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Ground Influence—It's Not a Property of the Antenna

We hear much chatter about this or that antenna having "a low take-off angle", or superior "take-off angle performance". There are two major flaws with such statements. First, for elevated antennas that hams use at HF, there is precious little that the antenna designer can do to influence the elevation pattern of an antenna, other than to change the directive gain. Second, the notion of *one* "take-off angle" is deceptive. The full set of "take-off angles" of an antenna is otherwise known as the *antenna pattern*. Furthermore, the ionosphere chooses the appropriate elevation angles to the DX, not your antenna.

Wait! What's that about that take-off angle again? There is not just one, but a full pattern of them. Antennas radiate at all angles for which there are no nulls. The antenna designer's task is to produce an antenna with a free space pattern that has *no nulls* in directions of interest for DXing. Of course, strong radiation in those directions is a bonus, but you cannot overcome a null in the pattern, as we will see.

Antenna "New Math"

To find the antenna pattern in the presence of a ground, take the free space pattern of your antenna, like the two element Yagi antenna in Figure 1, and multiply, angle for angle, by the interference pattern of a point source at a height *H* above the ground.

The influence of the ground can produce plenty of additional nulls—and it is *only* the height above ground that determines at what angles these additional nulls will occur. Once again with feeling, the nulls created by ground reflections have nothing to do with the antenna itself.

"New Math"? Not at all. Search for "pattern multiplication" or "pattern synthesis" with your browser or in your favorite antenna textbook. My favorite is *Antennas* by Prof. John D. Krause, W8JK [1]. The bottom line is "once a null, always a null" whether that null is created by the antenna pattern or by the ground-induced interference pattern. In the composite pattern, it remains a null.

Ah, but do we have any control over the ground-induced nulls? Yes, we do!

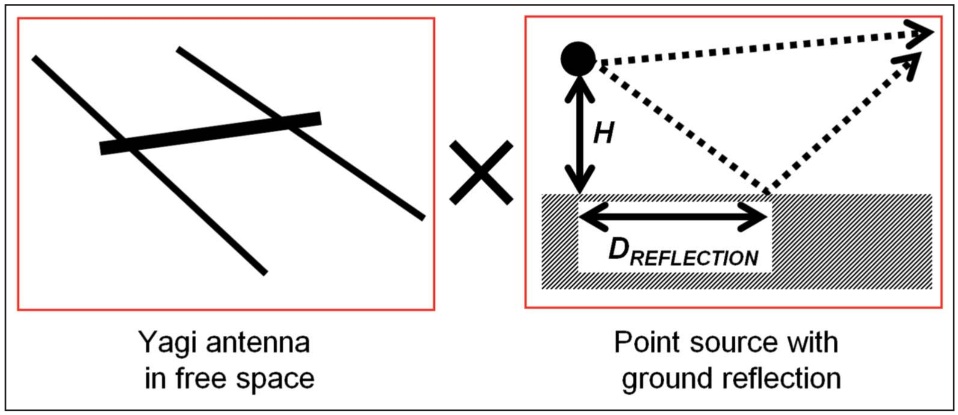

Figure 1—The elevation antenna pattern is the result of multiplying the antenna free space pattern by the pattern of a point source above ground.

Antenna in "Free Space"

View the antenna pattern in free space (Figure 2) to verify coverage at angles of interest to communications. For DX, we care about elevation angles ranging from 3 to 20 degrees, or higher angles if we expect NVIS (near vertical incidence skywave) performance.

You will not recover gaps or nulls in the antenna free space pattern coverage (like along the x-axis in Figure 2) from ground reflections. This is an important concept to grasp.

Influence of the Ground

The ground affects antennas and antenna patterns in two completely independent ways. First, for low antennas, the ground may influence the feed-point impedance of the antenna. This is strictly a mutual coupling effect with the ground directly under the antenna. The feed-point impedance change due to mutual coupling has *no effect* on the antenna pattern. None!

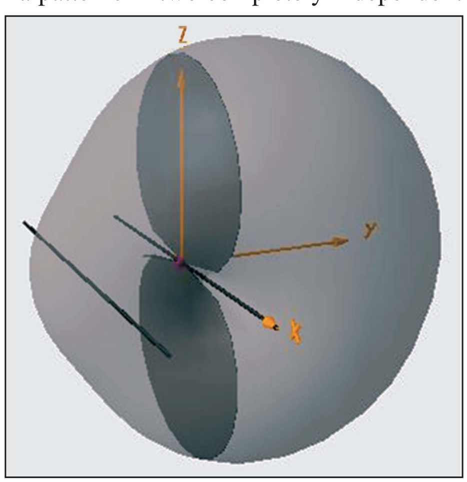

Figure 2—3-D pattern of the Yagi antenna in free space. The angular coverage around the y-axis direction of maximum gain is complete for all angles of interest.

Second, the reflection from the ground combines with the direct signal path from the antenna (right half of Figure 1). This reflection occurs far from the antenna for useful elevation angles.

$$D_{REFLECTION} = \frac{55H}{\theta_{DEGREES}} \qquad (1)$$

$D_{REFLECTION}$ is the distance from the antenna to the reflection region, *H* is the antenna height above ground, both in the same units, and $\theta_{DEGREES}$ is the pattern elevation angle in degrees. So, at an elevation angle of 3 degrees, the reflection for an antenna up 70 feet occurs 1283 feet away from the antenna—this is definitely not under the antenna!

Multiplying Patterns

As implied by Figure 1, the free space antenna pattern is multiplied (×) angle for angle, by the interference pattern of a point source elevated above ground. You can observe similar interference patterns by analyzing a horizontal dipole at the same height above ground. Figure 3 illustrates pattern multiplication.

