3D Printed Fixture
Simplifies Ground-Plane Antenna Construction

A custom plastic framework supports the elements of a homebrew VHF/UHF antenna.

John Portune, W6NBC

Amateur Radio operators have a well-deserved reputation for the ability to repurpose everyday materials for the needs of our hobby. Now, with the wide availability of inexpensive 3D printers, small plastic parts such as dipole feed-point fixtures, antenna trap forms, and special mounting brackets can be purpose-designed and printed out at the amateur's desktop. Figure 1 shows such a fixture — a framework that supports all the elements of a VHF/UHF ground-plane antenna built around an SO-239 coax connector that also conveniently mounts the assembly atop a ¾-inch PVC mast. I have adapted this design from the one published by Laagvlieger at **www.thingiverse.com/thing:1938947**. The design files are available for downloading from my website at **w6nbc.com/3d**.

Ground-Plane Antennas

The antenna is comprised of a half-wavelength ($\lambda/2$), center-fed vertical dipole with the bottom half ($\lambda/4$ monopole) fanned out into two or more radials. Gain and radiation patterns are essentially the same as a vertical dipole. A ground-plane antenna's attractive features include its small size, easy mast-mounting, and direct connectivity to coax.

In order to be directly connectable to coax feed line, the antenna's feed-point impedance is adjusted to that of the coax by varying the angle between the vertical and radial elements.

A full-size $\lambda/2$ dipole in free space has a center impedance of roughly 72 Ω. A ground-plane antenna, with its radial elements perpendicular to the vertical element, has a feed-point impedance of 36 Ω. This is because with straight-out radials, the radial currents are equal in amplitude and phase but run effectively in opposing directions. Hence, radial currents oppose each other and do not contribute to the radiation or the feed-point impedance. Only the half-size monopole of top radiates with half the impedance.

However, if the radials are bent downward away from the vertical element, the radial currents begin to participate in the radiation and feed-point impedance. Think about it this way: If the radials were drooped all the way down, a ground-plane antenna would effectively be a 72 Ω dipole. So, if the radials are bent about halfway down, the antenna will exhibit a feed-point impedance of 50 Ω, making it ideal for direct connection to 50 Ω coax.

This antenna has excellent bandwidth (see Figure 2), but if you use larger diameter elements than described here, the bandwidth will be modestly greater. Figure 3 compares the radiation pattern and gain of this antenna (red) to a vertical dipole or J-pole (blue), with both mounted 10 feet above average soil. With elements

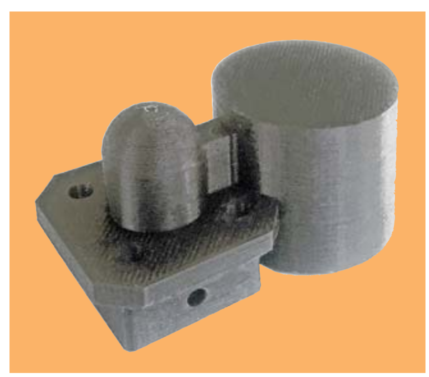

Figure 1 — Purpose-designed and 3D-printed plastic framework for an SO-239 VHF/UHF ground-plane antenna. The cylindrical cap at the right is sized to slip over the end of a ¾-inch PVC pipe mast. Four ground-plane radials bolt to the horizontal member at the left of the mast mounting cap. The SO-239 coax connector bolts to the radial elements through the bottom of the radial mount with the antenna's vertical element soldered to the connector's center pin and projecting through the dome of the small cylinder atop the radial mounting plate. Silicone is injected through the small hole in the side of the radial mounting plate for waterproofing.

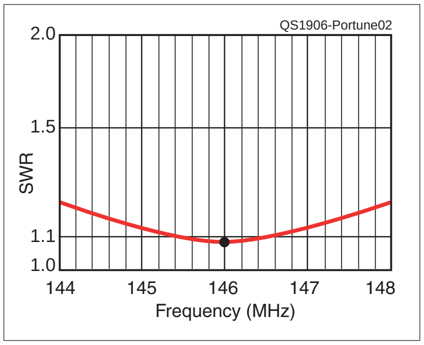

Figure 2 — SWR across the 2-meter band.

