K4SYU Loop Antenna

A compact, portable HF solution.

by Everett James K4SYU

Why a small *loop*? Why not a dipole or a quarter-wave vertical? The answer is size and versatility. The loop is small and inconspicuous. It can be set up on the porch of a condominium or used as a portable antenna for Field Day or used as an emergency antenna in case the wire antennas blow down.

The loop will not replace your favorite yagi or other gain antenna, but if you are restricted, as many hams are, to using inside antennas and are getting poor results, then this loop is just what you are looking for.

Let's look at what this small loop antenna has to offer:

1. It requires no radials (no external wires).
2. It requires no ground connection (reduced RFI).
3. It requires no antenna tuner (simplified tune-up).
4. It exhibits less noise than a dipole or quarter-wave antenna.
5. It is somewhat directional (also has good nulls).
6. It helps eliminate harmonic radiation (high Q).
7. It is multiband (quick and easy band change, five bands).
8. It is fairly efficient (good things do come small).
9. It is portable (can fit in the trunk of a car).
10. It is inexpensive and easy to build. (Need I say more?)

Are you interested? Then read on.

Theory

You all know that the loop antenna has been used for many years as a direction-finding antenna. In that type of service it made use of the sharp nulls off each side of the loop, but off each end is a nice fat lobe shaped like a doughnut. It is this large lobe structure that makes the loop so interesting to radio amateurs.

In theory, the loop antenna can be looked at as a single-turn parallel-tuned circuit not unlike the tank circuit. The opposite sides of the loop act as a pair of spaced antennas carrying RF currents of opposite polarity. The two RF currents tend to cancel each other out perpendicular to the plane of the loop. The magnetic radiation will be maximum off each end of the loop. As the loop readily accepts energy at its resonant frequency, it is only necessary to add an RF coupling device to transfer energy to and from the loop via a coaxial cable.

You know that the portion of the loop next to the capacitor has very high voltage, but if we go to a point halfway around the loop which is about the center of a corresponding one-turn coil, we reach a zero voltage point. This point, for all practical purposes, is neutral. It is at this point that the coaxial shield is attached.

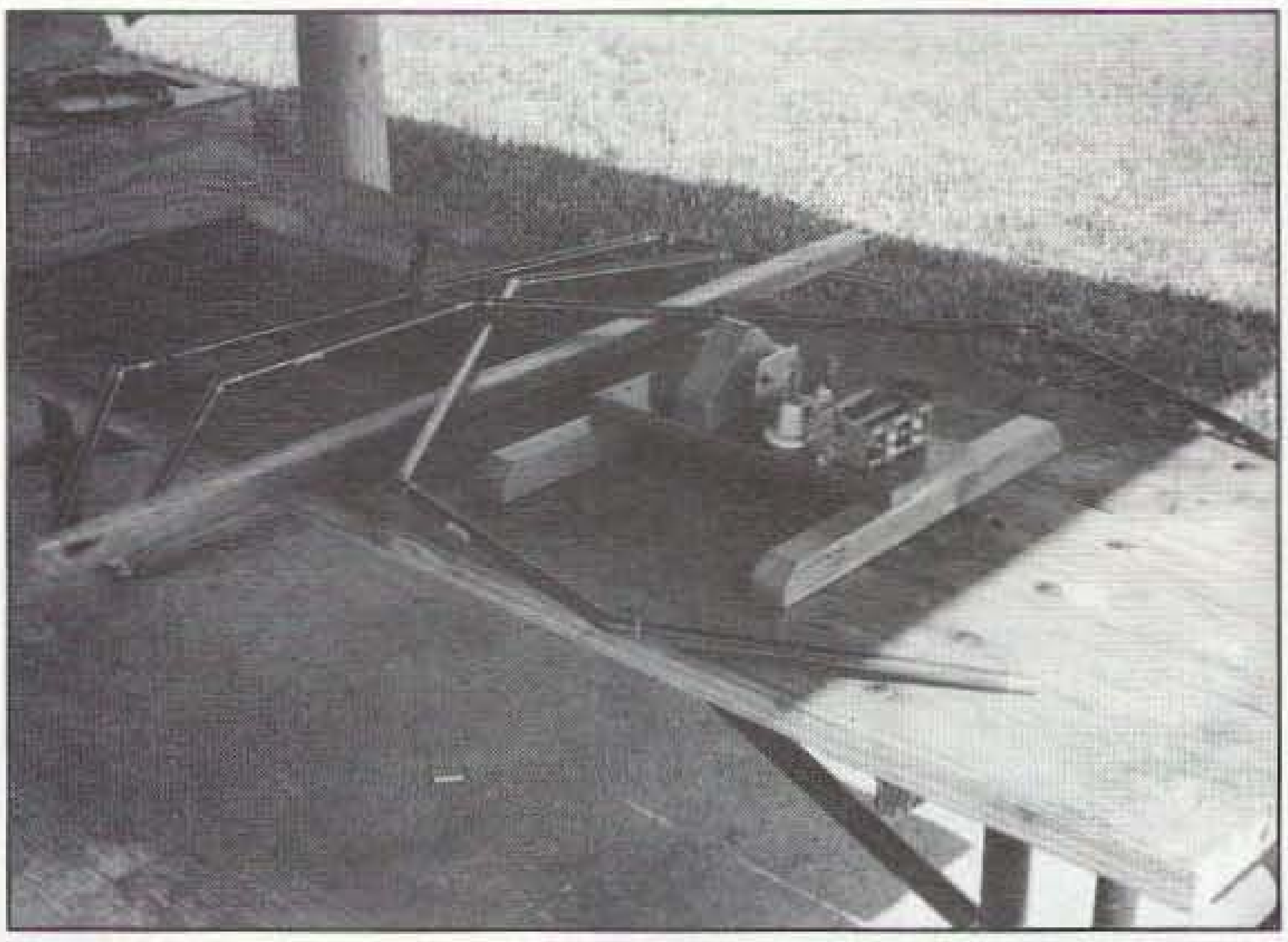

Photo A. The loop antenna in pieces before assembly. Assembly time is about five minutes.

The coaxial center conductor is connected to a number 12 wire which is separated slightly from the loop and connected at a point approximately 10 percent of the loop circumference away from the neutral point. This is very similar to the old-time method of using a tapped coil for impedance matching.

It is interesting that a reasonable match can be obtained on all five frequency bands using this simple matching device, without having to move the tap.