To obtain the antenna pattern over a ground (right column), multiply the free space antenna pattern (left column) by the interference pattern of the point source above ground (middle column). In an earlier 'Ionospherica' we saw that an optimum antenna height for DXing is about one wavelength for horizontal polarization, but here I chose outlandish heights to more clearly illustrate the physical principle [2].

The number of lobes in a quadrant of the center column interference patterns equals twice the number of wavelengths (λ) in height. Add a quarter wavelength to the heights in Figure 3 to maximize the upward lobe, if NVIS is your aim.

You can generate a lobe closer to the horizon by increasing the antenna height, but it is at the cost of placing one or more nulls in the desirable 3 to 20 degree elevation range. Note that there is *always* a ground reflection null at the horizon for an elevated antenna.

Recap

The elevation angles to DX stations are determined by the ionosphere and the distance to the DX station. Your antenna, and the height it is placed at, will determine whether you are coupling signals into the ionosphere at proper angles needed for the DX propagation you want.

References

1. J. D. Krause, *Antennas*, McGraw-Hill, 1950.

2. K. Siwiak, KE4PT, "Ionospherica, Pitching and Catching Radio Waves" *QRP Quarterly*, Vol 54 No. 2.

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

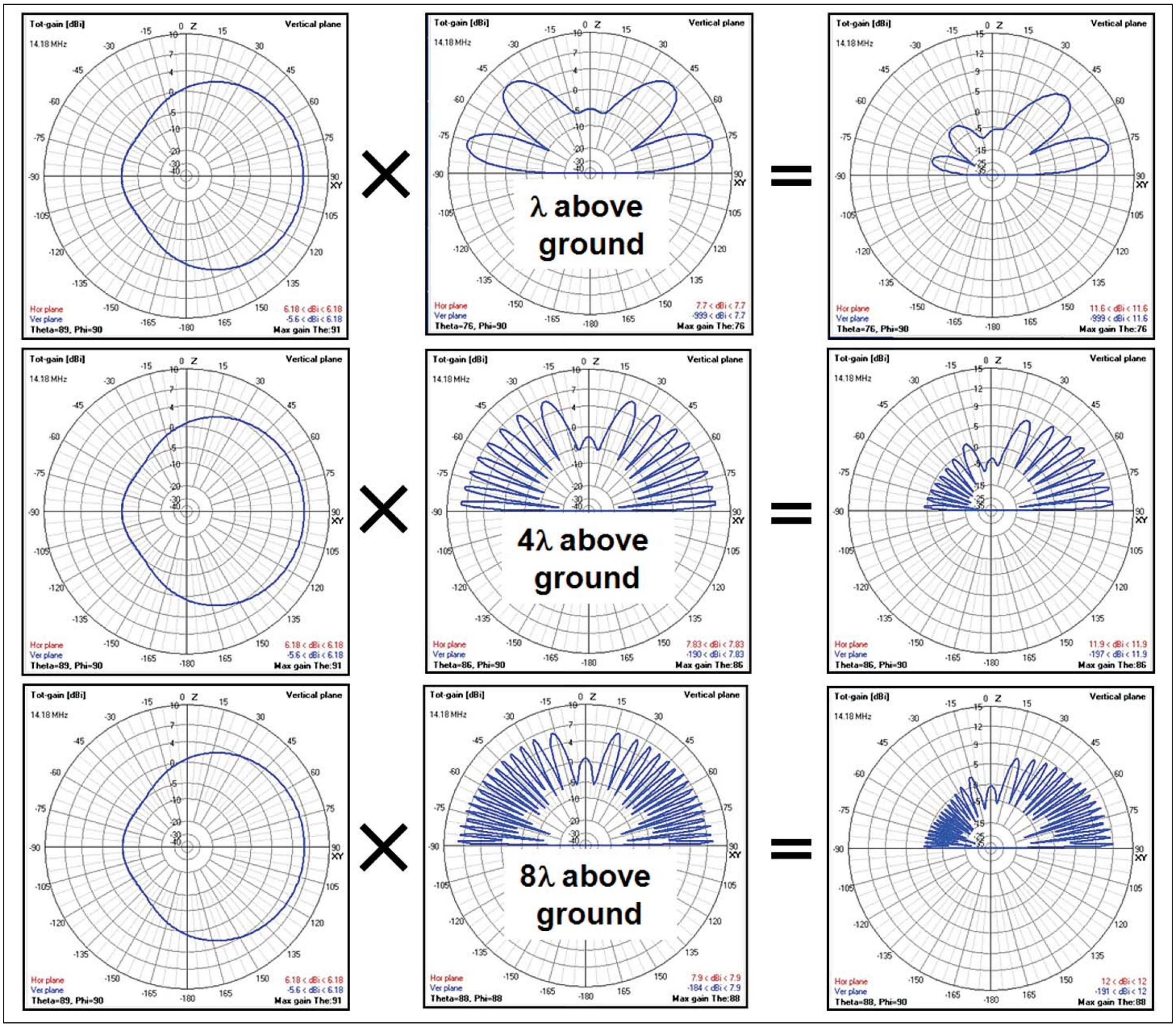

Figure 3—Left: free space Yagi antenna elevation pattern. Middle column: this is how the ground influences any antenna at various heights (shown in wavelengths, λ). Right: product of the Yagi antenna pattern and the ground influence pattern. Patterns were produced by 4nec2 [Ari Voors, www.qsl.net/4nec2/] using medium ground parameters.