A 40 Meter Vertical Antenna for Small Spaces

This antenna offers good performance in a compact footprint.

Here is the shortened vertical dipole antenna at my club's remote base site on Vandenberg Air Force Base.

John Portune, W6NBC

I wanted a high efficiency 40 meter antenna with a low-angle radiation pattern for working DX. My inverted V dipole antenna at 40 feet performs well, but it is "a cloud burner," best for contacts within a 500 mile radius. A vertical antenna seemed the obvious solution because verticals are low-angle radiators.

I began by considering a classic ¼ wavelength "ground plane" antenna installed 9 feet above the soil (a safe height for radials). And as expected, *EZNEC* antenna modeling software confirmed that it would satisfy my needs. However, I live in a mobile home with no space for radials (see Figure 1). Would perhaps a vertical *without* radials be possible?

How about a full-sized ½ wavelength vertical dipole? After all, a dipole antenna doesn't require radials. *EZNEC* confirmed that its gain and radiation angle are very similar to the classic ground plane, but a full-sized 40 meter vertical dipole is also 64 feet tall! I have CC&Rs (Covenants, Conditions, and Restrictions) where I live, and inquisitive neighbors would spot that violation in a heartbeat.

Why not just shorten a ½ wavelength vertical dipole by using a loading coil? Would it have the same performance? As it turns out, the antenna in this article, at only ⅔ the height of a full ½ wavelength vertical dipole, offers very good performance while blending nicely within the tree behind my home.

Figure 2 shows the *EZNEC* comparative gains (dBi) and radiation patterns. Notice that on 40 meters there is less than ½ 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 ⅔ the length, the height is now only 3 feet taller (46 feet) than a ground plane antenna with the feed point at the same height. It works so well, a second copy of this antenna is doing yeoman's service at my radio club's HF remote base station on Vandenberg Air Force Base in California.

The Compromises

In other *EZNEC* simulations I saw that I could shorten this same mechanical configuration even more and not compromise gain or radiation angle significantly. I modeled one as short as 18 feet, but as the length gets shorter, the loading coil becomes larger and two other characteristics of small antennas become serious issues: bandwidth and efficiency.

We'll examine these issues later. After running all my simulations, shortening to ⅔ wavelength turned out to be the best compromise. Readers may wish to experiment with less, however.

Construction

The top of this antenna remains a full ¼ wavelength monopole — nine sections of surplus aluminum military camouflage pole, better known as *camo poles*. Only the bottom is shortened; it is two aluminum camo pole sections and a single fiberglass

Figure 1 — My small mobile home. No room for radials, let alone big antennas!

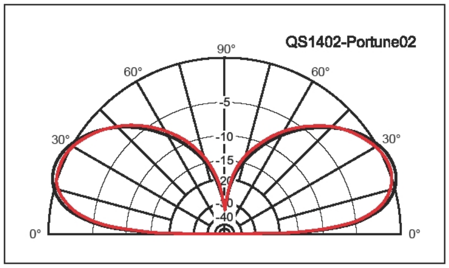

Figure 2 — Comparative *EZNEC* elevation patterns and gains of (red) shortened no-radial 40 meter ½ wavelength vertical and (black) ¼ wavelength ground plane antenna with four full-sized radials. Feed points are at 12 feet above ground. Gain is in dBi.

camo pole section, which supports a large low-loss loading coil.

I used camo poles because they are rugged, go up very easily, and transport easily for portable operation. They come both in aluminum and fiberglass versions. The nonmetallic sections were useful for the loading coil and the bottom insulator.

There are several sources for camo poles on the Internet. Mine came from Army Surplus Warehouse at **www.armysurpluswarehouse.com**. Other types of tubing can be used, but if you select tubing with outside diameter specifications other than 1¾ inches, or taper the tubing, the loading coil will need minor adjustment. Do not use steel; it has 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.

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

The loading coil is nominally eight to 10 turns of common ¼ inch soft aluminum or copper tubing. It must be at least this large in diameter and very widely spaced (>3 inches). Otherwise there will be added loss due to adjacent turns that are too close to each other. 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 inch hole pairs, three inches apart, on opposite sides of a fiberglass pole section as shown in Figure 3. Each turn requires 36½ inches 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 inches on the tubing with a permanent marker, beginning at 2 feet 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 inches 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 ¾ inch PVC pipe. Cut two appropriate lengths. Mark and drill hole pairs at 3 inch spacings along the length, beginning at 1 inch 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.

Now sandwich the loading coil turns between the stiffener halves and secure them with UV-stabilized tie-wraps. Position the stiffeners ⅓ 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 the tubing ends to the aluminum pole sections. Remember to scrape off the paint. The feed point is two 8-32 × 2¼ inch 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 initial erection to permit easy disassembly at a later date. Silicone grease also works.

