Here's a plumber's delight. A complete antenna, down to the tuning capacitor, made from commonly available copper pipe.

How To Build An Indoor Transmitting Loop Antenna
Part I—10 and 20 Meters

BY ROBERT H. JOHNS*, W3JIP

If your only option is an indoor antenna, a single-turn loop offers small size and high efficiency. However, a loop antenna has one major drawback: narrow bandwidth. It is a nuisance to retune the antenna when changing bands or making a large frequency change within a band. Considering the difficulties of indoor operation, however, narrow bandwidth is a reasonable price to pay for efficiency.

This article shows a small single-turn loop for 10-20 meters, and Part II describes a two-turn loop about 4 feet in diameter which covers 40 and 80 meters. They really work and put out respectable signals. Many contacts have expressed surprise that my signal was coming from an indoor antenna. They can be home-brewed and don't require expensive tuning capacitors or motor-driven tuning systems for indoor or portable operation, where the operator has access to the antenna for changing frequency. And the bandwidths aren't terribly restrictive on the higher frequency bands with this antenna (see Table I). The pinch comes on 40 and 80 meters with the larger loop.

Efficiency in a loop antenna requires very low resistance in the loop and the tuning capacitor, as discussed in the *ARRL Antenna Handbook*. Read the section on small transmitting loops in Chapter 5 for a discussion of loop theory and some other practical antennas. This antenna is made from ¾ inch thin-walled (Type M) copper pipe, which is actually ⅞ inch in diameter. The joints are standard 45 or 90 degree ells, soldered to the pipe. If you aren't concerned about packing up the antenna for storage or for portable operation, all the joints can be soldered together. The antenna in the pictures disassembles, as in fig. 5. One pipe is soldered into each ell, and the remaining connection is made with a hose clamp around the slotted ell and pipe when the loop is assembled. Tests described later indicate that there is no noticeable loss in efficiency with these temporary copper-to-copper joints.

A high-voltage, high-current tuning capacitor for the loop is formed by bringing the two ends of the loop parallel to one another and changing the spacing between them to change frequency. The length of straight pipe needed for the capacitor means that the top of the loop is square while the bottom is roughly octagonal.

Band (meters)	2:1 Bandwidth (kHz)	Cap. Spacing (inches)
10	91	1.7-3
12	60	1
15	55	0.5
17	39	0.25
20	21	0.13

Table I- The 2:1 SWR bandwidths of the loop as measured with the station SWR meter.

Changing bands is accomplished by loosening the plastic nuts in fig. 3, and moving the capacitor plates (pipes) closer together or farther apart by sliding the bolts in the slots of the insulators. Marks on the

Fig. 1- The 20-10 meter transmitting/receiving loop antenna. The tuning capacitor is the top of the loop, between the two parallel lengths of copper pipe.

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Fig. 2– For portable operation the base plate mounts on a 1 inch wood dowel. You still need to be able to reach the capacitor at the top to change frequency.

insulators indicate the approximate band spacings. A fine adjustment is afforded by turning both insulator handles, which moves the pipes lengthwise and also changes their separation a little. And a fine-tuning control is afforded by the aluminum capacitor plate above the pipes. It is mounted on a ¼ inch nylon bolt and is only capacitively coupled to the loop ends; there is no direct contact to either one. It provides about 100 kHz bandspread on 20 meters and about 1 MHz on 10 meters.

The antenna is tuned to a frequency by listening for the noise peak in a receiver while the variable capacitor is changed. The tuning capacitor "controls" are insulated to permit this. Final frequency adjustment is made with the top plate for minimum SWR, while a very small amount of RF is supplied to the antenna.

A gamma match is used to feed the loop with 50 ohm coax, with the SWR at resonance either flat or less than 1.3 on all bands. The presence of large metal objects, like heating ducts under the floor, can cause the SWR to rise, so some experimenting may be needed to find the best location. The base lets you stand the antenna on the floor or on a table or bookcase. If possible, get it out on a balcony. For portable operation, the large hole in the base provides a tight fit for a piece of 1 inch wood dowel. The dowel can then be mounted in a tripod, or sharpened and driven into the ground as in fig. 2.

Bandwidth

The 2:1 SWR bandwidths of the loop are listed in Table I, as measured with the station SWR meter. They are approximate.

The bandwidths for the loops in the *Antenna Handbook* are at the half power points, 3 dB down. They occur at an SWR of about 2.5:1, so they are a bit broader than the 2:1 usually used in amateur work. The bandwidths of this antenna are a little wider on some bands than those listed for a similar size octagon in the *Handbook*.

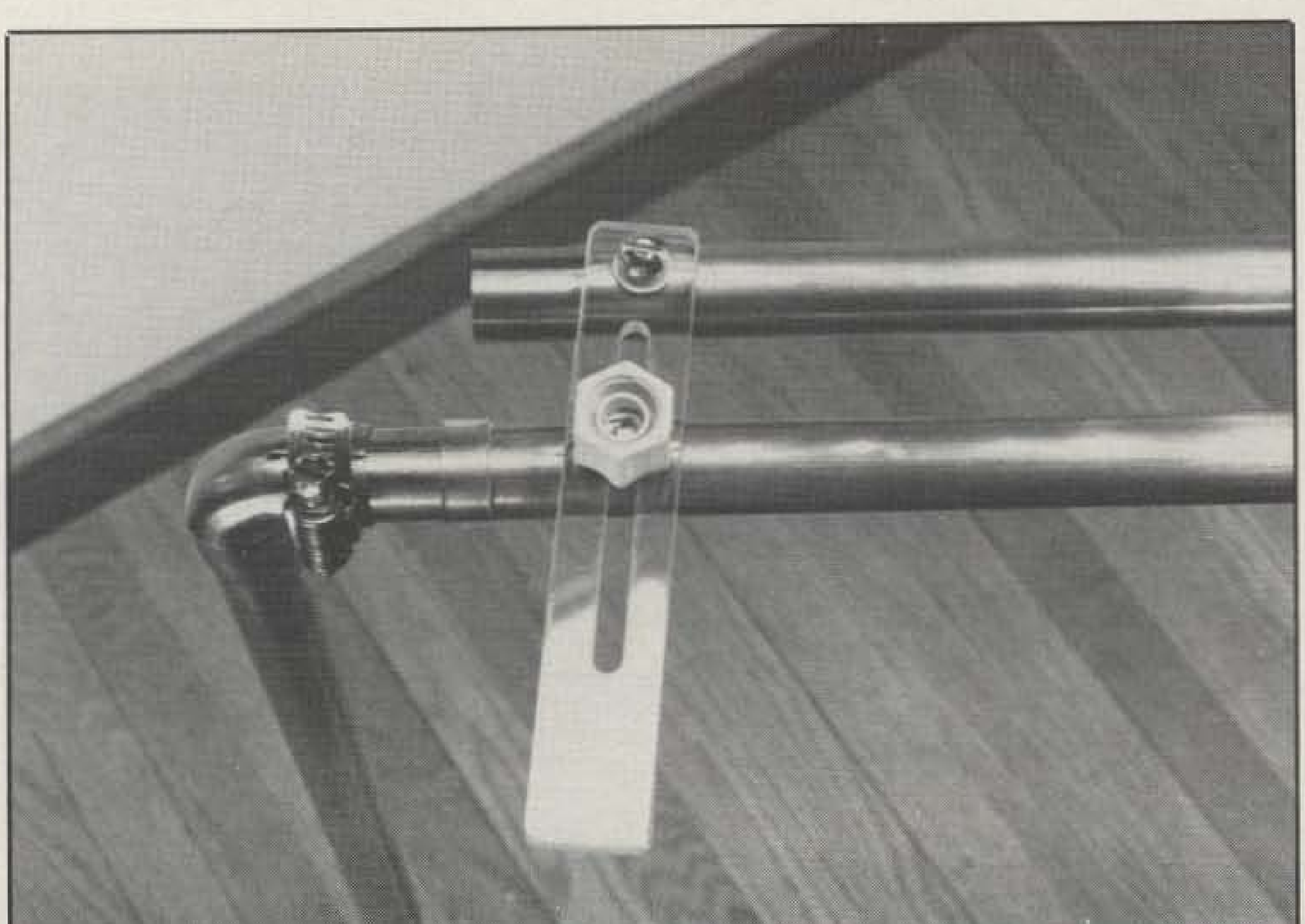

Fig. 3– The tuning capacitor pipes are held in place by the slotted insulators. The white knob has a nut inside it which loosens one pipe to slide closer or farther away from the other pipe to lower or raise the frequency of the loop.