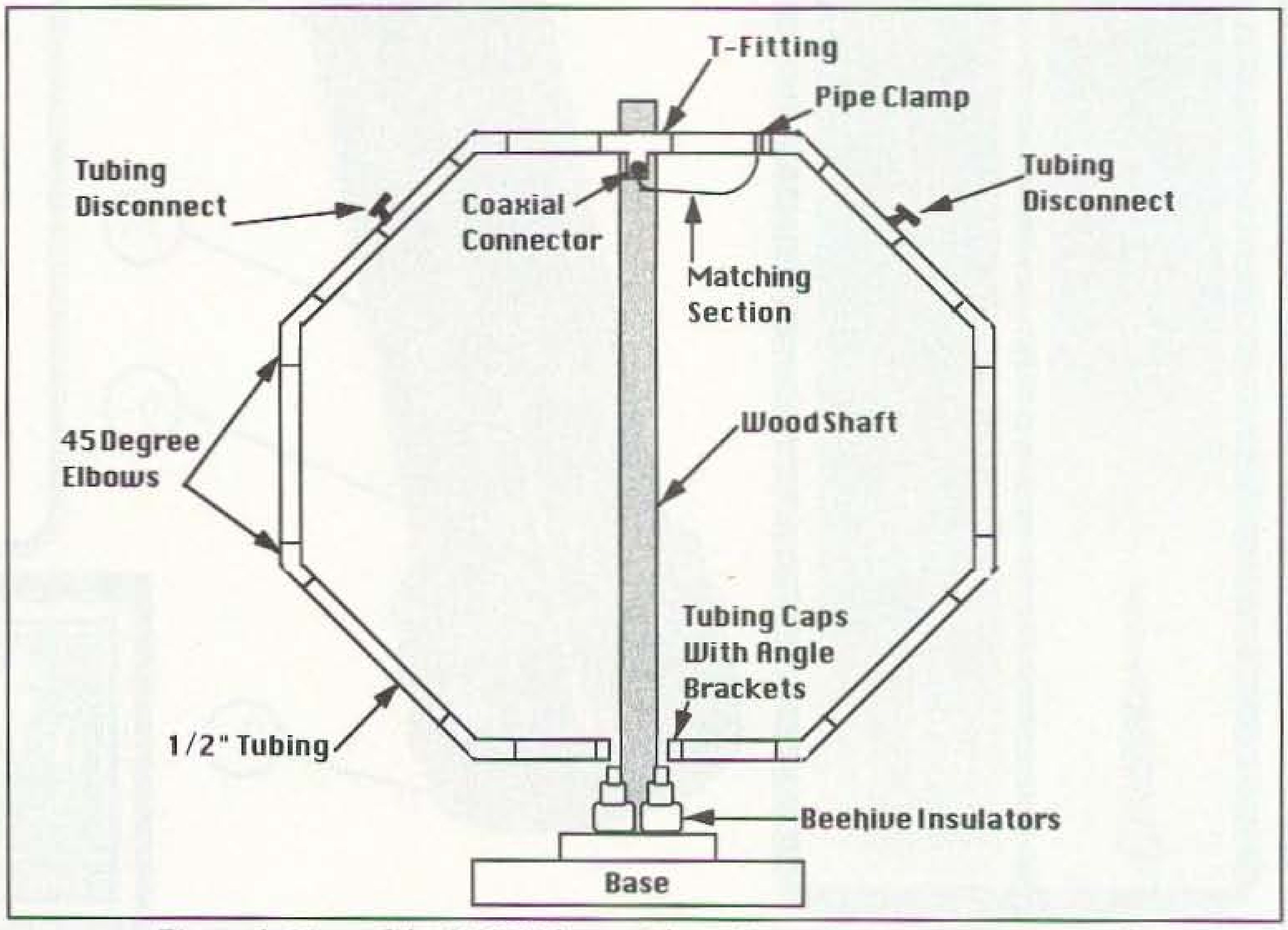

Figure 1. View of the K4SYU loop without the tuning capacitor mounted.

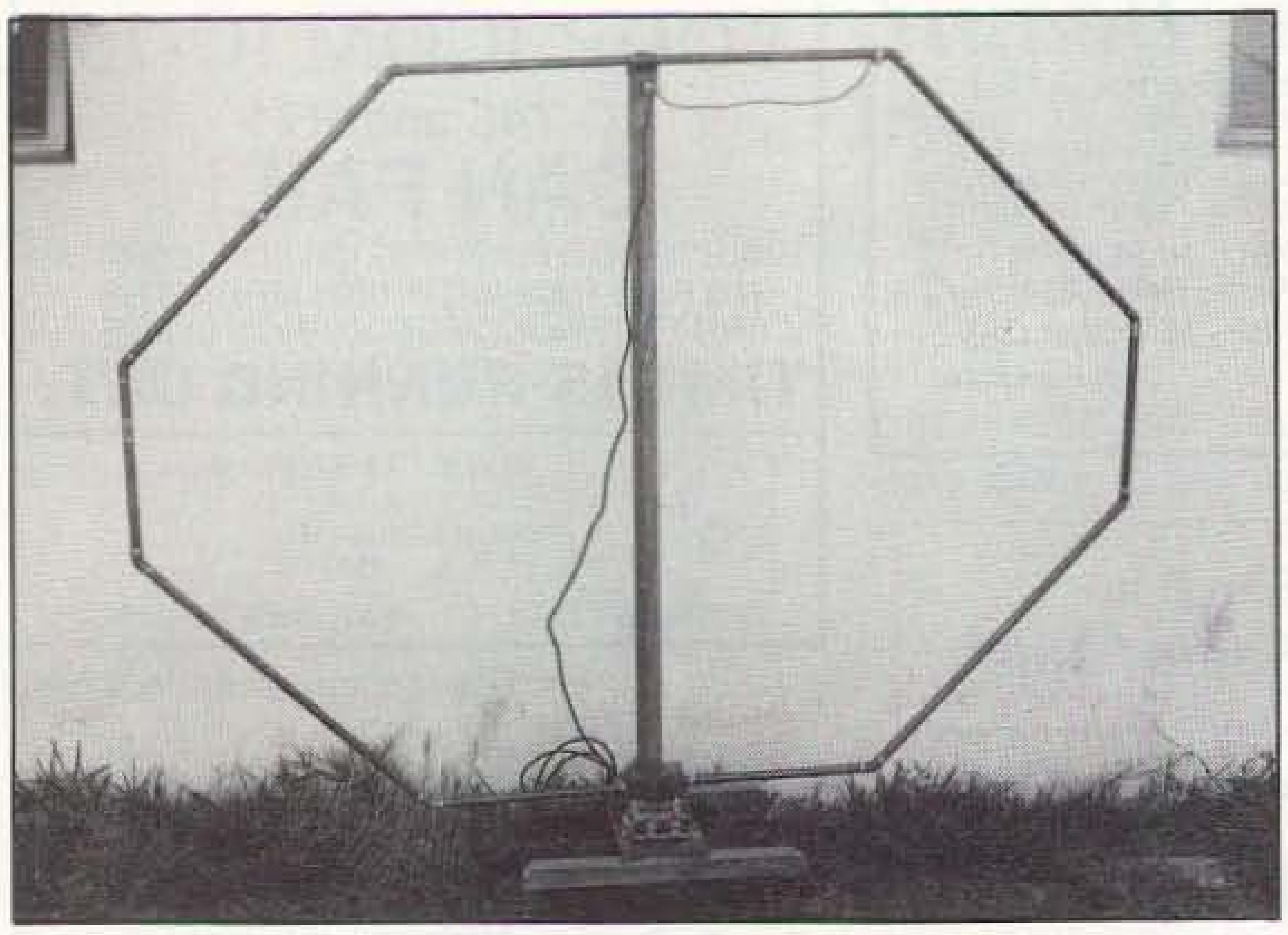

Photo B. The loop antenna, showing the matching section and coaxial cable feed point at the top.

