A Two-Element Vertical Parasitic Array for 75 Meters

What do a city lot, $50, about half the wire in a dipole, old coax and 6 dB of gain have in common? They all come together to make a DX-buster antenna on 75 meters!

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Many of us like to chase wintertime DX in the SSB window from 3790 to 3800 kHz, especially when the higher bands aren't open. There's a lot of activity in this narrow subband. Success is just a matter of listening and trying to stay on top of the pileup. Unlike higher bands, almost every such contact is the result of working through a pileup. Almost everyone uses a form of dipole antenna, whether it's an inverted V or some other shape. Few stations have directional arrays; fewer have beams at 100 feet or higher; some have tried a vertical, but most use a horizontal element about 40 feet above the ground. If this is the norm, it's no wonder that pileups persist; nearly everyone has identical signal strengths. Only those few who have a modest edge get through on their first or second call. It doesn't take much gain to surpass a typical dipole on this band. A few decibels make the difference, assuming that you use 1500 W, as it seems everyone does on this band.

K6STI's *Antenna Optimizer* software allows you to explore the performance of parasitic vertical arrays. I've had this idea for a long time, but found it impractical to pursue because of the time and effort required by trial-and-error and the difficulty of measuring the results. It's hard to be objective about antenna performance, especially on the lower bands. Far-field measurements may invade others' private property and require several people with field-strength meters to be at different places simultaneously. It's far more inviting to use computer-aided design, then try the antenna on the air.

The idea is a simple one: Since Yagi antennas are half-wave horizontal parasitic arrays, shouldn't a vertical quarter-wave array fashioned after the Yagi have the same behavior? A common Yagi configuration is a dipole (resonant at f_0) with a reflector (resonant slightly lower than f_0) behind it and one or more directors (resonant slightly higher than f_0) in front of it, with the parasitic elements providing forward gain and a front-to-back ratio. A simple ground-plane antenna could have a reflector and a director or two. Wouldn't this work in the same way? The answer is a resounding "*Yes!*", but not without realizing a few things first.

Ground effects, return-path losses and reflectivity, shape the vertical radiation patterns for all antennas, and ground loss is the reason most vertical antennas don't work as well as they could. To reduce ground losses and obtain the lowest radiation angle possible, horizontal antennas are positioned as high above ground as practical. Vertical antennas, on the other hand, can be ground-mounted and give a low radiation angle if ground reflectivity is excellent, but ground losses are significantly higher. Remember, we are talking *75 meters* here. Let's face it, the competition is not a Yagi at a hundred feet; it's a dipole at 40 to 60 feet. Here, a ground-mounted vertical array moves ahead of the typical competition.

The bottom line: It's a lot easier to get gain on 75 meters with a vertical antenna than with a horizontal one *if the ground losses and poor reflectivity can be conquered.*

The Vertical Parasitic Array—Practical Considerations

When designing this practical two-element vertical parasitic array, I set two constraints from the start:

- A $^1/_4$-λ radiator at 75 meters is about 62 feet long. Many hams don't have supports this high, so I chose a practical height limit of 30 feet. (Erecting towers to be the antenna elements is not nearly as practical as hanging wires from trees.)
- This project was not to be a phased array. (Such arrays require accurate control of the relative phase among elements. Such antennas are well known and have been in the literature for years.)

Wire-Yagi construction and performance are the goals, but on the ground! The first constraint requires that I physically shorten (load) the vertical elements by some means. I also strongly desired that this antenna be simple to construct and inexpensive. My research revealed a practical design that consists of two vertical elements approximately 27 feet high, each with a high-Q loading inductor. One element is a grounded gamma-matched radiator; the other is a grounded reflector.

Some Comparisons

Before going into the construction details, let's consider some comparisons to show that construction is worthwhile. First, let's assume that ground losses are zero. *Antenna Optimizer* assumes this anyway, although it uses real ground and the radial system to determine radiation angle.

