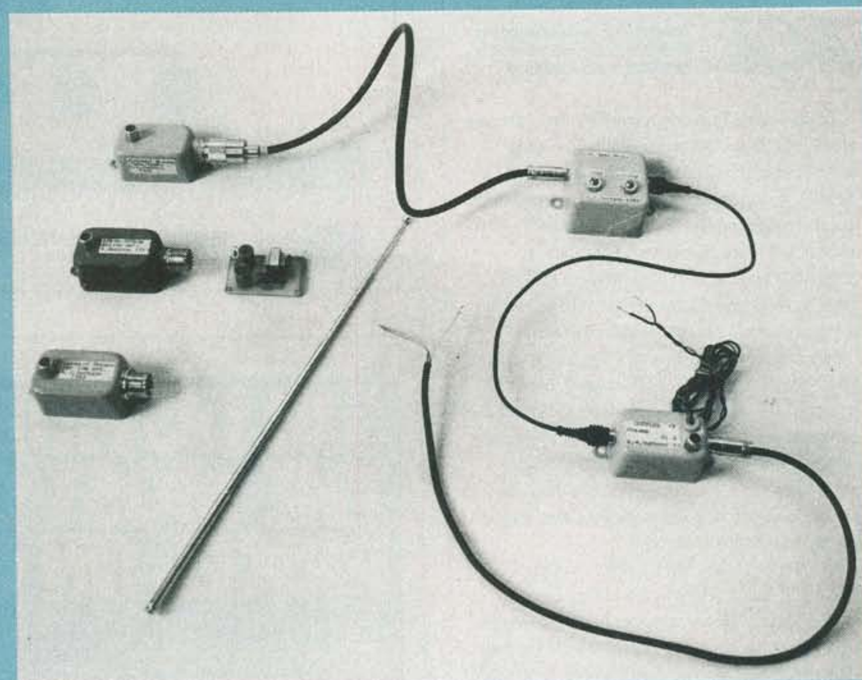
VLF-HF Active Antennas

Active receiving antennas can offer a surprising improvement in the capabilities of your receiver. However, as we will show you, building one does not have to be difficult.

R.W. BURHANS



Part 3 IN THE PREVIOUS TWO parts of this series on VLF-HF receiving techniques, we covered both the fundamentals of active receiving antennas and some practical circuits. Now we are ready to discuss the actual construction of those antennas.

The active-antenna system consists of three main parts: a whip antenna, a preamplifier, and a receiver coupler. The whip antenna is directly attached to the preamplifier, and both are remotely mounted. The receiver coupler is mounted at the receiver, and is connected to the preamplifier by a length of coaxial cable. Let's now take a look at the components of the system in more detail.

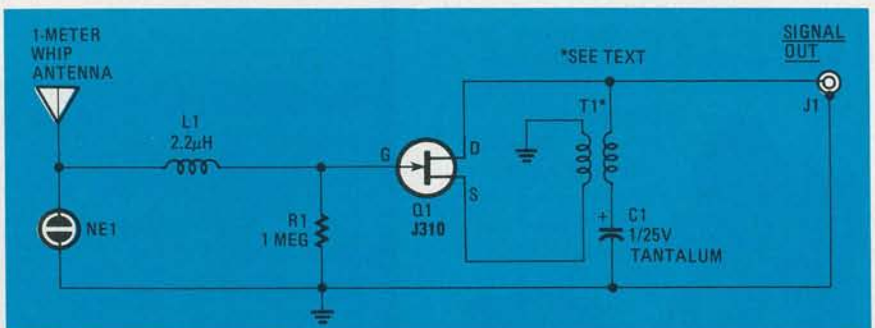


FIG. 1—WIDEBAND PREAMPLIFIER SCHEMATIC. The neon bulb, NE1, provides adequate input static charge protection.

Wideband preamplifier

The wideband preamplifier circuit was discussed in the March 1983 issue of **Radio-Electronics.** Its schematic is reproduced in Fig. 1.

