A big signal on a small lot.

A Two-Band Vertical Monopole Antenna

BY GEORGE F. MOYNAHAN, JR., Ph.D*, W6AXT

Some time before the publication of the September 1978 issue of *CQ Magazine,* which carried the excellent article by Russ Rennaker, W9CRC, entitled "An Effective 40 & 75 Meter Antenna," we had designed and built a vertical monopole to operate on those two bands and had begun to write an account of how it came to be made as well as a description of its construction. When the Rennaker paper appeared we nearly put aside the idea of writing about our antenna, for the two are certainly similar in several respects. However, there are also important electrical and mechanical differences between the two, and it seems that we studied some aspects of design not covered in the other article. Consequently, we decided to go ahead with our write-up.

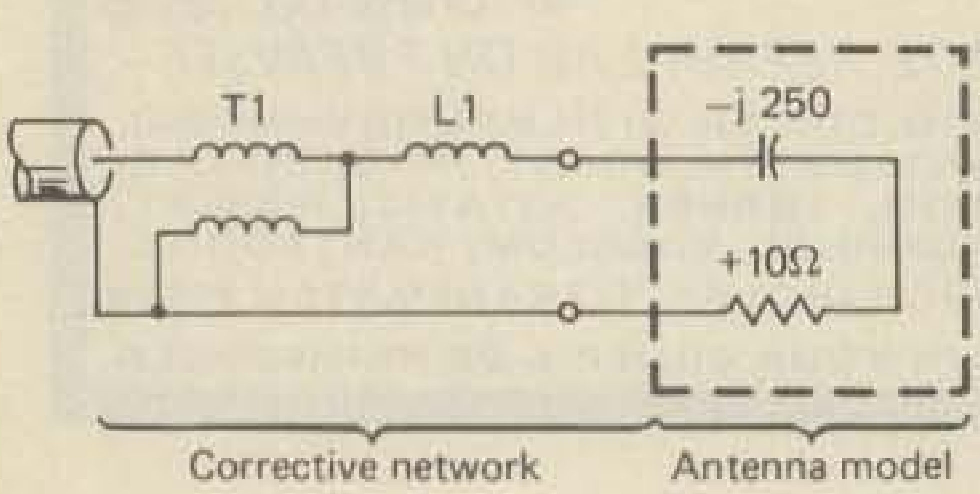


Fig. 1 - T_1 is a bifilar 4:1 transformer wound on an iron powder toroidal core. L_1 is the loading inductor (10.47 μH). The inductive reactance of L_1 is 250 ohms at 3.8 MHz.

Our requirement for a two-band vertical monopole antenna emerged from discussion of plans for a new home. We wanted to have effective radiators on all the high frequency bands but agreed that this should be accomplished without making the place look like the antenna farm of a commercial gateway radio station. The compromise on which we agreed was to limit the installation to two antennas. For the 14, 21, and 28 MHz bands there would be a conventional tri-band beam, supported by a free-standing, crank-up, tubular mast and for the 3.5 and 7.0 MHz bands we would get along with a single, slender whip-like vertical.

Recognizing that the performance of a short vertical radiator would depend to a large degree upon the characteristics of the associated ground-plane, we took special care to establish an effective radio-frequency ground. Since we were building a new home and since a lawn sprinkler systems are needed in this area the task was not too difficult. As trenches were dug to accomodate plastic water pipe, we laid in heavy copper wire parallel to the pipe and then interconnected the copper to form a rather extensive ground-plane mesh. In the

