Design of a Delta Loop by K0ZR
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Introduction

Why a Delta loop? A Delta loop can be made to radiate a horizontal or vertically polarized signal. In most cases one chooses the vertical polarization, hoping to work those lucrative DX stations. Implied by this remark is the low angle of radiation emanating from a vertically polarized Delta loop. If designed properly, an agreeable VSWR is possible without additional matching.

In side-by-side tests, my 80m Delta loop compares very favorably with my full-size 80m vertical which boasts 90 quarter-wave, or longer, radials. Broadside to the Delta loop, one gets ~ 4 dB of gain over the omnidirectional vertical, but one suffers the negative of this advantage in directions 90 degrees to the plane of the delta loop.

Phasing vertical antennas appears to be simpler and less complex than phasing a pair of delta loops, from simulations I have performed. It appears the degree of coupling with the full-wave Delta loop is so high that the bandwidth of the pair is impaired compared to a phased pair of vertical antennas.

What Next?

Using EZNEC, it is rather straight forward to come up with a three-segment design forming a Delta loop. It is not as easy to determine where to place the wavelength of wire, in other words, how much in the base of the triangle and how much in the two ascending sides of the triangle. This becomes increasingly important as the antenna's frequency band is lowered, such as for 80m. Most amateurs are limited in the height they have to work with so "blindly" going after an equilateral triangle configuration will result in, likely, immediate problems once one recognizes how high the apex must be.

Considered here are the simple calculations for an 80m Delta to ensure, given an overall length of wire, things come out "right" with enough wire for the baseline and for the two ascending sides.

Next comes VSWR. One is not guaranteed an optimal VSWR just by getting the length of wire used to add up to one wavelength. EZNEC simulation data presented herein will show that with proper selection of height, one can obtain close to a perfect match at the antenna's resonant frequency.

Trigonometry of the Delta

Consider Figure 1 for the following discussion. We assume the two ascending legs of the delta are equal length and the remainder of the wire (assuming one wavelength at F) forms the baseline. The angles forming the three corners of the delta are somewhat critical in that VSWR will be shown to vary with this angle (other parameters change as well, of course).

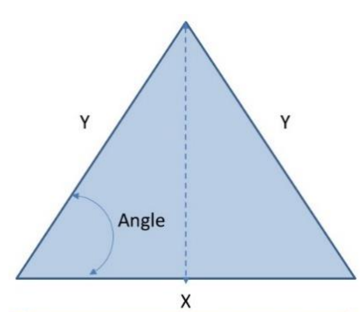

Figure 1 Delta Geometry

Using simple trigonometry, we see that

$$2Y + X = C \qquad \frac{X/2}{Y} = \cos(\theta) \qquad \rightarrow \qquad X = 2Y\cos(\theta)$$

Substituting the value for "X" into the far left expression, thus describing everything in terms of "Y", we get:

$$Y = \frac{C}{2\left(1+\cos(\theta)\right)} \quad \text{and} \quad X = C - 2Y \quad \text{where C is loop circumference}$$

At a frequency F_{MHz} it is known (see Handbook) that for a loop, $C \approx \frac{1005}{F_{MHz}}$

A simple Excel spreadsheet was constructed to make these calculations for dimensions. The information was then entered into EZNEC 6.0 and the simulations performed.

There are many variables differing from ideal which can and do give results slightly different in the real world. The most important aspects of the analysis here are:

1) Provides dimensions of wire so that it is possible to close the physical loop and not have too much or too little wire "left to do so"
2) Provides trend information related to gain, takeoff angle, resonant frequency, and VSWR

And one final note before getting into the simulation data. Whenever the "angle" is described, this is the angle between the Delta baseline and one of the ascending segments to the Delta's apex.

The next several graphs are examples of the output obtained using EZNEC. Simulations for the various configurations were conducted to investigate the impacts of leg lengths, Delta height, and feed-point.

Angle of 30°

Frequency		3.53		Circumference		293.3025
Base Angl	30					
Angle at Top						
Y	78.59018					
X	136.1222		X/2	68.06109		
h	39.29509					
Above Ground		6				
Total Hgt to Apex		45.29509				

