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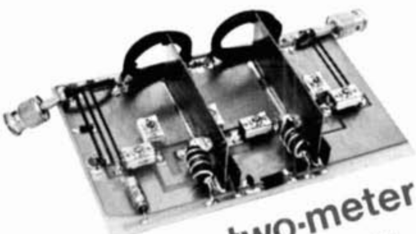

solid-state two-meter fm rf power amplifiers

this month

- vertical antenna 16
- ssb generator 22
- phase-angle meter 28
- printed circuit boards 58

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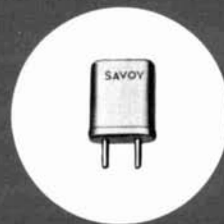

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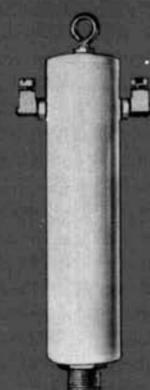

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More Details? CHECK–OFF Page 110

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contents

6 two-meter rf power amplifiers
Arthur R. Hall, W4CGC

16 the vertical radiator
John R. True, W4OQ

22 phasing-type ssb generator
Worthie Doyle, W7CMJ

28 phase-angle meter
R. G. Brearley, VE2AYU
Werner H. Korth

38 sensitive rf indicator
David L. Sprague, WB9DNI

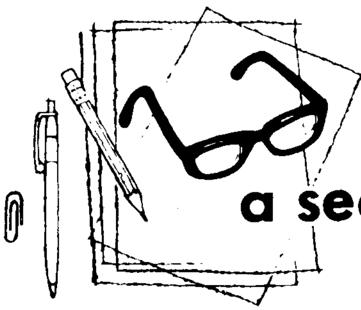
42 wwv receiver
Courtney Hall, WA5SNZ

48 alaskan wireless
Edmund H. Marriner, W6BLZ

58 printed-circuit boards
A. A. Kelley, K4EEU

68 morse code speed standards
Gaspard Lizee, VE2ZK

4 a second look
110 advertisers index
72 comments
99 flea market
70 ham notebook
74 new products
110 reader service



a second look

by jim fisk

Although any amateur who has worked on the high-frequency or vhf bands knows that geomagnetic storms can raise havoc with radio propagation, new evidence indicates that these same geomagnetic storms are linked to changes in our weather.

Upper air circulations over the Gulf of Alaska, which subsequently affect the weather over the North American continent, tend to become more intense after a period of severe geomagnetic disturbance. Although evidence of this phenomenon was reported over ten years ago, it's only been within the past couple of years that the subject has received serious study by scientists from the National Oceanic and Atmospheric Administration (NOAA) and the University Corporation for Atmospheric Research, both in Boulder, Colorado.

The studies to date have been based primarily on statistical studies — the number of high-altitude storms that follow a period of geomagnetic disturbance as opposed to the number of high-altitude storms following non-geomagnetic storm periods. Although the studies are far from complete, all evidence so far points to increased high-altitude storm activity 5 days to a week after a geomagnetic disturbance. If more can be learned about this storm intensification, it may provide a valuable new tool for increasing the accuracy of the 3- to 5-day weather predictions in the United States and Canada.

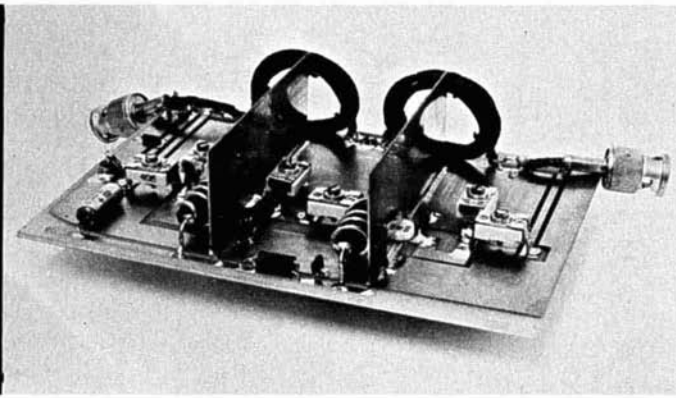
Although the cause and effect of geomagnetic storm intensification is not yet clearly understood, scientists speculate that it may result from geomagnetic modulation of the heat radiated to space from the relatively warm Alaskan Gulf during the winter. This may trigger the formation of cirrus clouds, change the ozone content, and result, possibly, in increased thunderstorm activity.

Satellite infrared data which indicates such changes during the winter of 1971/1972 are now being studied to test the idea of geomagnetic control of cirrus clouds, but further work is necessary. However, the study may provide important clues to the physical process by which the miniscule direct energy inputs from geomagnetic activity in the lower stratosphere can cause such large weather patterns that affect millions of people on the North American continent.

Once the mechanism of this phenomenon has been clearly understood, it suggests a possible way in which man might deliberately (or inadvertently) modify large-scale high-altitude air circulation, and hence, the weather. Controlling the weather, like flying and space exploration, has long been among man's fondest dreams. All it may take is a small amount of man-made magnetic energy, in the right amount and in the right place.

If all this comes to pass I can see it now — the skiiers will be lobbying for snow, the golfers will be lobbying for sunshine, and ecologists will be asking for moderation. More important to amateurs, perhaps, is that if geomagnetics can be used to control the weather, perhaps the same sort of technique can be used to improve long-distance radio propagation during periods of sunspot minimums.

Jim Fisk, W1DTY
editor



solid-state two-meter fm rf power amplifiers

Complete design and construction details for solid-state power amplifiers for two-meter fm

Arthur R. Hall, W4CGC, Woodburn Road, Annandale, Virginia

This article describes three solid-state vhf power amplifiers designed for use on two-meter fm. Since many of the fm transceivers now in use are in the one-watt class, such as the Drake TR-22, Motorola HT-220, and some Standard sets, I felt that the greatest need for more power would be from the one-watt level to approximately 30 to 35 watts, a power gain of approximately 15 dB. However, some readers are interested in somewhat higher input power ranges, so I have included basic designs for 1-watt in, 10-watts out, and 10-watts in, 35-watts out. Design and construction details, and tune-up procedures are the same as the 1-watt in, 35-watts out amplifier discussed in detail in the text.

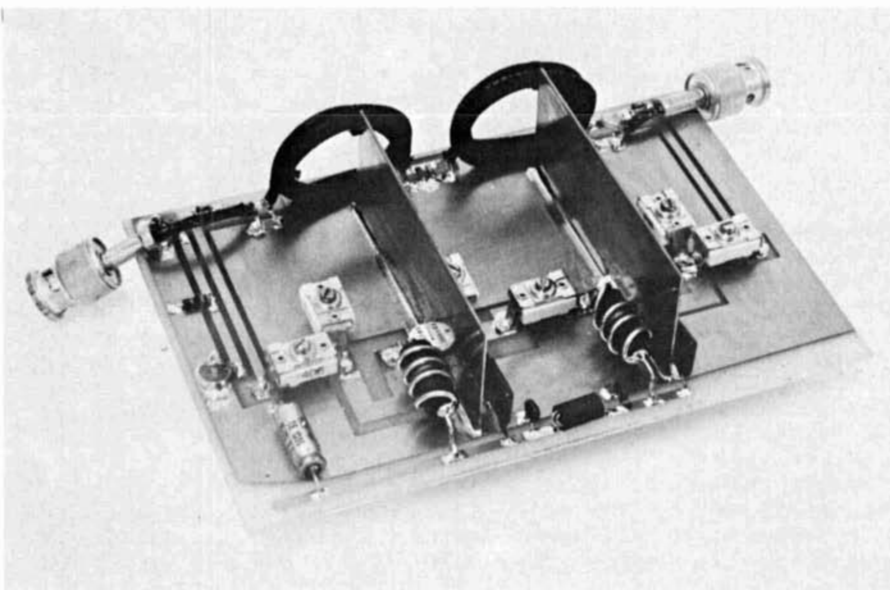
Undoubtedly, more amateurs would attempt to build their own power amplifier if they could be assured of success upon completion of the project. With this in mind, I have included several design features that will greatly assist in realizing this goal, including the use of printed circuit inductances, a built-in vswr and relative power indicator to aid in tune-up and operation, and the use of state-of-the art, high efficiency, rugged, yet low cost transistors. The manufacturer rates these transistors for *infinite* vswr, so you shouldn't burn them out if your antenna isn't what it's supposed to be.

Although it will not be necessary for the builder to do any design work on these amplifiers, I will provide a short dissertation on the basic needs and techniques in dealing with high-power vhf transistor circuit design. I will also go through the complete procedure for designing the 1-watt input/35-watt output amplifier.

35-watt power amplifier

This amplifier is a two-stage solid-state unit with 30 to 35 watts output in the 146- to 148-MHz range when driven by 1 to 1.5 watts input. The 1-watt input is amplified to approximately 10 watts by the first stage, a SD-1198 transistor. This stage drives the final, a SD-1197 transistor, to approximately 35 watts output (depending upon how hot the transistors are). The output power passes through a vswr/relative power indicator printed on the board similar to the units described in a previous article.[1] From there it passes through two switching diodes to the output jack. The switching diodes are part of an automatic TR switching network developed by WB4-JMD and WB4DRB, and described previously.[2]

The theory of operation of this switching network is as follows: In the receive mode all six diodes are non-conducting and, as such, present high resistance blockage paths. When an incoming signal appears at the output of the amplifier, CR5 and CR6 block the received signal from entering the output circuit of the amplifier. The signal travels through the two quarter wave RG-174/U coaxial lines to the input jack of the amplifier. Since CR3 and CR4 are non-conducting they do not affect the passing signal. Since CR1 and CR2 are likewise non-conducting, the signal is thus prevented from entering the input stage of the amplifier.



The solid-state two-meter power amplifier printed-circuit board includes etched inductors for both stages as well as a built-in swr bridge (upper left). Transmit-receive switching is accomplished with the two coiled quarter-wave lines at the rear of the board.

In the transmit mode, all six diodes are in conduction. Diodes CR3 and CR4 present a near short circuit to ground at the junction point of the two quarter-wave lines. Since a shorted quarter-wave line on one end looks like an open circuit on the other end, the line presents a very high impedance to the incoming driving power. Diodes CR1 and CR2 are now biased into conduction and pass the driving power to the amplifier input stage relatively unobstructed. CR5 and CR6 pass the amplified power from the output stage to the output jack. Again, CR3 and CR4 perform the same function as in the input circuit and short out the output quarter-wave line, blocking the output power signal.

Since the amplifier is zero biased and displays excellent immunity to spurious oscillations, there is no need to switch the 13.6 Vdc supply voltage each time the driving transceiver is keyed. This fact, along with the solid-state switching network, yields an rf power amplifier free of any switching relays (often a source of trouble, particularly at these frequencies).

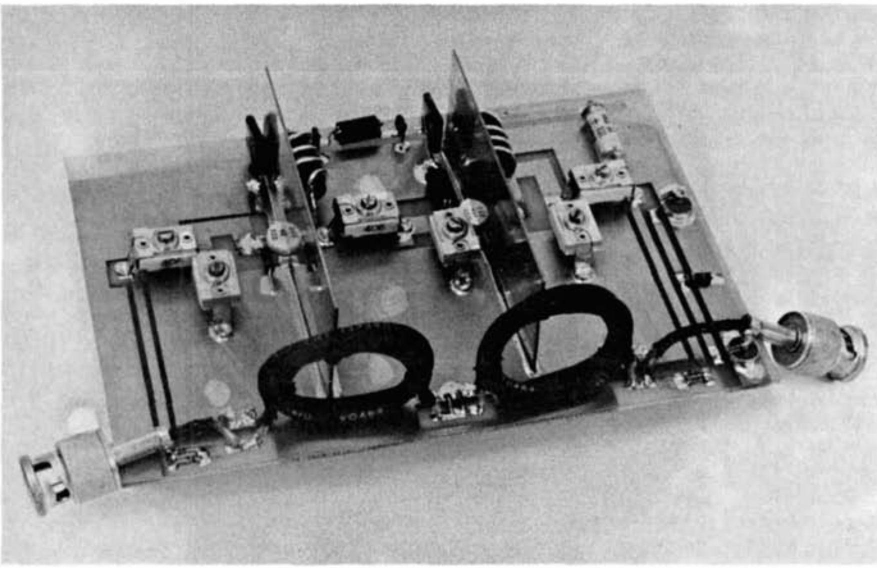
design considerations

Quite normally with any new design cost versus performance is one of the first considerations. It now appears that the Solid State Scientific Company's SD-1198 ($8.45) and SD-1197 ($12.30) vhf power transistors offer a good combination of reasonable cost and rugged construction while maintaining high performance in the power range of one watt in, 30 watts out.

After the determination has been made to use a certain type of transistor, the next step is to decide on what type of matching networks will work best. To do this, the designer must know the large-signal input and output impedances of the transistors he has chosen at the intended frequencies and operating power levels. Most manufacturers of high power rf transistors publish large-signal input and output matching information. Some companies omit the large-signal output real-part values that the transistor should be matched to. For these cases the designer may use the approximate equation:

$$R_{out} = \frac{(V_{CC})^2}{2P_O} \qquad (1)$$

Where V_{CC} is the dc input voltage, P_O is the rf power delivered to the load and R_{out} is the parallel output impedance in



Built-in transmit-receive switch uses diodes and quarter-wave coaxial lines (foreground). In this view the input stage is on the left, the output stage on the right. The built-in swr pickup line is etched on the right-hand side of the board.

ohms. For reasons that will be explained later, this parallel value, along with the output capacitance of the transistor, may have to be mathematically transformed into an equivalent series value. This can be accomplished by the following equations:

$$R_s = \frac{R_p}{1+(R_p/X_p)^2} \qquad (2)$$

$$X_s = R_s \frac{R_p}{X_p} \qquad (3)$$

Where R_s is the series resistance, X_s is the series reactance, R_p is the parallel resistance and X_p is the parallel reactance. Note that X_p is the transistor output capacitance in ohms at the frequency of operation.

Input matching information included on the manufacturer's specification sheet will include values for both resistance and reactance. Here again, if parallel values are given, it may be necessary, in some cases, to convert to equivalent series values.

Referring to the manufacturer's data sheets for the two transistors used in this amplifier, the input and output impedances at various power levels are given in series values:

SD-1198	input impedance at 1-watt input = 0.8 + j1.0
SD-1198	output impedance at 10-watts out = 4.0 − j1.2
SD-1197	input impedance at 10-watts input = 0.9 + j1.1
SD-1197	output impedance at 35-watts out = 2.2 − j0.1

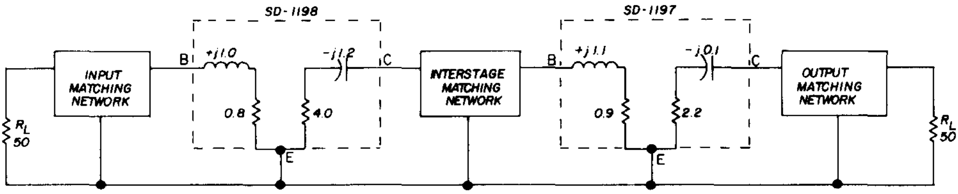


fig. 2. Series input and output impedances of the two transistors used in the two-meter power amplifier.

matching networks

When the input and output impedances have been determined, the next step is to select the best type of matching network for the input, interstage and output. The two most commonly used networks are the pi and the tee. Theoretically, either network may be used, but the tee network will produce more reasonable values of inductance and capacitance when you're working with low values of transistor impedance. After selecting a value of circuit Q between 5 and 10, the L and C reactances for the tee network (see **fig. 1**) are calculated from the following formulas:

$$X_L = QR1 - [X1] \qquad (4)$$

$$X_{C2} = AR2 + [X2]$$

$$X_{C1} = \frac{B}{Q - A}$$

Where:

$$A = \sqrt{\left[\frac{R1\ (1+Q^2)}{R2}\right] - 1}$$

$$B = R1\ (1 + Q^2)$$

When you use these equations to

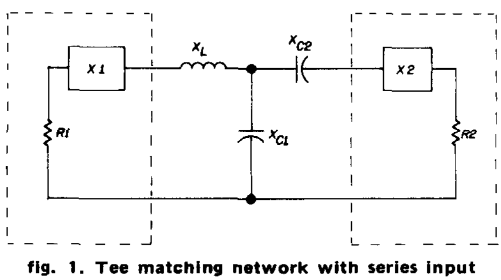


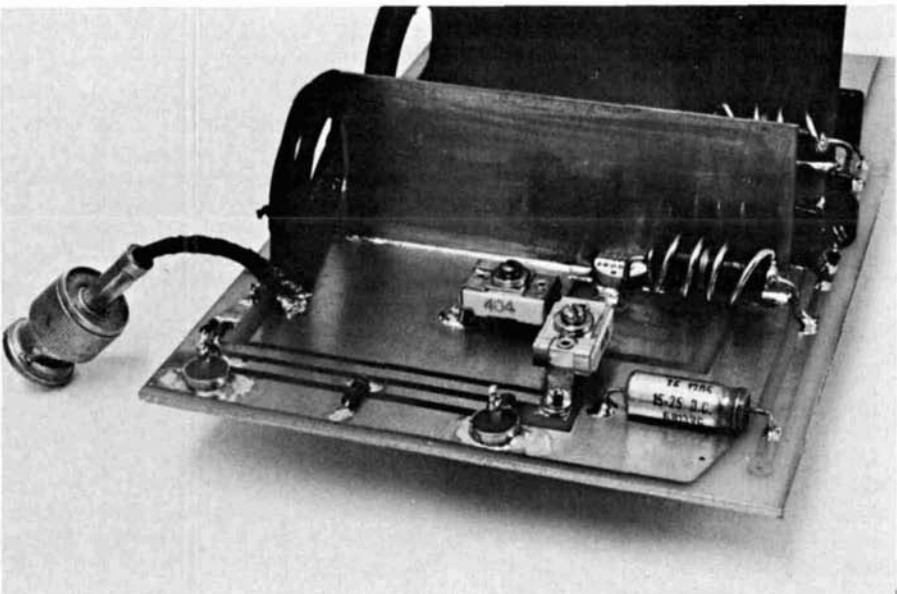
fig. 1. Tee matching network with series input and output impedances. Design formulas for this network are given in the text.

design a tee network, there are several rules which must be observed:

1. R1, X1, R2 and X2 must be expressed in series form. If they are given in parallel form on the data sheet, they must be converted to series equivalents using **eqs. 2** and **3**.

value except to stay within the 5 to 10 boundary. The designer arbitrarily picks the value he wants. It doesn't have to be calculated for this type of use. I picked a loaded Q of 10 for the input and output circuits, and a loaded Q of 7 for the interstage matching network.

The circuit for the input matching



Output tank circuit and swr bridge pickup line.

2. R1 must be lower in value than R2, and X_L must "look" into the lower of the two resistances. Arrange the tee circuit until this condition is met.

3. Enter X1 and X2 as a positive number if inductive; enter X1 and X2 as a negative number if capacitive.

At this point a word is in order about circuit Q. The Q in this case means the loaded Q, not unloaded. Experience has shown that a loaded Q between 5 and 10 works best in power amplifiers of this bandwidth (2 MHz at two meters). Too low Q will result in poor harmonic reduction and broad tuning. Too high Q will produce critical tuning, narrow bandwidth and poor transfer efficiency because of the high currents involved. Again, there is nothing magical about this

network is shown in **fig. 3**. Since R1, the real part of the SD-1198 transistor series input impedance, is smaller than R2, the 50-ohm input impedance, the configuration of **fig. 3** must be used for this matching network. Reactance X1 is the imaginary part of the transistor input impedance. Since there is no reactance at the input (see **fig. 2**) X2 is zero.

Using the values of **fig. 3** and the formulas of **eq. 4**, you will arrive at the

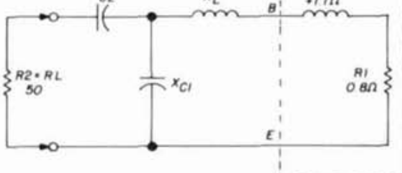


fig. 3. Input matching network.

following reactance values for the tee network components:

$X_L = 7$ ohms

$X_{C2} = 39.24$ ohms

$X_{C1} = 8.76$ ohms

The design of the interstage matching network shown in **fig. 4** follows the same procedure. Using the values of **fig. 4** in **eq. 4** will yield the following values for the interstage matching network:

$X_L = 5.2$ ohms

$X_{C2} = 11.6$ ohms

$X_{C1} = 11.8$ ohms

The same technique is used to design the output matching network shown in **fig. 5.** The reactance of the matching network components, from **eq. 4,** are:

$X_L = 22.1$ ohms

$X_{C2} = 92.8$ ohms

$X_{C1} = 27.3$ ohms

The only remaining calculation is to convert all of the inductive and capacitive reactance values into inductance (in nanohenries) and capacitance (in picofarads). This is accomplished with **eqs. 5** and **6.**

$$C = \frac{1}{2\pi f X_C} \quad (5)$$

$$L = \frac{X_L}{2\pi f} \quad (6)$$

where C is in microfarads, L is in microhenries, f is in megahertz and π is 3.1416. Remember that there are 10^6 picofarads in one microfarad, and 10^3 nanohenries in one microhenry.

The complete two-meter power amplifier with matching networks is shown in **fig. 6.** Note, however, that the required inductance values are very small. Therefore, printed-circuit inductances are one of the most practical ways to obtain the required values. The graph in **fig. 7** shows the inductance of 0.1- and 0.2-inch copper strips on G-10 epoxy printed-circuit boards. The required length does not have to be laid out in a straight line, but can be etched in a loop as was done in the completed amplifier shown in **fig. 8.** When the printed inductances are etched as loops, the total length is measured on the center line of the copper strip.

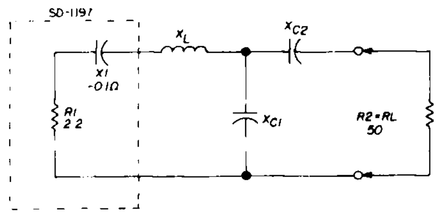


fig. 5. Output matching network.

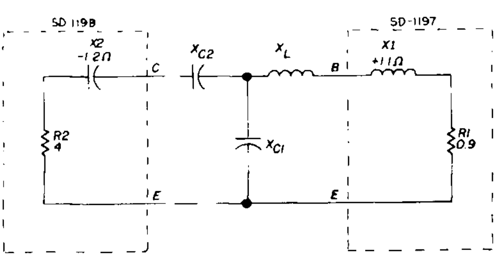


fig. 4. Interstage matching network.

Although the inductance and capacitance values shown in **fig. 6** will be accurate in an ideal amplifier where all stray inductances and capacitances are eliminated, such will *not* be the case in a practical amplifier because, alas, we do not live in an ideal world. Because of the inherent strays, even in the best designs, the actual inductance and capacitance values will vary somewhat. That is why you must use variable capacitors in all three matching networks.

parasitics

When designing an rf power amplifier you must minimize the possibility of low- or high-frequency parasitic oscillations. Parasitic and spurious oscillations can be controlled by observing several important rules of thumb:

1. The impedance of the base-emitter choke should be no more than 50 times, and no less than 5 times the large-signal input impedance of the transistor.

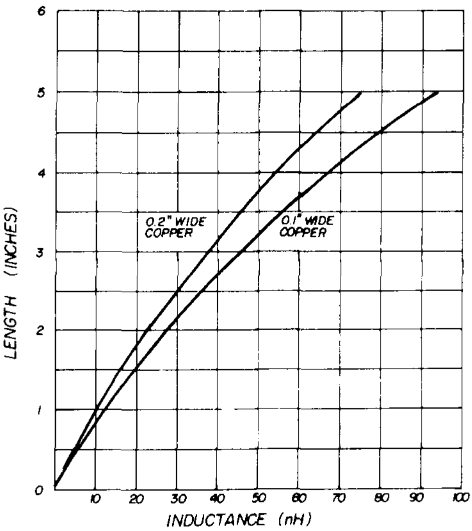


fig. 7. Inductance of 0.1- and 0.2-inch copper strips versus length. This graph may be used to determine the length of etched inductors on printed-circuit board (1-ounce copper).

2. The impedance of the rf choke in the collector circuit should be no greater than 10 times the large-signal output impedance of the transistor (10 times the load impedance seen by the transistor at the fundamental frequency or the lowest frequency of operation).

3. It is a good idea *not* to use a ferrite rf choke in the dc collector circuit due to the possibility of the ferrite saturating and turning the stage into a blocking oscillator.

4. *Use three separate bypass capacitors* on the B+ supply lead consisting of 10-μF, 1-μF and 0.1-μF capacitors. The 0.1-μF capacitor should be as small as possible with the shortest possible lead lengths.

If you are designing a two or more stage power amplifier, a husky ferrite rf choke should be installed between the stages in the power supply line with adequate bypassing to ground. In extremely tough cases of spurious oscillation, a carbon resistor from base to ground may help. Its value should be no more than 50 times, or no less than 5 times, the large-signal input impedance of the transistor.

The use of a metal shield which isolates the input and output circuits will sometimes increase power output by reducing degenerative feedback. Finally, when you are designing an rf power amplifier, try to use the newest transistor types available. They may cost a bit more, but the results will be well worth it.

heat sinks

A good, conservative rule of thumb for proper heat sinking is to use a heat sink capable of dissipating as much or more power than the amplifier produces. Silicon heat-sink grease should be used between the transistor header and the heat sink to insure maximum power transfer.

Use caution when tightening a transistor to its heat sink because the metal used in the threaded studs of most rf power transistors is very soft and can be easily twisted off if you use too much torque.

construction

The two-meter rf power amplifier shown in **fig. 8** is built on a G-10 epoxy

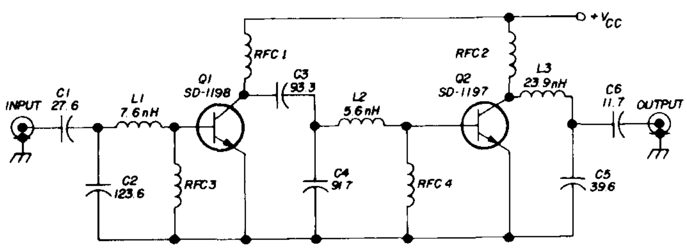
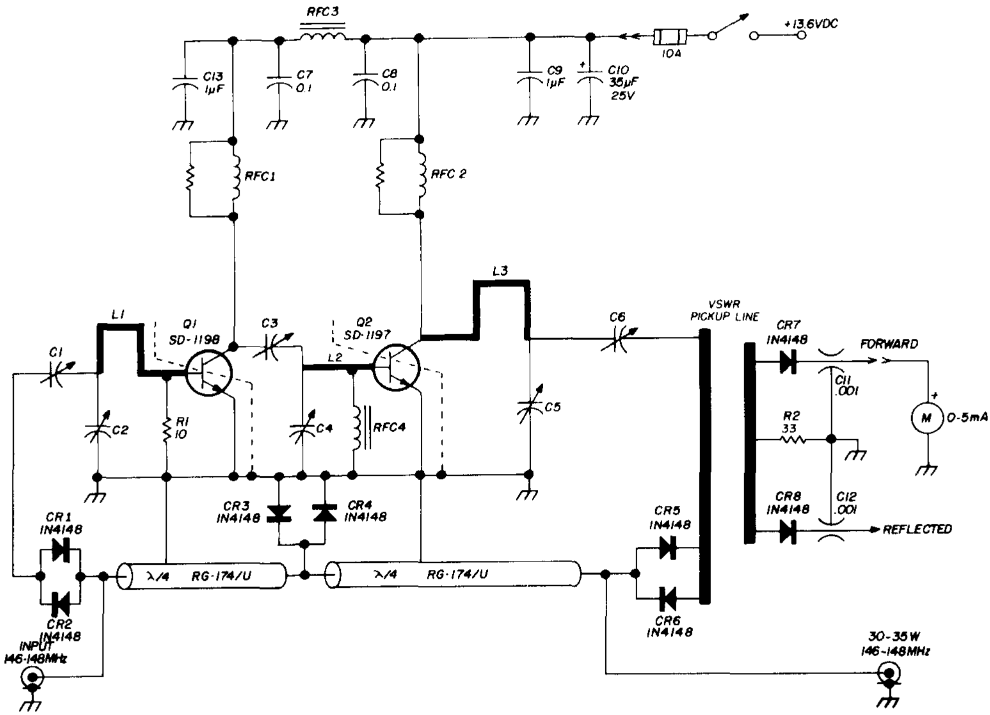


fig. 6. Basic design of the two-stage rf power amplifier.



