) No additional tuning of the gamma match was necessary in this case. Although optimized for cw, the Skywalker provided a good match across the entire band.

Performance

It has been a couple of months since the Skywalker was put into use, and the performance has been exceptional. Practically any DX pileup can be cracked with very little effort — many with only one call. Repeated testing with other local amateurs using triband Yagis at the same height has shown the superiority of the Skywalker. Signals emanating from the monobander are consistently louder than those from the tribanders, and often by a considerable margin. At no time did the tribanders provide a superior signal report while working DX stations.

Overall the 20-4CD Skywalker provides exceptional gain, front-to-back and front-to-side ratios. It should provide all the "muscle" even the most critical operators require. The 20-4CD Skywalker Yagi is manufactured by the Cushcraft Corporation, P.O. Box 4680, Manchester, NH 03108. Price class: $320. — *Dennis Lusis, W1LJ*

'm = ft × 0.3048; m^2 = ft^2 × 0.093; mm = in. × 25.4; kg = lb × 0.454.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

SIMPLIFYING ANTENNA MATCHER BAND CHANGING

☐ The article by Collin Dickman, ZS6U, in April 1981 *QST*, prompted me to write of my experience using an L-matching network for multiband operation. Since the L network is effective in matching high-impedance loads, anything longer than a quarter-wavelength wire can be matched effectively, regardless of the configuration (end-fed wire, inverted V, inverted L and so on).

Amateurs may avoid using an end-fed wire because of the inconvenience of having to adjust an antenna matcher each time they change bands. My desire for a quickly band-switched antenna for contest work resulted in the L network shown here. Although I use a 90-ft (27.4-m) end-fed inverted L, this network works well with most end-fed antennas. See Fig. 1.

I make semipermanent taps on the coil by using small alligator clips, leaving the capacitor settings alone. I can work a 100-kHz or greater segment of each band, with the SWR below 1.3:1. The capacitor values are not particularly critical, and I have found that most broadcast-band variable capacitors (C1, C2) are adequate for power levels up to a few hundred watts. As a rule, you will need smaller values of capacitance as you increase frequency: This is a good way to use some of those variable capacitors that have been gathering dust in your junk box. It won't take long to find the right combination of inductance and capacitance to attain a proper match for each band. Once the values are set, they will need only an occasional tweaking to compensate for ice or condensation on the antenna. This suggests the possibility of mounting the network remotely and using a motor-driven switch to change bands. I keep the tuner on my windowsill, with the antenna wire routed out the window.

As Dickman describes, the maximum radiation of an end-fed wire that is electrically long in terms of wavelength, is off the end of the antenna. This is true to such a degree on the higher bands (15 and 10 meters) that I prefer using dipoles on these bands for better general coverage, although this L network could easily be expanded to work on any existing or WARC-proposed bands. If you are looking for an easy antenna for multiband use, an end-fed wire of almost any configuration, with the L network described here, may be suitable for you. — *Paul Schaffenberger, KB8N, Petoskey, Michigan*

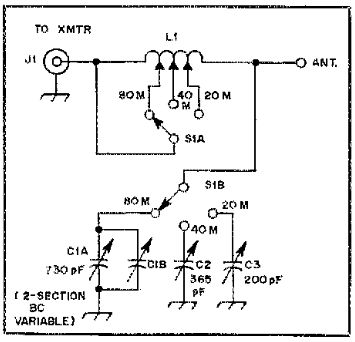


Fig. 1 — The simple band-switching method used by KB8N for his L network. S1 is a two-section, three-position (or more) wafer switch. L1 is a 5-inch length of B&W 3029 coil stock, 2-1/2 inches in diameter, 8 turns per inch, no. 16 wire. (mm = inches × 25.4)

A BROADBAND IMPEDANCE STEP-UP FOR ANTENNA MATCHERS

☐ Most Transmatches or tuners on the market today are the T-network type. These are designed primarily for matching a 50-ohm source to a low- or medium-impedance antenna. If you have difficulty getting your restricted-range "mobile" matcher to work with your all-band wire, try using this simple impedance step-up circuit. See Fig. 2.