With loss-less ground and 30 100-ft radials, Figure 1A shows the vertical-radiation patterns of an optimized two-element vertical parasitic array and a dipole at 40 feet. Only low angles of radiation are of interest here, say from 0° to 15°. For a radiation angle of 5°, the gain over the dipole is an astounding 10 dB! At 10°, the advantage is about 8 dB; and at 15°, about 7 dB. The gains are equal at a radiation angle of 33° on the vertical array's strong side. As expected, the vertical antenna shows a deep null at 90°, and there is some front-to-back ratio. The horizontal pattern (Figure 1B) shows the gain of each antenna in all directions, at an elevation angle of 5°. There is a gain depression of 6 dB off the ends of the dipole, while the vertical array shows a smooth 7 dB decrease in gain off the back. The vertical-array gain is greater than the dipole at any azimuth. Of these increases, about 1.5 dB of gain and 4 dB of F/B are produced by the parasitic element.

What happens if the dipole is at 60 feet? Not much. The gain of the vertical over the dipole drops 1 dB at a radiation angle of 10°, but it still has a 10-dB advantage at 5°.

The conclusion here must be that, assuming no ground losses, the maximum gain of the two-element vertical parasitic array beats that of a dipole at 40 to 60 feet "hands down" at a radiation angle of 5°, any azimuth. Keep this fact in mind as I make another comparison.

Ground Loss

Now, the real test: Enter ground loss! For now, assume that I've modeled the antenna correctly and that a truthful method to determine ground loss is forthcoming. We'll discuss construction later.

My test antenna consists of a single element: 26 feet $6^1/_2$ inches of wire with a loading coil placed 14 feet from the bottom. At the bottom, the wire connects to an

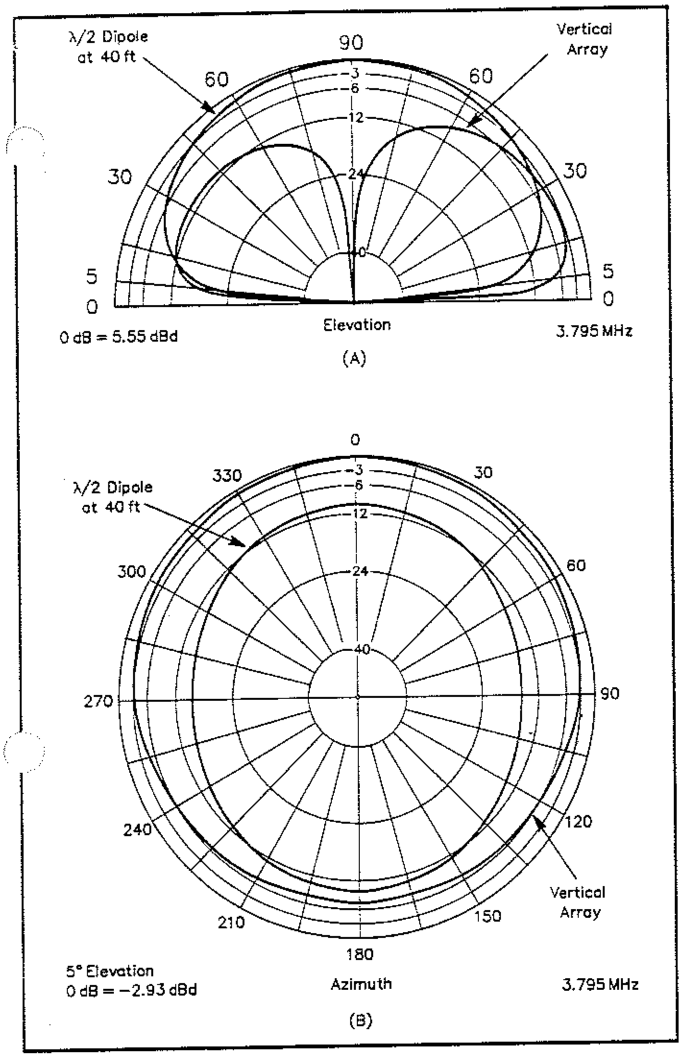

Figure 1—Part A shows elevation plots of the no-ground-loss, two-element vertical parasitic array and a dipole at 40 feet. At an elevation angle of 5°, the array shows about 10 dB of gain over the dipole. B shows azimuthal plots that demonstrate the ideal, no-loss vertical array has gain over the dipole in all directions at a radiation angle of 5°.