Figure 2 Geometry

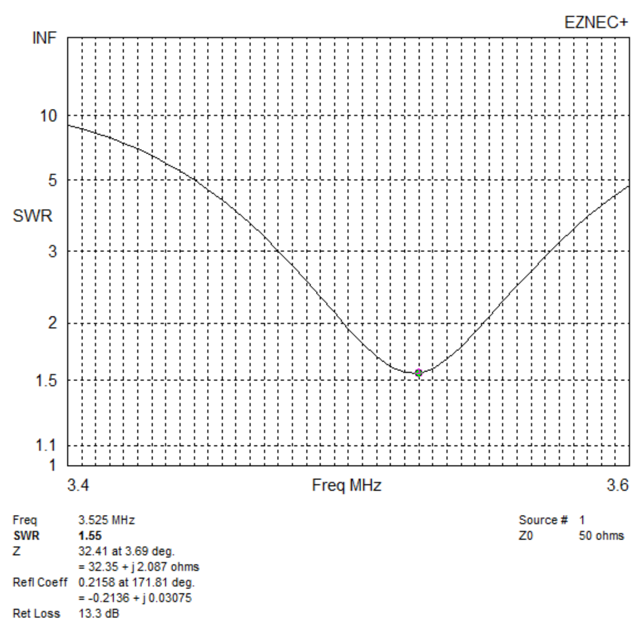

Figure 3 VSWR for Angle = 30°

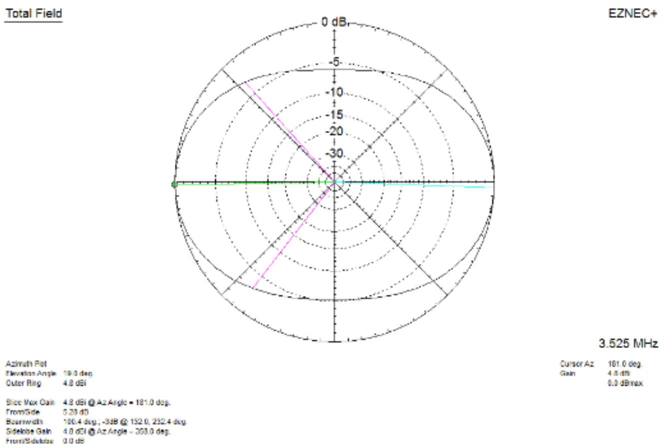

Figure 4 Azimuth Pattern for Angle = 30°

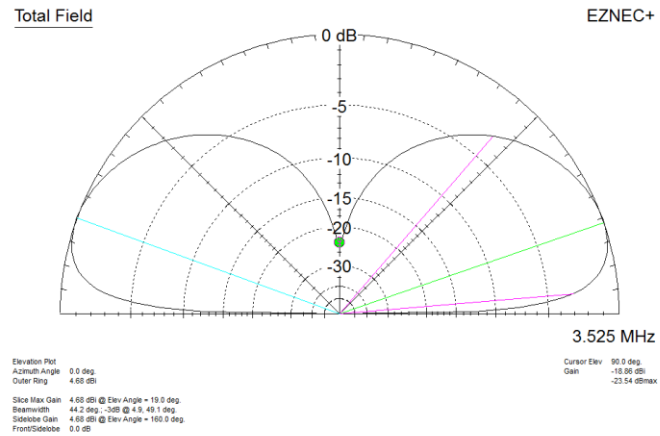

Figure 5 Elevation Pattern for Angle = 30°

Trends from Simulation Results

The raw data from all the simulations is captured at the end of this write-up. The process in developing this data was that the total circumference of wire was left unchanged for ALL runs, equal to 293.3 feet. Several summary remarks can be made from this simulation data.

Figure 7 illustrates an important concept: there is an optimum angle between the delta baseline and the two ascending segments to attain minimum VSWR. It is seen that ~ 35° is optimum for obtaining the best VSWR. There are other factors, although not touched upon here, that one would possibly wish to consider, one being bandwidth over which tuneable/matchable conditions occur.

Figure 8 shows that as this same angle is increased, the resonant frequency of the Delta loop decreases. The impact of angle on the resonant frequency of the 80m Delta loop design is shown here.

Figure 9 shows that as the feed point nears a corner vertex of the Delta loop, the depth of the notch decreases. The result is more concentration of power radiated at lower elevation angles.

Therefore, the following points can be made:

- An optimum angle of ~ 35° results in lowest VSWR
- Smaller angles lead to higher resonant frequencies of Delta
- As the feed point location gets closer to its associated Delta corner, radiation is improved at low elevation angles

Figure 6, to the right, is the EZNEC illustration of a Delta Loop. The small red circle is the feed point, in this case 18% up the length of the ascending leg. The purple lines illustrate the current distribution.

