The Double Inverted HF Delta Loop Vertical

A Skeleton Slot Vertical with Low-Angle Radiation, Azimuth Gain and Horizontal Polarization for Lower Noise

Here is an excellent example of what a slot antenna can do on the HF bands. This design for me is one of the biggest payoffs of a three-year adventure with slot antennas.

Figure 11-1: Tucked away in a corner of a small yard, it is less noticeable than a small beam on a tower.

HF Verticals

Vertical antennas mounted over ground radials are popular for low-angle radiation, reasonable size, lower cost, and less visibility to neighbors and HOA's. However, they have shortcomings that a skeleton slot as a vertical antenna is excellent at overcoming.

1. Verticals are more sensitive to atmospheric and man-made noise than horizontals, hence they are often comparatively plagued with band noise.

2. Unless they are employed in a multiple-antenna phased array, such as a quad-four, verticals are omnidirectional and have no azimuth/directional gain.

3. For verticals over ground radials, the current is strongest at the bottom, giving rise to higher ground loss than a horizontal beam antenna or a dipole mounted higher.

Here's an HF slot that's easy build. It is a no-radial, small-footprint, ground-mounted vertical HF slot antenna that overcomes the shortcomings and outperform other verticals of the same size, in the same location.

This design:

(1) Has lower sensitivity to atmospheric and man-made noise.

(2) Has directional (azimuth) gain, on the order of a small beam on 20 – 6m as well as workable modest performance on 40m and 80m.
(3) Radiates from higher above ground than ground-mounted verticals with radials.
(4) Retains the low-angle radiation of a conventional vertical.
(5) Is less noticeable than a comparable small HF beam on a tower.

Tucked away in a corner of my back yard, Figure 11-1, my "HOA has made no mention of it in the year since I put it up. It's visible, but to most it does not look like an antenna.

Horizontal Polarization

Respected ham author L. B. Cebik, W4RNL (SK) stated, "Most human-made noise [QRM] [and atmospheric noise, QRN] is vertically polarized and of ground wave propagation. Hence, [conventional] ground-mounted verticals are more susceptible [to noise]. A [horizontally-polarized] antenna generally shows an immediate 3 dB reduction." So while a classical vertical is vertically polarized; a tall narrow delta loop, due to its unique current distribution, is largely horizontally polarized.

Gain

Figures 11-2 is the EZNEC azimuth radiation patterns of the 30 ft. double delta slot over average soil. The individual loops (black), are made of stranded insulated 14 AWG primary copper wire connected in series. Maximum radiation occurs at 45 degrees to the loops. On 6m, the azimuth pattern is a four-leaf clover with similar gain in each of the four lobes. Elevation gains are shown in Figure 11-4

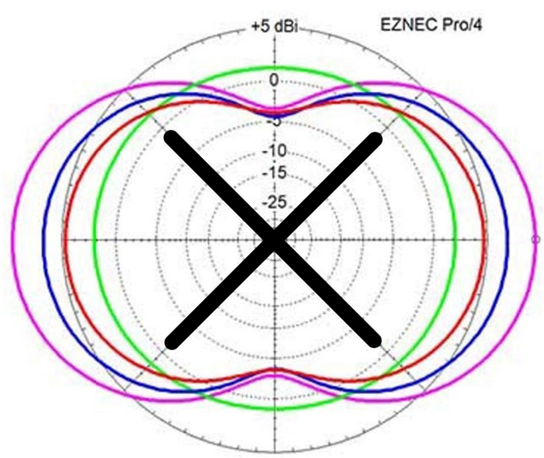


Figure 11-2: EZNEC azimuth radiation patterns, 80m (green), 40m (red), 20m (blue), 10m (violet). Gain in dBi.

A remote-relay switch box, Figure 11-3 permits the user to remotely reverse one of the loops, thereby rotating the bi-directional beam 90-degrees in azimuth for 360 degrees coverage. Low voltage DC (black cable) from the shack remotely controls the relay. It is best to orient the series connection of the loops so that the relay is not energized when the beam is in the most used direction.

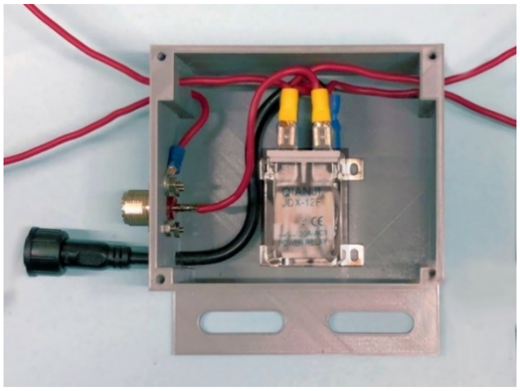


Figure 11-3: Interior of home-brew remote switch box for 90-degree rotation of azimuth gain. Black cable, DC relay control.

