AM Broadcast-Band Loop Antenna

Pulls in distant AM broadcast signals and lets you tune out strong interfering local signals

By Brad Thompson

A century ago, Dr. Heinrich Hertz made history by broadcasting radio waves across his laboratory. His spark-gap receiver detected the transmitted wave through a single-turn loop antenna. Ever since then, the loop antenna has been with us.

The modern loop antenna, commonly known as a "loopstick," consists of many turns of wire wound on a powdered-iron or ferrite core. Considering its small size, this type of antenna does a surprisingly good job of capturing radio signals. However, a larger antenna is sometimes needed for pulling in weak and distant AM signals. In this article, we will describe how the loop antenna works and show you how to fabricate a low-cost AM broadcast-band add-on loop that can improve your AM receiver's performance.

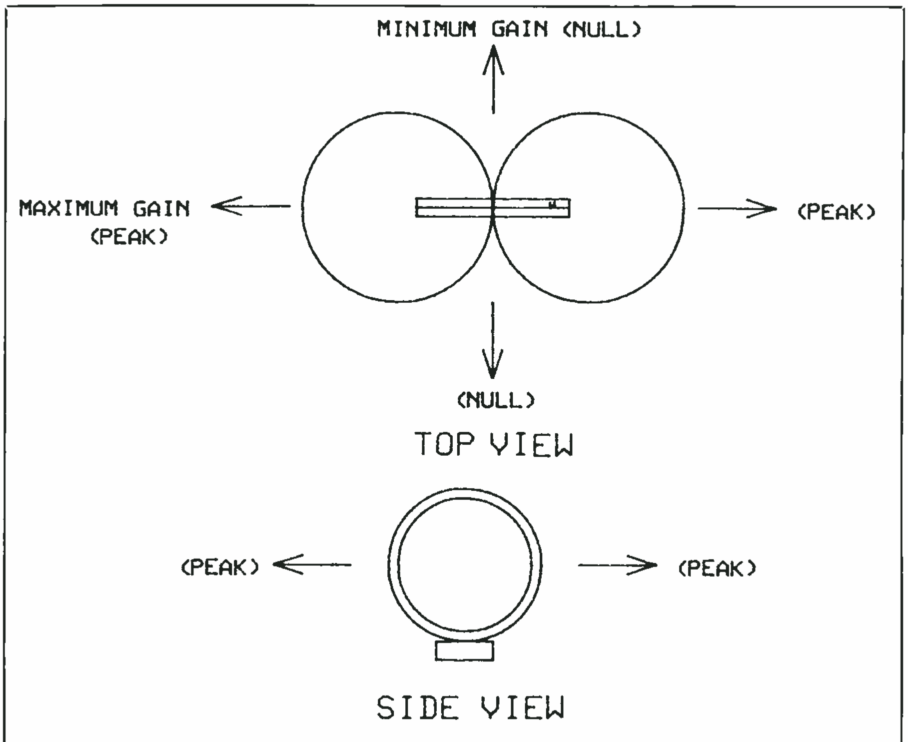


Fig. 1. Orientation of loop antenna for obtaining maximum gain.

Theory of Operation

A loop antenna typically consists of a number of turns of insulated wire (usually enameled or so-called "magnet" wire) wound on a round or square insulating frame. Loop size and number of turns are governed by the frequency range to be covered and assembly method used.

The loop antenna is basically a large inductor. Adding a variable capacitor to it produces a resonant circuit. By tuning the loop with the capacitor, unwanted off-frequency signals can be rejected to prevent overloading the receiver with which the antenna is being used.

When an electromagnetic (radio) wave is intercepted by a loop antenna, the wave induces a current in the antenna that, in turn, develops a voltage across the antenna's terminals. In general, the larger the loop, the more energy it intercepts and the greater the voltage it produces at its terminals.

If the loop is oriented broadside to an incoming radio signal, no voltage is developed across it because the amount of wire intercepting the signal energy is very small. By aiming the loop at the transmitting station, you can minimize the loop's pickup. Figure 1 shows the orientation of the loop antenna for maximum gain.