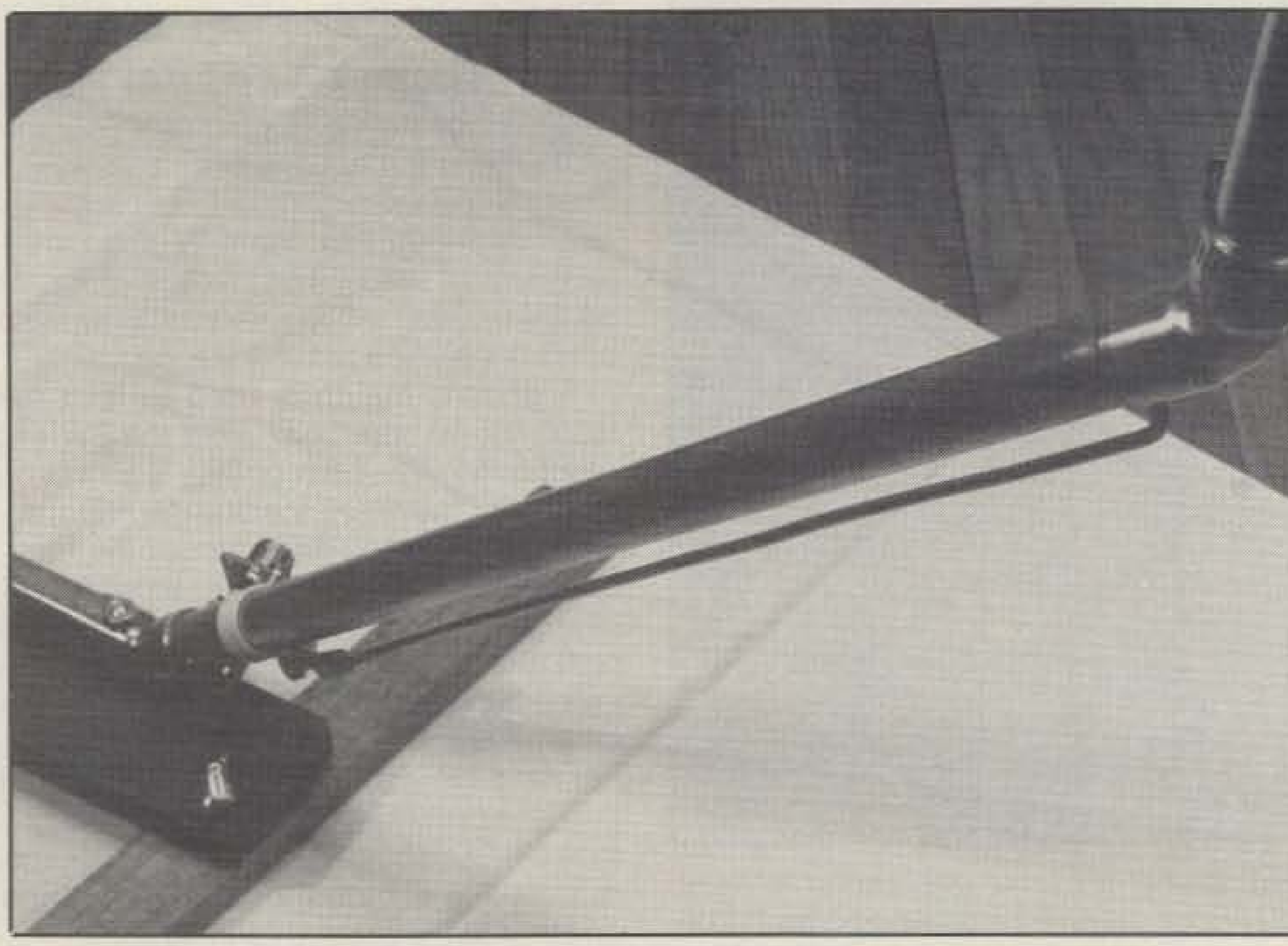

Fig. 4– The "foot" of the antenna, the gamma match, and the SO-239 coax connector.

Suspecting that the hose clamp connections were at fault, I soldered all the joints. To my surprise there was no change in the bandwidths! If there had been extra resistance caused by those connections, the antenna Q would have increased when all joints were soldered, and the bandwidth narrowed. Additional tests showed that the hose clamps had to be quite loose, almost slack, before the increased resistance at the temporary joints affected the antenna performance.

The resistance of the tight copper-to-copper pipe connection is in the same range as that of a soldered connection. In addition, measurements (made with 10 amps through the antenna and a digital voltmeter that resolves tenths of millivolts) showed that the DC resistance per inch of joints with clamped connections in them is actually less than the resistance per inch of the straight copper pipe. DC resistance is not the same as the RF skin effect resistance, which is about 20 times greater, but it is an interesting comparison. Overall, for indoor use where

