A Four-Band DX Antenna

LCDR. PAUL LEE, USN, W2EWP

c/o OPNAV, OP202XI, Navy Department, Washington, D.C.

Thought Provoking Design of a Vertical Radiator with Details of its Evolution and Construction

Do you have but little space for antennas? Do you want to be able to work four bands with one antenna? Do you have TVI troubles? Do you covet that *S9 Plus* report from half-way around the world? If you do, read on, for here is a reasonable and sensible answer to your wishes. If you aren't interested in any of these things, read on anyway, because here is an idea that you and the boys in your net can kick around a bit during "ragchews."

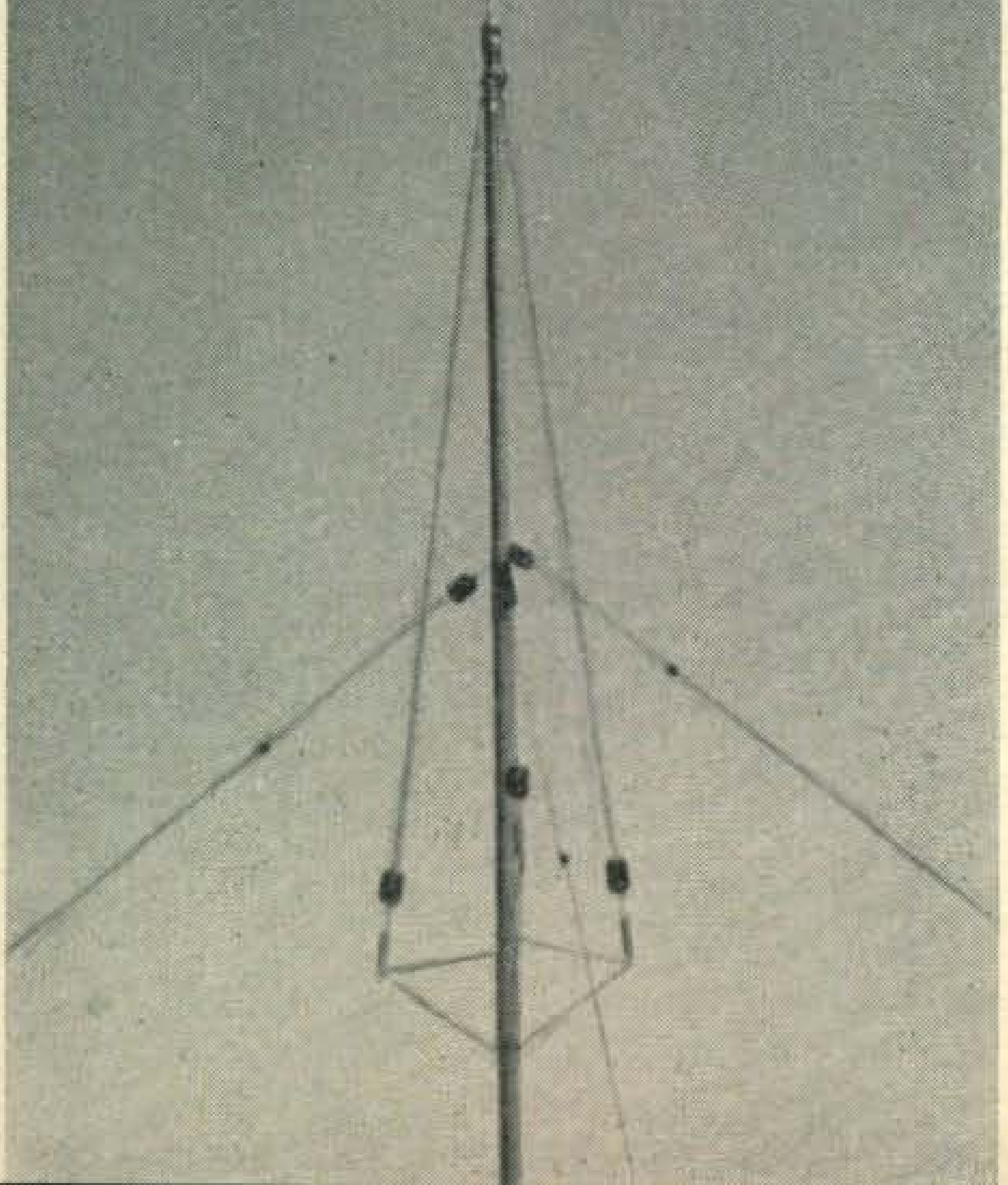
The antenna described here is a vertical radiator or perhaps we should say it is a combination of two vertical radiators. Looking back on our days in radio broadcast engineering, we remembered that a vertical radiator of the proper height is excellent for low-angle radiation. By reference to textbooks and past experience, we know that a height of 0.58 wavelength for our vertical radiator gives us the most low-angle radiation for our money. The calculated vertical radiation pattern for a 0.58 wavelength vertical radiator is shown in *Fig 1a*. Inasmuch as the length of an antenna in wavelengths varies directly as the frequency, we can select a length which will be 0.58 wavelengths at the highest frequency we wish to use.

