Number 10 on your Feedback card

The Challenge of 1750 Meters

No license required.

by David Curry WD4PLI/6

1750 meters is a hobby, just like amateur radio. In fact, it is much like old-time amateur radio; it separates the men from the boys! In the early days of radio, hams built their own equipment, and most operators did not even have licenses. 1750 meters is still true to that theme: "No license required, only skill desired."

Unfortunately, 1750 meters is a noisy, sometimes crowded, band filled with carriers and modulations. Well, guess what? Many of those carriers and modulations are European long-wave broadcast stations DXing over the Atlantic, and perhaps that code you hear in the background is actually a Lowfer sending his ID beacon. FCC rules limit transmitting antenna length to 50 feet and DC input to the PA to 1 watt. Even with these restrictions, surprising distances via ground-wave propagation occur regularly. Using a common noise blanker, audio filter, or even a phase-canceling device, an operator can clean up the band of light dimmers and power line noise that often can be discouraging. Simple receiving antennas such as an active whip or loop placed in a clear area and using a "virgin" ground (a separate, isolated ground that carries no power-line noise) can provide unimpeded reception.

Considering that communications technology has become so advanced, there is no reason why you can't enjoy the fun and challenge of 1750 meters just because the major ham manufacturers didn't include it in their rigs. Build your own radio, perhaps with a friend, and get on the air; it's that simple. You will find that you have more to talk about than the weather, and you'll share in the amazement of how a 1 watt signal can travel hundreds of miles under good conditions. Many hams can use their preexisting vertical ham antenna for 1750 meter operation using a loading coil at the base of the antenna. Most 160 meter antennas are ideal for work on 1750 meters.

1750 meters was originally set aside by the FCC as a frequency range for garage-door openers back in the early '60's, but as time passed, experimenters (many of them hams) found surprising success despite FCC limitations. These "experimenters" are referred to as "Lowfers," and are on virtually any day of the week. I can hear two or three of them on my TS-430S, loud and clear, from as far away as San Diego, 150+ miles away from my Burbank, California, QTH. In Hawaii, using a portable loop antenna, Sheldon Remington received Lowfer beacons Z2 and later H2, both located in California, over 3,000 miles away! SSB, AMTOR, RTTY, and packet have all been used successfully.

Design

Described here is a simple "introductory" CW two-way radio for 1750 meters. Antenna dimensions for 1750 meters can be found in *73 Magazine*, September 1991, in "Dual-Band Vertical" (for 160 and 1750 meters), page 38. Also of interest is "Noise Reduction Using Broadband Active Whip Antennas," *73 Magazine*, October 1992, page 38.

Please note Figures 1 and 2. The front-end preselector uses a tunable two-pole Chevychev bandpass filter to reduce unwanted signals, such as GWEN (Ground Wave Emergengy Network). The direct conversion receiver is an uncomplicated design using the NE602 chip. The NE602 Colpitts VFO provides the frequency reference for the transmitter section. The VFO can be PLL-controlled externally, facilitating CCW (Coher-

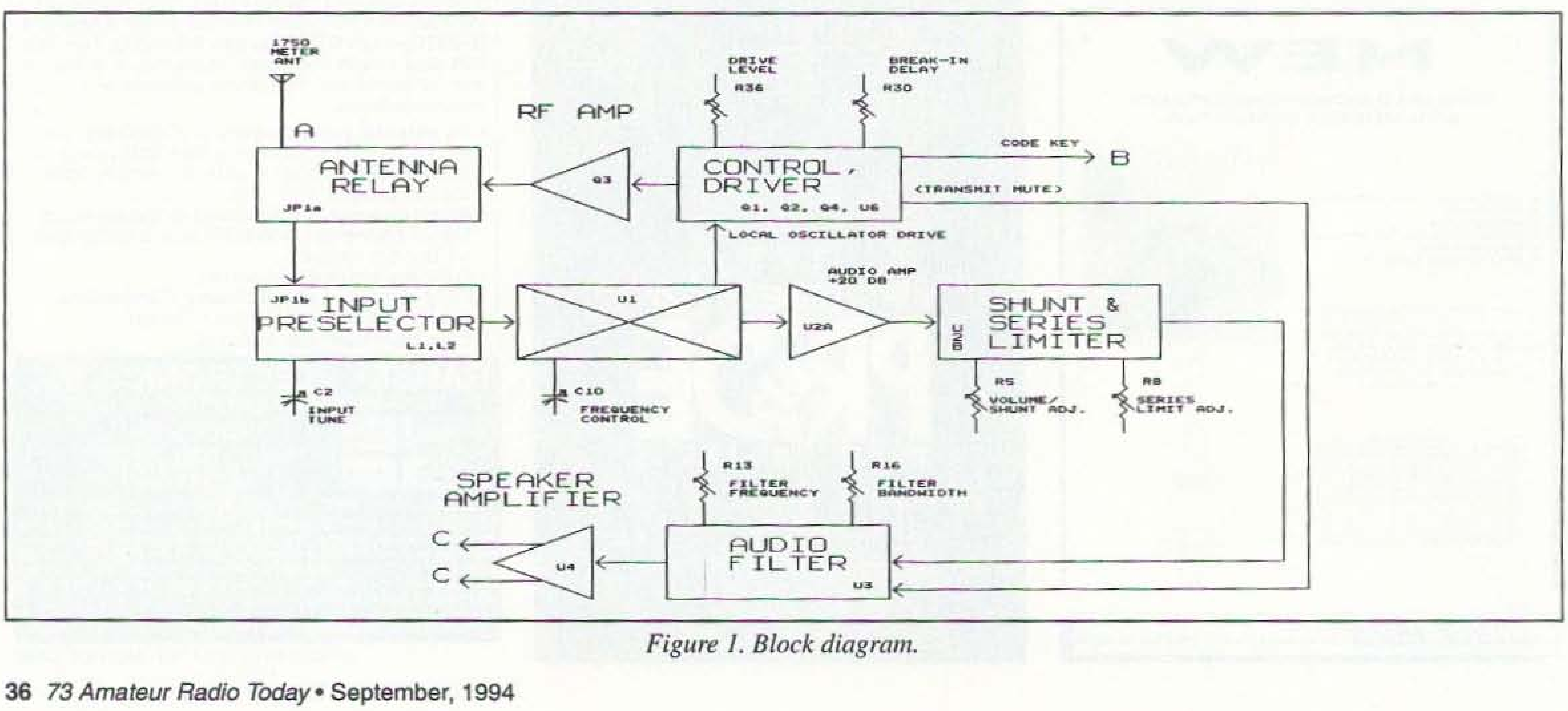


Figure 1. Block diagram.

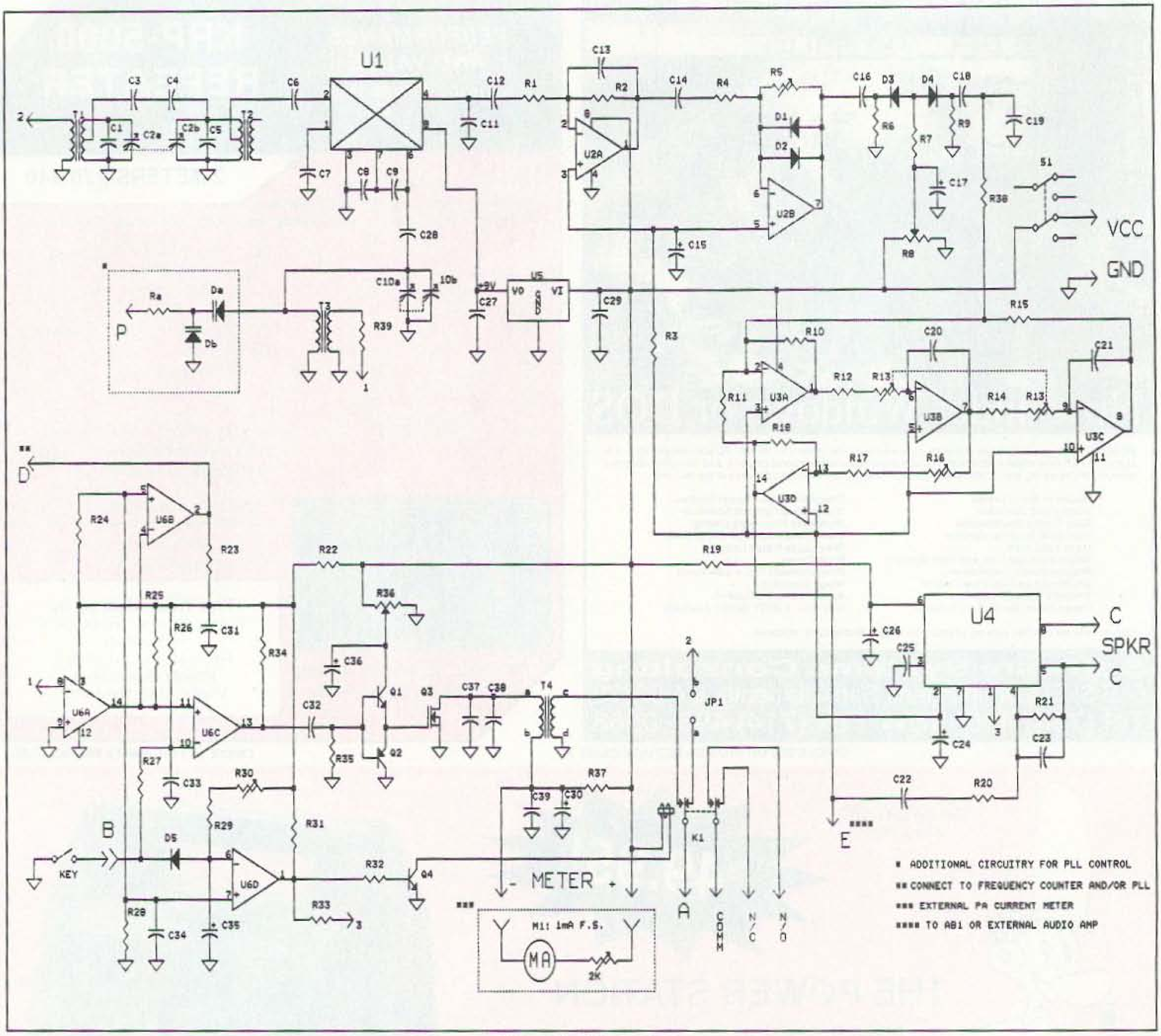


Figure 2. Schematic.

ent Continuous Wave) operation.

Noise is always a problem at these frequencies so two noise limiters are included to provide very effective limiting of high-amplitude man-made noise and static. A shunt limiter followed by a series limiter is used in this design, and this is superior to most designs found in commercial and military receivers. Audio filtering is included, with variable frequency and bandwidth control for precise filtering of the desired signal.

Ample audio output drives headphones and most speakers. This rig is capable of providing over 100 dB of gain with virtually no power supply hum. The transmitter section samples the VFO using a simple logic circuit, controlling the duty cycle and the keying of the amplified signal. The signal then drives a class E power output stage. This class of service is a very efficient 96%. Many thanks go to Mark Mallory for his excellent research into efficient class-E amplifiers and for sharing his information.

The transmitter section lends itself as an excellent beacon transmitter. Simply apply the beacon message to the code key input for reliable beacon transmission. As you probably know, purchasing components these days can be expensive; this was a major concern during the design of this project. All parts are "off the shelf," with the ordering part number given.

Beware: Simple "one-transistor" transceiver designs just do not work on 1750 meters. Don't be fooled!

Construction

Please note the component layout (Figure 3). You will notice that several component leads are soldered directly to the component side of the circuit board. This provides the ground connection for these components. When this occurs, be sure to solder the component lead to the ground plane *and* on the solder side. Note that capacitors are disc-shaped, while electrolytics are round and have the polarity marked. Transistors are designated by the half-moon shape, or round with a key. ICs are rectangular, with the "U" mark at the end.

I recommend soldering the ICs first. Notice that some pins must be soldered on the component side.

Next, solder transformers T1, T2, and T3. Dab some solder on the side of the transformer and ground plane to ensure a good ground.

Install all the capacitors, followed by the variables C1 and C10. C1 and C10 should be installed so that the side with five leads goes through the circuit board. Pull the leads firmly and bend at a 45-degree angle to hold while soldering. Note the small horizontal lead sticking out on the side of C1 and C10. Solder a wire from that lead through the hole in the circuit board under it.

