High Performance 40 Meters Vertical Without Radials

This shortened easy-to-build vertical, with no-radials, is made from surplus military camouflage poles. It has gain and wave angle comparable to a full-sized ¼λ ground plane antenna with radials

By John Portune W6NBC

I wanted high efficiency 40 Meter antenna with low-angle radiation. My inverted-V at 40 ft. performs well, but is “a cloud burner,” good for local contacts within 500 miles. A vertical seemed the obvious answer, a naturally low-angle radiator.

I began by looking at a classical quarter wavelength “ground plane” antenna at nine feet (safe height for radials). And as expected, EZNEC computer antenna modeling confirmed that it would satisfy my needs. However, I live in a mobile home with no space for radials, Figure 1. Would perhaps a vertical without radials be possible and not a compromise?

Figure 1: My small mobile home. No room for radials.

Figure 2: (A) at club's remote base site. (B) Hiding in the big oak tree behind my house. Note balun and turn-shorting jumper.

Well, how about a full-sized half wavelength vertical dipole? It has no radials? EZNEC confirmed that its gain and radiation angle are very similar. But, hold your horses, a full-sized dipole on 40 meters is 64 feet high. Too tall! I have CC&T toting neighbors. It needed to be hidden in the big oak tree behind my house.

Well then, and this is very elementary, why not just shorten a ½λ vertical with a loading coil? Would it have the same performance? The antenna in this article, at only 2/3 the height of a full ½λ vertical does just that. Figure 2 shows the EZNEC comparative gains (dBi) and radiation patterns. Some readers will note that this is close to the same length as the popular 5/8λ 43 ft vertical for 20m.

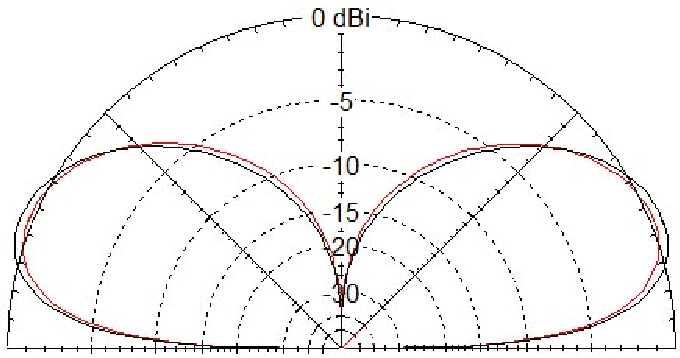

Figure 3: Comparative EZNEC elevation patterns and gains of (red) shortened no-radial 40 meter ½λ vertical and (black) ¼λ ground plane antenna with 4 full-sized radials. Feed points: 12 ft. above ground. Gain: dBi.

Notice that on 40m there is less than half a dB difference in gain (0.25 dBi vs. 0.66 dBi) and no difference in wave angle (22 degrees for both). But shortened to 2/3 the length, the height is now only 3 ft taller (46 ft.) than a ground plane antenna with the feed point at the same height. A second copy of this antenna is doing yeoman's service at my radio club's HF remote base station on Vandenberg AFB in California.

The Compromises

In other EZNEC simulations I saw that I actually could shorten this same mechanical configuration even more and not compromise gain or radiation angle significantly. I modeled one as short as 18 ft, but as the length gets shorter, the loading coil does become large and two other characteristics of small antennas become issues: (1) Bandwidth and (2) Efficiency

We'll look at these in "Bandwidth and Efficiency" below. But after all my simulations, shortening to 2/3 turned out to be the best compromise. Readers may wish to experiment with less, however.

Construction

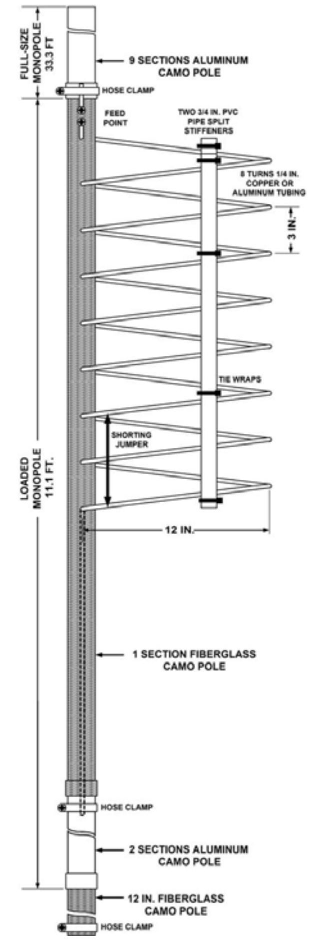

Figure 4: Shortened (to 2/3) ½λ 40 Meter vertical.
Note: aluminum camo pole sections foreshortened.