With the advent of the 21-Mc. band, and the more recent opening of it to phone operation, we were faced with the problem of selecting an antenna system which would work on four bands. We have neglected 28 Mc., because it is not going to be a very useful band to us for the next few years due to the trend of the sunspot cycle. We had been getting very good results with a drooping ground plane vertical radiator on 21 Mc., so the thought hit us, "Why not put it on top of our vertical radiator?", thus solving the problem as far as 21 Mc. was concerned.

Radiation Patterns

That left us 14, 7 and 3.9 Mc. still to be accounted for. So we then selected a *total antenna length of 39 feet* as being 0.58 wavelengths at 14 Mc. This length includes the 11-foot 21-Mc. drooping ground plane's whip. A length of 39 feet becomes 0.30 wavelengths at 7 Mc., and 0.16 wavelengths at 3.9 Mc. These are reasonable lengths for the lower frequencies. The calculated radiation patterns for 0.30 and 0.16 wavelength vertical radiators are shown in *Figs. 1b* and *1c*. As inspection of these curves will show, we are still able to get good low-angle radiation from our vertical at these frequencies.

Constructional details of the antenna are shown in *Fig. 2*. The mast is made from 2″ aluminum tubing. It rests upon a large and rugged standoff insulator, and is guyed at a point 20 feet from the ground, in three directions. The guys are broken up by "egg" insulators, so that no portion of any guy is as long as 11 feet.



The vertical radiator when the author was at W4RXO. The total over-all height is only thirty-nine feet. Three drooping radials are used on 21 Mc., and a ground screen on all other bands.

The fitting which holds the 21-Mc. whip at the top of the 2″ mast is a surplus type *MP-48* whip base insulator, complete with spring. It provides a means for fastening the coaxial feed-line internally. The whip is made of surplus *MS53, MS52, MS51* and *MS50* whip sections, with the last section cut to give an overall whip length above the base insulator of 11 feet. A machined fitting holds the base of the *MP-48* whip base tightly inside the top of the 2″ mast. The drooping ground plane radiator is fed by means of *RG-8/U* coaxial line which goes down through the mast, and which terminates in an

Fig. 2. Construction details of the 4-Band antenna. Only one radial has been shown in this drawing for the purpose of clarity.

SO-239 chassis type female connector set into the mast just above the base insulator. The outer conductor of this line is thus connected to the mast at top and bottom.

The three drooping ground plane radials are mechanically fastened to the *MP-48* whip base by means of three small "egg" insulators, and are electrically connected to the *MP-48* base at only one place, which is a bolt in the side of the "ground" portion of the *MP-48* base, above the spring. The length of each radial is exactly 11

