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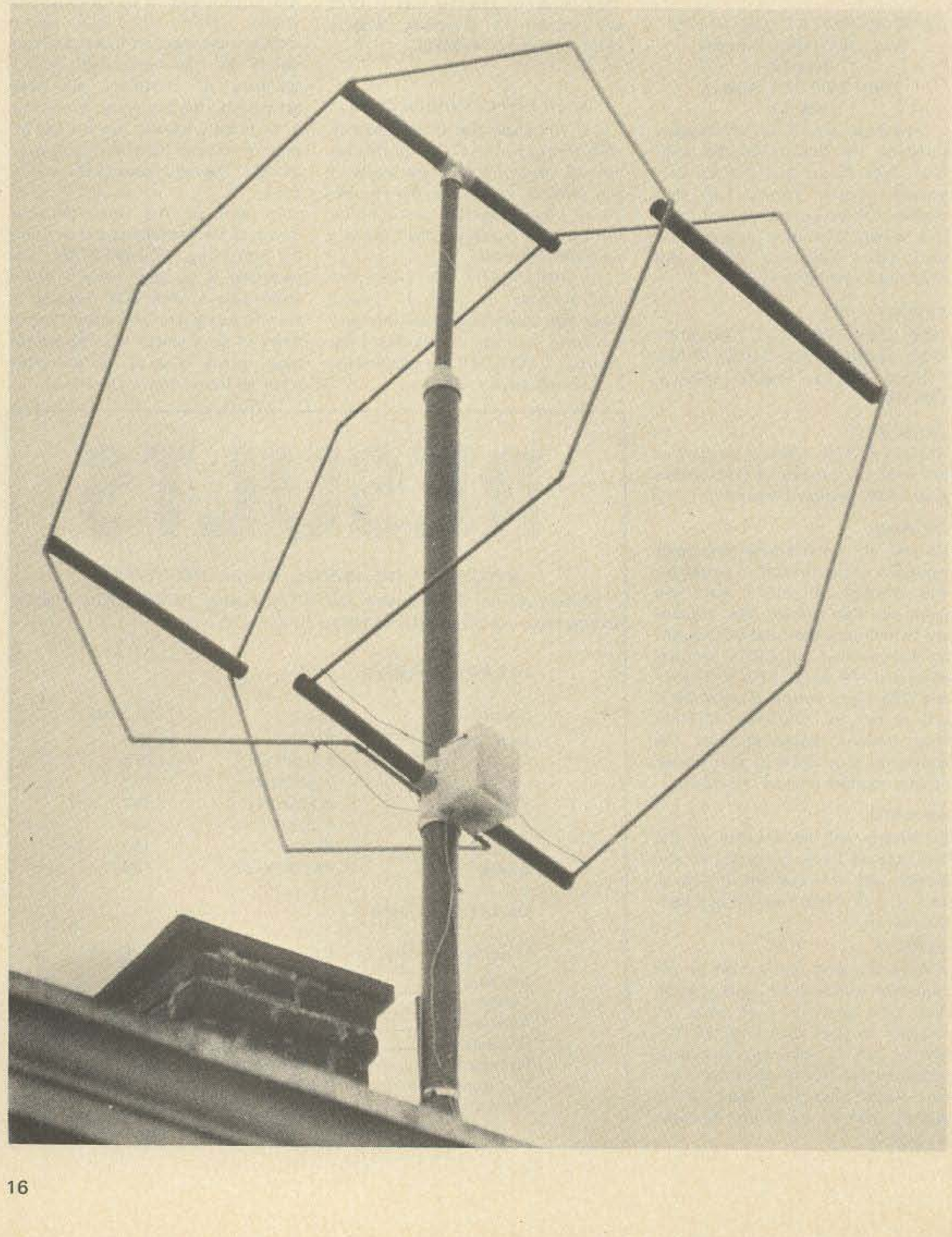
The Magnificent Sevens Microhelix

7 feet, 7MHz

The matching of a low band antenna of reasonable performance to either the high impedance of the Novice wallet or the much less than a quarter wavelength size of a city lot is a problem which not only faced me when my ticket arrived, but also can crop up on field day or in portable operations. When you only have room for a ten meter antenna and most Novice activity is on 40 and 80 meters, obviously you need a little of that spirit you sometimes hear from an old timer when he recalls the days when a rig was improved by rebuilding, rather than giving up two months pay for another brand or later model.