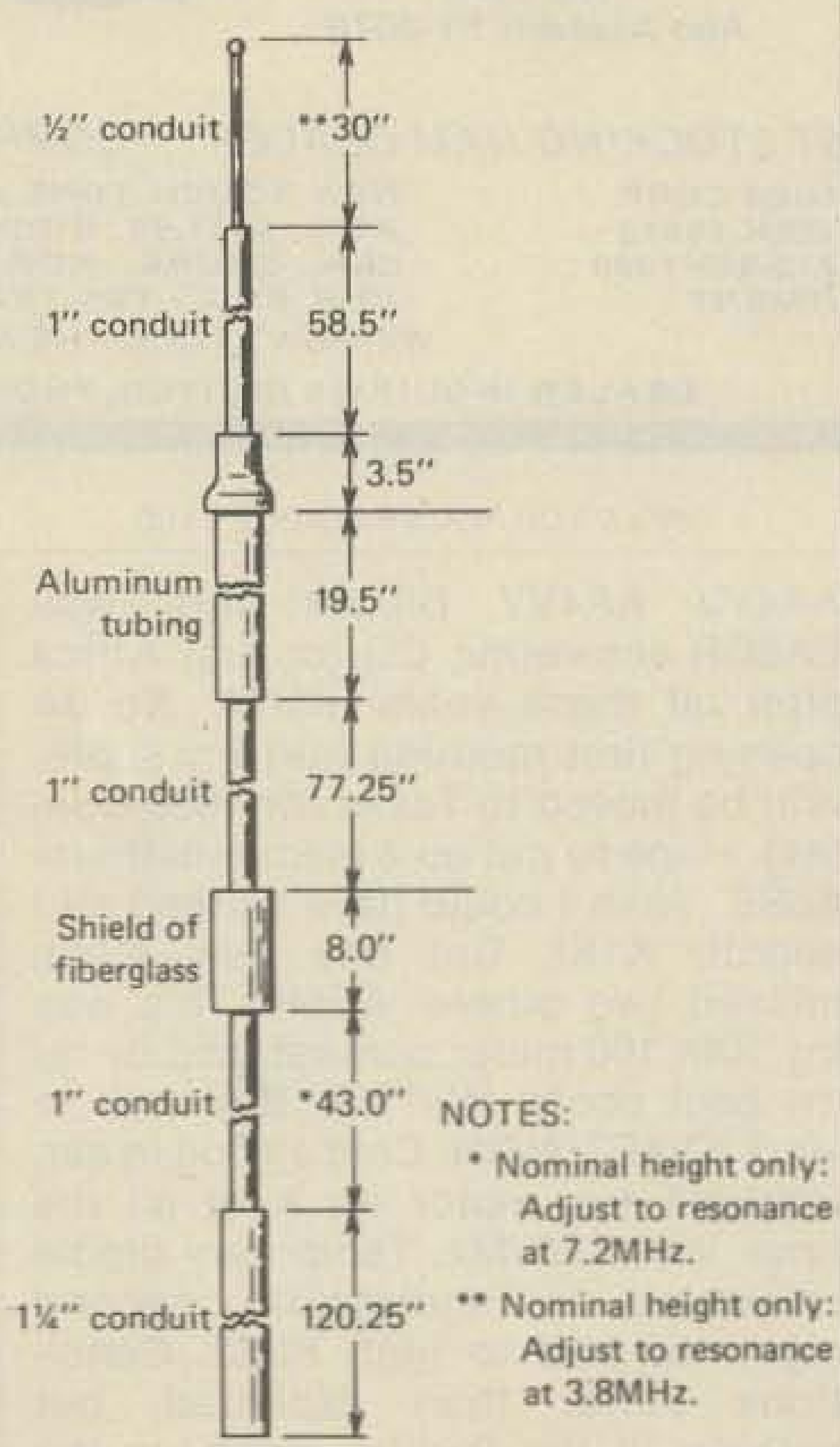


Fig. 2 - A dimensional sketch of the W6AXT monopole. This illustration is not drawn to scale.