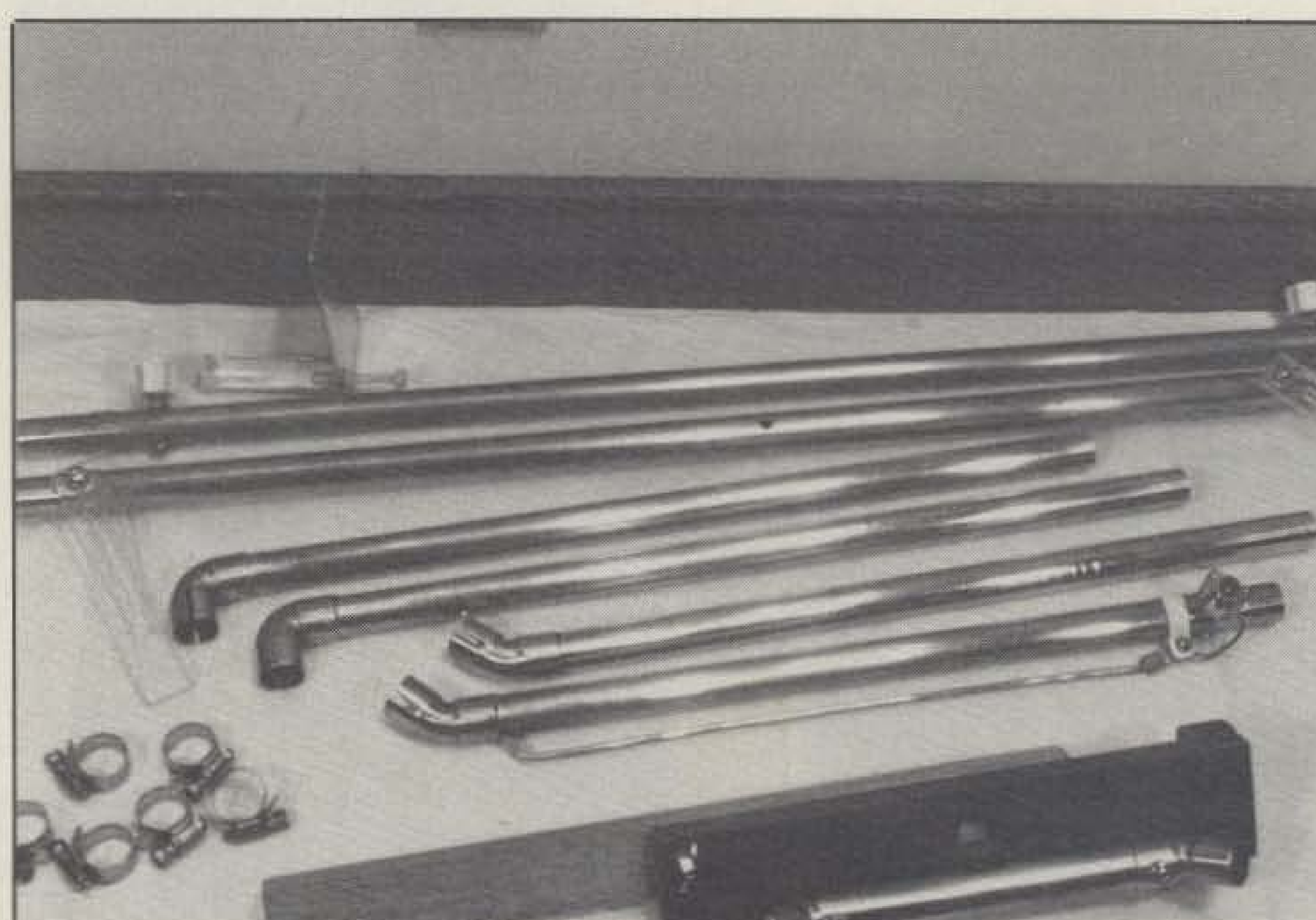

Fig. 5– The parts of the antenna ready for storage or travel.

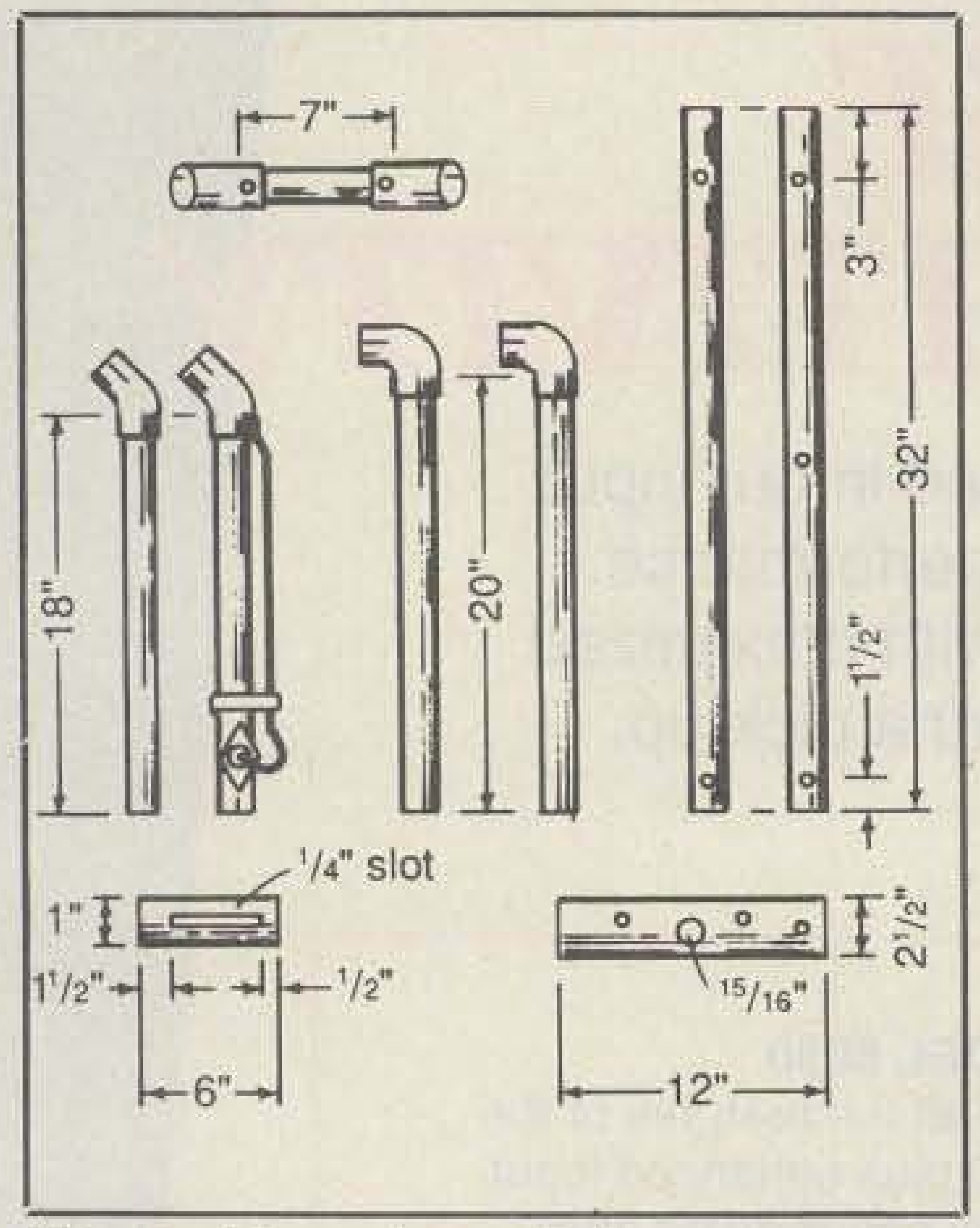

Fig. 6- Dimensions of the parts, not to scale. Lengths of pipe indicated are the lengths to be cut, before attaching the ell. Unlabelled holes are ¼ inch. Seven ¼ inch bolts 1¼ inches long, with nuts, are needed. Also, 12½ feet of ¾ inch copper pipe, four 45 degree ells and two 90 degree ells.

corrosion will not increase the contact resistance, I believe that this method of assembling a portable loop is a good one. And the performance of the loop is excellent, considering its location, size, and simplicity.

Construction

The ¾ inch copper pipe is available at hardware and discount stores, but be sure to get the Type M thin-walled tubing which is much lighter and costs less. The type will be inked on the tubing. You will need a propane (or MATT gas) torch to solder the pipe to the copper ells. You can use electronic solder, but the excess rosin in the solder core will make quite a mess. Better to buy solid solder and a small can of rosin flux with the pipe.

No previous experience with sweating or soldering copper pipe is necessary. Clean the surfaces to be soldered with steel wool and brush on a thin coating of flux. Heat the work hot enough to readily melt the solder and it will wet and flow into the joint by itself. Don't heat the solder directly with the torch, however. After soldering, clean up the copper with steel wool, and you will have a nice looking work of art suitable for display in the living room!

After soldering ells to the pipes, slot the copper ells with a hacksaw and carefully smooth out the inside of the cuts with a round file. Clean the inside surface with steel wool. Drill the quarter inch holes in the base section of the loop after the two 45 degree ells have been soldered to the 7 inch pipe. The quarter inch holes in the 32 inch lengths of pipe are located 1½ inches from one end and 3 inches from the other end. These holes in each pipe need to line up so that the bolts through them will be in the same plane.

The base plate can be made from any hard plastic, about ¾ inch thick, or even wood if it will be out of the weather. A cross-brace to make the antenna stand by itself is made from a 16 inch length of 1 × 2 inch wood. It is held to the base by a ¼ inch bolt 1½ inches long and a wing nut. Counter sink the head of the bolt into the wood so that it doesn't scratch the surface on which the antenna sits. Glue or screw a small piece of the 1 × 2 under the other end of the base plate to keep it level. Drill the large hole in the base plate with a 15/16 inch flat wood bit.

The slotted insulators in fig. 3 are ¼ inch thick Plexiglas in this antenna, but they too can be made from any stiff plastic that the junkbox yields, since the insulator is out of the most intense electric field between the pipes. Even at the hundred watt level there are thousands of volts across this gap! The ¼ inch wide slot is most easily cut with a router, but you can also drill many holes and connect them with a drill and a file. The insulated nut for the slotted insulator is made by squeezing a ¼ inch nut into the plastic hex nut with a vise. The plastic nut is a ⅜ inch ferrule nut with integral sleeve (JACO 0-6), made for plastic piping, and is available at plumbing or swimming pool distributors. If you can't locate it, drill a ½ inch hole into a ½ inch PVC threaded cap and force the ¼ inch nut into it.

