The 3-D Folded Loop Antenna

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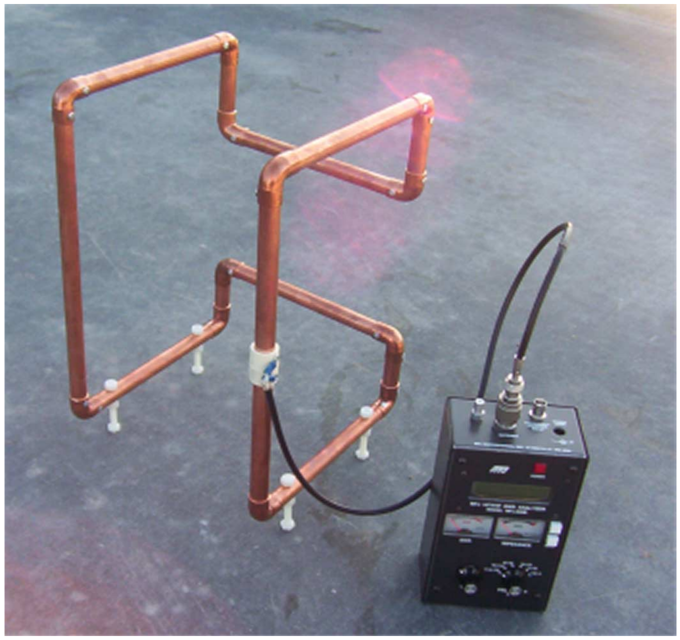


Introduction

This article will introduce you to an antenna I call the *3-Dimensional Folded Loop*. This antenna is the result of my continuing efforts to compact full-size antennas by folding and bending the elements. I will first describe the basic 3-DFL and then provide construction details for the 2-meter and 10-meter 3-DFL antennas.

Here are some features of the 3-DFL:

- Reduced height and footprint
- Full-sized antenna performance
- Wide bandwidth
- Ground independent
- Can be built using standard hardware store parts

Description

The 3-D Folded Loop, or simply the 3-DFL, is a one-wavelength loop that is reduced in height and width by being folded into *three* dimensions. A 28-MHz loop that is normally 9 feet on a side becomes a box-shaped antenna that is 3 by 3 by 5 feet. It exhibits performance that is competitive with a ground plane yet requires only 15 square feet of ground area versus 50 for the ground plane. So, compared to a ground plane it is only 60% as tall and has a footprint only 30% as large. And the 2-meter 3-DFL is so compact it can be placed on a table and connected to your HT for added range and reduced RF at the operating position.

3-DFL Theory of Operation

The familiar one-wavelength square loop is shown in **Fig. 1** and is fed in the center of one vertical wire. Note that the current in the vertical wires is high while the current in the horizontal wires and is low. The magnetic fields produced by the two vertical wires are high and in-phase while the magnetic fields produced by the two vertical wires are much lower. Therefore the vertical wires do virtually all of the radiating. Since the horizontal wires don't contribute much to the total radiation, we are free to fold them without greatly affecting the radiation characteristics of the loop. Also note the reduced current near the ends of the vertical wires. These ends can also be folded without greatly affecting the performance.