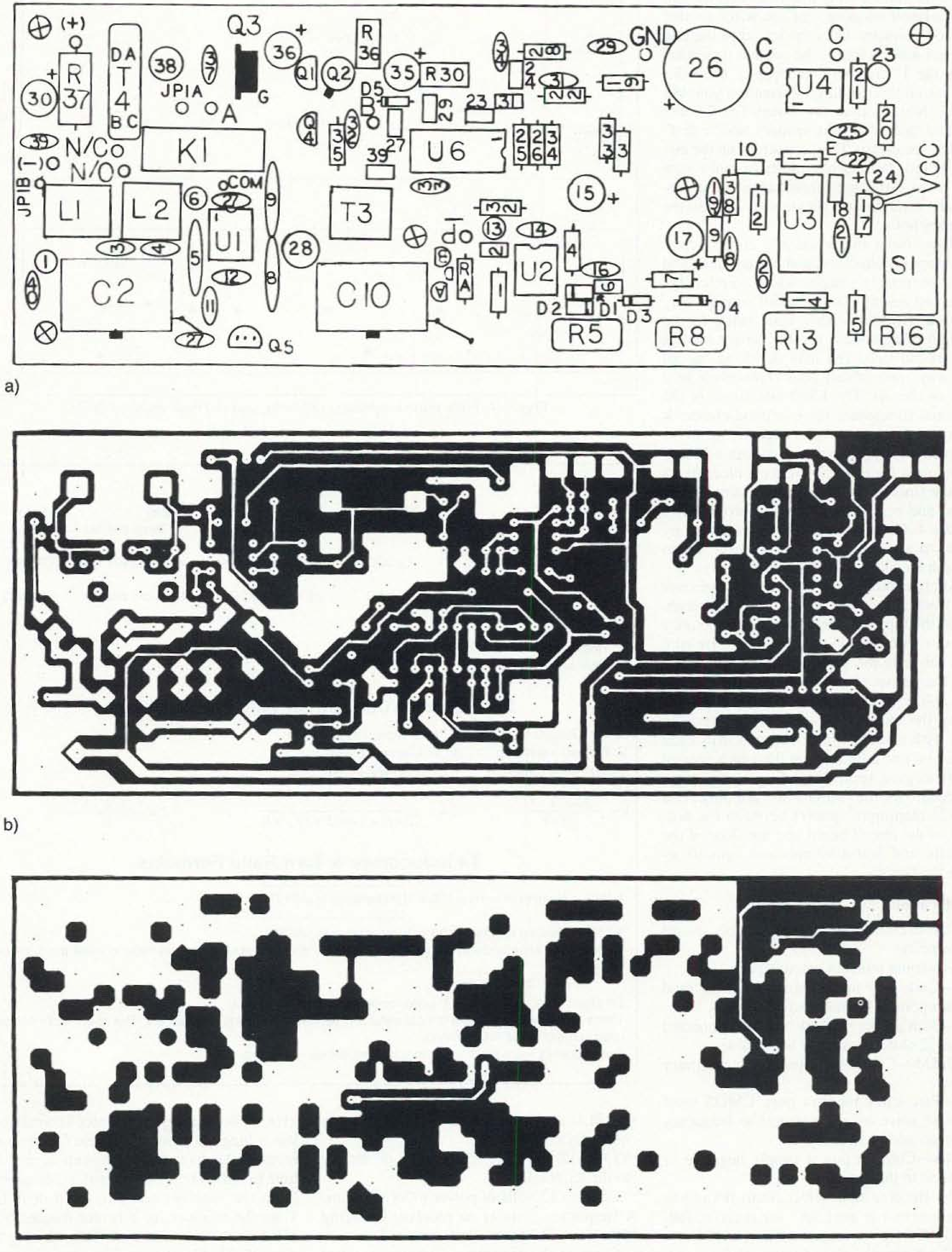


Figure 3. Double-sided PC board: (a)parts placement diagram, (b) top foil pattern, and (c) bottom foil pattern.

Transformer T4 must be wound by hand. Wind the turns evenly and firmly. After you are finished winding, cut the wires so that about 1" remains from the toroid to the end of each wire. Remove the enamel insulation from the 1" ends with sandpaper. The sidebar has all the winding information you will need. Notice that the holes for T4 are marked "a & b" for the primary, and "c & d" for the secondary. They crisscross on the circuit board. Use an ohmmeter to make sure the wires don't get mixed up and the secondary wind doesn't accidentally go into the primary holes!

Now solder the remaining components. Resistors installed horizontally are indicated by a rectangle shape, while vertically-mounted resistors are a small square. Any vertical resistor with a lead going to the ground plane should use the longer lead as the ground lead. You may decide to "go all the way" and install your transceiver in a box or chassis. The LMB box listed in the optional component list is a good choice. It provides extra room for a speaker, meter, or antenna switch. The meter is both a luxury item *and* a necessity. To make a nicer finish for the front of the chassis, templates for the front and rear face plates are provided in Figure 4. Go to a photocopy store and copy them to a transparency. Be careful not to scratch the black from the transparency.

Apply a thin film of clear epoxy glue over the front of the box. Size up the transparency so the top of the box on the transparency is even with the top of the chassis. Be sure you can *read* the transparency before pressing the transparency to the adhesive. After the epoxy has cured for a few hours, cut away the excess transparency around the box with a sharp knife. Tap and drill each hole to a size a little larger than each control shaft to give some play. Repeat the same procedure for the rear chassis face plate. Use 4-1/2" aluminum spacers between the bottom of the circuit board and the floor of the chassis, and four 4/40 nuts and bolts to secure the board.

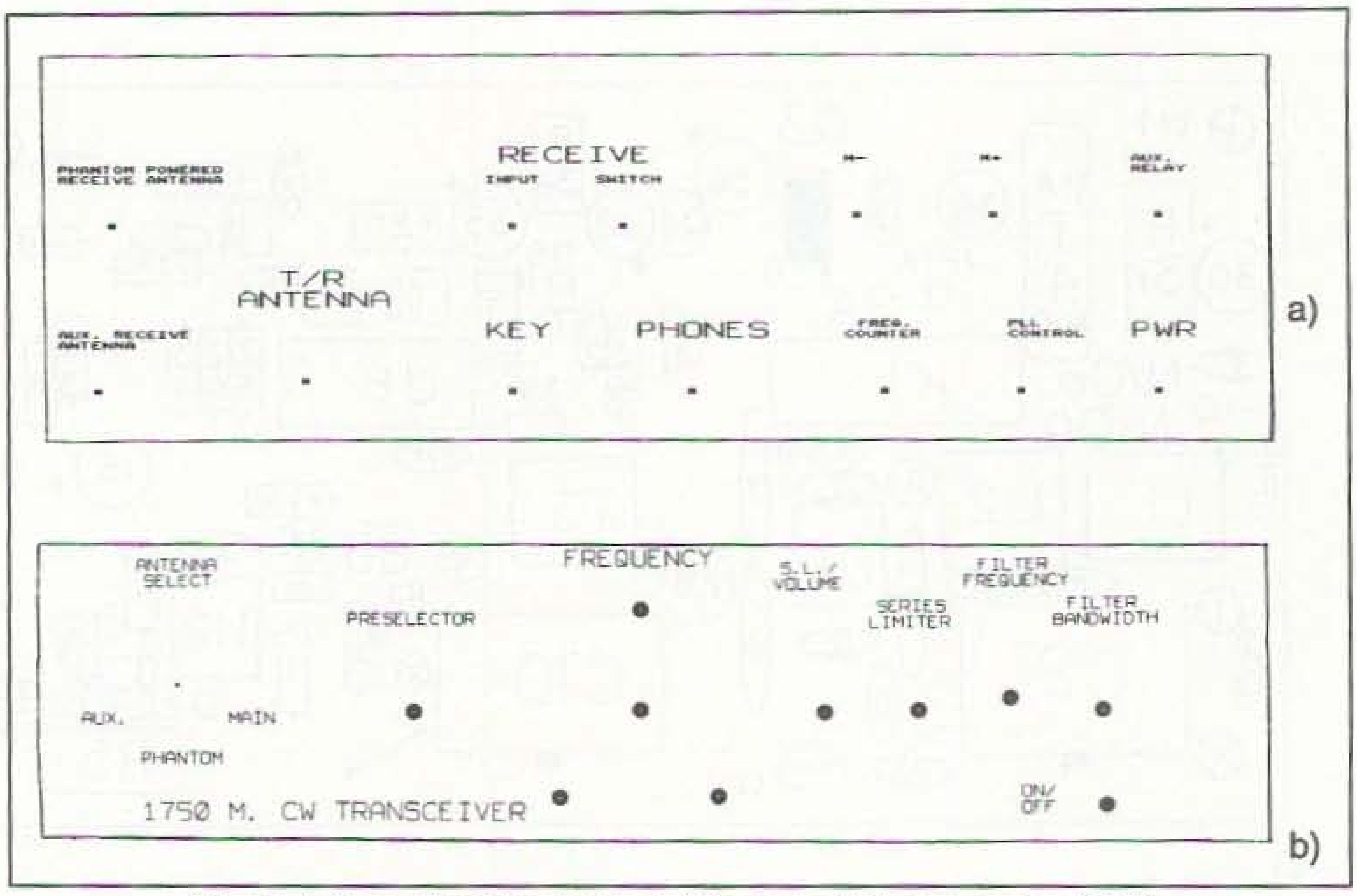


Figure 4. Face plate templates: (a) front, and (b) rear, reduced 50%.

T4 Winding Data

Power	C37	C38	VCC	T4a/b	T4c/d	Form
1 watt*	X	N/A	12 VDC	93 Turns #30 Ga.	49 Turns #24 Ga.	T-68-3
3.5 watt**	N/A	X	12 VDC	49 Turns #24 Ga.	48 Turns #24 Ga.	T-68-3
10 watts	X	X	18 VDC	33 Turns #20 Ga.	37 Turns #20 Ga.	T-130-3

N/A: Not used.
* Heat sink recommended.
** Heat sink required.

Formulas for Calculating Efficient PA Design

L: Tank inductance — C: Tank capacitance
Z: PA load resistance — V: VCC supply voltage
F: Operating frequency — P: Output/input power

$$L = \frac{.2085 \times V^2}{P \times F} \qquad C = \frac{1}{(2 \times pi \times 1.2915 \times F^2) \times L} \qquad Z = \frac{1.2638 \times V^2}{P}$$

T4 Inductance & Turn Ratio Formulas

T-68-3: Number of turns = $100 \times \sqrt{(\text{Inductance in uH}/195)}$

T-130-3: Number of turns = $100 \times \sqrt{(\text{Inductance in uH}/350)}$

To match the impedance at the drain of Q3 to a 50 ohm impedance, you will need to know the turns ration (Tr):

$$Tr: \sqrt{(Zd/Z1)}$$

Zd: Drain resistance — Z1: Load resistance (usually 50 ohms)

These formulas are included to help solve any particular matching requirement. The above table can be used to match most requirements.

The frequency value for "F" can work for frequencies +/- 10 kHz.

Calibration

Connect the antenna, power supply, etc. to these points:

- •A—50 ohm transmit antenna port.
- •B—Code key port. Transmit is initiated when point B is grounded.
- •C—Both points marked "C" are connected to 8-32 ohm speakers or headphones.
- •COMM—Common terminal for auxiliary relay.
- •D—Frequency monitor port. CMOS level square wave output connects to frequency counter and/or PLL input.
- •GND—Connect power supply negative or ground to this point.
- •JP1—Receive input select. Short JP1a&b to use antenna at port "A" for receive. RECEIVE ONLY antennas connect to JP1b.
- •N/C—Normally closed terminal for auxiliary relay control.
- •N/O—Normally open terminal for auxiliary relay control.
- •P—PLL or phase control of VFO. Section normally not used.
- •VCC—12-18 volts, filtered DC or battery to the terminal.

Connect 12 volts of power to VCC points. A frequency counter or receiver covering 150 kHz to 250 kHz will be required.

Connect the frequency counter to point "D." Turn the transceiver ON. Turn the tuning capacitor C10 maximum clockwise. Turn the slug in T3 until the frequency reads 189 kHz. If no frequency counter is available, use a long-wave receiver, general coverage receiver, or ham radio that can accurately tune to 190 kHz. Place a small piece of wire from the receiver antenna input near U1. Tune the receiver for a center frequency of 189 kHz. Listen for a tone while turning the slug of T3. Slowly turn the slug until you hear a zero beat on the receiver. Next, align the preselector. T1 and T2 must be tuned to the same frequency. If you have a signal generator, place a low-level (approximately 100 μV) signal of 175 kHz to the input at JP1b. On the transceiver, turn the Preselector and the Filter Frequency controls to the 12-o'clock position. Rotate the series limiter and the filter bandwidth controls to full counterclockwise.

Tune the Frequency control for 176 kHz.

Turn the slugs on T1 and T2 for maximum volume, decreasing the signal generator output as the tone becomes louder. If no signal generator is available, connect the antenna to JP1b and listen for any carriers by adjusting the Frequency dial and volume controls. Turn the Preselector capacitor to the same setting as the Frequency capacitor. Turn the slugs in T1 and T2 for maximum signal strength.

Operation

The Volume control will limit the amplitude of all signals past a certain point. This can be used to increase the gain of a desired signal that is buried in man-made noise, cutting off the peaks of the noise while leaving the signal unaffected. The series limiter can be used to lower the volume when the volume/shunt limiter control is used for extreme limiting. You will find that the volume/shunt limiter is better at reducing high-level man-made noise, while the series limiter is better for reducing static and occasional high-impulse noise. The audio filter frequency and bandwidth are adjusted for the desired amount of filtering.

An important feature is the input Preselector control. The preselector filter is very sharp, allowing only a small slice of the band to be received. If, for example, the beacon you want to hear is on 180 kHz, tune the Frequency control for a frequency of either 179 kHz or 181 kHz. The beacon message will be heard at a 1 kHz tone: 180 kHz-179 kHz = 1 kHz, or 181 kHz-180 kHz = 1 kHz. The preselector must be tuned to the desired signal at 180 kHz for maximum pickup. Choosing whether the upper or lower VFO frequency is best depends on which provides the clearest reception. An example of two-way operation could be you transmitting on 182 kHz with the preselector peaked to your friend's frequency of 182.4 kHz. Your friend's preselector would be peaked to your frequency of 182 kHz. As you can see, tuning the preselector above and below your center frequency provides a lot of flexibility.