Clearly, for a single band antenna, the frequency range of interest is quite narrow, covering 500 kHz at most and extending only 50 kHz (if only the Novice portion of the band is tuned). It is well known that an antenna whose size is a small fraction of a wavelength can provide an output equivalent to the full sized version, provided it is properly matched and losses are kept low. As the size of an antenna is reduced, a reactive component of the driving point impedance appears, and must be cancelled by one of opposite sign to leave the purely resistive radiation resistance term. A further complication is that as the antenna is made smaller and smaller the reactive cancellation becomes more and more frequency-dependent, requiring a "tuning" of the antenna as its operating frequency is changed.

Another undesirable side effect of the reduction in size

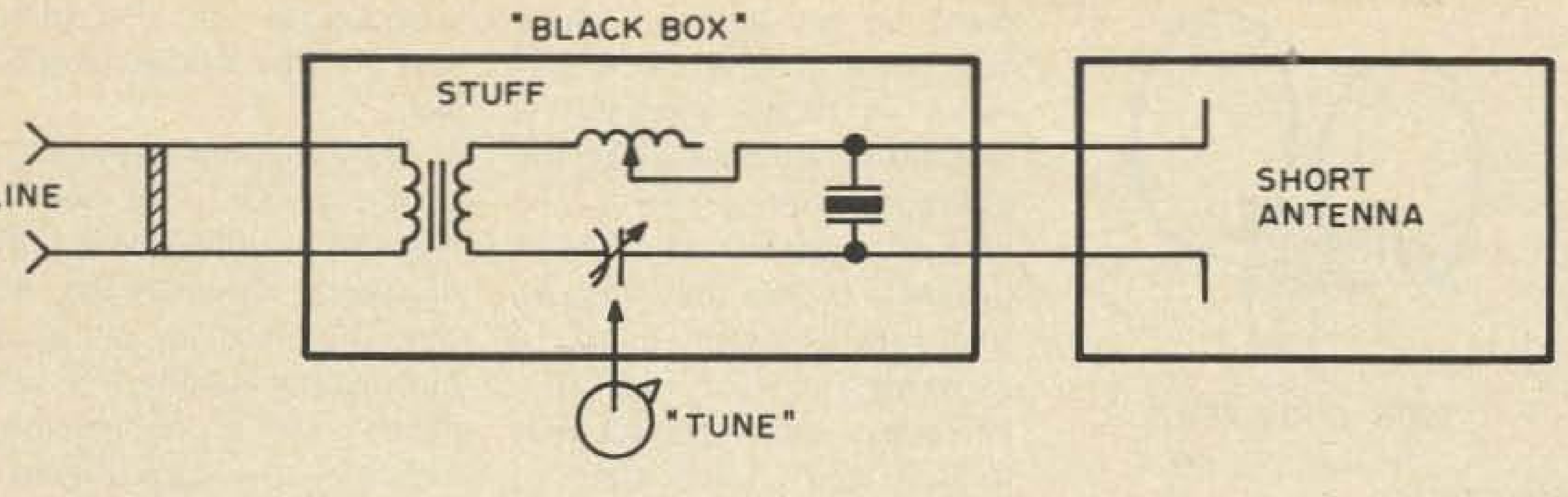


Fig. 1. The "nub."

is a reduction in the value of the radiation resistance, so that, even when the reactive components of the driving point impedance are eliminated, a transformer of some kind is required to raise the resistive portion from a value (in some cases) as low as a fraction of an Ohm to something suitable for matching a transmission line of reasonable dimensions.

Thus, the conceptual nub of our problem is a black box providing the matching functions necessary to make our small antenna have an output equivalent to a large one, i.e., to convert the undesirable output characteristics to those required to match the feed line. I found much poo-pooing of tuned small antennas among amateurs, because of the high losses found in most standard matching networks (although W2FMI has done much work with this approach and has reported excellent results in many *QST* articles). It seems to me, however, that many of these problems have arisen because attempts were made to actually build a "black box" full of coils, caps and stuff, rather than to allow the black box to remain simply a concept, which is then used as a starting point for thinking.