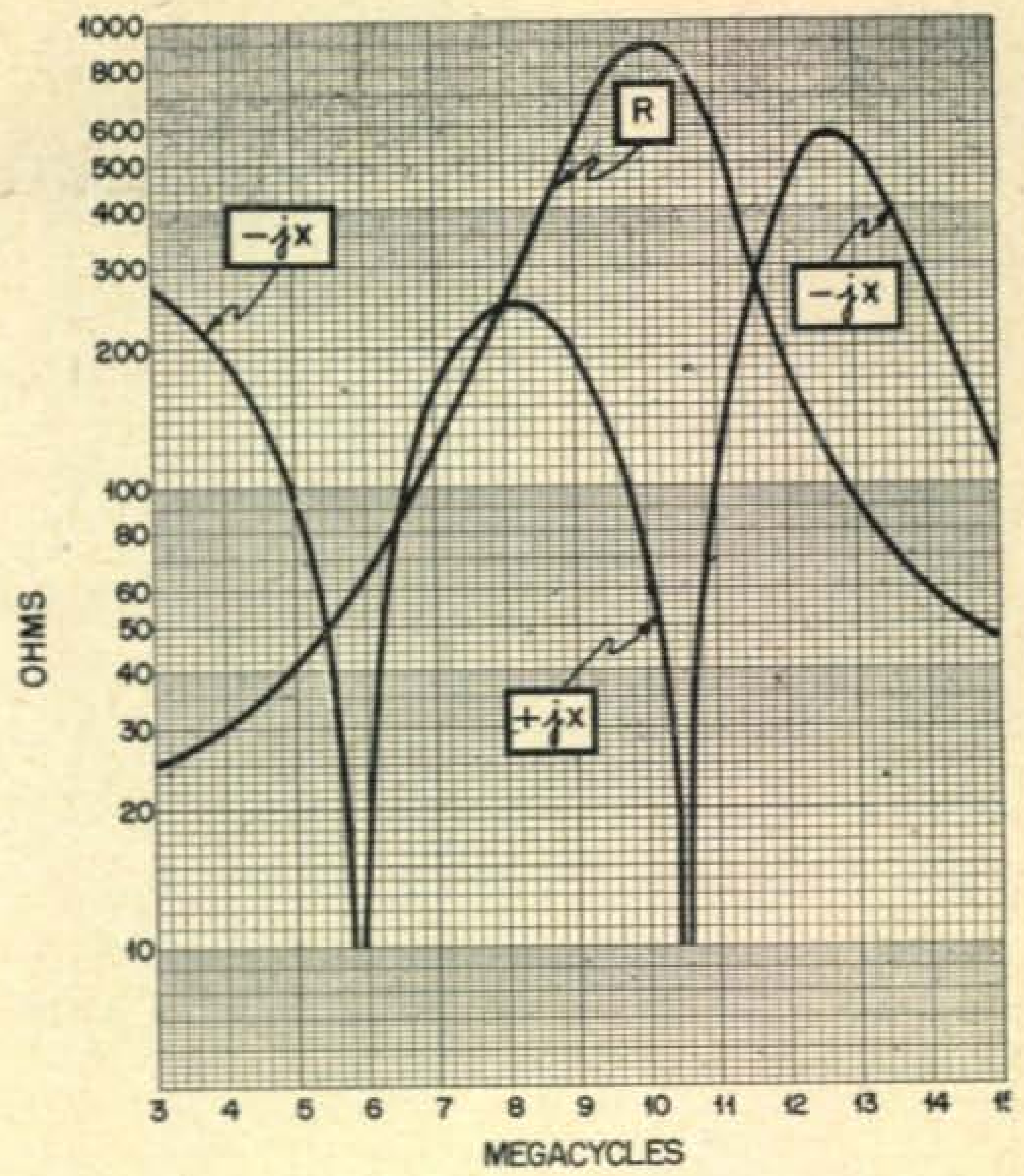


Fig. 3. Measured radiation resistance and reactance of the 4-Band antenna. The method of matching was developed after these measurements had been made.

feet, measured from this bolt. The bottom ends of the radials are secured to large "egg" insulators, which are fastened to brackets which hold the bottom ends of the radials a distance of 1 foot out from the mast.

At this point you are probably beginning to wonder how the 11-foot whip at the top of the mast is made to act as extension of the mast, and to radiate, at the three lower frequencies. Well, take a look at *Fig. 2,* and you will see that we have used a 7-foot 6-inch piece of *RG-8/U* coaxial line as a shorted quarter-wave stub cut for 21 Mc., the open end of which is connected between the whip and the drooping ground plane. The outer braid of the stub line is connected to the mast at several places along its length. The connection between inner conductor, outer braid, and mast itself, at the lower end of the stub, serves to effectively connect the whip to the mast at the three lower frequencies. This would not be true, of course, if the stub were insulated from the mast.

The Matching Network

Now, the question of feeding power to this antenna at four different frequencies arose.

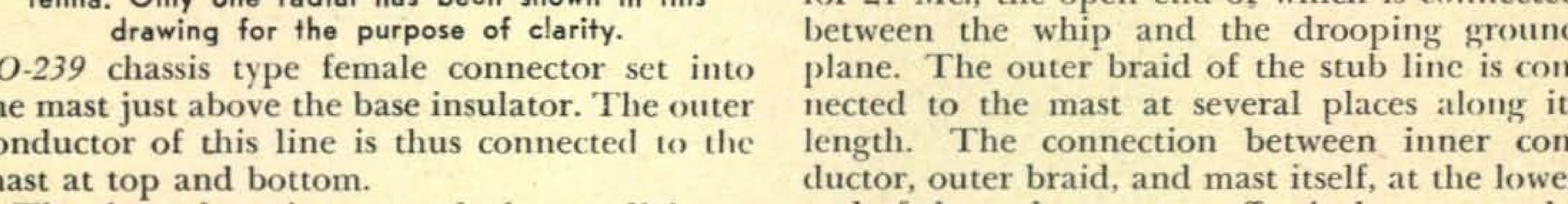
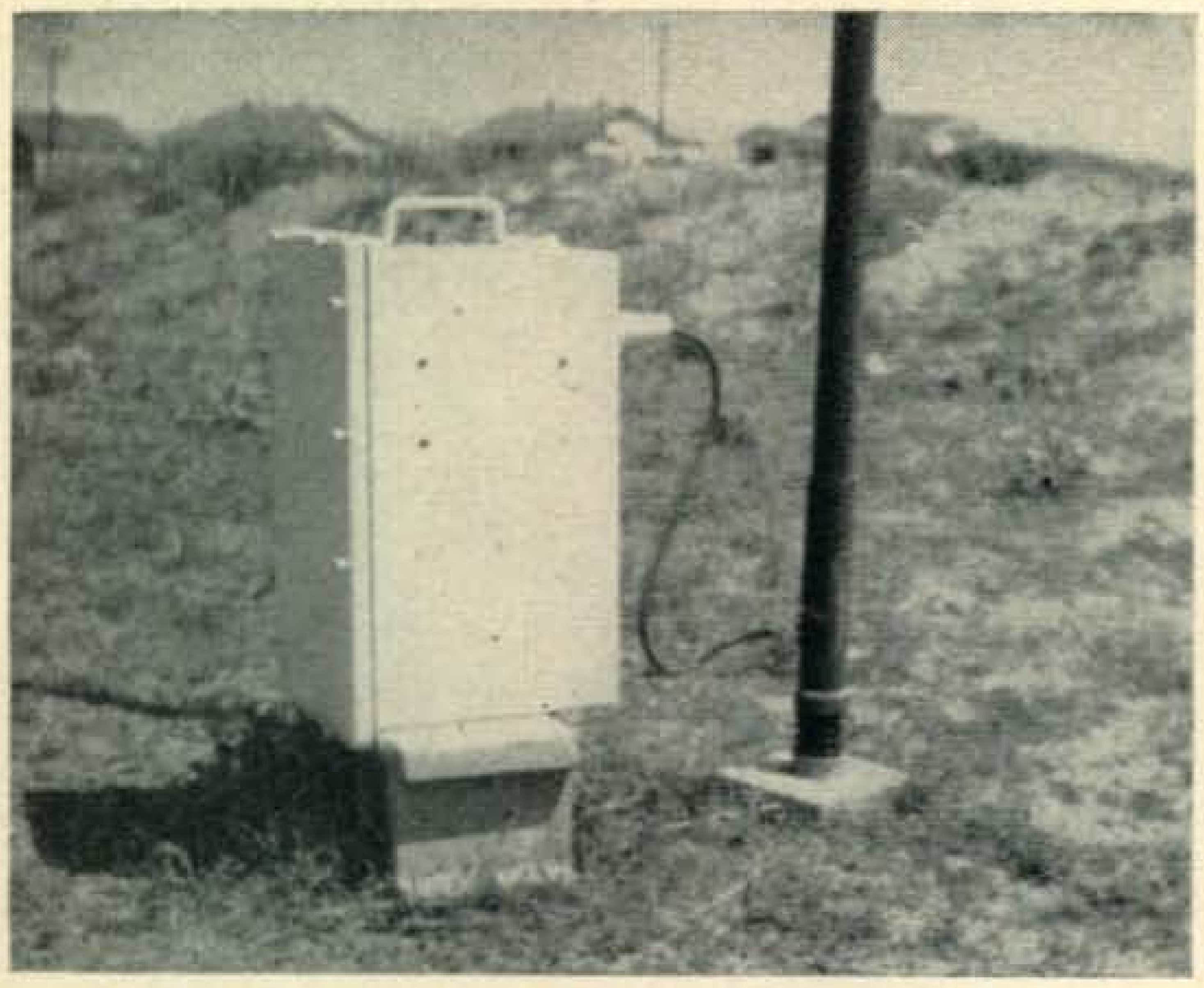