Sometimes, you may be less interested in obtaining maximum gain than in nulling out (eliminating) an interfering station's signal or a source of radio-frequency noise. The loop antenna produces a deep null when it is aimed broadside to the interfering

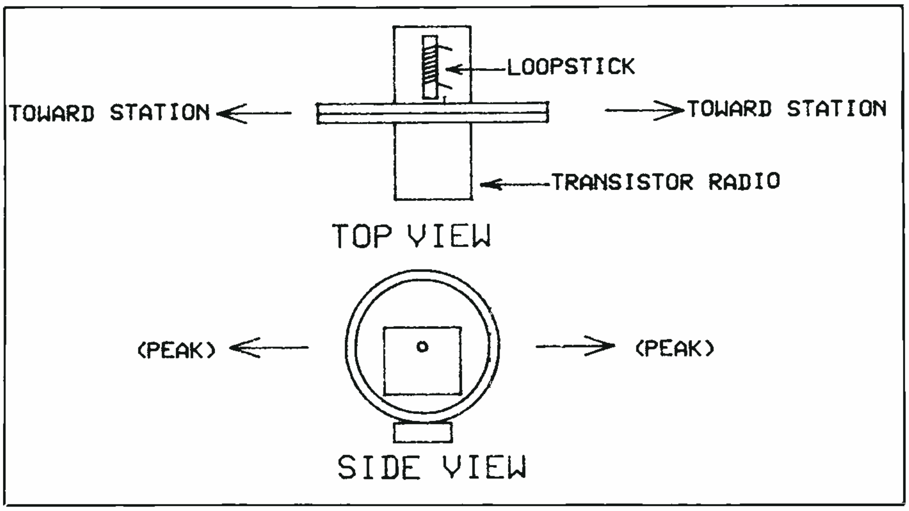


Fig. 2. Simplest method of connecting a loop antenna to a radio receiver.

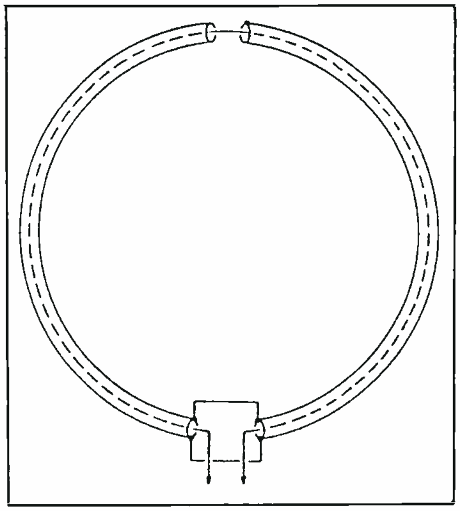


Fig. 4. One way of dealing with unwanted signal pickup is to use electrostatic shield around antenna windings. Note required gap in shield at top of drawing.

signal source. By orienting the antenna in this manner, a strong r-f interference source's signal can often be reduced so that a weaker, more-distant station's signal can get through.

There are several ways to connect the loop antenna to a radio receiver. Figure 2 shows the simplest way. Here, you place a transistor radio in the center of the loop so that the radio's loopstick antenna is aligned at a right angle to the external loop. Then you tune the radio to a station and adjust the loop's tuning capacitor for maximum signal strength, as indicated by an increase in volume and audio clarity. Be prepared for a surprise because the external loop antenna's much greater signal capture area will produce a dramatic increase in signal strength.

In this arrangement, the transistor radio's loopstick antenna serves as the secondary of a transformer whose primary is the external loop antenna. An incoming radio signal induces a current in the loop. The current creates an electromagnetic field that is then coupled into the radio's loopstick antenna.

Another way to couple the loop antenna to a radio uses an extra turn or two on the loop itself as the secondary winding of the transformer, as shown in Fig. 3. The extra winding reduces the detuning effect, which results when a low-impedance receiver is connected directly across the high-impedance tuned loop.