Fig. 1

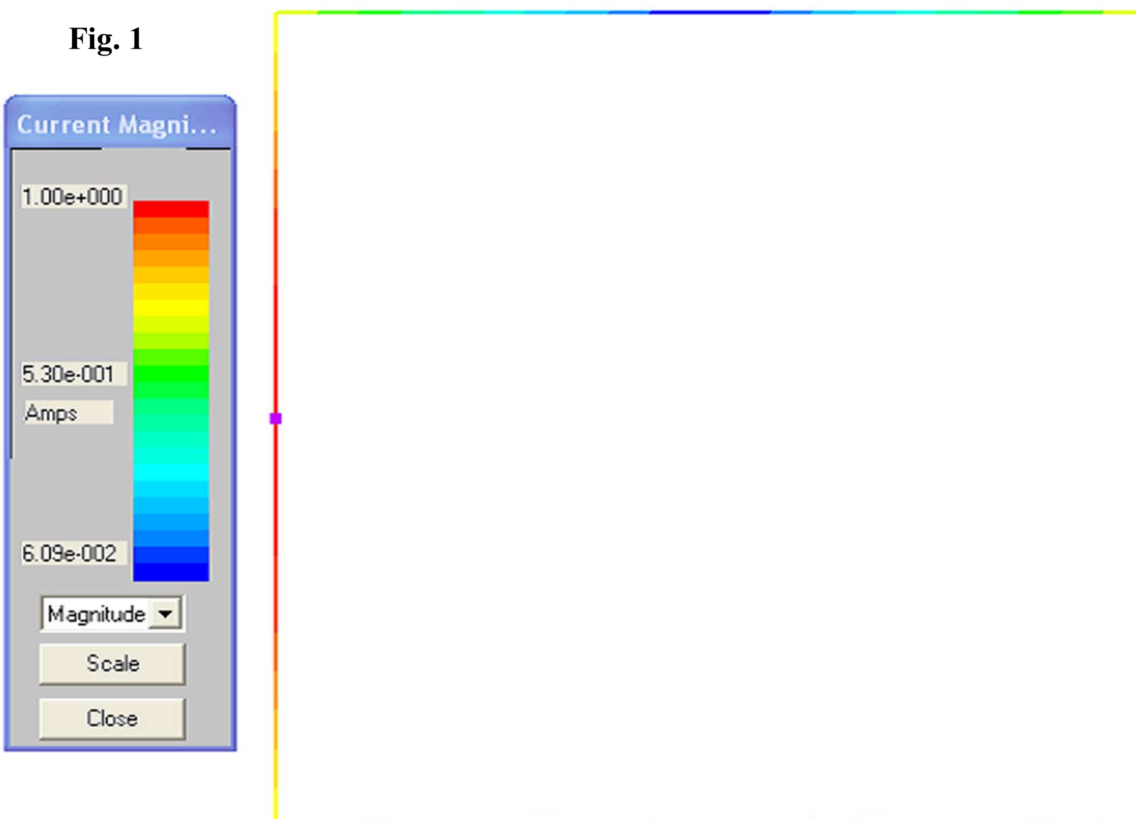
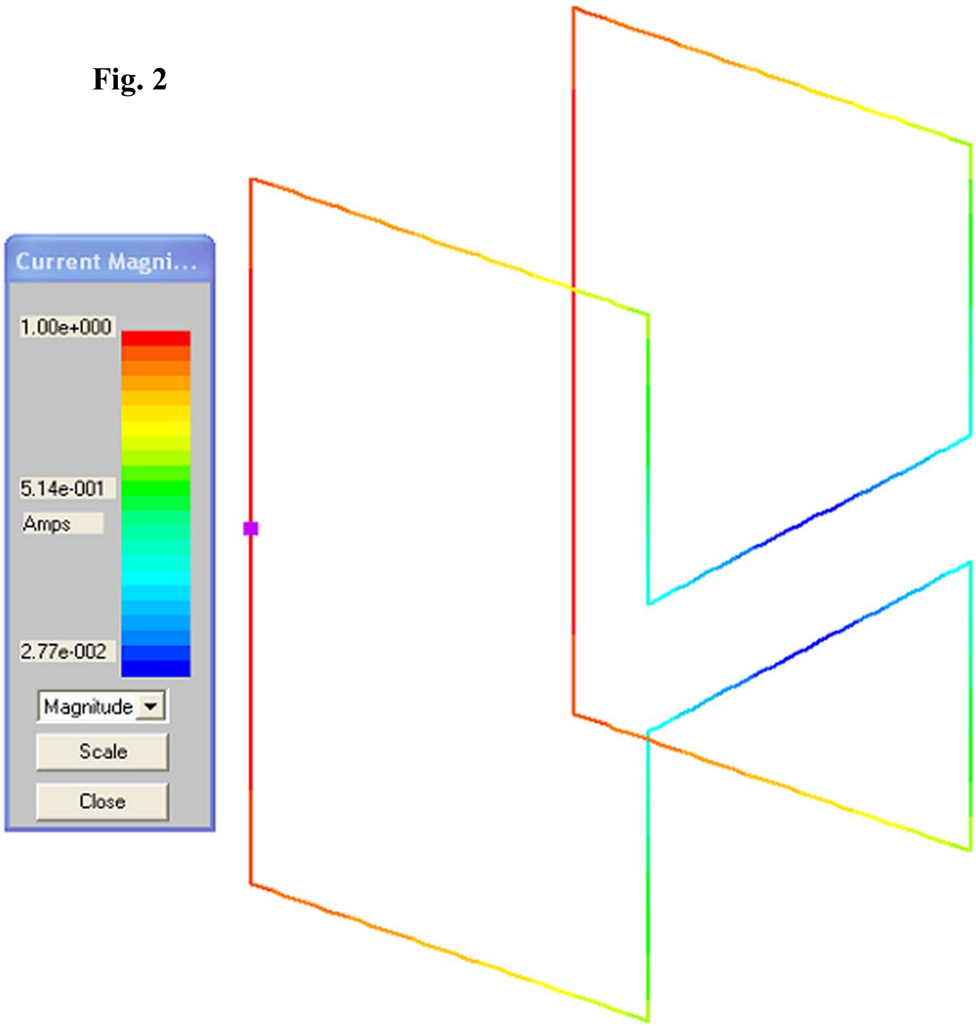