The gamma match (fig. 4) is made from a length of #6 or #8 solid copper ground wire, available at discount stores or electrical distributors. It is soldered to one of the 18 inch lengths of pipe near the ell at the end, leaving ¾ inch at the end to go into the ell. Use a hose clamp to hold the heavy wire in place while soldering; solder won't stick to the stainless steel clamp. The SO-239 coax connector is mounted near the other end of the pipe, leaving room to go into the base ell. Six-32 bolts 1½ inches long are used to mount the connector. One-half inch long standoff sleeves that fit around the mounting bolts can be made from ¼ inch brass tubing, available from hobby shops. The center pin of the SO-239 is trimmed shorter and a length of flexible hookup wire is soldered to it. A ¾ inch plastic strap for hanging electrical conduit is used to support the other end of the gamma wire and the short wire from the coax connector. A 6-32 screw ½ inch long will pass through the ends of the strap and secure two terminal lugs there.

As an aid in tuning up on 20 meters, I put a short collar of ⅞ inch ID, 1 inch OD plastic tubing around each top pipe (Plexiglass, Lexan, etc.). These 1/16 inch shims are slid between the pipes to space them the proper distance apart, and then they are slid out of the gap after the nuts have been tightened. This puts the antenna close to 20 meters. These collars aren't essential, though.

Operation

Assemble the loop from the base upwards, tightening the hose clamps only enough to keep the sections in place. Set the long top pipes to be about 1 inch apart, and then tighten all the hose clamps securely. Mount the slotted insulators on the pipes so that they both extend out like handles on the same side of the loop, as in fig. 1. The approximate spacings for each band are given in Table I.

Adjust the gamma rod for best match on all bands by bending it closer or farther away from the pipe. Start with it about ½ inch from the pipe. There is a little compromise, but the match is good on all bands. To help reduce RF feedback, wind chokes on ferrite cores at both ends of the coax feeding the antenna. The rectangular cores in plastic frames are widely available (Radio Shack, MFJ, etc.) and work well for this purpose. Make sure that the frames are tight and there is no air gap in the ferrite.

Although this loop could sit on the operating table or be close at hand for easy access for frequency changes, I prefer to place it in another room to minimize the amount of RF my body receives. I also turn it so that the operating position is on a perpendicular through the loop, since there is a null in the radiation pattern along that line. Also, make sure that no people or pets touch the antenna when you are transmitting. They could get a nasty RF burn.

Power

The antenna has been used at 100 watts. Although there is occasional arcing across the 1/16 inch gap on 20 meters, on 15, 12, and 10 meters it would handle the legal limit with ease. However, even 100 watts is too much for an indoor installation where there are other family members, especially young children, around! I just don't operate when anyone could possibly touch the loop.

In talking with amateurs at club meetings and hamfests, I find that a generation has come along that has experienced only solid-state rigs with low-impedance outputs, and coax transmission lines. Many have never felt an RF burn and are scornful of its hazards. (Only 100 watts?) Be advised that the thousands of volts from this antenna is a serious shock hazard and also a fire hazard if drapes or curtains should touch it! Care is essential.

(To Be Continued)

While your neighbors all think that you're redoing your kitchen or bathroom plumbing, we'll all know that you're building an indoor loop antenna.

How To Build An Indoor Transmitting Loop Antenna

Part II—40 and 80 Meters

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The loop in this installment covers 40 and 80 meters using only two turns. Even though this sacrifices some efficiency compared to a single-turn loop, the antenna still works and is a manageable indoor size. In operation from a first-floor apartment the loop in fig. 1 has been a very pleasant surprise, giving many fine QSOs up and down the east coast and into the midwest on 40 and 80 meters. The calculated efficiencies are 47% at 7 MHz and 9% at 3.8 MHz, which are very good compared to other indoor antennas for these bands.

The antenna uses a structure similar to the smaller version for 10–20 meters described in Part I. A ¾ inch thin-walled copper pipe is soldered together with standard copper ells to form octagons, and the ends of the loop are brought close together to make a variable capacitor. An additional fixed capacitor, which is also made from copper pipe and simple insulators, is added for 80 meters (see figs. 2 and 3). For storage or portable operation the loop can be assembled with slotted ell joints that are tightened with hose clamps. Fig. 5 shows the antenna disassembled for storage or travel.

The antenna stands on a base plate and can be operated on the floor or on a table. For outdoor use a large hole in the base accepts a 1 inch dowel for mounting the antenna on a stake or on a tripod, as shown in fig. 7. The SO-239 input connector and gamma match are shown in fig. 3.

Frequency changes are made by loosening the slotted insulators and changing the spacing between the capacitor pipes, as on the smaller loop for 10–20 meters. Ten calibration marks on the aluminum capacitor plate are a help in making small shifts. On 40 meters this capacitor changes the frequency by approximately 100 kHz, so that each of the marks represents 10 kHz. On 75 meters each mark is about 2 kHz.

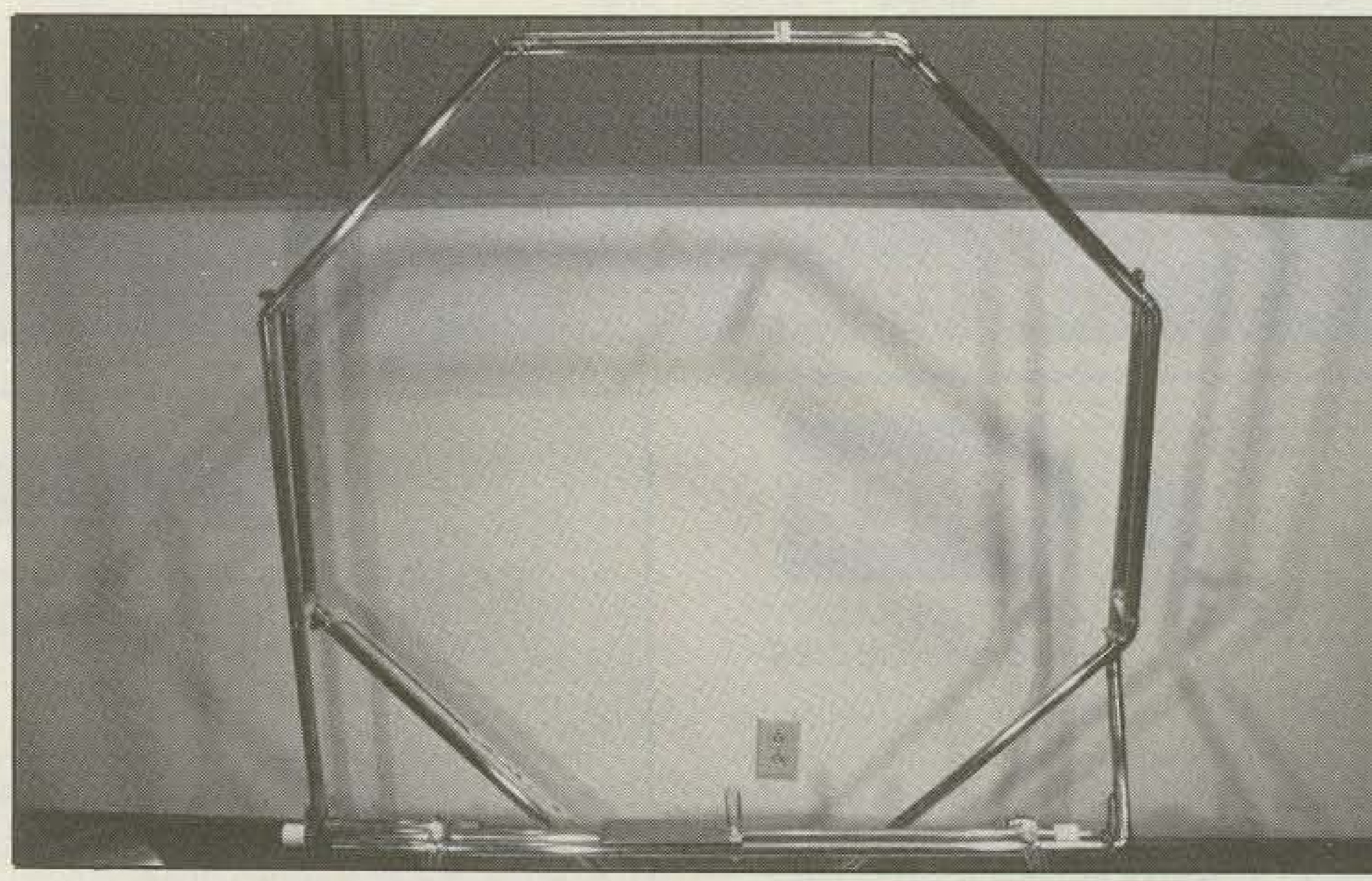

Fig. 1– The two-turn loop antenna for 40 and 80 meters.