C1,C3 C4,C6	15 to 115-pF trimmer (Arco 406)	CR1-CR8	1N4148 (Texas Instruments)
C2,C5	4 to 60-pF trimmer (Arco 404)	L1	7.6 nH printed inductor
C7,C8	0.1 μF, 50 V (Erie 8121-050-651-104M)	L2	5.6 nH printed inductor
C9,C13	1 μF, 50 V (Erie 8131-050-651-105M)	L3	23.9 nH printed inductor
C10	35 μF, 25 V electrolytic (Sprague TE-1208)	Q1	SD-1198
C11,12	.001 μF feedthrough (Allen-Bradley FA5C-102W)	Q2	SD-1197
		R1	10 ohms, 1/4 watt, 5% carbon
		R2	33 ohms, 1/4 watt, 5% carbon
		RFC1,RFC2	4 turns no. 18 on 470-ohm, 2-watt, carbon resistor
		RFC3,RFC4	ferrite choke (Ferroxcube VK-200-10/3B

fig. 8. Complete two-meter power amplifier with etched inductors, etched vswr/power indicator and solid-state TR switching. The two quarter-wave RG-174/U coaxial lines are each 14-3/16" long.

printed-circuit board with printed inductances and a printed vswr and relative power indicator.* The vswr and relative power indicator is similar to one previously described.[1] The use of a printed-circuit board allows the builder to produce a reliable power amplifier as close to the original design as possible with a minimum potential error.

The shield partition between the stages is made from 0.010-inch copper or brass, and is laid out as shown in **fig. 9**. The

*Completely etched and drilled printed-circuit boards for these amplifiers may be obtained from Artronics Company, Box 462, Merrifield, Virginia 22116. The board for the 1-watt input/35-watt output amplifier is priced at $13.50; boards for the other two units are priced at $11.50, each, postpaid.

The power transistors and other components for these amplifiers are available from Almo Electronics, Roosevelt Boulevard and Bluegrass Road, Philadelphia, Pennsylvania 19114. The price for the SD-1198, 10-watt power transistor is $8.45; the SD-1197, 35-watt power transistor is priced at $12.30.

heat sink is a 6-inch section of Wakefield 640 heat-sink extrusion, or equivalent.

Start construction by trimming all transistor leads to 3/16-inch long. Lightly tin the area of the PC board where the transistor leads and variable capacitors

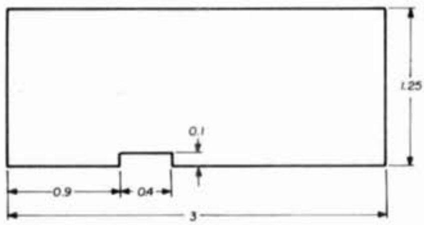


fig. 9. Layout of the copper or brass shield partitions used between stages (two required).

will be installed. Bend all variable-capacitor leads at the mid-point of the cutout slot. This will keep the adjustment screw from shorting out to ground after the capacitor is installed.

Install both transistors and solder them securely in place. Sweat solder the two shield partitions in place, and sweat solder the two .001-μF feedthrough capacitors in place and cut off the protruding lug on the heat-sink side of the PC board.

Now install the rf chokes, base resistors, bypass capacitors and switching diodes, including the two used in the vswr indicator. Install the 33-ohm resistor in the vswr circuit. Install the six variable capacitors and adjust C1 and C6 to maximum capacitance. Install the two quarter-wave RG-174/U coaxial lines.

Attach the printed-circuit assembly to the heat sink using Dow silicon heat-sink grease (or similar). Use caution when you tighten up the transistor stud nuts, as mentioned previously.

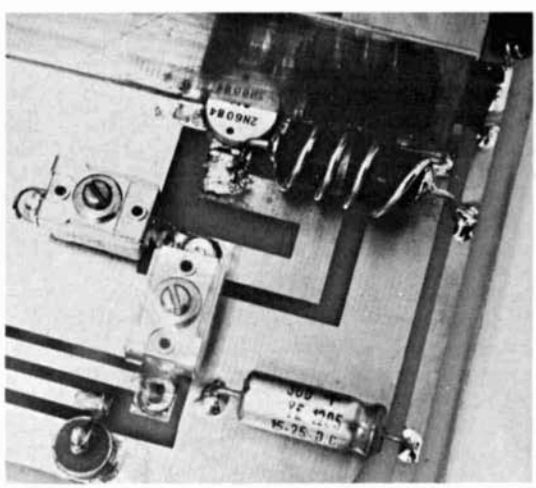
tuneup

Temporarily connect two short coaxial cable leads (RG-174/U) to the input and output points of the amplifier. Connect the output lead to a good non-reactive 50-ohm dummy load such as a Bird Termaline®, or perhaps, a Heath Cantenna. Do not use a light bulb as it is too reactive at this frequency.

Connect the input to a suitable 146-148-MHz driver with 1 to 2 watts output. Connect the B+ lead through a 7-amp quick-blow fuse to preferably a variable power supply. Connect a volt-ohmmeter (5 mA range) between the vswr feedthrough capacitor nearest the output transistor and ground. Slowly raise the supply voltage to approximately 10 to 11 volts. If there is no indication on the meter, a more sensitive range may help.

During initial tuneup it may be easier to monitor the dc ammeter on the power supply and tune for maximum current, up to about 4 amperes. By that time there should be an indication on the rf power output meter. From this point on all adjustments should be for maximum indication on the rf output meter. A reading of approximately 4 mA will indicate maximum rf power output of 30 to 35 watts. This should pull 5 or 6 amperes from the dc power supply.

The completed rf power amplifier can be installed in a Minibox or similar enclosure with the heat sink installed on the outside. Two test jacks may be brought out of the cabinet for monitoring vswr and output power. The 13.6-volt B+

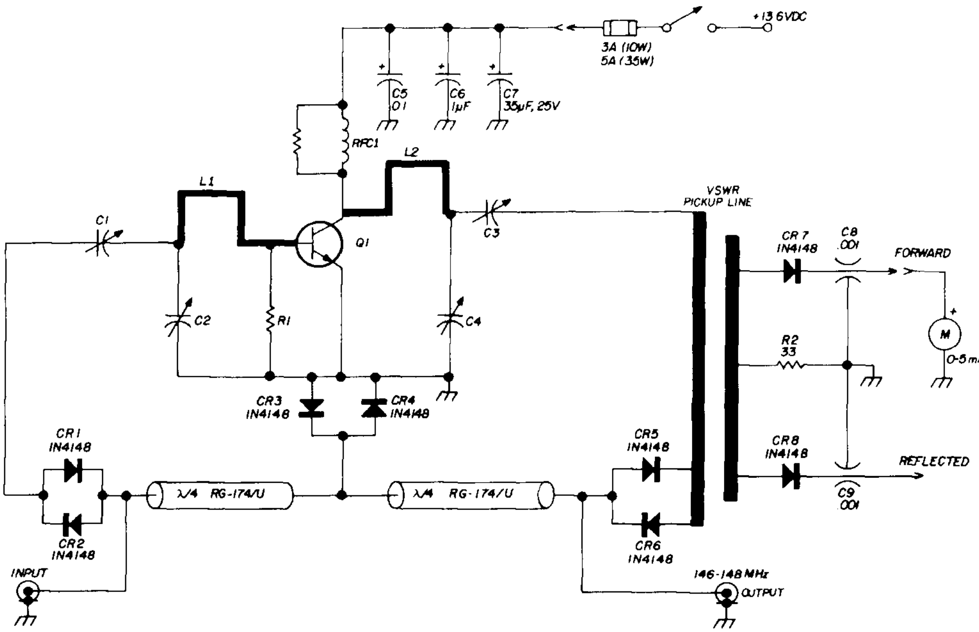


Closeup of 35-watt output stage shows construction simplicity that results from using printed-circuit inductors.

lead should be in series with a switch and a 10-amp quick-blow fuse to your automobile battery or other power supply.

acknowledgements

I would like to thank Chris Galfo, WB4JMD, and Marc Dressman, WB4DRB, for permission to use their solid-state TR switching technique. I would also like to thank John Gregory, W3ATE, for providing the photo-copy work for the printed-circuit board.



C1,C3	15 to 115-pF trimmer (Arco 406)	L1	10-watts output, 7-nH printed inductor
C2,C4	4 to 60-pF trimmer (Arco 404)		35-watts output, 8-nH printed inductor
C5	0.1 µF, 50 V (Erie 8121-050-651-104M)	L2	10-watts output, 28 nH printed inductor
C6	1 µF, 50 V (Erie 8131-050-651-105M)		35-watts output, 15 nH printed inductor
C7	35 µF, 25 V electrolytic (Sprague TE-1208)	Q1	SD-1198 for 10-watts output, SD-1197 for 35-watts output
C8,C9	.001 µF feedthrough (Allen-Bradley FA5C-102W)	R1	10 ohms, 5% carbon. ¼-watt for 10-watts output, ½-watt for 35-watts output
CR1-CR8	1N4148 (Texas Instruments)	R2	33 ohms, ¼ watt, 5% carbon
		RFC1	4 turns no. 18 on 470-ohm, 2-watt carbon resistor

fig. 10. Single-stage rf power amplifier for 1-watt input, 10-watts output or 10-watts input, 35 watts output. The two quarter-wave RG-174/U coaxial lines are each 14-3/16" long.

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ham radio

the vertical radiator

A discussion of the operating characteristics of simple vertical antennas for 40, 80 and 160

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On the 40-, 80- and 160-meter amateur bands, a vertical radiator is superior to the horizontally-oriented dipole. It gives omni-directional coverage with extremely low radiation angles when anchored in the earth, which will provide excellent long-range communication and good signal strengths at short range.[1] Further, if properly constructed, it will provide full band, low vswr coverage over the three amateur bands.

balanced horizontal radiator

The balanced horizontal radiator system is one of the most common systems in use. If a half-wave dipole antenna is horizontally oriented in space, free of all other objects, the radiation pattern is like a doughnut at right angles to the axis of the dipole wire. However, if the dipole is situated near the earth (quarter wavelength or less), the ground reflected ray cancels most of the direct ray of radiation at lower vertical angles. Only the higher angles are propagated with appreciable amplitude under these circumstances.

If the dipole is oriented about a half wavelength above the earth, the radiation pattern has two fairly broad major lobes at right angles to the wire in the vicinity of 25-35° above the horizontal. To reduce the major lobe to 10-20° the dipole has to be elevated to approximately one wavelength above the ground. Dipoles have little radiation below 15° in any direction if less than one wavelength above poor earth.

A typical half-wave dipole for 80 meters would be about 125 feet long. If it were made of no. 10 wire (0.1-inch diameter) it would have an extremely high characteristic impedance (over 2000 ohms). This would make an efficient radiator at resonance; however, due to its high characteristic impedance, it would have a very narrow operating bandwidth.

If the two halves of the dipole could be made into a multiwire cage about one foot in diameter, the characteristic impedance would be approximately halved and the bandwidth increased proportionally.

unbalanced vertical radiator

If, instead of a balanced dipole, an unbalanced system fed by unbalanced coaxial cable were used, and further, if the outer conductors of the coaxial cable were unbraided into a plane at right angles to the center conductor, an unbalanced radiator would result. This form of radiator is known as a monopole or unipole. If the center conductor is vertically anchored in the earth it becomes known as a vertical monopole, for obvious reasons. If the length of the center conductor is made an electrical quarter-wavelength long and the plane of outer conductors is also made one-quarter wavelength, it becomes a very efficient *omnidirectional* radiator at low vertical angles.

When the center conductor is about one-quarter wavelength, the vertical pattern is quite broad and extends from near 10° to about 50° at the half power points with the peak radiation at about 25° above the horizontal. When the length approaches 1/2 wave, the vertical pattern is concentrated between 30° and near 5°, with the peak of radiation near 15° above the horizontal. At 5/8-wavelength, the lobe is concentrated between zero and 20° with the peak radiation about 8° above the horizontal. Additionally, at this height there is a small high-angle lobe near 60°.

At lengths in excess of 5/8 wavelength the low-angle lobe diminishes in amplitude and the high-angle lobe increases until, at a height of one wavelength, the low-angle lobe disappears altogether and the high-angle lobe is at a maximum. See **figs. 1** and **2** for a comparison of the vertical pattern of a typical vertical radiator and a horizontal dipole.

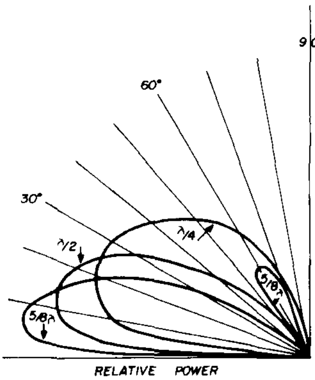


fig. 1. Radiation pattern of the vertical monopole antenna. The pattern is omnidirectional for heights of 1/4, 1/2 and 5/8 wavelength when an adequate ground plane is used.

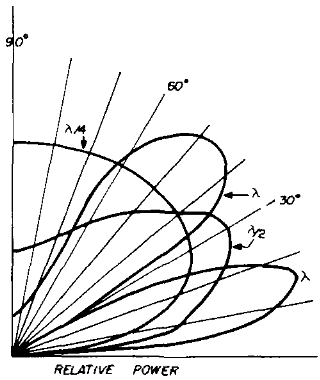
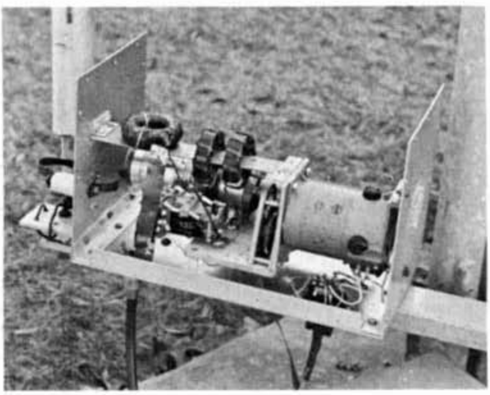


fig. 2. Radiation pattern of the horizontal dipole antenna. Pattern at right angles to the wire for heights of 1/4, 1/2 and 1 wavelength over a good ground.

If the vertical (center) conductor is small in diameter with respect to its length, its characteristic impedance would be a high value. Typically, a quarter-wave vertical conductor at 80 meters, made of 63 feet of no. 10 wire, would exhibit a characteristic impedance of over 1000 ohms. On the other hand, if the vertical conductor were to be made of a metal pole, 1 foot in diameter (30-inch diameter triangular tubing tower is the equivalent), it would have a characteristic impedance near 500 ohms. (This is about one-fourth the characteristic impedance of a thin dipole.) This would result in a much broader bandwidth characteristic and allow the use of the radiator throughout an amateur band without appreciable variation in its electrical characteristics. The bandwidth available for efficient operation is proportional to the radiating conductor's diameter to length radio.

ground plane

Other factors which affect the efficient operation of a radiator are the



Control box located at bottom of the tower. The geared motor on the right drives the voltage-variable capacitor which is nearly hidden by the two toroid inductors. The circuit for the control box is shown in fig. 3.

ohmic (rf) resistance of the system and dielectric losses induced by material of lossy characteristics between the two halves of the radiator. No one in his right mind would erect a dipole and then surround one of the two elements with several inches of lossy material such as grass, soil or clay! Ridiculous? Not at all! For years the designers of vertical radiators have been burying the outer conductor extension of the unbalanced vertical system in the earth "to get a good ground."

A good *ground* we do not want. A large plane of highly conductive material that the vertical radiating member can see without intervening lossy dielectric *is* what is needed! The current must flow between the two halves of the system without lossy material in the intervening space, and charge the medium that will carry the signal outward. The *ideal* outer conductor extension would be a continuous plane, at least one-quarter wave long of metal of high conductivity that would completely hide the earth in the near field (most model studies are made this way). Since this approach results in rather poor economics at the lower amateur frequencies a mat of mesh wire and/or a radial wire system, extending outward one-quarter wavelength in as many directions as the budget and available space will allow, will provide an adequate outer conductor extension of the unbalanced system. However, the mesh/wire should *not* be buried deeply.

Since the typical amateur's backyard location of an antenna system must be available for other purposes, as a compromise the radials may be placed into the sod of the grass, as shallow as is possible. They should not present an obstacle course, nor should they be buried so deeply that part of that expensive antenna power is used in warming the back yard.

How extensive should the outer-conductor extension plane be made? First, let's review the things not to do. It should *not* be made by merely connecting the bottom of the vertical member to several rods driven into the earth to get a good ground. Five ground rods 6-feet long (or three ground rods 10-feet long) connected to the tower base is good lightning insurance, however.

The extension plane need not be made one-quarter wavelength long in all 360° directions of the radial system. If an omnidirectional pattern is a requirement it should be about $\lambda/4$ in all directions but this is not mandatory if some pattern distortion is permissible or desirable. The individual wires need not be of large diameter if there are enough of them to satisfy the area and conductivity requirements indicated below.

Now, let's think of some of the things that should be done. The outer conductor extension place of the unbalanced vertical radiator should be made of material that has high conductivity. Also, between the base of the vertical and the extension plane the connecting conductors should be made of many large cross-section wires to reduce the chance of losses in this high-current part of the system.

The extension plane should have an near the tower base (10 to 15 feet out) to augment the radial wires.

If the radial wires are spaced not more than 0.1 wavelength at a distance of $\lambda/4$, they will intercept about 95% of the energy (16 radials meets this requirement). This is not a perfect design but will provide a good extension plane for

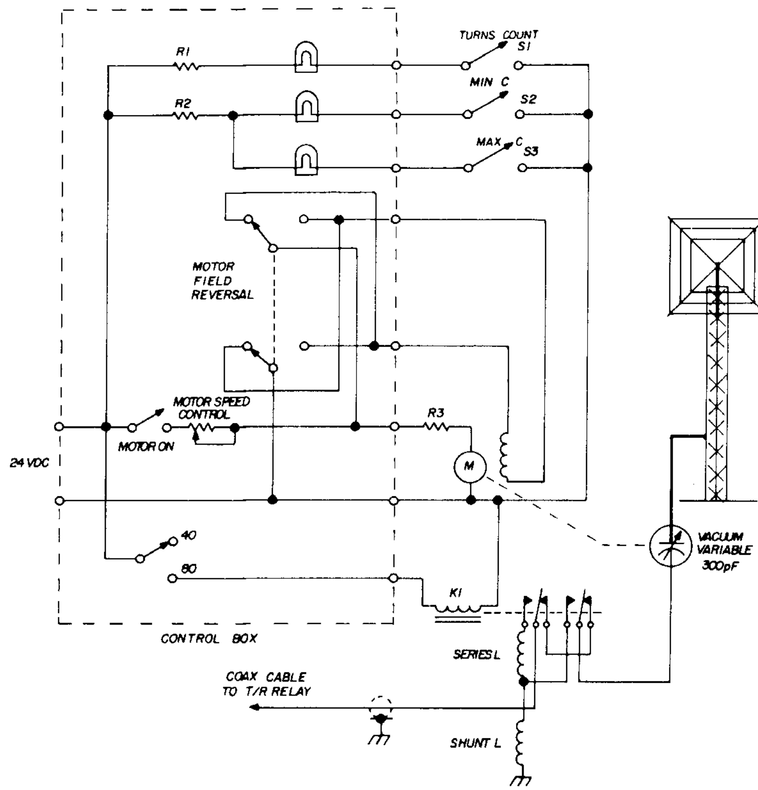
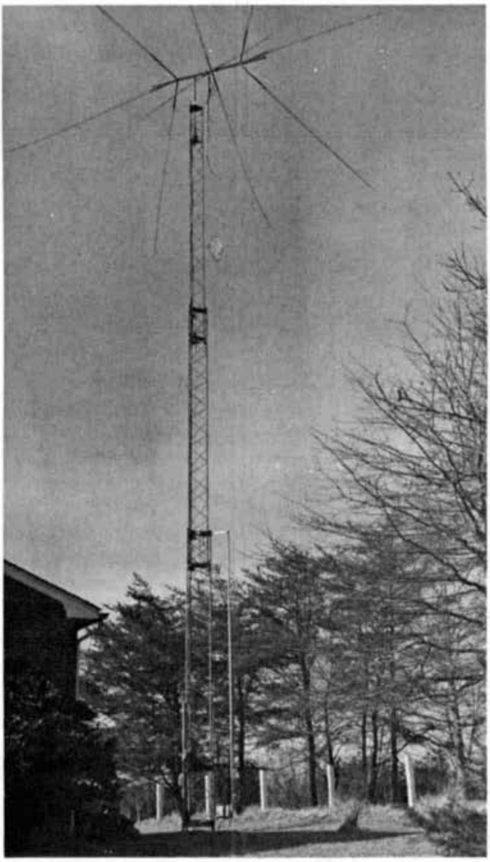


fig. 3. Electrical control system for the 40- and 80-meter vertical antenna. Microswitches S1, S2 and S3 are limit switches actuated by the motor system, which control the pilot lamps. R1 and R2 are pilot-lamp current-limiting resistors. R3 controls maximum motor speed. The motor is a 24-volt unit geared down to drive the vacuum variable capacitor.

area (total) approximately equal to the area of the vertical member. To build a capacitor with several square units of area on one plate and a single square unit of area on the other would not be good practice. A radiator is an L-C circuit; the length of its elements provide the inductance and the area of its members provide the capacity. Therefore, they should be roughly equal in area and length. If necessary, use wire matting (fence wire) the outer conductor. If the mesh mat is made of fence wire of the type that has each crosswire welded to the longitudinal wires it will provide a high capacitance at the base of the vertical radiator.

If some directivity is desired it may be concentrated in one direction both in length and spacing. Do not overdo the length, however. There is a point of diminishing returns beyond 3/8-wavelengths long.[1]

Excellent results can be obtained by using multielement, multiband, rotatable beams on 20 meters and above, especially if they are mounted on top of a tower that gets them far enough above the earth for low angle radiation (50 to 60 feet). They can be purchased or constructed at a nominal price. Also, they can be made



The W4OQ vertical-tower antenna system that covers all bands, 80 through 10 meters.

rugged enough to withstand rather heavy weather.

For the lower frequencies it is nearly impossible to get a large enough beam, with rugged characteristics, up a full wavelength in height for low-angle radiation, without excessive expenditure of funds and effort.

These are the reasons that this article is directed toward the use of the vertical radiator on 40 meters and lower. Further, the use of a beam supporting tower for the vertical member of the radiator is recommended as a bonus with minimum additional expenditure.

base impedance

There are many charts which show the characteristic impedance, as well as the resistive and reactive components, for the *ungrounded* vertical radiator when fed at the base. However, there are several reasons why the ungrounded vertical radiator is impractical for use by the radio amateur. For one thing, any static level and/or lightning strokes in the vicinity would channel this collected energy directly to the equipment to which it is connected. Also, any use of the tower for other purposes, such as for mounting hf or vhf beams, would require all the cables to be routed through a decoupling device at the base so that these cables would not short out the base insulators. The tower would almost certainly have to be guyed in order that too much stress will not be placed on the base insulators.

Whether the tower is ungrounded or grounded, towers that require guys should be insulated from metallic guys. These guys must be broken up with egg insulators into non-resonant lengths to reduce pattern distortion. Non-conductive guys of polypropalene are relatively invisible to rf at high frequencies and are reputed to be quite strong and inexpensive. Nylon stretches too much to be considered for use in tower guying.

Also, whether the tower is guyed or unguyed, any rf and control cables from the beams down to the base, should be routed inside the tower structure all the way to the bottom to reduce pattern distortion. Additionally, they should be routed underground a few inches from the tower base to the operating position. Here is a good place to use that lossy earth. It will attenuate any rf on the outside of the cables. This will also assist in TVI reduction.

There are few charts available for feed impedance versus tower heights for the grounded tower vertical radiator. Although there are too many variables in such a system to make an accurate prediction of the feed impedance some generalities can be stated.

A grounded-base tower can be easily shunt fed by the use of either the delta-or the gamma-type feed system. The delta system will radiate a little and distort the radiation pattern. Therefore, it is not considered practical. The gamma system is an excellent choice for shunt feeding the grounded radiator. Its feed impedance can be adjusted by changing the length of the vertical member. It can also be adjusted a small amount by changing the diameter and spacing of the gamma rod. In all cases where the gamma rod is less than one-quarter wavelength long, it will show inductive reactance. This reactance can be cancelled by a series variable capacitor. Typical R ± jX readings for various lengths of gamma rod and vertical antenna heights are given in **table 1**.

table 1. Typical resistance and reactance values for various lengths of gamma rods and vertical antennas.

tower height (wavelengths)	gamma length (wavelengths)	resistance (ohms)	reactance (+j ohms)
0.25	0.1	5-10	200-300
0.5	0.2	40-80	700-1000
0.5	0.25	over 500	over 1000'

note: The above readings were made with a fence-wire ground mat (two lengths, 100-feet long by 3-feet wide). The tower height was varied from 22 to 54 feet (a 3-element tri-band quad mounted on top). Another tower, ground plane or beam setup will have a different feed-point impedance but it should be near those figures listed above.

From **table 1** it becomes obvious that a gamma length too near one-quarter wavelength is to be avoided, especially if the vertical radiator is near one-half wave. At the other extreme, if the gamma rod is much shorter than 0.1 wavelength and the tower is well below one-quarter wave high, the feed-point resistive component may be so low that transformation to the coaxial-line impedance may be difficult.

If all three lower frequencies available to the amateur are to be used on one vertical antenna, it is recommended that the two higher frequencies be used with one gamma rod, and that a second gamma system be provided on the opposite (physical) side of the tower to reduce reaction between them. This second gamma system can be made physically longer on the tower than the other one which will increase the resistive component.

measurements and matching

After the gamma matching system has been installed the measurement of feed point reactance and resistive components can be accomplished by use of a commercial or home-made rf impedance bridge.[2] Once the electrical characteristics on each amateur band have been determined, the design of the reactance cancellation and resistance matching transformation to the coaxial feed impedance can be solved by the use of a graphical technique.[3] This technique requires no more exotic tools than a straight edge, a compass and graph paper. The mathematics required will not exceed simple arithmatic. Every amateur interested in antenna work should add this valuable set of tools to his experience and knowledge.