Transmitting a beacon is very useful while you're not on the air. It is especially helpful to other stations that want to know if they can hear you or not, and helps with antenna testing and band conditions. The transmitter is easy to use. Simply connect your beacon ID or code key or PK-232 CW to the key input. Adjust your time-delay potentiometer (R30) for the desired time delay. The PA drive control (R36) can be set for maximum VCC. The transmitter was designed for link or tap coupling, using 50 ohm coax from the transceiver to the antenna loading coil. Direct connection from the cold end of the loading coil to the secondary of T4 is fine.

A 1 mA meter may be used to monitor the PA current. However, meters can be expensive; you can use a VOM or VTVM instead. Connect this to the meter "–" and "+" points on the circuit board. The voltage indicated is the input current to the PA. 1 watt of input power is 83 mA at 12 volts, or 83 millivolts on the VOM or VTVM. Also remember to measure the PA voltage at the "-" meter point since there is a slight voltage drop across R37 when calculating input power.

Parts List

Part #	Description	Purchase
C1,C5	470 pF poly cap	Mouser: 23PS147
C11	0.047 μF film cap	Digi-Key: P4521
C13,C23	0.001 μF polystyrene cap	Mouser: 23PW210
C15,C17,C24, C30,C35,C36	10 μF/50 VDC elec. cap	Mouser: 140-XRL25V10
C18,C25,C31,C39,C27	1 μF monolithic cap	Newark: 90F1907
C19,C33	0.01 μF disc cap	Mouser: 140-CD50Z6-103M
C2,C10	400 pF tuning cap	Mouser: 24TR218
C20,C21	0.018 μF poly cap	Digi-Key: P3183
C26	2200 μF/16 VDC electro cap	Mouser: 140-XRL16V2200
C28,C38	0.01 μF polystyrene cap	Mouser: 23PW310
C3,C4	7.5 pF NPO disc cap	Mouser: 21CB008
C40	0.022 μF poly cap	Digi-Key: P3223
C6	0.0047 μF poly cap	Mouser: 23PW247
C7,C12,C14,C16,C22, C29,C32,C34	0.1 μF ceramic disc cap	Mouser: 140-CD12U6-104M
C8,C9,C37	0.0027 μF polystyrene cap	Mouser: 23PS227
D1,D2,D3,D4,D5	Diode	Mouser: 592-1N914A
K1	DPDT relay	Digi-Key: Z768-ND
Q1,Q4	2N2222A NPN transistor	Mouser: 511-2N2222A
Q2	2N2907A PNP transistor	Mouser: 511-2N2907A
Q3	Power MOSFET	Mouser: 511-IRF510
R1,R4,R20	3.3k ohm 1/4W	IME
R10,R11,R15	100k ohm 1/4W Metal 1%	Mouser: 29MF250-100k
R12,R14	4.02k ohm 1/4W 1% metal	Mouser: 29MF250-4.02k
R13	10k dual audio taper pot	Calrad: 25-396
R19,R22	12 ohm 1/4W	IME
R2	33k ohm 1/4W	IME
R23,R32,R33,R34	1k ohm 1/4W	IME
R25	560 ohm 1/4W	IME
R3,R7,R21,R29, R35,R38	82k ohm 1/4W	IME
R30	250k ohm PC trimpot	Mouser: 32RM503
R31,R39	2.2k ohm 1/4W	IME
R36	2k ohm PC trimpot	Mouser: 32RM302
R37	1 ohm 1W	Mouser: 29SJ901
R5,R16	500k ohm PC pot	Mouser: 31CW505
R6,R27,R28	6.8k ohm 1/4W	IME
R8	10k ohm PC linear pot	Mouser: 31CW401
R9,R17,R18,R24,R26	10k ohm 1/4W	IME
S1	DPDT PC switch & knob	Digi-Key: EG1003-ND
T1,T2,T3	0.63mH transformer	Digi-Key: TK1201
T4	Toroid transformer	Amidon: T-68-3
U1	NE602 mixer/amp	Digi-Key: NE602AN
U2	Low-noise op amp	Mouser: 511-LF353N
U3	Quad op amp	Mouser: 511-LF347N
U4	Audio PWR amp	Newark: MC34119P
U5	+9 VDC regulator	Mouser: 333-78L009AP
U6	Quad comparator	Mouser: 511-LM339AN

Sources:
Mouser Electronics—(800) 346-6873
Digi-Key Sales—(800) 344-4539
Calrad—(213) 465-3504
Newark Electronics—(818) 888-3718
Amidon Associates—(310) 763-5770
IME—(817) 473-1730

A drilled and etched PC board is available for $22 plus $3 S & H; and this project is available in a complete kit for $89 plus $3 S & H from: Curry Communications, 737 N. Fairview St., Burbank CA 91505; (818) 846-0617. Brochures are available; send SASE.

Dual-Band Vertical

For the 160 and 1750 meter bands.

by David F. Curry WD4PLI

Using a TV push-up mast, you can get surprising ground wave radiation from small vertical antennas (30 to 50 feet high) for the 1750 and 160 meter bands. Good antenna performance is critical; the antenna must be resonant with your operating frequency for transmission, and have a good ground system.

FCC regulations state a maximum-50 foot limit in the 160 to 190 kHz bands for both the feedline and antenna. Even with strict limits such as these, transmission and reception of ground wave signals from several hundred miles away are possible at low power levels of only 1 watt.

Many amateur operators would like to try this low band, but they can't find a good design for an antenna. A 160 meter antenna could easily be matched to work the 1750 meter band, but its dimensions might exceed the legal limits. In this article, I offer a good compromise, opening opportunities for someone with space restrictions.

Antenna Description

The basic antenna assembly is in three parts: the top hat and 160 meter loading coil, the push-up mast upper and lower section, and the loading/relay system for antenna matching.

The capacity hat is the key to good radiation resistance and low angle radiation for 160 meters, and greatly improves the efficiency on 1750 meters. The size shown in the picture is 10 feet in diameter, with a wire ring around the perimeter. The wire ring further increases capacitance, adding to overall efficiency.

The telescopic portion of the antenna is a galvanized steel push-up mast you can buy at almost any Radio Shack, electronics or possibly hardware store. Select the length that suits your requirements. A 40-foot mast seems to be a good compromise of rigidity and height vs. price.

Final matching will be done at the antenna site, using a relay for dual-band operation (not required for single-band operation), and a capacitor/inductor combination.

On the 160 meter band, the antenna is current-fed by the loading inductor just under the capacity hat. The actual antenna resonance is lower than the frequency of interest, and therefore must be electrically shortened by a series capacitor at the base of the antenna. The capacitor should be preferably an air dielectric, such as a large transmitting variable from 50 to 500 pF. A vacuum variable would also be ideal. The larger the tuning range of the variable, the greater the frequency swing across the 160 meter band. The capacitor connects between the antenna and the center of the coax lead, and is tuned for minimum VSWR. With the loading coil near the top of the antenna, most of the current will flow to the top, which is desired.

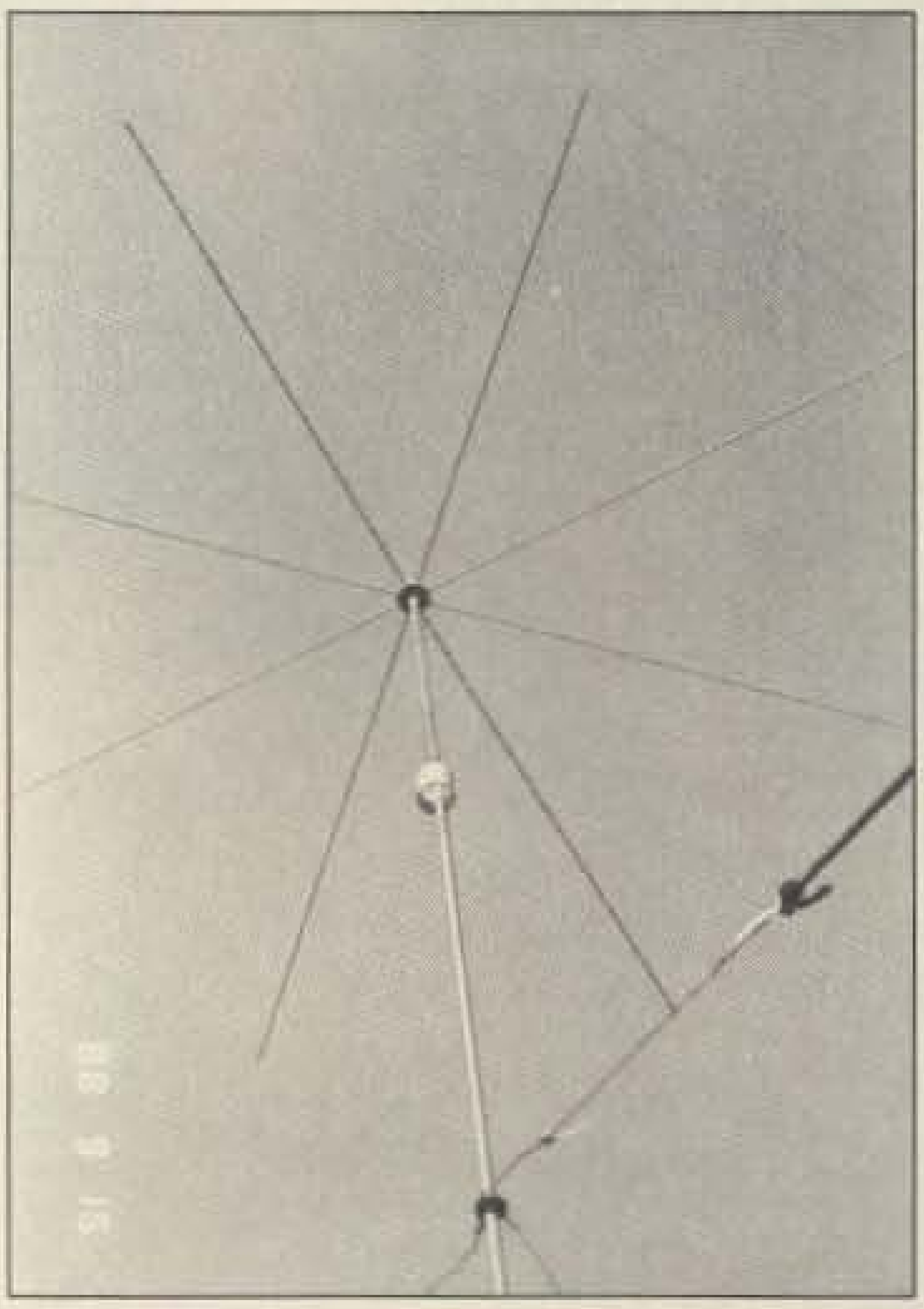


Photo. The dual-band vertical showing the capacity hat and top-loading coil.

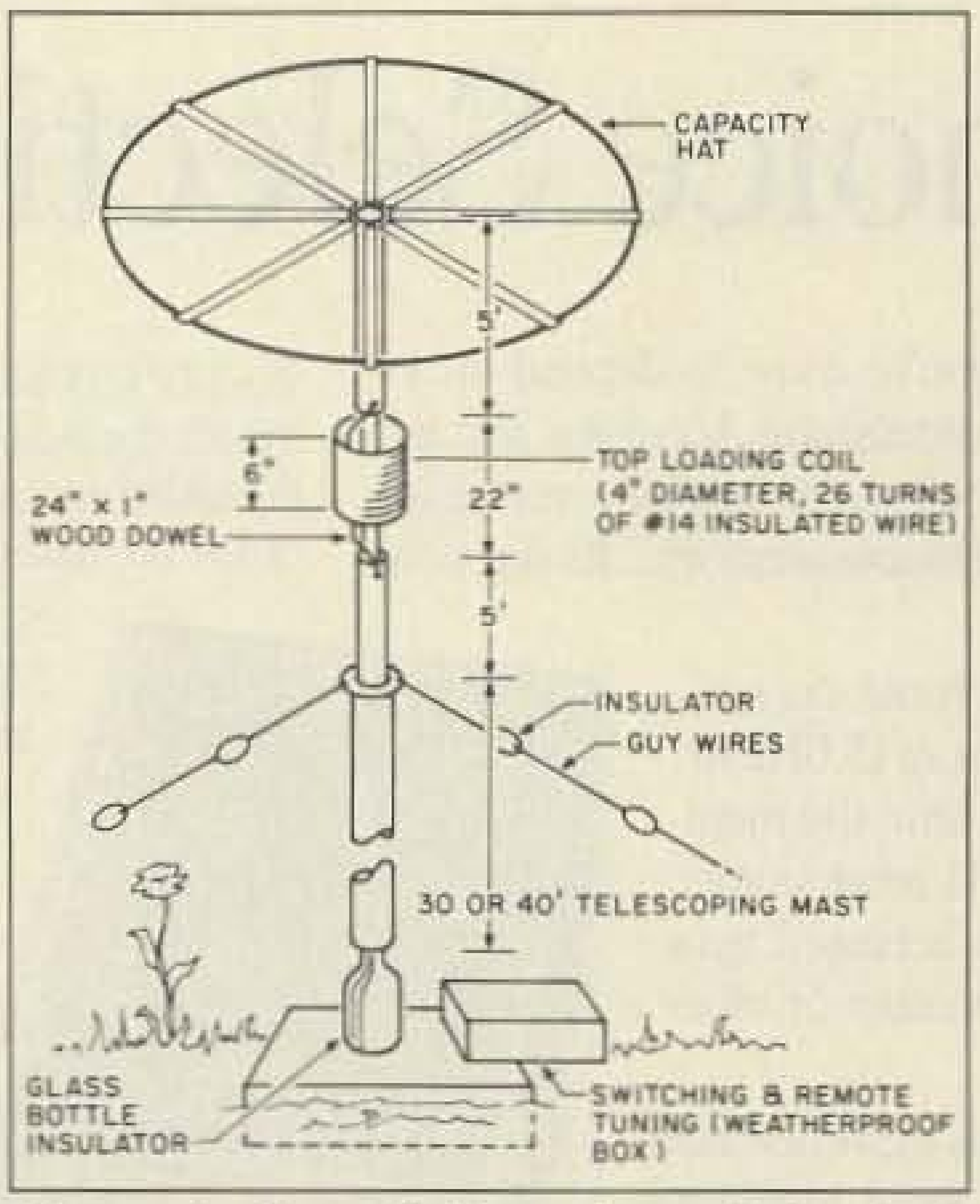


Figure 1. Overall dimensions of the dual-band vertical.