Bandwidth

The 2:1 bandwidths of this antenna are very narrow—about 19 kHz on 40 meters and about 7 kHz on 75 meters. An antenna tuner can double these bandwidths, but you will notice a drop in effectiveness if you move very far off the antenna's resonant frequency. A trick to get a little more operating room on 75/80 is to set the tuner to match the antenna about 5 kHz away from its resonant frequency, and then switch between the "straight through" position on the tuner and the matched position.

Construction

Commonly available ¾ inch thin-walled Type M copper tubing and standard 45° and 90° copper ells are used for the loop conductor. The two turns are spaced apart by four ⅞ inch Plexiglass rods 2.5 inches long, shown in fig. 4, that are drilled (5/32 inch) to accept #10 hex-washer-head sheet-metal screws 1.5 inches long. (Use a 5/16 inch nut driver or socket wrench to drive these in.)

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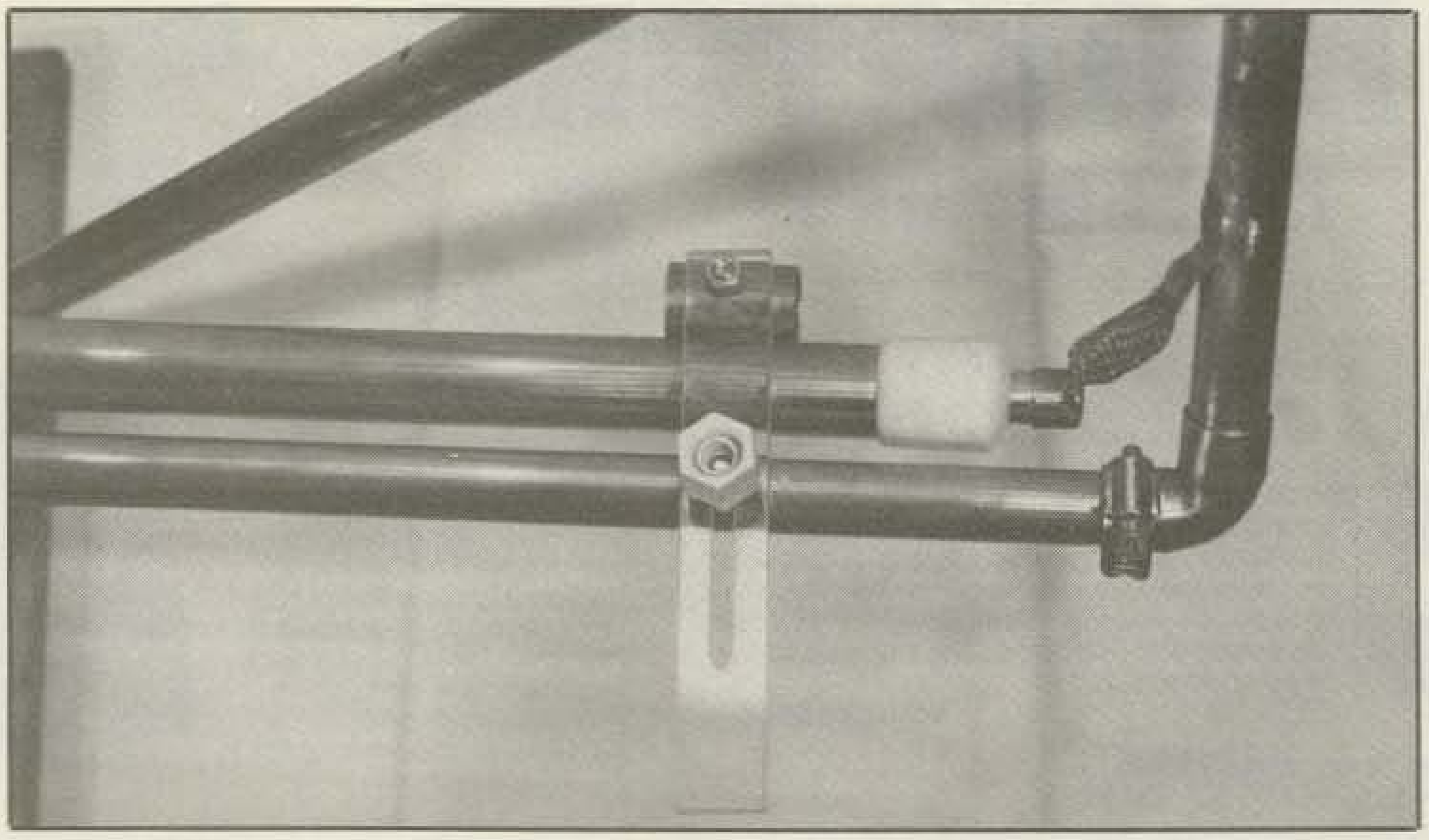


Fig. 2– The variable capacitor is adjusted by changing the spacing between the two pipes. The larger tube is a coaxial capacitor that is connected for 75/80M operation by the half inch copper cap and the braided strap.

The fixed capacitor for 80 meters is made from a ½ inch copper pipe mounted inside a 1 inch copper pipe by simple insulators. These are 1 ⅛ inch plastic furniture tips drilled out to let the smaller pipe pass through. A ⅝ inch flat wood bit drills this hole, which makes a snug fit over the larger inside copper pipe. The plastic furniture tip is easier to drill when it is mounted on a scrap of the large pipe.

A ½ inch copper cap is slotted and soldered to a braided strap to become the "switch" to connect the fixed capacitor into the antenna for 75/80 meter operation. This strap is also soldered to the nearby ¾ inch pipe, as shown in fig. 2. The cap can be tightened onto the inner capacitor pipe with a hose clamp, as the main loop joints are, but I have found that this is not necessary if the cap has been bent to make a snug fit. A way to determine whether this connection is contributing extra resistance is to carefully measure the bandwidth of the antenna, with and without the hose clamp. A wider bandwidth means more resistive loss, if everything else stays the same. Actually measuring very low resistances at radio frequencies is quite difficult, but comparing bandwidths across a high Q circuit like a loop is easy.

The 1 inch pipe is soldered to the ¾ inch loop pipe and ell as shown in figs. 2 and 7. Strap the pieces together with a large hose clamp before soldering, and the job is not difficult. A ¾ inch copper coupling is also soldered to the large 1 inch pipe near its other end to be a place to attach the slotted insulator.