Unfortunately, adding a direct connection or even a pickup winding degrades the loop's performance. Stray capacitance from the loop to the grounded end of the pickup

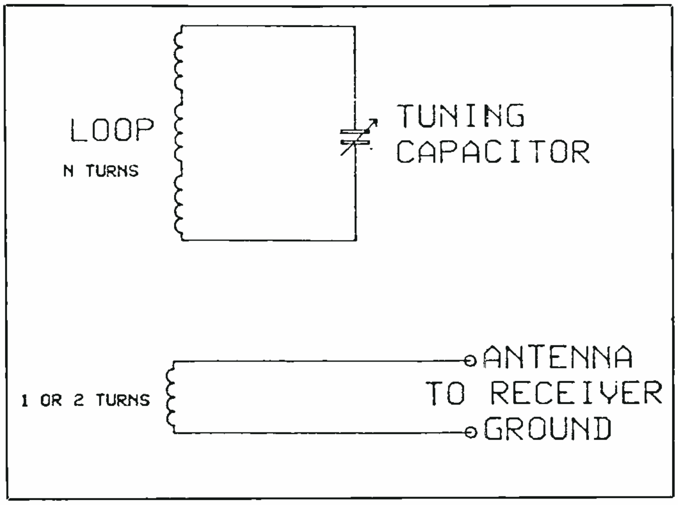


Fig. 3. Loop antenna and radio's loopstick antenna form primary and secondary of a transformer.

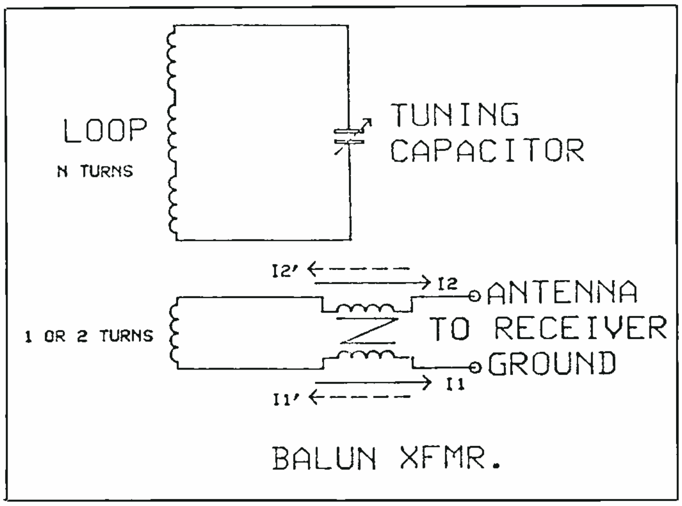


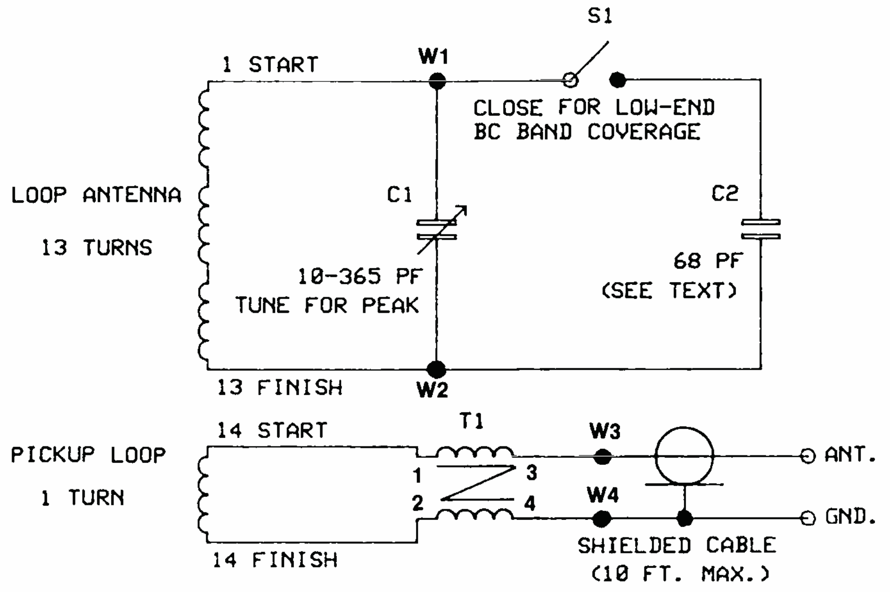
Fig. 5. Another approach to dealing with unwanted signal pickup is to use a balun transformer.

