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The 80 Meter Pile Crusher

— the ultimate vertical?

There is at least one advantage to operating exclusively on one amateur band — it encourages dreams of better antennas for that band.

At W2OZH, the band is 80 meters, and such hallucinations have led to a novel mobile configuration[1] and to an effective direction-switchable array using horizontal elements.[2] The satisfaction afforded by this latter configuration has led to speculation regarding direct comparison with a similar phased array using vertical elements.

"A Low-Frequency Phased Array"[2] described preliminary attempts to utilize the sixty-foot supporting masts as vertical radiators. However, subsequent attempts to improve this vertical system using additional ground radials were disappointing. Two factors contributed to this lack of success: (1) the undesired cross-coupling from the verticals to the horizontal elements, and (2) the proximity of the house, which interfered with the laying of a full symmetrical radial system. Thus, each radiator did not form a simple resonant circuit (for maximum current) and the radial system permitted a high degree of near-field ground penetration (with attendant ground losses).

As a result of these defects, I decided to start from scratch on a vertical array composed of two resonant radiators sixty feet (λ/4) apart in the rear lawn, sufficiently far from the house to permit a symmetrical ground radial system to be laid. This article describes the constructional details of these radiators.

Operating Principles

Sevick[3] and others have shown that vertical antennas which are much less than one-quarter wavelength long can be effective radiators if: (a) the losses in the antenna element and matching system are kept small, and (b) a low-loss image plane is provided using a large number of radials approximately a quarter wavelength long. Elwell[4] has pointed out that the current loop of a resonant vertical antenna can be moved upward away from the base by changing the tuning. The qualitative diagrams are shown in Fig. 1.

However, before you set about just copying what others have done, it is worthwhile to review some fundamentals in the light of where you want to go.

If you are to have low losses in the antenna element, you need only use large diameter conductors, including any loading coils which are used. However, you also need to consider what is necessary to achieve a low-loss image plane. Maxwell[5] has depicted clearly the rf current flow in the ground system of a typical vertical antenna (see Fig. 2).

The power loss in such a ground system occurs both in the resistance of the radial system and in the ground beneath the radial system (due to field penetration of the earth). Thus, if you wish to decrease these ground system losses, you should try to decrease the current flowing in the radial system near the base of the antenna. This will serve both to decrease the direct resistive losses and to decrease the penetrating field.

Referring to Figs. 1(c) and 2, you can see that Elwell is on the right track; the current at the base of the antenna and out into the radial system is small for this arrangement. However, his series feed at the base of the antenna presented matching problems due to the high impedance at this point. You need to retain the low base current, yet be able to feed the radiator directly from a low-impedance coaxial feedline without a matching network.

For guidance, let's review some antenna fundamentals. The basic rf resonance of a straight conductor is dipolar, that is, the instantaneous voltage at one end is (+) and at the other end (-). This is the mode shown in Fig. 1(b). It must be noted that, at resonance, the reactance is cancelled, and, at all points along the antenna, the impedance is a pure resistance. If you now look at Figs. 1(a) and 2, the so-called "λ/4 monopole," you see that the fundamental mode of resonance is still dipolar, that is, (+) to (-). The only difference is that the image plane acts like the other half of the λ/2 dipole. If you start with the situation at 1(a) and add top loading, you can arrive at the current distribution at 1(c).

Now, what does the impedance picture look like? In each of the three cases, the impedance has a high value at the top, marked (+), and at the dipolar image points, marked (-). At the intermediate position where the current is a maximum, the impedance has a minimum value — ~36 Ohms for the image plane antenna and ~72 Ohms for the ideal dipole, Fig. 1(b). The ideal way to feed such an antenna using