The transition between different pipe sizes could have been made with a reducing coupling or ell, but this would complicate the capacitor, requiring a spacer inside the large pipe. I did not find an insulator material t hat was readily available and that would stand up to the high voltage there. Many plastics would withstand the RF when first applied, but then soften and cook under steady power. The nice feature of the furniture-tip insulators is that they are out of the strongest electric field be-

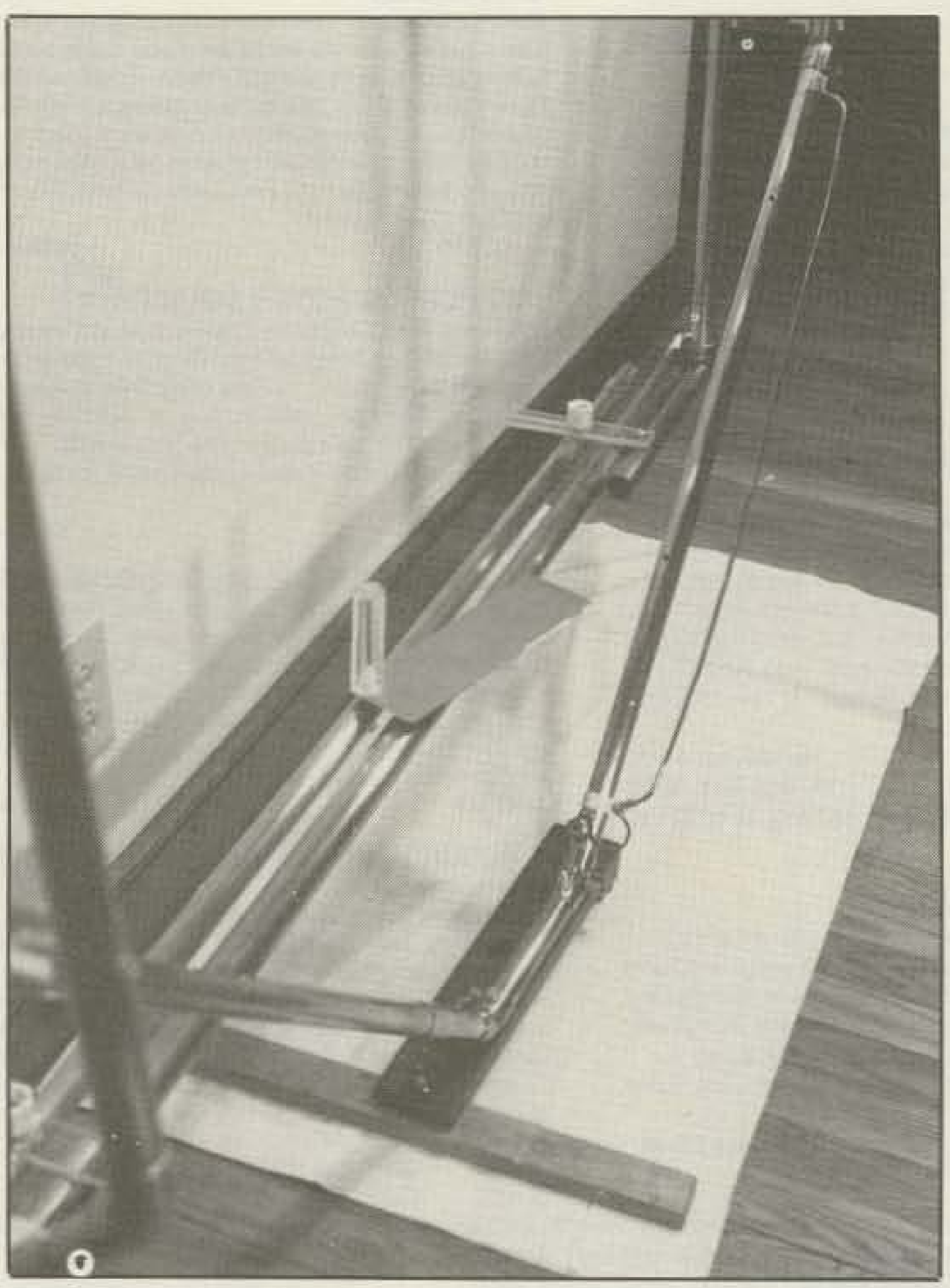
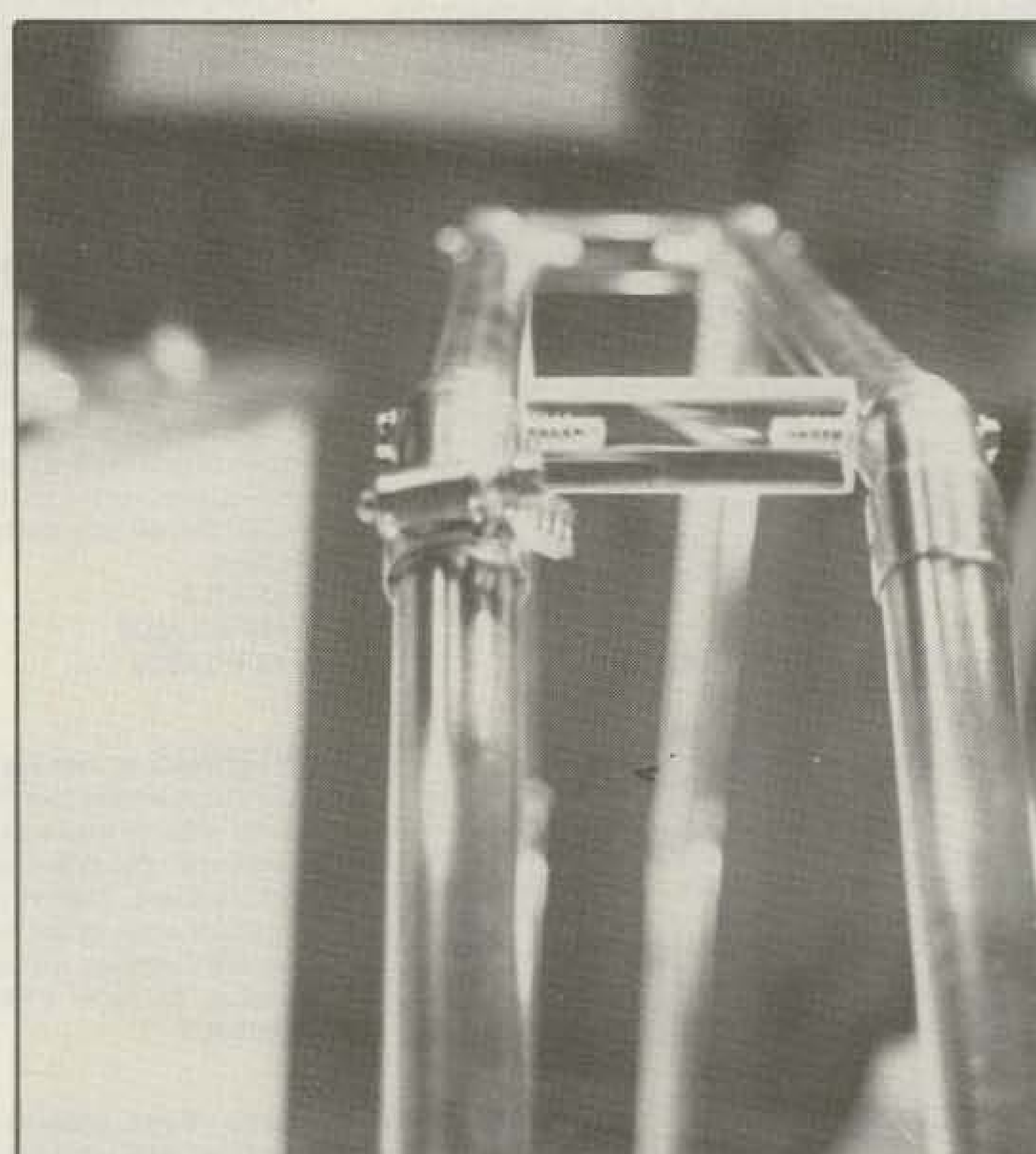


Fig. 3– The self-supporting base, the gamma match, and the capacitor plate for fine tuning the loop.

Fig. 4– The Plexiglass rods between the two turns of the loop are held in place by self-tapping screws through holes in the pipe.