Fig. 1. Theoretical vertical radiation patterns. The antenna is considered to be 0.58 wavelength on 20 meters, 0.30 wavelength on 40 meters and 0.16 wavelength on 75 meters. Radiation on all of these bands is at the most favorable angles.



Base and tuning unit at W4RXO. The two-inch diameter aluminum tubing rests on a surplus insulator.

Obviously, we needed some sort of matching system between the base of the mast and our *RG-8/U* transmission line for our three lower frequencies, and we also had to feed 21-Mc. power to the drooping ground plane radiator at the top of the mast.

The first step was to measure the radiation resistance and reactance of the antenna at 3.9, 7, and 14 Mc., with a *General Radio Model 916A* r-f bridge. In order to get the complete picture, we took measurements at one megacycle intervals from 3 to 15 megacycles, and the results are plotted in *Fig. 3*.

The base impedance of our antenna at the three lower frequencies is shown in this table:

	R	*X*
3.9 Mc.	30	−j200
7.25 Mc.	135	+j190
14.25 Mc.	59	−j195

These three impedances can be matched to our 52-ohm line by a network such as the one shown in *Fig. 4*. At 3.9 Mc. the large inductance is used as a tapped loading coil. The exact size of the coil can be calculated, using an inductive reactance of 200 ohms at 3.9 Mc., which is required to balance out the 200-ohm capacitive reactance of the antenna. The position of the tap can be determined easily by experiment. At 14 Mc., the tap on the coil is at a higher position. At 7 Mc., we have a simple *L*-network, with the series capacity in the feedline to balance out the inductive reactance of the antenna at this frequency. Adjustment of the 14-Mc. tap, and the setting of the variable condenser for 7 Mc., may be easily done by trial.