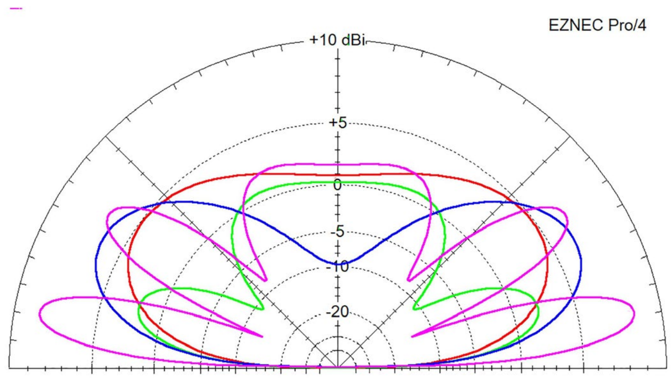
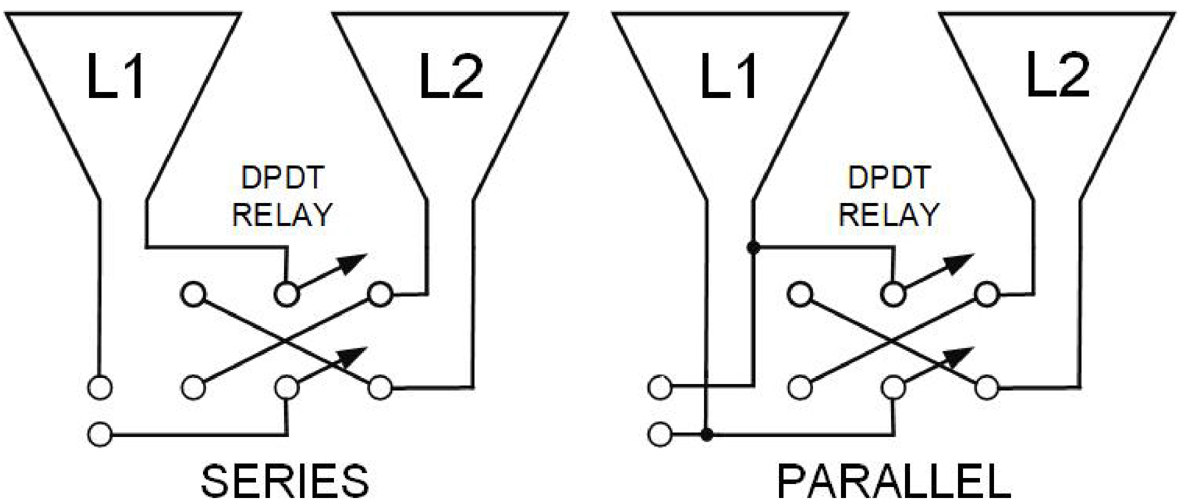


Figure 11-4: Azimuth gains dBi, 20m (red), 15m (blue), 10m (green), 6m (violet). Gain in dBi.



Higher Radiation

A further benefit of the inverted double delta slot delta loop over conventional verticals is that it radiates from higher up the antenna than a conventional vertical. The effective height is more like that of a beam on a tower. This reduces ground loss and improves gain.

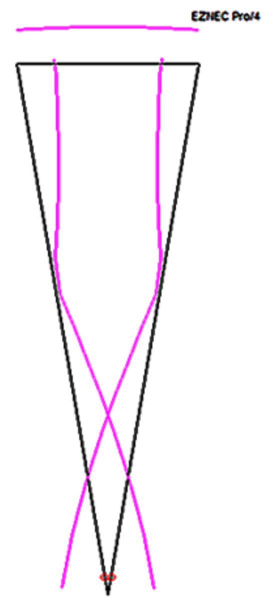


Figure 15-5: EZNEC current display (purple). Amplitude indicated by distance, phase by direction from wire.

To see why this happens, notice in Figure 11-5 that the currents at the bottom of the tall narrow loop are nearly equal and opposite. Therefore, most of the radiation cancels at the bottom. At the top, however, the current is only in the horizontal direction and is unopposed. This is the part of the loop that radiates, and it is also largely horizontally polarized.

GENERAL PRINCIPLE: Delta loops, fed at the base, are better mounted inverted to locate the radiating current at the top.

Feeding the Loops

The total length of the series double loops in this design can vary widely, permitting the antenna to be built to different heights. As is almost always true, the higher the antenna the better. But also to make it easier on the matching network or tuner required, it is better NOT to make the total loop length a resonant ½ or ¼ wavelength on any ham band. The natural resonant frequency of the 30 ft. delta is roughly 22 MHz, and is proportional on other frequencies.