The top of this antenna remains a full ¼λ, a monopole – nine sections of surplus aluminum military camouflage pole. Only the bottom is shortened. It is two aluminum camo-pole sections and a single fiberglass camo-pole section, which supports a large low-loss loading coil.

I used camo-poles for two reasons. First, they are rugged, go up very easily, and transport easily for portable operation, such as field day. Second, they come both in aluminum and fiberglass versions. The non-metallic sections were useful for the loading coil and the bottom insulator.

There are several sources for camo-poles on the Internet. Mine came from armysurpluswarehouse.com. Other types of tubing can be used, but if you select a diameter other than the camo-poles (1¾ in. OD) or taper the tubing, the loading coil will need minor adjustment. Do not use steel – too much conductor resistance.

Erecting the pole sections is easy. I pushed them straight up into the tree from the bottom, all by myself, one section at a time. One person can easily lift the entire assembly. For portable operation, you might wish to attach three light guy ropes for helpers as you add pole sections to the bottom. Don't assemble the whole mast horizontally on the ground and try to tip it up – the fiberglass section may split.

Figure 5: Heavy-duty surplus military aluminum and fiberglass camouflage poles – 44.4 in. long plus 3½ inch connector, 1¾ in. OD.

The bottom insulator, is 12 in. cut from the top of a fiberglass pole section. A small stake driven into the ground, inserted into the bottom of the insulator, will hold the antenna securely.

The loading coil is nominally 8-10 turns of common ¼ in. soft aluminum or copper tubing. It must be at least this large in diameter (>12 in.) and also very widely spaced (>3 in.). Otherwise there will be loss due to coil resistance and skin effect from adjacent turns. In EZNEC, rather that using the LOAD function to add a coil, I used the WIRES function and modeled a helix. This made it easy to adjust turn spacing, coil diameter and coil length.

To support the loading coil, depending on the number of turns you begin with, drill an appropriate number of 5/16 in. hole pairs, three inches apart, on opposite sides of a fiberglass pole section, as shown in Figure 4. Each turn requires 36½ in. of tubing. Add six inches at the top and two feet at the bottom for the connection to the aluminum pole sections.

To make coil assembly easier, make a mark every 36½ in. on the tubing with a Sharpie pen, beginning at 2 ft. from the bottom end. You will use these marks to align the turns. Next, bend the total length of tubing into a loose coil roughly 12 in. in diameter. This does not need to be precise. Next, feed the turns into the holes in the camo-pole from the bottom a few inches at a time. As you proceed, keep the marks on the tubing aligned vertically. Finally adjust the turns so they are round and parallel.

For rigidity, the loading coil also requires two stiffeners made from common 3/4in. PCV pipe. Cut two appropriate lengths of ¾ in. PVC. Mark and drill hole pairs at 3 in. spacing along the length, beginning at 1 in. from one end. Do this carefully so that the holes are opposite each other and in a straight line. Then, with a rotary hand tool and a thin cut-off disk, slice the PVC pipe lengthwise on both sides through the middle of the holes.

Then sandwich the loading coil turns between the stiffener halves and secure them with UV-stabilized tie-wraps. Position the stiffeners 1/3 of a turn apart on the coil. The stiffeners will sit at an angle to the camo-pole due to the holes being straight across.

Lastly, bend the excess coil tubing towards the ends. Cut to length, flatten and drill connection holes as required. Use stainless steel hose clamps to connect to the tubing ends to the aluminum pole sections. Remember to scrape off the paint. The feed point is two 8-32 by 2¼ in. brass screws. For strength, add another stainless steel hose clamp at the cut-off end of the insulator.

When you erect the antenna, use Noalox on the aluminum joints. This popular anti-corrosion agent for aluminum electrical connections is available at most hardware stores in the electrical department. I apply it to all aluminum antenna joints during intitial erection to permit easy disassembly at a later date. Silicon grease also works.

Loading Coil Inductance and Tuning

Like any highly tuned antenna, the environment of an antenna affects the resonant frequency. The closer the antenna is to other objects, the lower resonance will be. For example, ten turns, as shown in Figure 4 will resonate below the band in all situations. It is drawn this way just to provide a sufficient number of turns for tune-up. At my club’s remote base station only 5 turns were ultimately needed, and only 4 in my big oak tree. Make up a jumper (Figure 4) to short out unneeded turns during initial tune-up. Later you may eliminate unused turns.

Little-known Theory

Here’s some interesting theory, which not many hams grasp, that came to light in my many EZNEC simulations. It is that a vertical antenna does not profit much by mounting it higher at the heights of most hams’ lower-frequency HF antennas. In this range, height matters much more to horizontal, Figure 6.