Next month I will present some practical solutions to the construction of the vertical radiator and its ground plane. The use of the rf impedance bridge and solution of impedance matching by use of the graphical method will also be shown. A practical control system using a motor-driven vacuum-variable capacitor to cancel the reactance will be explained. Additionally, a switching system that will allow complete remote control of one vertical radiator over the 40- and 80-meter amateur bands will be illustrated.

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ham radio

phasing-type ssb generator

Complete construction information on a simple, all-passive phasing-type single-sideband generator

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Phasing-type single-sideband generators described in the literature use active devices, either to isolate the phase-shift networks from the modulators or as the modulators themselves. A few years ago it occurred to me that it should be possible to build a phasing-type sideband generator using only resistors, capacitors, inductors and diodes and using no dc power. This article describes a recent version of such a unit.

Its input requirements are about 3 volts peak rf across 50 ohms (0.1 watt) and a few tenths of a volt of audio across about 15 ohms. Output is from an rf transformer whose tuned winding can drive a vacuum tube or fet directly, while a transistor can be driven from an added low-impedance winding or a capacitive tap on the tuned winding. An attractive aspect of the circuit is that it could be fabricated as a compact, general purpose, sideband generator three-port, since only the two rf phase-shift reactors and the output transformer depend upon carrier frequency.

Usually, both phase-shift networks are designed for infinite impedance loads, automatically requiring that tubes or fets follow. On one memorable occasion, however, a design appeared for a relatively low-impedance network where the input impedances of the transistor loads were included in the resistive output branches of the audio phase shift network.[1] My unit carries this idea to the logical conclusion of dispensing with the drivers and simply including the impedances of the diode modulators in the design and adjustment of the output branch of the audio phase-shift network. The rf phase-shift network design also allows for the modulator impedance. Finally, since the diode modulator impedances vary somewhat with rf drive level, some swamping is used to simplify design and adjustment.

The result appears in **fig. 1**. The version shown operates at 10.5 MHz. Other versions have run at 12 and 7.25 MHz. The values shown for the audio phase-shift network components are those suggested by van Heddegem. The values actually used were scaled up a few percent in impedance to accomodate a couple of odd precision resistors in my own junk box. The test equipment used to build and adjust this circuit consisted of a diode rf probe connected to an ordinary vom, a low-frequency R-C bridge[2] and a receiver with a mechanical filter to verify sideband suppression.

The method of sideband switching is one I have not seen mentioned in print. It has the advantage that one side of every modulator input may remain permanently grounded. The only audio transformer required is the one driving the phase-shift network.

circuit description

The circuit consists of three sections, the audio and rf phase-shift networks and the two balanced modulators. The rf phase-shift network values are those I used, but other builders should be guided by what identical precision resistors are available. The diode balanced modulators are so arranged that both rf and audio inputs are single-ended with one side grounded. The audio and rf inputs are effectively in series, as usual.

The rf phase-shift network is an ordinary arrangement of plus and minus 45-degree sections, except that an estimate of the resistance looking into each modulator is made part of the resistive branches. To estimate this resistance, note that each diode conducts half the formance of the audio phase shift network. They have about 100 ohms reactance at 10.5 Mhz but do not significantly affect the rf phase shift, since they are in series with a few thousand ohms as well as combining in quadrature. Furthermore, any effects they have are identical for the two modulators, shifting phase slightly without changing the 90-degree relationship.

If 51 ohm resistors are used in the phase-shift networks, the modulator resistance is swamped by a factor of about 28, so a 28% error in the estimate of the modulator resistance is equivalent to a 1% error in the rf phase shift resistor. For

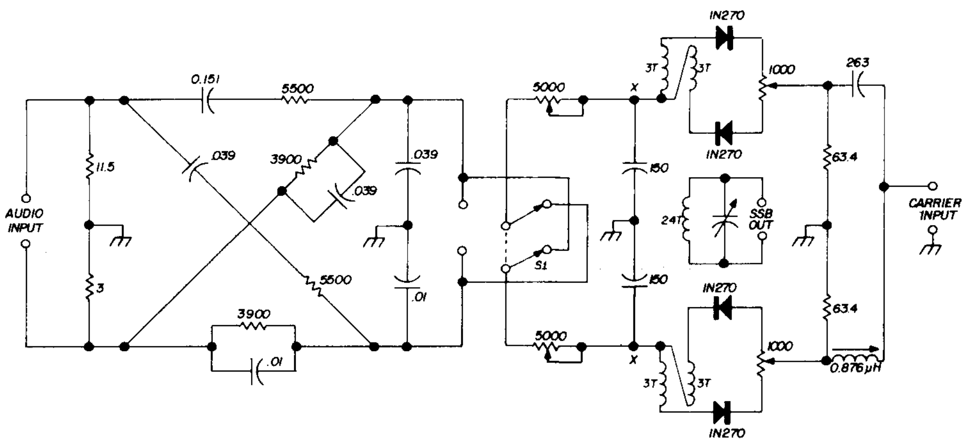

fig. 1. Circuit of a passive phasing-type ssb generator which uses no active devices.

time. With one diode conducting, the rf input resistance for each modulator is half the balancing pot, 500 ohms, plus a few hundred more ohms for the diode (varying somewhat with rf drive level) plus another 500 to 1000 ohms for the load seen at the output winding feeding the rf transformer. This load will depend on the Q of the rf transformer and on the load presented by the other balanced modulator. You can only guess at these values, but a reasonable guess is that they will nearly match the roughly 700 ohms of diode plus balancing pot, giving an estimate of about 1400 ohms.

The 150-pF bypass capacitors were made small to avoid affecting the performance this combination the effective resistances of the rf phase shifter output branches are about 49.2 ohms; the rf phase shifter L and C should have this reactance at the operating frequency.

My network was built by making the C from a precision unit a little above the calculated value in series with a larger low-precision unit. The L, a slug-tuned coil, was then adjusted so the rf voltages across the two phase shifter outputs were equal. As a check, note also that each of these outputs is about 70.7 percent of the whole rf input voltage. There is no reason why both L and C should not be variable. In that case you can forget about the exact modulator impedances as long as the two are built identically, but the rf phase-shift adjustment becomes more complicated.

audio phase-shift network

The audio phase-shift network was made of junk-box items. Resistors were precision types or a precision type shunted by a much larger ordinary resistor. Capacitors were paralleled from whatever was on hand. All R and C values were checked on the bridge before being wired in. I've built three audio phase-shift networks by this *dead-reckoning* method (no adjustments) and they all seemed to work fine as judged by listening to speech while switching sidebands.

The resistances at the input of the audio phase shift network should have a ratio of 3.83 with 1% accuracy, but actual values don't matter. I used 5.24 and 20 ohms because my junk box supplied them. Note that the sum of these two resistances should be matched to the audio driver. A junk output transformer from a midget broadcast set is ideal, since it has about the right turns ratio to match a medium-mu triode to 15 or 30 ohms and operating it at this higher impedance level will reduce low-frequency response below 300 or 400 Hz. Be sure neither old vc lead is grounded when using such a transformer.

The important adjustment in this unit is to make each output resistive branch look like the desired 3900 ohms. Each of these resistances is the sum of the trimpot resistance and the modulator audio input resistance. The modulator resistances will be about 700 ohms since the modulator rf transformer windings have negligible audio impedance. This shows that there is a swamping factor of about 5 for variations in the audio impedance of a modulator.

To insure that the resistance of this branch is correct under operating conditions, disconnect the input end (end at the dpdt switch) of each trimpot from the audio phase-shift network and connect this end of the trimpot and ground to the R-C measuring bridge. Set the bridge dial to 3900 ohms (or whatever the design resistance is for your own audio phase-shift network). Turn on the rf carrier oscillator to be used with this unit. It should be operating at the intended voltage, preferably regulated (I'm using a 6C4 fed from a VR150). Now adjust the trimpot for a bridge null. Repeat for the other trimpot and both output branches will have the desired effective resistance.

To insure proper combination of the two modulator outputs, all coils of the output transformer should be closely coupled and both sets of modulator windings should be identical bifilar windings. The easy way to do this, used in the unit described, is to wind the output rf transformer on a high-permeability toroid. The bifilar modulator windings are made from a slightly twisted pair of a few inches of thin magnet wire (cotton or silk covering increases your confidence in the absence of shorts) closely wound around the core.

The two modulator windings and the tuned output winding are all slightly spaced from one another so coupling will be mainly from flux through the core. The numbers of turns indicated in **fig. 1** worked at 10.5 MHz for a nice mystery core from the junk box. For your own core an easy solution is to use a grid-dip meter and the expected tuning capacitance (add 10 pF or so for strays) to discover how many turns are needed on the tuned winding. The modulator windings are then chosen for the indicated turns ratio.

Another arrangement I have used successfully is a solenoidal tuned winding with the two modulators connected to a quadrifilar winding made from four wires slightly twisted together and wound over the solenoid near the middle. A slug-tuned form is convenient in this case. The turns ratios are not critical. Cup cores are nice if you have small, steady fingers.

Balance pot adjustment also deserves some comment. Originally the usual 1000-ohm pots shown in the diagram were used. Later these were replaced by 100-ohm pots at the centers of pairs of 470-ohm resistors to ease carrier nulling.

This required some diode selection, unnecessary with the 1000-ohm pots. The diodes are 1N270s removed from computer boards, but any rf germanium diode is suitable.

In this diode balanced-modulator circuit an rf bypass is often shown across each 1000-ohm balance pot. Such bypasses will cause balance to occur far from pot center unless the diode back resistances are matched or swamped by about 50k across each diode. The reason is that this rf bypass assumes a steady voltage that applies reverse bias to the diodes. Since the diodes are in series for this bias, they divide it in proportion to their back resistances. Unless they are well balanced or swamped to equality the result is to require an eccentric setting of the carrier balance pots. The rf portions of the unit should be shielded so that balance is unaffected by hand capacitance.

sideband selection

The usual method of switching sidebands in a phasing-type sideband generator is to reverse the phase of one of the audio signals or one of the rf carrier inputs. This is not practical when all modulator inputs are to be single-ended with one side at ground. A dpdt switch could be used to reverse the connections of one pair of diodes to the corresponding modulator output winding, but this destroys the symmetry of the circuit and might degrade sideband suppression. At this point in thought I noticed that interchanging either the two audio signals or the two rf signals would also switch sidebands. Obviously, the audio signals are the ones to switch. I have never seen this method of sideband switching in print but assume the experts are aware of it.

results and afterthoughts

When I built the present unit, the rf phase shift C was computed and a fixed capacitor wired in; the coil was then adjusted to make the two modulator rf input voltages equal. The audio phase-shift network trimpots were then adjusted as described earlier and a voice-modulated signal tuned in on a receiver with a 3-kHz wide mechanical filter. The signal sounded normal. When the sideband switch was flipped only a few faint glitches were audible, indicating satisfactory sideband suppression. As noted, the test equipment used on this project is too rudimentary to permit any fancier assessment of unwanted sideband suppression. Suppression was audibly the same on either sideband position.

Having finished the unit and gotten it working, I noticed that I'd forgotten to include an audio balance adjustment to equalize the contributions from the two balanced modulators. In general such an adjustment should be included. Don't try to do it by twiddling the trim pots in the audio phase shift network. A suggested method is about 10k from one of the points X to ground and 5k pot plus 7.5k resistor from the other point X to ground. These resistors should be in the circuit with the variable branch set at 10k when the trim pots are adjusted.

The very small adjustment that is made to reach exact audio balance will not significantly affect the operation of the audio phase-shift network. If audio balance can't be reached (poor unwanted sideband suppression) look elsewhere for the trouble. A test of the audio phase-shift network can be made by checking that the output voltage at each trimpot (end away from modulator) is exactly half the voltage across the 3-ohm input resistor.

This unit has been on the air with conversion to the 75-meter band, where it was reported as sounding like a good, normal ssb signal. Of course, it also sounded normal, as monitored on my own receiver, before it was put on the air.

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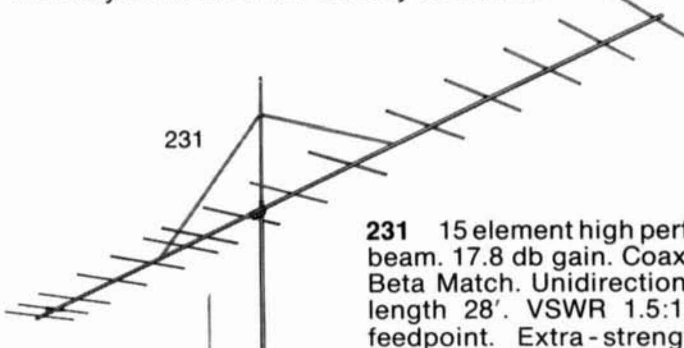

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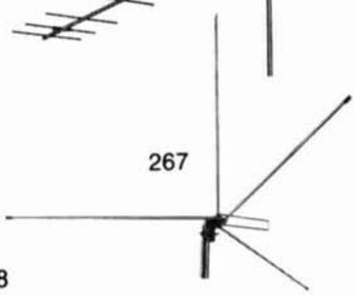

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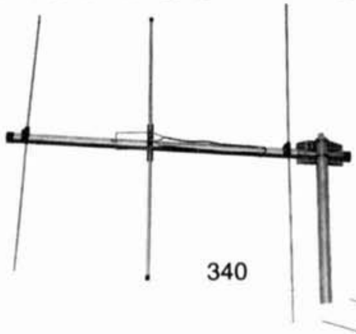

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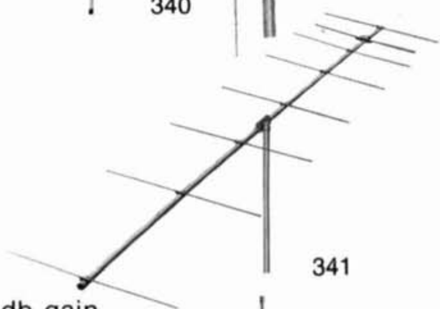
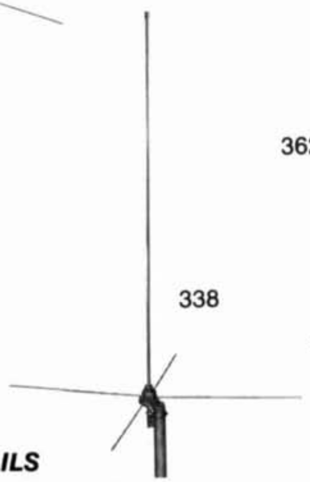


338 Colinear ground plane. 3.4 db gain omnidirectionally. Vertically polarized. 52 ohm match. Radiator of seamless aluminum tubing; radials of solid aluminum rod. VSWR less than 1.5:1. All steel parts iridite treated. Accepts PL-259.



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rf phase meter

An instrument for measuring the phase angle between elements of vertical antenna arrays

R. G. A. Brearley, VE2AYU, and Werner H. Korth, 805 Wake Street, Arvida, Quebec

Vertically polarized directional antennas are popular for use in the 40- and 80-meter amateur bands.[1] Successful operation of these antennas depends on the phase relationship between antenna elements. Described here is an instrument that permits phase-angle measurements within acceptable limits for aligning such antenna systems.

Computer studies[2] have shown that satisfactory antenna performance can be obtained if the lead-lag phase angles are within ±5 degrees of the target (design) figure and the current ratios are within ±5 percent of the target ratios. The phase meter described will perform within these limits to 7 MHz. The circuit uses standard components and is easily calibrated with a vtvm and oscilloscope. The circuit also has inherent lead-lag discrimination.[3]

The phase angle, $\emptyset$, by which waveform A leads B (**fig. 1**) can also be expressed as a time differential, Δt. The phase meter measures Δt, which can be read in terms of an average dc voltage at the output.

functional description

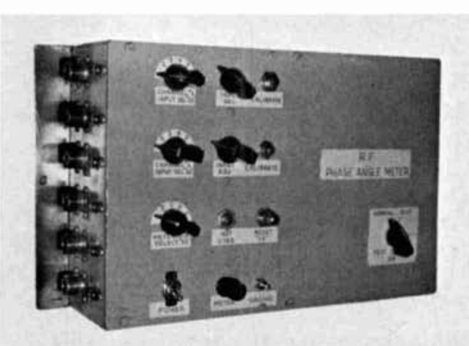
As an aid to understanding circuit functions, the truth tables and timing diagram of **figs. 3** and **4** should be used in conjunction with the block diagram, **fig. 2**.

Channels 1 and 2 are identical up to the Exclusive-OR gate. The input to the Schmitt trigger is provided by the pickup loops, which are not part of the circuit but are placed near the applicable antenna element. The Schmitt trigger squares the positive half of the incoming sine wave, and its output is fed to flip-flop 1.

A flip-flop is essentially an electronic switch. The devices each have two output terminals, one of which is on while the other is off. Every negative-going input pulse will cause the flip-flops to switch state. If, for instance, output A is on, then the next negative-going input pulse will switch A off and B on. The next negative-going input pulse will then switch the device to its original state; i. e. A to on and B to off. Thus, if A is the output terminal, it will be on for every second input pulse, and the input frequency will have been divided by two in the output. Two flip-flops are used in series to divide the signal frequency by four. The first flip-flop in Channel 1 is used to provide gating pulses for each NAND gate.

The Exclusive-OR gate provides an output if either A' or B' is present, but not if both are present or both are absent. Therefore its output consists of pulses exactly as wide as interval Δt, or the lead-lag angle, Ø.

A NAND gate will always have an output except when both inputs are present. The timing diagram shows that for a Channel 1 input leading that of Channel 2, NAND gate 1 output will be at a constant value, which is that of the logic on value. This average dc level will be directly proportional to the lead angle of Channel 1; it will decrease with increasing lead lead angle. If, on the other hand, Channel 2 input leads that of Channel 1 NAND gate 2 output will be creasing lead angle. If, on the other hand, Channel 2 input leads that of Channel 1



Top view of the assembled phase meter.

continuously on, while the average dc level of NAND gate 1 will vary with lead angle. Thus, the circuit provides a linear measurement of the lead-lag angle between two waveforms and also allows an unambiguous determination of which waveform leads or lags in relation to the other.

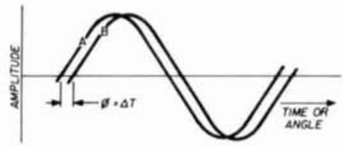


fig. 1. Relationship between two sine waves in terms of phase angle, Ø, and time, Δt.

circuit details

The phase-meter schematic is shown in **fig. 5**. A single pickup loop (for simplicity) is shown connected to the system. The pickup loop acts as a current transformer looking into coaxial lines terminated in their characteristic impedance, Z_O (R1-R6). Potentiometers R20, R21 are used to reduce and equalize input voltages to the logic circuits. The MC1550G and the 2N2369 operate as a combined Schmitt trigger (wave squarer) and interface to drive the following TTL stages.

The circuit was originally developed for use up to 5 MHz.[4] As modified here it's not a true Schmitt trigger but will produce reasonably square waves to 10 MHz. Calibration potentiometers R11, R12 are used to compensate for unequal phase shifts through each channel.

The frequency dividers and subsequent logic circuits must be connected as shown, otherwise errors and confusion in the phase lead-lag determination will result. The output metering points have RC filters that respond to the average value of the square waves. Various RC combinations were tried and did not seem critical. The circuit will work without the filters, but as a matter of principle it's not good practice to have rf hash floating around the chassis. Test switch S4 is used to check the operation of the Exclusive-OR circuit, and reset switch S5 is used to synchronize the channels.

power supply

The power supply is important because the calibration limits of the phase detector (Exclusive-OR) circuit output are 0.09 and 3.8 volts. Originally an unregulated supply was used. During the calibration of the meter these limits changed with variation in the house-current supply.

Since the power supply is mounted externally, the protective diodes are needed in case of wiring errors. The various voltage-dropping resistors ensure equal positive and negative voltages on each of the triggers and give the approximate 3 volts needed for the HI inputs of the flip-flops and gates. If you wish to use a built-in ±5 volt regulated supply, then only R26 and R27 will be needed.

component notes and layout

Details of the pickup coils are shown in **fig. 6**. With the transmitter running at 40 watts input, sufficient voltage was available to drive the meter. Although the length of the cables between coils and meter is not important, *all* cables must be the same length.

It is absolutely essential that the terminating resistors, R1-R6, are non-inductive. We used the meter described in reference 5 to check a couple dozen carbon ¼-watt resistors to find six suitable 52-54 ohm components.

The meter has six inputs rather than three so that phase angles in the antenna power divider could be measured as well as those between the antenna elements. The meter has two types of input connectors, which further enhances its versatility.

Wiring to the input selector switches must be as shown to avoid phase-shift errors (see the schematic and the bottom view of the chassis). Diode probe circuits C1, CR1, R7 (channel 1) and C2, CR2, R8 (channel 2) must have leads as short as possible. However, the wiring between R7, R8 to switch S3 can be 4 inches long, unshielded.

As can be seen in the photos and the component layout sketch, **fig. 7**, most of the circuit is on a PC board fitted with twelve 8-pin, dual in-line sockets. The

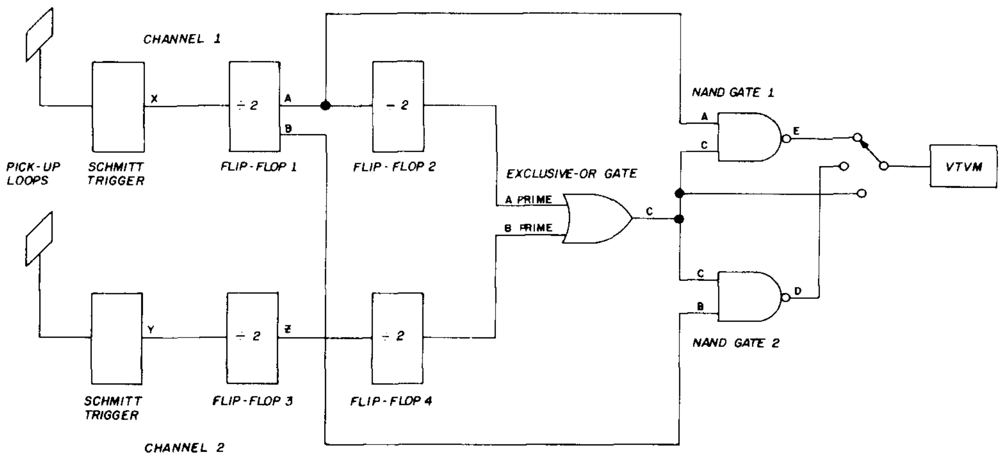


fig. 2. Functional block diagram.

input		output	input		output							
A	C	E	A'	B'	C	A'	B'	C	A	B	D	E
0	0	1	0	0	0	0	0	0	1	0	1	1
0	1	1	0	0	1	0	0	0	0	0	0	0
1	0	1	1	0	1	1	0	1	1	0	1	0
1	1	0	1	1	0	1	1	0	0	1	1	1
NAND gate 1			**exclusive-OR**			**combined logic**						

fig. 3. truth table.

board happened to be on hand and permitted about a dozen different variations in circuit layout, which accounts for the general disorder shown. If the project were to be started again, stick-on "Circuit Zaps" and a perforated board would be used. Note that wiring must be as direct as possible for the rf circuits. For example, switch S4 must be mounted near the flip-flop to which it's connected.

Voltage-dropping pots and isolating chokes are on a separate board and its location isn't critical. Number 26 hookup wire was used throughout, and coax was used only at the switches and Schmitt trigger inputs.

Carbon resistors rated ¼ watt should be used, because they perform well at high frequency. Pots R11, R12, R20, and R21 should be carbon. Chokes L1, L2 aren't critical but are needed to isolate the Schmitt triggers.

initial adjustments

The only test instruments needed to align the phase meter circuits are a scope with a 5-MHz bandwidth, an rf probe, a Heath vtvm, and an rf signal generator.

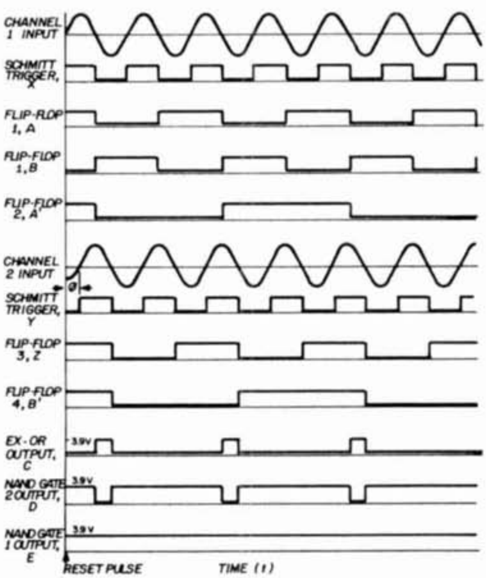
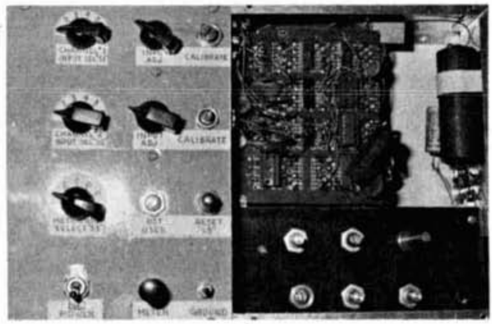


fig. 4. Timing diagram. In this example channel 2 lags channel 1 by Ø = 90 degrees. Note that the average values of C, D, E correspond to those in the calibration curve, fig. 8.

The following procedures should be followed for initial adjustments.

Before plugging in any devices, turn on the power and ensure that the correct polarities appear at the various device terminals. The power supply used here



Top view with cover removed.

provided ±5.8 volts at the input to the phase meter circuits. When all devices were installed, the voltage appearing after the protective diodes was about ±4.9 volts.

After checking voltages, turn off the power, connect the vtvm to the meter terminal of S3, and plug in the 7473s and the EX-OR gate devices. Adjust R26 for 3.0 volts at the EX-OR gate HI outputs. With S3 at position C and S4 in the normal position, the vtvm will indicate either 0.09 volt or 3.8 volts, which are the LO and HI outputs of the EX-OR gates. Pressing reset switch S5 will cause the 3.8 volts to decrease to 0.09 volt; or, if the reading is already 0.09 volt, pressing S5 will make no difference. Very often when the power is switched on, the reading will be 0.09 volt and no amount of pressing the reset switch will produce 3.8 volts; this is normal. With switch S3 still at position C and switch S4 in the opposite position, the meter will read 3.8 volts, and pressing the reset switch will have no effect.