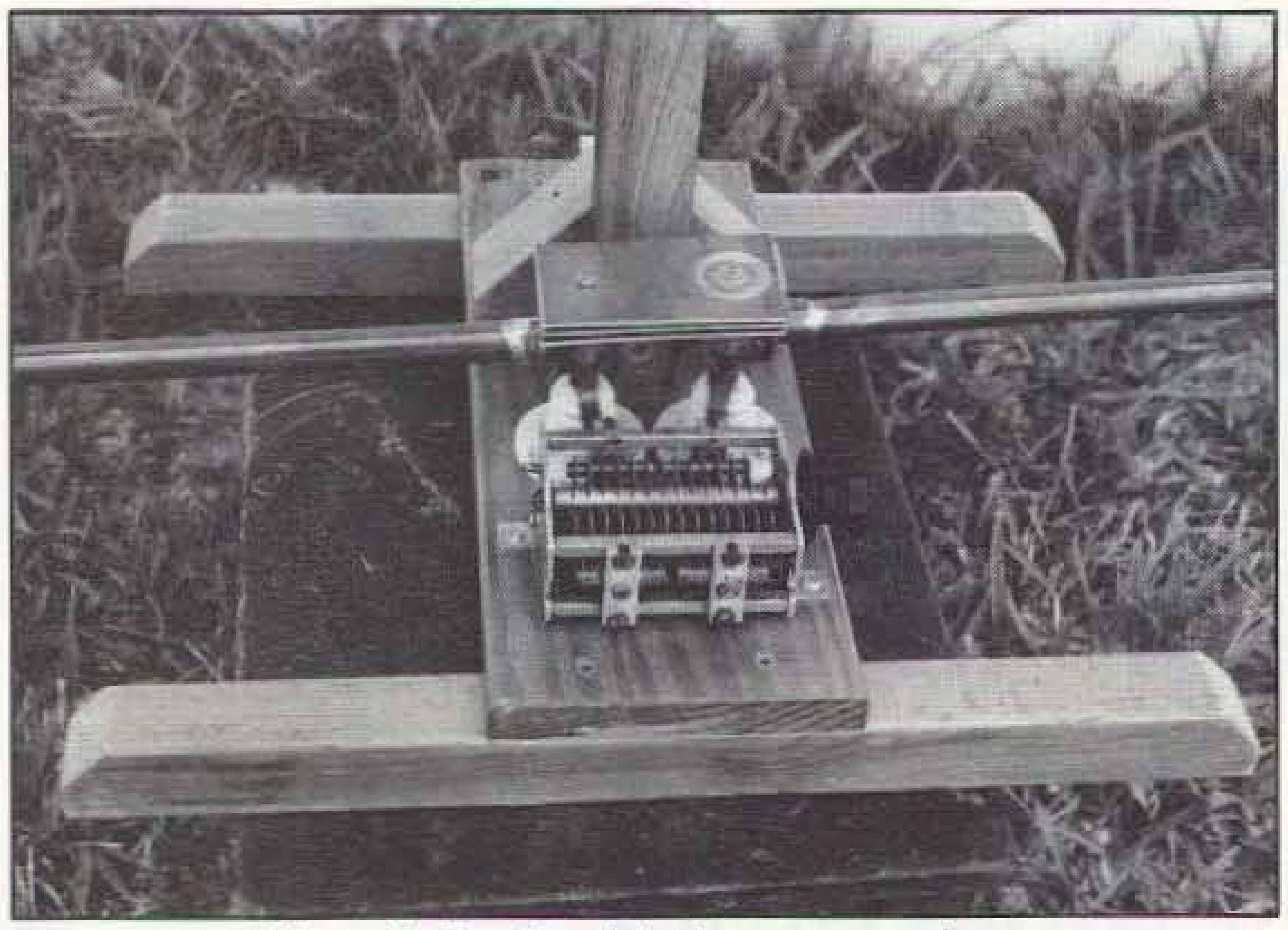

Photo C. Details of the loop antenna base.

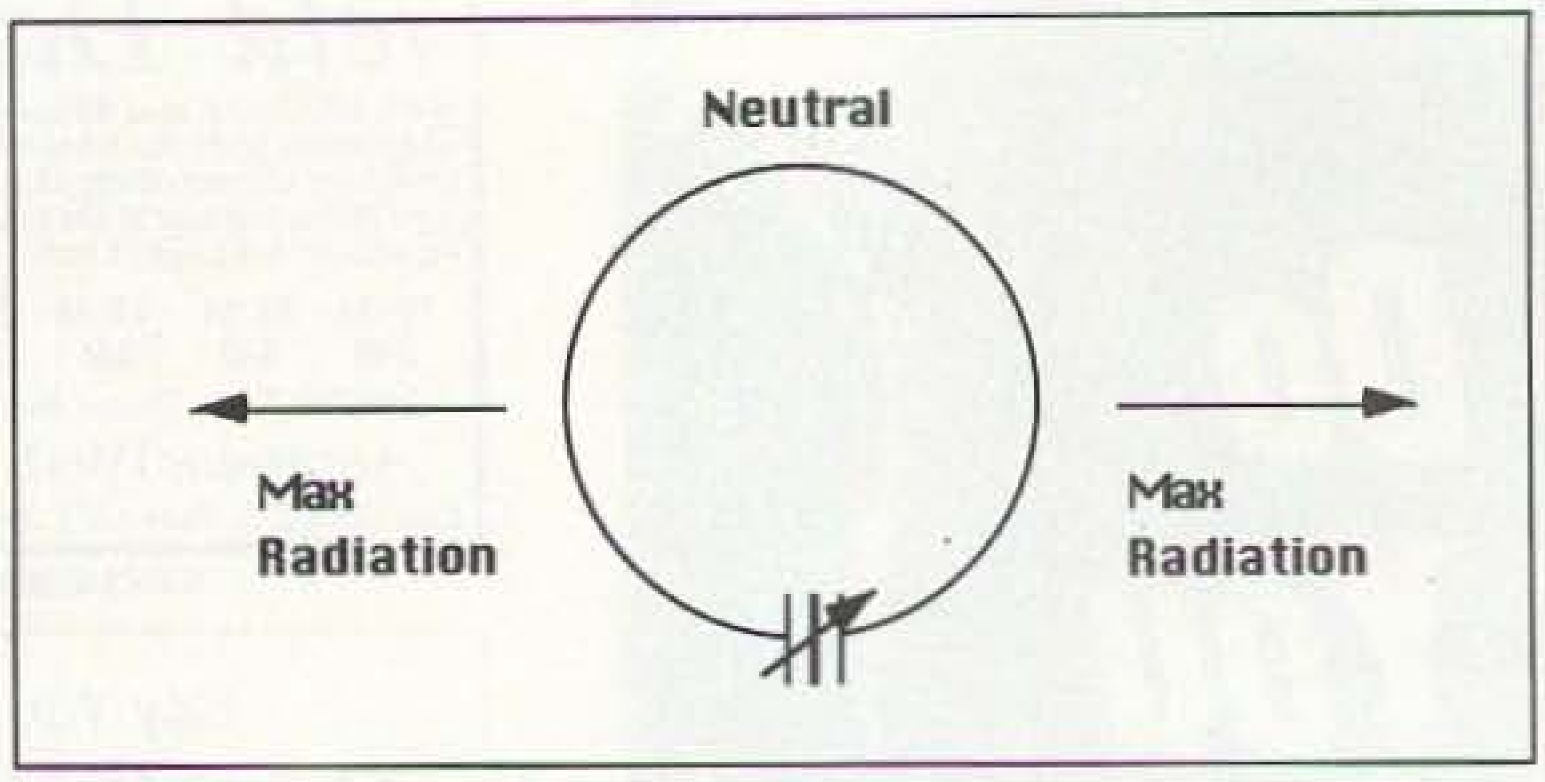

Figure 2. The loop's radiation pattern.