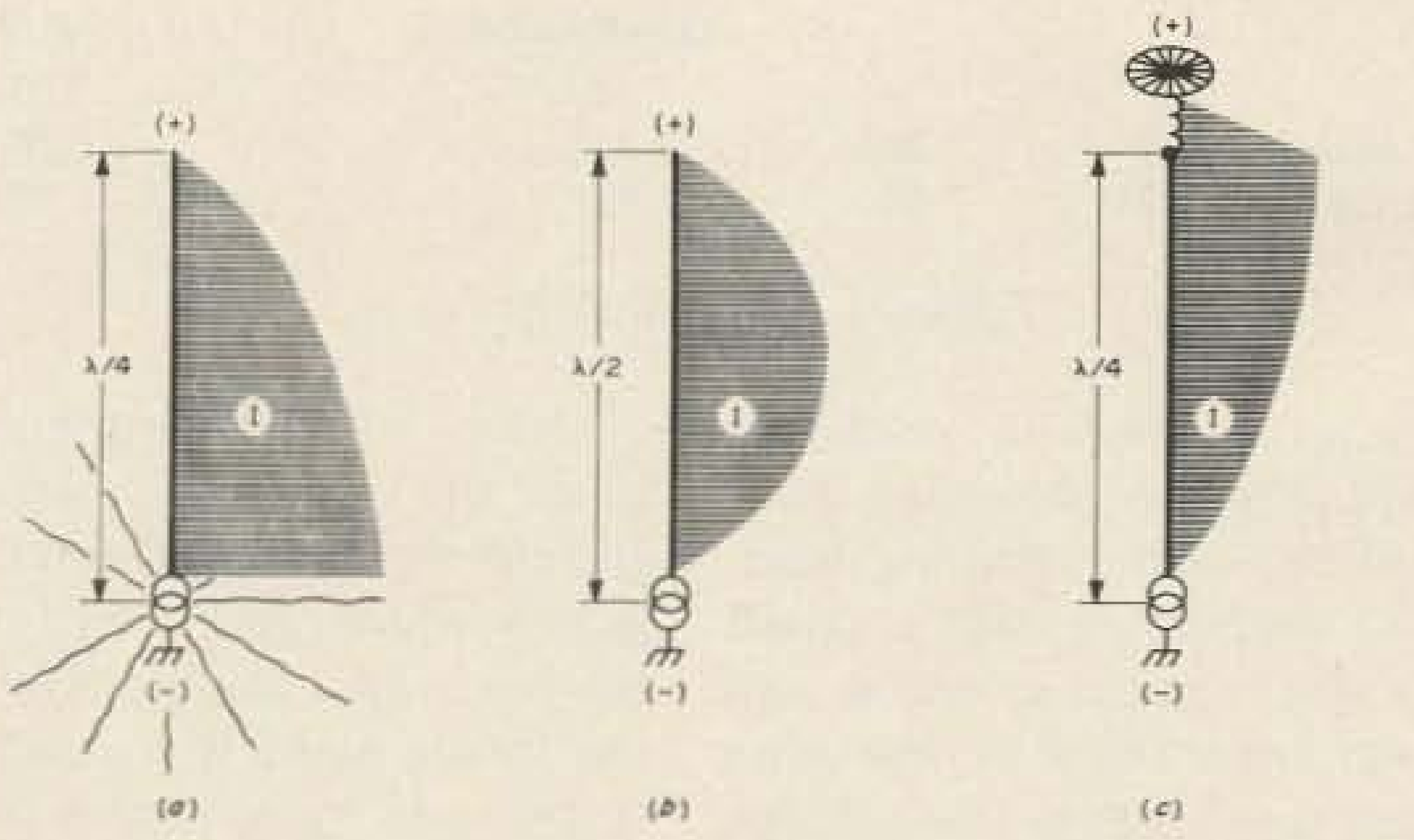

Fig. 1. Current distribution on three vertical antennas. The tuned circuit at C simulates ¼ wavelength.

52-Ohm coax would involve separating the antenna at a point near X, in Fig. 1(c), such that the impedance is 52 Ohms. But how can you avoid interaction with the shield of the coax? Read on!

Referring to Fig. 1(c), connect the bottom of the antenna directly to ground (eliminating the generator shown). Now assume that the bottom section of the antenna is in the form of a hollow pipe. If you place a coaxial feedline inside this pipe with the shield connected to the pipe at the top (point X) and the center conductor is then connected to the insulated top section, the feedpoint impedance, as described above, is presented across the feedline. If you choose the point X at an impedance level of 52 Ohms, the feedline will be exactly matched into 52 Ohms, resistive.

Thus, you have, in principle, arrived at a resonant vertical antenna configuration which has its current loop above the ground (thereby reducing current in the radial system) and which presents a perfect match to a low-impedance coaxial feedline. As a fringe benefit, the base of the antenna is at ground potential, a fact which offers simplified mechanical construction.

CONSTRUCTIONAL DETAILS

The Antenna

Two antennas were constructed following the principles outlined above. The antenna elements were assembled using aluminum irrigation pipe, as shown in Fig. 3.

There is, of course, a wide variety of constructional material available, but I have had such good luck using aluminum irrigation pipe for support of other antenna installations that this was an obvious choice in the present instance. The two vertical antennas were constructed at different times — the second approximately one year after the first. For this reason and because I wanted to experiment with different geometries (yielding different input impedances), I used different lengths of pipe for the two antennas. The compensating adjustable parameter is the coil inductance. The dimensions used for the two antennas are shown in Table 1.