Return S4 to normal and turn S3 to D and E, which are the NAND gate outputs. Normally 3.8 to 3.9 volts (HI) will be found, and no amount of pressing the

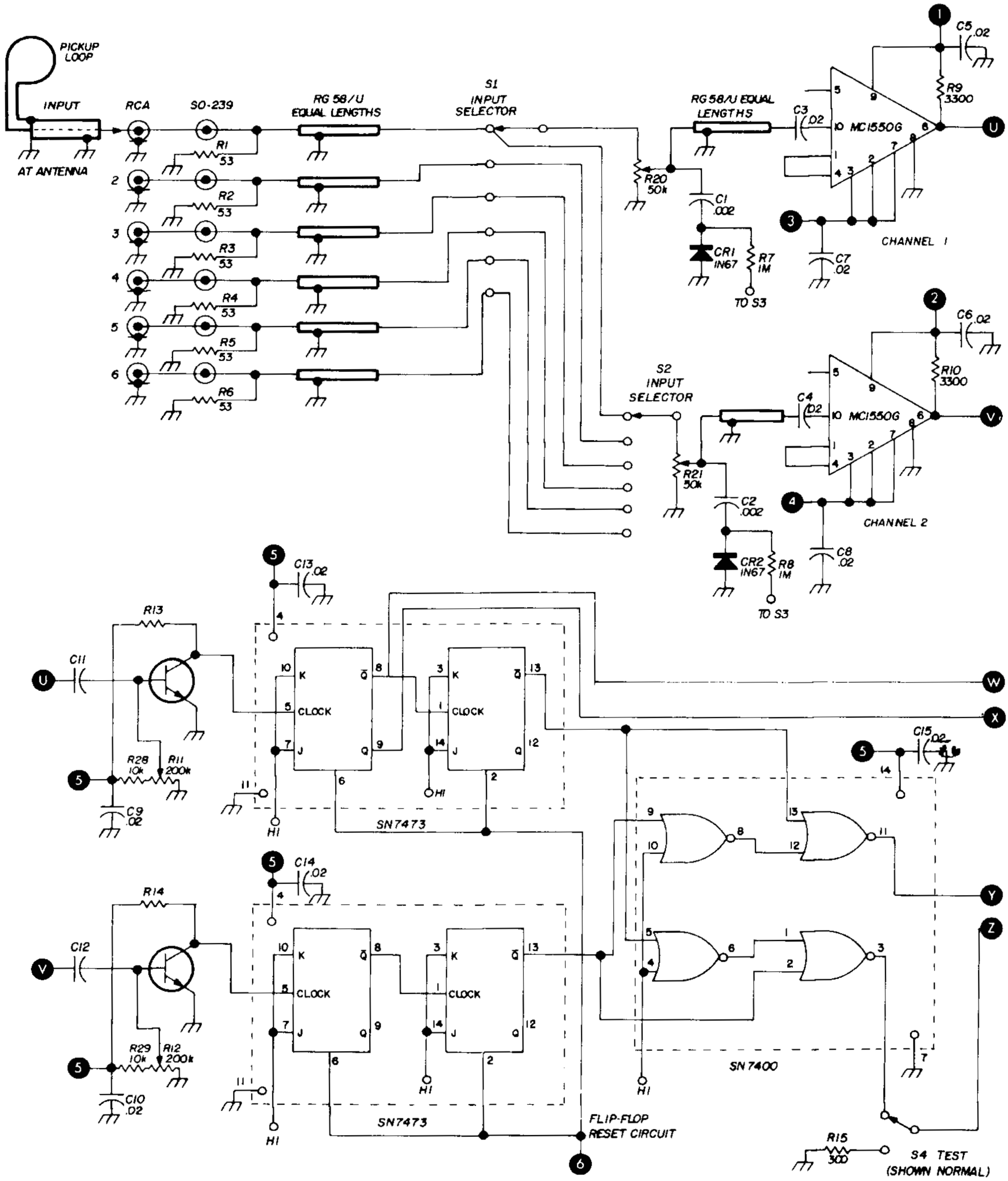
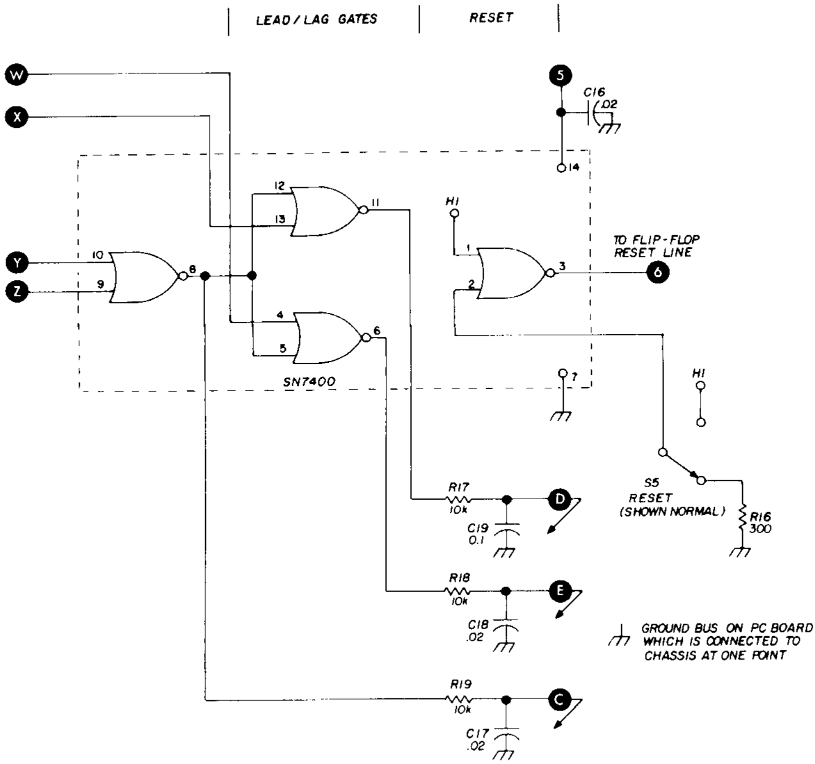
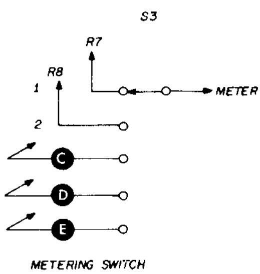


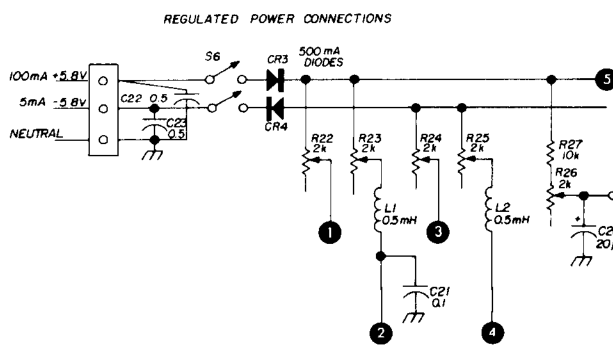
fig. 5. Phase meter schematic.

reset button should change this. With S3 at the opposite position, the meter will read the LO of the NAND gate. Note that the values of HI and LO depend on IC construction and the values mentioned here just happen to be what were found with these particular devices. If you don't get the above sequence of voltages you've made a mistake somewhere, and any further steps will be just a waste of time. Plug in the MC 1550s and 2N2369s and adjust the supply voltages by means of R22, 23, 24, 25 so that positive and negative voltages are equal at the IC terminals.

It's possible to adjust the instrument







at 7.5 MHz, but if difficulties are found it's easier to see where you're going at a lower frequency of, say, 1 MHz, where a relatively inexpensive scope will give a good picture. Hence the following procedure is based on 1 MHz, and one channel at a time will be aligned.

With S1 at Input 1 and R20 at maximum voltage, connect a signal level to produce about 0.2 Vdc on the meter. With the scope probe at the output of FF 2 (pin 13) you may be lucky and see some fuzz on the first shot. If not, slowly turn R11 one way or another until you do. Then increase the frequency slowly to 7.5 MHz and, if the fuzz disappears, readjust the pot until it reappears. Check that pressing the reset switch will make the fuzz disappear. If the fuzz cannot be controlled by the pots, then lower the values of R28 and R29 slightly.

Repeat the procedure for Channel 2 with a signal at input 2 and S2 at Input 2. Next, put the two channels in parallel via S1 and S2, and feed in a signal at 1 MHz

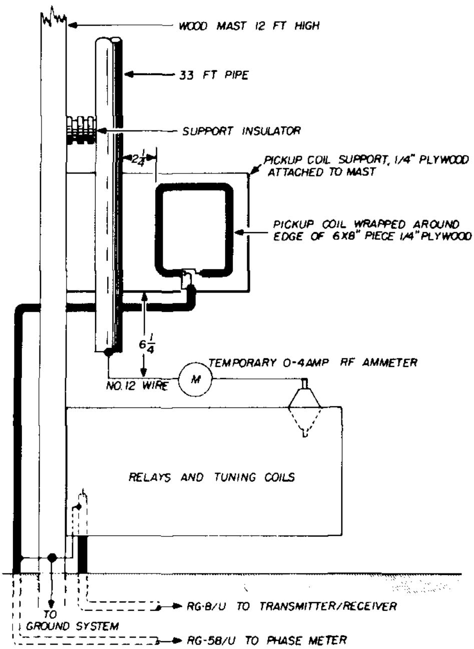


fig. 6. Antenna pickup loop details. The pickup coil must be in the plane formed by the L of the support pipe and the no. 12 wire.

(the pot setting for 7.5 MHz will also be good down to 1 MHz). Adjust R20 and R21 for equal voltages with switch S3 in positions 1 and 2 and switch S3 to C. The reading here will likely be anything up to 3.8 volts, and the object is to get it as close to 0.09 volt as possible. Press and release the reset button to ensure that 0.09 volt is possible. By carefully readjusting R11 and R12 the reading can be brought down to 0.09 volt. Then, when frequency is increased to 7.5 MHz, this reading will rise to about 0.18 volt. Further adjustment of R11 and R12 will bring this down to about 0.12 volt, which is at zero degrees of the calibration chart, **fig. 8.** Values of 3.7 and 3.9 volts should appear at positions D and E and these are also on the chart. If you can't get C down to 0.12 or 0.11 volt, then something may be wrong with metering circuits R20, C1, R7.

The meter is working in every respect when the above readings are obtained. Input signals as low as 0.05 volt and as high as 0.6 volt gave equal phase angle readings for a given length of test cable. A somewhat annoying feature of the basic circuit is that it covers 720 degrees, as shown on the timing diagram. This means that a phase angle of, say, 30 degrees gives a reading of 0.25 volt and also a reading of 390 degrees at about 2.05 volts. Hence, when the zero adjustment is made, the meter will occasionally pop up to 1.8 volts, and the reset switch must be pressed to bring it back to the proper value. This causes no ambiguity because the D and E readings change accordingly and, as will be explained in the next section, the sum of any two valid C readings must be around 1.88 volts.

calibration

The secret is to find six readings that correspond to a known lag or lead condition and plot the data. For example, with a signal frequency of 3.8 MHz fed to Channel 2 and a cable length of 45 ft. 9 in. connected between Channel 1 and Channel 2, Channel 2 will lead Channel 1 by 96.5 degrees, assuming a cable velocity factor of 0.66.

table 1. Channel 1 and 2 phase angle as a function of calibration voltage.

test	switch 3 position	meter reading (volts dc)	
	C	0.55	
1	D	3.34	Channel 2 leads Channel 1 by 96.5 degrees
	E	3.39	
		1.33	
		1.88*	
2	D	2.28	Channel 2 lags Channel 1 by 263.5 degrees
	E	4.03	

*Sum of any two C readings (validity check)

After adjusting the Schmitt trigger inputs to equal values (0.26 volt) and momentarily pressing the reset switch, the readings in test 1, **table 1**, were noted. Pressing the reset switch four or five times changed the values to those shown at test 2, **table 1**.

From the timing diagram and the magnitude of the HI and LO voltages of the EX-OR gate, it is known that a 90-degree lead will correspond roughly to 0.5 volt at C, 3.3 volts at D, and about 3.9 volts at E. The discrepancy at E in test 1 (**table 1**) is annoying but poses no difficulty. The values found during test 2 were about the expected complementary values. Note that the sum of the C readings is always about 1.88, and this fact is used as a validity check at all times.

The six values are plotted on the calibration chart, **fig. 8**. Pieces of coax of 4, 11 and 23 feet were on hand and were combined in various ways to obtain the complete calibration curve. From here on, all antenna measurements are in terms of Channel 2 as reference. Separate calibration curves are needed for 3.8 and 7.1 MHz. It is important that straight lines connect plotted points. Any attempt to draw a smooth curve will lead to frustration and inaccuracies. Note that curves D and E do not give much discrimination between lead and lag in the region of ±30 degrees. However, the readings of the complementary angles will reveal the answer. Sometimes when measuring very small angles (±5 degrees) the complementary angle couldn't be obtained. This problem was resolved by installing coax of known electrical length in series with one input, then repeating the measurement.

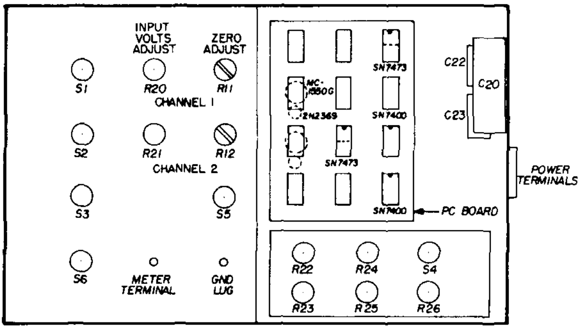


fig. 7. Component layout. Note that the MC1550G and 2N2369 devices are mounted in sockets, which in turn are soldered to the PC-board -mounted dual in-line sockets. (Other ICs are for experiments presently in progress.)

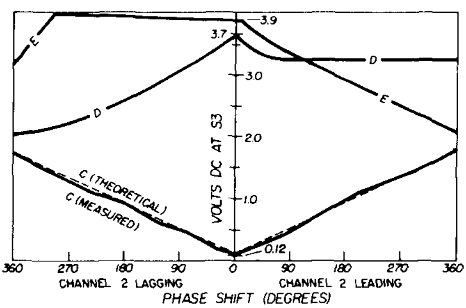


fig. 8. Calibration data for 3.8 MHz. Differences between theoretical and measured values of C are exaggerated to illustrate the need to connect points with straight lines. At 7.1 MHz the lines for C are similar, while those for D and E have the same shape but different values.

experimental notes

By feeding power to one antenna at a time, with the other antenna detuned, the pickup coils were positioned so that the voltage measured on the phase meter was identical for a given current flowing in the antenna. The results of typical calibration runs are shown in **fig. 9**.

To prove out the position of the pickup coils, the antenna elements were fed in parallel pairs, and nearly equal currents and small phase angles were noted. The coax cables to the antenna were of equal length but were only 0.9 wavelength electrically at 7.1 MHz. By increasing the coax lengths to 1.0 wavelength, unwanted phase shift due to high swr was eliminated. With the three antenna elements active and the phase shifters and power dividers correctly adjusted, the f/b ratio (on the air) was 25 dB, which confirmed our design objective. Theoretical antenna patterns are shown in **fig. 10.**

acknowledgements and conclusions

This project was a team effort that included contributors over a wide area. John Ravenscroft, VE2NV, Montreal, provided many ideas and encouragement. Mr. Sam Tilden, also of Montreal, provided the data for the pickup coil design. Norman Tweit and Wes Vincent, Scottsdale, Arizona, contributed the basic Schmitt trigger circuit. George Oshiro provided the basic gating idea. Our colleagues at work provided many suggestions and our employer, the Aluminum Company of Canada, made test equipment available.

Preliminary tests have indicated that this instrument will work at frequencies to 10 MHz, and the limitation is probably due to the Schmitt trigger. The circuit was examined with the aid of a Tektronix scope, and it looks as if the flip-flops are another limiting factor. Operation beyond 10 MHz would probably mean using a different family of ICs, such as the EECL. A PC board would be essential.

If one were to substitute the higher-speed TTL devices, the result would probably be a more linear calibration curve, which would permit the output meter to be calibrated in terms of phase angle.

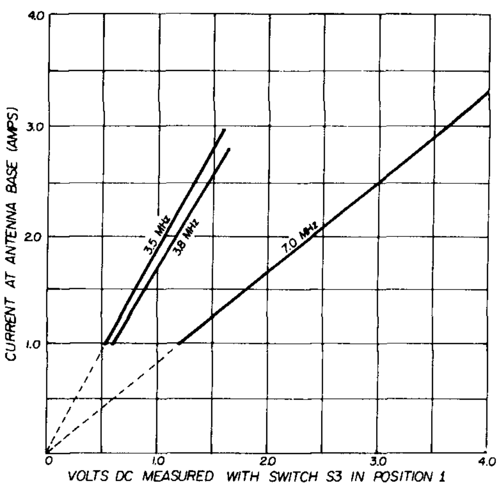


fig. 9. Pickup-coil calibration curves. The rf ammeter available was rated 0-4 A, and the meter scale was not calibrated in the 0-1 A range. Therefore the high-current points shown were used to prove system linearity and to correctly position the pickup coils.

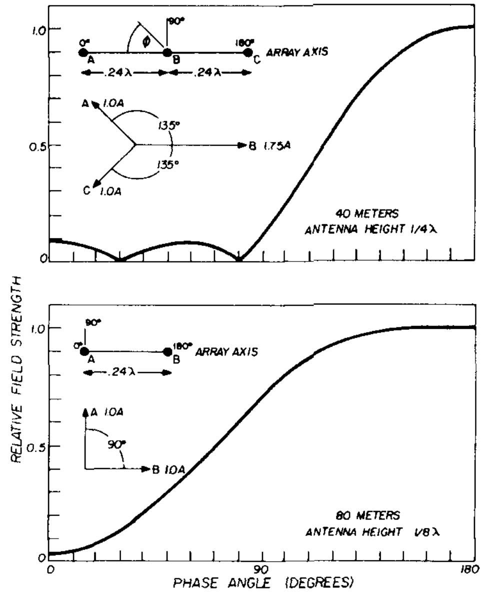


fig. 10. Antenna patterns. Data are shown in Cartesian rather than polar coordinates because null points are more easily identified. Data were plotted with the aid of a computer program (reference 2).

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HINT:— Add a battery charger to a battery-powered solid-state home installation and you can *regularly operate more efficiently.* It'll cost less than most A.C. power supplies. Even Swan's big SS-200 transceiver takes very little power drain from a battery – less than 500 ma on receive and averages about 6 amps when transmitting on single sideband (as low as 0.8 amps average, to transmit SSB on the SS-15).

Another thought – a solid-state mobile installation can mean a savings of up to $140.00 when compared to the special A.C. power supplies that must be purchased for mobile use of conventional tube-type transceivers.

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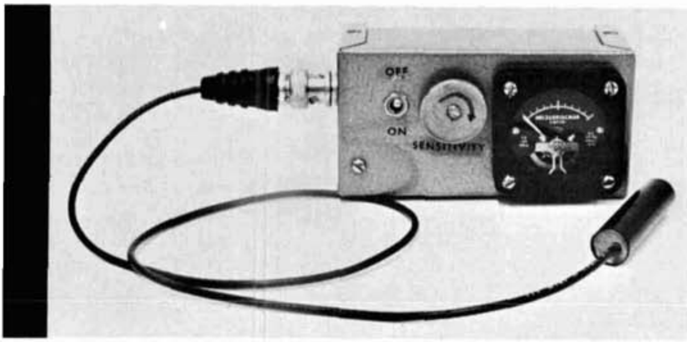

sensitive rf indicator

This high-gain amplifier circuit, when used with a DyComm Sniff-It, provides a sensitive rf indicator — the Snuff Box

D.L. Sprague, WB9DNI, 78 Paddock Street, Aurora, Illinois 60538

For some time now DyComm has offered an rf probe called the Sniff-It. This small black cylinder with a coax tail has proven to be quite useful in providing a dc current relative to an rf field. The manufacturer's instructions provided with the unit describe specific results of various applications, but do not provide general specifications such as frequency and power response. DyComm also has a very tight security rein on the contents of this midget marvel. So we approach the device as the classical black box. . . cylinder.

Art Householder, K9TRG, of Spectronics asked me to design an inexpensive relative rf indicator to be used with the Sniff-It, and the Snuff Box described here is the result of that request.

The Snuff-Box/Sniff-It combination is a portable rf level indicator useful in tracing problems in transmitters or receiver oscillator chains. By making the coax guide, also described in this article, leakage points in coax can be detected.

circuit description

The Snuff Box consists of a continuously variable gain dc amplifier feeding a five-volt meter. The gain can be varied from 1 to slightly more than 100. A μA741 frequency compensated operational amplifier comprises the active element. This device is both reliable and inexpensive. Because the 741 is internally compensated, an external frequency compensation network is not required. The dual inline package (DIP) was selected for the prototype. If desired, the metal can package can be substituted. However, the pin configuration given in **fig. 1** is for the DIP only.

The 741 IC is operated in the non-inverting mode to provide a relatively high input impedance. The input is protected by CR1, is a 5.6 V zener diode. R1 and R2 form a load for the Sniff-It with R1 acting to limit the input current when CR1 conducts. R2 was chosen by experiment as the approximate resistance for the desired power transfer. R3 and R4 form the negative feedback network which determines the gain of the op amp. Gain is represented by A

$$A = \frac{R3 + R4}{R3}$$

R5 and the 1-mA meter constitute a zero to 5 volt meter. The value of R5 is selected so that it's resistance, along with the meter's resistance, will equal 5000 ohms. There are numerous articles available which explain how to determine a meter's internal resistance. The 741 requires a bipolar power supply. I found the simplest to be two matched batteries.

construction

In this project, the meter is the prime consideration. Small 1-mA meters are very common junk box items, as this style was a favorite with military designers for many years. I recommend that the meter selected be of the ruggedized style. Many portable devices with non-ruggedized meters get quickly returned to the junk box!

Select the box for the meter. The prototype was built in a 2 x 4-inch Minibox. Layout is not critical. It's a good idea to use a socket for the μA741, as unsoldering 14 pins is a pain.

As purchased, the Sniff-It is not equipped with a connector. I suggest either a phone plug or a BNC type. Both are quick disconnect, and provide adequate shielding for low levels of dc current. However, the BNC is superior for high rf fields.

coax guide

Take two 3/8-inch cable clamps and cut as shown in the photograph. Pop rivet or bolt the two clamps together back to back, keeping them at right angles to one another. The Sniff-It will fit into one, leaving the second open to guide along RG-58/U coaxial cable.

operation

Let's examine the sensitivity of the Snuff Box. With R4 fully shorted, the

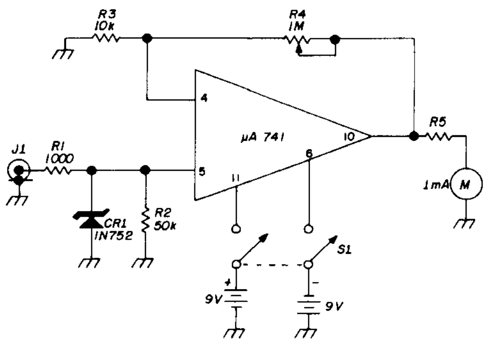

fig. 1. Circuit for the Snuff Box. DyComm Sniff-It is plugged into J1.

μA741 produces unity gain. Therefore, 5 volts across R2 will cause a full-scale deflection of the meter. This means that a current of 100 μA is being produced by the Sniff-It. Now, with a gain of 100, it will take only 1 μA for the highest setting of R4 to produce a full-scale reading. This sensitivity was sufficient for me to find the oscillating receiver crystal in my Regency HR-2.

DyComm's instruction sheet has many suggestions for the applications of the Sniff-It. The Snuff Box is ideal for most of these applications.

This unit is an invaluable aid in checking for rf on power supply leads, leaks in transmitter and antenna tuner cabinets, or for neutralizing detection. When peaking tuned circuits in a unit, the Sniff-It/Snuff Box is much handier than a grid dipper if you are just looking for maximum indications, since no tuning is necessary.

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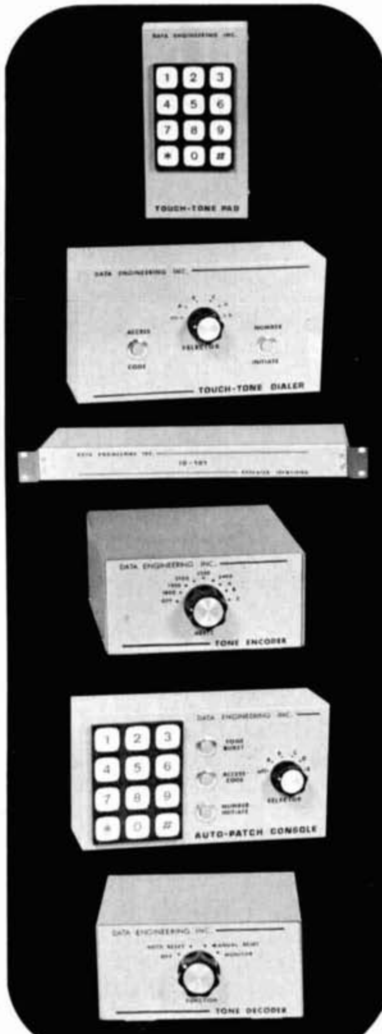

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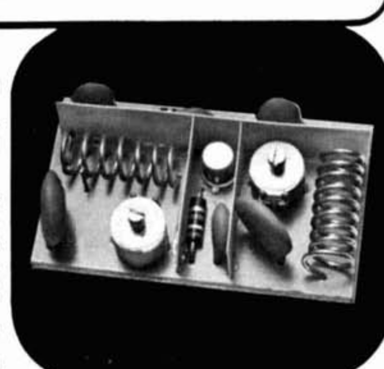
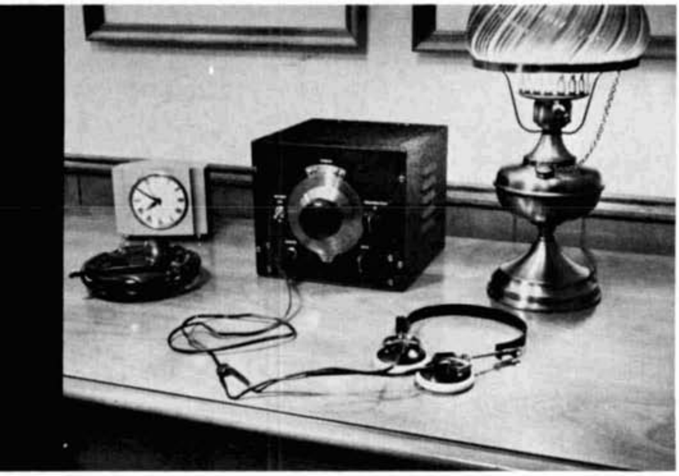




simple regenerative WWV receiver

This low-voltage WWV receiver tunes from 4.7 to 15.5 MHz, and is powered by one 1.5-volt flashlight battery

Courtney Hall, WA5SNZ, 7716 La Verdura, Dallas, Texas 75240

The receiver described here has a frequency range of approximately 4.7 to 15.5 MHz; this covers three of the WWV frequencies as well as the 20- and 40-meter amateur bands and several foreign broadcast bands. Its simplicity and economy are enhanced by the fact that it operates from a single flashlight battery.