The wideband preamplifier is assembled on a printed-circuit board. The foil pattern of that PC board is shown in Fig. 2, and its parts-placement diagram is shown in Fig. 3. You should note that there are some "extra" pads near the input terminal. They are there to accommodate different input filter networks and/or variations in the size of the components used. The board is intended to fit snugly in a 1¼ × 2 × 1 inch drawn-steel case, although it can be used, of course, with a larger box. The only "fussy" component is the toroidal transformer.

The toroidal transformer is wound by first measuring out two 15-inch lengths of different-colored, 30 gauge, solid, insulated, wire-wrap wire. Those wires are twisted together about 8 turns-per-inch, and then that cable made up of the twisted pair of wires is wound for 17 turns on an Amidon (12033 Ostego St., North Hollywood, CA 91607) part No. FT50-75 (or similar) ferrite core. The windings should be tight, with a small gap at the start/finish point. The wire is held in place at the ends with a small drop of cement, and about 1 inch is left for connection to the circuit board. The insulation at the ends of the wires is stripped back about ½ inch for soldering to the board.

One important note is that the windings should oppose each other. What that means, is that while one wire at one end of the two-wire cable is connected to ground, the other wire at the same end is connected to the drain of the JFET. To furthur clarify that, Fig. 3 shows a dot at the one end of each winding—the dots are at a common end of the cable.

After the transformer wires are connected through the circuit-board holes, the core assembly should be cemented to the board perpendicularly. Be sure to follow Fig. 3 and make sure that the necessary jumper wires are also connected on the board for the wideband version (a version of the preamp for restricted VLF and LF use uses the same circuit board, but some different components).

The lower 3-dB point (where the response of the preamp drops 3 dB from its maximum) is at 10 kHz, where the toroidal transformer has an inductance of about 1 mH. At high frequencies, the core material effectively disappears, and the

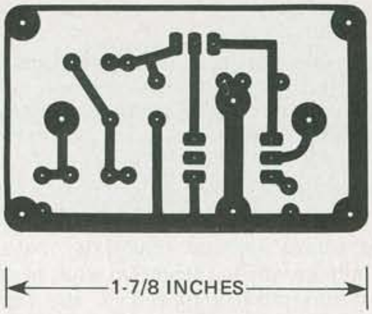


FIG. 2—FULL SIZE foil pattern for the the preamplifier circuit-board.

PARTS LIST
WIDEBAND ANTENNA PREAMP

R1—1 megohm, ¼ watt
C1—1 μF, 25 volts, tantalum
Q1—J310 FET (Siliconix or equivalent)
NE1—NE99 neon lamp
L1—2.2 μH (Mouser 43LS226 or equivalent)
T1—Bifilar wound transformer on Amidon FT50-75 core or equivalent (see text)
Miscellaneous:PC board, case, coaxial connectors, hardware, etc.

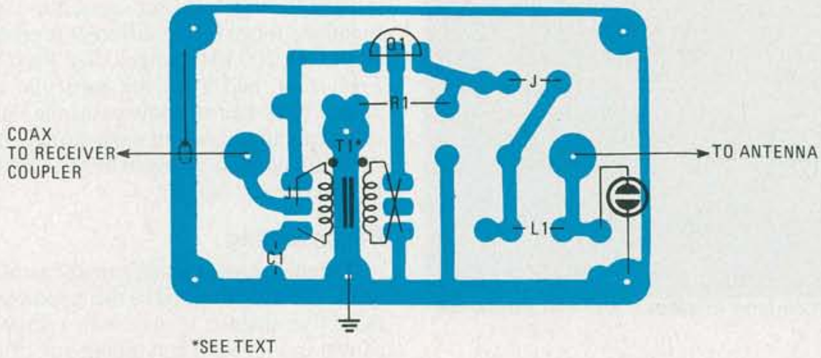


FIG. 3—PARTS-PLACEMENT DIAGRAM for the wideband version of the preamp.

response might be good to 100 MHz or so. However, the 2.2 μH input inductor (L1)—along with the board, the JFET capacitance, and the steel case—limits the preamp's upper 3-dB point to about 30 MHz. That helps to reduce interference from signals outside the desired band—say, TV and FM signals.

