

**The Long Wire Loop: an  
Omnidirectional, Multiband, Low Angle  
Radiator**

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## **Introduction: Something Old and Something New**

As the name implies, long wire loop is a marriage of the venerable long wire antenna and a horizontal loop. Each antenna has both advantages and disadvantages, but as shown by the results of this theoretical study, when combined together you get all the advantages of both and the disadvantages of neither. The end result is a multiband antenna that has a nearly omnidirectional radiation pattern, presents a reasonable feed impedance at all harmonics (not just the odd ones), and has a very low takeoff angle for excellent DX performance. The mechanism responsible for the low takeoff angle is suppression of vertical radiation, a process commonly used to produce gain on the horizon. The antenna has a feed point that presents a short at DC for elimination of static buildup and rain noise and also provides excellent rejection of out of band signals, giving very quiet receive performance. Added to this is the fact that the antenna is as simple as it is cheap, consisting only of wire and a few supports. So what's the downside? This antenna is BIG. But if you have lots of room the long wire loop is hard to beat from the standpoints of frequency and directional coverage, performance, and cost.

## **Theory of Operation: A Tale of Two Antennas**

### **1. The Long Wire**

Long wire antennas have been around nearly since the inception of radio. Usually configured in straight lines in the fashion of a dipole, these antennas are characterized as having a radiation pattern broken up into lobes, with strong peaks in some directions and deep nulls in others. If the long wire is operated at a resonant length consisting of an odd number of half wavelengths, the antenna will present a low feed impedance in the center of any one of the half wave sections, and there will be as many lobes on each side of the antenna as there are half wavelengths. On even harmonics, the same feed point presents a hard-to-match high impedance and the pattern still breaks into lobes (though with a different schedule). The pattern of a typical long wire antenna is shown in one of the traces in Fig. 1. At very long lengths, most of the energy tends to be directed in a small angle off the ends of the wire with less contained in the multi-lobed broadside pattern. This is the effect giving rise to the V-beam and rhombic, but that is another story. Thus as an antenna, the long wire provides consistent feed impedances only on odd harmonics and has a radiation pattern that gives excellent coverage in some directions, none in others.

### **2. The Loop**

Loop antennas take on different characteristics depending on how long their circumference is compared to a wavelength. The most common format in amateur practice is a loop with one wavelength circumference. Oriented vertically in a square shape the one-wavelength loop offers a bit over two dB of gain over a dipole. This structure is the building block of the high performance parasitic array known as the quad. As a single element antenna, the vertical one wavelength loop has also found popular service in the triangular format known as the delta loop.

In the mid eighty's, Dave Fischer, W0MHS published an article describing a one wavelength square loop oriented horizontally. He dubbed the antenna the "Loop Skywire". This antenna offers several attractive features including an omnidirectional pattern, simplicity, and a feed point presenting a reasonable impedance and a short at DC with the attendant low receiving noise. However, this antenna has acquired the reputation of being a "cloud warmer", or high angle radiator. Indeed, as shown in Fig. 2, it has less low angle radiation than a dipole mounted at the same height. Thus the one wavelength horizontal loop performs very well for local or near-vertical incidence work, but not as well as other antenna types for DX where a low takeoff angle is required.

### **The Long Wire Loop: Longer is Better**

One reason the one wavelength horizontal loop has poor low angle performance compared to a dipole is because of the inherent 2.2dB broadside gain of the loop: the antenna *wants* to direct most of its energy upward. But if operated on the second harmonic (or more), an overhead null is created. Conservation of energy requires the radiation to go somewhere, and if it can't go up, it must go out. Creation of an overhead null is the basic operating principle of most high performance low angle antennas including the pioneering 8JK two-element beam in which two side-by-side dipoles were driven out of phase. Figure 2 contrasts three antenna types mounted at the same operating height: a one wavelength horizontal loop (the Loop Skywire), a dipole, and a two-wavelength long wire loop. Low angle performance increases in just this order, with the long wire loop giving a lower takeoff angle than a dipole, which in turn gives a lower takeoff angle than the Loop Skywire. At longer harmonic lengths, the takeoff angle of the long wire loop gets even lower - remarkably so, as shown in Figure 6.