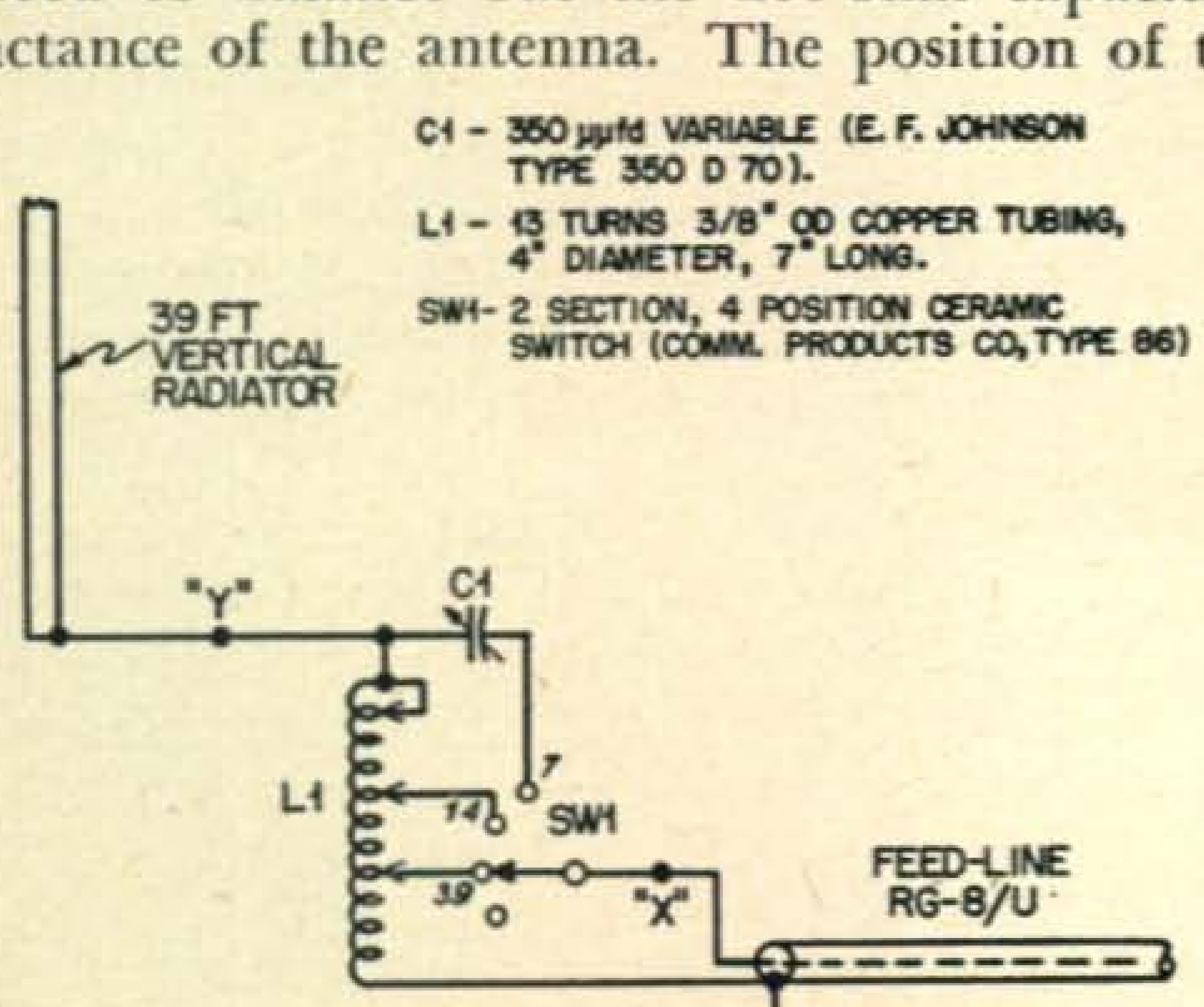


Fig. 4. Schematic of the matching network.

How did we feed the 21-Mc. power to the coaxial line up the mast? No, we didn't just plug it in when we wanted to go on 21 Mc. *We wound the large coil out of coaxial line,* and fed the 21-Mc. power through this line, and used coaxial line from the coil to the base of the mast as the lead-in for the three lower frequencies! Take a look at the sketch, *Fig. 5*, and at the photographs, and you will see how this was done.