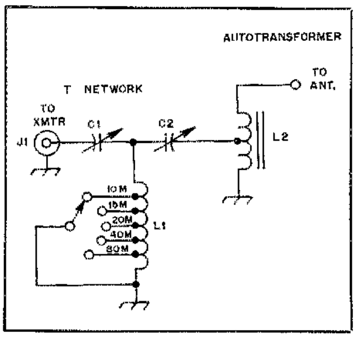


Fig. 2 — Typical "mobile" antenna tuner. Connect the transformer center tap to the tuner, one end to the ground system and the other end to your high-impedance antenna.

The circuit contains a simple broadband autotransformer that is wound on one or more Amidon T-200-2 forms, exactly as you would wind a 4:1 balun. I recommend the Amidon balun kit, which has winding information, a T-200-2 core and wire with high-voltage insulation. I suggest parallel spaced turns rather than twisted ones. Wrap the completed transformer with several layers of 3M glass electrical tape, and varnish the whole thing.

I mounted my transformer externally on the rear of my tuner, but it could be mounted in a box that can be removed quickly when the rig and tuner are pressed back into mobile service. — *James Coote, WB6AAM, Los Angeles, California*

INCREASED BANDSPREAD FOR THE ICOM 502

☐ Most 6-meter ssb operation occurs between 50.1 and 50.2 MHz. This simple modification will spread out the first 300 kHz of the band over the entire dial to allow smoother, easier tuning. Only one 47-pF silver-mica capacitor needs to be installed in the VFO.

To gain access to the VFO can, remove both side covers. Then remove the screws on top of the transceiver (front strap bracket). Remove the front rubber foot pad, and remove the screws under the pad. Next, remove the screw on each side of the front edge of the pc board, just below the VFO can. Finally, remove the two screws on the speaker frame as shown in Fig. 3. Now gently pull the front of the transceiver away from the case.

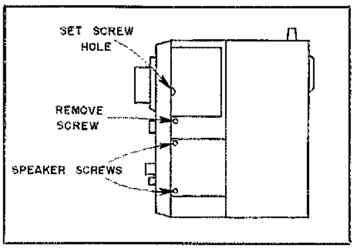


Fig. 3 — Diagram showing location of screws for access to the ICOM 502 VFO.

Six screws and one nut hold the cover of the VFO can to be removed. It may be necessary to free the tuning capacitor from the vernier control to remove the bottom screw. While facing the battery side, turn the dial until the recessed screw is visible in the oblong hole of the VFO mounting bracket. Loosen the screw, then turn the dial to 50.0 so the stop screw becomes visible, and loosen this screw. The VFO can now be pulled away from the front panel to allow access to the bottom screw.

Remove the cover from the VFO and look for C4 and C5, which are mounted in parallel on one side of the main-tuning capacitor. They are wired from the plates of one section to a stiff ground wire. Solder the 47-pF silver-mica capacitor in parallel with C4 and C5. Reassemble your IC-502.

To calibrate the dial, connect a frequency counter to J5 and J6 (ground side) on the main board. Set the dial to 50.0, and adjust the core of L1 in the VFO to obtain a reading of 36 MHz. Adjust trimmer C3 to obtain the highest possible reading, then readjust L1 to 36 MHz. Now rotate the dial, and make note of the 100-kHz points.

You may use the original dial markings for reference points of the new coverage, or for a more personalized job rotate the dial 180 degrees and use the blank side to make new calibration marks. To do this, remove all knobs and the recessed nut on the volume control. The front plastic will pull off and allow you to rotate the dial.

The nice thing about this is, should you ever want to sell or trade the rig, the "mod" can be undone with no one the wiser, but you. In the meantime, enjoy your increased bandspread. — *James Batka, WA9CUH, Nekoosa, Wisconsin*

*Assistant Technical Editor

UNIVERSAL QRP TRANSMITTER KEYING IMPROVEMENTS

☐ The Universal QRP Transmitter (ARRL's *Solid State Design for the Radio Amateur,* page 26) is an excellent performer, but the natural tendency is to add more stages to increase the power output. Unfortunately, the addition of Class C stages can cause severe key clicks because of the sharp keying characteristics of the transmitter and nonlinearity of the amplifier stages. Attempts to shape the oscillator keying with inductance and capacitance resulted in excessive chirp. The solution is to key the amplifier stage and process it separately from the oscillator keying. The oscillator must still be keyed to prevent a backwave and to allow break-in operation. Fig. 4 shows the circuit devised to perform this function.