1750 meter operation is very different, as this antenna is extremely short at these frequencies. With the size of capacity hat described, a top-loading coil would be very inefficient due to the high amount of inductance required, and the subsequent I^2R losses from the resistance of the wire. A much larger capacity hat would be required, and would involve consulting your neighbors! Instead we will voltage-feed the antenna using a large prehistoric-size loading coil at the base, and use a tap point on the coil to match it to a low impedance source (transmitter).

By using the capacitive reactance to tune the coil to resonance as a part of the antenna capacitance, the coax actually becomes part of the antenna matching system. This offsets the 50-foot antenna and feedline restriction by turning the coax from a non-reactive transmission line to a reactive component that is part of the tuning circuitry.

The loading coil L1 in Figure 7a can be a regular air-wound inductor, with the number of turns found experimentally. Or you could use a variometer (see the sidebar) that would greatly ease the tuning procedure.

Construction

Remember before starting that the top loading coil just below the capacity hat can be eliminated if you plan to operate only on 1750 meters.

The capacity hat is made of eight aluminum tubes, each 5-feet long and ¼-inch thick, purchased at a local hardware store for about a dollar a foot (see Figure 2). At the end of each tube, press a ½-inch area flat with pliers, and drill a small hole to accommodate a

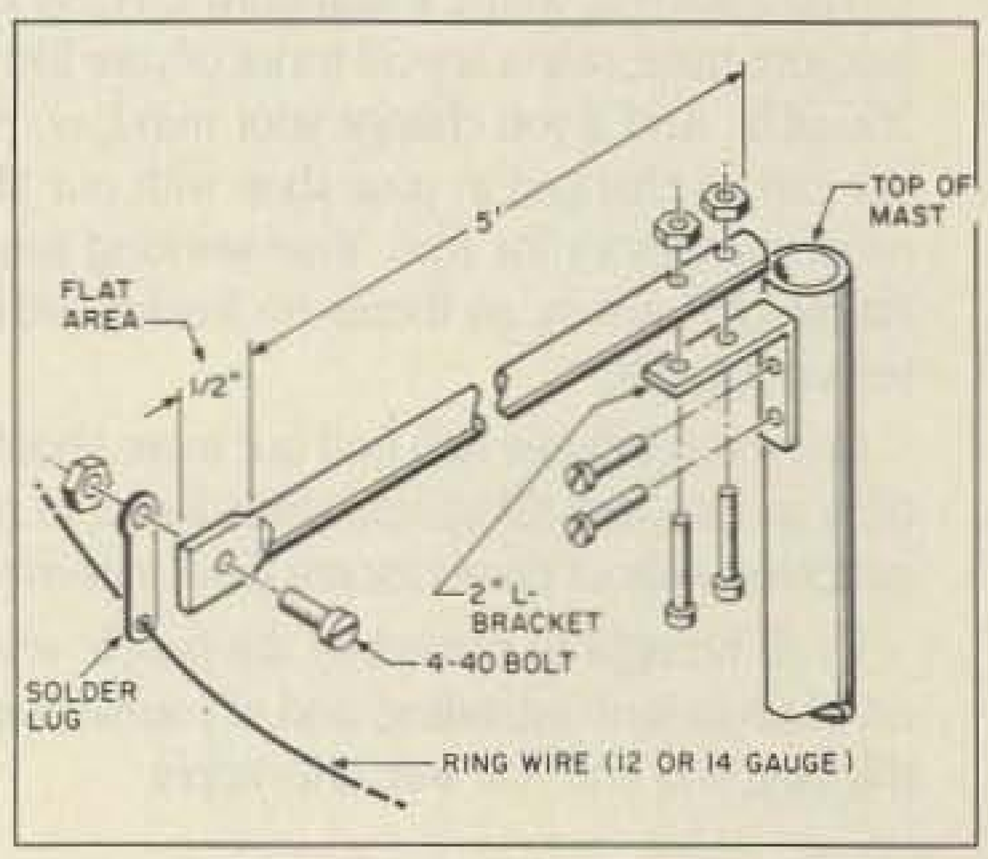


Figure 2. Construction details of the capacity hat tubes. A 2" steel L-bracket is used to attach each tube to the mast. Run a wire ring through the far ends of the tubes to form a large circle (solder the wire ring at the end of each tube).

4-40 nut and bolt. Use a solder lug so that the ring wire can be soldered securely after the solder lug is tightly fastened with the nut and bolt to the aluminum rod. This makes it easy to install the wire ring. At the other end of each tube, attach a 2-inch steel L-bracket. Drill 8 holes equidistant around the top end of the mast pipe so that the capacity hat tubes can be attached. Mount each tube to the mast as shown in Figure 2.

When you attach the top hat, be sure to twist each rod so that the solder lug at the end will be in a vertical position. The wire chosen as the ring wire should be of large solid variety, and can be insulated. String the wire through each solder lug hole, but not too tight. Clip and solder the end of the wire, and each remaining solder lug, with ample solder. Spray your favorite color of paint on the entire capacity hat assembly for weatherproofing, or paint marine varnish over all sections.

The top loading coil for 160 meters is constructed from 4-inch diameter white PVC pipe, about 5 inches long. 30 turns of #16 gauge stranded wire, Teflon™ insulated, is used for the initial inductor. You could use other coil-form material, such as Plexiglas™. Avoid black-colored PVC tubing!

Wind the coil tightly and paint it with Fiberglas resin. Use solder lugs to secure each end of the coil, and 6-inch wires to connect the coil to the top and bottom mast.

The top section of the mast is five feet of galvanized steel tubing, exactly like the top section of the telescopic vertical. The exact length is not critical since the coil can resonate to almost any reasonable length, but lengths beyond 10 feet can break due to wind resistance. Three to seven feet are recommended. *[Ed. Note: If you use a 40 or 50-foot telescoping mast for the antenna, you can cut the top 10-foot section in half to use as the top section.]*

When painting the coil, also paint a wooden dowel rod that's about one foot long and fits easily into each vertical section. The idea here is to provide good insulation and solid strength for the top section of the vertical and capacity hat. The wooden dowel works very well for this, and should be inserted into the top of the push-up mast after curing.

Final Assembly

Now you may have to make a big decision. Shall it go on the roof or in the yard?? It should be in the clear as much as possible, of course! Absorption from trees and surrounding structures can foul up an antenna of this type. Also, you have to consider a ground system after raising the antenna. Insulated radials (as many as practical) at 50-foot lengths should radiate from the antenna base in equal directions. On roof installations, use either radials, hot and cold water pipes (especially copper ones!), or chicken fence mesh. Many times a combination of these will do an adequate job, especially for the city dweller.

After you've determined the antenna site, make preparations for the insulated base. Many approaches can be used, but the old glass bottle trick works every time, and is

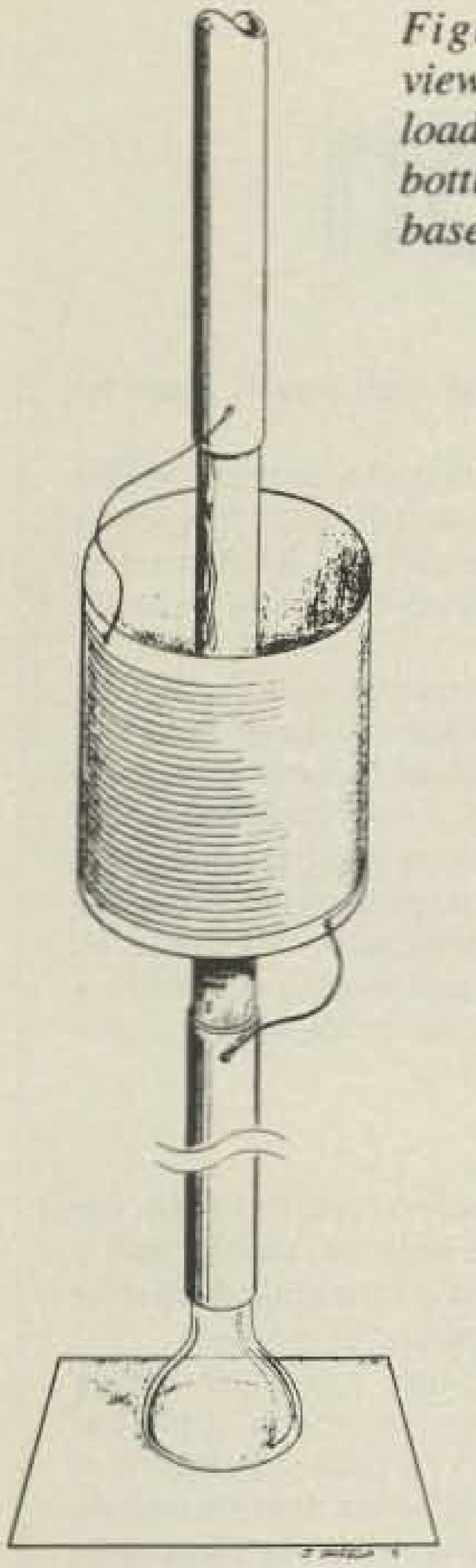


Figure 3. Close-up view of the 160m top loading coil and glass bottle insulator for the base.

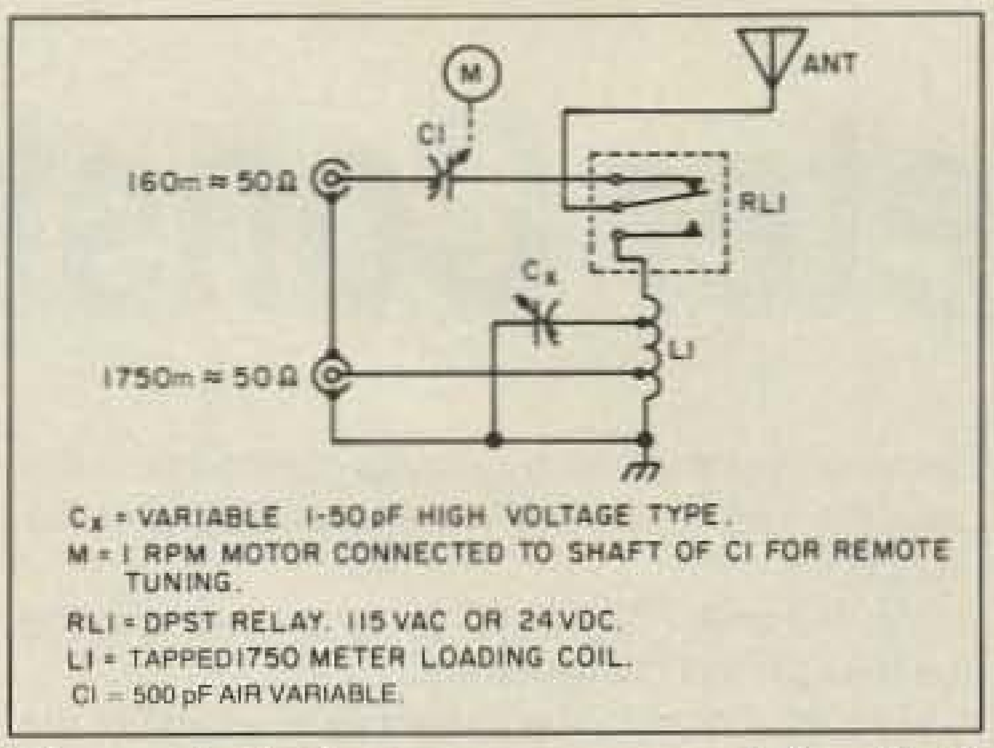


Figure 4. Switching arrangement for dual-band operation.