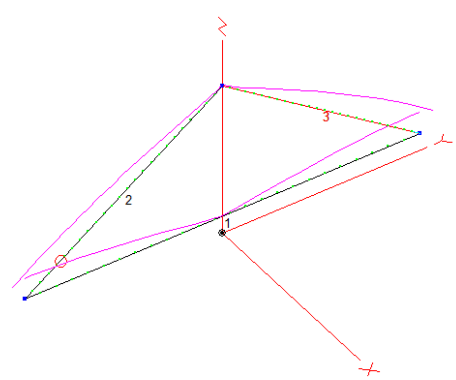

Figure 6

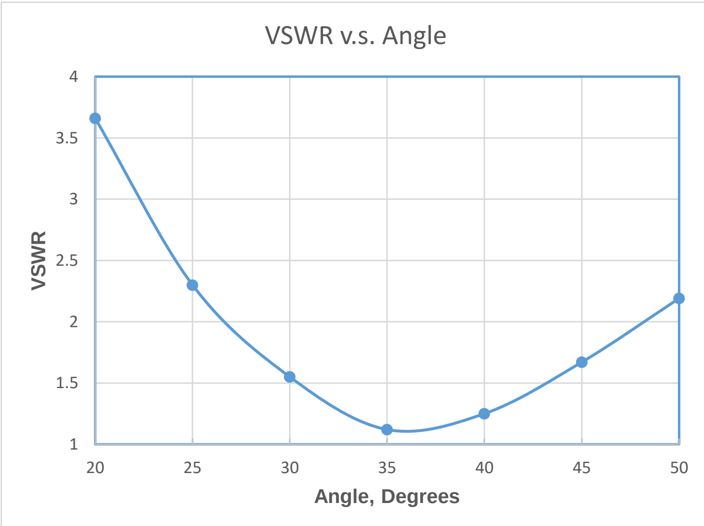

Figure 7

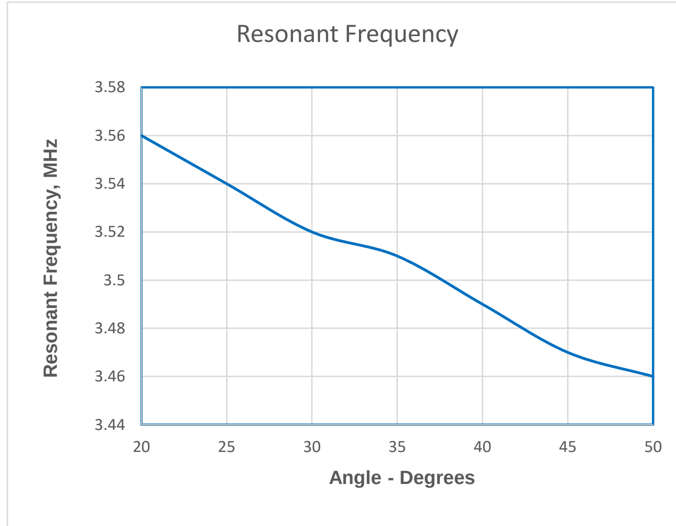

Figure 8

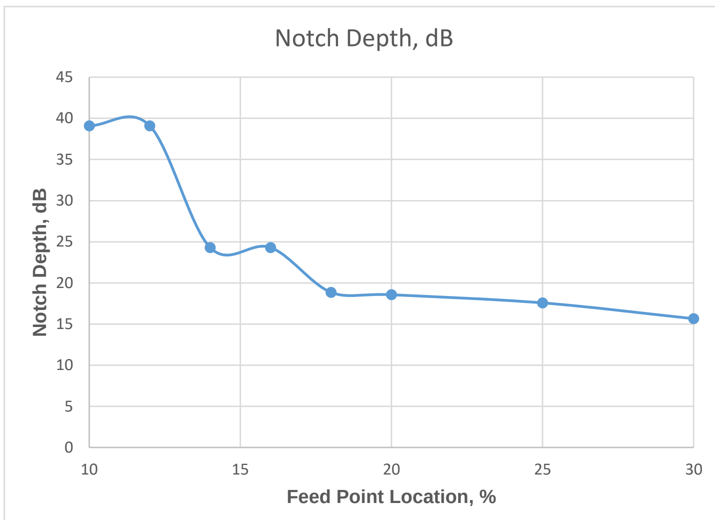

Figure 9

Conclusions

Although more tuning is required for my exact requirements, i.e. 3.53 MHz, the snapshot from my SARC-110 below in Figure 10, shows that the VSWR is 1.5:1. Originally I had been attempting to simultaneously get the Delta loop apex as high as possible while keeping the baseline around 6 feet above ground. No adjustments seemed to reduce the VSWR from around 2.2:1. At that point I took the time to assemble the simple Excel spreadsheet herein and run the multiple EZNEC simulations just described, to better understand what parameters were affecting VSWR. On my first attempt, using an angle = 35°, my results are shown in Figure 10 below.