The base section of each antenna is a length of three-inch-diameter irrigation pipe. The top sections are two-inch-diameter pipe. The top section telescopes inside the bottom section for a distance of three feet. Insulation is provided by PVC pipe fittings, as indicated in Fig. 3. The sections are anchored in position by hose clamps and by strategically positioned metal screws. Hose clamps are also placed at points of high stress to strengthen the base section.

The coil support is a 2-3/4-foot length of PVC pipe with an i.d. of 2 inches. The two-inch aluminum pipe telescopes into the ends of the PVC a distance of 12 inches, leaving a 9-inch length of insulation where the coil is located. The coil is approximately three inches long (30 turns, maximum) to provide an excess of turns for tuning adjustment. Since the coil fits loosely over the PVC pipe, it is supported by the connecting wires. After experimentation was completed, the coil was wrapped with 20-inch-wide fiberglass tape for additional support and protection.

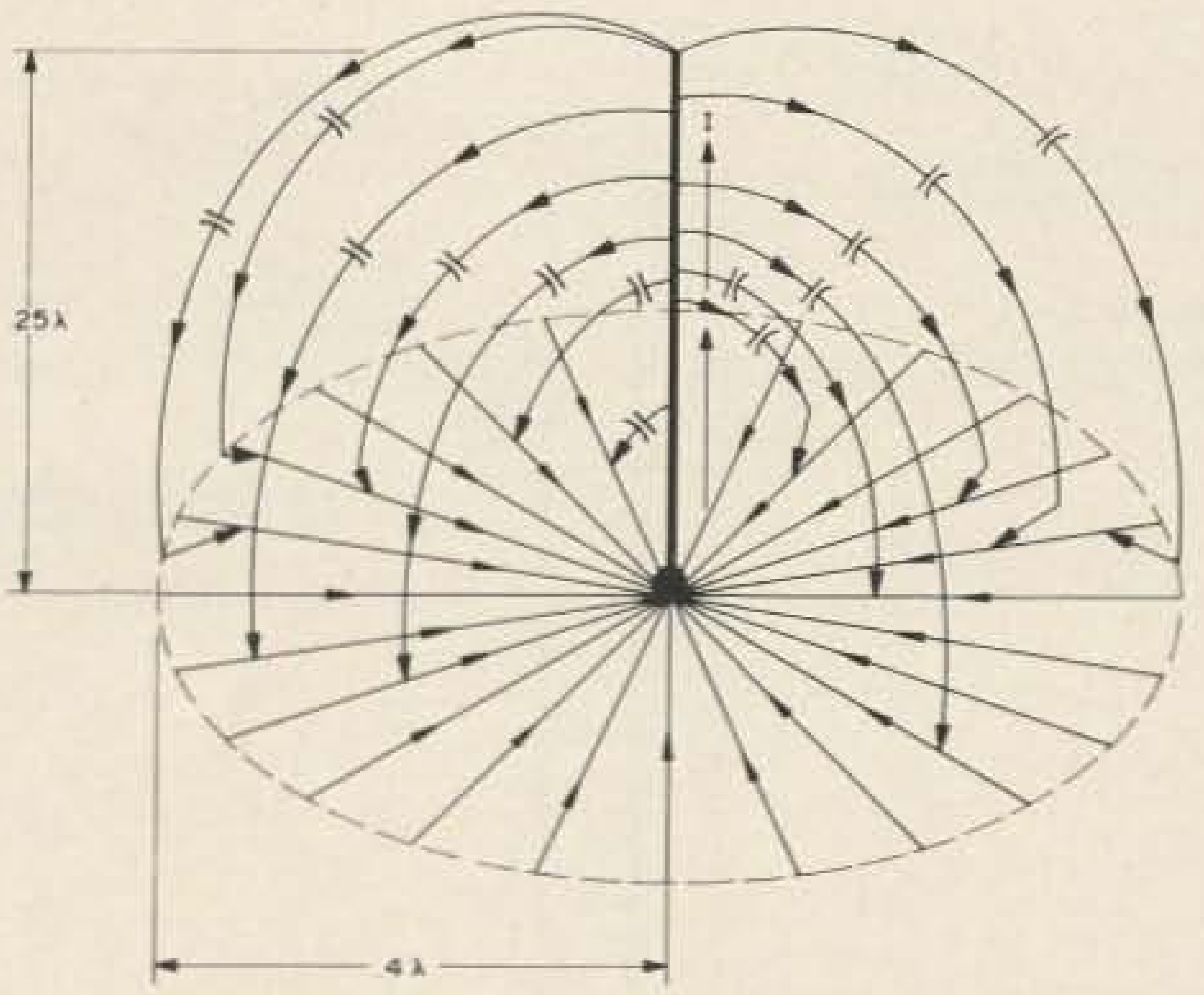

Fig. 2. The hemisphere of current which flows as a result of capacitance of a λ/4 vertical radiator to the earth or a radial system. At frequencies above 3 MHz, rf currents flow primarily in the top few inches of soil, as explained in the text. Ground rods are of little value at these frequencies, and spikes or large nails are sufficient to secure the outside end of each radial wire. With a sufficient number of radials, annular wires interconnecting the radials offer no improvement in antenna efficiency, as the current path is radial in nature.