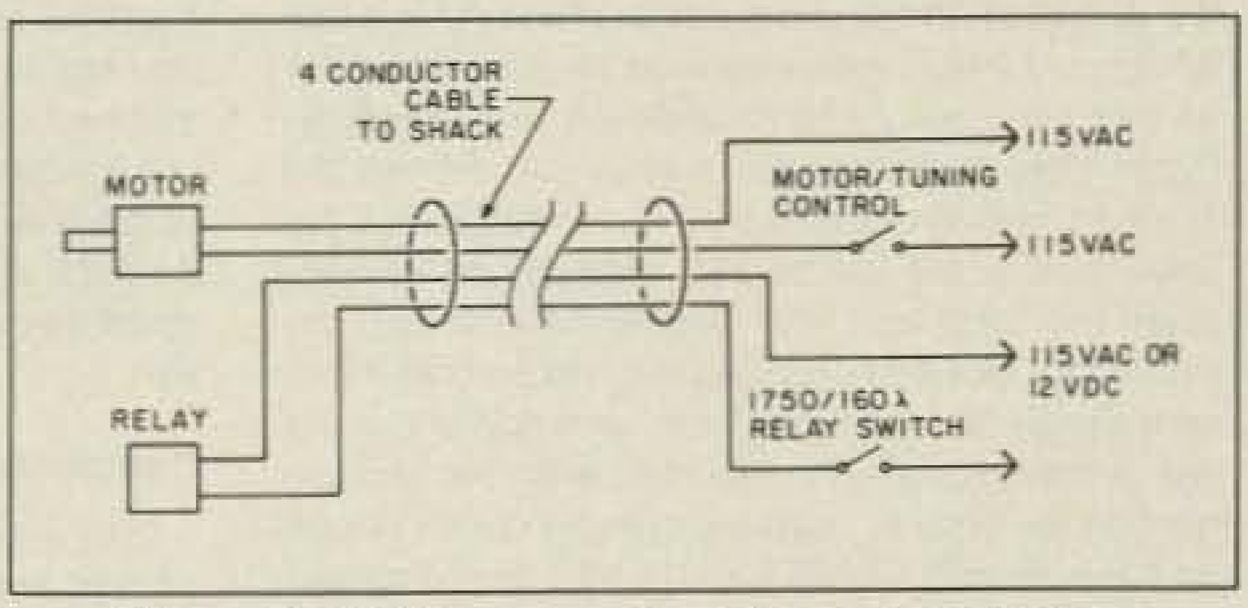


Figure 5. Cable connections for remote tuning.

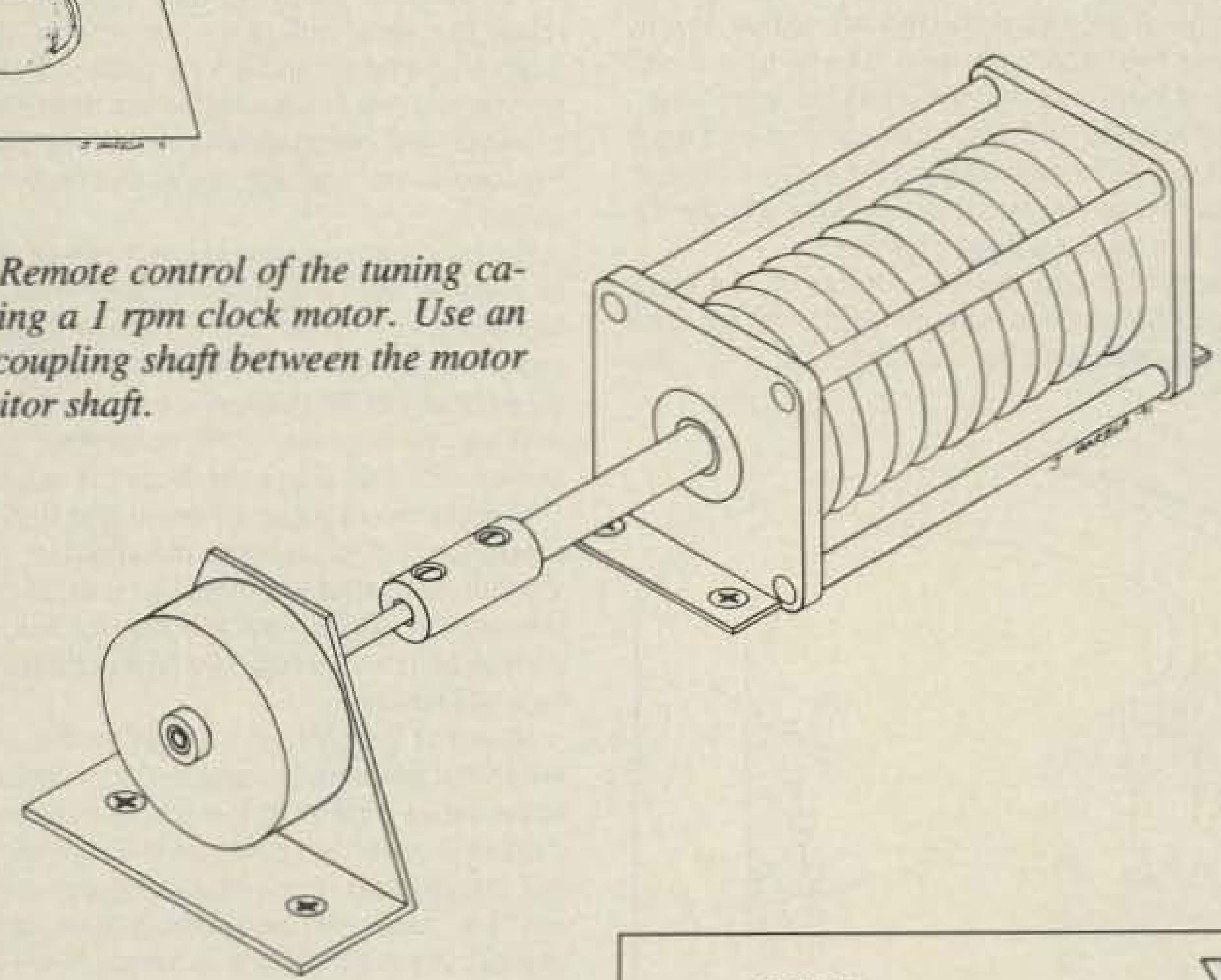


Figure 6. Remote control of the tuning capacitor using a 1 rpm clock motor. Use an insulated coupling shaft between the motor and capacitor shaft.

recommended. The bottle is simply placed in cement that has been prepared and drying. Insert the bottle about four inches into the cement. The cement may be poured into a hole in the ground, for ground installations. A vent pipe can be used for roof mount, but a strong solid insulator, such as a Plexiglas or Teflon rod, must be used as an insulated support. Plastic companies usually carry this product. Alternatively, a cement block can be used with a glass bottle for roof mounts. The guy cables are ¼-inch polypropylene rope which are adequate but need replacement every couple of years.

The collapsed mast is placed over the insulator and guyed at the 10-foot section. Additional guys are attached, usually at the 30-foot section.

If steel guy wire is used, be sure to use ceramic egg insulators, two per guy to insulate the vertical. Very high voltages exist

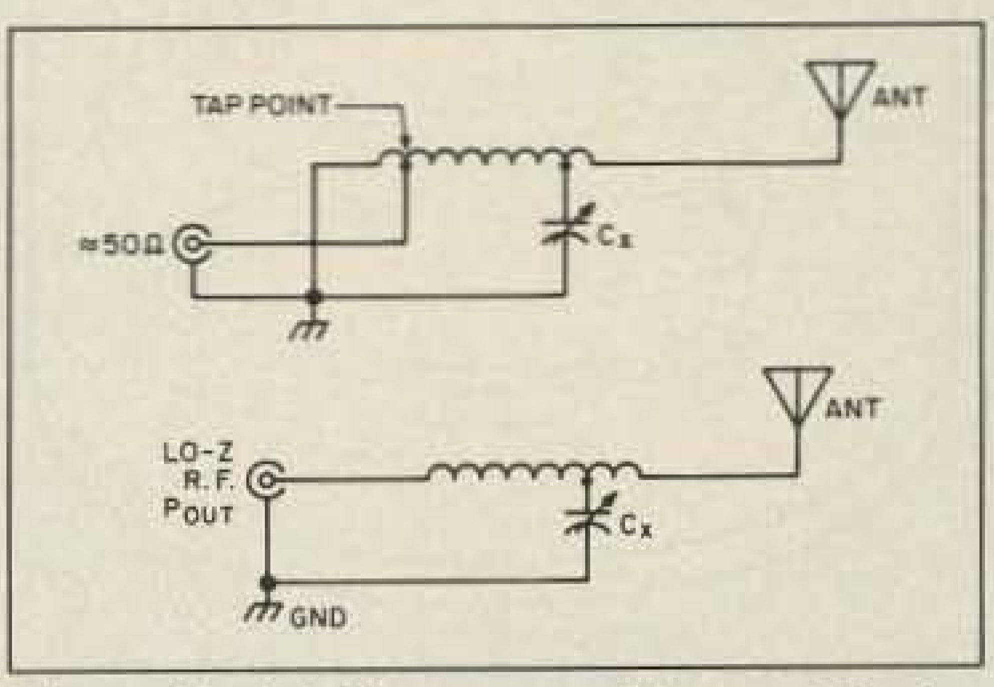


Figure 7. (a) Proper matching to 50 ohm coax. (b) Direct connection to the transmitter at the antenna site.

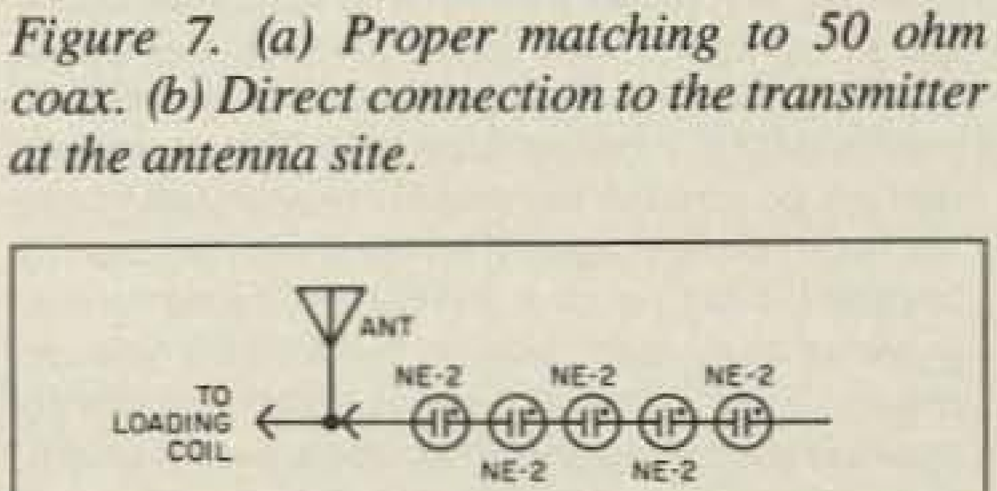


Figure 8. Neon bulbs soldered in series and connected to the antenna. When they reach maximum brilliance, the antenna is resonant.

Variometer Construction

A variometer provides an easy way to match low frequency antennas, such as vertical radiators, random length horizontal, or "L" shaped wire antennas, and resonate these at a desired frequency.

A variometer can be thought of simply as two inductors that can slide in and out of each other. Depending on the size of the inductor coil forms, the number of turns, and the size of wire used, the inductance will vary as the magnetic fields of both coils either aid or cancel each other as the two coils are moved within each other's proximity.

One of the coils can be made small enough to rotate inside the larger coil, and the magnetic flux can be added or subtracted by rotating the inside coil. To do this, both coils must be connected in series. The variometer is wired so that the smaller rotating inductor is connected within the large outer one. Optimum efficiency will occur when both coils aid or add to each other for maximum inductance.

During initial calibration, after rotating the inside inductor to resonance, it may be beneficial to remove wire from the variometer. This is especially desirable from the standpoint of higher efficiency and better *Q*.

The whole point of the variometer is to find the ballpark resonance of your antenna system, then optimize the variometer by removing or adding turns, if required.

Assembly

First, wind the large coil form.

Usually, a range of 5–8 mH for a 30–50 foot vertical antenna will be within the 1750 meter limits. A vertical antenna such as this should also have at least a 5-foot capacity hat for improved radiation resistance. Wire gauges from 18 to 26 work well, with the small gauge wire providing more turns per inch and more inductance. Number 22 gauge wire does a fine job overall, and you'll need at least 200 feet.

Two small holes, one at each end of the coil form, is used for terminating each end of wire after winding.

Tape one end of wire with masking or Scotch™ tape to, or near, a hole at the end of the coil form. Sit in a chair or couch with the form in your lap. The spool of wire should be on the floor, leading up to the form.

Turn the form with one hand and use the other hand to guide the wire taunt against the form. A tight, even layer is required. After 20 or 30 turns you might want to stop and push the turns closer, if required.

Masking tape will hold the turns in place when you stop. In the middle of the form are two 1/4-inch holes directly opposite each other, with a small hole next to each one. Wind the turns carefully around these holes so that you don't block them, because the holes will be used later on in assembly.

A 4-40 screw with a solder lug can be installed at the end hole to terminate the wire. The insulation should be removed with fine sandpaper or a stripping chemical, and then inserted through the eye of the solder lug and twisted. Make sure that there isn't any slack that could loosen the turns of the wire. Repeat this procedure for the other end of the coil using a 4-40 screw and nut, and a solder lug terminal. If desired, a spray varnish can be used to add weatherproofing and protection. Use only a clear varnish or enamel.

Now wind the smaller coil form in a similar fashion. Because this form is so small by comparison, it may not be necessary to take the same precautions as before. The only major difference is the way the wire is installed in the form itself. (See the figure.)

At this time, varnish or spray enamel may be used to protect the inside coil.

The final step in the assembly is to install the small coil inside the larger one, and wire the two inductors together. Locate the nylon threaded rod and nylon nuts. Push the rod through one end of the large coil and screw a nut on. Turn the rod and advance the nut, then screw on another nut. After an inch or so, place the smaller coil form inside the larger one, and place the end of the rod into the 1/4-inch hole in the center of the small form. Continue to turn the rod so that it advances into the small coil form and add another two nuts on the nylon rod. Continue turning the rod so that it can go through the small coil form, and add one more nut. A total of six nuts are used, with four of them holding the smaller coil directly in the center. Tighten the nuts with FINGERS ONLY! The rod should extend completely through the large coil, with one end longer to provide a knob to turn it with. At this end, add the last nut on the outside of the large coil, and screw it so it is tight with the inside screw, centering the small coil and providing a small amount of friction so that the small coil won't slip.

