Kazimierz "Kai" Siwiak—KE4PT ke4pt@amsat.org

Antenna Pattern Peaks and Nulls— A Calculator Solution

You can hand-sketch a pretty good approximation of the vertical pattern for a horizontally polarized antenna elevated above ground (Figure 1). Furthermore you don't need any electromagnetic modeling software such as numerical electromagnetic code (NEC) to do so.

NEC, as implemented in several popular software packages like EZNEC [1] and 4nec2 [2], can give excellent results for modeling your antenna in free space, or over a perfectly flat and perfectly smooth Earth. But a hand calculator is all you need to find basic pattern features like peak and null angles. A scientific calculator such as *calc.exe* is available in every version of Microsoft Windows, or a calculator app on your smart phone, will do the job. Just specify the antenna height above ground in wavelengths.

Imagine that you've set up camp and hung your portable station dipole up at about 10 m height (30 ft). You're ready to try some 28 MHz CW. Curious about the elevation plane dipole pattern?

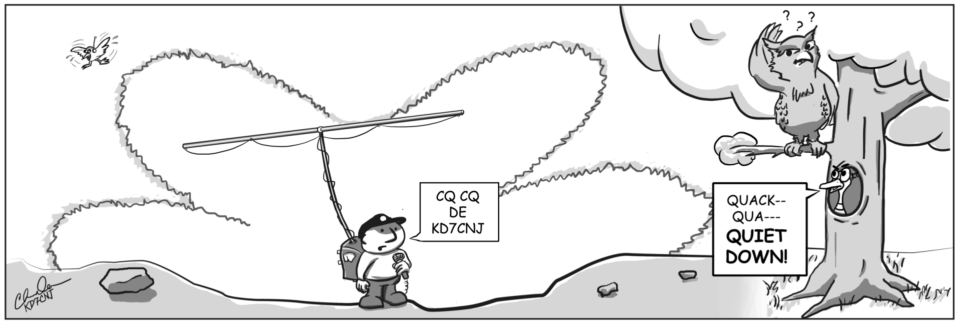

Figure 1—You can predict the number of peaks, and the peak and null angles of your horizontal dipole using calculator. [Chris Dean, KD7CNJ, image]

Elevation Peaks and Nulls

We've already seen the phenomenon responsible for pattern nulls and peaks due to ground reflections in the October 2013 Ionospherica column [3]. Signals arriving from the distant ionosphere take a direct and a ground-reflected path, to form a vertical standing wave pattern at the receiving antenna location.

In the present example, we've chosen an antenna height based on physical limitations at our camp site. Figure 2 shows the details of the signal paths. For signals transmitted to, or received from, an elevation angle α, there are two paths to/from the dipole placed at a height of H_λ wavelengths.

There is a direct path, and a ground-reflected path. The path lengths differ, and the ground reflected path undergoes a phase change upon ground reflection. For shallow angles that ground reflection coefficient is –1. So we immediately know that the "zero order null" in the elevation pattern is at $\alpha = 0º$!

The Pattern Nulls

First we determine how many peaks p there are in a forward quadrant of the antenna pattern. We answered that in the October 2015 Ionospherica,

$$p = 2H_\lambda \qquad (1)$$

Note that p need not be an integer—as H_λ increases, peaks continue to be added gradually from the vertical direction, while the lower angle peaks get compressed, see Figure 3.

Also, the straight up (90º elevation) peak maximum occurs for antennas that are at even multiples of a half wavelength, minus a quarter wavelength, such as 0.25λ, 0.75λ, 1.25λ, 1.75λ, and so on.

The number of nulls above the zero angle null is the integer part of p.

Using simple geometry and image theory, see Figure 2, we can see that the ground-reflected path is $2H_\lambda\sin(\alpha)$ longer than the direct path to the distant horizon. Also, signals along the ground reflected path are multiplied by the –1 ground reflection coefficient. The signal copies along the two paths will cancel whenever the added path length, or phase delay, is a multiple m of a wavelength λ. That is,

$$2H_\lambda\sin(\alpha) = m\lambda \qquad (2)$$

Solve for the angle α of the m^{th} null,

$$\alpha_{m\_NULL} = \arcsin(m/2H_\lambda) \qquad (3)$$

I used a simple scientific calculator with the inverse sine function!