winding bypasses some of the signal. The grounded side of the pickup loop receives more energy and behaves as a short vertical antenna. The voltage developed by the vertical antenna distorts the loop's "figure-8" reception pattern and degrades performance.

One way of dealing with unwanted pickup is to provide an electrostatic shield around the loop's windings, as shown in Fig. 4. The gap shown at the top of the shield is important because without it, the shield would prevent any r-f energy from entering the loop. Adding an electrostatic shield to a loop antenna can be mechanically messy, though, and usually more trouble than it is worth if you are building the antenna yourself.

Another approach is to add a "balun" (for balanced input to unbalanced output) transformer to the antenna's cable, as shown in Fig. 5. Unwanted capacitive signal pickup develops a voltage across the entire antenna. Equal currents I_1 and I_2 attempt to flow into the antenna and ground terminals through the windings of the balun transformer. If the transformer's two windings are identical, current I_1 induces current I_2', which cancels out I_2. Likewise, current I_2 produces current I_1', which cancels out I_1. Voltage developed across the pickup loop's terminals passes through untouched.

Adding a balun transformer makes a noticeable and worthwhile improvement in performance over an unshielded loop antenna and is the approach we will take here in building our loop antenna. However, you will still notice some hand capacitance effects during tuning.



PARTS LIST

C1—10-to-365-pF tuning capacitor (see text)
C2—68-pF, 100-volt silver-mica or NPO ceramic capacitor (see text)
S1—Miniature slide or toggle switch
T1—Balun transformer (hand-wound on Fair-Rite Part No. 283002402 or equivalent; see text)

Misc.—Printed-circuit board or perforated board and suitable Wire Wrap or soldering hardware (see text); two 14-pin IDC DIP plugs (3M Part No. 3406-0000 or equivalent); two 14-pin DIP sockets; 18″-diameter × 0.75″-wide by about 0.5″-thick wood embroidery hoop (see text); 60″ of 14-conductor ribbon cable; 12″ AWG No. 34 bifilar wire or two strands AWG No. 34 magnet wire twisted together for balun transformer (see Fig. 10); insulated control knob; plastic or Masonite for control panel; ¾″ or 1″ pine or plywood for base plate; two pieces 3¾″ × ¾″ × ⅜″ pine to secure sides of loop; double-sided tape; varnish; No. 6 × ½″ woodscrews; miscellaneous hardware; hookup wire; solder; etc.

Note: Details of the inductance calculation method and a 12″ sample of AWG No. 34 bifilar magnet wire are available free by sending a SASE to: Brad Thompson, GMT Interface Products., 56-A Main St., Suite 233, Maynard, MA 01754.

Fig. 6. Actual schematic diagram of loop antenna you can build from details given in text.

Electrical Considerations

The virtues of the loop antenna were fully recognized in the early days of radio, and many a primitive radio was equipped with a wood-and-wire spiderwork loop antenna. Making a duplicate of such a vintage antenna required woodworking skills and a lot of experience and patience. Fortunately, a little ingenuity and use of modern materials eliminate the need for a shop filled with woodworking tools, the need to be a master woodworker, and long construction time.