MHz	R	jX
3.8	8000	+8700
7.2	1	-4900
14.2	11	-800
28.5	19	+105
52	108	-335

Figure 11-6: Feed point R and +/- jX by band for a 30 ft inverted double delta slot loop.

Figure 11-6. shows the antenna's complex R and +/-jX feedpoint values by band, measured with a Rig Expert A-1400 antenna analyzer. Note that there is no ideal 50+/-j0 Ohm match impedance to coax on any ham band. This is true for most non-resonant antenna designs. This implies that the loop *must not* be fed directly with coax.

Some type of network is mandatory AT THE BASE of the antenna before connecting a feedline. To permit all-band operation, most builders prefer a base-mounted remote auto-tuner. There are several suitable models on the ham market, such as the LDG-RT600, my preference, Figure 11-7. Alternately, a set of home-brew relay-switched discrete L-match networks, one for each band would also be satisfactory.

Figure 11-7: LDG RT-600 remote auto-tuner and remote directivity switch box. Balun just out of view.

IN NO CASE, however, should one attempt to match the antenna with a tuner in the shack, followed only by a run of coax or other feedline connected directly to the antenna. If matching is not performed at the base of the antenna, even for a short run of low-loss coax, high SWR loss in the feedline will result. In particular, one must not attempt to use an automatic tuner built into a transceiver. This will likely damage the tuner.

Some have inquired if a 4:1 or a 9:1 balun might be substituted for a base tuner. CATAGORICALLY NO. Multi-impedance baluns, despite favorable reputation and popularity when used with certain types of antennas, are not tuners. Baluns are not capable of tuning out high reactance, which is naturally always present in a non-resonant antenna, such this double delta slot.

It is also necessary to provide a 1:1 current choke balun following the tuner or matching network to prevent common-mode currents (RF on the coax shield). Any commercial or home-brew balun of this type, rated for the power, is suitable.

Mast and Ground Mount

The mast shown, Figure 11-8, is [six] telescopic tapering nesting sections of [6 ft.] aluminum tubing each with a 1 ft. overlap. For a taller antenna, the base may be extended with larger diameter nested tubing sections. The 30 ft. mast shown tapers from an outside diameter of [2 in.]. to [1½ in.]. EZNEC simulations show that a metal mast has little effect on the radiation pattern or gain of the antenna.

A tapered telescopic mast is easy to collapse for transport or when the antenna is not in use. One person can easily carry and erect the antenna without assistance. Application of silicon grease or anti-seize compound to the sliding joints is advisable if the mast is to be put up and taken down frequently.

Figure 11-7: Mast and spreaders collapsed. Notice PVC conduit ground support pipe, top just visible. Auto-tuner not shown.

Free-standing, the antenna is supported in the 30 ft. version by 4 ft. of [2½] in. PVC electrical conduit buried in the soil. No concrete is needed at this depth in the soil. A ground auger or a home-brew water drill are easy ways to make the ground hole. It is also a good plan to bury a grounding rod or to use metal ground-support pipe to provide a ground connection for the tuner and any added lightning protection.

For temporary portable use, a single set of light-weight non-metallic guy lines, attached at roughly 10 feet, is sufficient for short-term support. An under-wheel car mount is also a good temporary portable mount.

Bill of Materials, 30 ft. Antenna

Qu.	Description ()
6	6 ft. lengths of thin-wall (.063in.) antenna tubing in 1/8 in. reducing nesting diameters from 2 in. to 1 ½ in.
4	4 ft. pultruded fiberglass tubing spreader arms, ½ in. OD x 4 ft.
125 ft.	14 AWG stranded insulated copper primary wire
1	Mast top assembly (see text)
1	Base-mounted automatic antenna tuner or other matching network
1	1:1 current choke balun
1	(optional) Home-brew remote loop reversing relay in weather proof box.
4 ft.	2 ½ in. plastic or steel EMT conduit for ground mount tube

Materials Sources

Two available sources at the time of writing for both the nesting thin-wall aluminum tubing and the pultruded fiberglass tubing spreader arms were: DX Engineering and HiGain Systems on the internet.

The mast-top assembly requires home-brew fabrication. I own a 3D printer, so I printed the slip-over block in Figure 11-8, shown installed on the mast with the spreader arms installed in Figure 11-9. Figure 11-10 shows a hand-fabricated version of the top assembly made from 1 ft. lengths of ¾

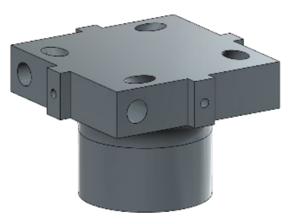


Figure 11-8: 3D printed mast-top assembly. Preferred printing filament: ASA for UV stability

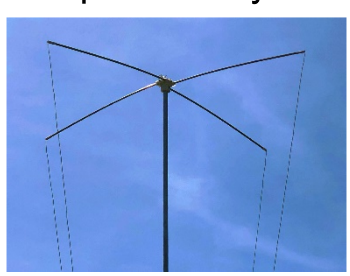


Figure 11-9: Top of mast with fiberglass spreader arms and antenna wire installed.