Fig. 2 shows the one-wavelength loop folded up into a 3-DFL. The magnetic fields produced by the horizontal wires are out-of-phase and tend to cancel. This lowers the radiation resistance and raises the antenna Q. A standard one-wavelength loop has a radiation resistance of 125 ohms. The 3-DFL-radiation resistance is lower and can be adjusted by changing the ratios of the height, width, and depth. The dimensions shown in this article provide a radiation resistance of approximately 50 ohms.

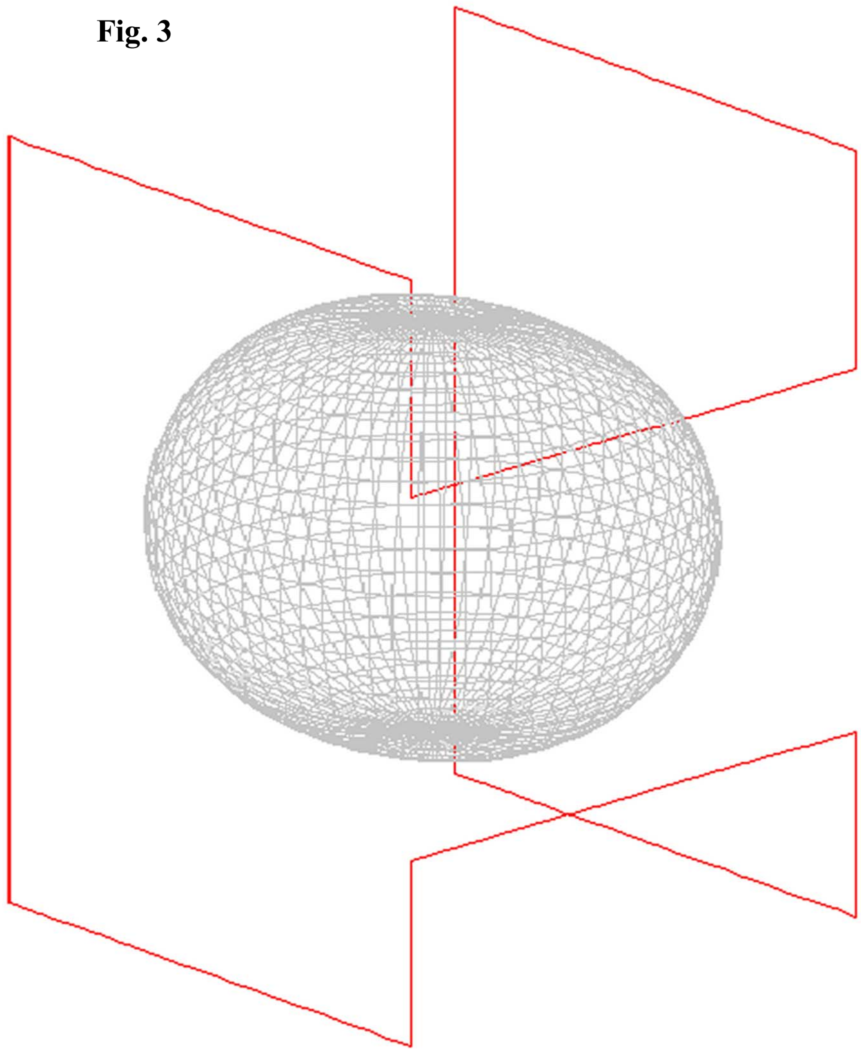
Fig. 2



Radiation Pattern and Polarization

The 3-DFL free-space three dimensional radiation pattern is shown in **Fig. 3**. Since all parts of the antenna radiate to some degree, the pattern is nearly isotropic with a front-to-side ratio of only 1.6 dB. The free-space broadside gain of a standard one-wavelength loop is 3.3 dBi while the broadside gain of the 3-DFL is 1.6 dBi. The 1.7 dB gain difference is due to the 3-DFL radiating in all directions. Since both the vertical and horizontal portions radiate to some degree, the electric field polarization is a mixture of vertical and horizontal polarization. Therefore, the 3-DFL can be considered to have *eliptical* polarization.