I chose a regenerative detector because it will perform well with a-m, CW, or ssb. Regenerative detectors use positive rf feedback to obtain large amounts of amplification and very high Q in the input tuned circuit. As feedback is increased, Q and gain increase until a point is reached where the detector goes into oscillation. When oscillating, the detector provides its own bfo signal. All of the selectivity is obtained in the single front end tuned circuit, thus cross modulation and/or intermodulation interference is very low because unwanted signals don't reach the first transistor.

battery power supply

By designing the receiver to operate from a single flashlight cell, a consider-able saving in battery expense has been achieved; also, battery changes are required much less frequently than if the popular 9-volt transistor radio battery is used.

Table 1 shows data extracted from battery performance curves in the Burgess Engineering Manual, 1967 edition. Only ordinary carbon-zinc batteries are shown. End-of-life voltage in each case was arbitrarily chosen to be 1.2 volts-per-cell, and all data is for continuous discharge at 70° F.

In comparing batteries, the important parameter is capacity in milliampere-hours; the 9-volt battery will supply 1 mA for 400 hours, but the D cell will supply 1 mA for 3200 hours, eight times as long as the 9-volt battery.

table 1. Carbon-zinc battery performance.

battery type	load current (mA)	life (hours)	capacity (mA-hours)
9 volt	1	400	400
AA	5	180	900
C	5	330	1650
D	20	160	3200

When you consider that the 9-volt battery may cost twice as much as the D cell, the cost-of-operation factor is about 16 to 1 in favor of the D cell. The above rational assumes the 9-volt circuit would draw the same current as the 1.5-volt circuit. If, however, the two circuits were designed to have the same output impedances, the 9-volt circuit could draw about six times as much current, making the cost-of-operation factor 96 to 1 in favor of the D cell.

headphone power

I used a subjective listening test to determine whether a 1.5-volt circuit could drive a pair of 2000-ohm headphones. The phones were connected to a 1-kHz audio oscillator, and an ac voltmeter used to measure the voltage across the phones. **Table 2** shows the results. Since 300 mV rms is about 0.85-volt peak-to-peak, and since an amplifier having a 1.5-volt supply should be able to have an output swing of 0.85-volt peak-to-peak, there should be more than enough power available to drive the phones.

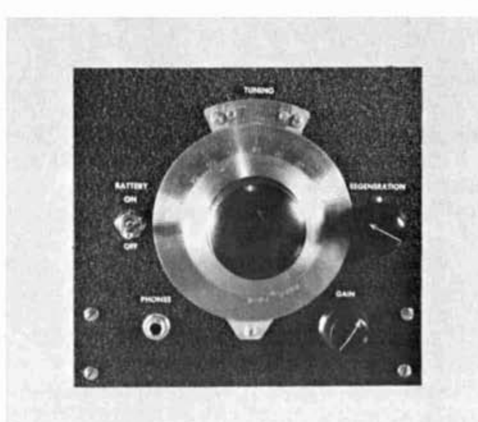
table 2. Headphone loudness vs supply voltage.

headphone voltage (mV rms)	power to headphones (microwatts)	observed loudness effect
2	0.002	detectable
30	0.45	comfortable
100	5.0	desirable
300	45.0	excessive

threshold howl

A common trouble in designing regenerative detectors is threshold howl. This is a loud audio-frequency oscillation heard when the regeneration control is advanced to the point of rf oscillation. It is caused by the circuit squegging or going in and out of rf oscillation at an audio rate. This is similar to the action of a superregenerative vhf detector which starts and stops its rf oscillations at a rate somewhere around 100 kHz.

According to Terman,[1] the tendency to have intermittent oscillations is reduced by decreasing the R-C time constants associated with the bias network. I had no trouble with threshold howl after I reduced the collector and base resistors of Q1 to the values shown in **fig. 1**. The



WWV receiver is built into an old Bud enclosure that was picked up at a swap-fest.

22-pF base coupling capacitor of Q1 should not be increased.

circuit

Fig. 1 is a schematic of the complete receiver. Battery drain is less than 1.5 mA.

Measure the dc voltage between the collector of Q4 and ground with a 20,000 ohm-per-volt vom or a vtvm. The audio gain should be set at minimum for this test, and 10 seconds allowed for the amplifier to stabilize after it is turned on. If the voltage is not in the range of 0.75 to 0.85 volt, substitute different size resistors for R_{fb} until the voltage is about 0.8; larger value resistors will raise the voltage, and smaller ones will lower it.

The large coil stock was used to make it easy to experiment with tap positions. Antenna coupling is varied by means of a minigator clip from the antenna terminal which can be clipped to the coil at any point. The emitter tap is one turn from ground. A 51-ohm resistor from emitter to ground was necessary to ensure that oscillation could be stopped at all frequencies; it also stabilizes the circuit against antenna impedance variations.

There is nothing critical in the construction of the receiver, but, as usual, electrical stability is improved by mechanical rigidity, and short leads should be used in the detector circuit. The Bud C-973 cabinet, with chassis, and the National type N-2 dial were salvaged from an old vacuum-tube vhf converter I bought at a swapfest for a dollar. The photographs show how the tuning capacitor is mounted to a 1.5-inch aluminum angle and coupled through a flexible coupling to the dial. Not shown is the rf choke and audio amplifier which are mounted below chassis. All detector components are mounted to solder terminal strips, and the audio amplifier is assembled on a piece of Vectorbord.

Important considerations are the need for a speed-reducing dial because of the high selectivity and wide tuning range, and the desirability of a smooth action ballbearing capacitor for the regeneration control. The regeneration setting is rather critical, and anything you can do to make it easier is quite worthwhile. I used Calectro A1-227 variable capacitors for both tuning and regeneration.

operation

Use a fresh flashlight battery; old ones may have developed enough internal resistance to provide coupling between

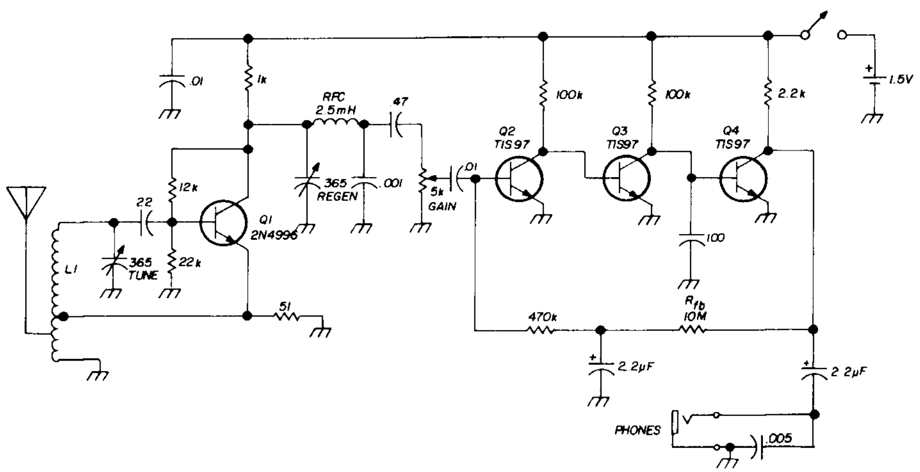


fig. 1. circuit diagram of the low-voltage WWV receiver which tunes from approximately 4.7 to 15.5 MHz. L1 is 3.8 µH (12 turns, 1½" diameter, 6 turns-per-inch coil stock).

circuits which results in undesired oscillations.

There will be about a 10-second delay after the battery switch is turned on before anything will be heard in the phones; this is because of the long time constant of the 10-megohm resistor and 2.2-μF capacitor in the audio amplifier feedback network.

The antenna tap should be set for the best compromise between sensitivity and selectivity. One or two turns from ground is about right for long antennas, but three or four turns can be used with short antennas. If selectivity is poor, move the tap toward ground.

Use only headphones having 2000 ohms, or more, impedance. Advance the regeneration control toward oscillation by increasing its capacitance (this turned out to be counter-clockwise with the variable capacitor I used). When the point of oscillation is reached, a sudden increase in the background hissing noise will be heard; if a signal is within a few kHz of the detector's frequency, a beat note will be heard.

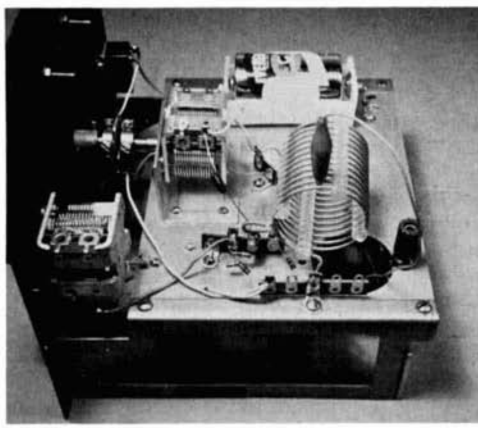
To tune in an a-m station, adjust the tuning dial and regeneration control simultaneously, keeping the regeneration just below the point of oscillation, until the station is clearly heard. There is interaction between the two controls, and some practice will be required to become proficient at tuning. Once the station is tuned in, it may be necessary to back off on the regeneration to eliminate distortion; the selectivity is so narrow at maximum circuit Q that sidebands can be clipped. CW signals should be tuned with the regeneration control set just above the point of oscillation.

With a tuning range of more than 10 MHz on 180 degrees of dial, it is a test of skill to tune in a ssb signal, but it can be done. The regeneration control should be set somewhat higher than for CW, and both tuning and regeneration carefully adjusted until the signal is clear.

High-powered amateur stations nearby can cause overload problems and be heard all across the dial, but this is not unusual, even with receivers of more sophisticated design. Moving the antenna tap toward ground will help.

conclusion

I hope the information above will help those who wish to build a simple general coverage receiver which is capable of good a-m performance. My reason for building it was to avail myself of WWV's accurate frequencies, time signals and propagation forecasts. I am well satisfied. Some will consider the critical two-handed tuning procedure a serious disadvantage, but I don't; things that require skill are more fun to do.



Construction of the WWV receiver. Audio amplifier is built on perforated board mounted underneath the chassis.

To my knowledge, this receiver is unique in that it can give good shortwave performance using a single flashlight battery power supply. Field Day enthusiasts and campers might consider adding a bandspread control for portable hamming. Regenerative receivers aren't as good as direct-conversion for CW and ssb, but they work.

reference

1. F.E. Terman, *Electronic and Radio Engineering,* 4th edition, McGraw-Hill, New York, pp 491-492.

ham radio

Heathkit® 2-Meter FM gear is here!

***• All solid-state design • Can be completely aligned without instruments • 36-channel capability** — independent push-button selection of 6 transmit and 6 receive crystals **• 10-Watts Minimum Output** — designed to operate into even an infinite VSWR without failure **• Optional Tone Burst Encoder** — mounts inside, gives front-panel selection of four presettable tones*

The Heathkit HW-202 compares with the best wired amateur 2M/FM rigs. Plus it has: 36-channel capability via independent selection of 6 transmit and 6 receive crystals. Solid-state circuitry with complete built-in alignment procedures using only the manual and the front-panel meter allow operation over a 1 MHz segment from 143.9 to 148.3 MHz. Removable front-panel bezel permits installation of the new Heathkit HWA-202-2 Tone Burst Encoder.

10-15 watts transmission into an infinite VSWR — indefinitely, with no failure! The HW-202 needs no automatic shut-down — it continues to generate a signal regardless of antenna condition. Transmitter deviation is fully adjustable from 0 to 7.5 kHz, with instantaneous deviation limiting. Harmonic output is greater than −45 dB from carrier. The push-to-talk ceramic microphone supplied has an audio response tailored to the HW-202.

Excellent reception — 0.5 uV or less produces 12 dB Sinad, or 15 dB quieting. Output at the built-in speaker is typically 2 watts at less than 3% total harmonic distortion. The receiver circuitry utilizes diode-protected dual-gate MOSFETS in the front end; an IC IF that completely limits with less than a 10 uV signal; dual conversion, 10.7 MHz and 455 kHz via a 4-pole monolithic 10.7 MHz crystal filter. Image response is −55 dB or better. Spurious response is −75 dB or better.

The Heathkit HW-202 comes with two crystals used in initial set-up and alignment, give you simplex operation on 146.94. Kit includes microphone, quick-connecting cable for 12-volt hook-up, heavy duty alligator clips for use with a temporary battery, antenna coax jack, gimbal bracket, and mobile mount that lets you remove the radio from the car by unscrewing two thumbscrews. The HWA-202-2 Tone Burst Encoder provides four presettable pushbuttons for instant repeater access. Fixed station operation is as easy as adding the HWA-202-1 AC Power Supply. The HA-202 2-Meter Amplifier puts out 40 watts for 10 watts in, and externally it's a perfect mate for your HW-202.

Kit HW-202, 11 lbs., mailable **179.95***

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HW-202 SPECIFICATIONS — RECEIVER — Sensitivity: 12 dB SINAD* (or 15 dB of quieting) at .5μv or less. **Squelch threshold:** 3 μv or less. **Audio output:** 2 W at less than 10% total harmonic distortion (THD). **Operating frequency stability:** Better than ±.0015%. **Image rejection:** Greater than 55 dB. **Spurious rejection:** Greater than 60 dB. **IF rejection:** Greater than 75 dB. **First IF frequency:** 10.7 MHz ±2 kHz. ***Second IF frequency:*** *455 kHz (adjustable).* **Receiver bandwidth:** 22 kHz nominal. **De-emphasis:** −6 dB per octave from 300 to 3000 Hz nominal. **Modulation acceptance:** 7.5 kHz minimum. **TRANSMITTER — Power output:** 10 watts minimum. **Spurious output:** Below −45 dB from carrier. **Stability:** Better than ±.0015%. **Oscillator frequency:** 6 MHz, approximately. **Multiplier factor:** X 24. **Modulation:** Phase, adjustable 0-7.5 kHz, with instantaneous limiting. **Duty cycle:** 100% with ∞ VSWR. **High VSWR shutdown:** None. **GENERAL — Speaker impedance:** 4 ohms. **Operating frequency range:** 143.9 to 148.3 MHz. **Current consumption: Receiver** (squelched): Less than 200 mA. Transmitter: Less than 2.2 amperes. **Operating temperature range:** −10° to 122° F (−30° to + 50° C). **Operating voltage range:** 12.6 to 16.0 VDC (13.8 VDC nominal). **Dimensions:** 2¾" H x 8¼" W x 9⅞" D.

$$\text{*SINAD} = \frac{\text{Signal + noise + distortion}}{\text{Noise + distortion}}$$

More Details? CHECK—OFF Page 110

...and here!

NEW Heathkit 2-Meter Amplifier for cleaner FM copy on the fringe... 69.95*

40 watts nominal out for 10 watts in *— requires only 12 VDC supply.*

Fully automatic operation *— with any 2-meter exciter delivering 5-15 watts drive.*

Solid-state design *— all components mount on single board for fast, easy assembly.*

If you're regularly working from a fringe area, the new Heathkit HA-202 can boost your mobile output to 40 watts (nominal), while pulling a meager 7 amps from your car's 12-volt battery.

Install it anywhere...in the trunk, under the hood or dashboard. Use it with any 2-meter exciter delivering 5-15 watts drive. Features fully automatic operation. An internal relay automatically switches the antenna from transmit to receiver mode when you release the mike button.

All solid-state design features rugged, emitter-ballasted transistors, combined with a highly efficient heat sink, permitting high VSWR loads. Tuned input-output circuits offer low spurious output to cover the 1.5 MHz segment of the 2-meter band without periodic readjustment. All components mount on a single printed circuit board for easy, 4-hour assembly. Manual shows exact alignment procedures using either a VOM or VTVM. And installation is just as simple.

Kit includes transceiver connecting cable, antenna connector. Operates from any 12 VDC system — additional power supplies are not required. Add HA-202 power to your mobile 2-meter rig, and boom out of the fringe. **Kit HA-202,** 4 lbs.

HA-202 SPECIFICATIONS — Frequency range: 143-149 MHz. **Power output:** 20W @ 5 W in, 30W @ 7.5W in, 40W @ 10 W in, 50W @ 15 W in. **Power input (rf drive):** 5 to 15W. **Input/output impedance:** 50 ohms, nominal. **Input VSWR:** 1.5:1 max. **Load VSWR:** 3:1 max. **Power supply requirements:** 12 to 16 VDC, 7 amps max. **Operating temperature range:** −30° F. to +140° F. **Dimensions:** 3″ H x 4¼″ W x 5½″ D.

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More Details? CHECK—OFF Page 110

first wireless in Alaska

The frigid weather and frozen tundra were overcome to place a commercial wireless system in operation in 1903

Ed Marriner, W6BLZ, 528 Colima Street, LaJolla, California 92037

At the turn of the century the Alaskan gold rush was in full swing. Army forts had been established to look after the gold seekers, and a reliable communications system was needed. A wireless communications system was established, later to be called the Western Alaska Military Communication and Telegraph System, which eventually employed many radio amateurs who as civilians became speed operators on one of the country's fastest CW nets. They were called WAMCATS.

How did it all start? Historically, it was the first communications system on all of the West Coast of America. During the various Alaskan gold rushes, starting in 1898, towns and camps mushroomed overnight, with plenty of tin horn gamblers and other characters (as described in the poems of Robert W. Service) wandering from place to place. By 1900, better communications than messages by boat or dog teams became a necessity.

In 1900 Congress gave the U.S. Army Signal Corps money to improve wireless communication and charged them with the responsibility for a cable line to Alaska and the interior. This cable line was constructed under great difficulty for the poles had to be set into permanently frozen ground. This was the first of many factors which launched the Army into wireless communications.

In 1903 the U. S. Army had strung

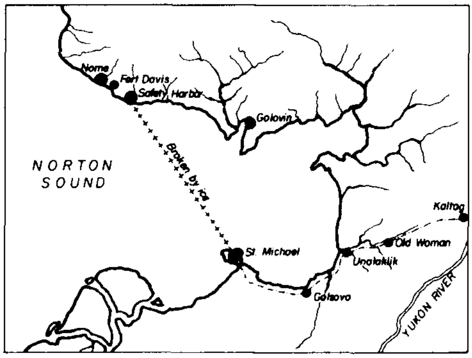
wires to St. Michaels, Alaska, and was faced with the problem of making it to Nome. This meant the choice of going around Norton Sound with a pole line under the worst of primitive conditions or laying a cable which would be carried away by ice each year.

The Signal Corps, by now, had used wireless telegraphy and decided that the last link between the stations at Nome and St. Michaels was to be a wireless one. The entire system consisted of 107 miles via wireless, followed up by 3883 miles of cable to Seattle. This same year, 1903, Dr. Lee DeForest experimented and exchanged satisfactory communication between Fort Safety, Alaska, and these stations which was the final report of the project which started back in 1899.

Leading up to the Alaskan Wireless Network was a report by the Chief Signal Officer who, in 1899, announced that the Signal Corps had devised a system of wireless telegraphy. This was the first publicly operated network in America. Improved in detail, it worked successfully over limited ranges between the harbor fortifications for which it was planned. Recognizing, however, that rapid advances were sure to be made by civilian experts, the Chief Signal Officer decided to adhere in this matter to his general policy. This meant that experimental work would be carried out by the Signal Corps only under those conditions where there wasn't any easy recourse to the commercial and industrial establishments of the United States.

Owing to repeated failure of several wireless telegraph companies to furnish a reliable and satisfactory system of wireless telegraphy in Alaska over a distance of 100 miles, the Chief Signal Officer decided in 1903 to have all existing systems examined with reference to their practical qualities. He decided to obtain by elimination, substitution or invention some system for Army use which would result in the reliable and successful transmission of messages.

The farsightedness of the Chief Signal Officer had already accumulated information and instruments which facilitated the solution of the problem. In addition to the systematic collection of all published data on wireless telegraphy, no efforts had been spared to supplement these by obtaining information from various inventors and experimenters. In addition,



Map showing the wireless circuit between Nome and Fort *St. Michael, Alaska, a distance of 100* miles. This circuit was put into operation by the U.S. Signal Corps in 1903 to replace the cable which was washed out by ice every year.

the Signal Corps purchased sample instruments and installations pertaining to every system that seemed worthy of test where a title to the instrument could be obtained for a reasonable price. In this way they acquired essential parts of important systems. Experimental work in wireless telegraphy had also been done by Maj. Samuel Reber, George O. Squier and Edgar Russel, all Signal Corps people, but none of these officers were available for assignment to the work.

For experimental work in connection with perfecting a permanent plant, Capt. Leonard D. Wildman, a graduate of Stevens Institute of Technology, who had displayed resourcefulness in various phases of field duty, was selected. With full authority to call on Major Reber and Capt. Russel for advice, the accumulated data and instruments were turned over to

Capt. Wildman, who began his work by testing the capacity and efficiency of the Braun-Halske wireless transmitter, a duplicate of the plant which operated successfully during the German maneuvers. While this transmitter was not unsuccessful, its maximum capacity for transmission of messages over 63 miles was not entirely satisfactory.

In addition to determining the best type of field wireless apparatus suited to the Army, he was particularly charged with the setting up of a permanent wireless plant which should be able to work successfully over distances exceeding 100 miles.

The chosen field of operation was between Fort Wright, Fisher Island, and Fort Schuyler, New York, 97 miles apart, of which 20 miles was across land. The use of these forts was a factor in the national defense as it established a wireless system over which, in times of great disturbance, a message could be quickly exchanged between the outlying defenses of New York.

With these ends in view, experiments were carried on under Capt. Wildman's personal supervision during the latter part of the year with instruments purchased from the Lodge-Muirhead Wireless Telegraph Company of Great Britain, the Brau-Siemans-Halske Wireless Telegraph Comapny of Germany, the National Electric Signal Company of Washington, D.C., and from the DeForest Wireless Telegraph Company of New York.

In addition to the instruments furnished by the above companies, experimental apparatus was purchased by the Chief Signal Officer from time to time. Comparative tests were also made between all receivers, responders and coherers on the market, as well as with many different types of special equipment.

Not withstanding the popular idea that wireless telegraphy over great distances was an accomplished commercial fact, *none* of the systems investigated proved satisfactory for Army use. (Have times changed?) Wireless telegraph systems seemed to have been developed by their inventors in the laboratory for their own use rather than to electrical and mechanical standards in which a reliable piece of equipment could be placed on the commercial market.

After an investigation of the existing systems, Capt. Wildman formulated, with the approval of the Chief Signal Officer, the following changes as being necessary for practical military uses:

1. Eliminate the necessity for an absolute electrical ground.

2. Construct all parts of the apparatus so that in case of the failure of any part, that part can be replaced without elaborate machinery by intelligent unskilled labor. Even in those days they had trouble getting technicians.

3. Replace all adjustments which require a knowledge of mathematics, or experience in manipulation by lettered dials or definite switch positions so that highly skilled operators would be unnecessary.

4. Reduce the necessary height of the antenna wires.

5. Produce a receiver which would not only receive the message intended for it, but which could, by adjustment, also receive any electromagnetic wave.

6. Eliminate disturbances due to atmospheric or static electricity.

7. Avoid, as far as practicable, all dangerous high-potential currents at points where there was a possibility of danger to employees.

8. Provide devices which would protect the instruments and machinery from destructive potentials.

9. Avoid, as far as possible, the use of patented devices and the consequent payment of large royalties.

10. Devise a system which could be easily transported in time of war and which would be capable of transmitting messages under all climatic and topographical conditions.

Extended tests were made on the DeForest System which in its original and earlier forms was successfully operated during the Army and Navy maneuvers in 1902 on Long Island Sound. This was the first time the Signal Corps applied wireless telegraphy to military purposes. During these tests the DeForest system barely covered the Schuyler-Wright course. Under the most favorable conditions a signal could be exchanged successfully, but when there were nearby interfering stations, signal exchange was impossible.

Undismayed by the situation Capt. Wildman applied himself to the problem of supplementing and improving the system, to the point that he solved the problem as far as the needs of the Signal Corps were concerned. His improvements were formulated and patented equally in the interests of the United States, to whom the patents were assigned, and of the inventor.

Although the Signal Corps system was not perfect, it was better than any system previously tried. It was not absolutely unbreakable, it could not be operated by men of a low order of intelligence, and it was not entirely free from interference from nearby stations, nor could it be operated during heavy thunderstorms. Although, from the looks of the tests, it did not meet many of Capt. Wildman's specifications, the U.S. Army was eager to give it a try in Alaska. A good substitute for a good electrical ground had been found, the operations and adjustments were simple enough, there was only one place within reach of the operator where there was a destructive potential, and the equipment was decided to be repairable enough.

Messages during the tests were sent daily in great numbers over the ninety-seven mile path for five weeks without any apparent deterioration in apparatus or machinery. The experiments furnished a large amount of accurate and valuable data on placement of antenna poles, their rigging, construction, dynamos and their design, transformers and their durability in moist weather, induction coils and their action, the various methods of tuning the antennas to each other, and to the closed oscillating circuits by which they were fed. The tests proved very valuable.

With the exception of the DeForest receiver, the Signal Corps system had no patentable devices other than those invented and designed by the officers and

Old wireless telegraph station at Fort St. Michael, Alaska. (Photo courtesy U.S. Signal Corps)

enlisted men of the Signal Corps. As usual, the general public recognized that they had been taken in by the extravagant claims of wireless telegraph experimenters. The public would have to wait for experience alone to prove whether the devices adopted by the Signal Corps performed properly when transferred from a temperate climate to places like Alaska where they had to be operated and maintained by unskilled labor in an unfavorable environment.

It appeared for certain, however, that for Army uses this system was better than anything previously available on the market. Time might disprove the utility of some of the features which seemed promising, but the Army felt it was an advance over other wireless systems then in use.

Capt. Wildman was about to tackle the job of installing a communications system in the cold wilds of Alaska, and acknowledged his indebtedness to Major Reber and Capt. Russel for valuable advice and assistance. Special commendation is due Capt. Wildman for the persistent and skillful manner in which he contributed to the efficiency of the Army in perfecting the Signal Corps system of wireless telegraphy. The improvements were largely his own devices. Two patents were obtained by him for wireless inventions and were assigned to the government. He went on to Alaska, completed his task and wrote the following report to the Chief Signal Officer in 1903:

wireless telegraphy

"The system of Wireless Telegraphy devised by the Signal Corps of the Army in 1899 has been improved in details, but its range of operation is limited. It was deemed advisable to stop experimental work along these lines pending the development of this science by experts in civil life.

In 1901, however, it became a matter of practical importance to the Signal Corps to establish wireless telegraphy over extended distances. A contract was made looking into the establishment of the wireless telegraph by the Fessenden system across Norton Sound from Nome (Fort Davis) to St. Michael, about 110 miles. The contractors failed, however, to make the installation and the contract was revoked.

In view of the failure of the contractor to install the wireless system across Norton Sound, Alaska, and in order to meet the desire of the Commanding General, Department of Columbia, for telegraphic communication with Fort Davis, the Signal Corps took up this problem and is now engaged in an effort to install a system that shall work from St. Michael to Safety Harbor, near Nome, Alaska, a distance of about 105 miles. Experimental work with separate and composite systems is being carried out in Long Island Sound by Capt. L.D. Wildman, Signal Corps, with a view to eventually be working between Fort Schuyler and Fort H.G. Wright, a distance of 105 miles, and of which about 10 miles are lowland. For this purpose masts 140 feet high have been constructed, and completed in order to make final tests. Captain Wildman now awaits special motor dynamos and transformers.