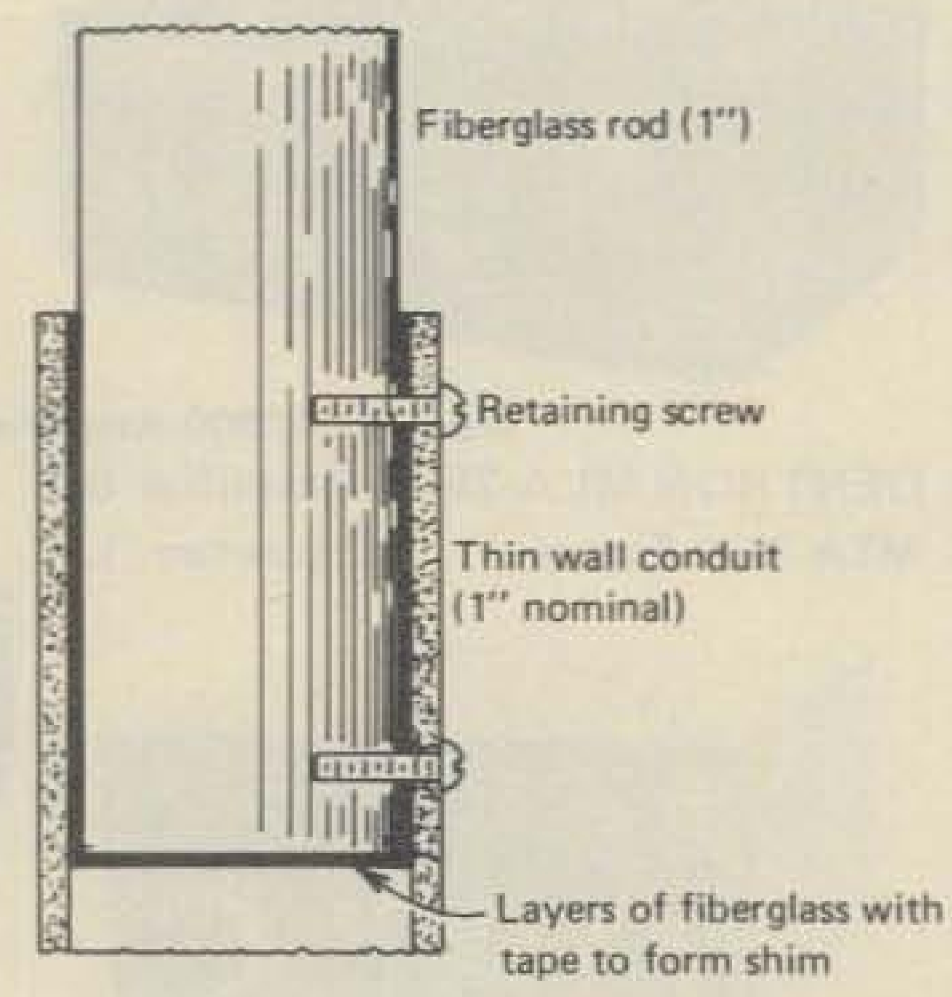


Fig. 3 - Splicing the fiberglass rod to the thin wall conduit.

center we imbedded, in concrete, an angle iron fixture arranged for attachment to insulated clamps designed to grip and hold the bottom of our vertical antenna. The outstanding results obtained later, when different vertical antennas were used with our ground system, indicated clearly that we had succeeded in reducing ground losses to a minimum and justified the time and effort spent on that part of the installation.

For two or three years the antenna that we used with this ground system was a simple 33-foot vertical which was resonant as a quarter-wave at approximately 7.2 MHz. It was constructed of thin-wall, galvanized, steel tubing (actually electrical conduit) and was tapered in steps from one and a quarter inch nominal size at the bottom to one-half inch at the top. It was mechanically strong, electrically effective and inexpensive, but without modification it was a single-band radiator, limited to use on the 7.0 MHz band. The difficulty in trying to use an antenna of this type, at frequencies where it is considerably less than a quarter-wave, is that it becomes highly reactive and so difficult to excite. In this case the driv-

*133 Piazza Way, San Jose CA 95127

ing point impedance changed from a pure resistance of about 35 ohms at 7.2 MHz to approximately (10 - j250) ohms at 3.8 MHz. Consequently, when we decided to extend our activity to include the 3.5-4.0 MHz band and still retain the capability to operate in the 7.0 MHz range, some major changes were in order.