The transmitter oscillator is turned on immediately upon closing the key, through U3B and Q1. U1 provides a short time delay (to allow for oscillator chirp) before turning on the amplifier with U3C and Q2. Note that Q2 does not turn on immediately; the amplifier keying is filtered by R and C. On releasing the key, U3C turns off, followed slowly by Q2 (again shaped by R and C). U2 provides a time delay to hold the oscillator on briefly while Q2 slowly turns off the amplifier.

The transmitter was followed by two push-pull transistor stages providing an output of 50 to 100 watts, depending on battery voltage (12 to 14 volts). On-the-air observations indicated good results. The oscilloscope envelope display appears fairly sharp with well-rounded corners. — *C. J. Klinert, WB6BIH, National City, California*

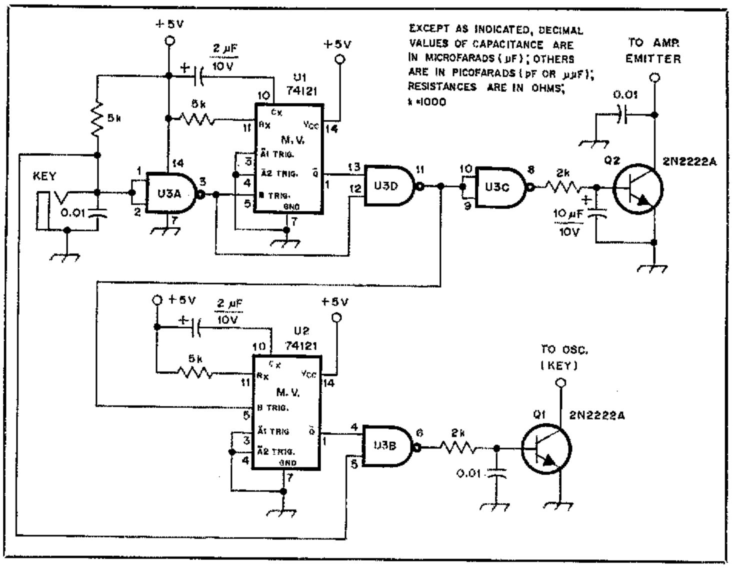


Fig. 4 — Differential keying circuit. U3 is a 7400 NAND gate. Lift the emitter of the amplifier, and connect it to the collector of Q2. The 0.01-µF bypass capacitor should be located near the amplifier emitter lead.

ACCIDENTAL TURN-ON OF THE CENTURY 21

☐ The Ten Tec Century 21 uses a push-on, pull-off type of ac power switch. A simple addition I made to my Century 21 front panel was a rubber grommet that fits snugly around the switch shaft to prevent an accidental push, which would turn the unit on. See Fig. 5. I found the correct grommet size to be 9/16-in. ID × 1-1/8-in. OD × 1/4-in. thick. I cut a piece approximately 3/16 in. wide from the grommet to allow it to stretch over and around the switch shaft and fit snugly between the front panel and the switch knob. The width of the grommet keeps the switch immovable. To keep the grommet handy I tied about 4 inches of 1/8-in. diameter Teflon tubing around it, opposite the cutout. I attached the other end of the Teflon to the screw on the front of the bottom panel, near the switch. — *Edward Bowley, W2VLH, Elmhurst, New York*

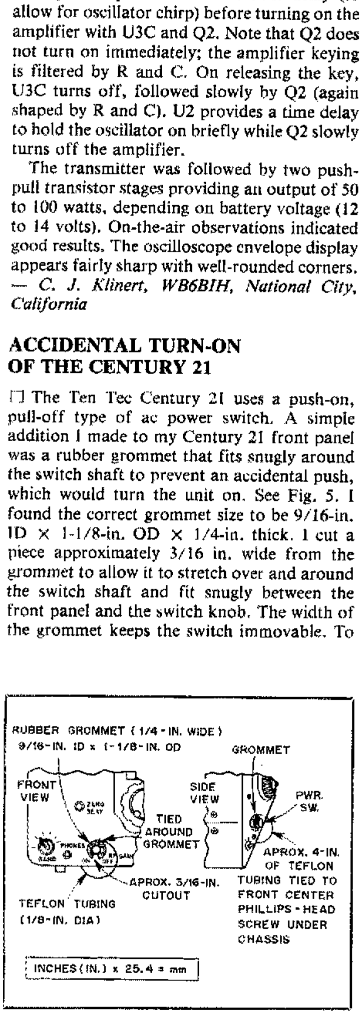


Fig. 5 — Sketch showing the addition of a rubber grommet between the front panel and the ac power switch on the Century 21 to prevent accidentally turning the rig on.