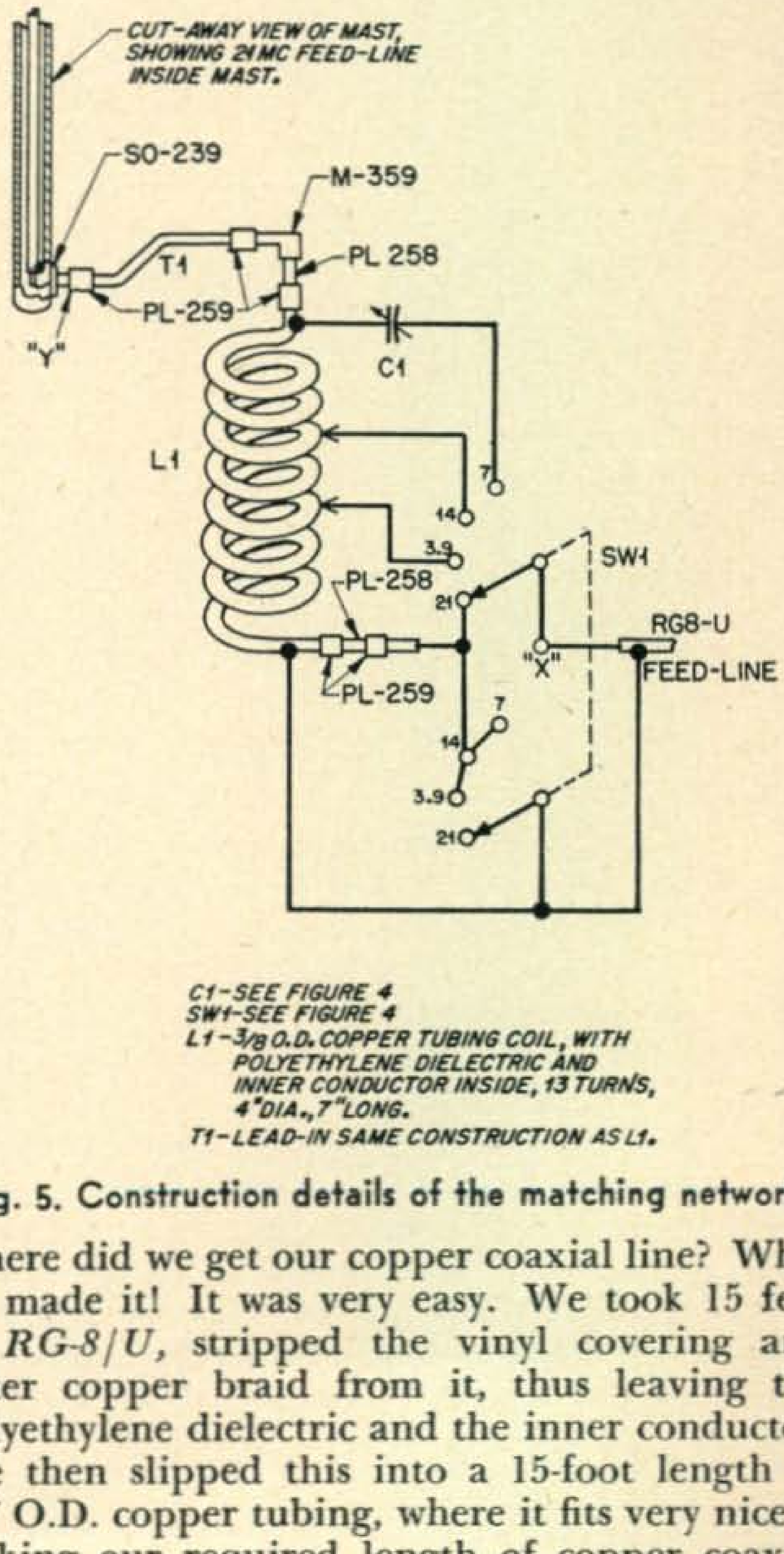


Fig. 5. Construction details of the matching network.

Where did we get our copper coaxial line? Why, we made it! It was very easy. We took 15 feet of *RG-8/U,* stripped the vinyl covering and outer copper braid from it, thus leaving the polyethylene dielectric and the inner conductor. We then slipped this into a 15-foot length of ⅜″ O.D. copper tubing, where it fits very nicely, making our required length of copper coaxial line, and we wound it into an inductance of the proper size. A *PL-259* coaxial male plug was soldered on each end of the coil, and through the use of *PL-258* female junction fittings, connection can be made to the feed-line at each end of the coil, with *PL-259* plugs. A similar short piece of this home-made copper tubing coaxial line was used between coil and mast fitting, as the lead-in. We passed it through an *E. F.*

Johnson Type 135-67 insulator before soldering the *PL-259* plugs on the ends. It fits very nicely through the hole in the insulator, after the bolt is removed. After installation, the hole was caulked with rubber cement to make it water proof.

We used one coaxial line for the 21 Mc. and lower frequency feeds from the transmitter The switching from 3.9 to 7 to 14 to 21 Mc. was done by means of a large rotary switch, as shown in *Fig. 5*. Relays may be installed to do this job by remote control, if desired.

Note that the inner conductor of the coaxial coil *L1* is grounded at 3.9, 7, and 14 Mc., at the ground end of *L1*, through the contacts of *Sw1*.

Ground System

Our tuning unit, built into a waterproof aluminum box, is shown in the photographs. Once adjusted, it is closed up and left alone. The rotary switch shaft projects through the side of the box with a rubber grommet to keep water out. It is turned by using a screwdriver.

An antenna of this kind needs a good ground system. We buried eight radials, of #12 bare copper wire, each 60 feet long. They are all tied together at the base of the antenna, and *one* ground lead is brought up to the tuning unit cabinet. A six-foot square piece of copper ground screen would be a very good addition to this ground system, and some day we intend to put one in. The radials should be soldered to it, as shown in the sketch, *Fig. 6*. Of course, the ground system was installed *before* the resistance and reactance measurements were made!

In tuning up, it was useful to insert a 0-5 ampere line-current r-f ammeter at point "X," and a 0-9 ampere antenna current r-f ammeter at point "Y." The antenna current meter