The receiver coupler

The foil pattern of the receiver-coupler board is shown in Fig. 4. (The receiver-coupler circuit was discussed in Part 2 of this series, in the March 1983 issue of **Radio-Electronics**. The schematic of the receiver coupler is reproduced here in Fig. 5). The board's parts placement is shown in Fig. 6. The board for the receiver coupler is the same size as that used in the preamp, and can be mounted in a similar case, if desired. In addition to the coaxial input and output terminals, a twisted pair of insulated wires are included for the power-supply leads (8–12 volts) and are fed through a small grommet or hole in the receiver-coupler case.

We will not discuss the construction of a power supply.

Preamplifier for VLF-LF

The circuit for the VLF-LF preamplifier was discussed in Part 2 of this series, in the March 1983 issue of **Radio-Electronics.** For your convenience, we have reproduced the schematic of that circuit in Fig. 7.

The circuit board for restricted VLF-LF operation is the same as the one used for the wideband preamp. (of course some components are different, and the jumpers that were used in the wideband case are not used here.) The parts-placement diagram is shown in Fig. 8. The RF chokes are short, encapasulated types that are designed for vertical PC-board mounting. The winding "polarity" or the start of the windings are indicated in Fig. 8 by black dots and on the choke package by a label dot and a longer lead.

The output transformer that we chose will fit exactly into the holes indicated, with the correct winding polarity already provided. Therefore—unlike the toroidal transfomer—it is unnecessary to cross over the transformer leads.

If you are in doubt about which side of the transformer is the primary or secondary, check with an ohmmeter. The higher resistance reading (around 20 ohms) will be the primary winding.

Preamplifier variations

In Part 2, we discussed several different resonant input circuits that could be used to provide low-frequency cutoffs, or to yield operation at a small, fixed band of frequencies. (The input networks were discussed in the "Resonant input circuits" section of Part 2.) The preamplifier can be modified with one of these input networks with relative ease. For example, a microminiature trimmer-capacitor can be soldered on the foil side of the board, directly across the 1-megohm input resistor (R1) after the board is mounted in the box. One possible source for the inductors and capacitors is Mouser Electronics (11433 Woodside

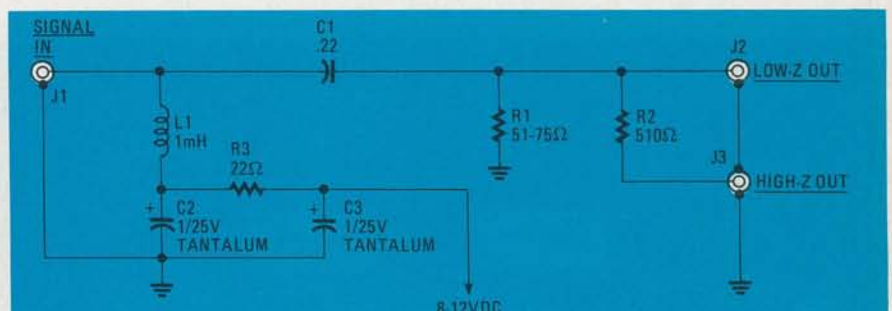


FIG. 5—The two outputs can be used to match the coupler to your particular receiver. They also make it easy to use the coupler with a receiver and monitor the coupler output with a scope at the same time.

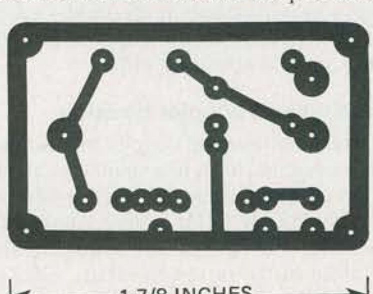


FIG. 4—FULL SIZE foil pattern for the receiver-coupler circuit-board.