The second area in which a long wire loop offers advantages is in azimuthal coverage. While a long wire antenna gives a pattern that breaks up into lobes, folding the same length of wire into a loop frustrates lobe creation and provides a nearly omnidirectional azimuth pattern. This is illustrated in Fig. 1, which shows the familiar multilobe structure of a traditional long wire antenna and the nearly uniform pattern of a long wire loop of the same length. Gone are the deep nulls and holes in azimuth coverage. If you have a big antenna that you can't rotate and you want to work anywhere without restriction, the closer you can get to omnidirectional the better.

The way in which the long wire loop defeats the formation of coverage nulls is worthy of a closer look. Figure 3 shows the horizontal pattern resolved into three field components: horizontal polarization, vertical polarization, and total field. As can be seen in the figure, the horizontal loop produces vertically polarized as well as horizontally polarized radiation. It is not that lobe structures are not formed, but that the vertically polarized pattern is complimentary to the horizontally polarized pattern. One peaks when the other nulls, leaving a total field pattern which is nearly omnidirectional. Since sky wave propagation randomizes polarization anyway, the fact that the horizontal loop initially radiates horizontal polarization in some directions and vertical in others is of no consequence.

The final platitude that can be ascribed to the long wire loop is multiband operation. Unlike a dipole, the loop resonates on all harmonics, not just the odd ones. The feed impedances are “friendly”, defined as not too high and non-reactive over a reasonable bandwidth. The loop resonates with a low feed impedance when there are an integral number of whole wavelengths in the circumference. The actual impedance varies with harmonic order, installation height, and ground characteristics but generally is between 35 and 200 ohms, an easy target for any antenna tuner. Figure 4 shows a swept VSWR plot of a long wire loop for 80 meters (one wavelength on 160 meters). The harmonic resonant structure that serves every amateur band to 10 meters is clearly evident. From a practical standpoint, the antenna should be fed with open wire (ladder) line and a suitable tuner with balanced outputs.

### **Performance vs Shape: The Proof is in the Patterns**

Tradeoffs in pattern and structural complexity exist regarding the actual shape of the long wire loop. As harmonic order increases, the azimuth pattern changes as a function of loop shape and some geometries are better than others. Thanks to the magnificent EZNEC by Roy Lewallen, W7EL, prediction of the patterns is, well, EZ. The Numerical Electromagnetics Code (NEC) is a computer program originally developed by the Navy to predict the performance of antennas using the method-of-moments simulation. The program breaks an antenna up into segments, calculates impedance and currents of each segment, and then integrates the results to predict the overall pattern and impedance of the antenna. Figure 5 shows the predicted total field azimuth patterns of octagonal, hexagonal, square, and triangular loops of one wavelength circumference on 160 meters at an installed height of 50-ft over average ground for the 160, 80, 60, 40, 20 and 10 meter amateur bands. Because of the foresight of the harmonic nature of the amateur frequency allocations, the antenna also works on the 30, 17, and 12-meter WARC bands but these were omitted to keep the figure a reasonable size. And yes, 60 meters isn't here yet, but one must have faith and it never hurts to plan ahead. As evidenced by the patterns, the triangular loop does a better job holding omnidirectionality across all bands. The square shape shows the most pattern lumpiness. These antennas would require respectively 8, 6, 4, and 3 supports and 546-ft of wire. To get a feel for the required real estate, the nearly circular octagonal loop would be about 173-ft in diameter and the triangular loop would be 182-ft on a side. A  $\frac{3}{4}$ -acre square patch of land would be required to erect the antenna.