Fig. 3



Modeling the 3-DFL

NEC-2 can accurately model this antenna. The only limitation I ran into was the large wire diameter used for the actual 2-meter antenna. NEC-2 requires that the minimum segment length be equal to or preferably much longer than the wire diameter. Convergence testing, along with measurements of the actual antenna, showed that the dimensions shown in **Table 1** yield an accurate model.

NEC-2 Model Parameters, 146 MHz 3-DFL, lengths in inches

Wire	Seg.	X1	Y1	Z1	X2	Y2	Z2	Dia.	Conduct	Src/Ld
1	20	0	0	0	0	0	12.25	0.625	Copper	1/0
2	13	0	0	12.25	8.375	0	12.25	0.625	Copper	0/0
3	6	8.375	0	12.25	8.375	0	8.75	0.625	Copper	0/0
4	13	8.375	0	8.75	8.375	8.375	8.75	0.625	Copper	0/0
5	6	8.375	8.375	8.75	8.375	8.375	12.25	0.625	Copper	0/0
6	13	8.375	8.375	12.25	0	8.375	12.25	0.625	Copper	0/0
7	20	0	8.375	12.25	0	8.375	0	0.625	Copper	0/0
8	13	0	8.375	0	8.375	8.375	0	0.625	Copper	0/0
9	6	8.375	8.375	0	8.375	8.375	3	0.625	Copper	0/0
10	13	8.375	8.375	3	8.375	0	3	0.625	Copper	0/0
11	6	8.375	0	3	8.375	0	0	0.625	Copper	0/0
12	13	8.375	0	0	0	0	0	0.625	Copper	0/0

Table 1

Ratios and Formulas

Designing this type of antenna with NEC requires a bit of cut-and-try. The ratios between the lengths of the various sections determine the radiation resistance and gain. And there is no perimeter formula that works for all combinations of length ratios and wire diameters. However, a starting point is to make the height 0.15 wavelengths and the total wire length (in inches) 13000/F_{MHz}.

The 2-meter 3-DFL

The 2-meter 3-DFL is a great addition to any HT and provides several dB of gain over a rubber duck, but it costs only five dollars. In addition to being more efficient, the 3-DFL can be placed away from the operator to reduce RF at the operating position. And, the antenna is small enough to be placed on a table or a bookshelf.

Construction and Assembly of the 2-meter 3-DFL

The 2-meter 3-DFL can be built using standard copper tubing available at most hardware stores. The materials are shown in **Table 2**, the cutting dimensions in **Table 3**, and the final antenna dimensions in **Table 4**. Don't worry if your antenna dimensions are off by a bit. The final tuning adjustment will take care of it. The 50-ohm coaxial feedline is connected to the center of a vertical section. This vertical section is made of two equal-length copper tubes joined by a PVC coupler. You can assemble the parts and secure the joints using pop rivets, self-taping screws, or solder. Leave the bottom short vertical tubes unsecured so that tuning adjustments can be made.

2-Meter 3-DFL Material List

QTY	MATERIAL
1	½-inch copper tubing, 10' length (77 inches is used)
12	½-inch copper elbow
1	PVC coupler for ½-inch copper tubing
4	¼-20 nylon bolts, 2 inches or longer
8	¼-20 nylon nuts
24	rivets

Table 2

2-Meter 3-DFL Tubing Cutting Table

QTY	MATERIAL	L	Tube
1	½-inch copper tubing	12"	Vertical, long
2	½-inch copper tubing	5.875"	Vertical tubes, feed line
6	½-inch copper tubing	7.5"	Horizontal
2	½-inch copper tubing	2.0"	Vertical, short bottom
2	½-inch copper tubing	3.0" (2.5" nominal)	Vertical, short top

Table 3

2-meter 3-DFL Final Dimensions, tubing center-to-center

Height	12.25"
Width	8.375"
Depth	8.375"
Folded Sections	3.0" & 3.5"

Table 4

Using a Balun

A balun it not needed to obtain good performance from the 3-DFL. A NEC-2 simulation reveals that the current, on the shield of a ¼-wavelength coaxial cable, to be 30 dB below the maximum antenna current. Actual testing showed that the coaxial cable could even be taped to the vertical feed tube with very little affect. So, simply attach the coaxial cable directly to the feedpoint and route it as needed.