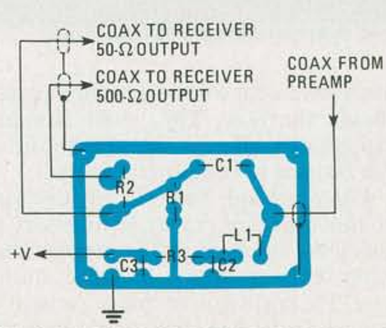


FIG. 6—PARTS-PLACEMENT DIAGRAM for the receiver-coupler board.

PARTS LIST
VLF-LF ANTENNA PREAMP

R1—1 megohm, ¼ watt
C1—1 μF, 25 volts, tantalum
C2—0.001 μF, ceramic
Q1—J310 FET (Siliconix or equivalent)
NE1—NE99 neon lamp
L1, L2—6.8 mH (Mouser 43LH268 or equivalent)
T1—Audio transformer (Mouser 42TL004 or equivalent)
Miscellaneous:PC board, case, coaxial connectors, hardware, etc.

TABLE 1

Frequency/Application	3-dB Bandwidth	Antenna length	C_a	L	C2	Gain
180 kHz Experimenters' Band	170–190 kHz	10 meters	120 pF	33 mH	.001	+20 dB
180 kHz Experimenters' Band	175–185 kHz	1 meter	10 pF	39 mH	.001	+15 dB
100 kHz LORAN-C	95–105 kHz	1 meter	10 pF	120 mH	.01	+6 dB
100 kHz LORAN-C	91–108 kHz	10 meters	120 pF	100 mH	.01	+12 dB
60 kHz WWVB	55–65 kHz	10 meters	120 pF	150 mH	.01	+10 dB
60 kHz WWVB	58–63 kHz	1 meter	10 pF	300 mH	.01	+6 dB

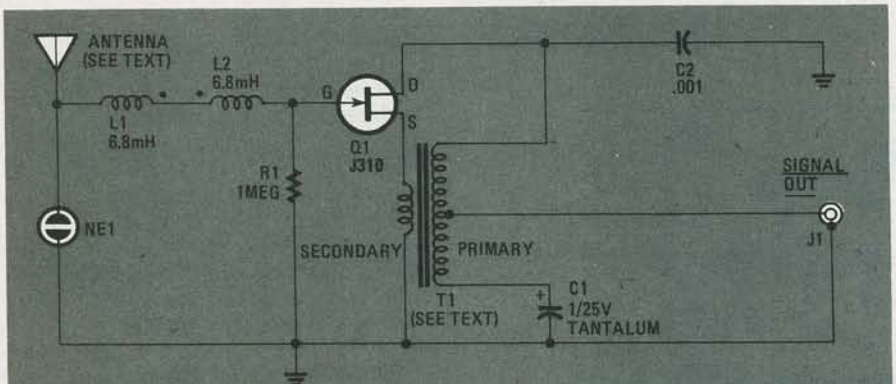


FIG. 7—THE INPUT INDUCTORS and circuit capacitances form a lowpass filter that makes this amplifier for restricted use in the VLF-LF range.

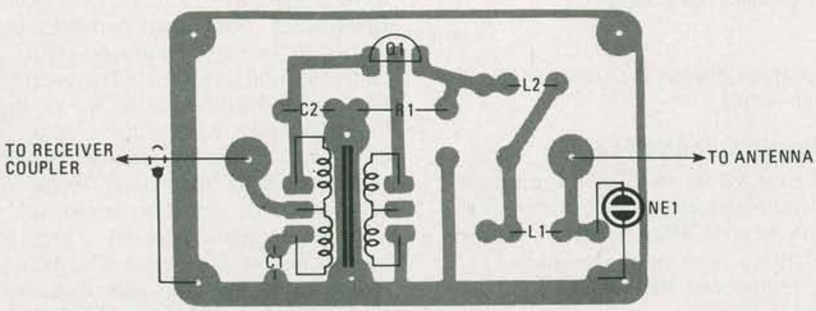


FIG. 8—PARTS-PLACEMENT DIAGRAM for the restricted-use (VLF–LF) version of the active antenna preamp.