The $m = 0$ null occurs at 0º, and the first null is at $\alpha_1 = \arcsin(1/2H_\lambda)$.

We hung our 28 MHz dipole at about a 10 m height (H_λ =1), So there are p = 2 complete lobes in the forward quadrant of the pattern, and 2 nulls above the 0º null: one at arcsin(1/2) = 30º, and the second at arcsin(2/2) = 90º.

The Pattern Peaks

The signal copies travel along the two paths and combine constructively to double the field strength (+6 dB above the free

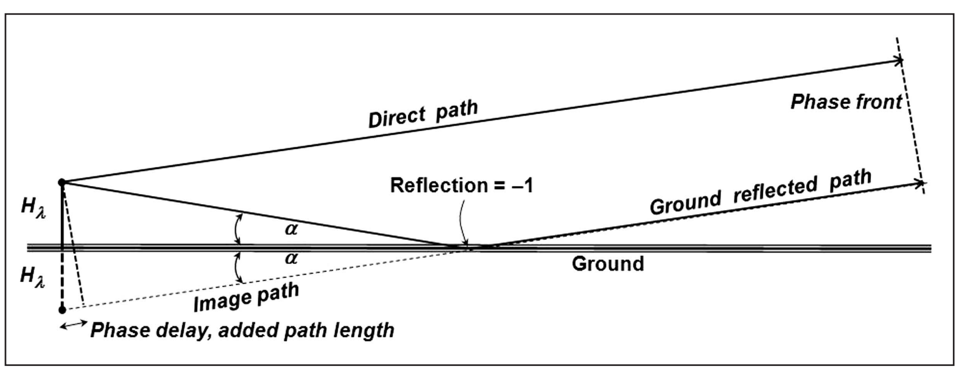

Figure 2—Using image theory and geometry, the added path length of the ground reflected path is $2H_\lambda \sin(\alpha)$, where H_λ is the antenna height.