Tune-up

With a 2:1 VSWR bandwidth of 8 MHz, the 2-meter 3-DFL can be built per the cutting table and it will probably work just fine. But, if you want it tuned exactly the length of the short vertical tubes can be adjusted for resonance at the desired frequency. Tune-up requires a 2-meter rig and an SWR meter. Alternatively, an antenna analyzer can be used. The measured VSWR is shown in **Fig. 4**.

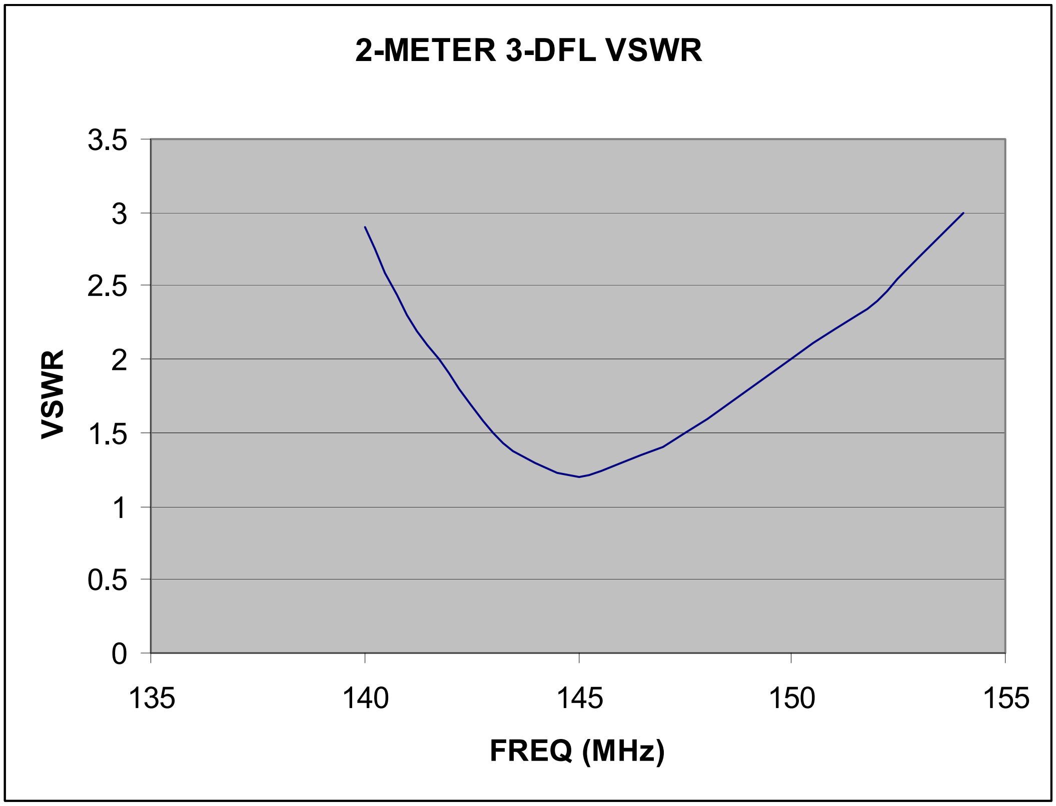


Fig. 4

The 10-meter 3-DFL

The 10-meter version of this antenna provides good performance and is just as easy to build. It can be built using the same type of tubing and hardware as the 2-meter antenna.

***Somewhat* Ground Independent**

Being a loop, the 3-DFL does not require a counterpoise or a ground connection. This is not to say that the 3-DFL is immune to earth losses. When placed near earth ground, some of the antenna field passes through earth, resulting in some loss. The 3-DFL will work well when placed only one foot above earth ground, but performance will improve as the height is raised. Gain as a function of height over average ground, for three different take-off angles, is shown in **Fig. 5**. For best DX performance the base can be placed 8 feet above earth ground.

