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Confused About Phased Arrays?

— educate yourself with this simple model

Confused about how phased antenna elements cause a certain radiation pattern? If you're thinking about two vertical elements, each fed with an equal amount of rf power, you can construct a simple model that'll tell you quickly and accurately just how the actual radiation pattern will look.

Here's what you'll need: a large square of cardboard or similar material, two pins, two pieces of string, and two different-colored marking pens—say, red and green. Establish some measure (inch, cm, etc.) to represent a half wavelength in space (not coaxial cable). Retain that unit of measure for all segments of your pattern checks.

Now here's what you do, taking for the first check the exploration of the radiation pattern of two vertical radiators spaced a half wave (180°) apart and fed in phase. See Fig. 1(a) for a suggested configuration. Take two equal-length strings. These should be several wavelengths long and preferably some multiple of a half wave in total length. Fasten a pin at an end of each string. Then color a half-wave portion of the free end of each string one color (say, red), and going back toward the pins, color the adjacent half-wave section the contrasting color (say, green). Continue this sequence for another half wave or two. Now each of the strings will have the same color combinations at their free ends.

Next, select a spot near the center of that large sheet of cardboard and mark two points, one being directly above the other, a half wavelength away. Stick the two pins into these points. These pins simulate the two radiating elements and establish their relative positions. Then stretch out the two strings horizontally, parallel to each other. Arbitrarily designate this direction as 0°.

Now read your results. Note that like colors are together at the ends of the strings. This shows that the

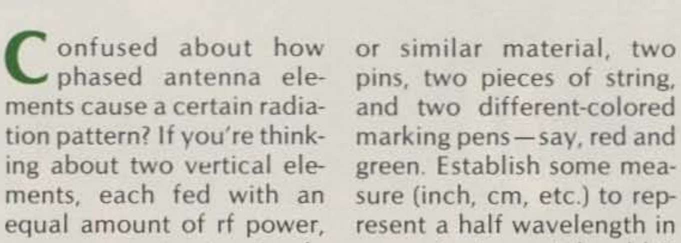

Fig. 1(a). This shows two different situations: the spacing and feed method for actual antennas and the method of simulating the generation of a radiation pattern. This simulation will show the radiation pattern of two antennas spaced a half wave apart and fed in phase with equal power to each antenna. A similar situation will exist at 180°.

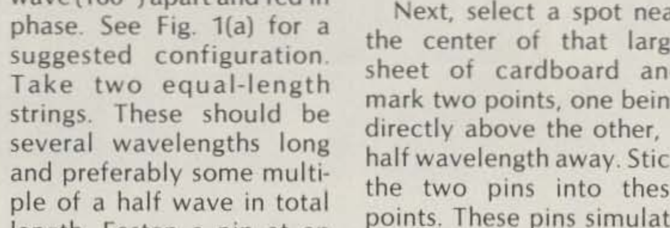

Fig. 1(b). Simulation of the phase relationship of radiation from two antennas spaced one-half wavelength apart and fed in phase with equal power to each antenna. Note the cancellation at 90°. A similar situation will exist at 270°.

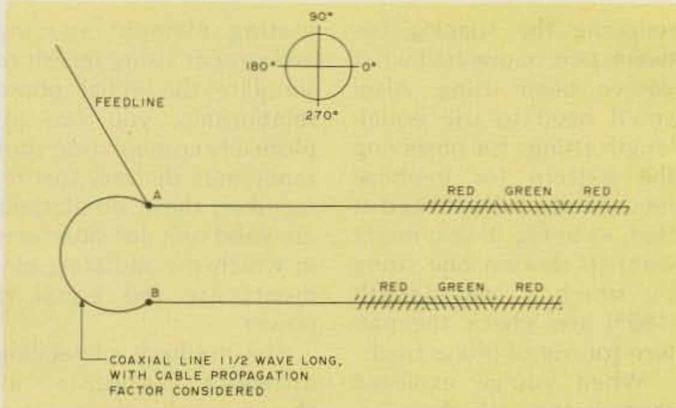

Fig. 2. Simulation of phase relationship at 0° for radiation from two antennas spaced one-half wavelength apart and fed equal power but out of phase. That is, the power fed to antenna B has been delayed 180° by an extra half wavelength of cable. Note the phase cancellation at 0°. A similar situation will exist at 180°. Mentally rotate the lines to 270° and you'll readily see the in-phase relationship. A similar situation exists at 90°.

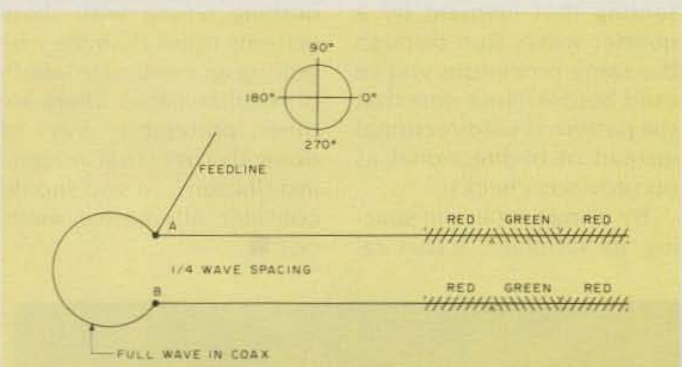

Fig. 3. Simulation for observing the radiation pattern of two antennas spaced a quarter wave apart and fed equal power in phase. Note that the pattern is similar to that of two antennas spaced a half wave apart and fed power in phase, except that the "nulls" are much less deep.

radiation from each antenna element is in phase with that of the other element, and that the total field strength in that direction (0°) is twice that which would be radiated from a single element. Now rotate the two strings (keeping them parallel to each other) a quarter turn (90°) counterclockwise. Observe the colors. Now you'll see that unlike colors are adjacent, showing that the phase of radiation from one element is unlike that from the other, so that the total field strength in that area is being reduced to nearly zero. Continue counterclockwise around 360° and you will have discovered the azimuthal radiation pattern of two vertical antennas spaced a half wave apart and fed in phase with equal rf power to each element.