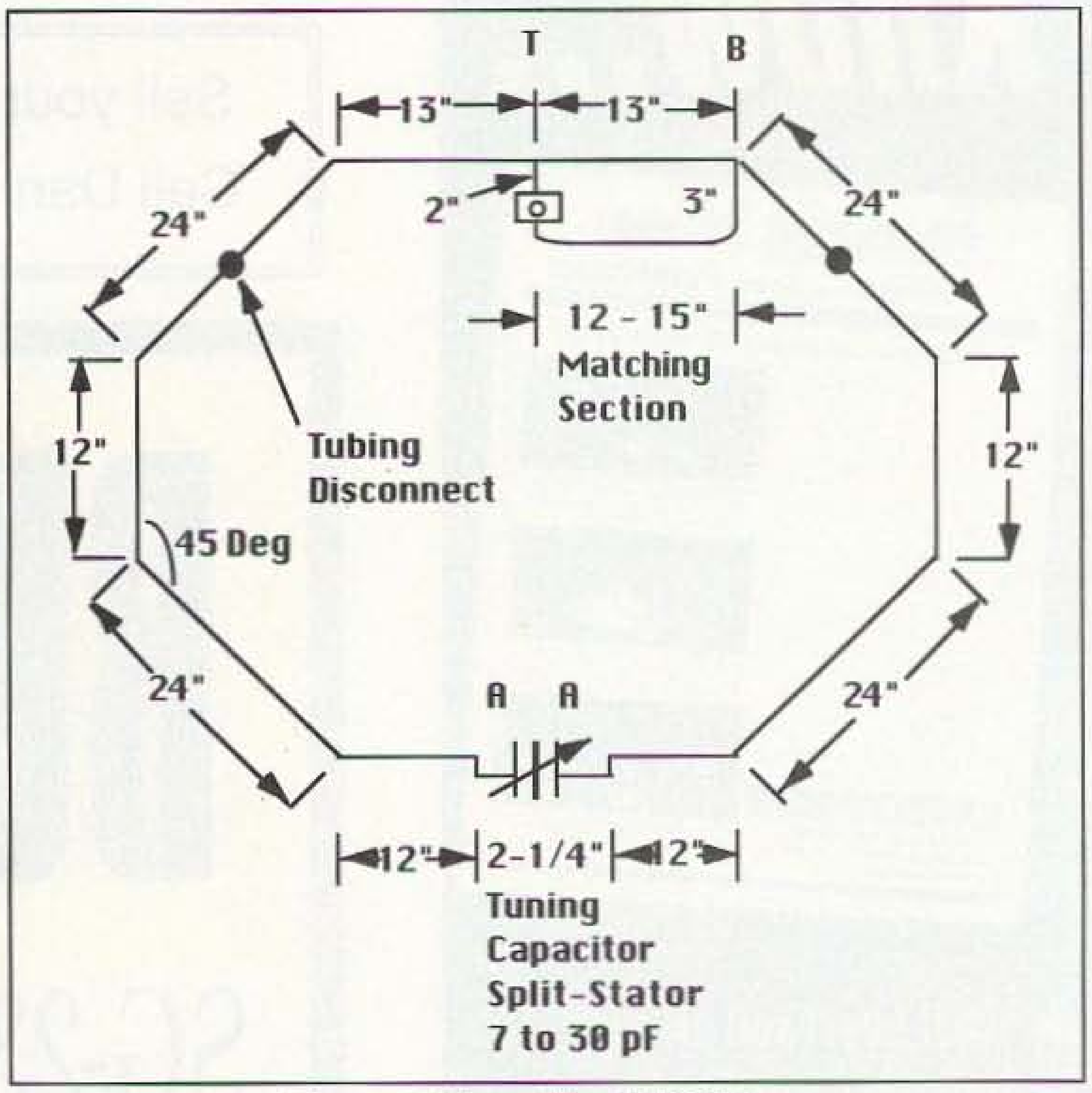

Figure 3. Plan of the K4SYU loop.

Bands

This loop covers the 15, 17, 20, 30, and 40 meter bands. That is not bad for an antenna which can be set up on a table top and take up not much more space than five feet.

Can a Loop Antenna This Small Be Efficient?

The answer is yes. This antenna was designed with the idea of operating it QRP. The calculated maximum gain for this loop on 20 meters is approximately 3.2 dB above isotropic. It also has nulls of approximately 12 dB off each side. Calculated losses below 100% efficiency are 0.13 dB for 21 MHz, 0.4 dB for 14 MHz, and 3.2 dB for 7 MHz.

The good news is that this loop will not cost you a bundle. The construction of this loop is simple enough that any radio amateur with ordinary mechanical skill and simple tools can build it. How about cost? I would estimate that the cost would be less than 35 dollars. Not bad for a five-band antenna! It could be even less if you have a good junk box. The half-inch hard drawn copper tubing and fittings cost me $11 at the local plumbing supply shop. The variable capacitor and beehive ceramic insulators were obtained at a hamfest for a few dollars, and the wooden stand was made out of scrap lumber. You can make yours real fancy if you desire.

You say you want a loop antenna but you do not want to be confined to QRP? Look no further; this small loop will handle power outputs up to 100 watts peak. The tuning capacitor that I am using is a medium-power transmitting type with 0.075-inch spacing between plates. The two stators are in series through the rotor, which gives a plate spacing of 0.15 inches but cuts the effective capacity in half. This spacing will handle more than 10k volts of RF.

Using a split-stator capacitor with each stator connected to one end of the loop, the RF voltage on the rotor and frame is near zero and the frame can be attached directly to the wooden base. The capacitor can be tuned using a good bakelite knob as shown in Photo D. Of course, if you want, you may add a motor drive. I do not recommend using a non-split-stator capacitor as the rotor will be at a high RF potential and there is a danger of RF burn. The inductance of this loop is approximately 5 μH. If you have a capacitor and you know its value, just use the formula

$$F = \frac{10^6}{2\pi\sqrt{LC}}$$

to find your frequency coverage at maximum and minimum capacity.

Tune-Up

The tune-up is very easy. First, select the band on which you wish to operate, then resonate the loop. When the loop is near resonance the received noise level and signals will peak.

You could operate with this tune-up but you probably would not get maximum power transfer. I recommend that you use a VSWR meter in the transmission line. Set the VSWR meter for reflected power, reduce the drive level at the transceiver until reflected power is mid-scale or less, then adjust the loop tuning capacitor for minimum return power. Increase power and re-adjust again for minimum. You should now have maximum power transfer for that segment of the band as allowed by your loop bandpass. Tune-up should not take much more than a minute if your rig is located near the loop antenna.

High Q and Bandpass

The high Q of the loop will work both for and against us. It will help reduce the received noise and it will attenuate harmonic