NO-MESS ETCHED-CIRCUIT BOARDS

☐ Homemade etched-circuit boards can add to the fun of an electronic project. Unfortunately the etching process is usually messy and not very exciting. The etchant should be poured into a nonmetallic container, which must be cleaned afterward (especially if you use a good plastic kitchen container!). Another problem is dredging the board up from the bottom of the container to check on progress (too long in the etchant means goodbye pattern). This may be accomplished by probing the dark depths of the etchant with a wooden stick or whatever is handy. (Don't use your best silverware!) Finally, the process can require a lot of time if a large amount of copper is to be removed, or if the etchant is near depletion. The etching process can be speeded up by heating the etchant, but that usually means time in a barely warm oven. These problems have a simple solution.

The key is a Ziploc[1] sandwich or storage bag. The etchant can be poured into the bag, and the board dropped (carefully) in. Seal the bag, and check for leaks. The bag can now be submerged in warm water to heat the etchant. Check the progress by pinching the board to the plastic. When the board is completed just pour the etchant back into its container, rinse the board, then seal and discard the bag. No mess! — *Tom Workman, KØTW, Tucson, Arizona*

[1]Ziploc is a registered trademark of the Dow Chemical Corp.

USE PERF-BOARD HOLES AS DRILL GUIDES FOR ETCHED-CIRCUIT BOARD IC SOCKETS

☐ Having trouble drawing and drilling holes for ICs on copper-clad pc boards? Here's a suggestion that may help. In most cases you can use carbon paper to trace the circuit onto the copper-clad board. Next, locate the parts of the circuit requiring IC sockets. Sandwich a micro-miniature (1/10-inch spaced holes)[2] perf board with the copper-clad board. Be sure the holes in the perf board line up with each individual IC drawing. Hold the sandwich together with small pieces of tape, and drill the required holes using the perf board as a guide. After all the IC socket holes are drilled, use resist ink to draw in the circuit, matching the circuit lines to the holes drilled for the ICs. Make sure the edges of the holes are well covered with the resist ink to protect them from the etchant. Continue with the normal process of etching, washing and drying. — *John Bentler, KE7I, Renton, Washington*

ECONOMICAL QST HOLDERS

☐ Recycle empty laundry-detergent boxes as files for your *QST* magazines. Use the family size, which should closely match the *QST* size. Cut the box at an angle and insert your magazines. This will allow the date to be seen for easy reference. Make the files more colorful by applying contact paper or wallpaper. — *Matt T. Shamonsky, W3OST, State College, Pennsylvania*

[2]mm = in. × 25.4.

Technical Correspondence

Conducted By
Doug DeMaw,* W1FB

The publishers of QST assume no responsibility for statements made herein by correspondents.

ON WINDING FERRITE CORES

□ The key to how effective a magnetic core is when it is contained in a coil field is the core permeability, P [expressed also as μ_i for initial permeability, and μ_e for effective permeability — Ed.]. Core manufacturers will state the permeability of their products. Manufacturing tolerances permit a variation of plus or minus 25 to 30 percent.

Many surplus magnetic cores find their way into the hands of experimenters, and the permeability is unknown. The following equations can be used as an aid to winding coils on cores of this type. Three factors are involved:

P = the *apparent permeability* of the core when it is fully engaged within the coil field. The *effective permeability* will vary in accordance with the core penetration into the field of the coil. In the case of pot cores and E-I cores, the air gap (space) allowed between the mating core sections will affect the permeability. This gap can be a valuable aid in obtaining a desired inductance.

LWO = The coil inductance with the core material absent.

LW = Coil inductance with the core in full penetration.

Therefore,

$$P = \frac{LW}{LWO} \text{ and } LWO = \frac{LW}{P}$$

The LWO equation is useful when you want to wind a specific inductance on a core of known permeability. The P equation will enable you to determine the permeability of unknown cores when you have provisions to measure inductance.