Let us do some thinking about losses. Losses in the antenna itself increase as the size of the antenna is reduced and it becomes more and more reactive. This is because increased reactance results in larger and larger currents flowing on the antenna, causing it to act more as a heater than an antenna. The answer is to make our antenna out of some low resistance material like silver and, further, to increase the surface area where the currents are flowing as much as possible, since heating is an I^2R effect and a small reduction in current density makes for a relatively large drop in losses. Hence, wire is out! Large diameter low resistance pipe is *in*. For experimenting, I chose easily soldered copper tubing in a relatively inexpensive and lightweight ½" size.

As an aside, I would mention that I once saw an article for the construction of a small low frequency antenna from steel exhaust pipe. This is the worst possible choice, since it is heavy, hard to work with, relatively resistive, and throws in, as a bonus, magnetic losses not found in non-magnetic metals. If your shack is heli-arc equipped, one inch or so diameter aluminum tubing would probably result in a much lighter antenna.

Our small antenna problem is now reduced to determining the configuration into which our pipes will be soldered, so that the antenna will become its own impedance matching network. Since it is usually much easier to step an impedance down (rather than up) without a transformer, we can ask, "Are there any short antennas with resistive terminal impedances larger than standard coax?" An inspection of short dipoles, loaded whips, etc., is discouraging, but wait! Again it's J. D. Kraus to the rescue. In his classic *Antennas* textbook we find that the small helix can have this property.

An examination of a typical impedance plot for a helical antenna, as given in Kraus and sketched in Fig. 2, shows that when the circumference is on the order of a wavelength, the terminal impedance is mostly resistive and loops around a value suitable for matching a standard coaxial line for a wide range of frequencies (producing the well-known broadband matching characteristics). In this size the helix radiates along its axis and hence is called an "axial mode" of propagation. As we go lower in frequency or build smaller and smaller antennas, these loops suddenly become very large and now pass quite quickly through the purely resistive points. Moreover, the antenna now radiates perpendicular to (i.e., "normal to") the axis of the helix and is thus termed the "normal mode" of propagation. For normal mode operation we are usually talking about maximum dimensions of less than one-half wave. In conclusion, it is seen that the normal mode helix has two useful operating points where the reactive impedance is zero: one where the resistive value is low (which would give rise to a matching problem equivalent to that of a short dipole), and also a high resistance operating point with a value much greater than standard coax (that can easily be matched by a tap down arrangement so that the antenna can, in effect, act as its own matching transformer).

Now that you know where on the impedance plot you wish to operate, the trick is to put that point at the frequency at which you wish to operate. Since an alteration