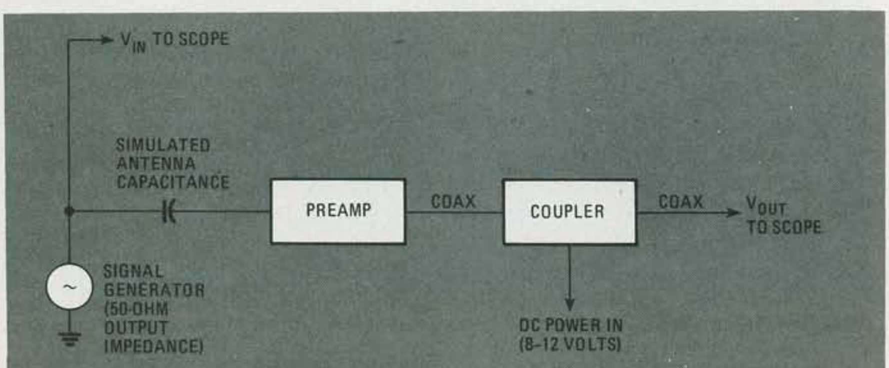


FIG. 9—USE THE APPROXIMATION of 1-pF per meter to determine the antenna capacitance

Ave., Santee, CA 92071), although other suppliers can be found by checking the ads in the back of this magazine.

You may have to bend the leads or change the part orientation if a particular component will not exactly fit the board holes. If you use 100–150-mH RF chokes (for a tuned amplifier for 60-kHz to 100-kHz operation), they will be quite close to the board edges because of their larger size. That will alter the circuit capacitance somewhat when the board is placed inside the box. The small trimmer capacitor—on the foil side of the board—can be used to compensate for that.

For wideband, lower-Q circuits with no trim capacitor, it may be necessary to check the response of the preamp after temporarily mounting it in the shield/case. The board can, of course, be used in a much larger box, with larger inductor assemblies, but keep in mind that for maximum antenna sensitivity with a minimum antenna height (in other words, for maximum efficiency), the input capacitance at the antenna terminal should be as low as possible.

Table 1 shows the results of tests made with different inductor-capacitor combinations for covering different segments of the 60–200 kHz range. (See Part 2—Figs. 1, 4, and 5 for the particular circuits.) Note that in some cases the value of the preamp's output capacitor (C2) at the drain of Q1 is changed to improve the low-frequency cutoff.

For information on availability (including custom-built active-antenna preamps and coupler assemblies), send a SASE to R. W. Burhans, 161 Grosvenor St., Athens, Ohio 45701

Bench testing

A signal generator and suitable oscilloscope are used to observe the response of the active antenna system with a setup as shown in Fig. 9. When tuning any of the amplifier variations on the bench, or when checking the response of the amplifier, a small coupling capacitor—of a value equal to the expected antenna capacitance—is connected to the input terminal of the preamp. (A vertical or slant-wire antenna will have an approximate capacitance of about 10 pF-per-meter.) That will roughly simulate the response of the electric field at the antenna. A tuned preamp assembly can be aligned on the bench and then the antenna can be plugged in for operation. The input/output response obtained this way will fairly-well resemble the response that you will obtain in the field—except for the K factor that is dependant on the local ground-shielding effect.