Coupled Coils

Some experimenters miscalculate the inductance values of coils that are used in series or in parallel, treating them like resistances in determining the net inductance. This approach is unsuitable when the coils are coupled closely, with the windings aiding (wound in the same sense). These equations are useful in situations of this kind:

$$\text{Series } Lt = L1 + L2 + 2M \text{ and}$$

$$Lt = \frac{1}{\frac{1}{L1 + M} + \frac{1}{L2 + M}}$$

where Lt is the total inductance, M is the mutual inductance, and L1 and L2 is expressed as the self-inductance of each coil.

It is hoped that this information will be useful to amateurs who like to experiment. — *Ken Cornell, W2IMB, 225 Baltimore Ave., Point Pleasant Beach, NJ 08742*

DBM LO INJECTION LEVEL VERSUS VSWR

□ *QST* and *Handbook* presentations about high-performance mixers have elicited some interesting questions among our readers. One of them I have answered frequently concerns the effect of the local-oscillator injection power on a diode-ring, doubly balanced mixer (DBM). That is, a number of amateurs indicated that they had VFOs or synthesizers that delivered marginal or insufficient output power for a DBM. They wondered if this would significantly impair the mixer performance. The answer is a resounding "yes."

We must recognize the specified operating parameters given by the manufacturers of diode-ring mixers: The impedance of the ports is given as 50 ohms over the bandwidth of the mixer, and the LO injection power is stated as +7 dBm for most low-level DBMs. This means that we must deliver 5 mW (0.005 W) of rf power into 50 ohms (0.5-V rms) to have a VFO or synthesizer with proper injection capability. Since commercially made mixers are presumed to have a specified LO injection power range that ensures a 50-ohm port characteristic, it is wise to adhere to the dBm levels specified. Mixer conversion loss is also a function of the LO injection power.

VSWR can be considered the degree of mismatch presented to the interfacing circuits. This is also a function of the LO power and operating temperature. The VSWR of a mixer can be determined by

$$VSWR = \frac{1 + |\rho|}{1 - |\rho|}$$

where

$$\rho = \frac{Z_L - Z_o}{Z_L + Z_o}$$

with ρ being the reflection coefficient, Z_L the mixer input impedance and Z_o the system characteristic impedance.

But, the VSWR doesn't represent the phase of ρ, so we don't know if Z_L is close to the specified 50-ohm characteristic mixer impedance. To confuse the issue even more, if a VSWR of 2:1 was measured in the 50-ohm line to the LO port of the mixer, we would not know if the port impedance was 25 or 100 ohms. Typically, a large number of complex impedances are present when we move the LO frequency over a broad range.

The VSWR measured at the rf, i-f and LO ports of the DBM are related directly to the LO power. Any change that occurs at the LO port is reflected to the two remaining ports. The LO port is the significant one in this discussion, since the signal levels at the rf and i-f ports are too low to have a major effect on the biasing of the mixer diodes (Schottky types). We can see from this that as the LO power changes, the resulting shift in diode impedance is seen as VSWR at the three mixer ports.

When we build homemade DBMs it is important to set the LO injection level so that the VSWR is optimum, consistent with the specified power rating stated by the diode manufacturer. Once this is done we can tailor the rf and i-f ports to match their respective load impedances in our composite circuit. The advantage is, of course, to ensure maximum signal-power transfer at each mixer port. Maximum power transfer occurs when an optimum impedance match exists — a fundamental law of electronics. — *Doug DeMaw, W1FB*

ANTENNA TOWERS — A WARNING!

□ Peter O'Dell's article in July 1981 *QST* on towers must not be construed by readers as an opening of the door to "home brewing" towers. I am writing this letter the day after the Kansas City Hyatt Hotel walkway collapsed!

The cardinal advice is to obtain a building permit prior to installing a tower. It can be obtained from your local city engineer, building-permit department. Seek his verbal advice and a list of requirements. This will vary by locale, owing to wind differences, icing conditions, seismic effects, load factors and so on.

The tower manufacturer should mail the necessary stress calculations, drawings and other data that the building inspector might request. If the required data is not available from the tower manufacturer, consult a registered civil engineer.