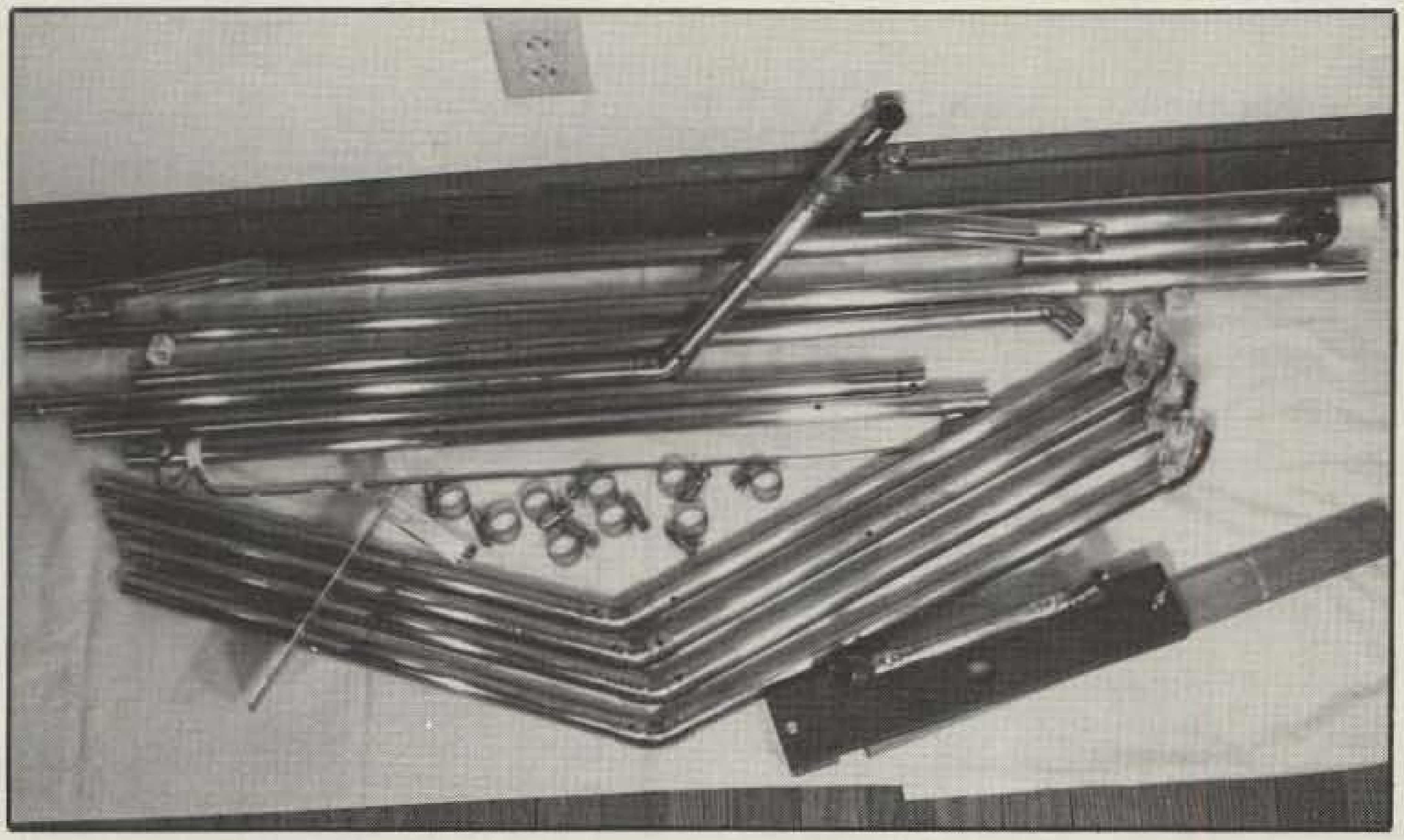


Fig. 5– The antenna disassembled for storage or travel.

tween the coaxial conductors, and only subjected to the smaller fringing field. But if, while operating, you notice the SWR changing during a transmission, shut down and check for insulators that are warming up. Another problem likely to appear is arcing, which can occur when insulators fail or are dirty. This will show up as a rapid jump in SWR. The surfaces of the pipes that make up the capacitor must be clean and smooth and free of things like wisps of steel wool, or sparks will jump across the capacitor gap. Even though this loop structure is simple and rugged, you must put care and attention into the construction of the capacitor.

The input SO-239 and gamma match are similar to the ones for the small antenna in Part I. The gamma rod is spaced about 2 inches from the pipe and should be placed on the side away from the tuning capacitors when building the antenna. The base plate and slotted insulator handles are the same as those on the small loop. Note that the base pipe section is only 6 inches here, however.

Assembly

Start assembling the loops by inserting the gamma section and its twin length into the base section and tightening them with hose clamps. Attach a Plexiglass spacer to each of the four bent sections, as in fig. 5, and build up a loop with overlap at the top. Connect the overlapping sections together with screws into the spacers at the top. Add the 30 inch pipe so that it descends down past the gamma match. Attach the other descending section so that the 45° piece crosses over the middle plane toward the other side of the loop to meet the capacitor (see fig. 6).

Assemble the two long capacitor pipes together with the slotted insulator handles, as in the photos, and connect the capacitor to the two descending sections.

Polarization

For an antenna that must be close to the ground, vertical polarization is preferred. This is because a vertically polarized wave reflected from the ground has little phase change, while a horizontally polarized wave undergoes a phase reversal. Waves reflected from a ground plane under a vertical antenna reinforce the direct wave as though they had come from an image antenna below ground. But the waves reflected below a low horizontal dipole would tend to cancel the high-angle radiation from the dipole. This is why a loop, es-