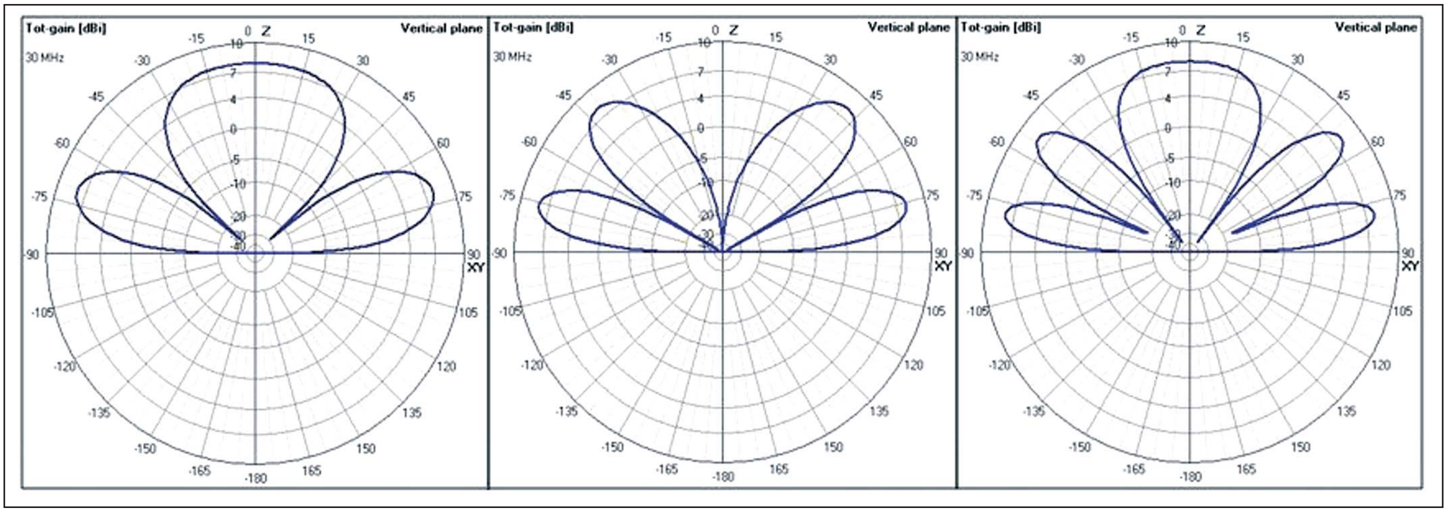

Figure 3—For a horizontally polarized antenna H_λ wavelengths above ground, use Eq (1), (3) and (5) to discover the number of peaks *p*, in the forward quadrant, the elevation angles α above the horizon of nulls and peaks, which can be verified with 4nec2 as shown above.

[LEFT] H_λ = 0.75, so there are *p* = 1.5 lobes in the forward quadrant; my calculator shows the peaks are at α = 19.5º and 90º above the horizon, and the nulls are at α = 0º and 41.8º.

[CENTER] H_λ = 1.0, so there are *p* = 2.0 lobes in the forward quadrant, the peaks are at α = 14.5º and 48.6º above the horizon, and the nulls are at α = 0º, 30º and 90º above the horizon.

[RIGHT] H_λ = 1.25, so there are *p* = 2.5 lobes in the forward quadrant, the peaks are at α = 11.5º, 36.9º and 90º above the horizon, and the nulls are at α = 0º, 23.6º and 53.1º above the horizon.

When H_λ is a multiple of a half wavelength minus a quarter wavelength, [LEFT and RIGHT], there is a peak 90º above the horizon, whereas if H_λ is a multiple of a half wavelength [CENTER] there is a null at 90º.

space value) for a perfect ground—or about 4-5 dB for medium ground—whenever the path difference, or phase delay, is an odd multiple *m* of a half wavelength. That is,

$$2H_\lambda \sin(\alpha) = (2m-1)/\lambda \quad (4)$$

Solve for the angle α,

$$\alpha_{m\_PEAK} = \arcsin\{(2m-1)/4H_\lambda\} \quad (5)$$

which is easily computed on a scientific calculator using the inverse sine function!

The first peak (there is no zero-order peak) happens at $\alpha = \arcsin(1/4H_\lambda)$.

For the 28 MHz dipole at height of 10 m (H_λ =1), the first peak occurs at arcsin(1/4) = 14.5º, and the second one is at arcsin (3/4) = 48.6º as seen in the CENTER pattern in Figure 3.

Verify with NEC

I set up three scenarios with the dipole at 0.75, 1.0, and 1.25 wavelengths above the ground, and used Eq (1) to get the number of nulls *p* in the forward quadrant, and then Eq (3) and (5) to find the elevation angles of the nulls and peaks.

I then used 4nec2, with a perfect ground, to calculate the antenna patterns to verify my hand-calculated results. Had I used a medium ground, the nulls would not have been so deep, and peaks would be slightly less pronounced, but angles would still match.

A Calculator is All You Need

Knowing the height in wavelengths of your dipole antenna, apply the three simple formulas to predict the number of peaks, and the elevation angles of the pattern peaks and nulls.

The peak lobe amplitude is 4 to 6 dBi above the free space value depending on the type of ground.

References

1. EZNEC antenna modeling software, Roy Lewallen, W7EL, www.eznec.com.

2. NEC modeling software 4nec2 by Ari Voors, www.qsl.net/4nec2.

3. K. Siwiak, KE4PT, "Ionospherica, Pitching and Catching Radio Waves—The Last Bounce", *QRP Quarterly* Vol 54 No. 4, Oct 2013, pp 32-33.

Kazimierz (Kai) Siwiak, KE4PT, is an avid DXer who packs a DX Go-Bag station on his travels.