A Review of the Performance Capabilites of Antenna Arrays

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This tutorial shows some of the coverage patterns that can be obtained with antenna arrays, with the intent of illustrating array capabilities to engineers who do not regularly work with antennas

Antenna arrays are back in the news for engineers, with MIMO (multiple input, multiple output) technology beginning to be deployed for improved wireless communications. When we also consider established technologies such as radar and broadcasting, it's clear that antenna arrays are an important part of RF and microwave systems.

This subject is far too detailed to explain in one short tutorial, so readers are encouraged to do more reading, beginning with the references at the end of this article.

Evolution of Arrays from Single Antennas

At some time in our education, we are exposed to the basic "figure eight" pattern of the dipole, or the omnidirectional horizontal pattern of a vertical monopole. For this article, the antenna elements are short dipoles, operating in free space, oriented vertically so that they are omnidirectional in the horizontal plane. The plots are one-half of the resulting horizontal patterns.

Figure 1 begins the discussion by showing the pattern shape obtained with two elements, spaced one-half wavelength, fed in-phase with equal currents. The improvement of two elements compared to the omnidirectional pattern of one element is quite significant. This illustrates the power of arrays—large directivity and gain improvements can be had with relatively simple arrays having only a few elements.

Figure 2 is one step toward greater complexity, a three-element array. As with all the examples in this article, the elements are arranged in line—they would be left to right across the bottom of each plot.

If we had simply extended the array of Figure 1 and maintained all elements in-phase and with equal currents, the resulting pattern would have had large sidelobes. Instead, the current is "tapered," with the center element having more than twice as much current as the two outer elements. For maximum radiation directly broadside, all currents are in-phase.

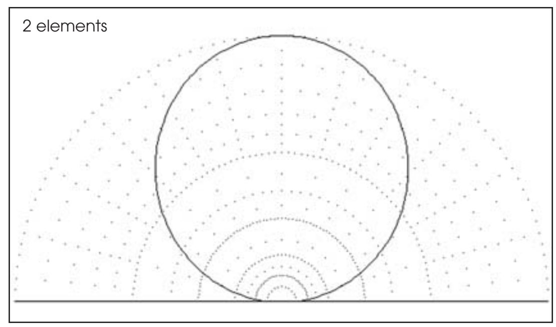

Figure 1 · This is the pattern shape obtained from two antenna elements spaced λ/2, fed with equal in-phase currents.

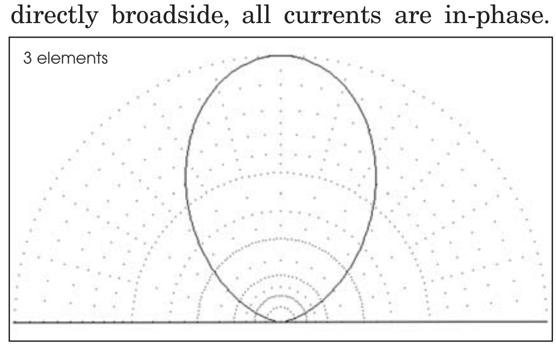

Figure 2 · When a third element is added, with currents adjusted to minimize unwanted sidelobes, a narrower pattern is achieved.