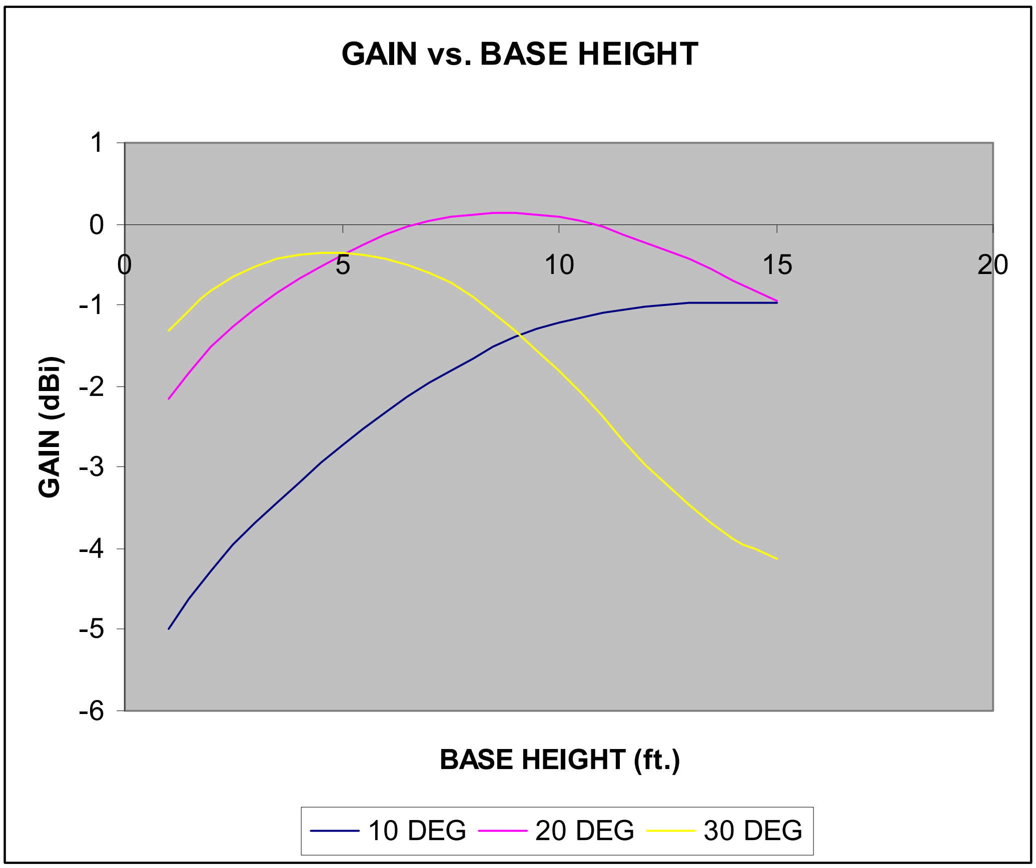


Fig. 5

Radiation Resistance and Height

Interaction with earth ground does affect the radiation resistance of the 3-DFL. As shown in **Fig. 6**, the radiation resistance increases as the antenna is brought closer to ground. The antenna can be designed to provide an input impedance of 50-ohms at any height above ground. The dimensions shown here result in 50-ohms when the antenna is placed one foot above average ground. For greater heights above ground the 3-DFL vertical dimensions can be increased to raise the radiation resistance to 50 ohms.