The loop antenna whose construction details follow is shown schematically in Fig. 6. Note that this circuit is made up of the basic multi-turn loop consisting of 13 turns of wire wound on an 18″-diameter form, a secondary pickup loop consisting of a single turn of wire and connected to a balun transformer *(T1)*, a 10-to-365-picofarad tuning capacitor *(C1)*. The purpose of the switch *(S1)* and capacitor *(C2)* arrangement will be made clear presently.

Note in Fig. 6 that the basic antenna actually consists of 13 turns of wire plus a one-turn loop that is used as a coupling link to a low-impedance receiver input. That one-turn coupling loop causes the antenna to lose some inductance so that instead of tuning down 540 kHz as it should when $C1$ is fully meshed, tuning will bottom out at about 574 kHz. To compensate for this, $C2$ adds another 68 picofarads in shunt with $C1$ when $S1$ is closed. You close $S1$ when tuning the low end of the broadcast band and open it when tuning the high end of the band.

Construction

A wooden embroidery hoop, used as the frame on which to wind the turns of wire that make up the antenna, eliminates the need for woodworking skills on your part, as well as the need for specialized tools. You can buy such a hoop in any sewing center and most housewares stores for about $8.50 or so, depending on make.

The embroidery hoop consists of two separate wood rings, one continuous and the other split at one point. The latter is sized to fit around the former. At the split are blocks of wood through which a long bolt is passed so that tightening a wing nut clinches the larger ring tight around the smaller with fabric between the two. Neither the screw nor the wing nut are used in this application.

The space between the inner and outer rings that make up the embroidery hoop provides a convenient protected place to locate the loop antenna's windings. While it would be possible to wind the antenna's loop with enameled magnet wire, keeping the wire under tension as you attempt to maintain proper turn-to-turn spacing is difficult to do. Fortunately, there is a better way to "wind" the turns.

Multiconductor flat ribbon cable of the type commonly used as a means for interconnecting computer subassemblies can be used in place of the usual enameled magnet wire used for winding the loop antenna. The ribbon cable consists of a number of No. 28 tinned conductors that are separated from each other on 0.05" centers by a coating of ridged PVC plastic insulation. By wrapping a length of ribbon cable around the wood hoop form, each conductor can be connected to provide a loop with the next. (By a fortuitous combination of circumstances, a loop of 14-conductor ribbon cable wound on an 18"-diameter circular form resonates over the entire AM broadcast band from 540 to 1,620 kHz when tuned with a 10-to-365-picofarad capacitor, as in Fig. 6. The Table details the inductance of the antenna, loop by loop, when No. 28 ribbon cable is used.)

Inductance vs. Number of Turns*

Number of Turns	Calculated Inductance in microhenries
1	1.74
2	5.56
3	14.08
4	24.07
5	36.36
6	50.82
7	67.35
8	85.84
9	106.23
10	128.43
11	152.40
12	178.07
13	205.40
14	234.33

*With loop made from No. 28 ribbon cable wound on 18"-diameter wooden form as described in text.

To make each successive turn, you simply connect the finish end of the first conductor to the start end of the second conductor, the finish end of the second conductor to the start end of the third conductor and so on until all conductor ends are connected, except the start end of the first and the finish end of the last. If properly done, you will end up with a series of continuous, equally spaced loops.

If you were to simply twist together the conductor ends at each point and solder each connection, you might run into difficulties. This is because once the individual conductors are separated (as they would have to be to prepare them for end-to-end connection), any attempt to solder the connections with a hot soldering iron would cause the insulation to melt and shrivel away from the wires. Once again, there is a simpler—and better—way to make the required connections.

The 14-conductor cable used to make the antenna's windings makes it an easy proposition to use dual in-line package (DIP) plugs. These greatly simplify the connection task and eliminate direct soldering of the cable altogether. You simply attach a 14-pin plug to each end of the ribbon cable and then insert the plugs into matching sockets on a circuit-board assembly on which all soldering is safely performed. Assembly details for the loop and circuit board are shown in Fig. 7.