PARTS LIST
RECEIVER COUPLER

All resistors are ¼ watt, 5% unless otherwise specified
R1—51 ohms
R2—510 ohms
R3—22 ohms
C1—0.22 µF, Mylar
C2, C3—1 µF, 25 volts, tantalum
L1—1 mH (Mouser 43LR103 or equivalent)

Preamp and coupler housing

The amplifier and coupler boards have been designed to fit in a small cast aluminium or drawn-steel case such as Mouser part No. 537-M12 for compact assembly. (See Fig. 10.) The circuit boards are held in place in the boxes by short, solid jumper wires that are soldered to the antenna input terminal and to the coax receptacles. The ground connections can be

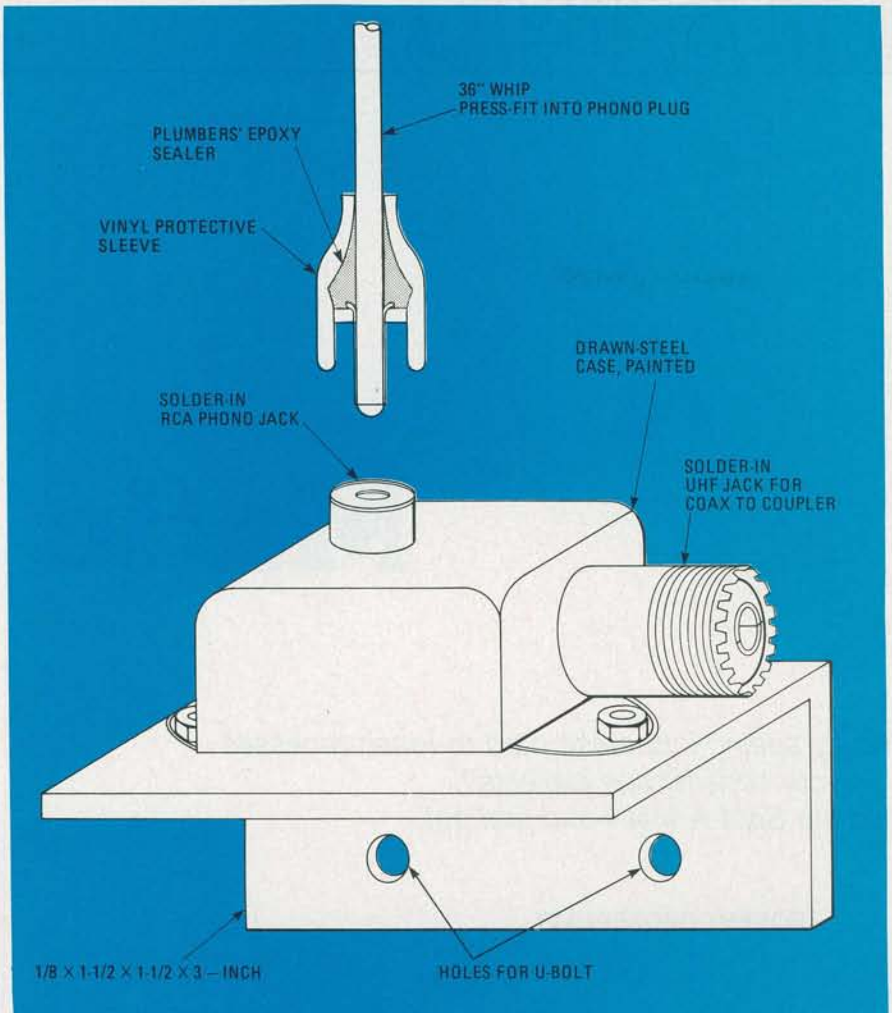


FIG. 10—TO WEATHER-PROOF the case, seal all joints and drill a small bleed hole for drainage.

either short jumper wires to the ground lug on the cable receptacle or the circuit board ground can be directly soldered to inside edges of the drawn-steel case.