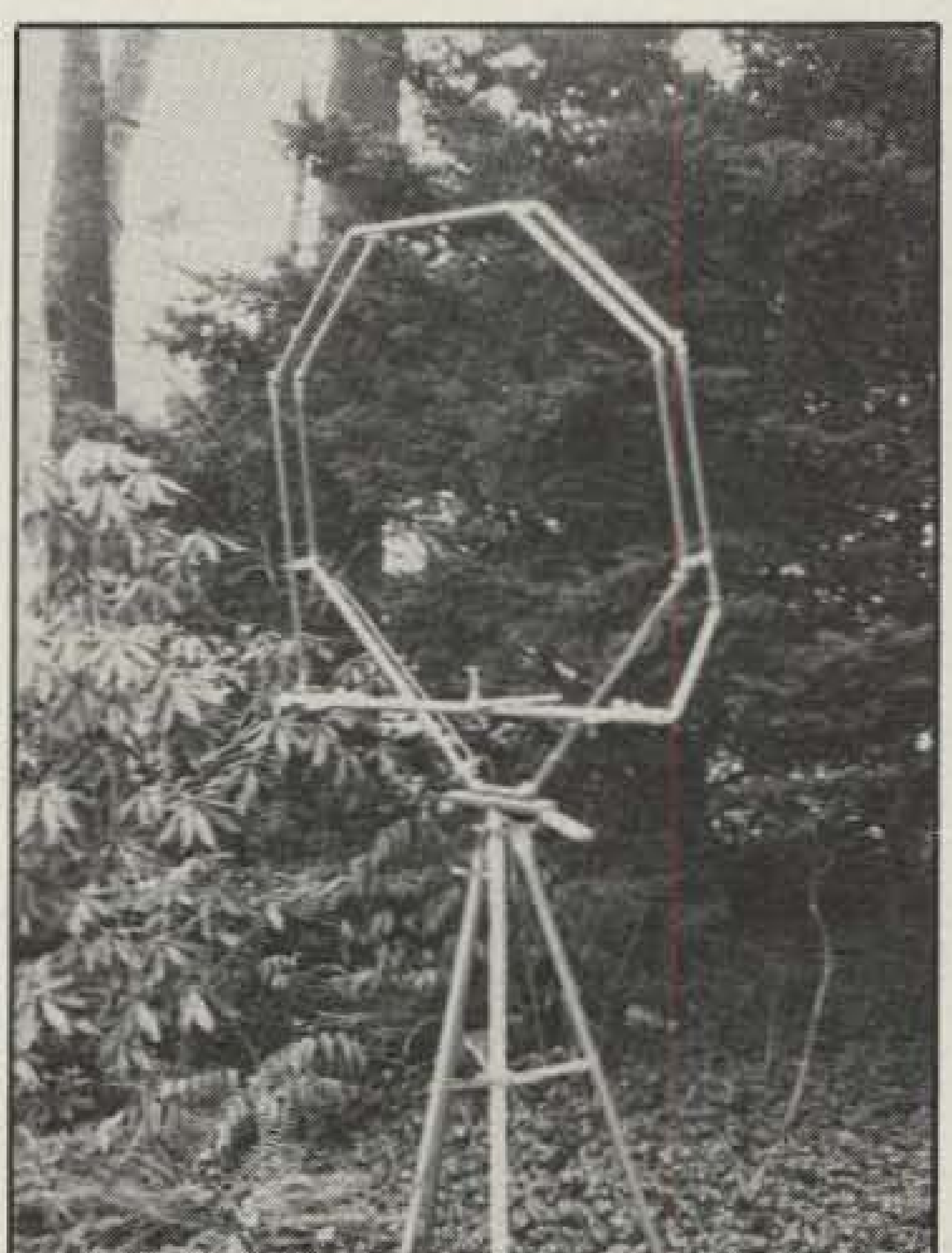


Fig. 6– For portable operation the loop is on a tripod. The capacitor at the base must still be accessible for changing frequency.

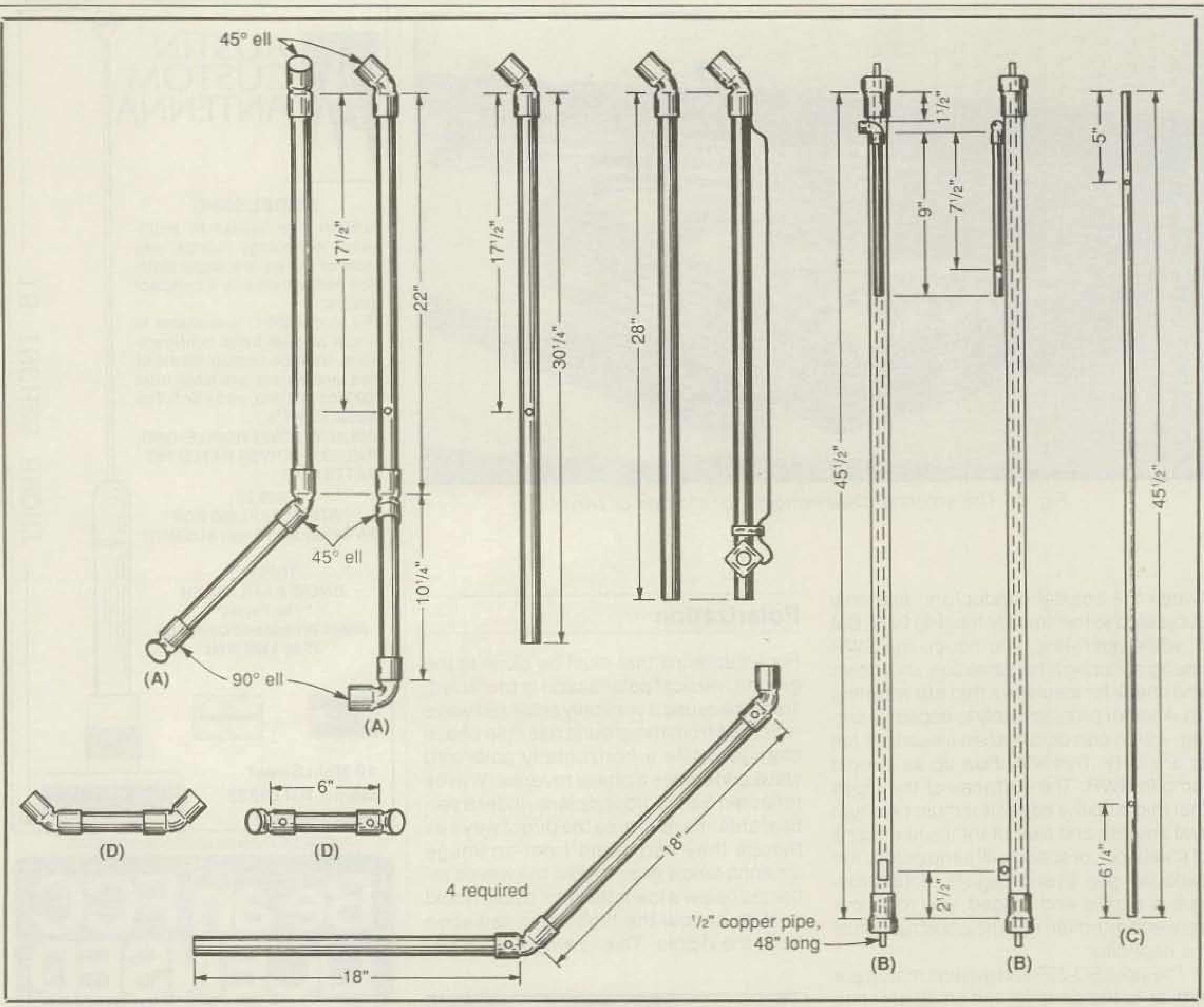


Fig. 7– Dimensions of the pipe components. All holes are ¼ inch. The pipe lengths are the length of pipe to be cut, before an ell is added. The two views marked (A) are of the same pipe, to clarify the positions of the hole and the ells on it. Check the photos to make sure you see how this descending pipe fits and connects to the capacitor pipe (C), at the lower right of the antenna in figs. 1, 2, and 6. Two views are also shown of the large capacitor pipe (B). The 9 inch long pipe with a 90° ell at one end is soldered to the 1 inch pipe. This 90° ell connects to the 30 inch vertical pipe that is at the left of the antenna in figs. 1 and 6. Near the other end of the large pipe (B) is a small length of ¾ inch pipe that also is soldered to the large pipe. The hole in this small piece is needed to accept the ¼ inch bolt that holds the insulating handle to the large capacitor pipe. The short pipe (D) with two 45° ells is the base section that is bolted to the plastic or wood base. Twenty-six feet of ¾ inch, 4 feet of 1 inch, and 4 feet of ½ inch copper pipe, Type M, are required. Also thirteen 45° and two 90° copper ells.

pecially one for the low-frequency bands, should be mounted vertically. In addition, the building services that include heating ducts, water piping, and electrical wiring tend to be distributed in layers, in the floors of a building. An apartment dweller is probably trapped between two "grounds," immediately above and below him/her. And there are also wiring and pipes in the walls! Most of the radiation that escapes this "cage" will come after several reflections, so the antenna should be oriented to produce the strongest, in-phase reflections.

The radiation pattern of a loop is a figure-eight, with a null along the axis of the loop. At high angles from a vertical loop, however, the doughnut pattern is almost omnidirectional. In practice I notice some directional effect on the higher frequency bands, and point the edge of the loop toward the DX I am working with the small loop. On 40 and 80 meters any directional effects are the result of the building layout, I believe.

Operation

To tune the antenna to a particular frequency, listen for a peak in received noise as the variable capacitor pipes are adjusted. This doesn't work as well when there are stations operating on or near that frequency. Turn off the receiver AVC if possible. If you can't, you will get only a general peak and you will need to find the resonance with an SWR dip. Use minimum power and the most sensitive range of your SWR meter. (The MFJ-207 SWR Analyser would be ideal here.) As with the small loop, the insulator handles will slide the pipes lengthwise and change the frequency a little. Use the aluminum capacitor plate for fine tuning. This also lets you back away from the loop and reduce the hand and body capacitance to it.

It's an interesting project that will teach you a bit about antennas, operating, and the layout of your local home-improvement store. CQ