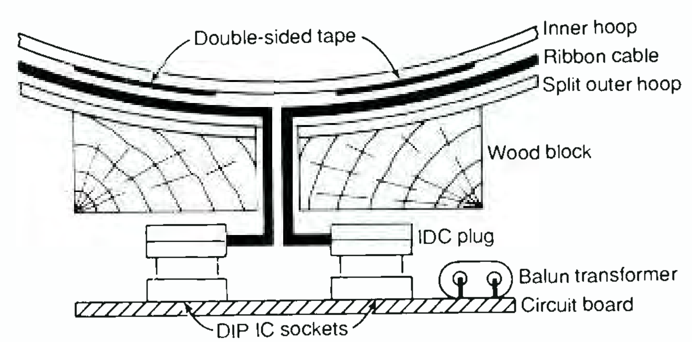


Fig. 7. Mechanical assembly details for loop and circuit-board assembly.

To attach the connectors to the ends of the 60", 14-conductor ribbon cable required for this project, you will have to sacrifice a 14-pin DIP integrated-circuit socket. Before doing anything else, cut off the socket (not plug) pins flush with the bottom of the frame (or bend them flat against the frame). Plug a connector into the socket, place one end of the ribbon cable against the IDC pins on the socket and follow up with the socket cap. Holding the assembly firmly together, place it in the jaws of a bench vise and slowly force the cap into place. When the cap snaps into place, the IDC (insulation-displacement connection) points in the plug will pierce the ribbon cable's insulation and make positive connection with the correct pins of the socket. Repeat with the remaining IDC connector at the other end of the cable, using the same 14-pin IC socket to protect the connector pins from damage.

If you prefer not to make your own connector-terminated cable yourself, you can have one made by a computer cable supplier or electronics wholesaler. Whether you order the cable ready-made or make it yourself, make sure that it measures 60" long between connectors.

Balun transformer *T1* consists of six turns of AWG No. 34 bifilar wire wound on a "binocular" core, as shown in Fig. 8. Similar cores can also be found on old vhf TV tuners, where a balun is used to match the 300-ohm twinlead transmission line from the antenna to the single-ended input of the tuner. Depending on the characteristics of the core used, you may have to wind more than six turns if the balun transformer does not appear to be working during the checkout procedure.

Once you have terminated the ribbon cable in DIP plugs, make a printed-circuit board, using the actual-size etching-and-drilling guide shown at the top in Fig. 9. Alternatively, you can use perforated board, suitable Wire Wrap or soldering hardware and point-to-point wiring in place of the pc board. If you take this route, make sure to carefully follow the conductor pattern shown in the etching-and-drilling guide when wiring the board.