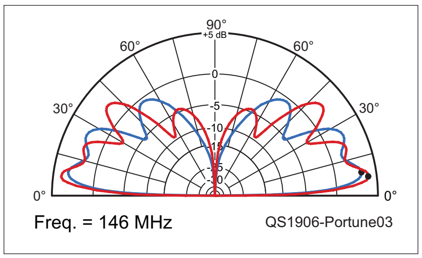

Figure 3 — Radiation pattern and gain of the ground-plane antenna (red) vs a vertical dipole or **J**-pole (blue).

made of either wire of tubing, the efficiency is high.

Construction

There are many materials suitable for the whip and radials. The most convenient is solid copper wire, with or without insulation. The lead figure shows #10 AWG bare copper buss wire for the whip and #14 AWG insulated solid house wire for the radials. Attach the radials to the SO-239 connector with either crimp-on ring terminals or small loops bent at the ends.

Soft ¼-inch copper or aluminum tubing also make excellent radial materials. Just flatten ⅜ inch of one end and drill a hole for a 6-32 screw, as shown in Figure 4.

The vertical whip generally needs to be copper or brass so it can be soldered to the connector's center conductor. It is, however, possible with acid flux and liberal scraping to tin the end of a stainless-steel whip for soldering. Note that the plastic part is printed with a tiny hole for the vertical monopole, which must be enlarged to fit your choice of whip.

Four-hole chassis-mount Type N connectors also fit the printed part, and have the added advantage of being more weather resistant than SO-239 connectors. With either, complete the weatherproofing of the coax with vinyl electrical tape.

I added a six-turn 1:1 coiled-coax current choke balun onto the PVC mast (see the lead figure). Secure the balun coax with tie-wraps through 3⁄16-inch holes in the mast. Alternately, you may run the coax inside the mast and out through a hole in the side. In that case, small mix-61 ferrite beads can be used for the balun inside the mast. Also, as this is a VHF/UHF antenna, use a minimum of small-diameter coax.

Table 1 gives starting lengths by band for both the radials and whip. The lengths are greater than needed to allow for tuning. Some antenna references show different lengths for radials and whip. This helps with impedance matching on ground-plane antennas with non-drooping radials. Equal lengths work just as well with drooped radials. Impedance is easily set by adjusting the radial droop.

Table 1
Starting Element Lengths

Band (MHz)	Length (inches)
144	22
220	14
440	7

Matching and Tuning

Begin with the radials bent down from the horizontal at roughly 45°. Use an antenna analyzer to find the initial resonant dip, which will be below the band due to the overlong elements. The first step when tuning and matching almost any antenna is to achieve a low SWR (i.e., a good match). Now, simply adjust the droop angle of the radials to obtain the minimum SWR.

The SWR will change only a little with frequency adjustment. Set the frequency (i.e., tune the antenna) by shortening the whip and

Figure 4 — Radials fashioned from ¼-inch metal tubing and attached to the fixture with 6-32 hardware.

radials in small increments, keeping all lengths equal. Note that each radial's 1-inch mounting screw is part of its length. As the last step, touch up the SWR by again adjusting the radial droop angle.

Conclusion

The 3D-printed fixture eases construction while serving to align and precisely mount all the antenna elements and provide a convenient mast mount. As such, it makes a great teaching tool because its setup procedure is readily demonstrated to a group.

Photos by the author.

John Portune, W6NBC, is an ARRL member and frequent contributor to *QST*. He has been licensed for 53 years and has held an Amateur Extra-class license since 1972. John has a BS in physics and also holds FCC Commercial General Radiotelephone Operator and FCC Radiotelegraph licenses. He retired as a broadcast television engineer and technical instructor at KNBC in Burbank and then from Sony Electronics in San Jose, California. You can reach John via email at **jportune@aol.com** or through his website at **www.w6nbc.com**.

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