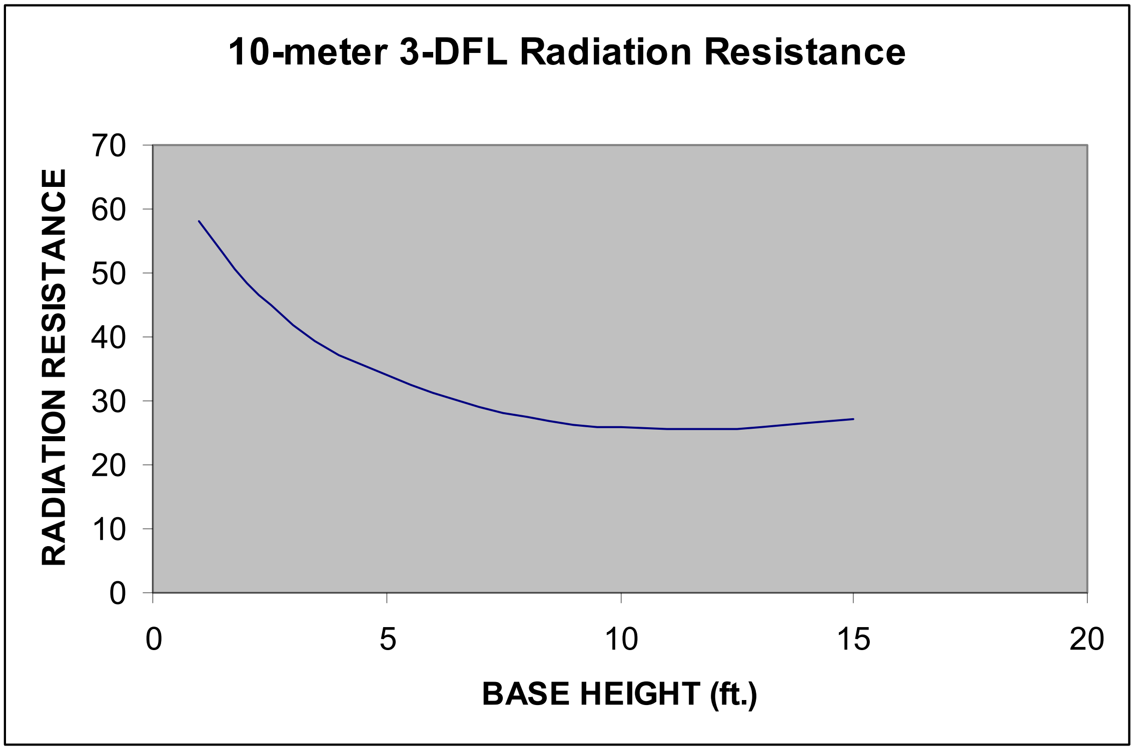


Fig. 6

10-meter 3-DFL Elevation Pattern

Notice the mixture of horizontal and vertical polarization shown in the elevation pattern (**Fig. 7**). There is good high-angle pattern fill that would be great for low band work.

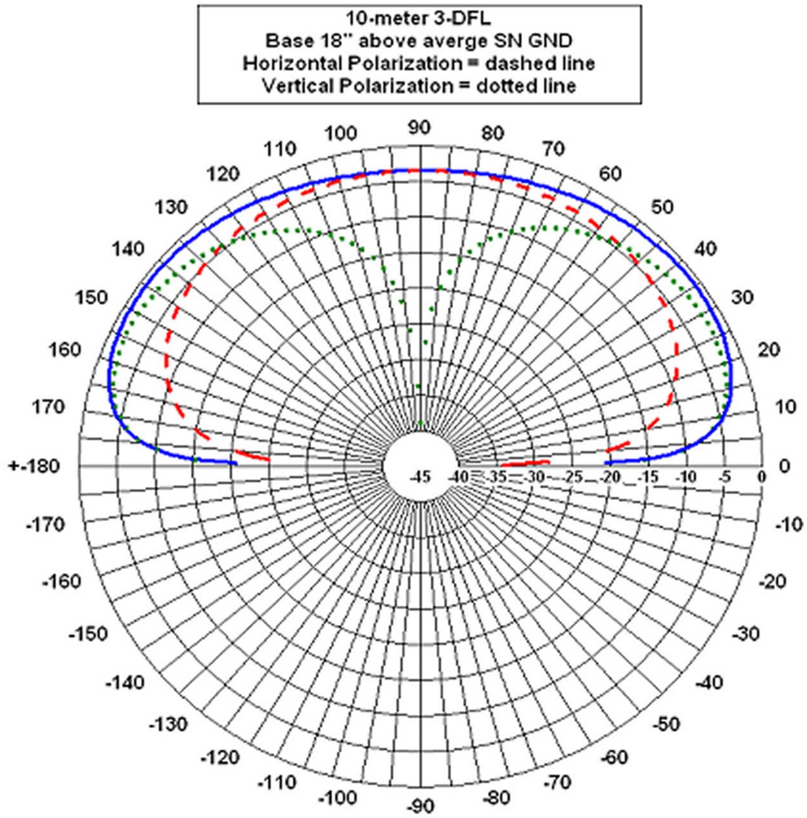


Fig. 7

Construction of the 10-meter 3-DFL

The 10-meter version of this antenna was built using ½-inch copper tubing and the top folded section needed to be braced with a piece of PVC tubing. Larger diameter tubing is recommended to make a sturdy antenna. See **Table 5** and **Table 6**.