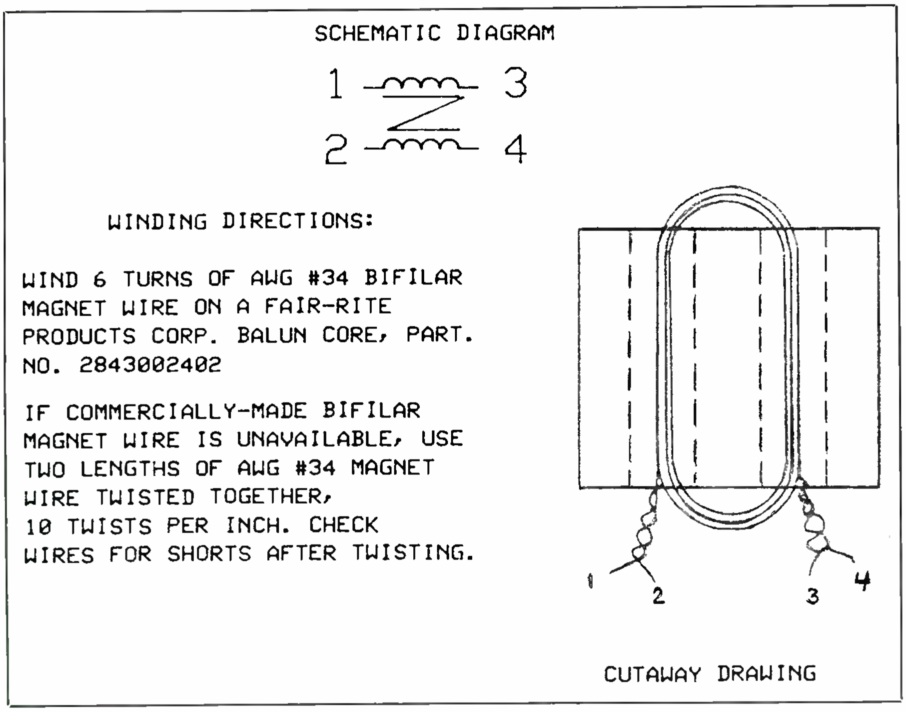


Fig. 8. Balun transformer is wound on a "binocular"-shaped ferrite core using bifilar magnet wire.

Install the IC sockets on the circuit board now and solder their pins to the copper pads. If you are using perforated board, wire the pins of the sockets now, and install appropriate pins for the balun transformer *(T1)*, ANTENNA and GND transmission-line tie points, tuning capacitor *C1* and the *S1/C2* network. (In Fig. 9, the wiring guide at the center details component location, the drawing at the bottom how the ribbon cables are formed into a series of continuous loops when the DIP plugs are inserted into the sockets on the board.)

Separate the wooden rings of the embroidery hoop, remove and discard the bolt and wing nut and give each ring a couple of coats of varnish to seal out moisture. When the varnish has dried, attach the ribbon cable to the inner hoop by pressing 4"-long pieces of double-sided tape between the two, starting and ending where the ribbon cable ends come together (see Fig. 7).

Lay the cable/ring assembly on a flat surface and place the split outer hoop over the ribbon cable. Orient the opening so that the ends of the ribbon cable pass through the split and are of equal length. Then attach strips of wood to the sides of the outer hoop's mounting blocks to hold everything solidly together. Use No. 6 × ½" woodscrews to fasten the strips in place.

Final mechanical assembly will depend on how you plan to use the loop antenna. Avid broadcast-band DX'ers will want to devise some sort of turntable so that they can easily rotate the antenna to orient it for best reception. Those who wish to receive only one station can mount the antenna in a fixed orientation. Keep in mind that your choice of tuning capacitor for *C1* in Fig. 6 will affect final assembly details.

Mount tuning capacitor *C1* and

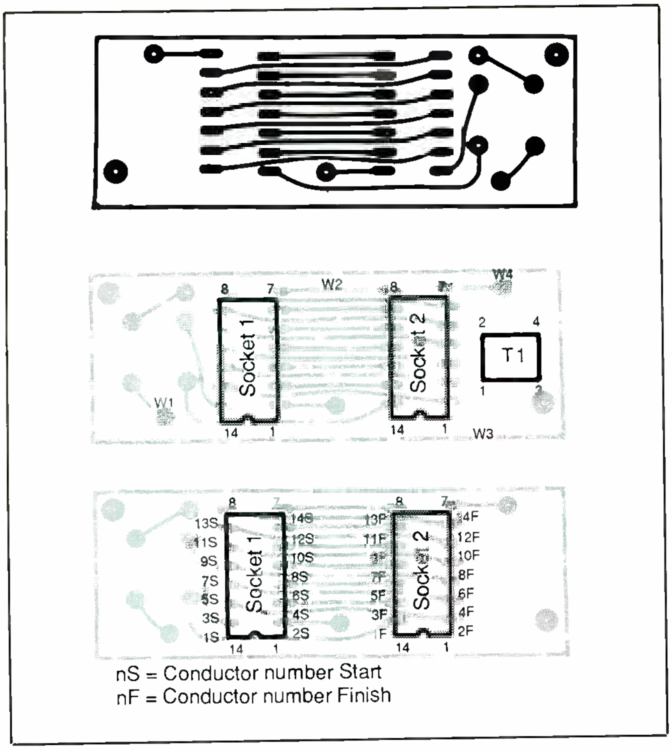
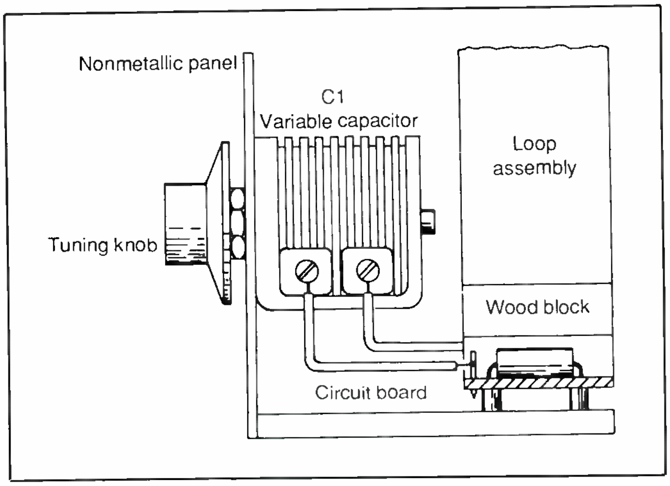