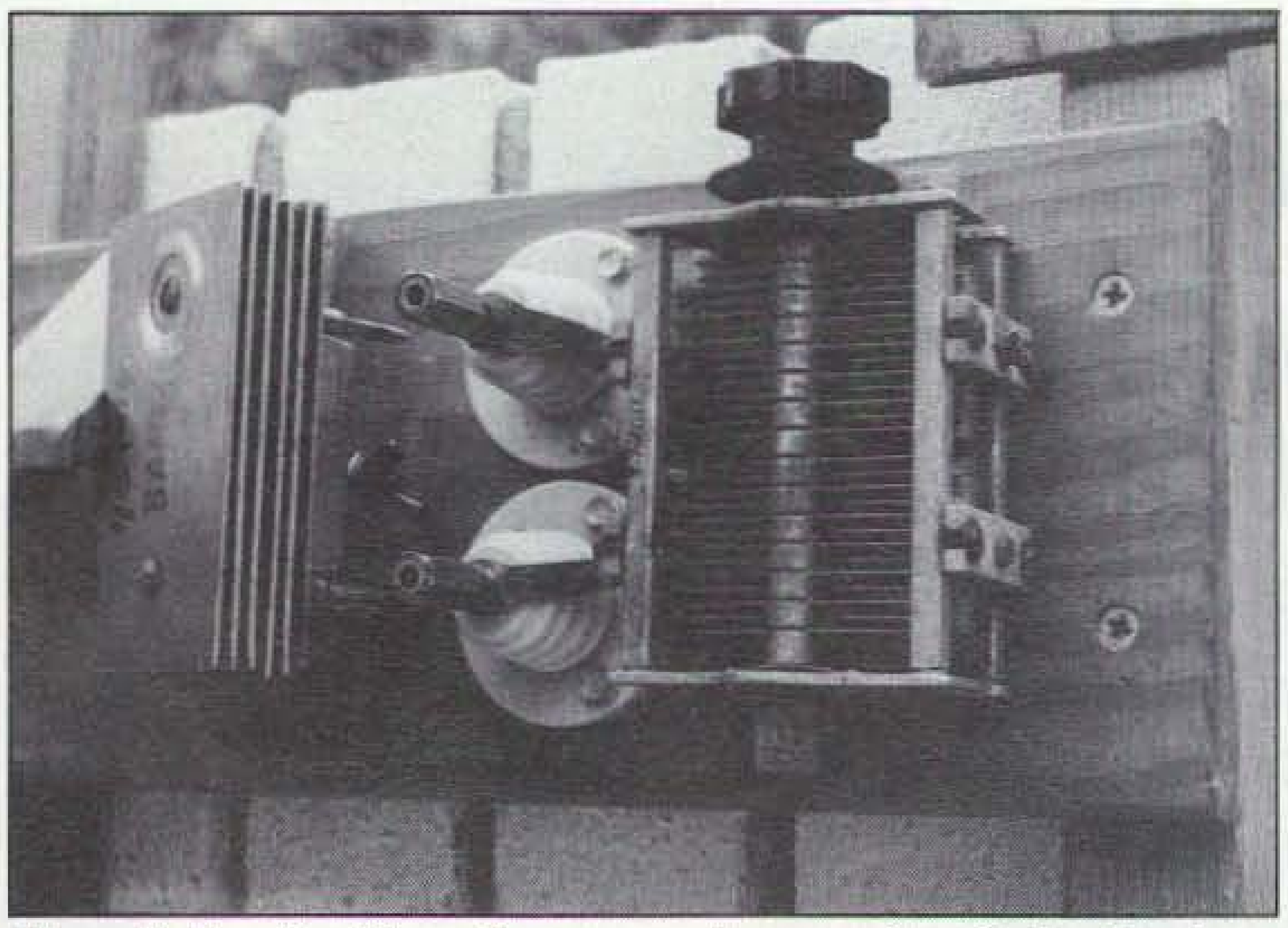

Photo D. Details of the split-stator tuning capacitor, the beehive insulators, and the plug-in 40 meter capacitor.

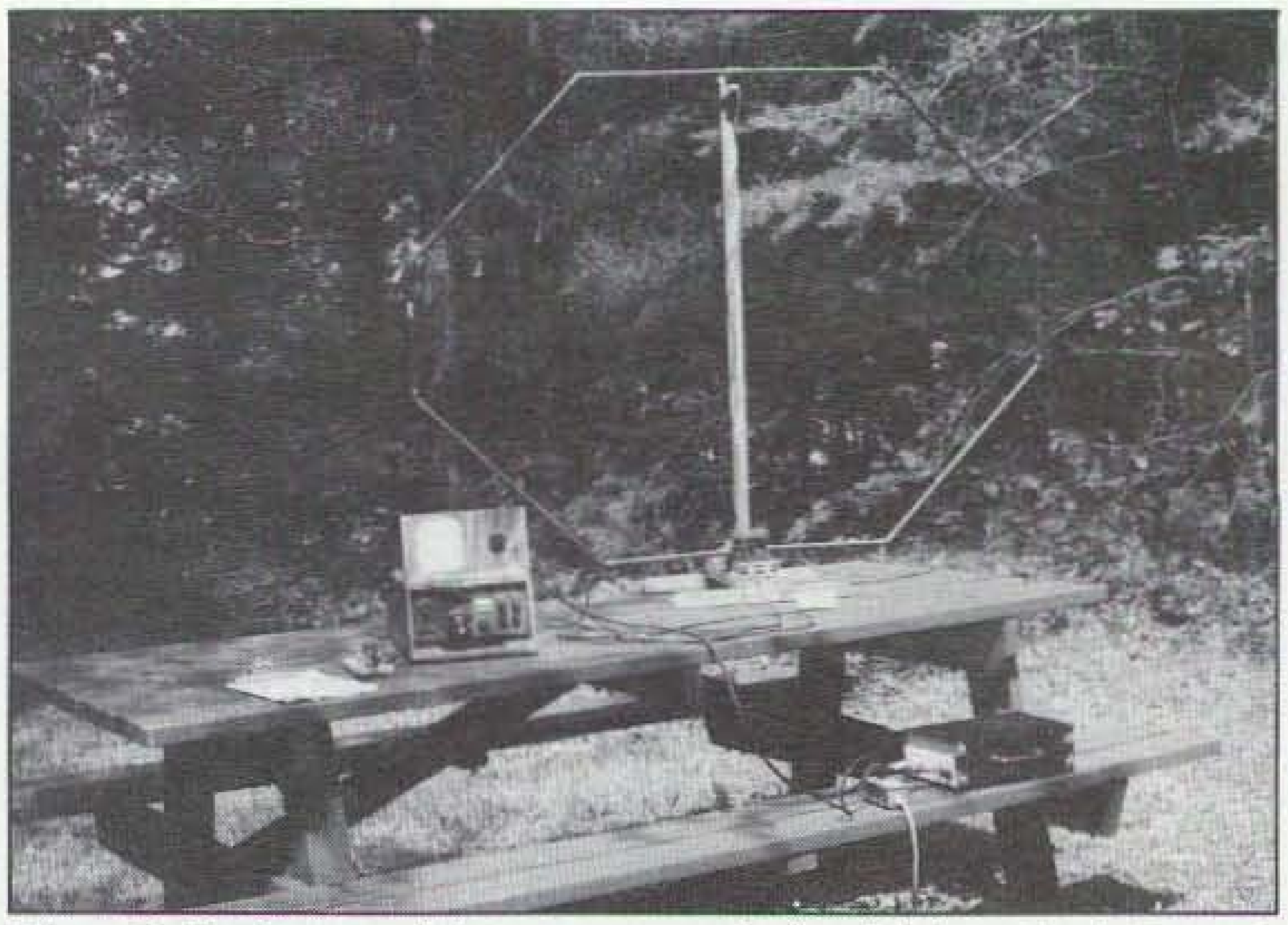

Photo E. The loop and rig set up on a picnic table in a North Georgia park.

radiation. It will not allow us to move up and down the band without re-resonating the loop to the new operating frequency.

The following bandpass figures were measured using this loop:

Band	Bandpass
15 meters	138 kHz
17 meters	Not measured
20 meters	57 kHz
30 meters	23 kHz
40 meters	15 kHz

These bandpass figures indicate the limits between 2.5:1 VSWR points for each band. It is easy to see that as the frequency decreases the bandpass becomes smaller, the tuning of the loop becomes more critical and the efficiency also decreases.

I haven't encountered any problems thus far in manually tuning this loop, as the loop is operated next to the transceiver. If the loop is to be operated at a location at a distance from the rig, then a motor drive mechanical tuner will be required.

Construction

As you can see in Figure 3, the loop antenna is octagon-shaped, but is a little shorter than it is wide. This was done in order to provide clearance from the ceiling when operated from a tabletop.

About 16 linear feet of half-inch hard-drawn copper tubing is required. Using a tubing cutter or hacksaw, cut the tubing to the lengths shown in Figure 3. Clean the portions of the tubing to be soldered, using emery cloth. Also clean the interior of all fittings. Make two copper angle brackets and attach them to the two copper pipe caps with self-tapping screws. Clean the caps and brackets for soldering.

Lay the parts out flat on a concrete floor. Use acid soldering flux on all joints and assemble the loop. Use wooden blocks to raise the loop above the level of the floor, keeping it flat for soldering. Use a propane torch and heat the fittings one at a time. Use lead-tin solder, the same as is used in radio work. The solder will be drawn into each joint when hot enough. You may wipe excess solder off using a damp cloth if you wish.