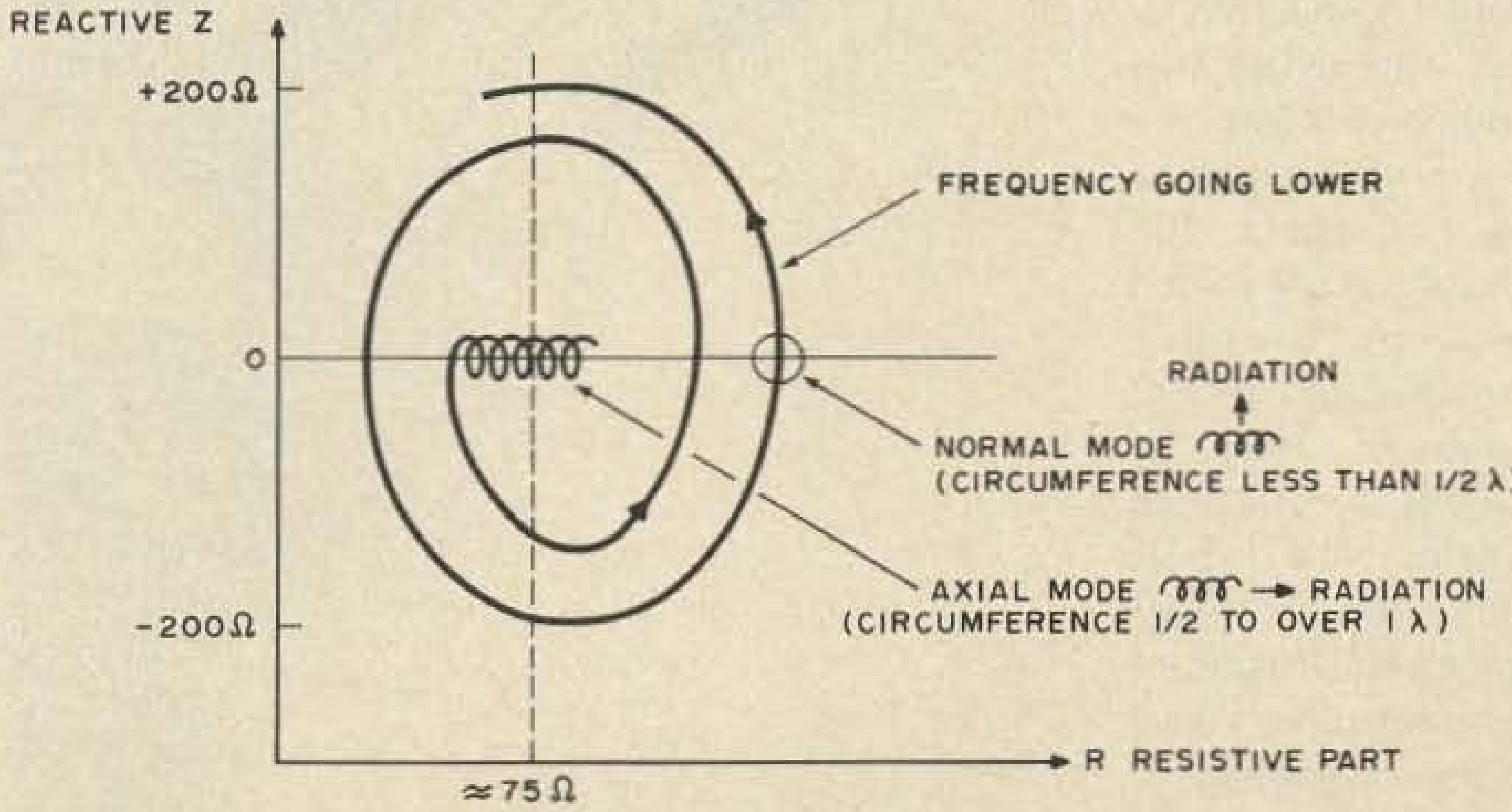


Fig. 2. Helix terminal impedance.

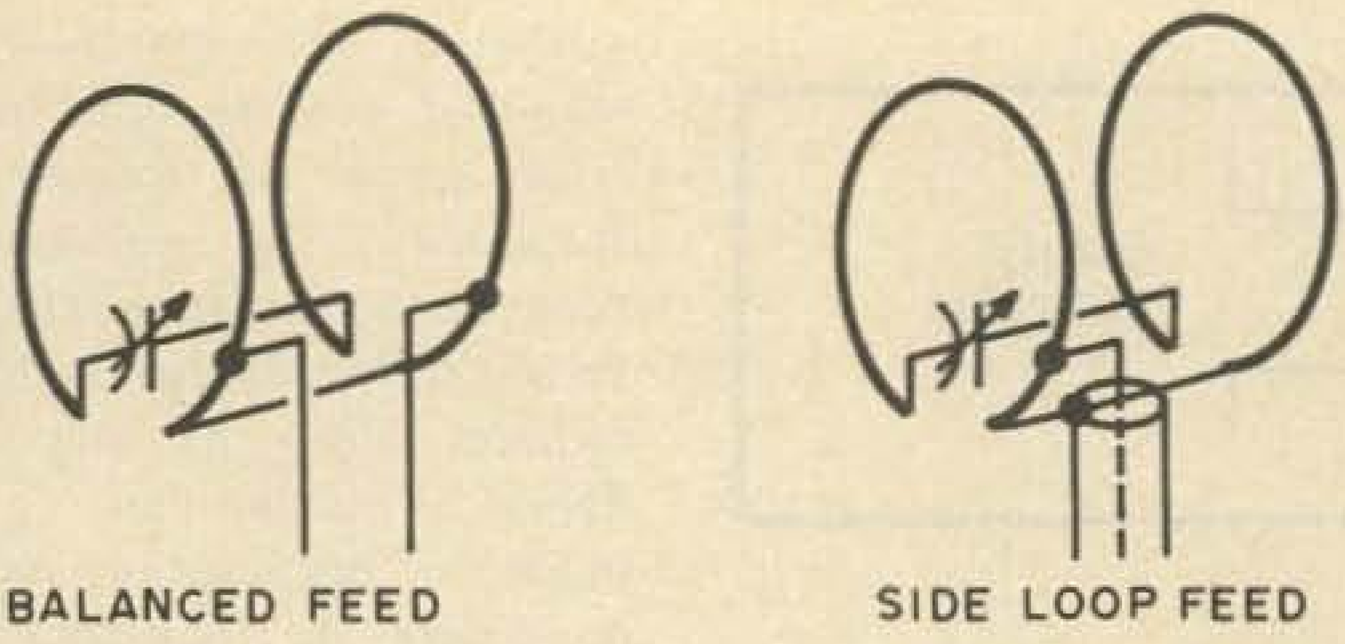


Fig. 3. Feedpoints.