Fig. 9. Actual-size etching-and-drilling guide for printed-circuit board (top), wiring guide for board (center) and how conductor pattern completes ends of ribbon cable's conductors to form multi-turn loop (bottom).

Fig. 10. Mechanical details of final assembly. Use nonmetallic control panel and keep all wiring as short as possible.



switch *S1* on a nonmetallic panel and install the panel near the base of the loop. Connect and solder one lead of *C2* to one lug of the switch and the other lead, via a short length of insulated hookup wire if needed, to one side of *C1*. Then connect and solder a short length of hookup wire to the other lug of the switch and the free end to the unused lug of *C1*. Finally, connect short lengths of hookup wire between the two lugs of *C1* to points W1 and W2 on the circuit board (see Fig. 9). Keep the wiring from the capacitor to the loop connector panel as short as possible to avoid any "antenna" effects.

Install an insulated tuning knob on the shaft of tuning capacitor *C2*. Then mount the circuit board assembly on a board and fasten the tuning panel to the board as illustrated in Fig. 10. Insert the loop's plugs into the sockets on the circuit board.

Checkout and Use

Tune a transistor radio to a weak station in the middle of the AM broadcast band and place it in the center of the loop, as shown in Fig. 2. Now tune the loop antenna by adjusting its variable capacitor until you hear an increase in the radio's volume. You may have to reorient the loop antenna if it is not pointing toward the tuned station.

If you hear no increase at any setting of the tuning capacitor, check all wiring for shorts and opens or poorly soldered connections. One potential trouble source is the mica tuning capacitor located on the side of older variable capacitors. If the trimmer's adjusting screw has been over-tightened, the mica may be punctured, resulting in a shorted capacitor.

To check the balun transformer, tune the radio to a weak station near the middle of the band, tune the loop's capacitor for maximum signal, and move the loop until peak signal is obtained. If no peak is noted, wrap your hand around the loop; now if you note a significant drop in signal strength, the balun transformer has a reversed winding or lacks inductance.

Once the loop antenna is working properly, tune the radio to a weak station at the upper end of the broadcast band and retune the loop's tuning capacitor for maximum signal. If there is no increase in signal strength when the capacitor's plates are fully separated, loosen the capacitor's trimmer adjustment screw.

Retune the radio and loop to a weak station at the lower end of the band. Use a well-shielded cable to connect the loop to the receiver, and close the switch to put shunt capacitor *C2* into the circuit. For best results, keep the cable to less than 10 feet in length. Otherwise, signal pickup by the cable may defeat the loop's directional pickup characteristic. Retune the loop to compensate for cable capacitance.

This easy-to-build loop antenna readily lends itself to experimentation. Try using it as a tuning coil for a crystal or a regenerative receiver. Also, frequency range of the loop can be extended by cutting away turns to raise the range or adding tuning capacitance to lower the range. **ME**