But the conversion from cloud warmer to barn burner doesn't happen until there are at least two wavelengths in the loop. To get the low angle benefit on the top band, the antenna has to be twice as big, requiring 1092-ft of wire and placing the fundamental resonance near 925 kHz. This antenna was also studied using EZNEC, and the predicted performance was impressive. The triangular shape again produced the most uniform patterns with a slight variation: a triangle with a 40-degree apex angle at the feed point gave more uniform patterns than a 60-degree equiangular triangle. The complete pattern set organized by shape has been omitted for brevity but the 40-degree triangle data is given in Figure 6. This antenna would fit on a mere 3-acre lot.

An examination of the azimuth predictions reveals that the average azimuth gain of the long wire loop is around +5dBi. This is very comparable to that obtained in the peak response of a resonant dipole cut for each band and mounted at the same height over the same ground type. The extra gain over the +2.14dBi figure for a free space dipole comes from the ground reflection and the superposition of fields from all parts of the antenna. Thus, operationally, using a long wire loop is like having a separate rotatable dipole for each band, always pointed towards the station you are working but with a lower takeoff angle.

### **Scaling: When Bigger Just Can't Be**

The motivation for the long wire loop admittedly was to garner high performance, omnidirectional coverage on the low frequency bands of 160 through 40 meters, in response to our inexorable slide down the backside of the current sunspot cycle. Thus the antennas described above tend to be big. But that is not to say that the long wire loop concept can't be scaled to cover only the higher frequency bands to make them smaller. To get the low angle benefit from an overhead null, it is required only to have at least two wavelengths in the loop. Thus to make a long wire loop for, say, 10 meters, one could erect a one-wavelength loop cut for 20 meters. The formula for the length of wire required to make a one wavelength loop is:

$$L = 1005/f,$$

where L = length in feet, f = frequency in MHz. To make a long wire loop, simply double this amount. In this example, the long wire loop for 28.5 MHz would be only 70.5-ft in circumference, or 23.5-ft on a side for a triangular shape. The point should also be made that although low angle enhancement does not occur for a one-wavelength loop, the antenna is far from unusable. It is excellent for regional work and many swear by its overall performance. As another example, a one-wavelength loop cut for 80 meters is four times smaller than the two-wavelength 160-meter loop, gives good regional performance on 80, and is still a long wire loop on 40 meters and up. As with all horizontal antennas, height is a virtue so the antenna should be mounted as high and in the clear as possible.

### **Conclusions: at Home on a Range**

Long wire loop antennas have been predicted to produce patterns that can be nearly omnidirectional in azimuth and free of the coverage nulls usually associated with long wire antennas. NEC modeling shows that this occurs through generation of complimentary vertical and horizontal polarization field components. If the loop contains more than one wavelength in circumference the vertically incident energy is suppressed, giving rise to a low takeoff angle for excellent DX performance. The overall average gain is about the same as an optimally oriented, resonant dipole cut for each band, but all at the same time, in almost all directions, and at a lower takeoff angle. As far as DX goes, it will not outperform an optimally pointed yagi mounted on a tall tower but it will provide solid performance in all directions, on all bands, and at a fraction of the cost.

Because a loop is resonant on all harmonics, the long wire loop can be used on all amateur bands from 160 through 10 meters with a modest antenna tuner and balanced feed with open wire line. The loop appears as a short at DC and has a low lightning profile compared to a tower, giving some measure of lightning protection. The combination of the DC short and harmonic resonant nature of the long wire loop minimizes out of band noise pickup, making the antenna very quiet on receive.

The shape of the loop affects the azimuth pattern and a triangular shape has been shown to produce particularly uniform azimuth patterns with a very low takeoff angle over many bands. The triangular shape has the additional advantage of requiring the fewest number of supports necessary to put up a loop. Other shapes are possible and perhaps even better. If strict omnidirectionality isn't as important as expediency, the antenna can be tailored to fit in an existing space.

The data presented above came from a theoretical study using NEC and the user-friendly EZNEC embodiment by W7EL, a very effective method of predicting antenna performance. The author is in the process of building a long wire loop and will present measured performance data in a future article.