Figure 11-10: Hand fabricated mast top assembly from ¾ in. square aluminum tubing and bolts.

in. square aluminum tubing held together and secured to the mast with stainless ¼-20 bolts and nuts. The spreader arms slip inside the tubing. Square aluminum tubing is available at most local metals supply dealers.

Assembly Instructions

1. Use a permanent marker to draw a circle around each pole section, one foot from the bottom end. These marks are essential when telescoping the mast to full height.

2. Insert all the pole sections into each other and fix a stainless hose clamp roughly 3 in. from the end of each. When the mast is fully collapsed, the clamps tightened prevent the tube sections from sliding down all the way. You will move and re-tightened them to hold the mast sections at full height.

3. Insert the collapsed mast into the ground support pipe and install the pole-top fixture.

4. Cut two individual lengths of 12 AWG stranded insulated wire, one for each loop.

5. Place the end caps on the four spreaders and thread the two loops through a spreader and through the top fixture. Then pass each loop wire through the opposing spreader. Do not insert the spreaders into the top fixture at this time.

6. Pull each loop through the top fixture and spreaders until both wire halves are equal.

7. Insert the spreaders into the top fixture and tighten the securing bolts. Adjust each loop until there is only a small arch crossing the top of the fixture.

8. Lay out all four wires on the ground in a straight line, not crossing. Avoid dropping the wires in a random pile. Wires have an innate tendency to snarl and kink. Keep your eye on them as you elevate the mast to keep them straight.

9. Then begin by pushing up the upper-most section (smallest-diameter) a short distance. Hold the section with your hand to prevent it from slipping down. Then loosen the stainless clamp and slide it down as you push the section farther up. Stop immediately when you reach the mark you made near the bottom of the section. Then re-tighter the hose clamp.

10. Repeat step 10 until all pole sections are at full height.

11. At the bottom, gather and insert the antenna wires into the securing collar, directly below the respective spreaders. Gently snug up all wires, securing each with a single wrap around the collar and a further wrap around the down wire.

12. Cut each wire to roughly 6 in. beyond the securing collar and crimp on a male ¼ in. disconnect terminal. These terminals will connect to female ¼ in disconnect terminals on the wires coming from the directivity switch box.

13. Attach the auto-tuner and directivity switch box at the bottom of the mast. Connect the feed coax, the short coax jumper, the 12 VDC relay control cable and the antenna wires as shown in Figure 5.

14. Install a 1:1 current balun after the tuner with an additional short coax jumper. Add lightning protection if desired.

15. Ground the ground terminal of the tuner to the ground rod or aluminum pipe section buried in the ground.

Possible Modifications

As mentioned above, EZNEC modeling shows that improved performance can be achieved by extending the antenna to a height of 40 or even 50 ft. A taller version is also easier for the tuner to tune on the lower frequency bands. Add larger-diameter nesting tubing sections at the bottom, more wire and longer-heavier top arms. Guying is advisable at greater height.

For optimum efficiency and gain, the width of the delta should be roughly 1/3 of its height. 4 ft arms are suitable for a 30 ft. delta and 7 ft for 40 ft.. Alternately, a commercial steel or heavy-duty fiberglass masts is very suitable. Two popular user choices are the MFJ 1906HD 38 ft. heavy-duty push up telescopic fiberglass mast and the Channel Master CM1850 40 ft. telescopic push-up steel mast. A very light-weight and highly portable version can be realized with a carbon fiber mast. However, do not make the wire too fine or the overall antenna efficiency will suffer. For this lighter version, consider using ¼ in. fiberglass bicycle safety flag whips for the top spreaders.

On-air experience, and testimonials from around the world, have shown that a tall narrow horizontally polarized inverted double delta loop vertical is an excellent performer. It has the same low-angle radiation as a conventional vertical, up to 3dB less band noise and also less soil loss due to near-top radiation. Plus, it has nearly the gain of a small beam on a small tower. As a portable, it is especially well suited for field day and other temporary situations. The collapsed mast, wire, cables, tuner and hardware travel well and are quickly set up. In a permanent installation, this antenna is also far less noticeable than a small beam of comparable performance on a tower.

John Portune W6NBC, 519 W. Taylor St unit 111, Santa Maria CA, 93458, jportune@aol.com, w6nbc.com.