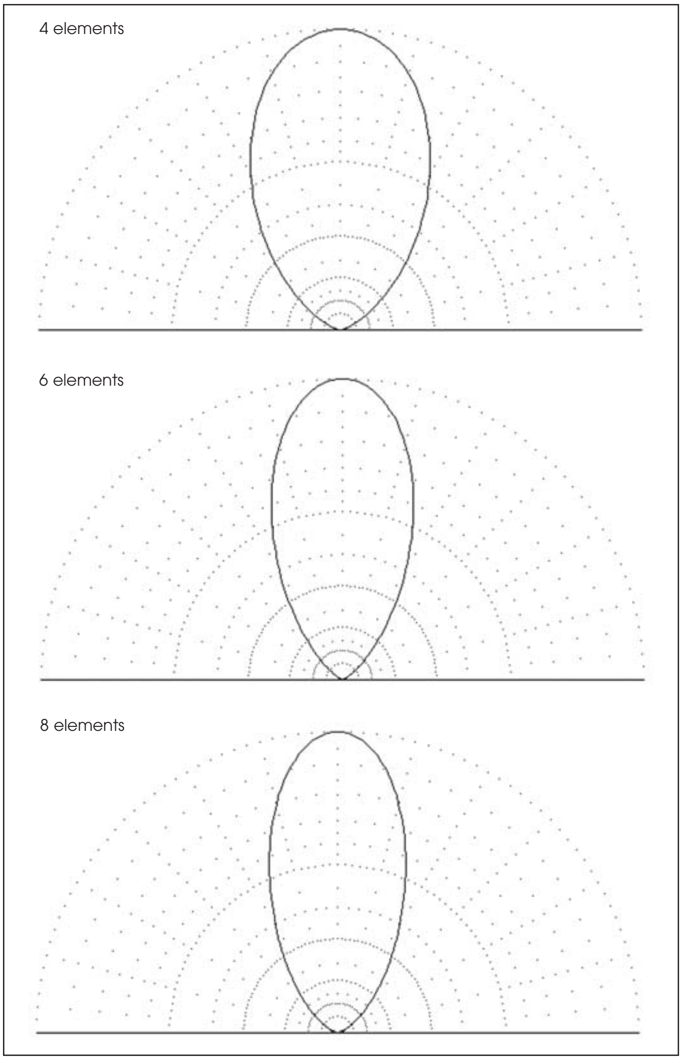

Figure 3 · From top to bottom are the progressively narower minimum-sidelobe patterns for inline arrays of 4, 6 and 8 elements, respectively.

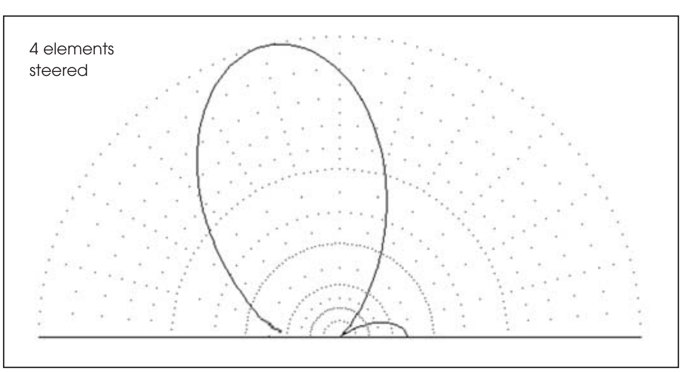

Figure 4 · The narrow beam of a multi-element array-can be steered by adjusting the phase and currents for each element. This 4-element offset pattern was created using straightforward phasing and the same current distribution of the boresight array at the top of Figure 3.

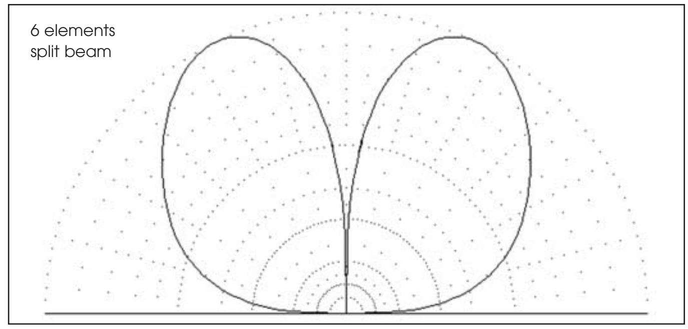

Figure 5 · More complex patterns may also be obtained, such as this beam with a deep notch at boresight, flanked by two major lobes.

The narrower pattern of three elements is clearly seen in comparison with the two-element array.

Figure 3 shows progressively narrower patterns with more elements. From top to bottom, these are arrays of four, six and eight elements. Note the very small improvement from six to eight elements. The eight-element array would benefit from further optimization.

The relative phases and currents of antenna elements can create a huge variety of pattern shapes. For example, a smart antenna might simply have an electronically steerable array. Figure 4 shows a four-element array with phases selected to move the main beam 15 degrees from the broadside direction. This figure does not have optimized phases and currents, so a significant sidelobe is seen toward the right side. Although not optimized, this sidelobe is more than 20 dB down from the main lobe and may be acceptable without further adjustment.

Finally, Figure 5 shows a more complex pattern, with a deep notch in the broadside direction, which would be useful for eliminating a strong interfering signal arriving from that direction. This pattern has two moderately broad lobes on either side, but patterns with single major lobes can also be achieved.

Summary Comments

A the old saying goes, pictures often show more than words. This "bite-size" tutorial is intended to illustrate some of the pattern characteristics of antenna arrays. We hope this is useful as a beginning to your appreciation of this part of communication engineering.

References

1. John Kraus, *Antennas*, McGraw-Hill, (any edition) 1950 to present. Current 3rd edition is co-authored by Ronald Marhefka.
2. Henry Jasik, editor, *Antenna Engineering Handbook*, McGraw-Hill, (any edition) 1961 to present. Current 4th edition is edited by John Volakis.
3. Plots created using EZNEC+, www.eznec.com