An additional attraction is the fact that the antenna is very low in cost, consisting of only wire and as few as three supports. On the downside, to cover the low frequency amateur bands the antenna has to be big. But if you've got the room or are just looking for something else to do with your ranch, this might be the antenna for you.

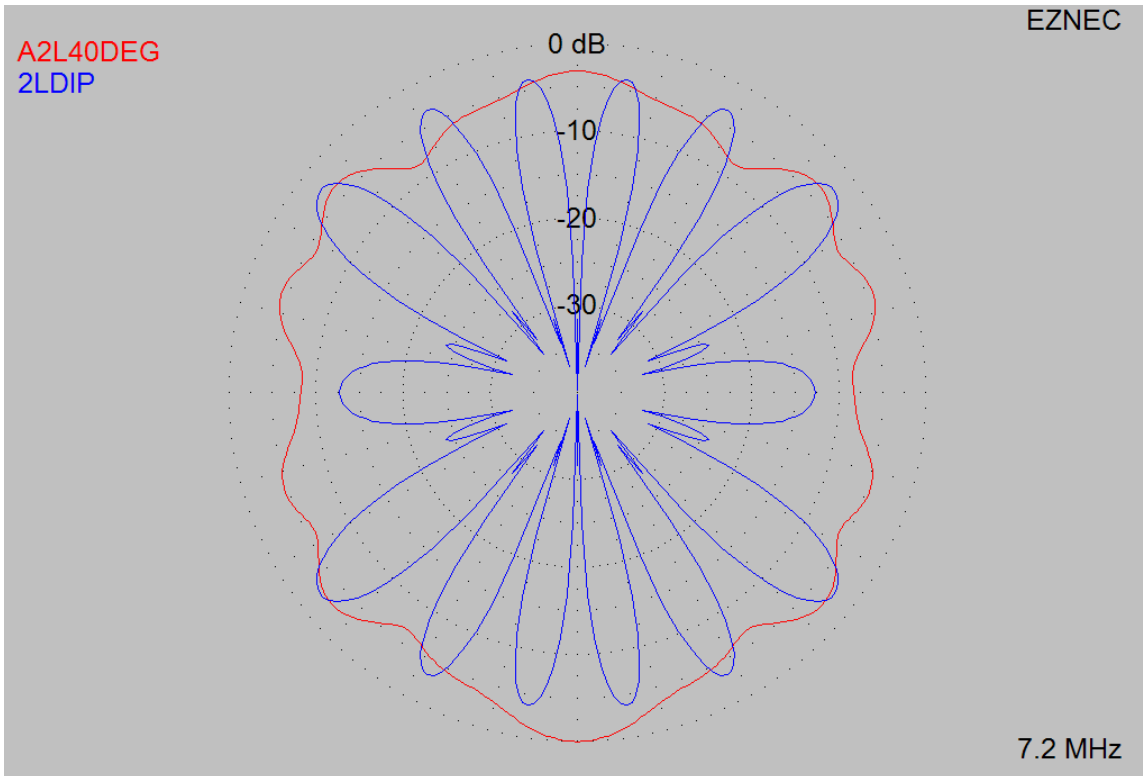


Figure 1. Total Field Azimuth Pattern of A Long Wire Antenna and the Same Length Wire Folded into a Loop. The Long Wire Loop Provides Essentially Omnidirectional Performance with No Nulls.