The Adjustable Top-Loading

The key enabling device

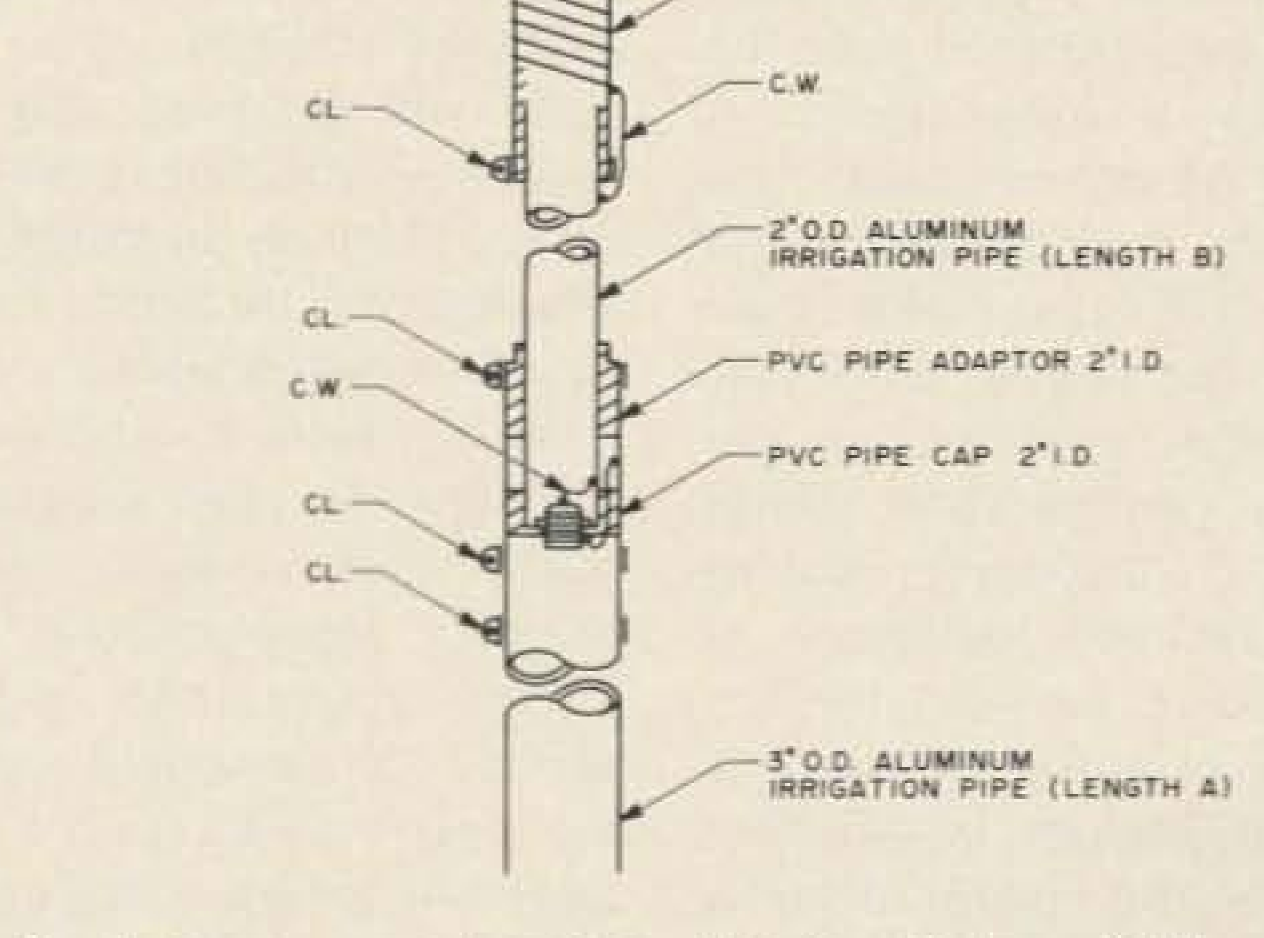

Fig. 3. Antenna construction details. Notes: C.W. — connecting wire to solder lugs; CL. — radiator hose clamp; Coil — Polycoil 2½" diameter #16, 10 turns per inch.