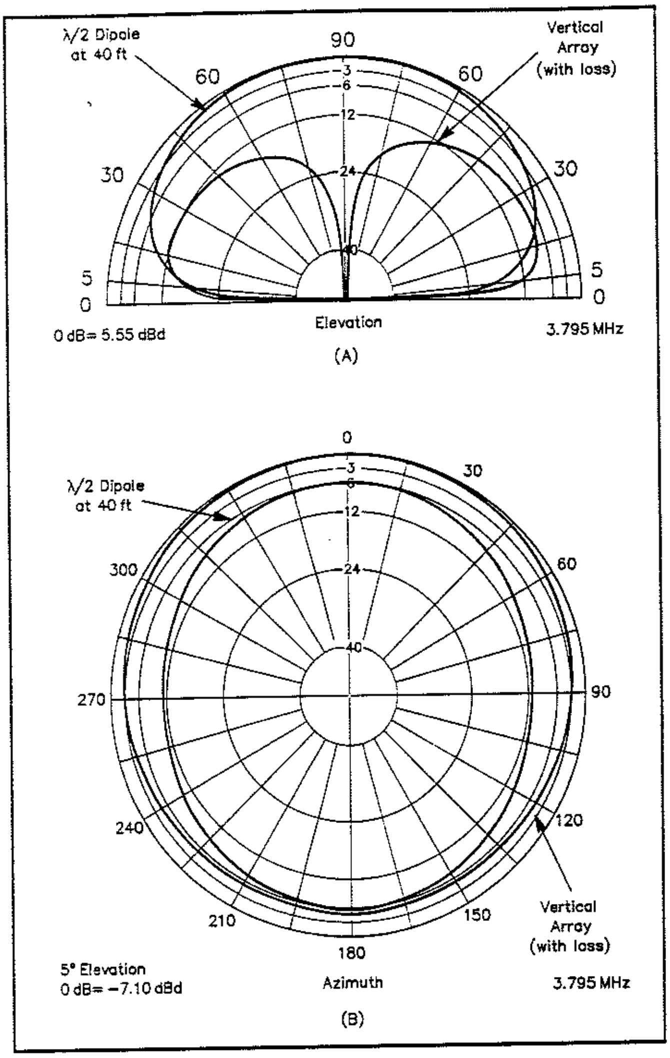

Figure 2—Here is the comparison of Figure 1, revisited with realistic ground losses added to the two-element vertical array. Gain of the vertical is still 6 dB at a radiation angle of 5° compared to a dipole at 40 feet. This gain is similar to that of a three-element beam over a dipole on 20 meters.

SO-239 coaxial connector. The coax outer conductor connects to a set of ground radials (assumed to be of sufficient number and length to do the job).

At this point, the antenna is a single-element, center-loaded vertical groundplane. I measured the unmatched feedpoint impedance with an HP-8753C Network Analyzer, which makes a believable measurement easily. I adjusted the wire length above the coil for resonance (the measured reactive term is as close to zero as possible) at 3795 kHz. The resonant feedpoint impedance was $32 + j0\ \Omega$. I didn't know how much of the R term was loss and how much was radiation resistance.

Antenna Optimizer says an antenna like this, using a loading coil with a measured Q of 400, should have a feedpoint impedance of $12 + j0\ \Omega$ over perfect ground. This implies 20 Ω of ground loss, for a best-possible efficiency of $^{12}/_{32}$, or 38%—unless something is done about the radial system! I thought that the radials would be good enough; this was not the case. The radials consisted of about 20 #18 insulated wires running over ground with lengths that varied between 20 and 60 feet. The system needed more radials, perhaps of much larger wire. I remembered that I had about 1000 feet of old RG-11 coax in my junk box. I figured the braid should make great radials. I duplicated the existing radials with the coax and connected them to the SO-239 ground side at the feedpoint. Then, the measured antenna impedance was $22 + j0\ \Omega$. The added radials eliminated 10 Ω (50%) of the ground loss. (I left it at that, considering the effort that would be needed to further reduce the loss. My points are that this kind of antenna can't have too many radials and the effectiveness of a radial system is often overestimated.) With this feedpoint impedance, the maximum efficiency is $^{12}/_{22}$, or 54%. Accepting this, the gain of this antenna is about 3 dB less than that of its ideal version (no ground loss), but I still consider it worthwhile. At this point, I realized that 10 Ω of ground loss, each, in the radiator and reflector (since it is of identical construction) would have to be acceptable. So be it!