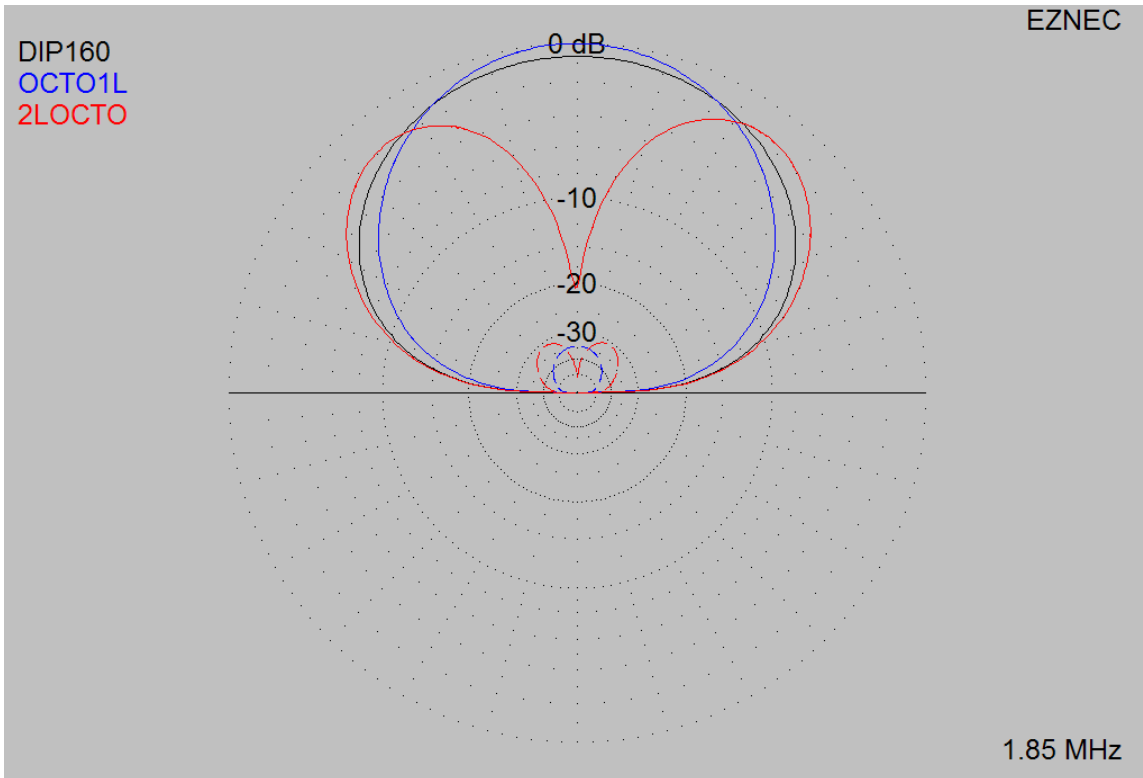


Figure 2. Vertical Radiation Patterns of a One Wavelength Loop (OCTO1L), a Dipole (DIP160), and a Two Wavelength Loop (2LOCTO). By Producing an Overhead Null, the Two Wavelength Loop Achieves the Lowest Takeoff Angle. The One Wavelength Loop Produces the Highest Takeoff Angle, Earning it the Reputation of a Cloud Warmer.