The first remedy that came to mind was to devise a corrective network which would cancel the high reactive component of the driving point impedance and raise the resistive component to something near 50 ohms so that it would be a suitable termination for a 50 ohm line. Of course, there are many ways to do this; the method we chose and which is probably as simple and straight-forward as any is illustrated in fig. 1. A series loading coil with 10.47 μH inductance (and so +250 ohms reactance at 3.8 MHz) cancels the reactance of the

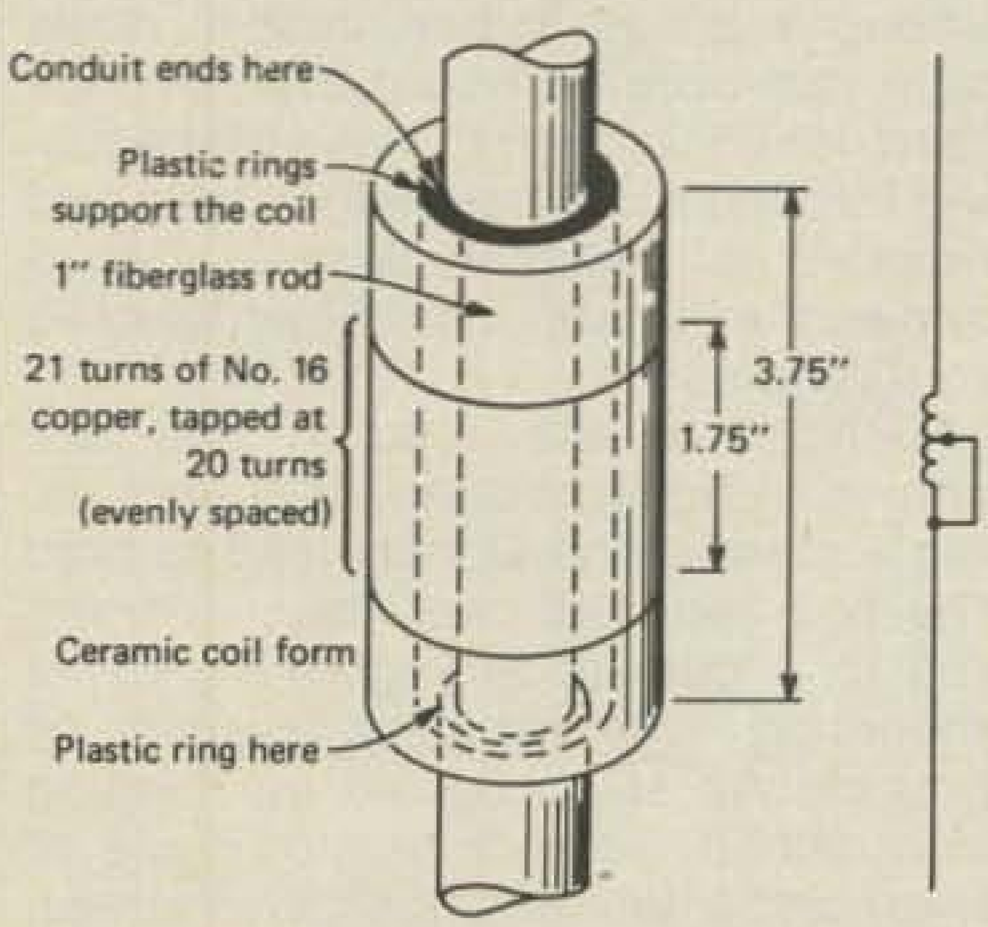
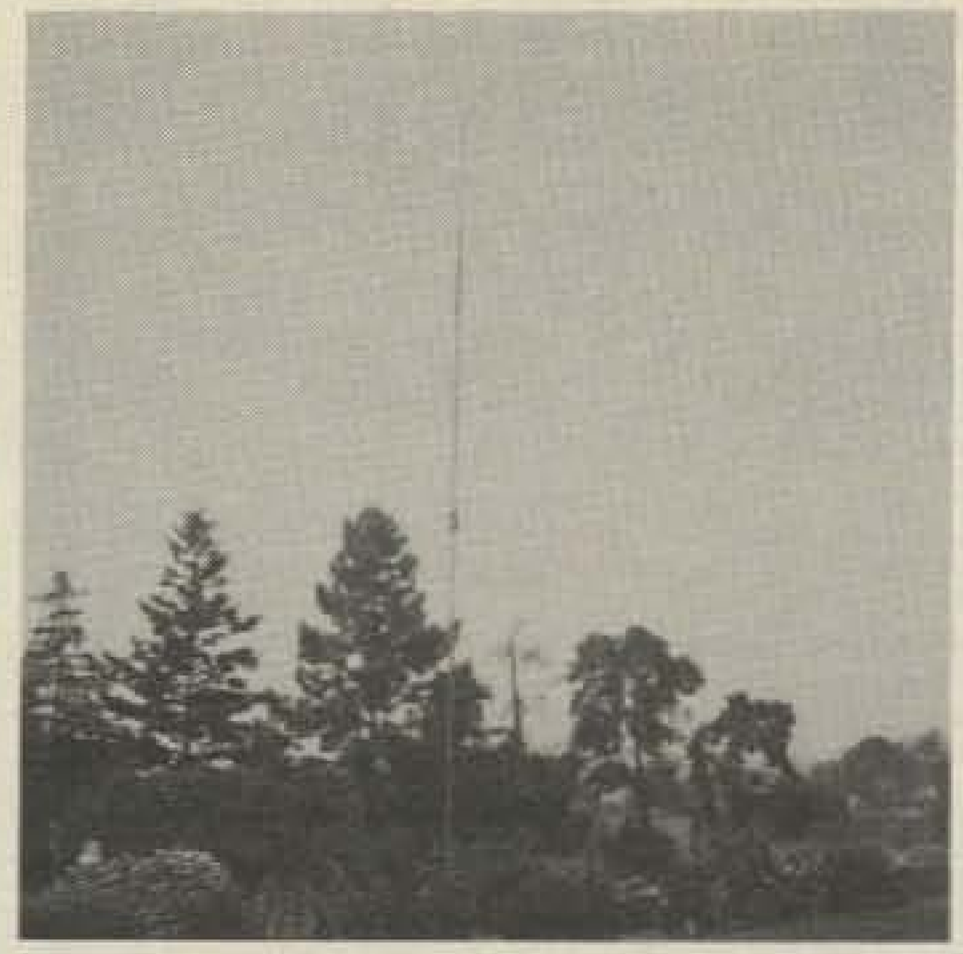