Now for some more comparisons with the dipole, this time with 10-Ω resistors (representing ground loss) inserted in series with the radiator and reflector at their bases. Figure 2A shows a gain over the dipole at 40 feet, at a radiation angle of 5°, to be 6 dB (4 dB at an angle of 10°). It is equal to that of a dipole at about 19°. This isn't too bad because the long-haul DX comes in at 5° to 10°. The vertical array still looks like a three-element beam when compared to a dipole with 6 dB of gain at a elevation angle of 5°. Figure 2B shows that, at 5°, it has gain over the dipole in all directions.

Construction Notes

Figure 3 shows the electrical and physical dimensions of the antenna. To minimize losses, use nothing but bare #14 copper wire for the antenna elements. Tinned

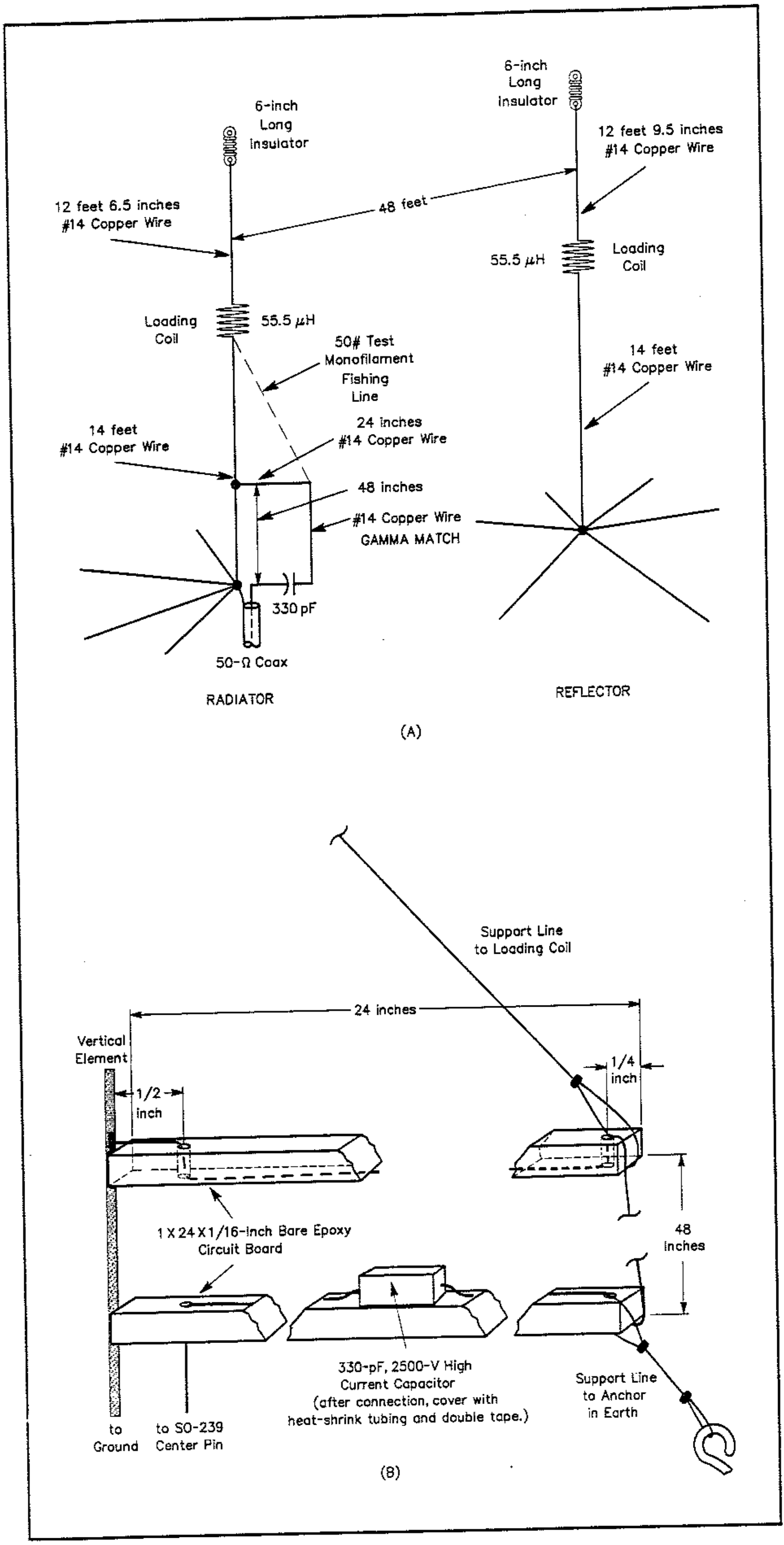

Figure 3—Physical details of the two-element vertical array. Notice both elements and the gamma match section of the radiator. Adhere to the dimensions shown to easily duplicate this antenna. B shows details of the gamma match.

hook-up wire won't do. It's lossy, even at this frequency. Use coax or a similarly large conductor for the radials. As demonstrated, old coax works fine; but small-gauge wire doesn't do much. For typical sites (average to good conductivity and reflectivity), use at least 30 50-ft radials (100 ft is better) to achieve the performance described here.

At the top of each vertical wire, use a long (6-inch or longer) ceramic or glass insulator. Even at modest power levels, the voltage at the element ends reaches tens of kilovolts. Do not use nylon support rope; it will catch fire if placed near the top of the antenna. (Nylon is too lossy at this frequency.) Use a few feet of 50-pound-test monofilament fishing line to span from a long insulator to a support rope. Don't burn down the forest; "skyhooks" are hard to find!

Tune the radiator to resonance as described earlier for the test antenna (with no matching section and the reflector collapsed on the ground). Check to see that the real term is near 22 Ω. If it's less, you are doing better than I did. If it's higher, either add more radials or be satisfied; 12 Ω means no ground loss at all. Note that poor ground reflectivity will reduce low-angle performance below that indicated by measured ground loss. Next, lower the radiator and adjust the reflector to resonance (substitute a temporary coax connector in place of its ground connection). You should be able to duplicate the radiator's impedance. Once it's resonant, reconnect the reflector to ground and add 3 inches of wire above the coil to properly tune it as a reflector.