Note the position of the copper T-fitting (Figures 4 and 5) at the top of the loop. It is used as the upper support, as it fits into a hole in the vertical support shaft.

When all of the tubing joints are soldered the loop should look like the plan drawing in Figure 3. The loop will be rigid and have no loose joints. Make a vertical wooden shaft 1-1/2" x 1-1/2" x 52" long.

Make a 14" x 18" wooden base as shown in Photo A. Make a wooden support for the vertical shaft to hold it at right angles to the base.

A copper bracket is required for the SO-239 coax fitting. It may be screwed or soldered to the copper T-fitting as desired. Mount the beehive insulators on the wooden base along with the split stator capacitor. Fasten parts down with wood or sheet metal screws using brackets as needed on the capacitor frame.

Make connectors out of copper strip to go between the insulator tops and the capacitor stators. Try to have these connectors as short as possible.

The loop as presently set up will cover the 15, 17, and 20 meter bands. In order to resonate it on the 30 and 40 meter bands, additional capacitance must be added in parallel with the existing split-stator variable capacitor. This is done by attaching two banana jacks to the top of the beehive insulators. Fixed plug-in capacitors can then be added in order to work the 30 and 40 meter bands.

Construction of the Fixed Capacitors

The fixed capacitors are made of double-sided copper printed circuit board using air as a dielectric. The printed circuit board is cut into plates which are stacked in such a way as to make a high-voltage capacitor.

Figure 6 shows the size and shape of the fixed capacitor plates. Three plates are used for the 30 meter capacitor; six for the 40 meter capacitor. The approximate capacity of the 30 meter capacitor is 30 pF; 75 pF for 40 meters.

All plates are cut with a large pair of tin snips.

The plates are then stacked and holes drilled to accept two 6-32 screws. Remove the copper from around the hole on one end of each plate. As we are using double-sided printed circuit board, the copper must be

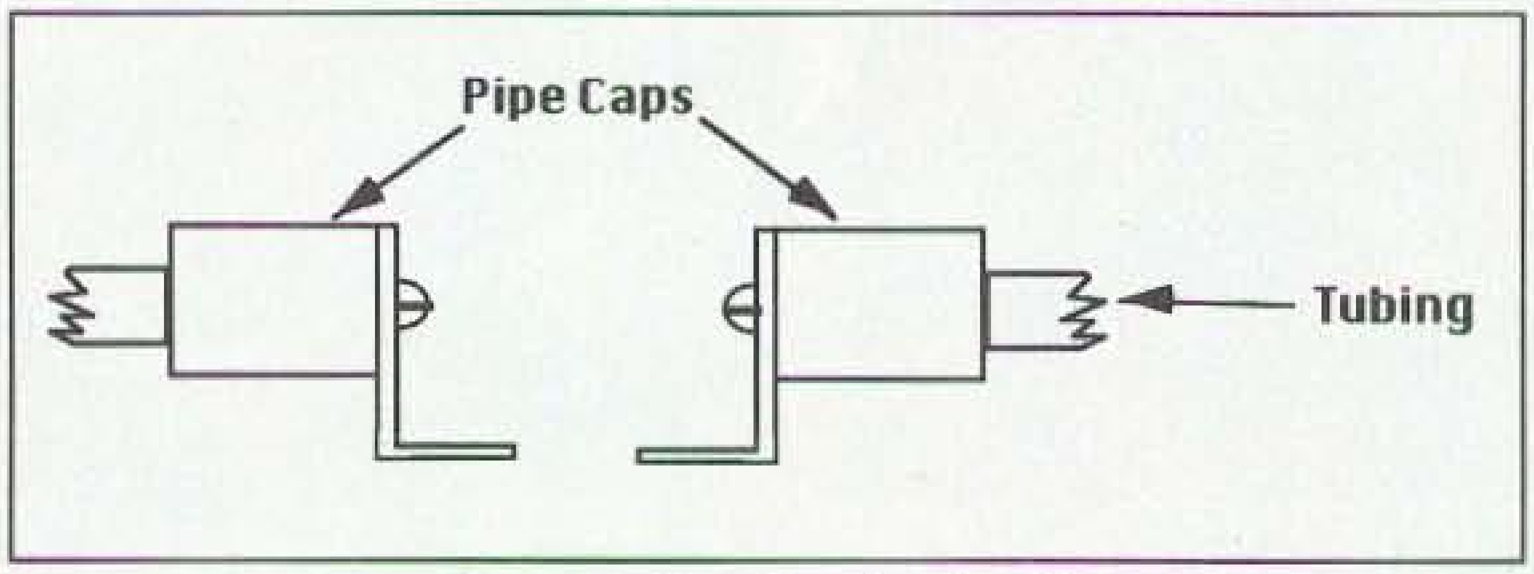

Figure 4. Base bracket detail.

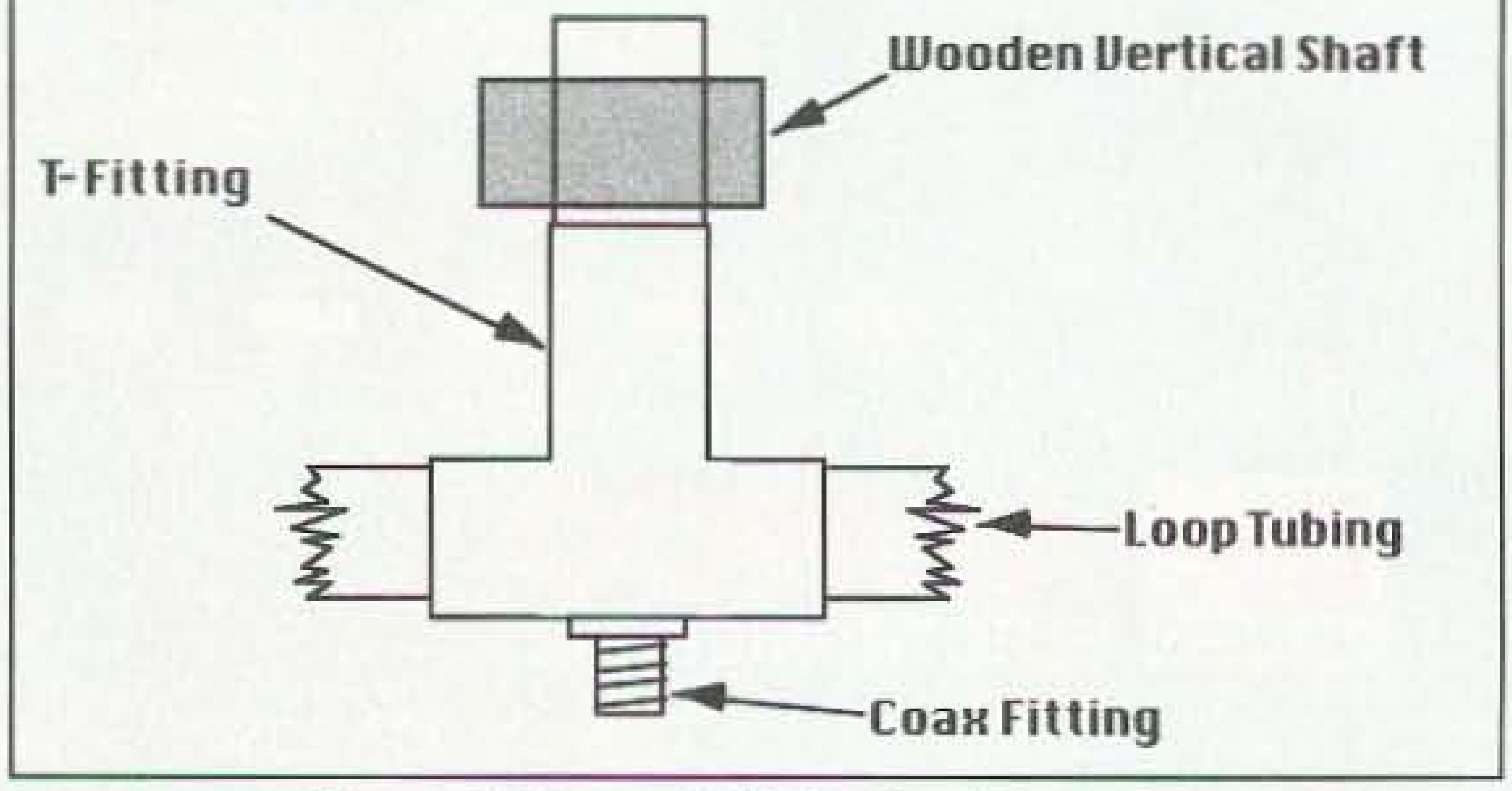

Figure 5. Copper T-fitting detail, top view.