Fig. 4 - Loading coil arrangement and mounting.

antenna leaving the 10 ohm resistive component. This resistance is then raised to 40 ohms by an auto-transformer which was made with a bifilar winding on an iron powder toroidal core. This base-loading arrangement functioned very well electrically but introduced two disadvantageous features that are typical of schemes that use electrically short, base-loaded radiators. First and most obvious of these shortcomings is the inconvenience of having to switch the matching network in or out of the circuit when changing from one band to the other. Second, and far more objectionable, is the danger that such an arrangement generates in the form of high-voltage, radio-frequency emf, at the base of the antenna, right where there is the greatest likelihood of accidental personal contact. To illustrate the extent of this hazard, consider that a peak current of 10 amperes is needed to deliver one kilowatt p.e.p. to a resistance of 10 ohms and that this current, flowing



The W6AXT two-band vertical monopole antenna.

through 250 ohms reactance produces a peak radio-frequency emf of 2,500 volts, a potential source of injury.

The disadvantages of base-loading the short radiator, as described above, and the desire to continue operation on both the 3.5 and 7.0 MHz bands led us to consider design objectives for an antenna that would be safe and convenient and still meet our requirements. Specifically, the required characteristics were as follows:

1. **Safety,** to be improved by removal of dangerously high voltage from the base and from any other touchable part of the antenna.
2. **Convenience,** to be increased by elimination of any need to switch a network in or out of the system when changing bands,