The case should be mounted on an angle bracket for bolting to a short mast. A press-in or solder-in type RCA phono receptacle (Mouser part No. 16PJ051) is soldered on the inside of the box for the antenna terminal. That has a capacitance of only 5 pF at most, and it is suppled with a ceramic spacer. The output coax connector can be a UHF type. We have used SO-239 type receptacles by breaking off the flanges and pressing into a hole carefully reamed to fit. The output coax connector can be a single-hole-mounting type that uses a nut on the inside of the case. However, that takes up room inside the case and the PC board will have to be further cut and filed. Whichever type of connector you use, make sure you solder it to the inside of the case.

Prior to mounting the connectors, the box should be degreased with solvent, polished with steel wool both inside and out, and (after soldering the connectors) it should be painted *outside* with automobile primer and finally with a clear plastic spray. When painting the box, temporarily cover the connectors with masking tape to avoid getting paint on them.

To mount the circuit board in the drawn steel case, solid copper wires (22 to 20 gauge) are soldered to the center terminals of the antenna and coax connectors. Those wires are then bent to align with the holes on the circuit board. It is necessary to file the edges of the board to round the corners, in order for the board to fit inside the case. The board is then slipped down over the input/output wires so that the foil side of the board faces outside and the components inside. The board should be about 3/16 inch below the outer edge of the box for clearance. The ground of the board is then tack-soldered at a couple of points to the inside of the cleaned box. Be sure to solder the input/output wires to the terminals on the foil side and cut off all excess length from component leads.

The receiver-coupler box can be assembled in a very similar manner. Again, the fit can be compact, although it will be so newhat crowded if UHF fittings are used. It is better to use RCA phono connectors for all the coax fittings and to use shielded phono plugs with good quality RG-58U cable for interconnecting the preamp to the coupler and the coupler to the receiver. However, it is common practice to use the old-fashioned large size UHF fittings for RF, even though the metal-sleeve RCA phono types are much more compact and convenient to use. You can also use BNC type cable fittings and receptacles if desired. Some commercial systems even use type-N RF fittings for the antenna mount in place of the RCA solder-in receptacle.

Final assembly

For a short whip antenna, a mobile VHF-type stainless steel whip about 36 inches long will fit inside the typical RCA phono plug connector pin for a tight press fit. If that type of whip is not available, a copper-coated welding rod can be substituted and soldered into the phono-plug pin. After the antenna is mounted in the plug's center pin, the fitting is sealed with plumber's epoxy putty and a vinyl sleeve pushed down over the whole assembly to aid in waterproofing. A wire antenna can also be used—it is soldered to the center pin, and the phono connector is sealed similarly. For final assembly and mounting of both the antenna connector and the coax output connector at the preamplifier, we wrapped the connector with Coax-Seal, a putty-like tape, for extra waterproofing. The preamp box is bolted to the angle bracket and the joint sealed with cement or a gasket made from Coax-Seal tape. As an extra precaution against water in the box, a small bleed hole is drilled directly under the box mounting area to drain away any moisture that may enter the assembly.

Your receiver may have an auxiliary-output power source already available. For the RF input, the observer should first try the 500-ohm output from the coupler box at the VLF-LF region. More signal can sometimes be developed if the other output of the coupler is used. That indicates that the receiver is not too sensitive to antenna output-impedance. In all cases, the appropriate receiver input-terminal that is designed for the frequency range should be used. The 50-ohm coupler-output is almost always required for receivers operating in the range of 2 MHz to 30 MHz.

It may be convenient to connect a monitor oscilloscope to the 500-ohm output of the coupler and use the 50-ohm coupler terminal to drive the receiver. The scope display is useful for monitoring interference and the dominating signals in your area. By selecting various scope sweep-rates, you can get an approximate indication of the frequency of the various signals that are present. Thus, once you figure out what is causing the interference (for example, you may be able to see 60-Hz harmonics), then you can take steps to minimize it. Do not forget, however, that a wideband preamplifier is sensitive to all frequencies present at the antenna input bandwidth—not only the ones you want to amplify. **R-E**