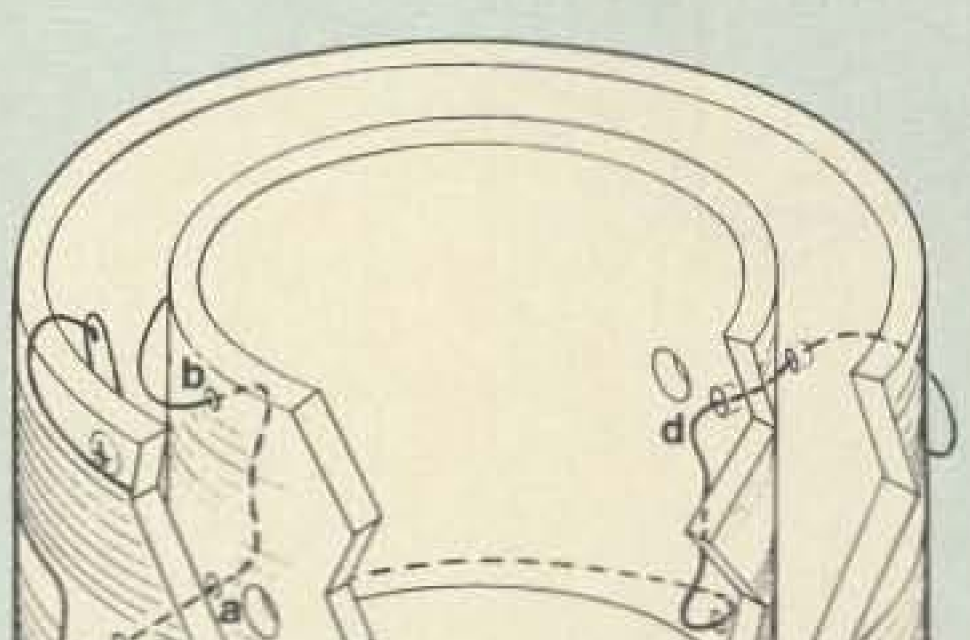
Take the wires from the small coil and lead each wire through the small holes on the larger coil form.

These two wires should follow closely to the nylon rod, and have no kinks or twists.

Once fed through the small holes on the large form, clip the excess wire so that only 1/4 inch remains extending from the large coil form. Remove the enamel so that each wire is clean for soldering.

At this point, cut the wire on the large coil, where it goes between the two 1/4-inch holes. This will be right in the middle of the coil, and will be easy to locate since it is a single wire in between the upper and lower sections.

If no varnish has been applied to the larger coil, you will need to add tape over the upper and lower sections so the turns will not become loose after you cut the wire. Each of the cut wires should be trimmed back and soldered to one of the wires from the inside coil. Snip the wires from the larger coil and solder, one on each side, to the 1/4-inch wires on each side from the small rotating coil. Allow a small amount of slack on the inside wires for rotation.



The diagram shows that the wire is first fed backwards out of the hole (A), and down the inside toward the center (B), and then outside with approximately 3–4 inches remaining. This remaining end will go through the small hole at the center of the large coil form later. With the wire at (A) and (B) installed, wind the form completely, being sure to leave an open space around the 1/4-inch holes at the end. Push tightly all turns so that the most wire possible can fit on the form. Before cutting any wire, add approximately two feet, after inserting the wire through the hole (C). Now, cut the wire and feed it through hole (C), down inside toward the center and through hole (D), to the outside.

Operation

The variometer is connected between the ground systems and the antenna, usually with a tap point several turns up from the ground side that connects to the transmitter and/or receiver.

For systems involving only a receiver, simply rotate the small coil of the variometer at the frequency of interest and note a peak in reception. If there is no peak in signal strength, then it is entirely possible that resonance is occurring elsewhere. Remove turns from the top of the outer coil if required.

For transmitting purposes, remove as much wire as possible from the outer coil after the frequency has been determined and experimentation has located the variometer's point of resonance. Measure either the RF voltage across the 50 ohm load with an oscilloscope or RF voltmeter, or the RF current to the 50 ohm load. Note the value.

Monitor the radiated RF level and turn the variometer control to resonate the antenna. A receive monitor, field strength meter, or a small neon bulb placed near the antenna is useful for this. Antenna voltage can be very high. Avoid touching the antenna while tuning.

Note the current or voltage at the tap point. When the antenna is resonant, this should be the same value as that of the 50 ohm resistor. If the current is lower, go down on the tap point toward the ground end. For voltage measurements that are low, raise the tap point higher, away from ground. Re-resonate the antenna every time you change the tap point.

An optimum point will be reached where the tap point will have the same voltage and/or current, as was noted with the 50 ohm resistor, when the antenna is a resonance. Using a nonreactive 50 ohm load as a reference makes it very easy to adjust transmitters and antennas on 1750 meters.

Sophisticated equipment, such as an oscilloscope, is handy, but a small Ne-2 bulb will suffice in a pinch. Several Ne-2 bulbs soldered together in series will also work as a reference for monitoring voltage across the antenna. This is only for reference and does not indicate antenna efficiency.

Sometimes there may be difficulty in rotating the inner coil due to rubbing between the two. Adjusting the four screws that secure the inner coil will either expand or contract the coil center. Wire turns around the coil form sometimes warps the form slightly. Placing pressure will compensate for this. After this is done, set the two nuts on the outer coil form to gently hold the inner coil in the center.

A complete variometer kit is available (not including wire) for $68.95 postpaid from: Curry Communications, 852 North Lima Street, Burbank CA 91505.

when you use the antenna on 1750 meters, and high voltages exist on the capacity hat on both 160 and 1750 meters. You'll need a ladder next to the vertical, and rigid gloves to raise each section. Insert the wooden dowel with the top-loading coil placed about two inches above the mast.

With two small screws, bolt the coil to the side of the dowel. Clean the top of the mast in a small area. The wire from the bottom of the coil is soldered at this point. Place the top vertical and capacity hat section on the dowel rod, and clean it for soldering to the top of the loading coil. Raise the top section of the mast and tighten the section after being extended. Raise the next section and secure this after being fully extended. After all sections have been raised, check the guys and adjust the antenna into a vertical position.

You can add strength to the vertical joints by drilling ¼-inch holes through each joint and securing them with a nut and bolt through the smaller hole where the cotter pin is usually located. These masts can be quite flimsy when you're raising them. Be extra careful around power lines.

Loading Coil and Matching

Figure 4 shows remote switching and tuning of the antenna. A 1 rpm motor (M) is connected to capacitor C1 (Figure 6). Relay RL1, a power relay, will withstand at least 220 volts. This is required since high voltages exist with this type of antenna on 1750 meters. Using these will provide easy control right in the comfort of your own shack!

160 Meter Calibration

Connect an SWR meter between the transmitter and antenna. Place the transmitter into the transmit position, using low power in a clear portion of the 160 meter band that will be the frequency of interest.

Rotate the capacitor and notice the SWR meter for a dip. If no dip is indicated, try a lower or higher frequency. The top loading coil may need turns removed or added to facilitate tuning and lowest SWR. Capacitance of C1 lower than 50 pF should be avoided.

Poor ground systems will also deteriorate the lowest possible SWR. Shorting C1 will cause the antenna to resonate at its natural resonant frequency, which should be around 1750 kHz. The capacitor shortens the wavelength of the antenna into the 160 meter band, but a point of no-return can happen if the natural resonant frequency of the antenna is much lower than 1750 kHz.

1750 Meter Band Operation

Three to seven mH will be required to resonate this antenna on 1750 meters. A variometer (see the sidebar) is a convenient way to find resonance and match the antenna. Figure 7a shows proper matching to a coax, and Figure 7b can be used for direct connection to a transmitter at the antenna site. The coil in Figures 7a and b is tapped approximately five turns from the ground end, and can be found by simulating the tap point with a 50 ohm load.

Tune-Up

Transmit a signal on the desired frequency into a 50 ohm load and note either the current or voltage across to load. Replace the load with the tap point at the antenna site, and resonate the antenna by varying the inductance of the coil. Capacitor Cx is a 25 pF (value not critical) high voltage variable that is temporarily inserted to aid in finding the ballpark frequency resonance of the antenna, in case it's off-frequency. Cx should be removed or minimized for best efficiency. Adjust Cx and then add or remove turns on L1 until Cx becomes a very small value or not required at all.

Monitor the signal strength with a remote receiver or field strength meter. Figure 8 shows several neon bulbs soldered in series that are connected to the antenna. As the antenna approaches resonance, the bulbs begin to shine brighter. Once our aim, maximum brilliance, has been reached, note the current or voltage at the tap point. If there is a difference between this value and the value noted across the 50 ohm resistor, change the tap point and re-resonate the antenna. Do this procedure several times until the antenna is resonant and the SAME value is indicated at the tap point as with the value noted with the 50 ohm resistor.

This is the relative 50 ohm tap point on the loading coil, when the antenna is resonant at that specific frequency. The reactive element of the coax is absorbed by resonating the coil and antenna, providing a part of the total matching system. The direct coil method in Figure 7b can be used for beacon transmitters (for example), with the loading coil ground end connected instead to the transmitter output.

The loading coil can be made by using a large coil form, about six inches in diameter and 10 inches long, wound tightly with #18 gauge enameled wire. Plexiglas or white PVC tubing is excellent for this application. You'll have to experiment to find the exact amount of inductance required for antenna resonance. It is easy to accidentally resonant the antenna on the second harmonic. Check the signal with a receiver on both fundamental and harmonic frequencies to confirm power output on the fundamental frequency.

A car battery box (or any weatherproof enclosure) can be used to house the capacitor, relay and 1 rpm motor. The coil should be located in the clear with a coat of marine varnish after installation is complete.

Check out information on mobile 160 meter antennas for an understanding of how 1750 short verticals operate. They are very similar in principle. These short vertical antennas offer reliable results, and they're a good compromise of size vs. performance. 73

You may reach David F. Curry WD4PLI at 852 N. Lima Street, Burbank CA 91505. The owner of Curry Communications, David offers a variometer kit for this project for $68.95, postage paid.

Noise Reduction Using Broadband Active Whip Antennas

Clear reception for the VLF/LF bands.

by D. F. Curry WD4PLI/6

Active whip antennas can be used successfully in a number of applications where man-made noise such as light dimmers, power line hash, TV horizontal oscillators and other types must be reduced or eliminated in the LF/VLF spectrum.

The technique involves the use of two active whip antennas, both electrically identical but physically placed in a manner that allows phase cancellation of the noise, while allowing the signal to remain undisturbed. Similar systems have been developed (about the same time as my design), as noted in an exemplary article by Dave Robinson, "Active Wideband Interferometer Using Active Whips," featured in *Lowdown*, August 1990.

My particular requirement was the elimination of power line hash from a nearby high tension line. Noise blankers are effective for removing impulse noise with high amplitude spikes, but a poor choice when trying to remove "complex" noise such as power line hash that typically masks itself as the final word on your S-meter.

This circuit not only phase-canceled the power line hash but as an extra bonus substantially reduced the neighbors' TV horizontal oscillator harmonic, rendering another portion of the 1750 meter band usable. Figure 1 shows the basic block diagram of the two whip antennas and the phasing unit, along with the other equipment I used.

Keep in mind that this addition to any receiving station should be part of a "receiving system" that incorporates other beneficial receiving aids such as receiving processors and regenerative preamplifiers. The phasing unit will allow accurate adjustment of phase and amplitude of both signals independently. High quality active whip components can be purchased from manufacturers listed at the end of this article, or built from scratch using the circuit shown in Figure 2. The completed layout for the active antenna preamplifier and the phase shifter is shown in Figures 4 and 5. The PC boards shown in Figures 4 and 5 are available from Curry Communications (see the Parts List for details). The active antenna circuit boards are housed in small Hammond die-cast aluminum boxes for weatherproofing.

For the signal antenna, an SO-239 connector is used for the physical support and electrical connections to the wood mast and the steel CB whip. The "L" bracket is a common CB accessory, found at Radio Shack or other electronic stores.