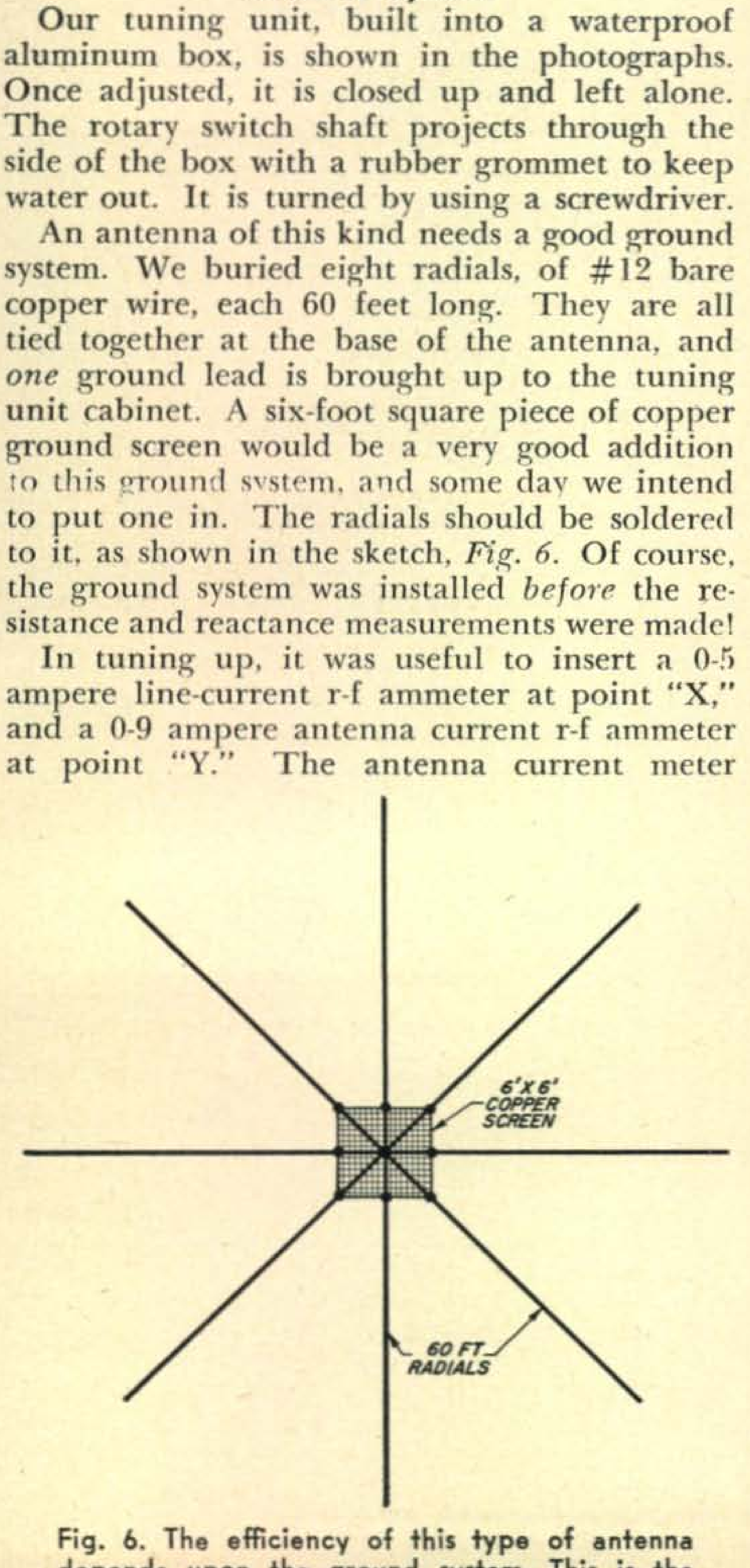


Fig. 6. The efficiency of this type of antenna depends upon the ground system. This is the suggested arrangement for radials at the base of the antenna.

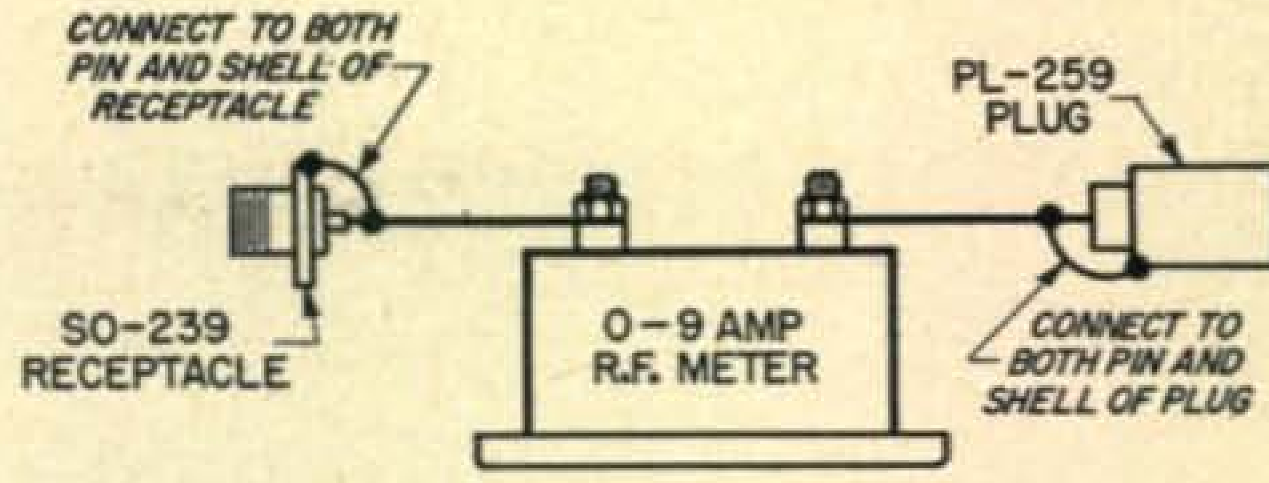


Fig. 7. This antenna current meter should be inserted at point "Y" in Fig 5 while the antenna is being tuned up.

needed an adapter to enable it to be plugged in between the coaxial lead-in and the connector at the base of the mast. This is shown in *Fig. 7*. For r-f current measurement purposes, the inner and outer conductors of the coaxial lead-in were connected together, as shown. When the system is properly tuned up on any one of the lower frequency bands, the power in the feedline and antenna can be easily computed by Ohm's Law, for the line impedance is 52 ohms, and the radiation resistance of the antenna is known. These two power readings should be equal, and should also be equal to the final amplifier's power input multiplied by a reasonable efficiency figure, of say 70%. In our case our power *output* is approximately 670 watts.