of the scale of the antenna is more or less out, I chose an end-loading capacitor (≈ 40 pF) between the two loop ends to electrically alter the antenna's apparent length. This has the disadvantage of putting your tuning element at the high voltage point of your antenna, but does result in a small C variation (thereby resulting in a wide tuning range, which, with careful construction, does not arc over at Novice power levels). Other tuning methods are possible, including warping the antenna to alter its size (which would probably be a superior method if high power operation were a goal).

I am not going to be too specific on the actual construction details, since this project is basically a junk box el cheapo affair. Each loop is made by the mathematical operation of dividing four ½"D 10 ft. copper tubes into four 30 inch pieces each, and using standard 45° pipe fittings to solder up 2 octagons, about 2 meters across. They are not completely joined, however. One connection is left unmade, where the two loops are joined crosswise by a short piece of tube and two 90° elbows to make a 20" separation between the joined ends of the loops. The other ends are stretched out to 39" when mounted and the tuning capacitor is connected between them. The whole works is supported on a mast and crossmembers made of ABS plastic sewer pipe. I have found that the availability of sewer pipe and fitting varies considerably from time to time and from store to store, so I leave it to you to resonate the bins at your local plumbing supply to get a combination that will work. Metal supports and towers will tend to soak up your power, so try to keep them away — but if you use much pipe as a mast, probably 6" ABS would be better than the 4" I used. I have survived 60-70 mph winds on 4" but as you can see in the photo my mast section is very short. As a finishing touch, the copper can be cleaned and sprayed with clear plastic to protect it from corrosion.

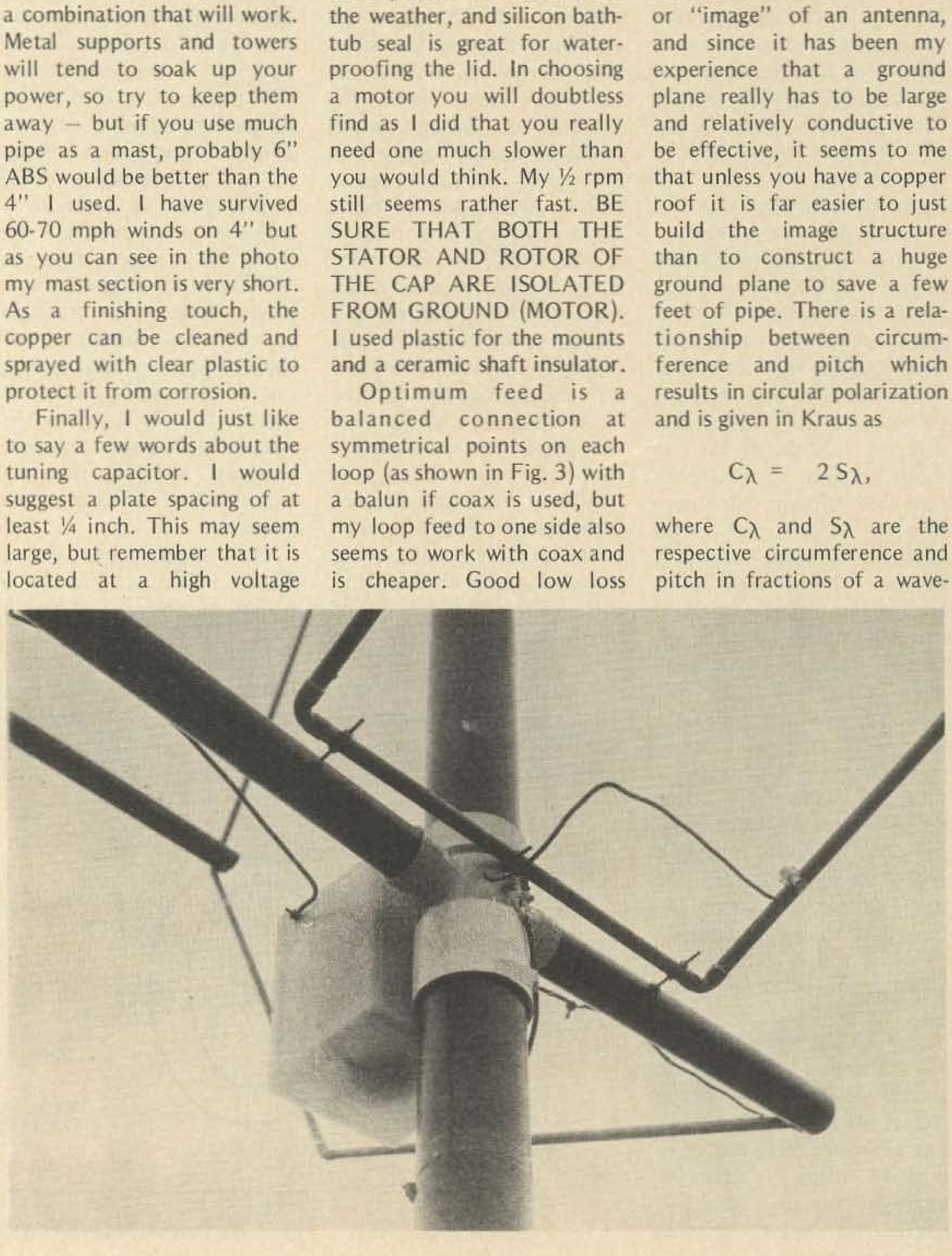
Finally, I would just like to say a few words about the tuning capacitor. I would suggest a plate spacing of at least ¼ inch. This may seem large, but remember that it is located at a high voltage point on the antenna and I had some trouble with arcovers in damp weather. A vacuum variable would be the optimum, but tends to be rather expensive (even surplus). If you only wish to tune the Novice band, a tuning motor is not necessary, but I predict that if you don't take time to install one, later you will wish you had (especially since I've noticed a slight shift of tuning point with the weather). I used a plastic refrigerator box to protect the capacitor and motor from the weather, and silicon bathtub seal is great for waterproofing the lid. In choosing a motor you will doubtless find as I did that you really need one much slower than you would think. My ½ rpm still seems rather fast. BE SURE THAT BOTH THE STATOR AND ROTOR OF THE CAP ARE ISOLATED FROM GROUND (MOTOR). I used plastic for the mounts and a ceramic shaft insulator.