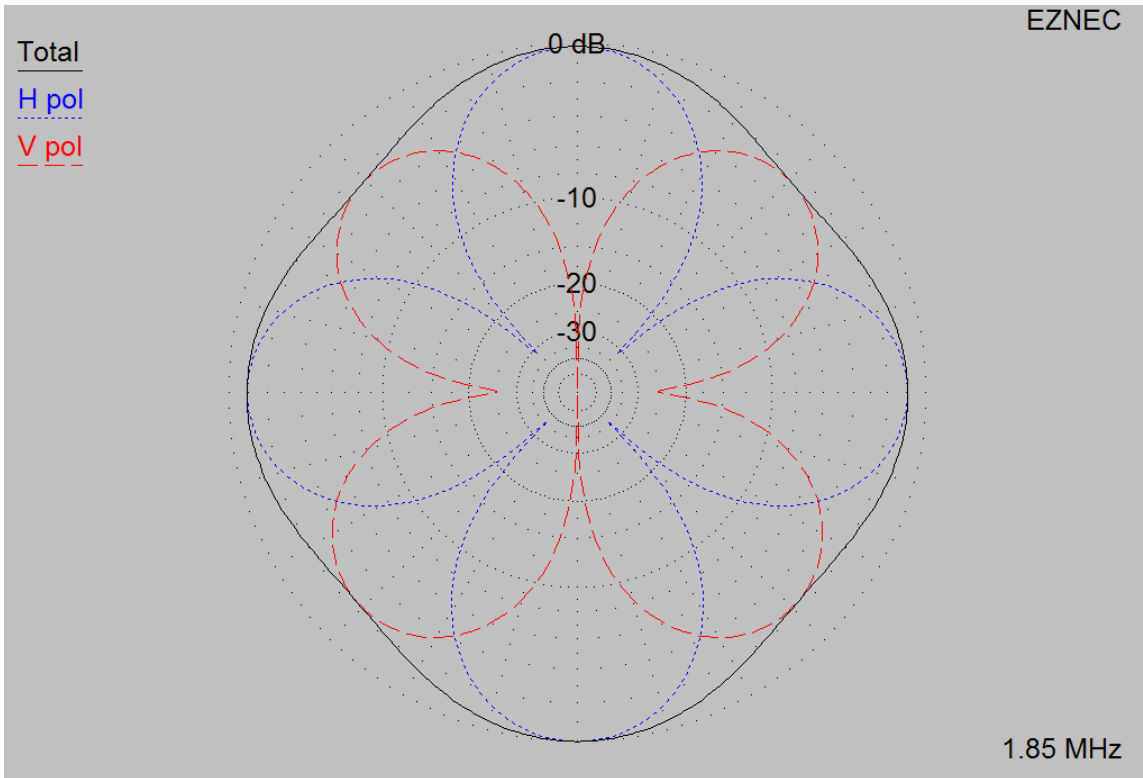


Figure 3. Azimuth Pattern of a Long Wire Loop Showing Generation of Both Horizontally and Vertically Polarized Components. The Complimentary Nature of the Patterns Gives Rise to a Total Field Pattern that is nearly Omnidirectional.

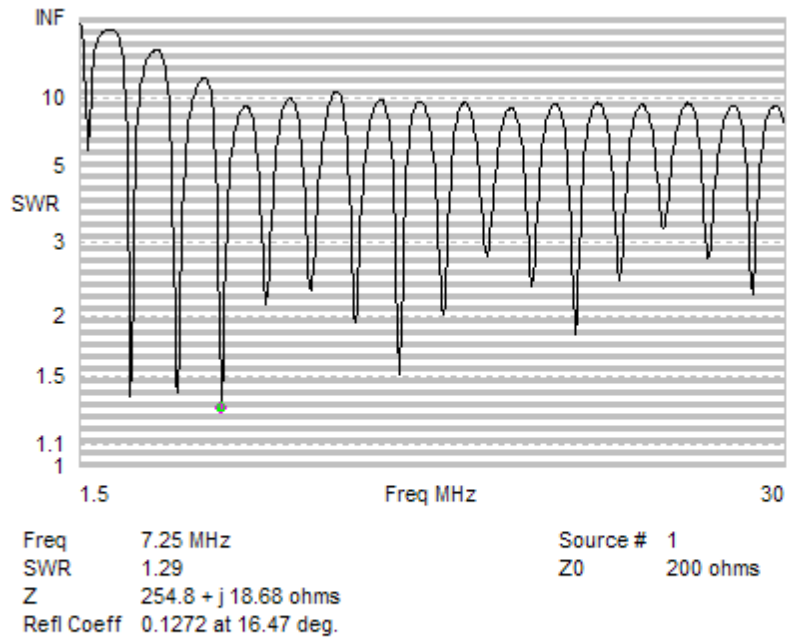


Figure 4. Swept SWR graph of a Long Wire Loop Showing Resonances on All Harmonics. The Loop is Fundamentally Resonant on 160 meters.