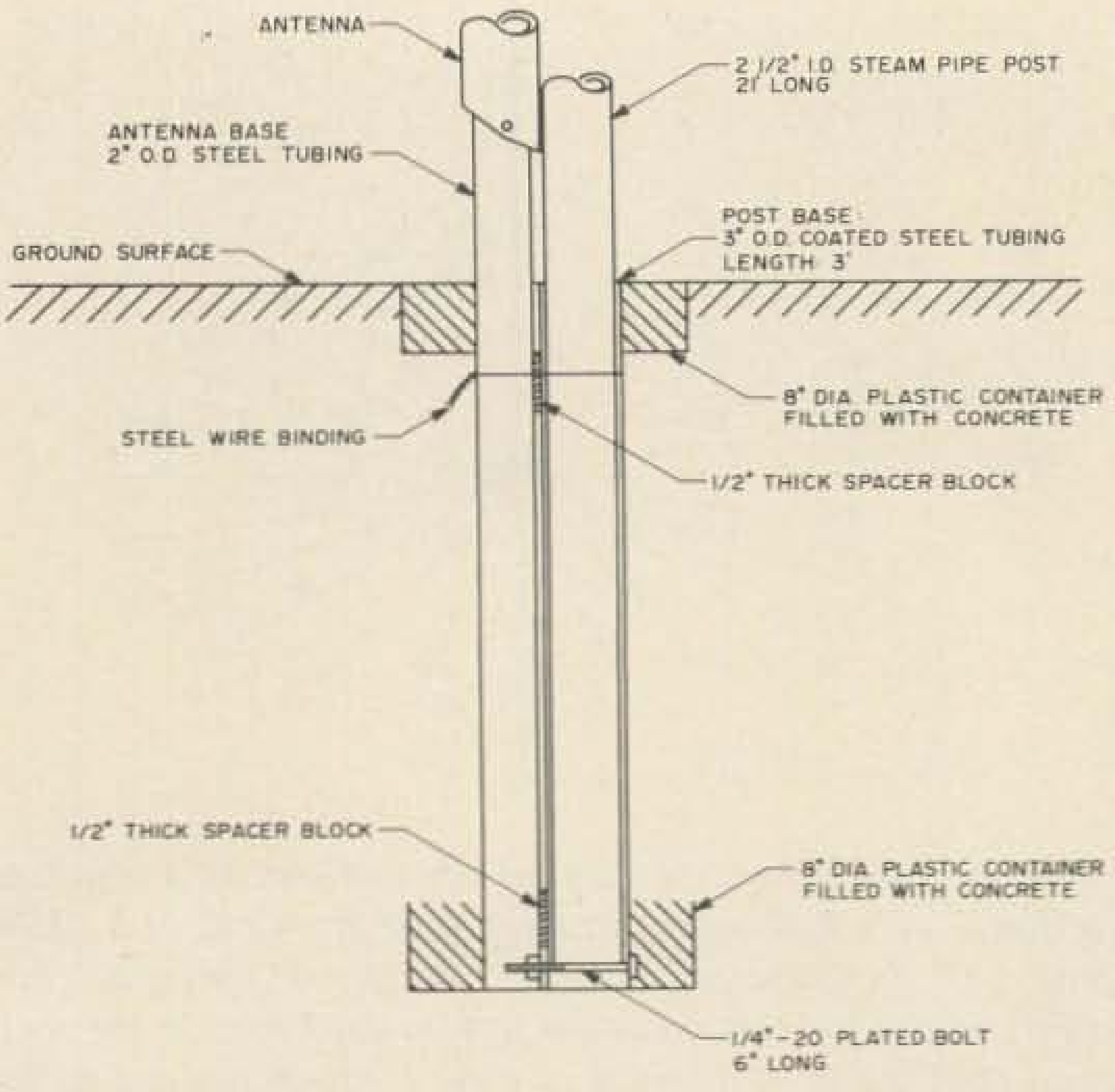

Fig. 4. Supporting base construction details.

	Dimensions			Coil
	A	B	C	Turns
Antenna no. 1	30'	11½'	8½'	20
Antenna no. 2	20'	12'	12'	12

Table 1. Antenna dimensions.

which makes this antenna system practical is the method of tuning the radiator to resonance from the ground level. Usually, a roller inductor or other tuning method is necessary at the base of the antenna, which sacrifices mechanical and electrical flexibility. Remember, you want to have the antenna self-resonant so that, in effect, when the feedline is connected, it works into a resistive load.