After some 30 years of designing commercial and amateur towers, I have seen some unfortunate "after the fact" situations. With today's society so inclined to sue, a ham without a building permit is similar to a person driving an automobile without registration tags! — *Jesse G. Ball, W6BFO (registered civil engr.), 7112 Deveron Ridge Rd., Cunoga Park, CA 91307*

MORE ON 50-OHM HELIX FEED

□ The June 1981 *QST* article, "Easy 50-Ohm Feed for a Helix," brought to mind how the North Dakota Highway Department engineers fed and matched helical antennas for their 460-MHz radio equipment. My friend, Dick Moritz, came up with a "tin-snip" method. The resultant capacitive transformers proved to be rugged, reliable and unaffected by ice, rain and dust over a 15-year period.

A coaxial N connector, hollow "bee hive" cone or similar standoff insulator, piece of no. 14 wire and an aluminum plate (about 205 mm square) are required. The details are given in Fig. 1.

First, drill and tap all of the holes necessary to mount the connector and standoff retainer ring on the ground plane. This feed assembly is mounted at the beginning of the helix, as shown in Fig. 4 of the original *QST* article. Then determine the proper length and shape for the copper wire, to permit the bolt to be soldered to one end and the connector to the remaining end. Assemble the connector on the ground plane, slip the standoff over the bolt (on the helix side), install the retainer ring, then attach the aluminum plate and helix end on the top of the standoff. Tighten carefully!

Now, use a wattmeter and 50-ohm dummy load that are suitable for the operating frequency, and tune up the transmitter into the dummy load. Note the power output and PA current. Next, remove the dummy load and connect the helical antenna. Point the antenna

*Senior Technical Editor

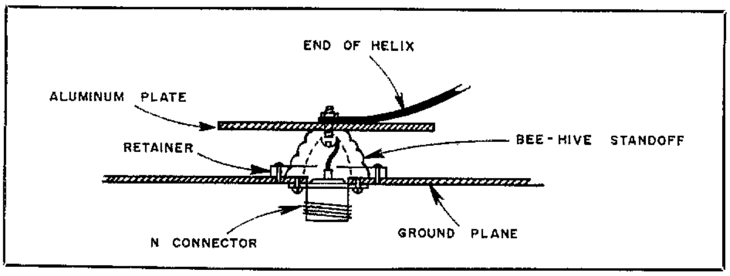


Fig. 1 — Construction details of the feed assembly for helical antennas. The VSWR is adjusted by using the "tin-snip" tuning method.

straight up and away from conductive objects. Use a pair of tin snips to trim away some small pieces of the aluminum plate, rounding off the corners first. Trim the plate for minimum indicated reflected power, with the forward power reading equal to that delivered earlier to the dummy load. The PA should be drawing the same current as when the dummy load was used. When these conditions are met, the feed line has been matched to the antenna. — *Dennis R. Murphy, K0GRM, 1109 Memorial Hwy., No. 4, Bismarck, ND 58501*

MR. H. H. BEVERAGE ON BEVERAGE ANTENNAS

☐ I read with great interest the article on page 51 of September 1981 *QST*, entitled "Beverage Antenna for Amateur Communications," by John S. Belrose. He apparently expressed the effective height of the antenna in terms of decibels below the length of the antenna. I have calculated the effective height of the antenna and expressed it as the height of an equivalent vertical antenna. I used the equation for wave tilt, which is

$$T = 0.235 \times 10^{-10} \frac{f}{\sigma} \qquad \text{(Eq. 1)}$$

where f is the frequency in Hz and σ is the ground conductivity in emu.

Eq. 1 does not include any effect related to the dielectric constant of the earth, which may explain some of the difference of my calculations compared with the results reported by Mr. Belrose, assuming that he took the earth dielectric constant into account. At very low frequencies the effect of the dielectric constant is negligible compared with the conductance of the earth. At high frequencies, the dielectric constant of the earth will reduce the wave tilt, T, resulting in a lower effective height.

I have calculated the example of an antenna 100 meters long at 2,000,000 Hz versus ground conductivity (see table).

My calculations appear to be in fair agreement with the results reported by Mr. Belrose for an antenna height of 1 meter above ground. As Mr. Belrose pointed out, the effective height is slightly greater for an antenna a few feet above ground. I expect that this results from the increased velocity of the current along the antenna keeping closer in phase with the wave in space, which is traveling at the velocity of light.