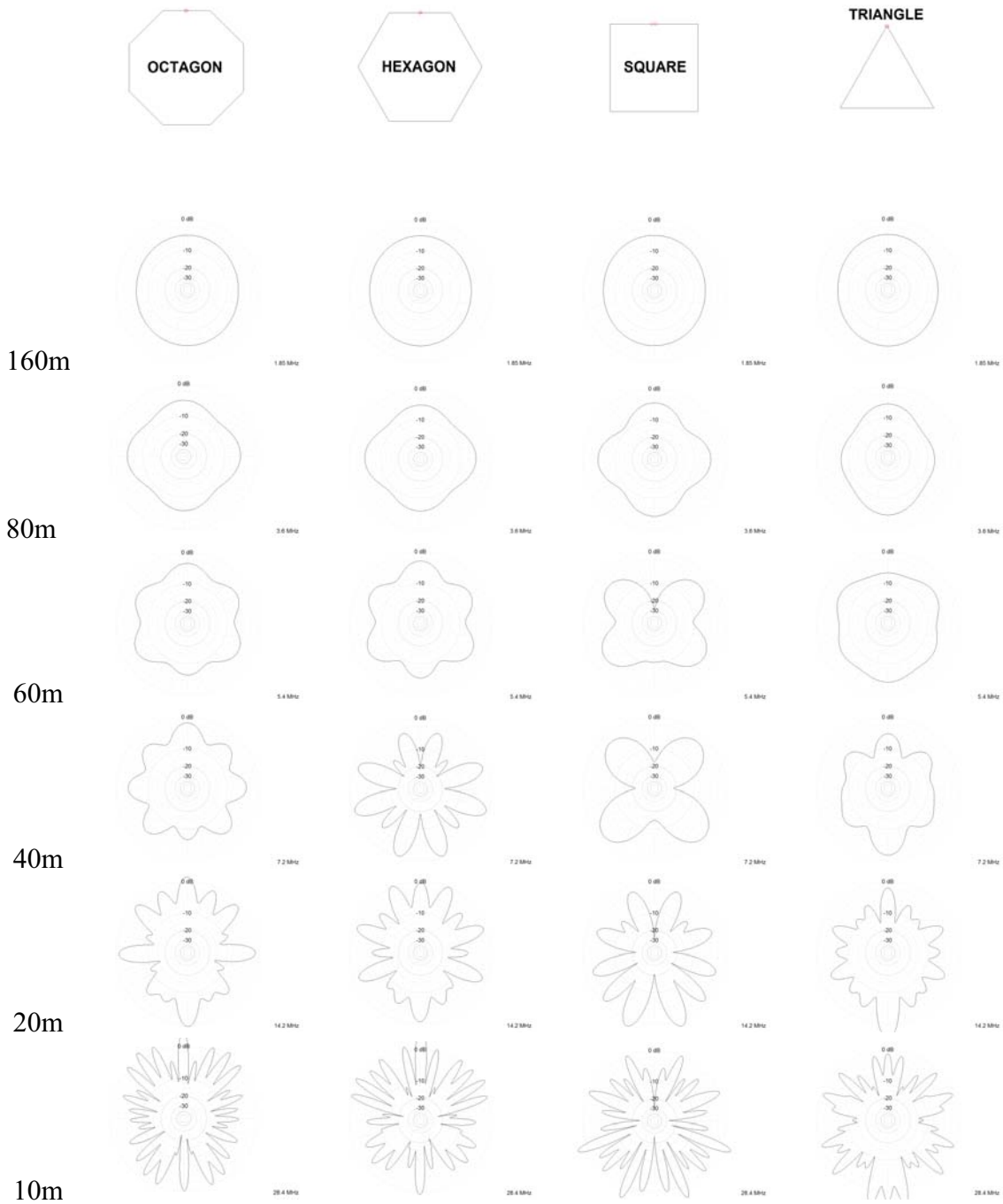


Figure 5. Horizontal Total Field Patterns for Long Wire Loops of One Wavelength Circumference on 160 meters (546-ft). All Antenna Models are at an Installed Height of 50-ft over Average Ground. Outer Ring is +10dBi for all Plots.