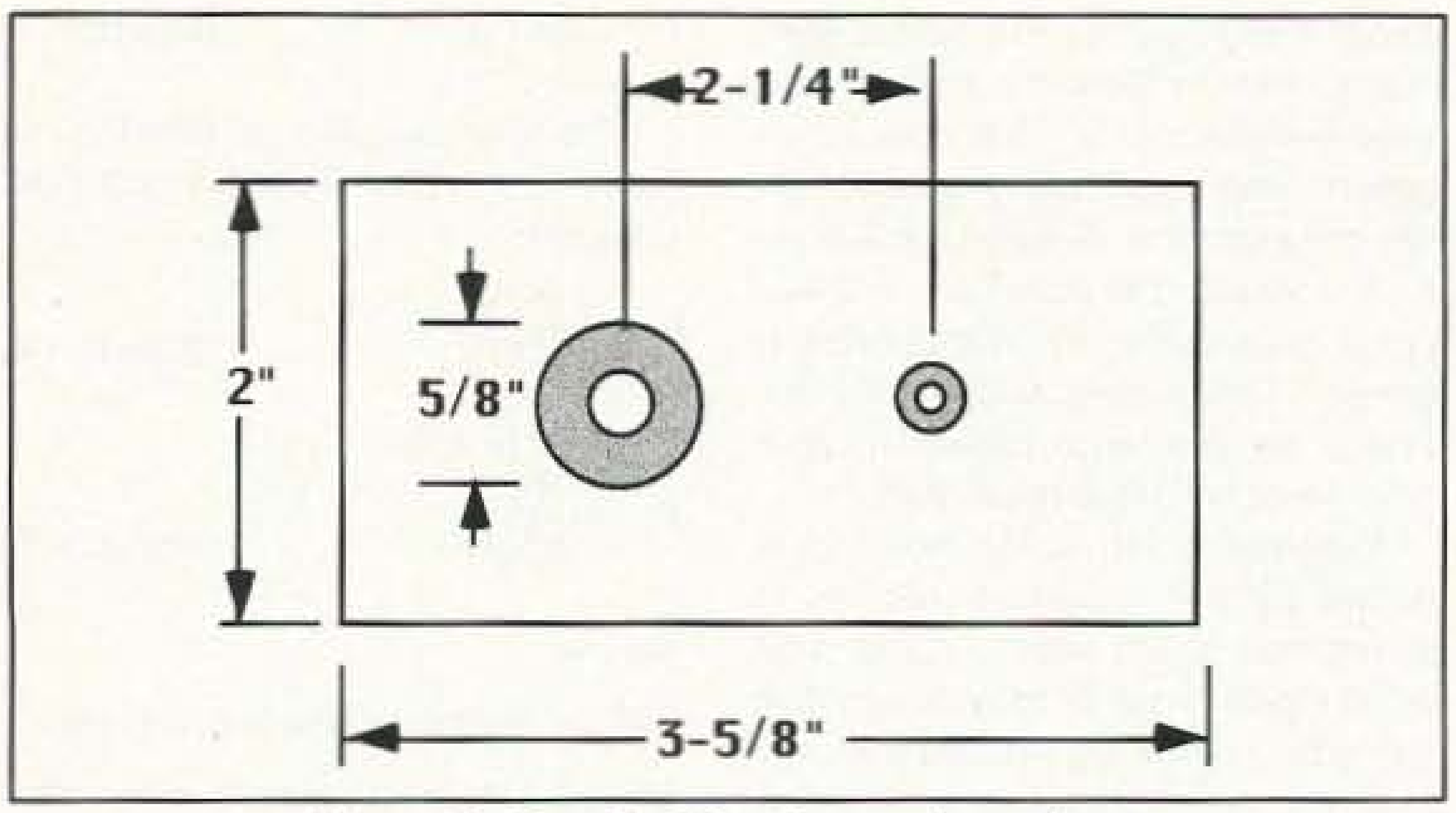

Figure 6. Detail of fixed capacitor plates.

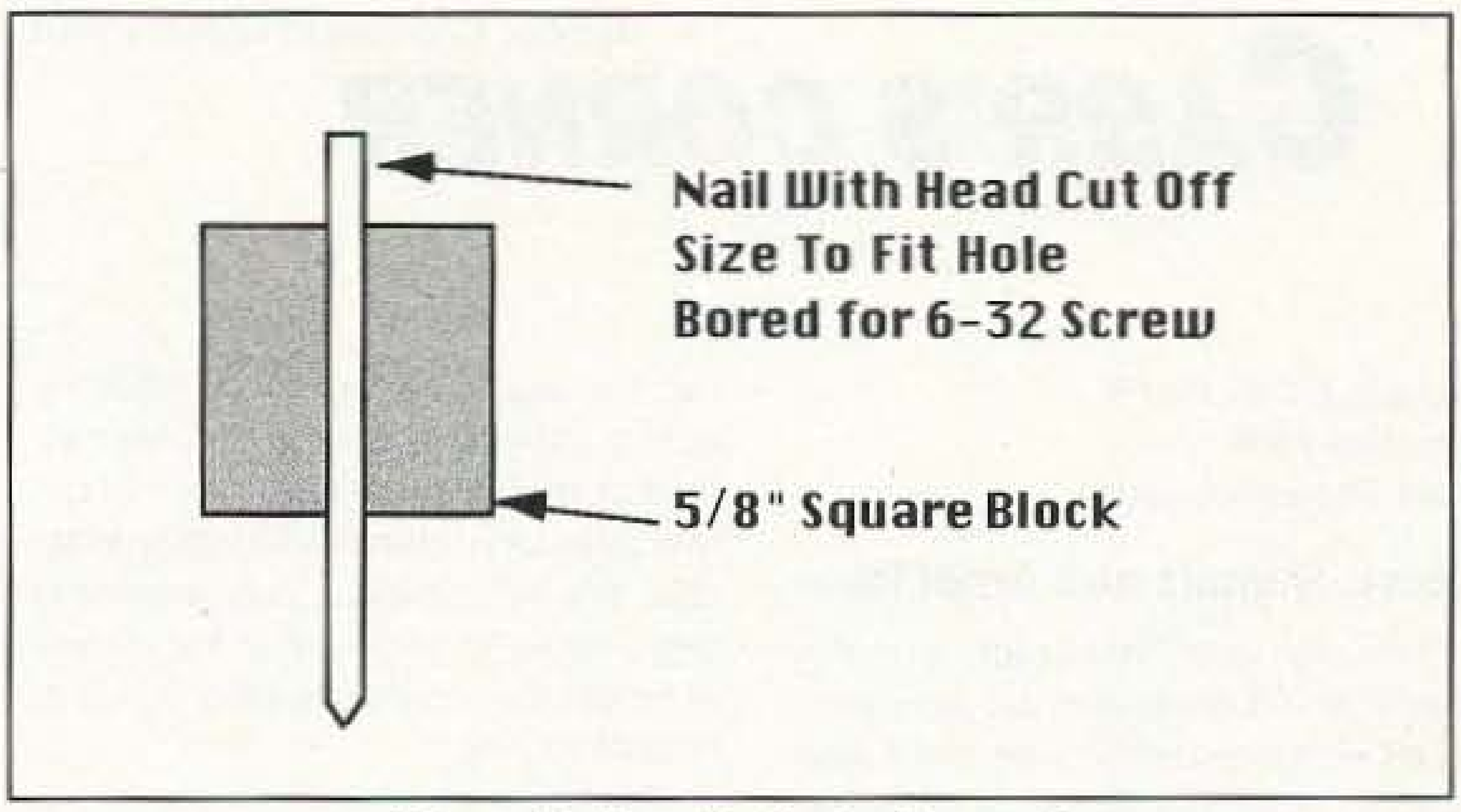

Figure 7. Detail of grinding tool.