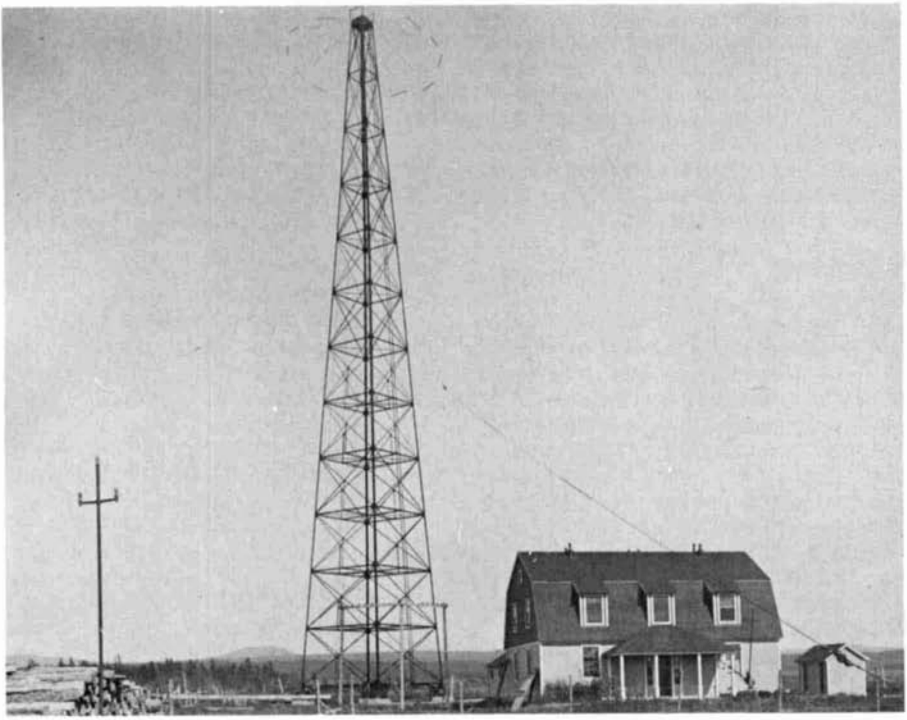
Meanwhile to the delay, installations of masts and antennas are now being made at Safety Harbor and St. Michael, so that whatever system proves satisfactory in Long Island Sound, can be utilized in Alaska by 1904 with the suitable sending and receiving apparatus. At both St. Michael and Safety Harbor the permanent plants are now in process of transportation and erection. There are to be at each station two triple masts 200 feet high, between which are to be a suspended fan shaped antenna, consisting of 125 copper wires one-foot apart. The motor power is to consist of a 5 hp gasoline engine and a 3 kW motor dynamo, 60-cycle alternator. At one station will be a transformer, stepping up from 500 to 20,000 volts, and at the other, stepping up from 500 to 25,000 volts. The large Muirhead receivers, which now seem to be the best available type, are to be utilized in this work unless meantime other experiments produce something superior.

Another contract was made with the American-Marconi Wireless Telegraph Company to establish wireless communication between two points in the Tanana Valley where great difficulties were expected in constructing an ordinary telegraph line and in maintaining it satisfactorily, the contract locating the connecting of two points about 164 miles apart with an intermediate station should the Marconi company so decide. It was hoped that this installation would be made by October 1902, but the contractors were not able to install the system last year. They were at work during the summer of 1903, but to this date no success has been reported. It has, therefore, been necessary for the Chief of Signal Officer of the Army to direct the efficient maintenance of the land lines in the lower valley of the Tanana, such action being imperatively necessary in view of the failure of the wireless installations in a reasonable time.

As we stated in the last annual report, the DeForest system of wireless telegraphy was utilized during the Army and Navy maneuvers on Long Island Sound. This year the same system has been used to replace a broken cable in New York Harbor, between Forts Wadsworth and Hancock, and it has worked most satisfactorily over this distance of 12 miles. In this system a motor dynamo of one kilowatt capacity, driven by the power of the post plant at 110 volts, produces an alternating current of 500 volts at 60 cycles. This runs through a two-kilowatt transformer, which steps up the voltage across the spark gap. Messages are received by the telephone and DeForest responder."

Report to the War Department, Washington, D.C., October 3, 1903

"While communication is now heard regularly by telegraph between the civilized world and the Yukon Valley westward to St. Michael, yet restoration of communication with Nome has so far proved impractical. The cable between Nome and St. Michael was so badly injured by ice, some 40 miles of it having been carried away, that its repair meet the urgent recommendations of the Commanding General, Department of Columbia. Efforts are being made, with prospects of success in 1904, to establish communication by wireless telegraphy



United States Signal Corps station FD at Nome, Alaska, 1903. (Photo courtesy U.S. Signal Corps)

between St. Michael and Nome across Norton Sound, Alaska, a distance of 108 miles."

October 4, 1904, from Capt. Wildman

"The Signal Corps wireless station at Nome could communicate with a similar station on the Kamchatkca Coast, but the infertile and sparsely inhabited country through that section, and it became necessary for the Chief Signal Officer of the Army to undertake through the officers and men of his Corps, a wireless installation across Norton Sound, and work commenced along two lines: First, to install those available and then perfecting the system later. Second, as the short navigable season of four months in Norton Sound rendered it impracticable to

Inside the Signal Corps station FK at Circle City, Alaska, 1909. (Photo courtesy U.S. Signal Corps)

thence to the nearest Russian station of Nikolaevisk would render any such enterprise unlikely should it be suggested. As has been stated in previous annual reports, efforts to establish a wireless system across Norton Sound and in the valley of the Tanana, awarded to different companies under public proposals, failed entirely.

The contract to establish communication was abandoned in its primary stages in one case, while in the other the efforts proved fruitless after two or more years trying to construct a permanent line carry on experimental work in Alaska, it was decided to establish two stations in connection with the coast defenses of the United States, where they would have a permanent value, and after devising a successful typical plant, transfer its sending and receiving apparatus to Alaska."

The arrangements for the temporary plant were made under the general directions of Major Russel, whose special and important duty in connection with the Alaskan cable installation left him but scant time for arrangements, whose executive duty must necessarily be carried out

2,000 miles away by an assistant not under his personal observation.

In the late summer of 1903 the Norton Sound base was established. At Safety Harbor and St. Michael there were built portable houses, in which were installed engines, batteries and wireless instruments, supplemented by two masts at each station 210 feet high, between which were suspended fan-shaped antennas. These poles, the highest ever erected on the Pacific Coast, and the antenna were installed through the resourcefulness and professional skill of Mr. R.D. Ross, a civil engineer employed for this purpose.

Unfortunately, part of the wireless material failed to reach St. Michael because the steamer it was on, the *Meteor*, was disabled enroute. First Lt. A. T. Clifton, with a selected force of signal-men familiar with wireless work, jury-rigged instruments through which meager wireless signals were exchanged during the winter.

Meanwhile, experimental work was carried on in Long Island Sound by Capt. Wildman with separate and composite systems. He eventually devised a composite plant, originally based on the DeForest system, but largely modified by inventions of his own. This plant worked with great success between Fort Wright and Fort Schuyler New York. The transfer of the wireless equipment from Long Island Sound to Norton Sound was accomplished by Capt. Wildman during the next summer. The method of installation was such that the installation was easily made.

Capt. Wildman, at St. Michael, and Sergeant Treffinger, at Safety Harbor, installed their respective systems in less than two days. Capt. Wildman reported that the wireless material was landed and delivered at St. Michael by noon of August 4, and said:

"At 9 o'clock AM on the 6th, complete messages were exchanged, and the telegram from me at Safety Harbor was released and set forward. No serious trouble of any kind was experienced and every part of the machinery worked in a perfectly satisfactorily manner. Since that time we have been pushing the machinery about 20% overloaded in order to see if it could be broken down. The signals are fine and louder than I have ever heard them at either the stations when at Schuyler or Wright. The operators have no difficulty in reading the messages while the relay is working in the same room and with the engine running in the next room and men walking about and talking in an ordinary voice anywhere in the house."

table 1. Callsigns of some of the early U.S. Army Stations in Alaska.

FB	Fairbanks
FD	Nome
FE	Mouth of the Yukon
FG	Fort Gibson
FK	Circle City
FM	Ft. St. Michael
FP	Petersburg
FQ	Ft. Egbert
FX	Ft. Worden

On August 17, 1903, the Nome station was thrown open for commercial business with the rest of the world, and the wireless section of the Alaskan Telegraph System was an everyday adjunct of the electrical appliances of the twentieth century. It daily transmitted the entire telegraphic business of the Seward Peninsula. In one afternoon 5000 words were exchanged between Safety Harbor and St. Michael.

Through the professional skill of Capt. Wildman and his subordinates, the Signal Corps had started operating the longest wireless section network of any commercial telegraphy system in the world. Some of this early equipment was still functioning as late as 1922, in Craig, Alaska. The old 3-kW transmitter was still run by the gas engine, and the transformer, glass-plate condensers, straight open spark gap with cup-like electrodes and plain helix were still going after all those years. Wireless proved itself easier to maintain than telegraph wires.

ham radio

More Details? CHECK—OFF Page 110

how to make your own printed-circuit boards

Complete directions on how to make your own printed-circuit boards — a practical AFSK generator is included as an example

Bert Kelley, K4EEU, 2307 South Clark Avenue, Tampa, Florida 33609

Today's solid-state components are small with terminals close together. Often the mechanical support and the terminal pins are one and the same, and printed-circuit construction eliminates the difficulties of wrapping wires around IC pins only a tenth of an inch apart without shorting adjacent pins. PC boards also solve the mounting problem. Wiring then becomes very easy, high parts density is possible with little effort, and the printed-circuit assembly is rugged — not likely to fall apart under vibration or use.

The main requirement is to carefully plan the parts layout on the board. This may be a different approach from the old vacuum-tube days when wiring began when all the tube sockets were mounted, often without much planning. But planning actually makes the wiring go faster because once the board is etched, the resistors, capacitors, and ICs almost literally fall in place and the project is finished in a very short time. Making your own circuit boards is not at all difficult if you assemble the material and tools I suggest and follow the following instructions.

tools

Many hobbyists already have the few tools required (see **fig. 1**). First of all, you need a tool to cut the circuit board. Phenolic board is brittle and splits when cut by a hacksaw unless it is carefully clamped. If you do much construction work, you will find that a saber saw does a better and faster cutting job and is useful for chassis metal work. You will also need a quarter-inch drill, preferably variable speed.

The drills shown will handle most of the board drilling you will do. I use a no. 60 drill for all IC and transistor leads. IC pins will fit into number-77 holes but I don't recommend them as you might want to remove the component later, and the tight fit only makes the job more difficult. The rest of the drills needed will be in a small drill set. This will cover holes for PC board mounting, transformer mounting, 2-watt resistors, PC pots and the like.

The awl is used to transfer hole markings from a circuit template to the circuit board. This is shown in one of the photos. Crocus cloth is used to smooth the copper side of the board after drilling before application of resist ink.

The soldering iron should have a small tip. A device is shown for removal of solder in case you get solder in the wrong places or want to remove a component from a board. A similar tool is sold by Radio Shack (no. 64-2085). You can also remove solder by using a short length of fresh coax braid as a blotter, but since there is some risk of overheating the circuit board it is better to equip yourself with the proper tools.

fig. 1. A few simple tools are required for building your own printed-circuit boards.

etching stand

For best results an etching stand is necessary **(fig. 2)**. It agitates the solution and gives a uniform, faster etching job. **Fig. 3** shows one large enough for almost any amateur project. It consists of a 1/8-inch aluminum plate (which may be cut from an old rack panel) upon which the plastic etchant tray is placed. The aluminum plate is supported by two hinges at its center of gravity and is tilted by action of a small electric motor, **fig. 4**. The base is cut from plywood. The motor may be from four to eight rpm, such as the motors used to operate small animated signs. They can be found in stores listed in the *Yellow Pages* under "Display Fixtures." Try to locate one with the mechanical linkage attached that fits the small diameter shaft. The detailed drawing and photos show construction and mounting of the motor mechanism.

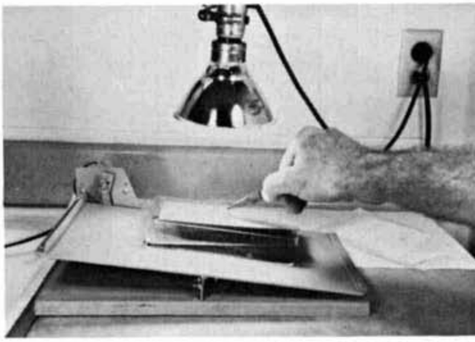


fig. 2. An etching stand is required for best results. Complete construction details are shown in fig. 3. Floodlamp is used to heat the etching solution.

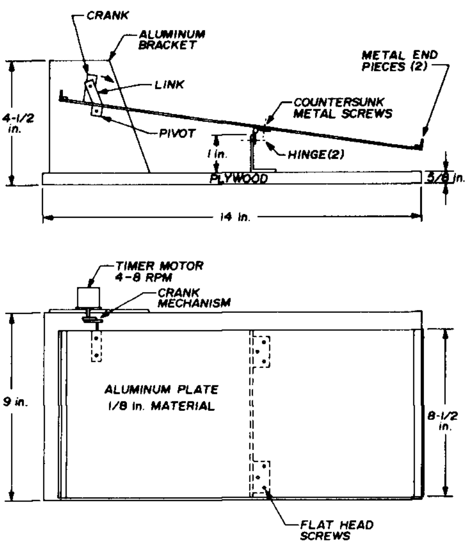
Fasten small aluminum angles or strips to each end of the tilting plate so that large trays will not slide off the stand. Use plastic trays slightly larger than the board you intend to etch; this conserves etchant. Pyrex baking dishes and photo developing trays make good containers for the larger jobs.

A strong light suspended over the etching tray will speed the etching by keeping both the board and etching solution warm. I use an ordinary clamp-on fixture with a 150-watt floodlamp temporarily clamped to a cabinet above the sink. With this setup a board will be completely etched in less than ten minutes.

etching materials

The photograph shows the etching tape, masking tape is the most reliable and covers large board areas well. Any substitute should be tested on a sample board. I use a Kepro RMP-700 resist pen which has a fine enough point to mark IC pins easily and effectively resists the action of the etchant.

The common brown phenolic circuit-board stock, copper clad on one side, is satisfactory for anything except preamps for vhf or uhf. Epoxy boards should be used where better insulation or greater



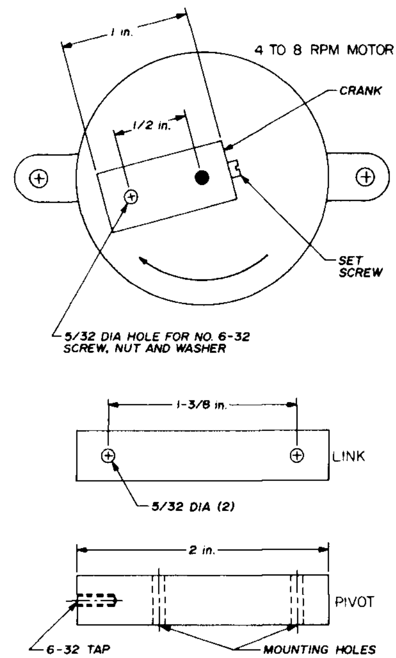


fig. 3. Construction of the printed-circuit etching stand. Sheet of 1/8-inch aluminum can be made from an old rack panel. Motor-drive system is shown on the right. A closeup photograph of the motor drive is shown in fig. 4.

materials that I use (**fig. 5**). There is a variety of materials available, and this is a matter of preference. I find etching powder more convenient to store and keep several bags on hand. Once mixed, the powder should be used immediately as it will not keep it's etching strength. Use only as much as you need and seal the plastic bag so the etching powder will not absorb moisture from the atmosphere. The small bag shown in the photo will do about three 3 x 6-inch boards and costs $1.00. It is sold by Amidon Associates.*

Of the various substitutes for resist such as paint, marking pens, and masking strength is required. Unfortunately, epoxy boards are relatively hard on drills. Double-sided boards are not needed for most projects and only make layout and component removal difficult. However, double-sided boards are used where an excellent ground plane is necessary.

The circuit-board template is made on a 10-line-per-inch ruled pad. Most electronic components have lead spacings that are multiples of 0.10 inch. One-half watt resistors require 5 spaces, IC pins use

*Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607.

1 space, etc., so layout is facilitated by using this paper. It may be obtained at any stationery store.

procedure

All components for the project should be on hand so they can be checked for size when layout begins. You can save here because the layout may be made to fit the parts you have, rather than in reverse. When you must buy new parts get small ones. There is no advantage, for example, in getting large 600-volt paper capacitors when small 50- to 100-volt units will be more than adequate and save much space. Always pre-test the parts where this is practical. Even experienced counter personnel at supply houses will sometimes misread the color code on resistors. Such errors can be difficult to detect after the parts are mounted on the circuit board.

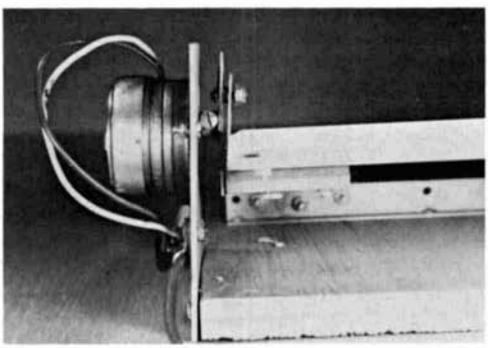


fig. 4. Small electric motor is used to agitate the etching stand.

Lay out the parts on the board roughly as they will appear in the schematic diagram **(fig. 7.)**. Then, consider the layout, move components around in an effort to shorten leads, eliminate possible feedback, space parts more evenly, provide for external connections and reduce trail crossovers. This is the most important phase of the layout procedure. Where possible, refer to the author's original layout or photograph. If this is not given and the project is too complex to visualize as a complete unit, place all the components on top of the proposed circuit board and measure the resulting area. This will give the size of the board needed and the size of the enclosure.

fig. 5. Etching materials are available from a variety of sources.

Now, select the enclosure, if you have not already done so. Miniboxes are available to fit the majority of small electronic projects. Mount the unetched board inside the enclosure. A mounting method that works well is to use threaded brass spacers like H.H. Smith no. 2372 at each board corner. Another simple mount may be constructed by running extra nuts on long 4-40 or 6-32 machine screws and using these for spacers.

layout

Now, make the detailed layout. Every hole in the circuit board should be shown in this layout and every circuit trail should be penciled in as it will appear on the finished product **(fig. 9)**. It helps to

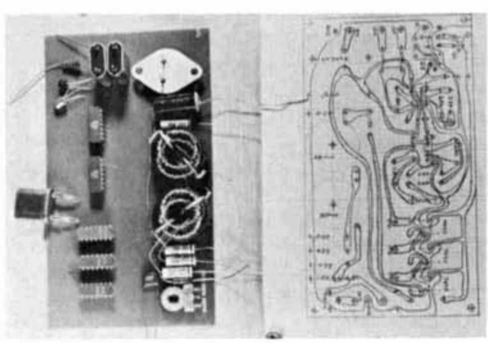


fig. 7. Before starting the printed-circuit layout, lay out the components on the board roughly as they appear in the schematic diagram.

overline a copy of the schematic so that nothing is overlooked. Try to keep trails as direct as practical, and have a minimum of crossovers. On your first few boards you may find it necessary to scrap the first effort and start over, if, during the late stages of the layout a better approach occurs to you. This is the time to make changes — when they can be easily done.

Keep in mind that the components will be mounted on the board with the leads facing you as you make the template. The pin arrangements for ICs are given as top views, while you will be laying out the pin wiring as viewed from the bottom. Also, be sure you have the pin layout for the particular IC you are using because there often are other pin arrangements for different packages of the same type IC.

A sample layout is shown for an AFSK generator intended for radio teletype use (**fig. 6**). The tones are crystal controlled and provide low distortion output. It is not difficult to construct and illustrate the principles of home workshop printed-circuit construction. It will be seen that the board layout closely follows the schematic and only two jumpers have been used. A common ground has been drawn around the outside edge of the board and the metal corner spacers will continue this connection to the case.

A few kinks are useful. The crystals may be made to plug in by using contacts salvaged from crushed miniature tube sockets. They are then spot soldered to

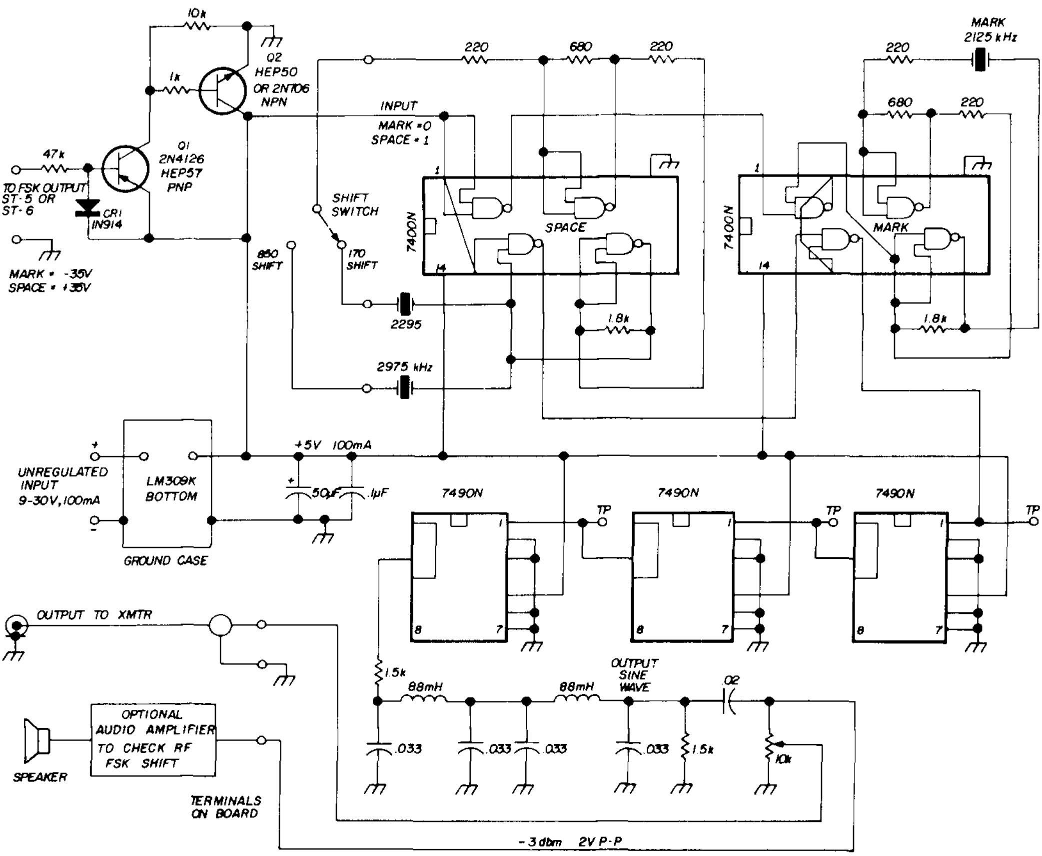


fig. 6. Circuit of RTTY AFSK generator used to demonstrate printed-circuit construction.

the circuit board. Faucet washers make an effective mount for the 88-millihenry inductors. Thread a long 6-32 screw through one. The taper of the washer will center the screw and the resilient washer material will prevent coil damage.

An excellent way to connect to circuit boards is also shown. Force 1/4-inch lengths of no. 12 wire in 5/64-inch holes in the circuit board and etch trails to these points, under the board. These make secure test points or external connection points at almost no cost.

After checking, the completed template is taped to the copper side of the circuit board and the hole centers are transferred to the copper-clad board with an awl, using light hammer blows, **fig. 10.** When all holes are marked in this way the paper is removed and all marks drilled with a no. 60 drill. Larger holes are then located and re-drilled to size. Remove all drilling burrs with the crocus cloth so the board is smooth and ready for the resist pen. Avoid coarse sandpaper as it will scratch the board and make complete application of resist difficult. The etchant will later eat through these scratches causing hairline opens in the circuit trails.

The final step before etching is application of resist ink. This only takes a few minutes since you follow the trail layout you have previously marked on the template. Make the resist trails solid and dark.

The etching stand is set up and the lamp secured in place over it. Mix the required amount of etchant in hot water and float the board, copper side down, in

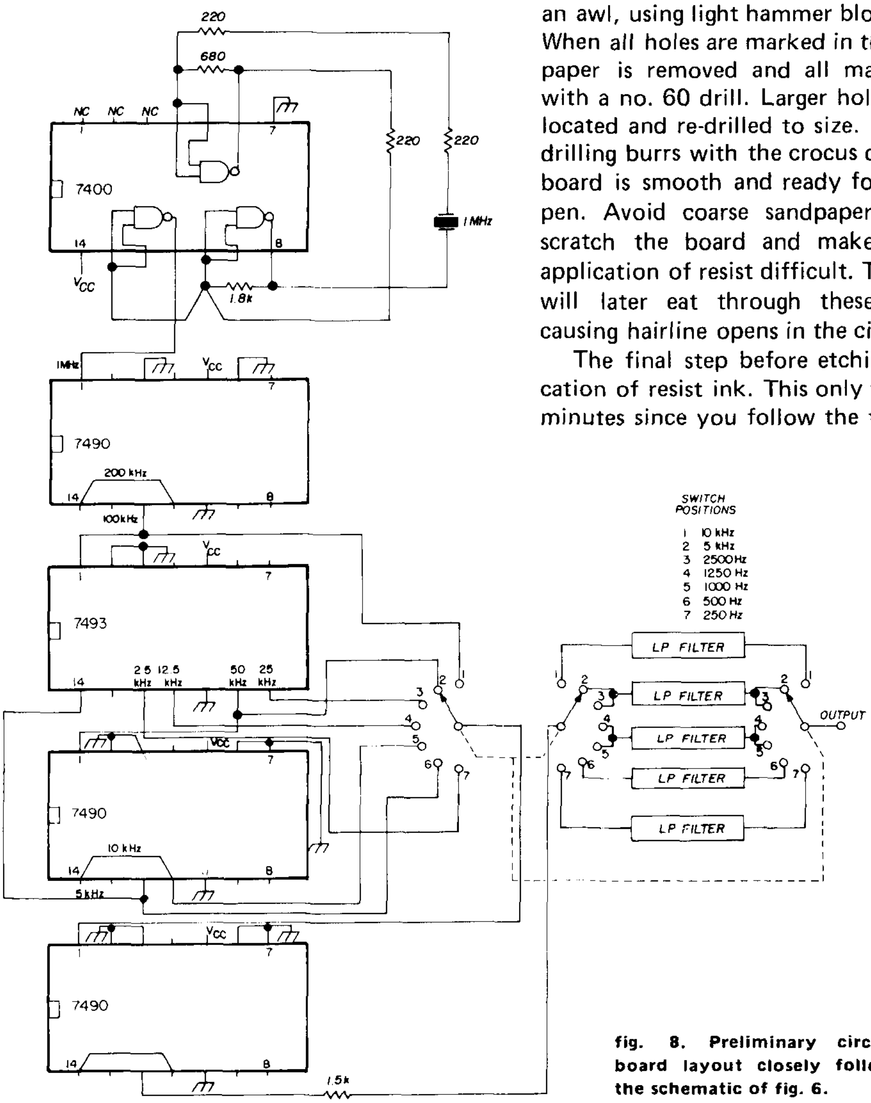


fig. 8. Preliminary circuit-board layout closely follows the schematic of fig. 6.

this solution. The board should be frequently lifted during the etching process to free accumulated air bubbles, **fig. 11.** One way to do this is to attach a small enameled wire through existing holes near the center so that it may be grasped by long-nose pliers. Do not overetch. As soon as the board is finished, remove it from the tray, turn off the light, and wash the board with cool water. Scrub the resist ink off with steel wool. The used etchant will be greenish in color and hot. Handle it carefully, dump it down the drain, and immediately flush with plenty of water.