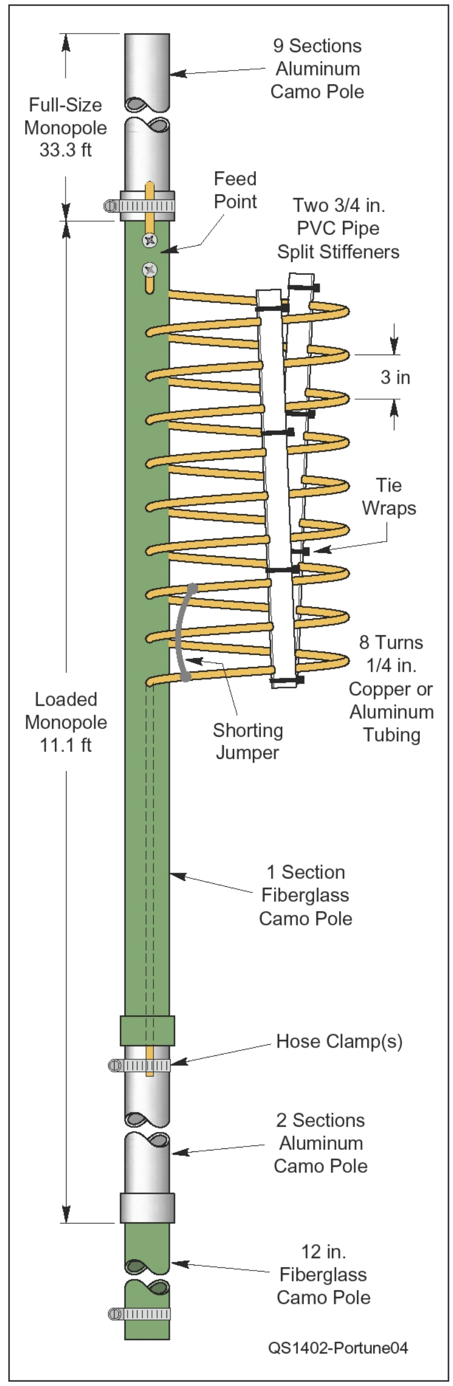

Figure 3 — Construction diagram of the shortened (to ⅔) ½ wavelength 40 meter vertical antenna. Note that the aluminum camo pole sections are foreshortened.

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, 10 turns, as shown in Figure 3, 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

Figure 4 — A close-up view of the vertical dipole hiding in the big oak tree behind my mobile home. Note the choke balun and turn-shorting jumper to the right of the coil.

remote base station only five turns were ultimately needed, and only four were required for the antenna in my big oak tree. Make up a jumper (Figure 4) to short out unneeded turns during initial tune-up. Later you can eliminate unused turns.

The Role of Height

Here is an interesting discovery that came to light during my many *EZNEC* simulations. I found that a vertical antenna does not profit much by being mounted far above the soil. Height above ground is much more important for horizontal antennas.

See Figure 5. The figure compares vertical and horizontal 40 meter dipoles at heights up to 128 feet. 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 antenna (blue) doesn't.

As former *QST* Technical Editor Joel Hallas, W1ZR, pointed out on page 57 of the March 2012 issue of *QST*, this is related to the phase reversal ground reflection with vertical antennas, but not horizontals. This is what makes low-mounted verticals low-angle radiators and low-mounted horizontals "cloud burners." Yet from my earliest days in Amateur Radio, I had always heard

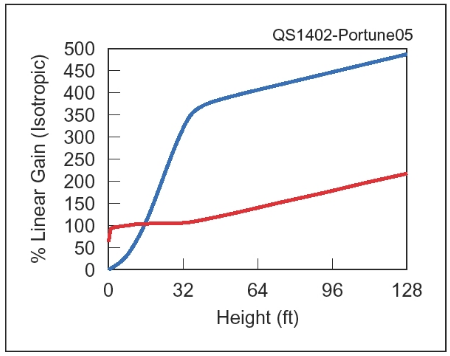

Figure 5 — Comparing vertical and horizontal 40 meter dipoles at heights up to 128 feet. The gain of the vertical dipole is shown in red; the horizontal dipole is in blue.

it proclaimed, "More height is always better." This is clearly not a universal truism!

Bandwidth and Efficiency

As mentioned above, this antenna is shortened to only ⅔ the length of a full vertical dipole; this was the maximum height I could live with. As I also mentioned earlier, more shortening will not compromise gain or wave angle much at all, but it *will* reduce the bandwidth. For this ⅔ wavelength antenna, the bandwidth is still very reasonable, as shown in Figure 6.

Another potential shortcoming of shortening, which I paid careful attention to in this design, is antenna efficiency. Efficiency is the ratio of radiation resistance to 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 Ω. Conductor resistance, including the skin effect loss for the loading coil, is roughly 0.5 Ω. Together these result in high efficiency. In loading coils, turn spacing is the biggest efficiency factor; adjacent-turn-loss is higher in a closely spaced coil. My initial version used 1 inch turn spacing and the loss was noticeable. At 3 inches it is negligible.

For those interested in experimenting, the same number of camo pole sections will work on 75/80 meters. Again, to minimize loss, it is important to keep the 3 inch spacing and to only increase the coil's

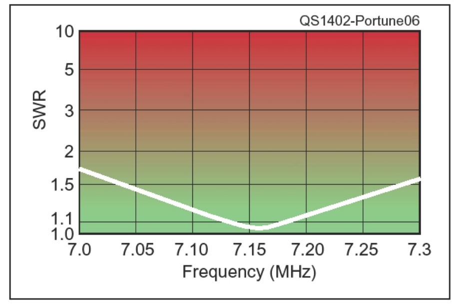

Figure 6 — The *EZNEC* bandwidth plot, assuming average soil and a normal amount of nearby objects.

diameter. Larger tubing is not required. My *EZNEC* simulation at 3.8 MHz called for a coil diameter of 30 inches. More support for the coil would obviously be required.

A 20 meter version has some advantage in radiation pattern as Joel Hallas' article in the April 2012 issue of *QST* illustrates.

Final Considerations

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

I suggest applying a common mode choke to the coax after it leaves the antenna. If the coax must be run along the bottom section of the antenna, the choke will be most effective if it is applied a few feet away. My preference is a ferrite-bead choke balun. HexKit sells a reasonably priced kit at **www.hexkit.com/rfchoke.html**.

Finally, apply weather sealant to 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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