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Antenna systems

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SOMEONE ONCE SAID SOMETHING TO the effect that the more things change, the more they remain the same. That thought came to mind recently while traveling through the "outback" of our country—the "Wild West."

Back in the East, most VHF communications antennas are omnidirectional, meaning they radiate RF (*R*adio *F*requency) energy equally in all directions; a directional VHF antenna is rarely seen. But out West it often becomes quite necessary to beam a signal up a canyon, down a mountain—or, anything but omnidirectional. That's because there's no sense in wasting RF energy by beaming it where it's not needed. It is, therefore, not uncommon to run across directional VHF antennas—usually two verticals sticking up from an arm that protrudes from a mast or tower.

Seeing those vertical beams reminded me that one of the standard questions on the FCC Radiotelephone License exam concerns two quarter-wavelength vertical broadcast-band antennas that are spaced one half-wavelength (180 degrees) apart, and are fed out-of-phase by 180 degrees. "What is the radiation pattern," the exam asks. You are supposed to know the answer: "Bi-directional, in-line with the two antennas."

For more than 35 years, the FCC has asked essentially the same question as it concerns antennas for the standard broadcast-band. However, the same technique is used for VHF communications antennas. The only difference is that it's easier to feed the smaller, low-power VHF antennas because ordinary coaxial cable can be used for the phasing networks. So that you can better understand the characteristics of phasing networks, let's look at a couple of examples.

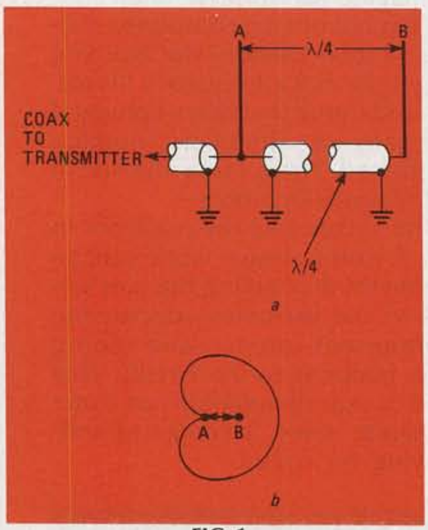

FIG. 1

Antenna Phasing Networks

Figure 1-a shows how two vertical antennas can be installed to provide a unidirectional radiating pattern or, more precisely, a cardioid pattern. A cardioid is a heart-shaped closed curve formed by the overlapping of two equal fixed circles. That pattern is shown in Fig. 1-b. A unidirectional antenna would have greater forward energy and even less energy at the sides; but with an inexpensive antenna system, the cardioid pattern is as unidirectional as we're going to get. For a highly unidirectional radiation pattern, we would use a multi-element yagi or stacked yagi's—a subject for detailed future discussion.

The two antennas in Fig. 1-a are physically spaced a quarter-wavelength apart, and the RF signal is fed to them 90-degrees out of phase with each other. To accomplish the phase difference, antenna A is fed directly from the transmission line, and a quarter-wavelength section of coax is placed between antennas A and B. The coax cable between the two antennas is an electrical quarter-wavelength, so it delays the energy to antenna B by 90 degrees. By the time the signal reaches antenna B, the wavefront from A has already arrived; the energy from A and B combine in the forward direction. But, if you calculate the energy toward the rear you will find that it cancels, because the wavefront from antenna B arrives at A 180-degrees out of phase. What a simple way to get a directional radiation pattern! All that is needed is just a couple of pieces of wire and some coaxial cable.

However, there is one major problem with that arrangement: The coaxial phasing section won't reach from antenna A to B. And because the coax effectively slows down RF flow within the cable, a half-wavelength of coax is less than a half-wavelength in free space. The reduced speed of the RF flow is called the *"velocity factor"* which, for coaxial cable, is nominally 66% of the calculated wavelength in free space. For example, if a wavelength in free space is 10 feet, an electrical wavelength of coax is 6.6 feet. Let's consider a second example: If a quarter wavelength in free space is three feet, a quarter-wavelength of coax is just short of two feet. Therefore, if the antennas are spaced a quarter-wavelength apart and fed a quarter-wavelength out of phase, the coax from antenna A to B is obviously not going to reach—it will reach only 66% of the required distance.

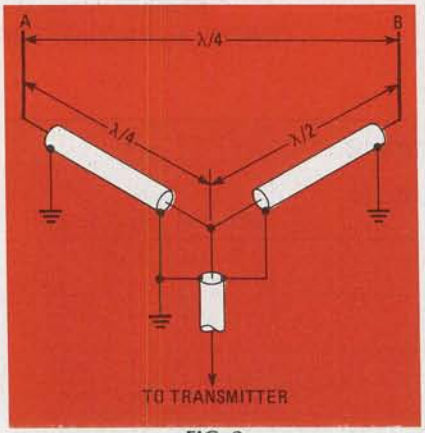

FIG. 2

The way we "stretch" the coax is by changing the method by which the two antennas are fed. One such solution is shown in Fig. 2. There, instead of the coax from the transmitter going directly to point A as in Fig. 1, it is connected through a quarter-wavelength section of coax. From the junction of the main transmission line and the quarter-wavelength coax, a half-wavelength section is connected to point B.

At first glance it might appear as if everything is out of joint, but take a moment to study the phase relationships more closely. Though we have delayed the signal to point A by 90 degrees, we have delayed the signal to point B by 180 degrees. The phase difference between the two is still the desired 90 degrees—the only problem now is that we have more coax than we need going to point B. And since the half-wavelength section is about 30% oversize, we can coil the excess and tape it to the mast or tower if necessary.

You can play with the antenna spacing and coax phasing-sections to handle almost any problem that comes up. For example, let's go

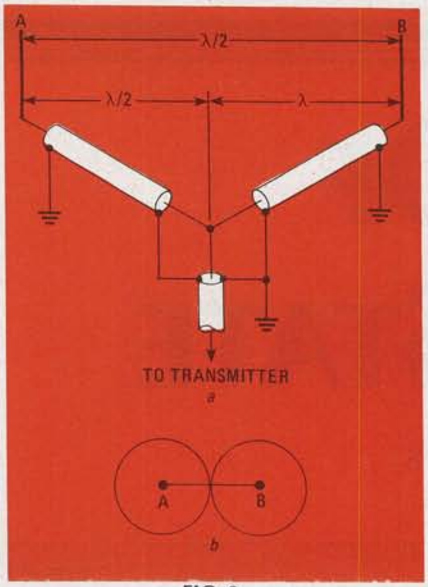

FIG. 3

back to that question of which the FCC is so fond. Imagine that a VHF station for a tow-truck service is to be located in the center of a long, thin island. An omnidirectional antenna is obviously going to radiate RF energy over the water, where it won't do anyone any good. What's needed is a bi-directional or a figure-8 radiation pattern—the same one that is on the FCC tests.

Figure 3 shows the desired pattern and how it's attained. Here the antennas (in Fig. 3-a) are spaced a half-wavelength apart; the signal is fed to them 180 degrees out of phase with each other by using a half-wavelength coax section to antenna A and a full-wavelength coax section to antenna B. The difference between a half-wavelength and a full-wavelength is 180 degrees—the value needed for the bi-directional pattern, and exactly the answer needed for the FCC's question.

Determining how transmission-line phasing-sections work is not only fun, but also gives a good understanding of how to use ordinary coaxial cable to overcome unusual antenna-installation problems. Try working the examples shown using unusual feedline arrangements, such as bringing the feed into point B instead of point A, or experimenting to see how much length must be added to a coax cable to reach from one antenna to the next to achieve the desired phase difference. **R-E**