Optimum feed is a balanced connection at symmetrical points on each loop (as shown in Fig. 3) with a balun if coax is used, but my loop feed to one side also seems to work with coax and is cheaper. Good low loss connections are also important in this feed network as well.

Now that our basic plan of attack is laid out we can begin to examine the specifics of helical antennas. We note that there are several critical dimensions suitable for variations in experimenting, including the turn diameter, the pitch of each turn, and the number of turns. Helical antennas can be built with or without ground planes, but since the ground plane is just a device used to eliminate the construction of the other side or "image" of an antenna, and since it has been my experience that a ground plane really has to be large and relatively conductive to be effective, it seems to me that unless you have a copper roof it is far easier to just build the image structure than to construct a huge ground plane to save a few feet of pipe. There is a relationship between circumference and pitch which results in circular polarization and is given in Kraus as

$$C_\lambda = 2 S_\lambda,$$

where C_λ and S_λ are the respective circumference and pitch in fractions of a wave-



length (but I see no special advantage in insuring circular polarization for amateur use).

The final choice of circumference, pitch, and number of turns now becomes a matter of experimentation and the antenna "arts." As a rule of thumb, it probably pays to make the diameter as large as the mechanics of mounting it allow and, for simplicity, I chose n equal to one (i.e., one turn on each side). The pitch can go from zero to any reasonable value, and it is interesting to note that in this light the mysterious DDRR antenna would appear to be nothing more than a normal mode helix of pitch zero with a ground plane. The pitch on my final antenna version was determined experimentally and was used only because it seemed to work the best, rather than because of some long-winded theoretical justification. I used small ¼" copper tubing for my feed connections.