I have not attempted to check Mr. Belrose's calculations for antennas of different lengths in terms of the wavelength of the signals being received. In general, the velocity of the current along the antenna will vary between 80 and 90 percent of the velocity of light, depending on several variables. Because of the lower velocity, optimum results are obtained with an antenna one wavelength long. With antennas more than two wavelengths long, there may be sufficient phase lag, such that the signal strength will actually decrease with an increase in the antenna length. — *Harold H. Beverage, ex-W2BML, P.O. Box BX, Stony Brook, NY 11790*

From QST			Calculated by Eq. 1		H_{eff}	
Condition	*dBi*	*Ratio*	*emu*	*T × L (m)*	*m*	*Feet*
Poor Gnd.	−9.3	0.343	1.0×10^{-14}	0.331 × 100	33.1	108
Average Gnd.	−12.0	0.251	1.9×10^{-14}	0.248 × 100	24.8	81
Good Gnd.	−15.0	0.178	4.0×10^{-14}	0.166 × 100	16.6	54

THE HELIOGRAPH REVISITED

☐ I found the Technical Correspondence item on unguided light beams (August 1981 *QST*) very interesting. During World War II when I lived on Long Island, Western Union had some experimental towers out there, and we were told that they were being used for experimental infrared beam communications. As the Technical Correspondence item suggested, the idea of light beams has surfaced periodically over the years, and I fully expect it will be utilized in practical ways eventually. I suspect it has been sidetracked in the push for radio development. Some years ago I became interested in the signaling heliograph. The heliograph is of historic interest now, but is fascinating, nevertheless.

I heard that the Army electronics lab at Fort Huachuca, Arizona, got out some old helio instruments, just to see if anything could be learned from a new look at an old idea. I have two helio instruments. One is homemade, and the other is Canadian surplus. A friend has done some helio work with me, using 2-meter gear for backup. Actually, light flashes — whether helio or from another source — are easy for any competent cw operator to read. But it requires a different kind of concentration than we are used to. In 1894 a world record of 183 miles in communication was established by means of heliograph between Colorado and Utah. Distances of 25 to 50 miles were common during Apache campaigns in Arizona. Thanks for the good work in *QST*. — *Lewis B. Coe, W9CNY, 115 E. 113th Ave., Crown Point, IN 46307*

PHOTOPHONE — ALEXANDER GRAHAM BELL'S OTHER VISION

☐ I refer to W1FB's motivating article titled, "Communication via Unguided Light Beams," in August 1981 *QST* and would like to offer the following for consideration within the frame of his topic.

According to a report in a segment of the book *Light Beam Communications* by F. Mims III (Howard W. Sams no. 21147, $4.95), Alexander Graham Bell invented also a so-called "Photophone." The article claims that Bell was more enthused about this Photophone than his better-known telephone that used wires. In addition to mention of that invention, its principles are explained and those applied much later by various other countries for, primarily, military purposes, because this system precludes detection of signals.

I assume that *QST* readers will be interested in this information, per se, and for experiments in the spirit of the W1FB Technical Correspondence item in August 1981 *QST*. — *Rudolf Steiner, WD6CDG, 3624 Inglewood Blvd., Los Angeles, CA 90066*

Feedback

☐ In the article "Crystal Filter Design with Small Computers" by Dr. Ulrich L. Rohde, DJ2LR, in May 1981 *QST*, Table 2 is for narrow-bandwidth filters. The reference to 41-MHz in the heading for Table 4 should be eliminated. Fig. 4 is for crystals that can be manufactured.

☐ Laurence B. Stein, W1BIY, points out an error in Fig. 6 of "Meet the Friendly Oscilloscope!" (page 42 of September 1981 *QST*). The 100-kΩ resistor shown in series between the 1-MΩ resistor and the coaxial cable should be shown wired in shunt. Remove the right end of the 100-kΩ resistor from the coaxial cable and connect it to chassis ground. Attach the coaxial cable center conductor to the common connection of the three components. The probe ratio is 11:1; for a 10:1 ratio, the shunt resistor should have a value of 110 kΩ.

☐ In the Beginner's Bench article, "CW Filtering for the Beginner," October 1981 *QST*, the coupling capacitors for the passive audio filter in Fig. 4, page 40, should be 1.0-μF units rather than the 0.1-μF types listed. Thanks to ARRL TA Ed Wetherhold, W3NQN, for calling this to our attention.