For the next portion of your tour of discovery, look at Fig. 2, which tells you how to simulate the radiation from two antenna elements spaced a half wave apart but fed equal rf power with that of one element delayed 180° (½ wave) relative to the other. This is another way of saying they're fed out of phase. For this, you'll need to shorten one string (the one fastened to the pin representing the antenna element fed with the delayed rf power) by one half wave so as to duplicate the effect of delaying the phase of the

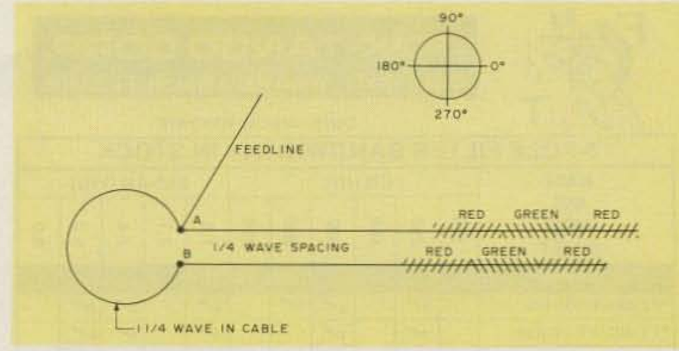

Fig. 4(a). Simulation for observing radiation pattern of two antennas spaced a quarter wave apart and fed equal power but with power fed to antenna B delayed by an extra quarter wavelength of cable. Note partial cancellation, partial enhancement of the pattern at 0°. A similar situation exists at 180°.

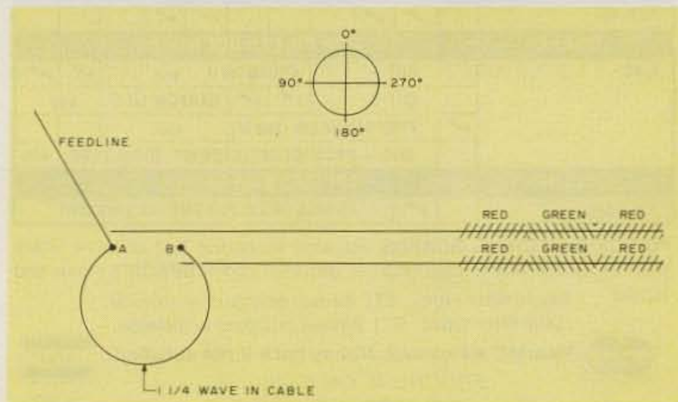

Fig. 4(b). Radiation pattern as observed at 270°. Note full enhancement. A similar situation will not *exist at 90°.*

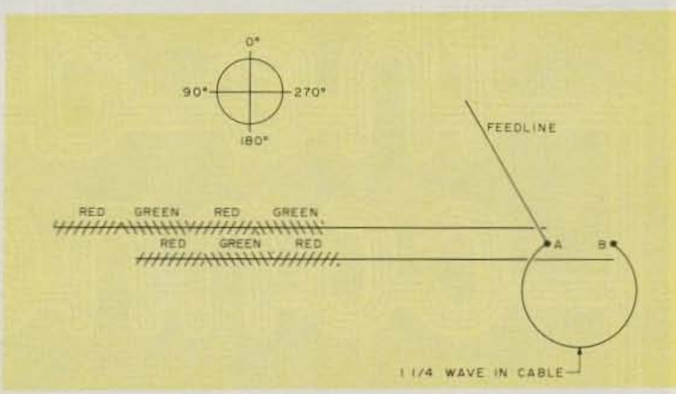

Fig. 4(c). Radiation pattern as observed at 90°. Note cancellation. Contrast this with the pattern observed at 270°, and you'll see the unidirectional effect of this antenna-and-feed configuration.

radiation from that element by 180°.

If you start with the strings pulled out in the same direction, 0°, as in the first portion of the prior check, you'll notice the adjacent colors are unlike. This indicates a minimum (a near null) in field strength at 0°, quite unlike what you found before. As you then swing the "elements" counterclockwise around 360°, you'll note a radiation pattern quite similar to that of the first check but having the points of minimum and maximum field strength displaced by 90°.

But what about other spacing of the radiating elements? Let's try 90° (¼-wave) spacing. This calls for reducing the spacing between pins to one-half what you've been using. Also, you'll need to use equal-length strings for observing the pattern for in-phase feed. After you've looked at that, as in Fig. 3, you might want to shorten one string by one-half wavelength (180°) and check the pattern for out-of-phase feed.

When you've explored those patterns, look at Fig. 4. In this setup, you retain the quarter-wave spacing between elements but delay the rf power fed to one element by 90° (¼ wave). To compensate for this delay, you'll need to shorten the string for the pin representing that element by a quarter wave. Run through the same procedure you've used before. Note now that the pattern is unidirectional instead of bi-directional as on previous checks.

By using proper pin spacing to simulate actual radiating element spacing and proper string length to simulate the initial phase relationship, you can explore any combination your fancy may dictate! Just remember, these simulations are valid only for situations in which the radiating elements are fed equal rf power.

The methods of feeding antenna elements, as shown in the several figures, are displayed in a manner intended to show clearly the delay (or lack of delay) in the phase of rf power fed to one element as related to the phase of rf power delivered to its paired element. There's nothing wrong with these systems other than their requiring an inordinate length of feedline cable. There are other, preferable, ways of doing this in actual antenna installations, so you should consider alternative methods. ■