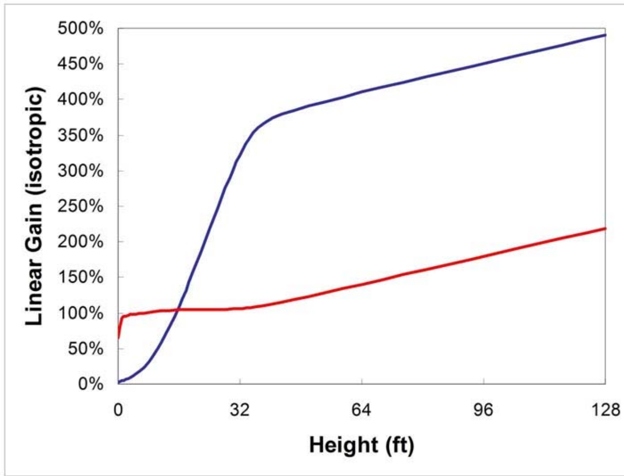

Figure 6: EZNEC Gains of a vertical (red) dipole compared to a horizontal (blue) dipole on 40 Meter.

The figure compares vertical and horizontal 40 meter dipoles at heights up to 128 ft. I was surprised to see that that the vertical (red) keeps essentially the same gain from close to the ground to all the way up to 32 feet, whereas the horizontal (blue) doesn't.

As Joel Hallas, W1ZR, QST's technical editor perceptively points out on p. 57 of QST for March 2012, this is related to the phase reversal of the ground reflection with verticals but not horizontals. This is what makes low-mounted verticals low-angle radiators but low-mounted horizontals "cloud burners." Yet from square one in ham radio, now nearly fifty years ago, I had always heard it proclaimed, "More height is ALWAYS better. This is not a universal truism.

Bandwidth and Efficiency

As mentioned above, this antenna is shortened to only 2/3 the length of a full vertical dipole. This was the maximum height I could live with. As I mentioned earlier, more shortening will not compromise gain or wave angle much at all, but it will reduce the bandwidth. For this 2/3 antenna, the bandwidth is still very reasonable, though, Figure 7.

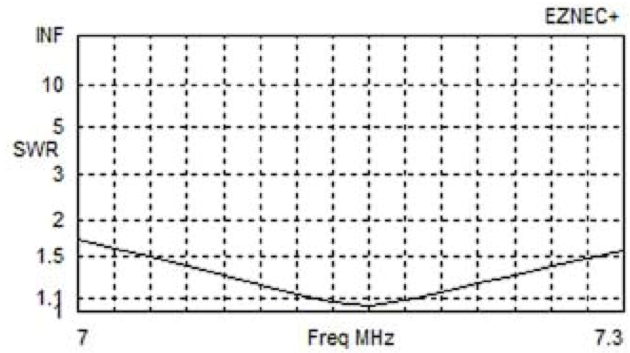

Figure 7: EZNEC bandwidth plot, over average soil and a normal amount of nearby objects.

Another potential shortcoming of shortening, which I paid careful attention to in this design, is antenna efficiency. Efficiency is the ratio (radiation resistance) : (real resistance+radiation resistance). Both types of resistance are in series in all antennas.

Loss occurs when the power divides naturally between radiation resistance and conductor resistance. Only the part that goes to radiation resistance makes radio waves. the other part is lost as heat. This is a major cause of low efficiency in small antennas such as HF mobiles and compact transmitting loops.

In this case, EZNEC predicts a radiation resistance of roughly 48 Ohms. Conductor resistance, including the skin effect loss for the loading coil, is roughly ½ Ohm. Together these give a 99% efficiency. In loading coils, turn spacing is the biggest efficiency factor. Skin effect loss is much higher in a close-spaced coil. My initial version used only 1 in. turn spacing, and the loss was noticeable. At 3 in. it is negligible.

For those interested in experimenting, the same number of camo-pole sections will work on 75/80 meters. Again, to minimize skin effect loss, it is important to keep the 3 in. spacing and to only increase the coil's diameter. Larger tubing is not required. My EZNEC simulation at 3.8 MHz called for a coil diameter of 30 in. More support for the coil would obviously be required.

A 20 meter version is possible, but height-wise is already short enough for stealth reasons. It does, though, have some advantage in radiation pattern as Joel Hallas' article in April 2012 QST, p. 30, illustrates.

Final Considerations

For positioning the feed coax, you have two choices. Lead it away at a right angle, or drill a hole just below the loading coil and run it out through the bottom. Keep the coax spaced away from the loading coil.

Also with all coax-fed antennas, it is best to use a balun. My preference is a ferrite-bead choke balun. Palomar Engineering sells two reasonably-priced kits, one for small coax such as RG-58 or mini RG-8x, the other for RG-8 sized coax.

Finally, as always, apply weather sealant to all exposed connections, such as the feed point and the turns-shorting jumper. Silicone sealant diluted 1 to 1 with paint thinner or turpentine paints on easily.

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