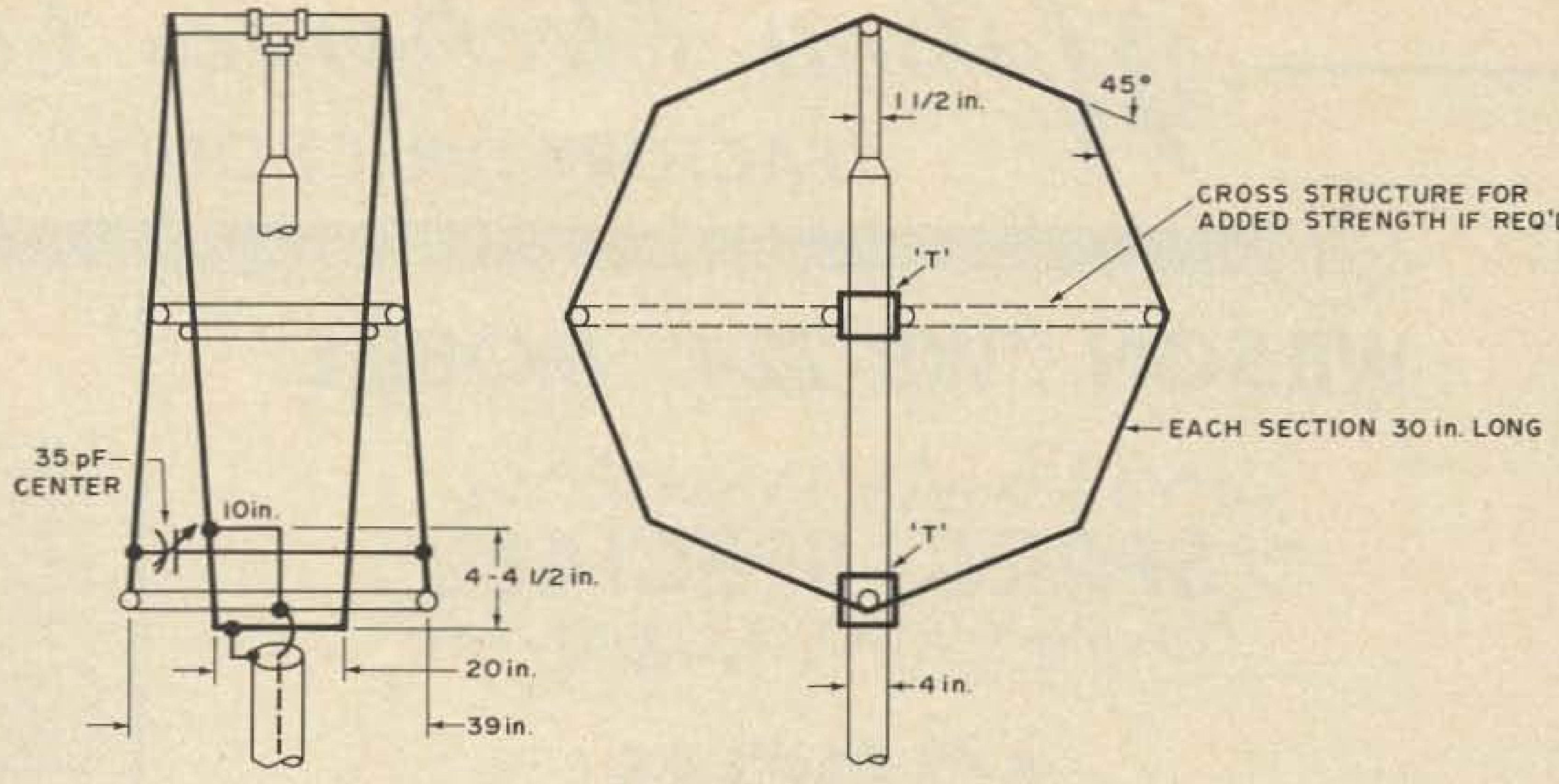


Fig. 4. Forty meter normal mode helix.

The antenna pattern is directional, having a figure 8 dipole pattern when mounted with the helix axis horizontal and a low angle omnidirectional radiation when mounted with the helix axis vertical. For all around use with both high and low angle radiation, the horizontal mounting is best, while for DX a vertical axis mounting with the antenna ¼ wave above the ground should give optimum results.

The swr of the antenna should be less than 2 over the entire Novice band and should be phenomenally close to 1 at the frequency to which the antenna is tuned — if your matching tap is properly located.

I have compared this antenna to a wire dipole and found it to be only a little over one dB down. Here in the city, however, the big problem is not signal but noise, and the helix clearly had less noise pickup than the dipole. Weak signals that were nearly obscured by noise with the dipole were easily copyable with the helix. ■