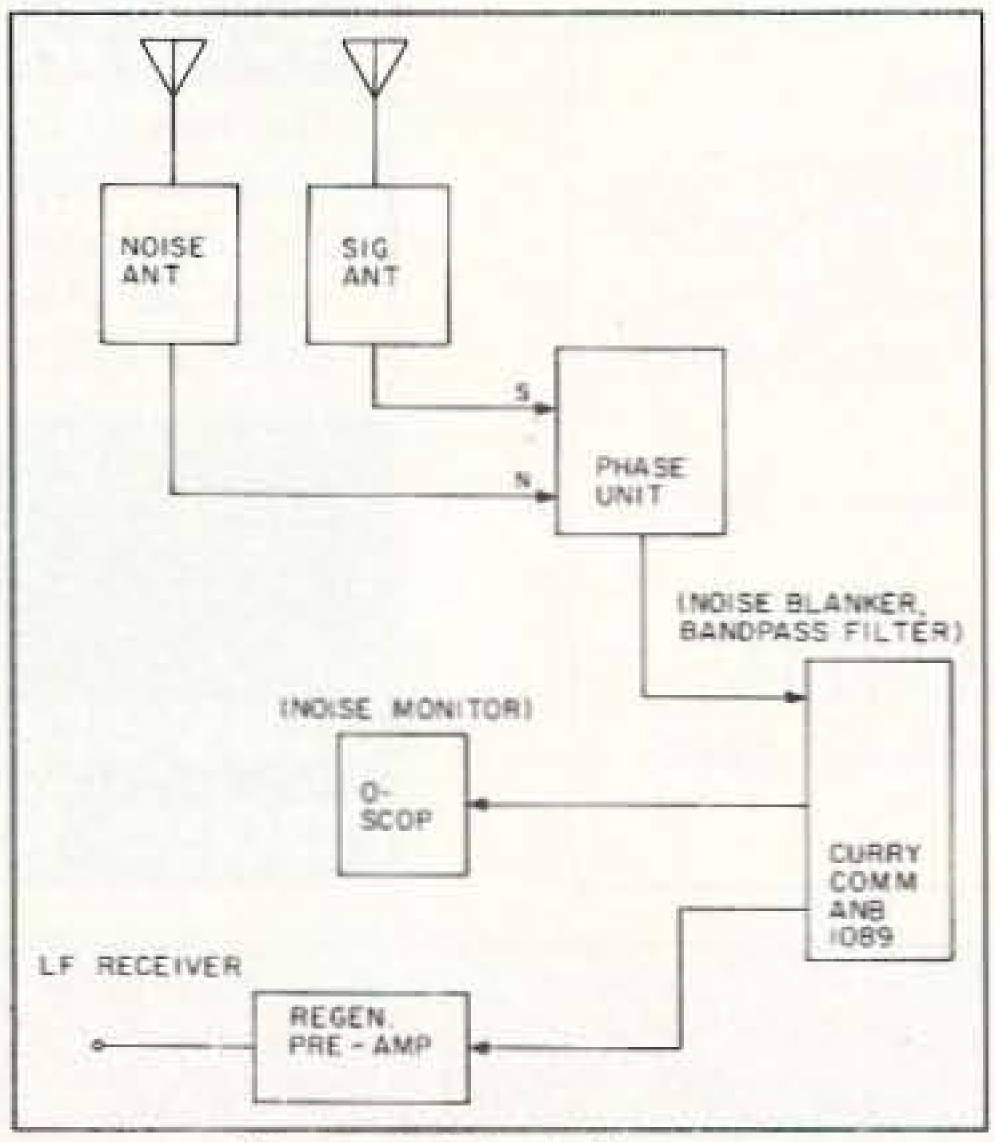


Figure 1. Block diagram.

The noise antenna can use either wire (for low profile) or aluminum rod antennas (as shown) for more rugged installations. Both work very well. If you use the rod version I recommend using two or three rods, approximately three feet long each. Flatten and drill the ends so they can be physically joined to a feed-through connection.

Connect equal lengths of coax to each preamplifier, using BNC connectors. After final installation and an operational check, spray the boxes and connections with a quality marine varnish.

The actual location for active antennas such as these is critical; sometimes the difference of only a few feet from nearby objects can make or break reception. The strategy behind experimenting with antenna placement is to find the lowest noise area possible *before* you begin the phase-canceling scenario.

The lowest noise spot at my location ended up being in the front yard, away from the house and power lines. Also, a separate ground system should be used for active antennas to eliminate ground loops and extraneous coupling of noise from power line related ground systems in the shack. The copper pipe used as the ground rod also supports the wood mast. The braid of each coax cable is connected to the ground rod. The noise is typically installed only a foot or two above the ground.

Phase Shifter

Figure 3 shows the phase-shift schematic, with input T1 and T2 used as isolation transformers to accomplish the necessary separation for the "house" and antenna ground systems. Switch SW1 A-D is an on/off switch and battery charge switch all in one. Please note that the switch, the batteries, and R17/R18 are not mounted on the circuit board, but wired separately. Also note the polarity of B1 and B2 wired to points E and F on the circuit board ground.

Points A-D are jumpers from the circuit board to SW1. Switch SW2 can change the input phase 180 degrees if required. R1 and R2 are load resistors after the voltage step-up transformers T1 and T2, providing an honest to god 50 ohm match at inputs J1 and J2. U1a and U2a are simple broadband amplifiers, with an amplification of 3.1 for buffering and overcoming some losses in the circuit. R7 and R8 are the volume or amplitude adjustment controls, which set the level to the phase-shifting stages, U1b and U2b. The phase-shift circuit is your classic "all pass" variety—it varies the phase from 0 to almost 180 degrees by controlling the potentiometers R11 and R12. R11 is used as a coarse adjustment while R12 is for fine tuning. Output from U1b and U2b is matched to the 50 ohm receiving port at J3 through R15 and R16 and phase shift transformer T3, an audio transformer that places the output signals from U1 and U2 180 degrees out of phase. This output from T3 is connected to your next stage, or your receiver.

Excellent nulls of 70 dB or better have been measured from 50 to 450 kHz using a signal generator as the common input source to J1 and J2, and an oscilloscope monitoring the output. Separate 9-volt batteries are used to power the phase shifter and active antennas. Using a 4PDT switch, rechargeable batteries can be recharged when the phase unit

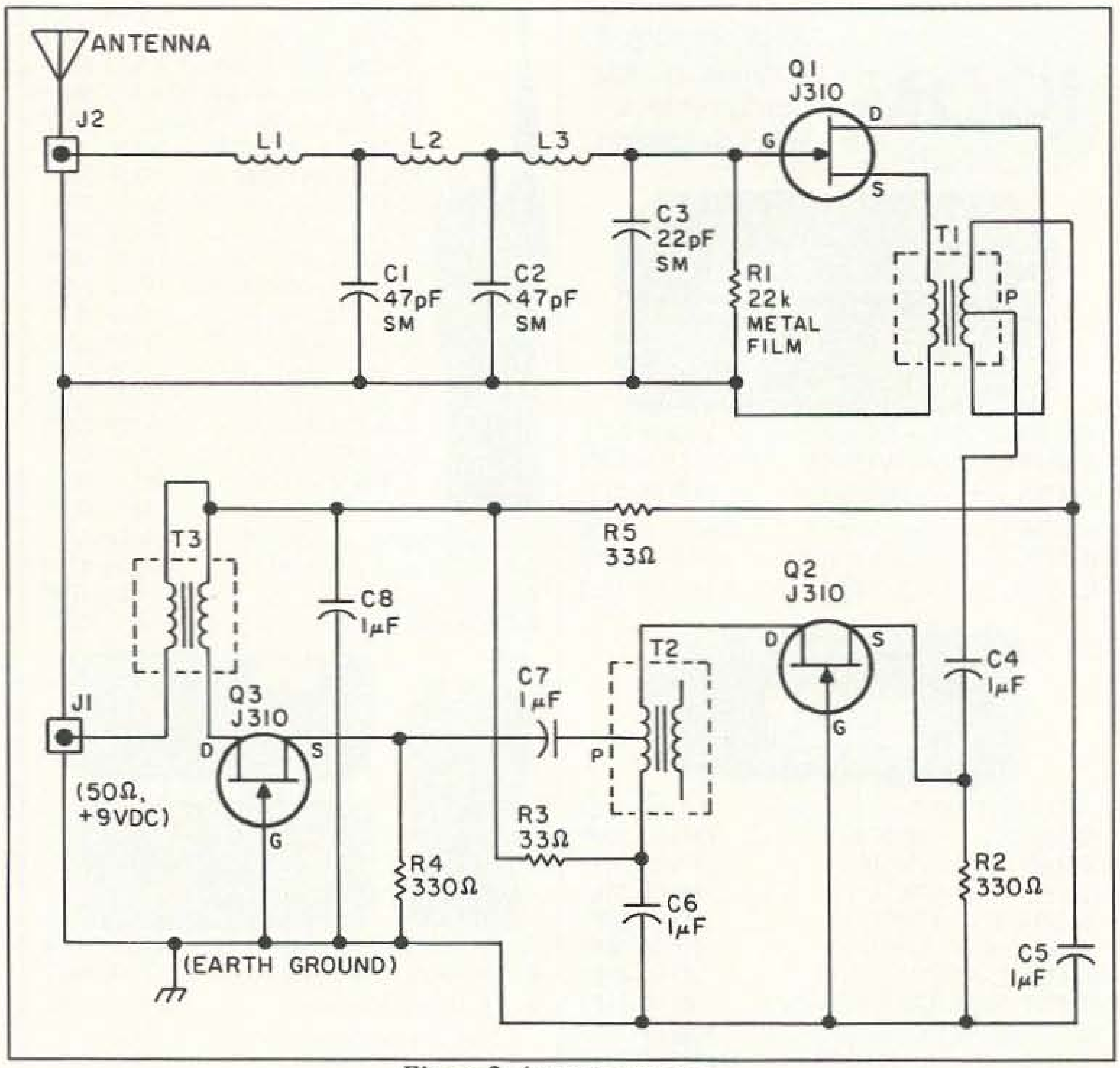


Figure 2. Antenna preamp.

is off. Note the jumpers on the circuit board, points AA and BB. The phase unit circuit board can be made from the positive in Figure 5.

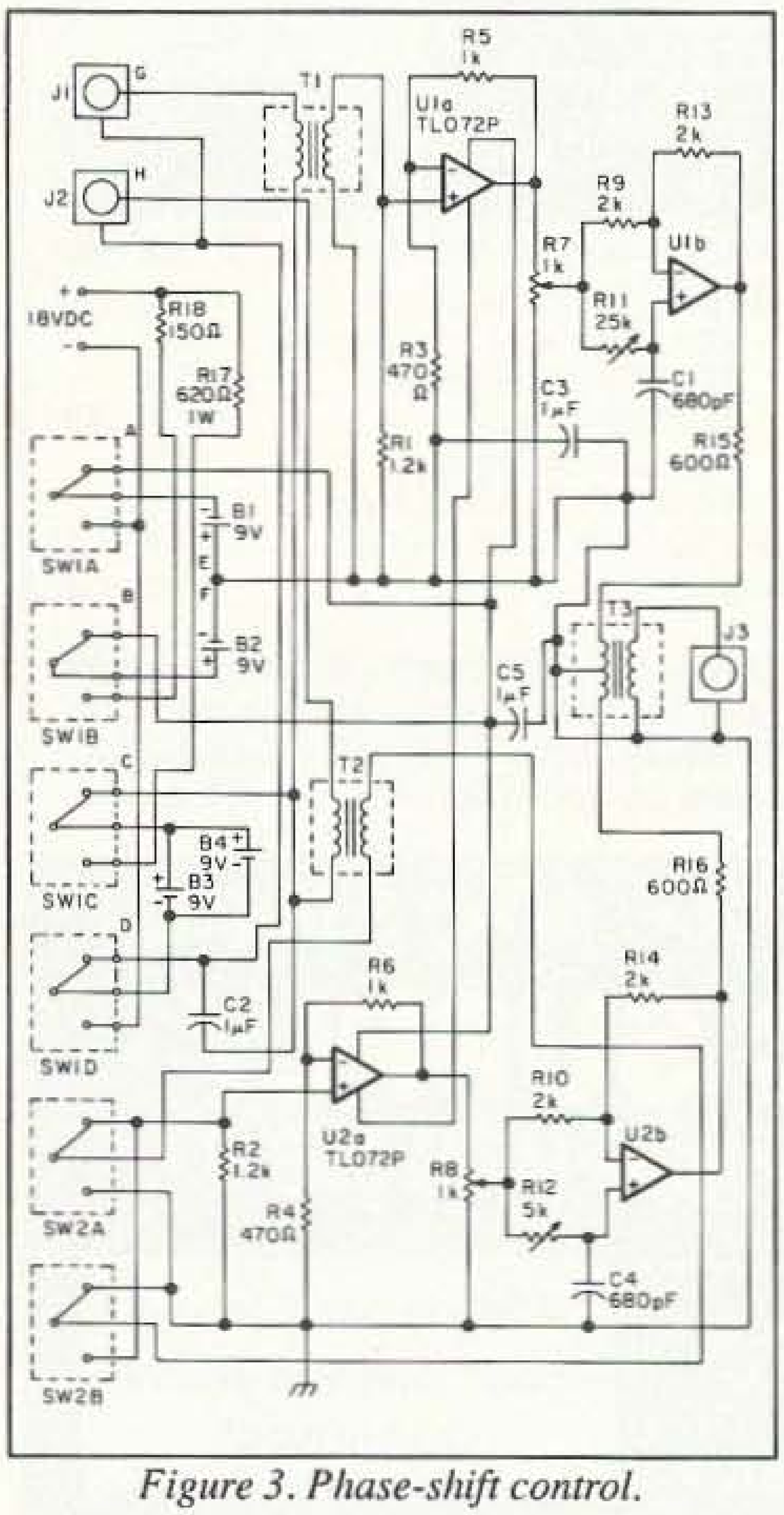


Figure 3. Phase-shift control.