Results

The results obtained with this antenna system on all four bands have been most gratifying. The drooping ground plane gives us very good low-angle radiation on 21 Mc. You may wonder why we "drooped" the radials so much, when the usual practice is to run them out at about 45 degrees from vertical. Well, we wanted to lower our angle of radiation, for one thing. And then, too, we wanted to keep them down alongside the mast so that they would not have a tendency to act as top-loading at the lower frequency bands and thus throw off our antenna height pattern calculations. By installing them as shown, there is a slight mismatch between the *RG-8/U* line and the ground plane antenna, but our standing-wave ratio on the line at 21 Mc. is only in the order of 1.35:1.0, and we did not consider this to be objectionable. We could perhaps eliminate standing waves entirely by making adjustments to the shorted quarter-wave stub, but it's not worth climbing a 2" pipe mast to do it! However, one of our dreams is to some day use a short, triangular tower of the "TV antenna" type as our vertical radiator, and then we'll be able to climb it and make such adjustments.

On 14 Mc. we can notice the difference between this antenna and the usual half-wave doublet or quarter-wave vertical, both of which we had used previously. Overseas signals are much stronger, and there is less "short-skip," or "stateside" QRM, because of the shape of the vertical radiation pattern, shown in *Fig. 1*. On 7 Mc. it performs beautifully, giving us *S9* plus reports on almost every contact. On 3.9

(Continued on page 58)

(from page 57)

superb DX worked with the equipment described. Well, why should a VHF man not have this privilege? The first QSO using this BC-625 gismo resulted in breaking the then world's record with W5ONS on 220 Mc.

SERVO MECHANISMS

(from page 16)

swung more than 180 degrees, the antenna will rotate in the opposite direction; therefore a habit of swinging the *controller* more than a half turn could soon result in the feeders being torn off, in spite of the stop.

To prevent the antenna from rotating in the opposite direction, first turn the *controller* slightly less than a half a turn. Allow the antenna to rotate far enough, so that an additional rotation of less than 180 degrees will put the antenna in the desired position; then bring the *controller* to the final position.

A normally closed "limit" switch in each motor lead will give positive protection against tangling the feeders. There are a pair of them in the AYLC 1591 motor that must be removed. They may be remounted externally for this purpose.

Although my antenna can only be rotated about a revolution and a half without damage to the feeders, I never relished the though of having to swing a beam 340 degrees to achieve a net change in position of twenty degrees. Therefore, I use no method to limit rotation. So far, I have never wrapped up the feeders. One reason may be that it is easy to inspect them, if I suspect that they are twisting.

DX ANTENNA

(from page 23)

Mc., because it is somewhat shorter than a quarter-wave, its efficiency is reduced, but it does put out a very good signal both locally and at distances of several hundred miles. At night on 3.9 Mc., we have worked stations over 1,000 miles away with this antenna, in the Western U. S., and the West Indies, from W4RXO.

Now for a word about TVI. This antenna definitely helps that situation. In the first place, it is fed by coaxial line, which is buried underground from the transmitter out to the tuning unit. Use of coaxial line enables us to insert a low-pass filter in the line as it leaves the transmitter. If any harmonics to do get by the filter, they are discriminated against by the antenna

(Continued on page 60)

(from page 58)

itself, because as we go above 0.58 wavelengths in length, the radiation from a vertical antenna shifts from low to high-angle, where it can't do any harm to your neighbor's TV picture. The 21-Mc., drooping ground plane also discriminates against harmonics because of the mismatch which occurs at harmonic frequencies between antenna and feed-line.

And there you have it—a four-band antenna which takes very little space, which is neat in appearance, and which is easily erected. Comments and questions from readers will be welcomed.

PROPAGATION

(from page 45)

ionosphere to tilt so that they deviate considerably from being parallel to the earth, thus causing a transmission to be scattered in many directions rather than being normally reflected along its great circle path. Additionally, because of the tilt of the horizontal reflecting surfaces, the signal arriving from one direction will strike the reflection surface at a different angle than will a signal arriving from the reciprocal direction. This produces different reflecting characteristics and scattered signals of this nature do not usually obey the laws of reciprocity, and may result in "one way skip." "One way skip" due to scattering can usually be detected by the weakness and characteristic fluttery or warbly fade associated with scattered signals. Scattered signals also usually arrive from directions that seem to bear no visible relationship to the direction of the transmitting station.

Scattering can take place from the regular layers of the ionosphere, Sporadic E layer, from Auroras and also from ground reflection points.

"One way skip" is therefore usually attributed to the geographical variation in atmospheric noise levels or scattering from irregular surfaces.

Thanks to all of you who have taken the time to send me comments regarding "DX and the Sun" which appeared in the July and August issues of CQ. It is gratifying to know that the article was found to be helpful in explaining some aspects of the mechanism that makes it possible for us to transmit radio signals over great distances.

THE NOVICE SHACK

(from page 50)

line similar to the one in the picture, although it may be much shorter than that one.

To tune a sixty-five foot antenna on 3.7 Mc., connect the stator of the condenser to one end of the coil, its rotor to ground, and the antenna to the other end of the coil.

If you wish to tune this antenna to 7.2 Mc., or a 130-foot antenna to either band, connect the condenser across the coil, grounding the rotor end, and conect the antenna to the stator end.

Tuning with either arrangement consists in adjusting the antenna condenser for maximum plate current, then returning *C1* for the "dip" in plate current, varying the number of turns in *L2* to vary loading. Use the minimum number of turns that will permit drawing the desired current.

(Continued on next page)