The center of the SO-239 at the radiator connects to the lower 24-inch horizontal arm of the gamma match (only a few inches above ground). It is interrupted at about half its run by a 330-pF, 2500-V, high-Q, high-current fixed-value capacitor. (I used one made by American Technical Ceramics, ATC.) Details of the gamma match appear in Figure 3B.

A good low-loss loading coil of 55.5 µH is necessary near the center of each vertical element. "Low loss" means a large-diameter conductor wound on a stiff form o large diameter. Two coil forms are necessary. Each consists of a pair of nearly identical 1/4-inch-thick Plexiglas plates a shown in Figure 4.

The width of each plate is 6 1/2 inche from slotted edge to slotted edge. Th length is 7 inches. Make the slots to hol the turns in place like this: Drill a line o 5/32-inch holes centered 1/4 inch from eac 7-inch edge and spaced 1/4 inch on center Cut away the plastic from the 7-inch edg to each hole by making a pair of tangenti cuts. This forms a series of adjacent dee slots. (I used a band saw.) Slots on the op posite edges of the same plate can b aligned to be the same distance from th ends of the plate so that if the plate could b folded about a centerline from end to en the slots would overlap. The mating plat

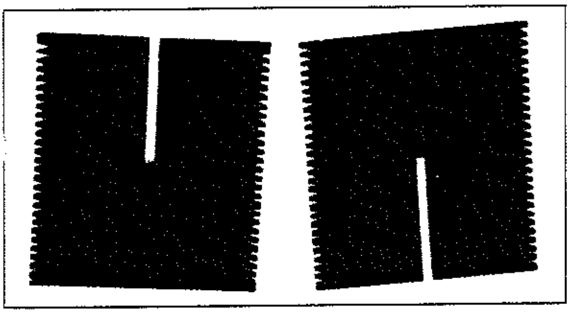

Figure 4—Two ¼-inch-thick plates of Plexiglas make an X-shaped coil form when dovetailed together. The pieces are 6½ by 7 inches, with slots in the 7-inch sides to hold ⅛-inch copper refrigeration tubing at 4 turns per inch. The slots are made by drilling a line of 5/32-inch holes centered ¼ inch in from the 7-inch edge and spaced ¼ inch center to center. I used a band saw to cut away plastic from the edge, which forms the slots. Offset the slots by ⅛ inch between mating pairs.

however, should have its slots offset ⅛ inch from those on the first plate. In other words, the plastic separating slots on one plate should coincide with the slots on the mating plate. This provides a pitch as you wind the turns. The coils should have four turns per inch with a diameter of 6 inches.