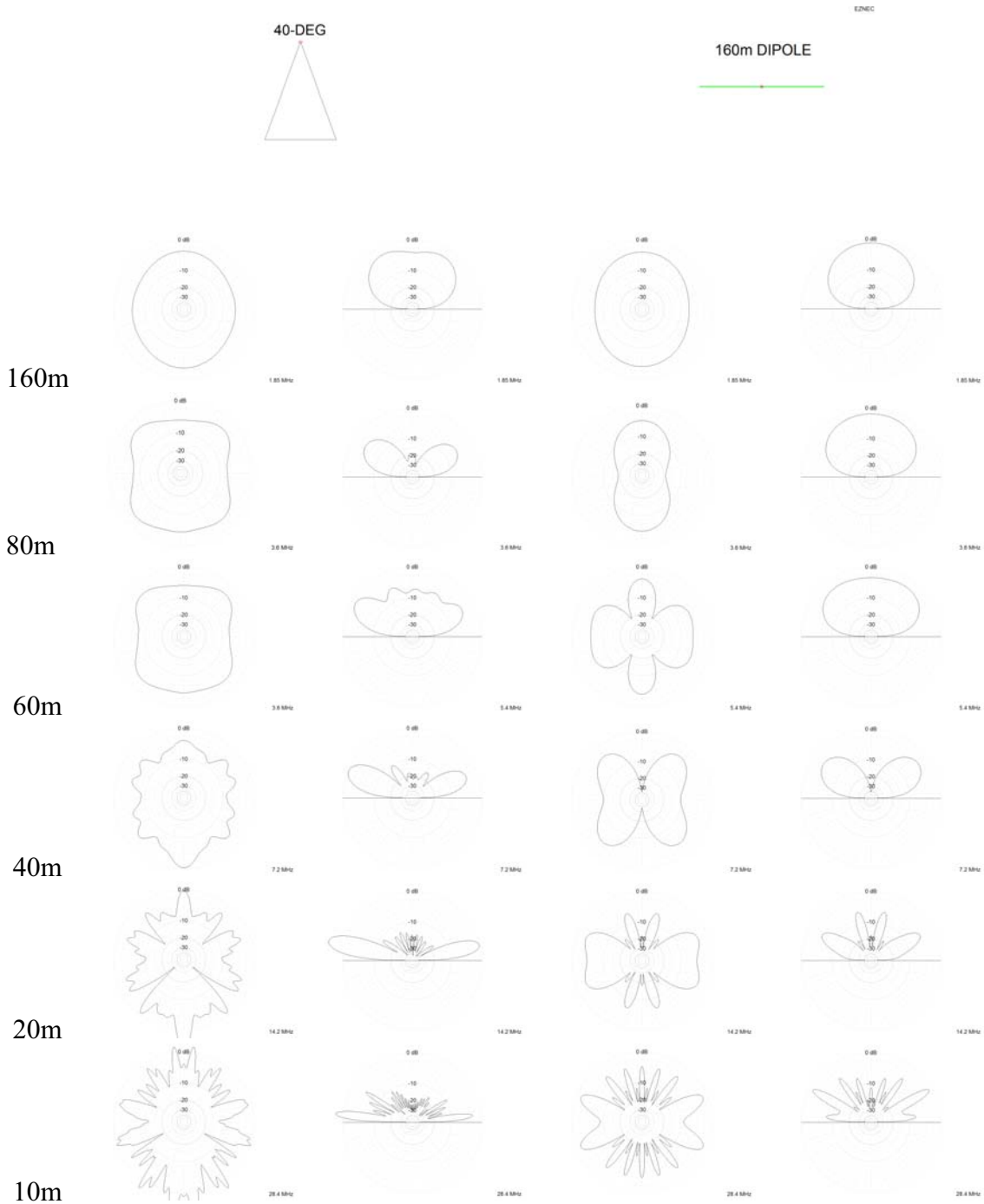


Figure 6. Horizontal and Vertical Total Field Patterns For a Long Wire Loop (2 wavelengths on 160m) and a 160m Dipole Reference. Both Antenna Models are at an Installed Height of 50-ft over Average Ground. Outer Ring is +10dBi for all Plots.