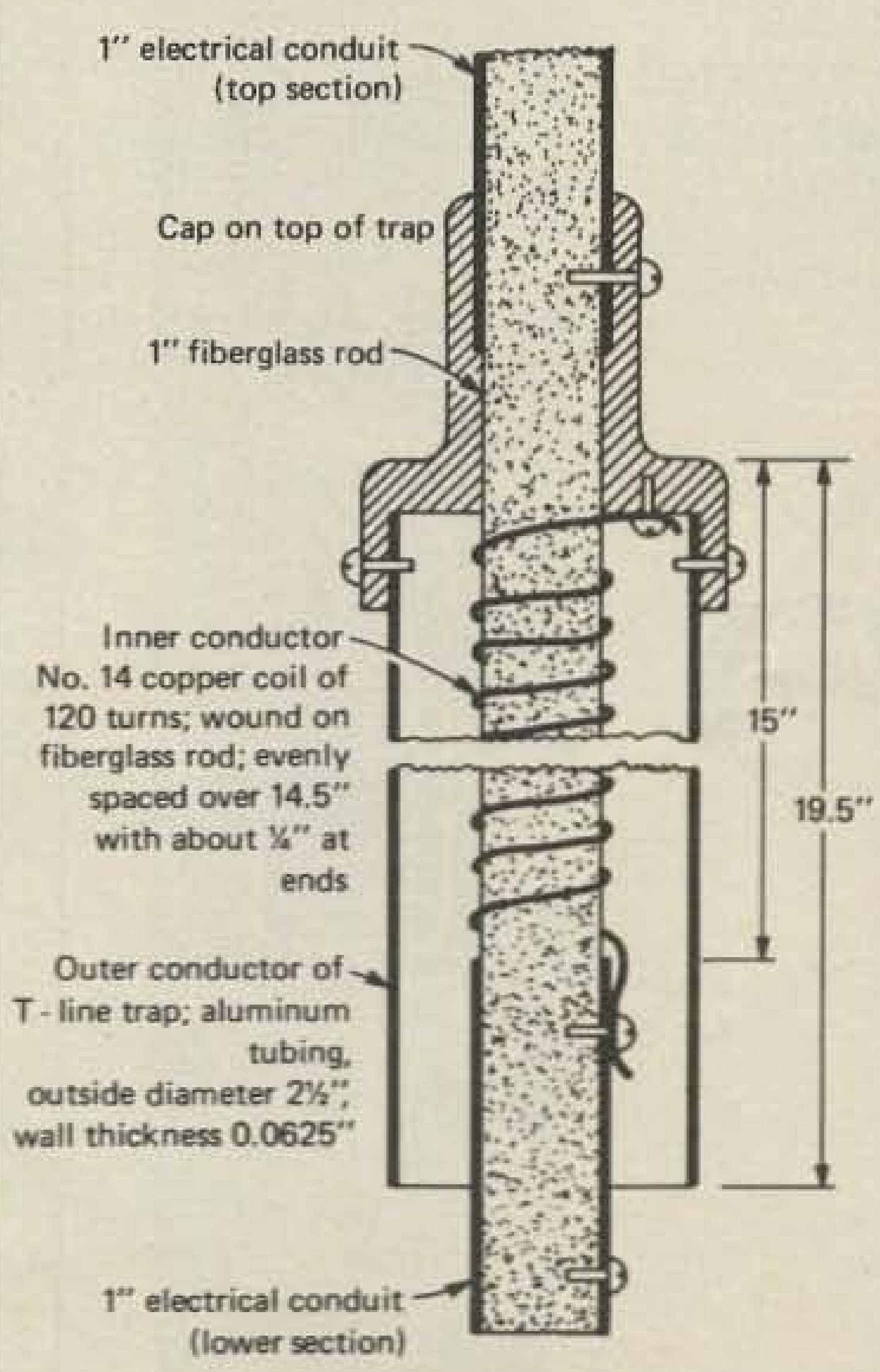


Fig. 5 - Transmission-line type trap for 7.2 MHz. This illustration is not drawn to scale.

3. **Electrical performance,** including radiation pattern, driving point impedance and efficiency to approximate closely those of two individual quarter-wave antennas cut to frequency for the respective bands.
4. **Mechanical characteristics**, including size and configuration to be about the same as those of the single-band 7 MHz antenna, with a maximum height no greater than 30 feet. Material for construction should be mainly the same inexpensive steel conduit as that used for the single-band job.