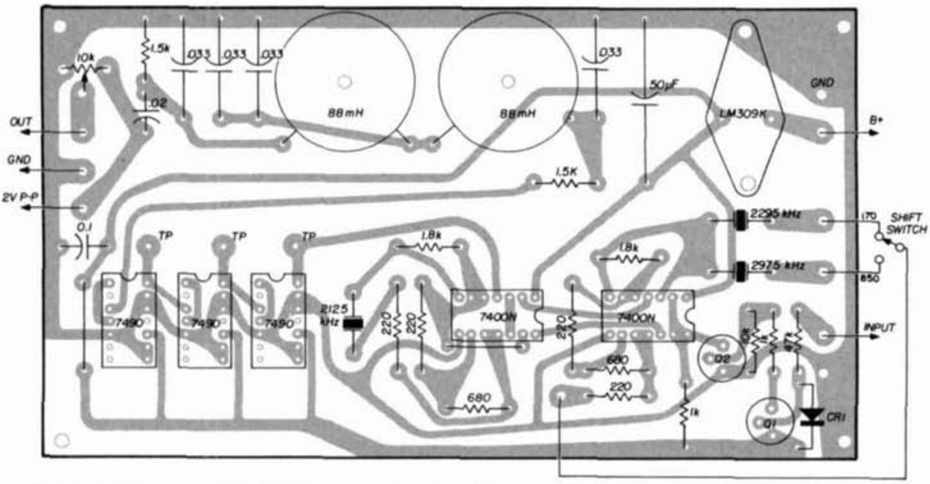


fig. 9. Detailed layout of the AFSK generator circuit board.

weekend project

This audio frequency shift keyer is an example of the type of equipment you can rapidly assemble on your own circuit boards. Though designed for teletype, with slight modifications the same circuit may be used as a crystal calibrator or as a high precision audio oscillator. As a crystal calibrator only one 7400 IC would be needed, a crystal zeroing trimmer added, and a rotary selector switch installed to tap into different points in the 7490 divider chain. Each 7490 IC divides by 5 and then by 2. The divide-by-5 point is at the strap between pins 11 and 14. With a 1000-kHz crystal, 200-, 100-, 20-, 10-, 2-, and 1-kHz outputs would be available. The lowpass filter would not be used.

Perhaps you need a no-drift audio oscillator. Crystals could be selected by plug-in or by rotary switch and different filters switched in as needed. Such an oscillator would not drift even one hertz and would have excellent distortion characteristics. If you want to divide the crystal frequency by some other factor, the 7492 IC will divide by 2, 6 and 12; the 7493 IC will divide by 2, 4, 8 or 16 without changes.

As an AFSK keyer, this unit has excellent performance at low cost. The original design by WB8AAK used RTL

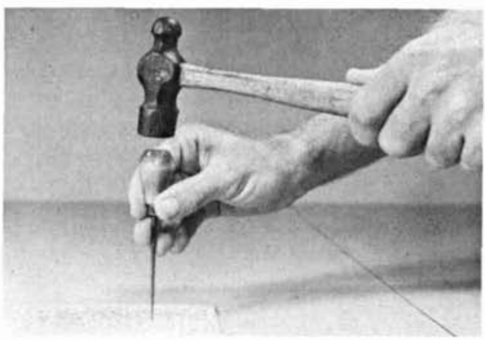


fig. 10. Component mounting points on the paper layout are transferred to the copper-clad board with an awl.

logic. However, the price of TTL devices has dropped so much that it was worthwhile to re-design the circuit to use TTL. The two 7400 gates are 22 cents each and the 7490 decade dividers are only 90 cents each, bringing total logic cost to $3.14. It does not require a counter to set up or adjust.

Even the most inexpensive crystals may be used. JAN stocks the 2125- and 2976-kHz crystals for $1.75 each. Use of a 2976-kHz stock crystal instead of the nominal 2975-kHz crystal only results in a one hertz error in output frequency which is undetectable for most purposes. The remaining crystal – the 2295 kHz unit for 170 shift – may be custom made for $3.00. Everything used in the generator is available from advertisers in *ham radio*. Note that IC supply house prices will be higher than those quoted, which are for surplus devices.

Transistors are another item that may vary considerably in price depending on source. Feel free to substitute. There is nothing critical about the two transistors used in this unit except that they must be silicon types. There are dozens of transistors which may be used. Two types are given as examples.

the circuit

Both crystal oscillators run continuously. Sections of the 7400 ICs gate the oscillator output desired to the 7490 divider string. The output of the 7490 dividers is a square wave which aids in filtering. The TTL dividers are powerful enough to drive the filters and output directly. With the recommended 5 volts on the TTL devices the current drain is 100 mA. The input to the LM309K regulator should be connected to a dc voltage source of from 8 to 30 volts. This may be an existing unit or built for this purpose. The output level is adjustable from -3 dBm down to any value to suit your transmitter.

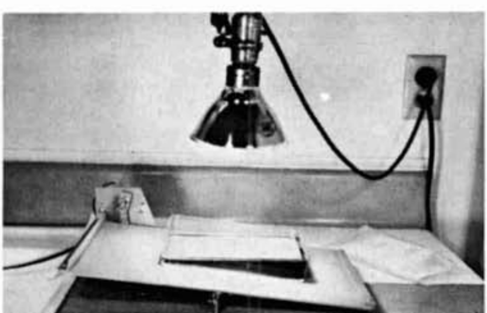


fig. 11. After inking in the circuit traces with the resist pen the board is placed in a tray of etching solution.

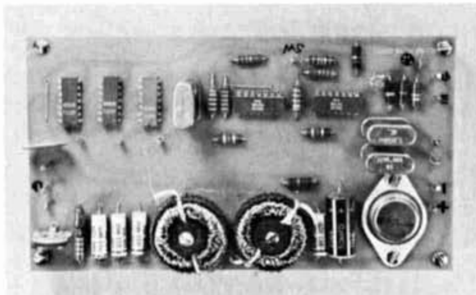


fig. 12. Completed audio-frequency shift keyer board provides crystal-controlled, low-distortion audio tones.

performance

The completed keyer run through checks to verify its performance. The generator was keyed with a 100-Hz square wave and observed on a dual-trace scope to confirm equal *mark* and *space* audio levels and good keying (see **fig. 13**). Filter ringing accounts for the small transient I observed. Frequency measurement with a digital counter confirmed that output frequencies were accurate to the hertz. Several crystals were tried to confirm this.

Audio distortion was then measured on a Hewlett-Packard distortion analyzer with some interesting results. Harmonic distortion measured only 0.25% at 2975 Hz but 3% at 2295 Hz and 4.2% at 2125 Hz. Scope analysis of the distortion products showed them to be almost entirely third harmonic, as was expected. Obviously, the filter was doing an excellent job at 2975 but only fair at 2125 Hz. The filter design was an old standard and had been used in the original design and other highly regarded AFSK keyers when 850 shift was popular.

However, 850 shift is now becoming obsolete. If you use only 170 shift, a minor modification of the lowpass filter will give excellent distortion characteristics. Simply add one .022-μF capacitor across each of the .033-μF capacitors in the filter. The distortion will then measure 1% at 2125 Hz *(mark)* and 0.7% at 2295 Hz *(space)* frequencies. This is good enough so that it may be used with any filter-type ssb transmitter.

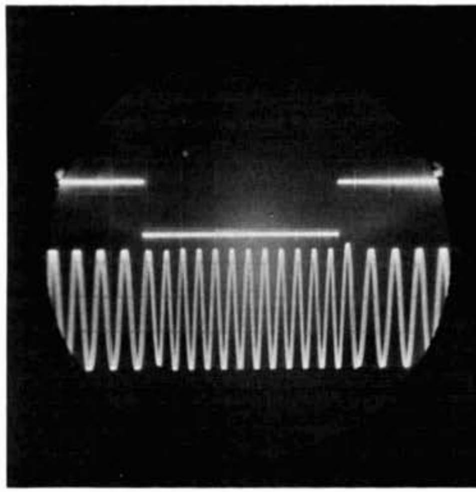


fig. 13. Audio output of AFSK unit provides excellent waveform continuity between mark (2295 Hz) and space (2975 Hz).

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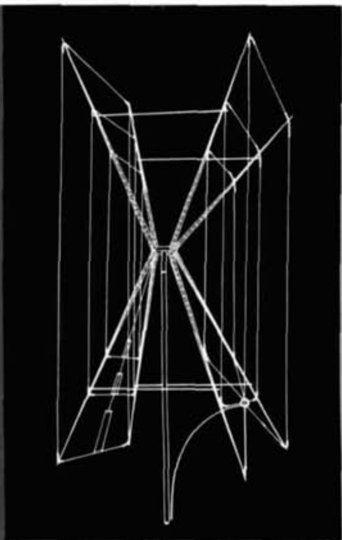
ham radio



USE CHECK OFF ON PAGE 110 FOR FULL DETAILS

speed standards for international morse code

How to use standard words to determine the words-per-minute speed of your keyer

Gaspard Lizee, VE2ZK, 135 Carillon, Sherbroke, Quebec, Canada

In the formation of the International Morse code used by amateurs, there are two basic *sounds* and three basic *spaces*: the dot, which is 3 time-unit or baud, the dash, which is 3 bauds, a space between each element of a Morse character, which is one baud, a letter space of 3 bauds and a word space of 7 bauds.

Numerals are separated in the same way, and punctuation is preceded by a 3-baud space and followed by a 7-baud space. Therefore, the letter E, one dit, consists of two bauds — a one-baud sound plus a one-baud space. The letter T, one dah followed by a one-baud space, contains four bauds. With this in mind, the ratio of the dit with its space to the dah with its space is 1:2.

counting words per minute

If you key a string of dits for one minute at a constant rate to obtain a total of 25 dits you have used 25 bauds for sounds and 25 bauds for spaces, for a total of 50 bauds in 60 seconds. This rate represents one word per minute. If you only count the number of dits, dividing that total by 25 will also give you the keyer speed in words per minute.

However, it's much easier to count dahs, particularly at higher speeds. Since the ratio of dots to dashes (including spaces) is 1:2, simply count the number of dahs per minute and divide that total by 12.5 to arrive at the equivalent speed in words per minute.

adjusting your keyer

To obtain the proper ratio of dots to dashes first count the number of dits per minute. Then adjust your keyer so you have exactly half the number of dahs in the same time span. When this is done your keyer is properly adjusted, including the spaces. For example, if you key a string of 250 dits in one minute, you must adjust your keyer to provide 125 dahs in one minute to provide the proper timing ratio.

To arrive at the word-per-minute speed of this keyer setting simply divide the 250 dits by 25 (or the 125 dahs by 12.5) to arrive at 10 words per minute. To calibrate the speed dial for other speeds simply count the number of dahs in one minute and divide by 12.5. If you want to use less than one minute, count the number of dahs in 24 seconds and divide by 5 – it will give you the same result.

automatic keyers

Automatic Morse Keying heads used by the FCC and ARRL are adjusted to a 50-baud word standard. That standard word is PARIS. If the speed of the automatic keyer is set to send the word PARIS ten times in one minute, the sending speed is exactly 10 words per minute.

If you count the total number of bauds in PARIS you come up with a total of 50:

· — — ·	P	8 bauds sound
		3 bauds element space
		3 bauds letter space = 14 bauds
· —	A	4 bauds sound
		1 baud element space
		3 bauds letter space = 8 bauds
· — ·	R	5 bauds sound
		2 bauds element space
		3 bauds letter space = 10 bauds
· ·	I	2 bauds sound
		1 baud element space
		3 bauds letter space = 6 bauds
· · ·	S	3 bauds sound
		2 bauds element space
		7 bauds word space = 12 bauds
		total 50 bauds

Any other word that has a total of 50 timing units could also be used for the same purpose. It doesn't matter if it has more or less letters so long as it contains a total of 50 bauds.

military stations

Most military stations use a standard 60-baud word to set the speed of their keying heads, using the standard word CODEZ for this purpose. If you count the number of bauds in CODEZ you will come up with a total of 60.

With a 60-baud standard, the number of words per minute appears to be much faster. If you want to experiment a bit, listen to an automatic Morse station that announces its code speed. Copy the station for one minute, count the total number of bauds, and divide by 50. You'll quickly find out what standard they use for setting up their keying heads.

The ARRL code-practice sessions transmitted by W1AW, for example, are based on a 50-baud standard. For comparison, try to copy WAR on a Tuesday evening – it will be much faster than the announced speed. It takes only a minute to figure out that 10 words per minute using the 50-baud standard is only 8.33 words per minute with a 60-baud standard.

The two different standards are a result of two different types of transmission. Most military stations transmit 5-letter code groups; amateur radio operators transmit clear text which uses a larger number of the letters E and I. The two different standards compensate for this difference.

The difference in words per minute with the two standards increases markedly at higher speeds. Sixty words-per-minute clear text (50-baud base) is equivalent to 41.66 words per minute of coded letter groups (60-baud base). This is probably very near the upper possible limit that a human ear is able to differentiate. The current world record, held by the late Ted McElroy, is 75.2 words per minute. This might stimulate someone to suggest a new award, "The Ted McElroy Gold Medal." Anyone interested?

ham radio

the ham notebook

5/8-wave whip for 2 meters

A standard 102-inch Citizens Band whip can be easily converted into either a fixed station 5/8-wave groundplane or an effective mobile gain antenna. Gain for either antenna was measured at about 2.5 dB over a quarter-wave groundplane. Both antennas are electrically sound and do not have mechanical joints to corrode and break down. The overall view of the home-station version is shown in **fig. 1**, and the mobile version in **fig. 2**.

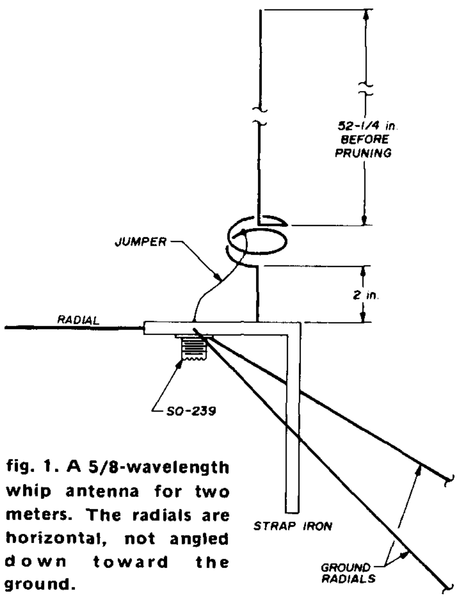


fig. 1. A 5/8-wavelength whip antenna for two meters. The radials are horizontal, not angled down toward the ground.

For the home-station groundplane, measure down 52¼ inches from the antenna's tip and place the antenna in a vise. Using a torch (propane does well), heat the whip cherry red and bend a 90° angle when the metal will allow itself to be bent without undue force. Using a jig made from 2-inch diameter pipe (**fig. 3**), bend the coil slowly while constantly applying heat. Bend 1½ turns with at least ½-inch spacing and finish the coil so that the straight section of the antenna below the coil is lined up with the longer section above the coil. Leave 2 inches of wire below the coil and remove the rest.

The antenna base is made from a seven-inch section of 3/8-inch by 2-inch galvanized flat iron. Drill the flat iron as shown in **fig. 4** for an SO-239 coax

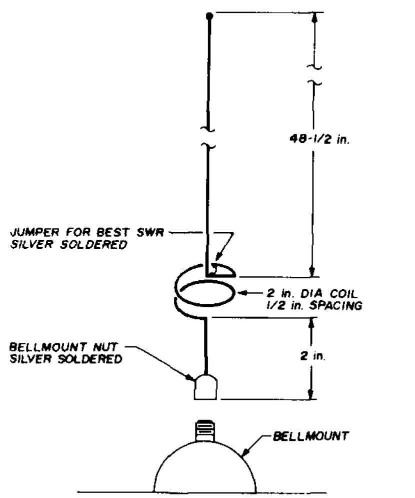


fig. 2. Using the 5/8-wavelength antenna for mobile operation.

connector and its mounting screws. Be sure to ream out the underside of this hole to allow the connector to sit flush with the flat iron. Drill 1/8-inch holes for the ground plane elements and the whip. Heat the iron and make a 90 degree bend as illustrated.

Cut three ground radials from 1/8-inch round rod such as galvanized lathers ceiling rod. Each radial should be 19-inches long. Insert them into the three holes drilled into the side of the bracket and bend the two side radials so there is 120° spacing between all three radials. Insert the whip into its mounting hole until its bottom is flush with the bottom of the hole. Weld or silver-solder the whip and the radials in place. Install the coax connector and solder a short length of solid number 12 copper wire to the center pin (this will go to the tap on the base coil eventually).

The rest of the procedure is simply tuning and pruning. Wrap the free end of the copper wire about one half turn from the bottom of the coil and, with a vswr meter in the feedline, adjust the tap point for best swr. Trim the end of the antenna by filing a notch and breaking off about 1/8-inch of rod at a time. By working back and forth between readjusting the tap and trimming the antenna length, you should be able to tune the antenna for zero reflected power. At this time, silver-solder the copper wire to the coil. Seal around the coax connector and around the copper wire with silicon seal to protect your rf feedline in case of heavy rain or ice build up. It is also worthwhile to paint any spots that might have been exposed to excess heat in the construction. Simply mount the base to your tower or mast.

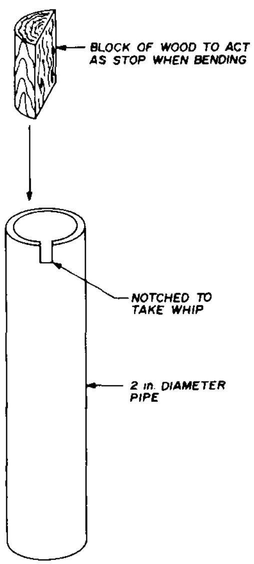


fig. 3. Jig used for bending the base coil (see text).

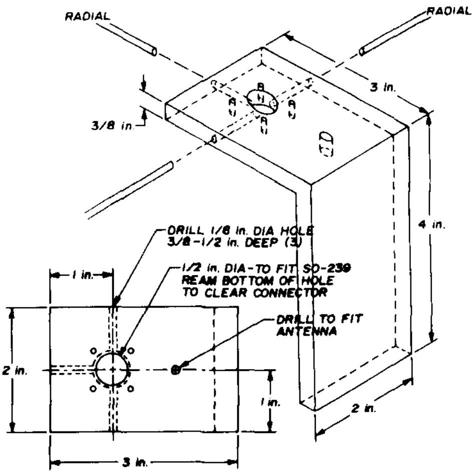
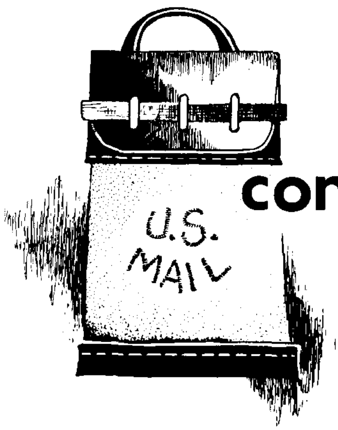


fig. 4. Construction of the antenna base. Horizontal radials are installed and welded in place.

A mobile version of this antenna is made in basically the same manner. The radiator (after the coil) is cut to 48½-inches rather than 52¼-inches, and the base of the coil is connected to an ordinary bell mount. The base coil is wound just like the home-station version. The mobile antenna is not a grounded system, however. It is tuned for minimum vswr by adjusting the tap point for a short jumper from the junction of the base of the radiator section and the top of the coil to a point on the coil. In my case, by juggling the antenna length and the tap point, I found the best tap point by shorting about 1¼ turns. Silver solder the jumper in place.

John Dobroshinsky, VE3DDD



comments

ssb detector

Dear HR:

Regarding the ssb detector circuit on page 68 of the December, 1972, issue of *ham radio*, the tuning capacitors required to resonate the Collins filter at 455 kHz are omitted, which will result in a substantial insertion loss. The input impedance at pin 1 of the CA-3028 is specified at from 3k to 5k ohms and the impedance at the source of the MPF102 is approximately 2.7k ohms. The lack of matching to these impedances will result in shape and ripple degradation. Therefore, it would be necessary to provide proper matching for either series resonance of the filter which is 600 ohms, or parallel resonance at 100k ohms.

Also omitted is the required bypass capacitor from the drain of the MPF102 to ground.

M.H. Gonsior, W6VFR
Fullerton, California

As I pointed out in my article, there are quite a few things left out. W6VFR has found them.

I do not have any data on the Collins filter and when I breadboarded the circuit back in March, 1972, I felt such a sense of urgency that I did not stop to investigate the impedance of the filter. Now that I have been given the impedance values, finding the capacitor values will be easier.

The gain of the amplifier was marginal; however, I was testing the detector, not the amplifier. It is too bad that I have already disassembled the circuit. It would be interesting to see how much of an improvement could be gained by matching the impedances.

In the circuit, the MPF102 and the NE561B were physically close together and the 0.5 μF capacitor shown near the IC served as a bypass capacitor for both devices.

Max Robinson, K4ODS

touch-tone modification

Dear HR:

I have not had a single transistor failure due to the mobile touch-tone circuit as originally presented in the August, 1972 issue of *ham radio*. However, I will admit that WB8NAT's change was better.

The following addition to the unit, one which I did not think of originally, will prevent any filter capacitors from charging up, discharging, then re-charging after the +12 volts dc has been removed. In short, the switch labeled *burst/pad* for dc switching is changed to a dpdt switch rather than a center-off spdt unit. The improved circuit is shown in **fig. 1**.

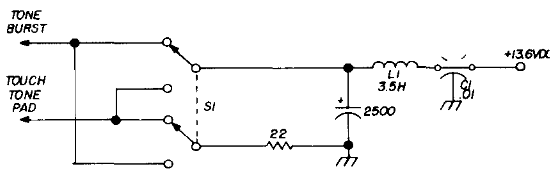


fig. 1. Improved Touch-Tone circuit.

Bill Lambing, WØLPQ
Marion, Iowa

satellite communications

Dear HR:

In the satellite communications article by K1TMA in the November, 1972, issue the comment concerning antenna gain on page 55 states: "The primary concern of the *system loss formula* is to know the amount of rf gain there is in a particular array in the desired direction of transmission, relative to half-wavelength dipole or that hypothetical antenna, the isotropic source."

Actually, there is a 2.14 dB theoretical gain that a dipole has over an isotropic radiator, so to be on the level in calculations the isotropic radiator should always be chosen as the reference antenna. This will entail a knowledge of the *gain-over-isotropic* of a particular array. It should be borne in mind that some handbooks use gain over isotropic, while others, notably the ARRL *VHF Manual*, use gain over an ideal dipole. Most commercial manufacturers use gain over isotropic in the specification sheets. In any case, use of the *system loss formula in engineering* fashion means referencing all antennas to the point source or isotrope.

Another point not specified is the reference for computing transmitter output power in dB; power output should be specified in dBW, or dB above 1 watt. While this parameter is not specified in the system loss formula, it is nonetheless important; the result of the system loss formula, as indicated in the article, will be a large negative number in dB. Thus,

$$LS + \frac{S + N}{N} = P_O + S$$

where LS is system loss, P_O is power output in dBW, S is effective receiver sensitivity in dBm, and (S + N)/N is the *required signal to marginal communications* (use 3 dB for CW, 6 dB for ssb).

P.H. Bock, Jr. K4MSG
Avon, North Carolina

sstv synch generator

Dear HR:

I have just finished reading WA2EWO's article on the sstv synch generator, and in my opinion, the design is too costly and complex. I have a similar unit which is built on a piece of Vector board, 2 x 5 inches. Total cost for all the ICs is $4.04 including three 74121 single-shots, one 7473 divide-by-four, one 7490 divide-by-ten and one 7492 divide-by-12 connected as shown in **fig. 2**. The cost of WA2EWO's synch generator is nearly $20.

Gordon P. Stanys, W1IA
Stamford, Connecticut

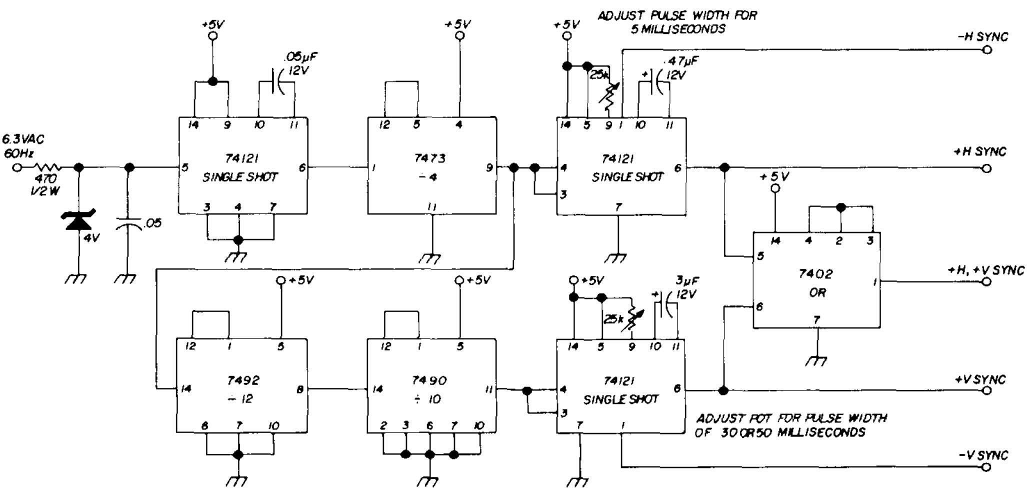
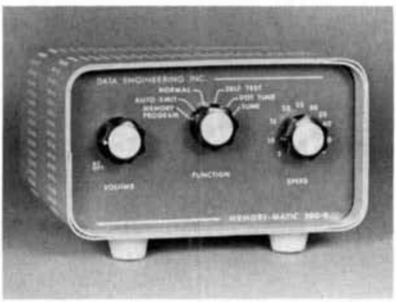


fig. 2. Block diagram of the sstv synch generator.

new products

memory-matic 500-B

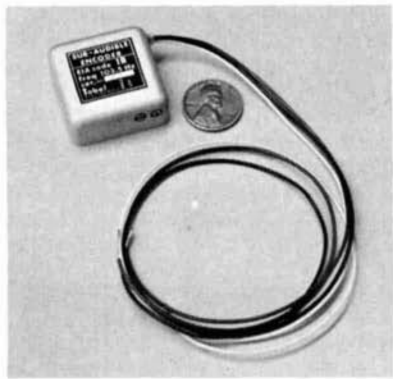


Data Engineering's reprogrammable memory keyer has been improved and updated. The Memory-Matic 500-B today features a choice of 500-bit or 800-bit memory and provision for remote control of the message start and message stop function. The dot to dash weight ratio is also completely variable and the type of keying is selectable – choosing, dot memory only, dash memory only, no memory operation or full dot and dash memory operation – all with or without automatic character and word spacing.