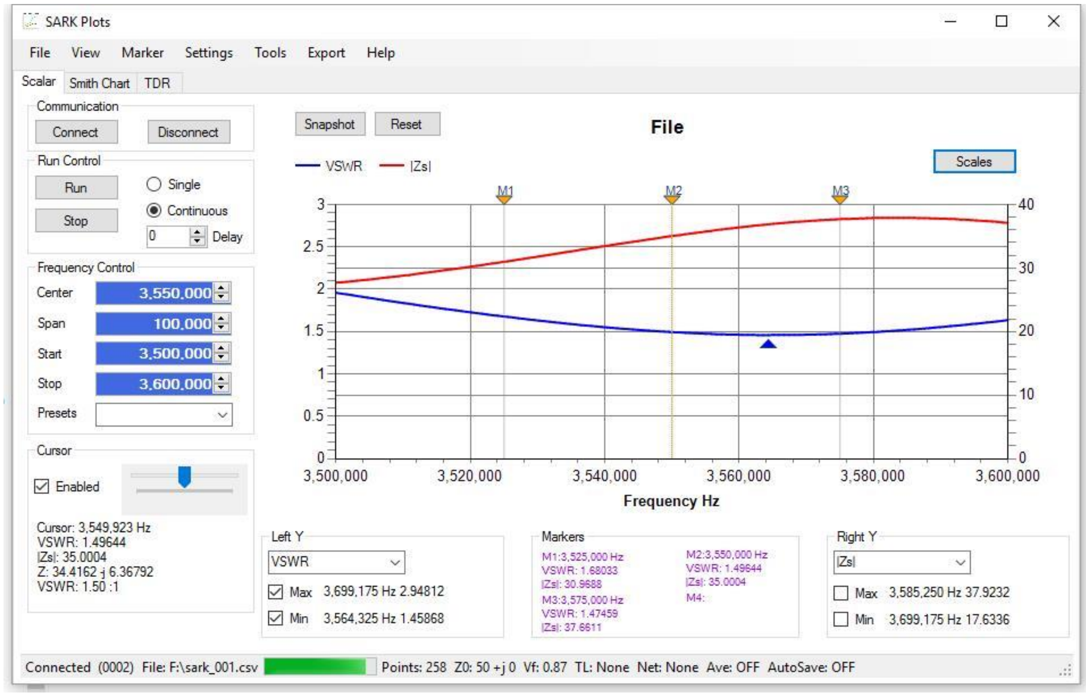

Figure 10 Almost Complete 80m Delta Loop

One obviously asks why is the VSWR 1.5:1 rather than 1.1:1. A number of factors are responsible. First, and foremost, the Delta loop is in close proximity to multiple trees, some branches almost “touching” the antenna. This is clearly not “free-space”. Additionally, the ground below the Delta’s baseline is cupped-up, being highest on the two ends and lowest in the center. The difference is a good two feet or more between each end and “center”. If one wishes to duplicate the data herein, I used ZERO copper losses in all simulations.

Design of K0ZR 80m Delta Loop

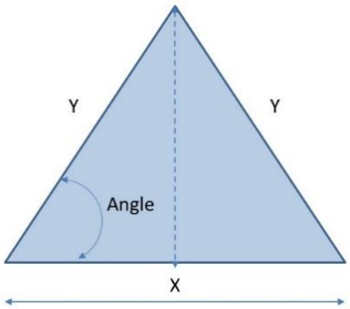

Figure 11 General Delta Loop

Looking at Figure 11 to the left, the following dimensions are in use:

Angle: 35°

Y = 80.6 Ft   X = 132 Ft

H = 46 Ft (distance from baseline of delta to apex)

Tot Hgt = 52 Ft (Delta base 6 ft above ground and H = 46)

In the end, some adjustment to the position of the insulator on the bottom-left corner was made to accommodate slack.

Raw Simulation Results

Baseline Height	6 Ft			
Angle	**Res Freq**	**VSWR**	**Gain, dB**	**Elev Ang**
20	3.56	3.66	5.02	20
25	3.54	2.3	4.92	20
30	3.52	1.55	4.8	20
35	3.51	1.12	4.67	20
40	3.49	1.25	4.54	19
45	3.47	1.67	4.35	18
50	3.46	2.19	4.18	18

Baseline Height	8 Ft			
Angle	**Res Freq**	**VSWR**	**Gain, dB**	**Elev Ang**
20	3.57	3.68	5.03	20
25	3.55	2.31	4.94	20
30	3.53	1.57	4.83	20
35	3.52	1.11	4.68	19
40	3.5	1.25	4.53	19
45	3.49	1.65	4.38	18
50	3.475	2.18	4.19	18

Angle	VSWR
20	3.66
25	2.3
30	1.55
35	1.12
40	1.25
45	1.67
50	2.19

Angle	Res Freq
20	3.56
25	3.54
30	3.52
35	3.51
40	3.49
45	3.47
50	3.46

Feed Point %	Notch Depth, dB
10	39.1
12	39.1
14	24.3
16	24.3
18	18.86
20	18.56
25	17.57
30	15.65