10-meter 3-DFL Material List

QTY	MATERIAL
4	copper tubing, 10' length
12	copper elbow
1	PVC coupler for the copper tubing
4	PVC pipe for the brace and legs
24	rivets

Table 5

10-Meter 3-DFL Tubing Cutting Table for 28.5 MHz

QTY	MATERIAL	L	Tube
1	copper tubing	56"	Vertical, long
2	copper tubing	27.875"	Vertical tubes, feed line
6	copper tubing	35"	Horizontal
4	copper tubing	25"	Vertical

Table 6

10-meter 3-DFL Tune-up

Tuning requires a rig and an SWR meter. Or, an antenna analyzer can be used to speed up the process. Adjust the short vertical sections for the desired frequency. The measured and simulated VSWR are shown in **Fig. 8**.

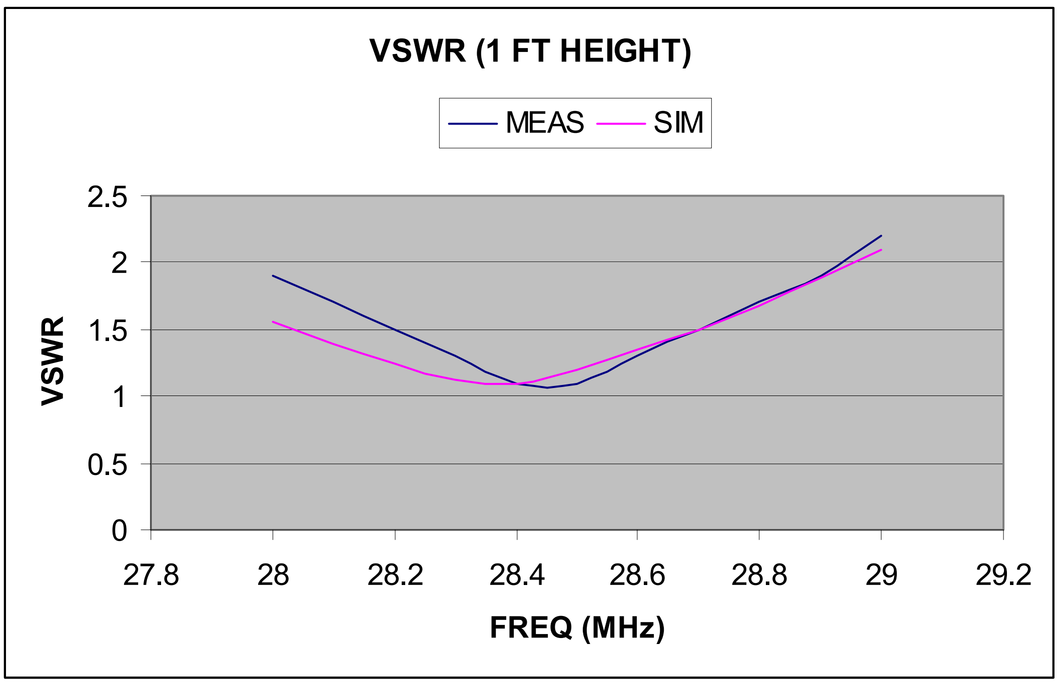


Fig. 8

Scaling to Other Bands

Electrically the 3-DFL can be scaled to any frequency. Mechanically, the materials used for the 10-meter antenna will be suitable for something as large as a 15-meter 3-DFL or as small as a 2-meter 3-DFL. For lower bands, and good wind survival, aluminum tubing would be the ideal material.

Conclusion

You now have a new addition to your antenna "tool box" that just might be the antenna to solve that space limitation. So go ahead and give the 3-DFL a try! **–30-**

References

The ARRL Antenna Book, 18th Edition

Brief Biography of Author:

- **1979-1988 Hughes Aircraft ~ Designed a wide variety of test equipment for high-power microwave tubes including high voltage and RF designs.**
- **1988-1995 Tektronix ~ Worked on microwave hybrids, PLL design, and in-house test equipment design for the 2784 Spectrum Analyzer. Sustaining engineering and switching power supply design for several oscilloscope lines. Designed a 0.025 lambda monopole for a commercial control device.**
- **1995-1997 Advanced Energy ~ Sustaining engineering for multi-kilowatt plasma power supplies.**
- **1997- present Micron Technology ~ A Micron Fellow since 2001, Analog and EMC engineering to support IC manufacturing.**
- **Five FCC licenses including a commercial radiotelegraph license.**
- **Certified NARTE (National Association of Radio and Telecommunications Engineers) Electromagnetic Compatibility Engineer.**
- **As part of my amateur radioactivities I have built small antennas since 1972.**
- **Active member of the GARDS, an International Group of compact antenna researchers.**

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