Operation

Apply power to the phase shifter and antennas. The volume controls should be adjusted and reception confirmed. Adjust your receiver to a beacon or signal that you are familiar with, if possible. The volume setting of the SIGNAL channel should be about 3/4 to maximum, and the NOISE channel should be approximately the same. Rotate the FINE adjust phase-shift control to almost fully counterclockwise, and the COARSE phase-shift control adjusted while monitoring the noise floor. SW1 may also be switched for the correct phase input. The best results occur when the phase and amplitude of the noise of each channel is the same, and then canceled by T3. If you are unsure whether the channels are working correctly, a simple check can be done by connecting a single antenna or signal generator to BOTH inputs to confirm actual operation of the phase unit. With

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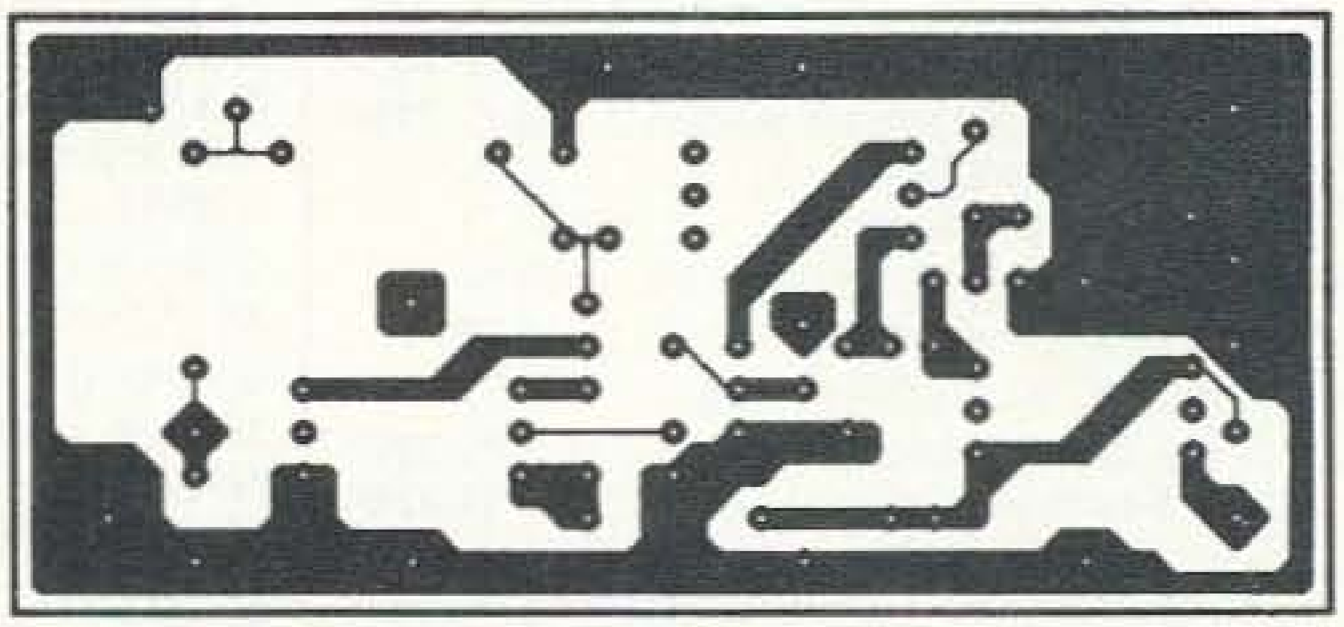
PHASE UNIT PARTS LIST

B1-4	9 volt rechargeable batteries
C1, 4	680 pF Monolithic capacitor (or silver mica)
C2, 3, 5	1 μF monolithic 50 VDC capacitor
J1-3	BNC female chassis connectors
R1, 2	1.2k ohm 1/4 watt resistor Metal film recommended
R3, 4	470 ohm 1/4 watt resistor Metal film recommended
R5, 6	1k ohm 1/4 watt resistor
R7, 8	1k ohm 1/8 watt potentiometer, Mouser #31CX301
R9,10,13,14	2K ohm 1/4 watt resistors (metal film recommended)
R11	25K ohm 3/4 watt potentiometers, 20-turn Mouser #594-43P203. Also order cover, Mouser #594-612.
R12	5k ohm 3/4 watt potentiometer, 20-turn Mouser #594-43P502. Also order cover, Mouser #594-612.
R15, 16	600 ohm 1/4 watt resistor (metal film recommended)
R17, 18	Current limiting resistors, typically 620 ohms 1 watt for R17, and 150 ohms 1/4 watt for R18.
SW1	4PDT switch
SW2	DPDT switch, PC mount
T1-3	Mouser #42TL004. Note the "P" on the transformer, indicating the primary side.
U1, 2	TL072P low noise op amp

WHIP ANTENNA PREAMP PARTS LIST

C1, 2	47 pF silver mica
C3	22 pF silver mica
C4-8	1 μF monolithic chip/50 VDC
J1	BNC chassis female connector
J2	SO-239 chassis female connector
Q1-3	J310 low noise JFET
R1	22k ohm 1/4 watt resistor (metal film recommended)
R2, 4	330 ohm 1/4 watt resistor
R3, 5	33 ohm 1/4 watt resistor
T1-3	Mouser 42TL004 transformer, Note "P" for primary
L1-L3	J.W. Miller 70F823AI iron-core only
Box	Hammond 1590A (Available at Mouser #546-1590A)

Complete kits containing all components and PC boards are available from Curry Communications, 852 N. Lima St., Burbank CA 91505: The Phase Unit kit is $48 and the Antenna Preamp kit is also $48.00. Blank etched and drilled PC boards are available separately from Far Circuits, 18N640 Field Court, Dundee, IL 60118; the Antenna Preamp board is $3 and the Phase Unit board is $4. *Order L1-L3 directly from J.W. Miller at (213) 537-5200.



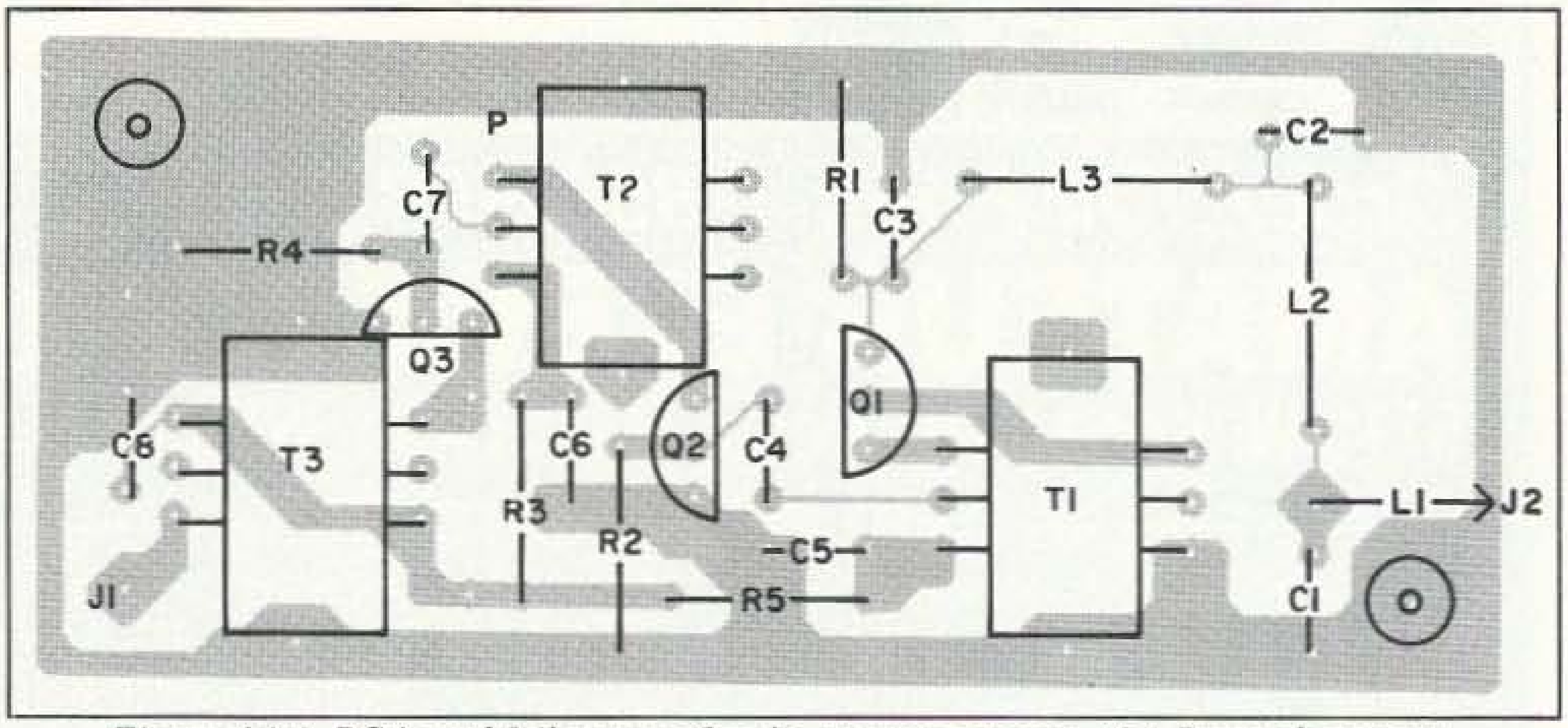


Figure 4.(a). PC board foil pattern for the antenna preamp. (b). Parts placement.

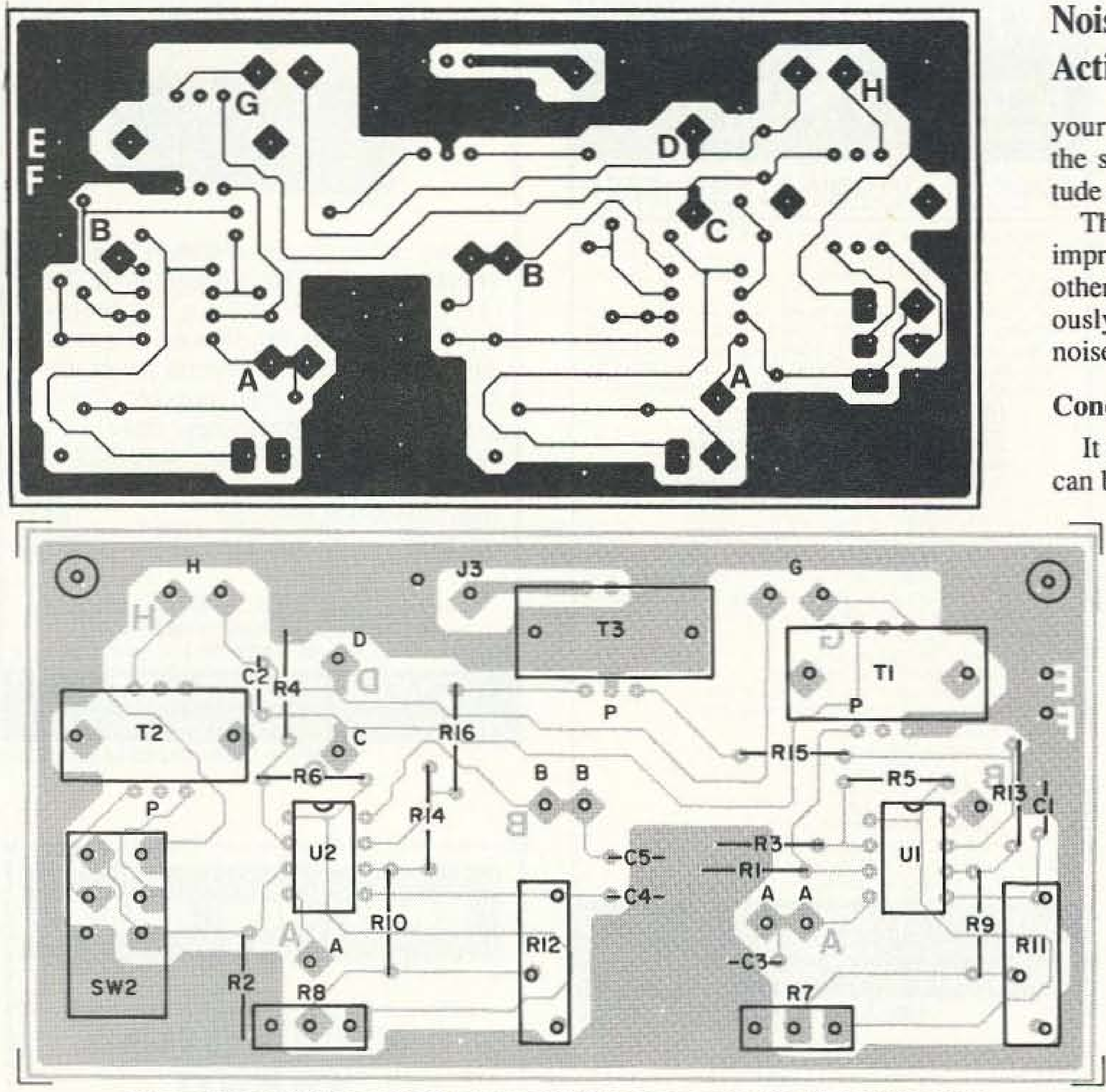


Figure 5.(a). PC board foil pattern for the phase unit. (b). Parts placment.

Noise Reduction Using Broadband Active Whip Antennas

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your system working properly, a complete null of the signal should occur when the phase and amplitude of each channel are equally balanced.

This phasing unit is part of a system approach to improved long-wave reception. The combination of other benefits, as mentioned earlier, should be seriously considered for the best possible reduction in noise and enhancement of the desired signal.

Conclusion

It astonishes me how a simple system such as this can be so effective when dealing with problems such as noise, and help to open up opportunities for radio communication in the low frequency region. This system could probably be used with loop antennas and perhaps even more elaborate circuitry that would provide unusual types of reception patterns for further reducing noise and/or unwanted signals.

Some parts sources for this and other LF/VLF projects are:

LF Engineering, 17 Jeffry Road,
East Haven CT 06513

BURHANS Electronics, 161 Grosvenor St., Athens OH 45701

Curry Communications, 852 N. Lima St., Burbank CA 91505

Ken Cornell's "Radio Scrap Book" Sixth edition, pg. 9.