Terminate the ends of the coil with ⅛-inch eye lugs and secure them to the ends of the form with #6-32 brass bolts at each end. Drill and tap two holes for these bolts into each end edge of each plastic plate, perhaps 1 inch each side of the center line. Install a #14 humped wire (with solder lugs at the ends) between each pair of bolts. Position the humps to peak along the centerline. Attach the upper and lower wires of the antenna to the hump centers.

Figure 5 shows a completed 55.5 µH coil ($Q \approx 400$). As shown, I did not use the entire form length. This allows some flexibility should you want the coils to reach the CW subband (more inductance is necessary).

An inverted disposable plastic paint bucket covers each coil (bottom side up with a small hole in the bottom to pass the upper wire) for weather protection. Similar buckets (four needed in all) keep weather away from the SO-239 connector and the soldered radial connections at the bottom of the radiator and reflector.

Parts

The most expensive part of the antenna (apart from real estate) is the copper refrigeration tubing, which is about $13 for 50-foot roll. Two rolls are necessary because each coil requires about 31 feet of tubing. The antenna requires just under 70 feet of wire, including the gamma match (perhaps $7). Plexiglas scrap is inexpensive and often found as giveaways. The capacitor recommended is a first-class device; don't compromise! It may sound expensive for a small chunk of porcelain, but it is well worth it when antenna loss is so costly. I used an American Technical Ceramics part number ATC100E331JCA2500X. It has an equivalent series resistance of 0.02 Ω at 30 MHz and can conduct 10 A of RF current at 4 MHz. Parts with "P" rather than "CA" in the part number are okay; the difference has to do with the amount of solder on the ends. You can order the part from ATC by telephone (516-547-5700). Price may vary, but I suspect that a single-piece purchase would cost less than $10.

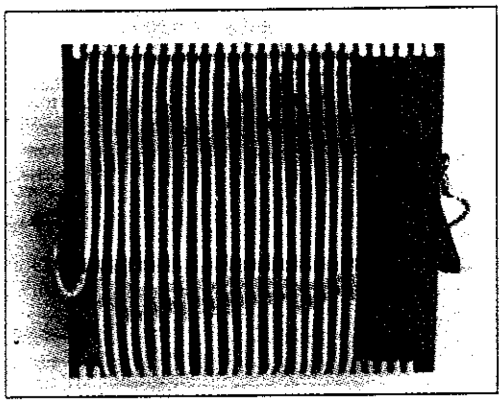

Figure 5—For an inductance of 55.5 µH, 19½ turns are needed. Coil Q measures about 400. The CW part of the band requires more turns, and there is enough form for this (5 or 6 more turns should make it to the bottom of the band). When winding the coil, keep it as round as possible.

Results and Conclusions

I installed this antenna among pine trees in March 1995, catching the near end of the winter DX season on 75 meters. Its major lobe is to the northeast, toward Europe, and delivers spectacular results. For ten weeks, until the end of May, called stations consistently answered me after my first call in any pileup, *regardless of direction*. Figure 2A indicates 6 dB of gain, but Figure 2B also shows gain over a typical dipole in all directions at a 5° elevation angle. Working the VKs and JAs became as easy as working Europe!

The operating bandwidth of the antenna is admittedly quite narrow. The 1.5:1 SWR bandwidth stretches from 3785 to 3800 kHz, but this is a DX antenna, and that is sufficient. The same tune-up procedure may be used for any part of the CW band by adding a few turns to each loading coil (keeping them the same) and pruning the wire lengths above them for resonance, *j*0. After reflector resonance is found, add 3 inches of wire to that above the reflector loading coil.

Remember that gain over the competition is what matters and that most of the competition uses a dipole, or some variation, at relatively low height. This antenna will not take second place unless you are competing with a station much closer to the DX station or one with a Yagi at 100 feet.

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