The desired tuning is achieved by means of an adjustable top-loading arrangement made of two Citizens Band whips which project from either side of the top of the radiator. Lengths of nylon cord are attached to the ends of these whips and pass through awning pulleys which are supported from the mast by a hose clamp. A length of nylon cord runs down the mast to the ground level. Pulling on this cord flexes the whips from the horizontal positon to the circular configuration shown in Fig. 3, thereby producing the desired variation of capacitance between the top of the antenna and ground. This adjustment is sufficient to cover the entire 75 meter phone band without changing the coil inductance — a very useful capability.

The Antenna Support

It was desired that this vertical antenna be placed in an unguyed position in the back lawn of a typical suburban lot. Accordingly, a 21-foot length of 2½-inch (nominal) steam pipe (2-7/8 inches o.d.) was mounted in the ground to serve as a supporting post. Inasmuch as this was to be an adaptable installation for future experimentation rather than a fixed arrangement, the supporting pipe was mounted in such a manner that it could be removed without disturbing the buried system of radial ground wires. This was achieved by telescoping the supporting post into a three-foot length of three-inch-diameter coated steel tubing buried in the vertical position as shown in Fig. 4.

It will be seen that the antenna is pivoted at the base on a 5/16-inch-diameter bolt which passes through a length of two-inch-diameter steel tubing, which is attached to the base for the supporting post. This tubing, which projects approximately four inches above the ground surface, is assembled against the post base to form a rigid assembly before being cast in concrete as shown. Thus, when completed, this assembly forms a rigid buried support structure, made of the antenna mounting base and the post mounting base. The supporting post is raised to the vertical position and then lowered into the pipe base to complete the antenna supporting structure; this is a two-man job.

Antenna Erection

As shown in Fig. 4, the antenna is pivoted at the base on a 5/16-inch-diameter bolt. The antenna can be "walked up" — easily by two men or with greater strain by one (young) man. If I am that one man, I prefer to use a rope hoist. After erection, the antenna is held rigidly in place by two hose clamps which are tightened around the antenna and the supporting pipe.

The coaxial feedline passes upward through the antenna, and its shield is connected to the lower section of the radiator, both at the feedpoint and, by means of a length of flexible braid, at the base of the radiator. Here, it is connected to the center of the system of ground radials. The coaxial cable is then buried so that it becomes a part of the radial image plane.

The Image Plane

Sevick and others have shown that a large number of ground radials is required if an effective image plane is to be achieved in localities where the soil has but modest electrical conductivity.

Guided by this previous work and by the dimensions of the available plot, I chose to use for each vertical radiator 73 radials (5° radials plus the coaxial feedline), each having an approximate length of one-quarter wavelength. The image plane took the form shown schematically in Fig. 5. For clarity, not all of the wires are shown in the sketch. Since this vertical system was superimposed over the grid of parallel ground wires (spaced ten feet apart) which were used for the horizontal phased array,[2] the image plane is connected to this grid by soldered crossovers at the median grid wire, as shown.

ADJUSTMENTS

Resonance

After erection of the vertical radiators and completion of the image plane installation, it is only necessary to adjust the system to resonance. This is accomplished by means of a noise bridge. The two feedlines were first trimmed to an electrical length of one wavelength at the operating frequency (3.955 MHz). Since the feedline is an integral multiple of half waves, the measurements are as if made at the antenna feedpoints directly. The noise bridge was connected at one antenna input, while the other antenna was terminated in a 52-Ohm resistive load. The resonant frequency is measured by detection of the null of the noise bridge. This resonant frequency is then altered by pulling the rope which flexes the whips at the top of the antenna. For example, if the measured resonant frequency is too high, the whips are extended more, thereby lowering the resonance point. If there is, at first, not enough range in this adjustment, the antenna is lowered and the number of coil turns is increased. Once the desired resonant frequency is attained, this antenna is terminated while the other radiator is adjusted. A slight "tweaking" of the first antenna now completes the adjustments.