Preliminary study indicated that the most practical way of meeting these design goals would be to build a mid-loaded trap antenna and our later practical experience justified this conclusion. The antenna that we visualized was to have its 7.0 MHz element limited to about 20 feet in height, but with this section divided and loaded at a point above its middle so that it would behave as a quarter-wave at 7.2 MHz. At this frequency, it would be isolated at the top, from a remaining extension, by means of a shortened quarter-wave transmission-line type trap. When

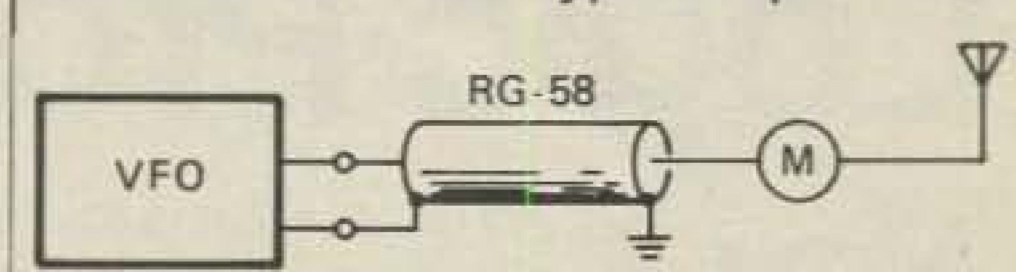


Fig. 6 - Method of determination of resonance frequency. M represents an r.f. milliammeter.

operated at 3.8 MHz, this trap, as well as the loading coil would add to the electrical length so that only a short section above the trap would be required to bring it to resonance at the lower frequency. A dimensional sketch of the arrangement is shown in fig. 2. It should be noted that we hedged some by providing two sliding joints so that the device can be fine-tuned on both bands. This provision for adjustment worked out very well and made construction of both the loading coil and the trap less critical than would otherwise have been the case. The reason for this can be understood best by thinking of the lower section, that is the loaded 7.2 MHz part as a short transmission line and the trap above it as another short line section. Resonance of the two, connected in this manner, takes place when the combination of the two represents a shorted half-wavelength transmission line and does not require that each, individually represent a quarter-wavelength. This is fortunate, for it means that the desired resonant condition in the 7 MHz region can be obtained merely by adjusting the height of the lower section, by means if the sliding joint, without any trimming of either the loading coil or the trap.

After considering the electrical and mechanical properties of available insulating material, which could be used to isolate sections of the tubing at the loading coil and trap positions we decided to use fiberglass rod. Both splices were to be located in nominal one-inch sections of the tubing, which turned out to be somewhat larger than an inch in internal diameter, and so when we found that the largest fiberglass rod obtainable in this area was precisely one inch in diameter it looked as though we had a problem. Fortunately, what appeared to be a hurdle actually proved to be an advantage for, by simply laying a few layers of readily available fiberglass tape parallel to the axis of the rod, we were able to shim it so well that it had to be forced into the tubing and so formed a strong and tight splice. Just to make sure that nothing would ever slip, we then drilled through the wall of the tubing into the rod, threaded the hole and inserted a machine screw. Fig. 3 shows the details of the fiberglass rod to tubing splice.

Details of the loading coil are shown in fig. 4. We mounted ours using a plastic ring at each end to hold the coil centered over the insulating rod in a coaxial arrangement. Other mounting schemes may be used, of course. We also covered our loading coil with a weather shield, made of three and a half inch fiberglass tubing, which we happened to have, but this was probably not necessary.

Probably the most interesting component of our antenna is the shortened quarter-wave coaxial line used as a resonant trap. By winding the center conductor of this trap on the fiberglass insulating rod, as a solenoid, the phase velocity of propagation was decreased to such an extent that the quarter-trap, at 7.2 MHz is only about 20 inches long. The construction of this trap is outlined in fig. 5.

Our method of tuning the antenna was very straight-forward as can be seen in fig. 6. We simply link-coupled the driving point terminals (base of the antenna and ground) to a small oscillator and observed antenna current as indicated by a sensitive radio-frequency milliammeter. The first step was to adjust the system to resonance at 7.2 MHz by means of the lower sliding joint. Adjustment must be made in this order because while the adjustment for resonance at the higher frequency effects the behavior of the antenna when operated at 3.5-4.0 MHz, the length of the extension above the trap has virtually no effect on the ant's 7 MHz behavior. ■