A memory stop switch allows the insertion of some information in the midst of a list of sequential memory transmissions. An example of this operation would be the manual insertion of a station's signal report in a preprogrammed message including a greeting, your location and your name.

The unit features iambic squeeze keying, built-in adjustable monitor and speaker, rf-proofing, and built-in 117 Vac power supply. The new keyer sells for $198.50 with a 500-bit memory reprogrammable memory or $219.50 with an 800-bit reprogrammable memory. Full details on all the features of this new keyer are available from Data Engineering, Inc., Ravensworth Industrial Park, 5554 Port Royal Road, Springfield, Virginia 22151 or by using *check-off* on page 110.

sub-audible encoder



The new Tobel CTCSS encoders fill the void for a low cost, sub-audible, miniature tone encoder and are ideally suited for mounting in solid-state transceivers, as well as, larger tube-type 2-way radios. Extensive field tests have proven the CTCSS encoders to be superior in both design and performance to older mechanical reed-type devices. Tobel encoders provide faster starting time, lower power consumption and immunity to damage from mechanical vibration. Low power consumption (2.5 mA at 12 V) and small size make Tobel encoders a natural for small hand-held transceivers and other battery operated communications equipment. Minimal effort and expense is required to convert your FM radio to sub-audible tone coding.

CTCSS (Continuous-Tone, Controlled Squelch System) makes possible positive repeater access and receiver squelch control under conditions of high noise, weak signals, and mobile flutter. CTCSS encoders are available for any EIA code L1 thru 7A as standard units and must be specified when ordering. Non-standard frequencies are available on special order.

More Details? CHECK–OFF Page 110

For more information, write to Tobel Electronics, 7920 Alida Street, LaMesa, California 92041, or use *check-off* on page 110.

solid-state high-frequency ssb transceiver

Swan Electronics has just introduced a full line of completely solid-state ssb transceivers for use on 80 through 10 meters. Models are available for 200, 100 and 15 watts PEP ssb, and all transceivers feature all solid-state, broadband transmitting circuits, as well as full coverage, 80 through 10 meters, CW and ssb. The new Swan solid-state transceivers have built-in VOX and a built-in noise blanker with variable blanking control. The transmitter circuits, which require no tuning, have infinite vswr protection from an open to a short circuit, so it's impossible to damage the final power transistor because of poor antenna matching.

Receiver sensitivity for the solid-state Swan transceivers is less than 0.5 microvolt at 50 ohms impedance for a signal-plus-noise-to-noise ratio of 10 dB. Minimum image rejection is -55 dB at 30 MHz, increasing to better than -75 dB at 3 MHz. Audio response is essentially flat from 300 to 3000 Hz ±3 dB. Audio output, to an external 3.2-ohm speaker, is 4 watts with less than 10% distortion. I-f selectivity is provided by a 2.7-kHz wide crystal filter with a 1.7 shape factor.

In the transmit mode the unwanted sideband is down more than 50 dB and the carrier is suppressed greater than 60 dB. Distortion products are approximately -30 dB. Transmitter output impedance is 50-ohms nominal. An audio sidetone is

provided to CW monitoring, and CW keying is equivalent to grid-block keying and features semi-break-in with VOX.

The vswr protection circuit cuts output power by 20% when the vswr is 3:1 or higher. Under these conditions, infinite vswr protection is provided, including open or short circuits.

Three models are available, the SS-200, with 200 watts PEP ssb minimum on all bands and 200 watts dc input on CW; the model SS-100, 100 watts PEP minimum on ssb and 100 watts CW; the model SS-15, 15 watts PEP minimum on ssb and 15 watts CW. All transceivers are designed for 13.5 Vdc power supplies, the nominal supply voltage of a 12-volt automobile system. All units require 500 mA in the receive mode. For ssb transmission, the SS-200 requires 6 amps average; the SS-100, 3.5 amps average, and the SS-15, 800 mA average. For CW operation, the current drain is higher, being 20, 11 and 2 amps respectively for the SS-200, SS-100 and SS-15. Accessory power supplies are available for operation in the home station from 117 Vac utility lines.

Other accessories include the SS-208 external vfo for split-frequency operation, the 610X crystal-controlled oscillator, the SS-16B 16-pole super-selective crystal filter with a 1.28 shape factor, and the SS-1200 1200-watt PEP linear amplifier using four 6LQ6 tubes for 117-Vac operation.

The SS-15 ssb transceiver is priced at $579.00. The SS-100 is $699.00, while the SS-200 is $779.00. The 1200-watt SS-1200 linear amplifier is priced at $299.00.

For more information, write to Swan Electronics, 305 Airport Road, Oceanside, California 92054, or use *check-off* on page 110.

great circle charts

As a service to radio amateurs WB5CBC is making available, to amateurs anywhere in the world, a comprehensive chart of great-circle bearings to 660 locations throughout the world for the unbelievable price of $1.00, postpaid. These

More Details? CHECK–OFF Page 110

charts, which are a handy 8½ by 11 inches, contain great circle bearings to the nearest degree, distances in miles and kilometers, and return bearings. Directional accuracy of the charts is to the nearest degree while distances are to the nearest mile and kilometer.

The magnetic bearing is not given on these charts because magnetic declination at any location varies from year to year, sometimes as much as 10°. It is easier to zero your antenna on true north (using the North star) and forget it.

The return bearing, a particularly useful feature of this chart, is the bearing from the distant location to your station. The return bearing is *not* a simple 180° difference from the outward bearing, but must be derived through spherical trigonometry. The ability to give a station being worked the correct bearing for aligning his antenna will produce results which are nothing short of amazing. When the chart indicates a distance greater than 8000 to 10,000 miles, the long path, which is simply 180° opposite the indicated bearing, can be considered. The same is true for the return bearing.

Charts consist of six pages and are available for any location in the world. To order a chart, the following information is needed:

1. Name and postal address.

2. The city for which the chart is wanted (include state and/or country).

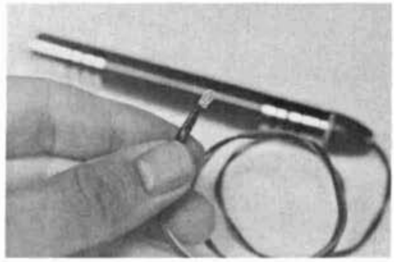
3. If the population of the city is less than 10,000 or if the location is a rural area, also include the latitude (indicate north or south) and longitude (east or west) in degrees and minutes.

4. Include payment of $1.00 (postpaid worldwide) or $1.75 (airmail worldwide). Cost to overseas stations is 7 IRCs (12 IRCs for airmail).

Send your order to William D. Johnston, WB5CBC, Great Circle, 1808 Pamona Drive, Las Cruces, New Mexico 88001. Queries for additional information should be accompanied by a self-addressed, stamped envelope.

More Details? CHECK—OFF Page 110

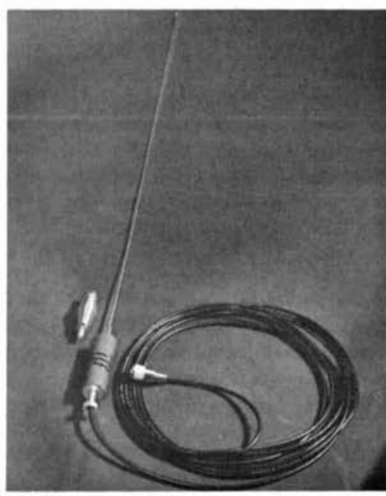
inspection lamp



Put an end to the frustration of attempting to look into a small opening while shining a flashlight into that same opening. This ultra miniature grain-of-wheat inspection lamp can be inserted into the opening and will illuminate the entire interior without blocking your vision. It can be used in the repair of radio equipment, typewriters, engines and other mechanical gadgets, as well as the inspection of gun barrels, dies, machined parts, plumbing, etc.

The price for the inspection lamp and flashlight is $2.50 postpaid. Write to Spacetrom, Box 84, Broadview, Illinois 60153, or use *check-off* on page 110.

mobile gain antenna



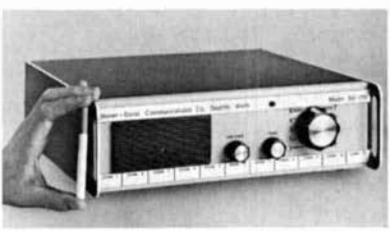
The new Antenna Engineering M-series antenna is a full 5/8-wavelength vertical whip with a bottom-load matching transformer which is designed for vehicle mounting. The adjustable threaded bushing allows for either roof-mounting or mounting through double-panels. The

More Details? CHECK–OFF Page 110

matching transformer is encased in a fiberglass sheath which is nearly indestructable. The whip is of 1/8-inch spring-temper type 302 stainless steel; the coil tip unscrews to accept a chrome-plated spring (optional at extra cost) for severe service applications.

This antenna is available for all amateur and commercial frequencies in the 140-175 MHz, 220-225 MHz and 420-470 MHz bands. The M-series antennas are at dc ground for dissapation of static, and are supplied with 20 feet of type RG-58A/U coax and ugf connector. Prices range from $16.95 for the 140-175 MHz version to $15.95 for the 420-470 MHz version. For more information, write to Antenna Engineering Company, Inc., Box 19449, Indianapolis, Indiana 46219, or use *check-off* on page 110.

solid-state ssb radiotelephone



Stoner-Goral Communications has introduced their new ssb radiotelephone. It is believed to be the first all solid-state 100-watt MF/HF marine single-sideband radiotelephone and was designed as a direct replacement for obsolete a-m equipment.

The unit operates on frequencies between 1.6 and 9.0 MHz and has a capacity for 11 duplex or 22 simplex channels. Any channel may be programmed for AME as well as suppressed or reduced (-16 dB) carrier operation. A variety of power supplies and accessories permit its use in land-based, mobile and marine stations.

The exciter portion of the radiotelephone is an up-conversion scheme and uses integrated circuits almost exclusively. Simplified channelizing involves inserting crystals and "netting" to frequency. The use of bandpass filters eliminates tuned circuits and individual channel alignment, even in the transmitter.

Exceptional reliability is claimed for the new SG-711. Heating has been reduced through the use of solid-state power amplifiers. They are fully protected against problems caused by open or shorted antennas and high temperature operation. The SG-711 is small and light weight, less than 7 pounds.

For additional information, contact Donald L. Stoner, Director of Marketing, Stoner-Goral Communications Co., Box 233, Mercer Island, Washington 98040, or use *check-off* on page 110.

switchable keyer

The Space-Matic 21-B electronic keyer is the only non-reprogrammable keyer that lets you select your particular input keying preference. With three switches, you can select from a keyer with no dot or dash memory, just a dot memory, just a dash memory or with both dot and dash memories – all with or without automatic character and word spacing.

The unit features iambic keying, jam-proof spacing and self-completion.

The unit can be used with any key, features a regular tune position and a dot tune position for ssb transmitters. An adjustable monitor is built in, the unit is rf-proofed and can be run from 12 Vdc or 117 Vac. There are many other features of this $89.50 keyer. Details are available by writing to Data Engineering, Inc., Ravensworth Industrial Park, 5554 Port Royal Road, Springfield, Virginia 22151 or by using *check-off* on page 110.

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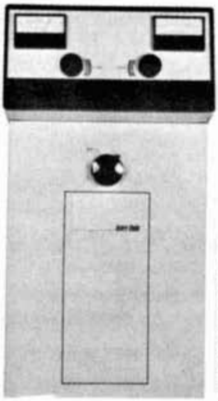

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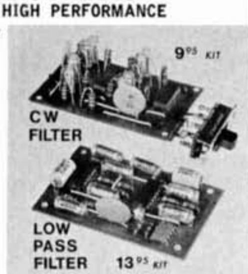

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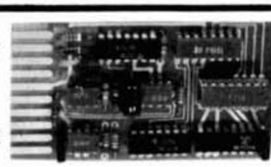

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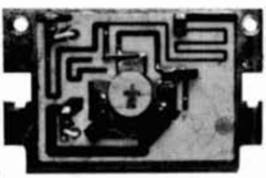

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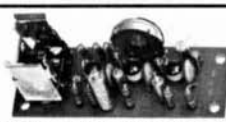

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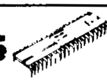

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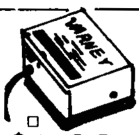

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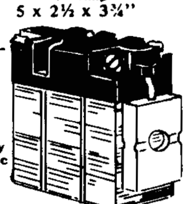

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22nd ANNUAL DAYTON HAMVENTION will be held on April 28, 1973 at Wampler's Dayton Hara Arena. Technical sessions, exhibits, hidden transmitter hunt, flea market, and special program for the XYL. For info write Dayton Hamvention, Dept. H, Box 44, Dayton, Ohio 45401.

WORLD QSL — See ad page 96.

BARGAIN HUNTERS! Don't miss out. Closeout of 18th Edition of W6SAI's Radio Handbook, list $13.50, only $7.95 ppd. while they last. Comtec, Greenville, N. H. 03048.

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SELL: Polytechnic Research Development — Precision Frequency Meter — Navy type 560-cavity tuned 2400-3400 MC./S. A gem instrument. Make offer. W9CO, 604 Wyatt, Lincoln, Illinois 62656.

NEED 4D32 for 32V2 rig, or circuit diagram for 6146A/B or other. will pay. Jerry, WA7RYS, Box 389, Christmas, Ariz. 85292.

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GREATER BALTIMORE HAMBOREE will be held Sunday, April 8, 1973, at 10 a.m. at Calvert Hall College, Putty Hill and Goucher Boulevard, Towson, Maryland (1 mile south of Exit 28 Beltway - Interstate 695), food service, flea market, prizes. registration $2.00. No table charge or percentage. Info: Joe Lochte, 5400 Roland Avenue, Baltimore, Maryland 21210.

HALLICRAFTERS SR-150 & PS-150, $275; Gonset 3212 2 meter power amplifier, $125; Poly-Comm 62-B, $100; all in good condition with manuals. W2WRI, J. A. Kammerer, 23 New Street, Katonah, N. Y. 10536 (914-232-8349).

HAMFEST — Wabash County ARC Fifth Annual Hamfest, Sunday May 20, rain or shine. Admission is still only $1. Flea market, food, tech talks and much more. For information write Bob Mitting, 663 Spring, Wabash, In. 46992.

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THE SPRING AUCTION of the Rockaway Amateur Radio Club will be held Friday evening, April 27th at the Hall of Science, Worlds Fair Grounds, Flushing, N. Y. Doors will be open at 6:00 p.m. to accept items for the sale. The auction is scheduled to begin at 8:00 p.m. A one dollar donation will be accepted at the door. For further information contact: Al Smith, WA2TAQ, P. O. Box 341, Lynbrook, N. Y. 11563.

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FIGHT TVI with the RSO Low Pass Filter — p115 March 73 — write for brochure — Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada.

WANTED: Lafayette HA46, Bob, K6GEV, 11 Wool, San Francisco 94110.

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THE FOURTEENTH ANNUAL HAMFEST, *sponsored* by the Southern Tier Amateur Radio Clubs, is scheduled for 2:00 p.m., April 14, 1973, at St. John's Ukranian Hall, Johnson City, New York. Admission to lectures and flea market is free; awards and excellent dinner held to \$5.00. For tickets or further information, write STARC, P. O. Box 11, Endicott, N. Y. 13760. Advance ticket sales only by April 11, 1973.

WANTED: Magnetics specialist *or college professor* thoroughly familiar with conventional magnetic theory to assist the editor in evaluating a new con*cept in explaining magnetism.* Write to Jim Fisk, W1DTY, editor, Ham Radio Magazine, Greenville, N. H. 03048.

THE GREATER BALTIMORE HAMBOREE will be held at Calvert Hall College, Putty Hill and Goucher Boulevard, Towson, Maryland (one mile south of Exit 28 of Beltway-Interstate 695), on Sunday, April 8, 1973 at 10 a.m. Food service, Flea market, prizes. Registration: \$2.00. No table or percentage charges. *Info.: Joe Lochte, 5400 Roland Avenue,* Baltimore, Maryland 21210.

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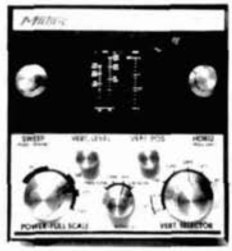

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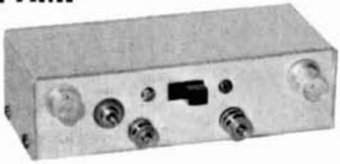

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INDEX

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—E S P
—Fair
—Frank
—Gateway
—Gray
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—HAL
—Ham Radio
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—Hobby
—Hy-Gain
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—International Crystal
—Jan
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—L. A.
—Linear
—MFJ
—MPQ
—Matric
—Meshna
—Miida
—PM
—Palomar
—Peter Meacham
—Poly Paks
—RP
—Racom
—Callbook
—Raytheon
—Rochester
—Sams
—Saroc
—Savoy
—Signal Systems
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—Space-Military
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—Spectronics, FM
—Spectrum International
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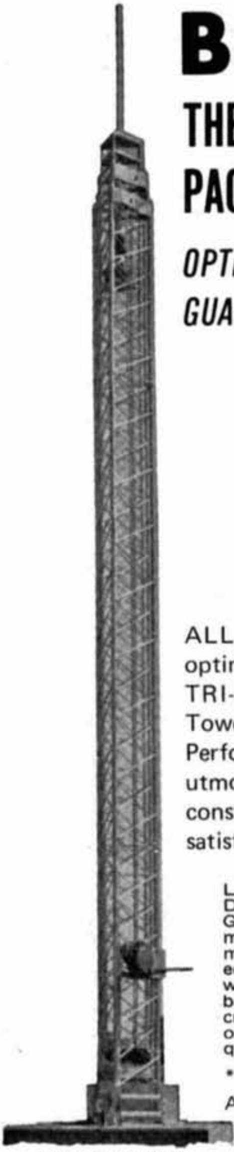
Advertisers iNdex

ATV Research 89
Amateur-Wholesale Electronics 90, 92
Antenna King 56, 57
Arizona Semi-Conductor 84
Babylon Electronics 89
Barker & Williamson, Inc. 84
Barry 88, 89
Bauman, R. H. Sales 94
CFP Enterprises 86
CTG Bitcil 109
Camp Albert Butler 84
Caringella Electronics 81
Chronometric Products 92
Circuit Specialists Co. 108
Command Productions 101
Communications Specialists 96
Communications World, Inc. 66
Comtec 82, 83, 104, 105
Curtis 96
Cushcraft 101
Data Engineering, Inc. 40, 41
Dayton Hamvention 94
Display Electronics 101
Dycomm 94
Ehrhorn Technological Operations, Inc. 1
Eimac, Div. of Varian Assoc. ..... Cover IV
Emporium Sounds of Pompano 76
Fair Radio Sales 105
Frank Electronics 96
G & G Radio Supply Co. 90
Gateway Electronics 80
Goodheart Co., Inc. R. E. 96
Gray Electronics 86
H & L Associates 92
HAL Communications Corp. 91
Ham Radio 87, 103
Heath Company 2, 46, 47
Henry Radio Stores ..... Cover III
Hobby Industry 75
Hy-Gain Electronics Corp. 26, 27, 106, 107
Icom 105
International Crystal Mfg. Co. Inc. 112
Jan Crystals 90
Janel Labs 89
K-Enterprises 96
K. E. Electronics 92
KW Electronics 109
L. A. Electronix Sales 111
Linear Systems, Inc. 85
MFJ Enterprises 92
MPQ 94
Matric 104
Meshna, John, Jr. 84
Miida Electronics 93
PM Electronics, Inc. 66
Palomar Engineers 80
Payne Radio 78
Peter Meacham Associates 101
Poly Paks 98
RP Electronics 76
Racom Electronics, Inc. 89
Radio Amateur Callbook 81, 96
Raytheon Company 5
Rochester Hamfest 109
Sams, Howard W. and Co., Inc. 100
Saroc 86
Savoy Electronics ..... Cover II
Signal Systems 92
Solid State Systems, Inc. 102
Space-Military Electronics 101
Spectronics, FM 95
Spectrum International 77
Star-Tronics 86
Standard Communications Corp. 97
Structural Glass 67
Swan Electronics 37
VHF Engineering 86
Vanguard Labs 104
Weinschenker, M. 79
Wolf, S. 90
World QSL Bureau 96
Y & C Electronics 78



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Complete with one of the following antennas:

HY-GAIN TH2MK3	$290
HY-GAIN TH3JR	$290
HY-GAIN DB10-15A	$299
HY-GAIN HY QUAD	$329
HY-GAIN TH3MK3	$339
*TR-44 rotor w/cable add:	$ 35
HAM-M rotor w/cable add:	$ 65

LAE W51 "DELUXE" 51 Ft. Package (Free Standing, 9 Sq. Ft. - 50 MPH)
CDR TR-44 rotor*
100 ft. RG58A/U coax cable
100 ft. control cable
Complete with one of the following antennas:

HY-GAIN DB 10-15A	$620
HY-GAIN HY QUAD	$650
HY-GAIN 204BA	$660
HY-GAIN TH3MK3	$655
HY-GAIN TH6DXX	$675

Free stdg. base incld. NO/CHARGE
*HAM-M rotor w/RG8/U add: $ 60

LAE LM354 "SUPER" 54 Ft. Package (16 Sq. Ft. - 60 MPH)
CDR HAM-M Rotor
100 ft. RG8/U coax cable
100 ft. control cable
Complete with one of the following antennas:

HY-GAIN TH3MK3	$835
HY-GAIN 204BA	$839
HY-GAIN TH6DXX	$860

Freight PREPAID to your door in the Continental USA west of the Rockies. For shipment east of the Rockies, add $15.00. Substitutions may be made. . . write for prices.

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More Details? CHECK—OFF Page 110

for the EXPERIMENTER!

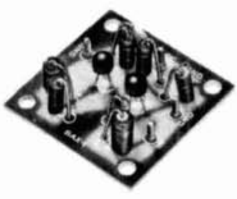
INTERNATIONAL EX CRYSTAL & EX KITS

OSCILLATOR • RF MIXER • RF AMPLIFIER • POWER AMPLIFIER

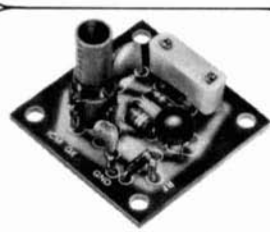
1. MXX-1 TRANSISTOR RF MIXER
A single tuned circuit intended for signal conversion in the 3 to 170 MHz range. Harmonics of the OX oscillator are used for injection in the 60 to 170 MHz range. Lo Kit 3 to 20 MHz, Hi Kit 20 to 170 MHz (Specify when ordering) **$3.50**

2. SAX-1 TRANSISTOR RF AMP
A small signal amplifier to drive MXX-1 mixer. Single tuned input and link output. Lo Kit 3 to 20 MHz, Hi Kit 20 to 170 MHz (Specify when ordering) **$3.50**

3. PAX-1 TRANSISTOR RF POWER AMP
A single tuned output amplifier designed to follow the OX oscillator. Outputs up to 200 mw, depending on the frequency and voltage. Amplifier can be amplitude modulated. Frequency 3,000 to 30,000 KHz **$3.75**



4. BAX-1 BROADBAND AMP
General purpose unit which may be used as a tuned or untuned amplifier in RF and audio applications 20 Hz to 150 MHz. Provides 6 to 30 db gain. Ideal for SWL. Experimenter or Amateur **$3.75**



5. OX OSCILLATOR
Crystal controlled transistor type. Lo Kit 3,000 to 19,999 KHz, Hi Kit 20,000 to 60,000 KHz. (Specify when ordering) **$2.95**

6. TYPE EX CRYSTAL
Available from 3,000 to 60,000 KHz. Supplied only in HC 6/U holder. Calibration is ± .02% when operated in International OX circuit or its equivalent. (Specify frequency) **$3.95**

for the COMMERCIAL user...

INTERNATIONAL PRECISION RADIO CRYSTALS

International Crystals are available from 70 KHz to 160 MHz in a wide variety of holders. Crystals for use in military equipment can be supplied to meet specifications MIL-C-3098E.

CRYSTAL TYPES:
(GP) for "General Purpose" applications
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(HA) for "High Accuracy" close temperature tolerance requirements.

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More Details? CHECK—OFF Page 110

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2K-4 . . . THE "WORKHORSE"

The 2K-4 linear amplifier offers engineering, construction and features second to none, and at a price that makes it the best amplifier value ever offered to the amateur. Constructed with a ruggedness guaranteed to provide a long life of reliable service, its heavy duty components allow it to loaf along even at full legal power. If you want to put that strong clear signal on the air that you've probably heard from other 2K users, now is the time. Move up to the 2K-4. Floor console or desk model . . . $845.00

2K-ULTRA . . . THE "ULTIMATE"

There has never been an amateur linear amplifier like the new 2K-ULTRA. Small and lightweight, yet rugged and reliable . . . all that the name implies. The ULTRA loafs along at full legal power without even the sound of a blower. Its anode heat is silently and efficiently conducted to a heat sink through the use of a pair of Eimac 8873 tubes. In fact, all of its components are the very best obtainable. The price . . . $845.00

TEMPO/2001

Small but powerful, reliable but inexpensive, this amplifier is another top value from Henry Radio. Using two 8874 grounded grid triodes from Eimac, the Tempo 2001 offers a full kilowatt of power for SSB operation in an unbelievably compact package (total volume is .8 cu. ft.). The 2001 has a built-in solid state power supply, a built-in antenna relay, and built-in quality to match much more expensive amplifiers. This equipment is totally compatible with the Tempo One as well as most other amateur transceivers. Completely wired and ready for operation, the 2001 includes an internal blower, a relative RF power indicator, and full amateur band coverage from 80-10 meters. $545.00

TEMPO/6N2

The Tempo 6N2 combines most of the fine features of the 2001 for 6 and 2 meter amateur operation. The amplifier uses the same small cabinet, the same modern tubes, the same inherent quality for 2000 watts PEP input on SSB or 1000 watts input on FM or CW. The rig is completely wired in one small package with an internal solid-state power supply, built-in blower, and RF relative power indicator. $595.00

3K-A COMMERCIAL/MILITARY AMPLIFIER

A high quality linear amplifier designed for commercial and military uses. The 3K-A employs two rugged Eimac 3-500Z grounded grid triodes for superior linearity and provides a conservative three kilowatts PEP input on SSB with efficiencies in the range of 60%. This results in PEP output in excess of 2000 watts. In addition, the 3K-A provides a heavy duty power supply capable of furnishing 2000 watts of continuous duty input for either RTTY or CW with 1200 watts output. Price . . . $1080.00

Prices subject to change without notice

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