Matching

Referring to Table 1, it is seen from a comparison of

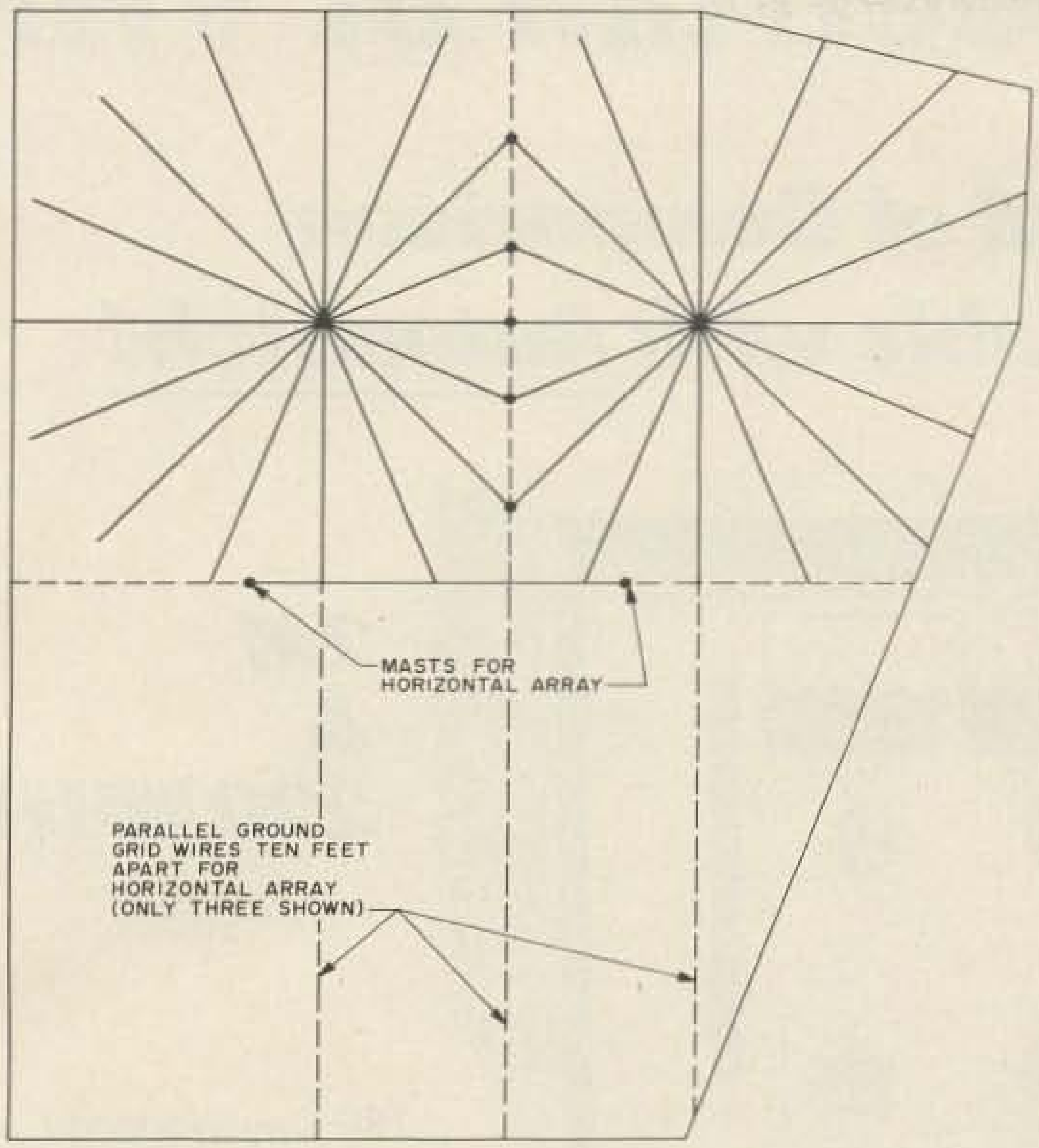

Fig. 5.

dimensions that probably the feedpoint impedance of antenna no. 1 will be greater than that of antenna no. 2. This is surmised because, viewed as a dipole-image antenna system, this feedpoint is probably further off center than is that for antenna no. 2. This proves to be the case – noise bridge measurements indicate this feedpoint resistance of no. 1 to be 70 Ohms, whereas that for configuration no. 2 measures 40 Ohms. Rather than change the antenna dimensions to realize an input resistance of 52 Ohms for each, it is simpler to utilize broadband toroidal transformers to match each antenna to the 52-Ohm source.

Since the frequency used is relatively low, the transformers were wound with 15 turns of zip cord on a 2-inch-diameter toroidal form (T-200). These units were connected in the autotransformer mode, and, for each, the tap was adjusted empirically using the noise bridge. Residual inductance was tuned out using series capacitors. The details for these transformer connections are shown in Fig. 6. The input resistances were each adjusted to 50 Ohms.

Operation

This antenna system has been operated as a two-element phased array using the same delay-line switching manifold as has been used with the horizontal system.[2]

Electrically, the operation is as expected. Swrs are below 1.1 for all combinations of the radiators. The front-to-back ratios are consistently above 10 decibels. The phasing is monitored by the Lissajous pattern on an oscilloscope. The in-phase, quadrature, and 45° patterns are as expected.