removed from around the same hole on both sides. This can be done quickly by grinding the copper away using a homemade tool in an electrical drill or drill press (Figure 7).

Fasten a small strip of emery cloth to the grinding tool, passing the nail through the emery cloth. Insert nail in one side of the printed circuit board in the drilled hole, and rotate the tool using an electric drill. The copper will be removed quite rapidly.

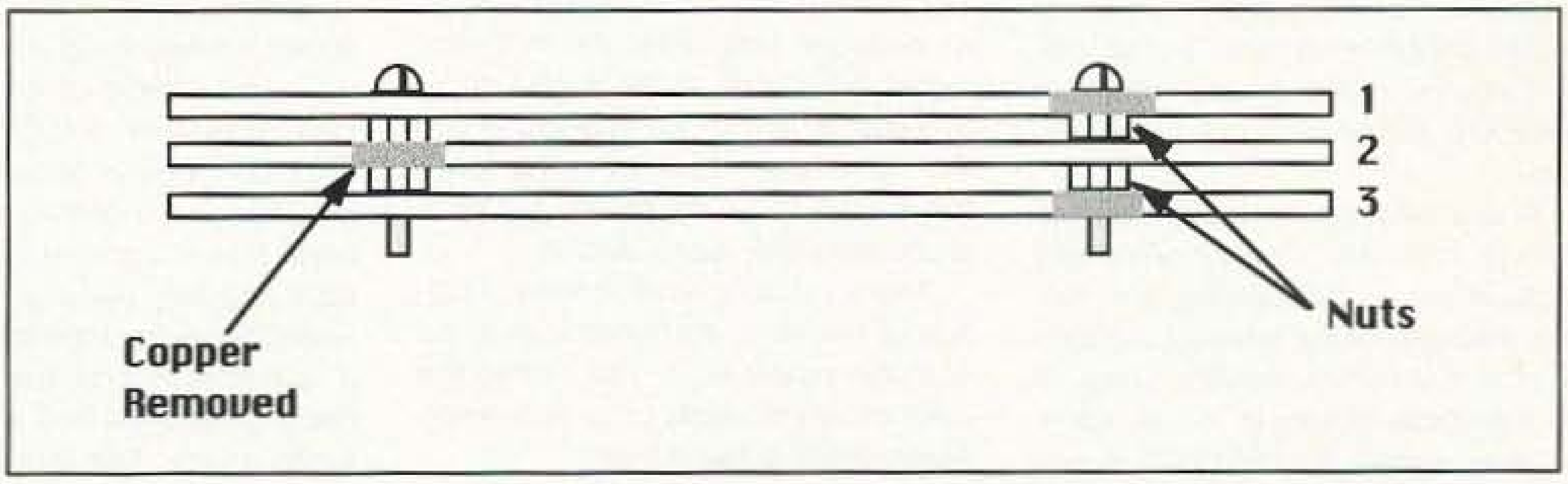

Figure 8. Stacking the capacitor plates.

Stacking the Capacitor Plates

Referring to Figure 8, you can see that on the left-hand terminal plates 1 and 3 are connected while the right-hand terminal is connected only to plate 2. A common 6-32 nut is placed on the screw between each plate and on top of the stack of plates. This gives a spacing of about 0.1 inch.

Loop Antenna Tubing Disconnects

For those radio amateurs who intend to use the loop as a portable antenna or frequently move it from one place to another, it can be equipped with tubing disconnects. The loop will then break down into three sections of no more than four feet in overall length, which will allow it to be easily carried in the trunk of a car. The tubing is cut at the two tubing disconnect points. A brass insert is made with a good fit to the interior of the tubing. It is soldered into one section and, with the loop assembled, a hole is drilled through the mating tubing section. The brass insert is then tapped for a screw thread. A 6-32 or 8-32 screw, as available, can be used to secure the sections of the loop together and make a good mechanical and electrical connection.

A word of caution: This loop concentrates very high levels of magnetic radiation and should be kept away from people and metal objects, both of which will absorb energy. This could cause a hazard.

Conclusion

For the past six months, I've used this loop antenna every Tuesday in a mini-Field-Day operation to make contact on schedule with W2GUM in New Jersey on 20 meter CW. Signal reports have frequently been S9, even with poor band conditions. Some of the contacts were made using QRP. The setup as shown in Photo E is portable from a park in North Georgia. My rig is a Ten-Tec Argosy. Its output is either 5 or 50 watts, depending upon whether I want to operate QRP. The antenna has helped make many contacts on 15, 20, 30, and 40 meters. Most of the operation has been portable battery-powered from a city park in Melbourne, Florida. The loop has also performed very well on DX contacts.

We have a small QRP club, and two other members, W4MPT and N4MPD, have built loops from these plans. Both are very happy with the results.

My recommendation is, try it, you will like it.

For more information see the Ted Hart W5QJR article in the June 1986 issue of *QST*. I would like to thank Burt Bittner KØWQN for his suggestions and computer tab-outs modeling this antenna. For loop theory, see *Electronic and Radio Engineering* by Terman. 73

Parts List

8	Copper elbows 1/2" dia.
1	Copper T-fitting 1/2" dia.
2	Copper end caps 1/2" dia.
14-1/2'	Hard-drawn copper tubing, 1/2" dia.
1	Coaxial connector, female type SO-239
2	Beehive insulators
1	About 2' of No. 12 solid copper wire
1	2" x 4" copper flashing
1	Tuning capacitor, split-stator type*
1	Wooden base, 1" x 6" x 14"
2	Wooden legs, 1-1/2" x 1-1/2" x 18"
1	Wooden vertical shaft, 1" x 1-1/2" x 51"
1	Double-sided circuit board, 3-5/8" x 18"**
1	Banana jacks**
4	Banana plugs with 6-32 threaded ends**
4	Brass screws, 6-32, 1" long**
18	Nuts 6-32 to fasten plates**
1	Hose clamp, small, stainless steel

* Note: The split-stator capacitor which I used was made by Cardwell, and was removed from a plug-in unit from a surplus SCR 188 MOPA transmitter. The capacitor was not split-stator and it measured about 30 to 130 pF. The stator was supported by four insulators attached to the frame. I drilled and filed through the center of the bars holding the stator plates. I removed the center stator plate and made two separate stator sections with 3/16-inch spacing between the stator bar sections.

** Note: If you have trouble finding the banana plugs and the double-sided printed circuit board, a transmitting type variable capacitor may be substituted and may be connected to the loop using battery clips. The variable capacitor should have a maximum capacity of about 100 pF. It does not need to be a split-stator type.

If this substitution is made, then all ** items may be omitted.