As mentioned earlier, detailed comparisons with the horizontal array are planned. Preliminary results indicate that, for short-distance (out to fifteen miles) ground wave, the vertical system is consistently stronger. For distances out to about 200 miles, the horizontal system is substantially stronger. For distances greater than 200 miles, the vertical system is stronger only if propagation conditions are favorable. It is my feeling that this will be strongly dependent upon the sunspot cycle. It would appear that the low-angle refraction for this relatively long wavelength radiation may depend upon the "smoothness" of the ionosphere. If this is true, one might expect inferior performance of the low-angle (vertical) system during sunspot lows when the ionization is "rough," producing excessive scattering during the oblique-angle refraction. As the sunspot cycle improves, one would expect the ionization to be more uniform, or "smoother," so that the low-angle antenna system would come into its own, perhaps producing substantially stronger signals than the higher-angle horizontal system. If this proves to be true, it would explain much of the conflicting data which has been reported down through the years regarding the effectiveness of vertical antenna systems on 75 meters. ■

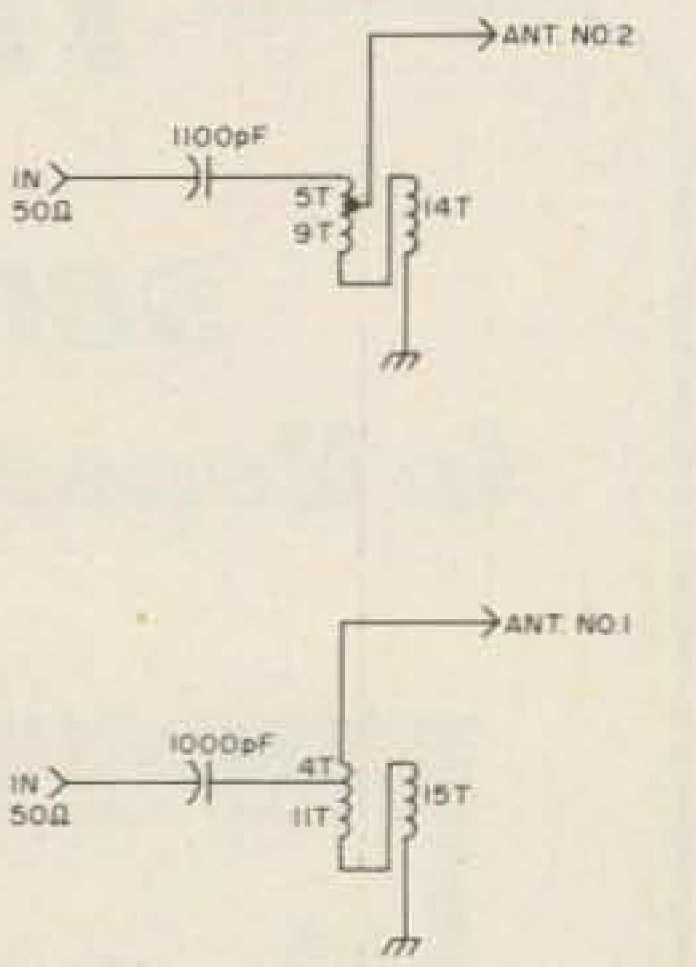

Fig. 6. Toroidal matching transformers.

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1. "The Mobiloop," J. E. Taylor, *QST*, November, 1968.
2. "A Low-Frequency Phased Array," J. E. Taylor, *73*, July, 1974.
3. "The W2FMI Ground-Mounted Short Vertical," J. Sevick, *QST*, March, 1973.
4. "Top-Loaded Vertical for 80 Meters," H. G. Elwell, Jr., *Ham Radio*, September, 1971.
5. "Another Look at Reflections," M. W. Maxwell, *QST*, April, 1974.

LETTERS

from page 75

power (5 Watts), because it was all I could afford, and nearly quit amateur radio. I guess I could fill page after page about lost contacts and no contacts because of QRM from the really "strong" stations on nearby frequencies.

It seems like this letter has started one way and is headed somewhere else, but the point is: "How can the average person afford an A-1 radio station?"

I enjoy amateur radio. I know it is growing because there are more hams in our area than there have ever been. With this growth, there have been growing pains. I have some suggestions for helping:

1. Manufacturers are putting more and more into each radio. Why not start with a radio that is one band (40 meters) and operates CW only? Then, as the amateur progresses, the radio would have add-on accessories to increase the number of bands and add SSB and other such items to upgrade the equipment.
2. Why don't they allocate band segments for low-power (QRPp) use?

These things will not solve *all* the problems of amateur radio, but I feel that they would help the Novice operator in two ways: He will be able to afford the equipment to operate and he will therefore retain his interest in amateur radio.

Maybe somebody agrees with me—maybe not. Anyway, I've said it and I believe it.

Lewis M. Todd WB5SYP
Natchez MS

I'd be interested in letters from readers with ideas on how to work DX without spending a lot

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