How's your antenna?

Part II—The halfwave antenna is expanded into many other configurations, each having specific contributions to how RF energy is sent or received.

By Patrick E. Buller

In the past, antennas were generally used for fixed, single-frequency operations. Today's needs require antennas to have a much broader bandwidth to cover more frequencies. These new requirements include repeaters with wide frequency separation or the combining of more than two transmitters into one antenna.

One approach to increased bandwidth is the incorporation of larger-diameter material that lowers the antenna "Q" (discussed in Part I). Methods used to accomplish this incorporation include increasing conductor diameter or using more than one paralleled conductor. Parallel conductors define a circle that has the effect of a single conductor with a diameter equal to the spacing of the parallel conductors.

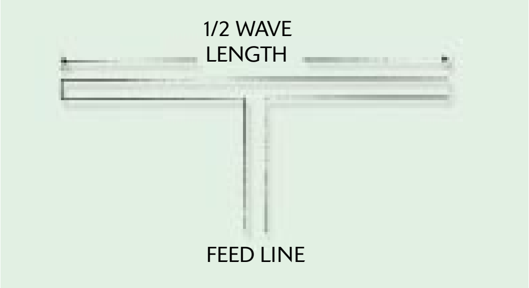

Figure 1. One halfwave antenna.

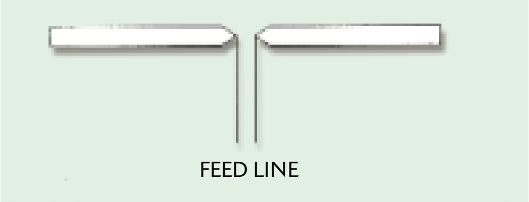

Figure 2. One halfwave antenna.

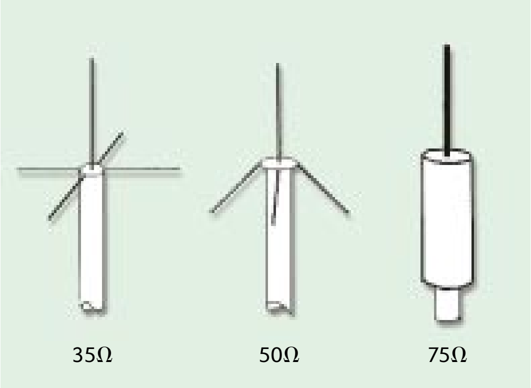

Figure 3. Impedance change by angle.

The bow tie antenna is another example of a large surface area that also increases bandwidth, often used in antennas for 450MHz and above. The folded conductor of a bow tie antenna also changes impedance.

Impedance change

In a classic, folded dipole antenna, as shown in Figure 1 at the left, there are parallel conductors, but only one conductor is fed power. It raises the impedance of the feed point by the relationship of quantity of conductors, squared, times the antenna impedance. For example, a pair of wires $(2)^2 = 4 \times 72\Omega = 288\Omega$.

A three-conductor antenna raises the impedance nine times, providing all conductors are the same diameter. If diameters are equal, then spacing between wires and conductors is not a factor. If the diameters of the conductors are not the same, the spacing is indeed important.

If, instead of feeding only one of the two conductors, both conductors of each leg are made common, as shown in Figure 2 at the left, then the bandwidth is the same as the folded dipole, but the impedance is close to the classic 72Ω. Why the impedance difference? The folded dipole shares the current equally between the parallel wires; therefore the current in each wire is half that of a single conductor.

The folded dipole has several features that make it useful as a vertical collinear antenna. Besides increased bandwidth, wind loading is somewhat increased, but vibration is drastically reduced, which eliminates metal fatigue that is common in single elements of ground-plane antennas. Noise caused by particles whizzing past during high winds is reduced, and the lack of sharp points eliminates *corona noise*. Corona noise is observed by hearing a high-pitched squeal sounding like a siren with ever-changing pitch. Corona noise stops immediately after a lightning strike.

Impedance changes when different diameter conductors are part of the feed. The final impedance is a function of the ratio of diameters of each element and the spacing between conductors.

When comparing the impedance of a center-fed dipole of 72Ω to that of a ground-plane antenna of 36Ω, consider the geometry. The dipole is two conductors in the same plane, and the vertical antenna has one vertical, the other horizontal. Moving the horizontal element from horizontal down to about 40° raises the impedance to around

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50Ω, which is valid for a single-element vertical antenna with a modified ground plane as shown in Figure 3 at the left.

The collinear antenna

Collinear means having axes lying end to end in a straight line. Collinear antennas for the two-way radio market are usually made up in pairs. This is a gain of 3dB when one more element is added to a single element. For an additional 3dB, the two elements must be doubled, yielding four elements for a total antenna gain of 6dB.

The most common 6dBd vertical antenna for the 150MHz band consists of four halfwave rigid coax cable pieces fed at the bottom with an impedance-matching transformer enclosed in a fiberglass tube as shown in Figure 4 at the right. Note that the coax antenna elements have conductors changing positions between elements. All elements must have the same phase relationship for each element to contribute energy perpendicular to the elements. Therefore, it is necessary to have correct polarity. Remember that the phase changes 180° in halfwavelength. If the polarity were not changed, and elements were not transposed, the antenna would be two wavelengths long. No energy would radiate perpendicular to the elements, meaning no signal on the horizontal—just a four-leaf clover pattern with no radiation broadside or off the ends. In reality, the coax linear is not a true 6dBd but about 5.4dBd because of the uneven power distribution. The bottom element has to feed the other three, and the top element feeds none.

Another common antenna in the two-way industry is the folded dipole array. It is fed with equal lengths of coax cable, which allows energy to arrive at all antenna elements at the same time. Figure 5 at the right shows a cable arrangement that is not only acting as a phasing harness but is impedance matching as well. Quarterwave transmission lines will also perform as transformers. The advantage of this type of antenna, compared with the coax collinear, is each element is fed the same amount of power and its gain is near the full 6dBd. Arranging the elements around the vertical support can modify the radiation pattern. This option is not available with the coax collinear antenna.

Downtilt

Collinear VHF antennas with a 12° beamwidth that are installed in high elevations do not cover nearby low elevations. In short, these antennas talk well mountaintop-to-mountaintop, but not down to the highway, where they are needed. *Downtilt* is when the beam is electrically lowered below the horizontal plane. This is done by a phase shift of power between each radiating element. This phase difference between elements forces the beam down from the horizontal.

Figure 6 on the next page shows the phasing required for downtilt. Each element going in the vertical direction has leading phase from the lower element. The downtilt is limited to about 6°. Beyond this limit, side lobes appear that defeat the goal of downtilt and gain.

Phased arrays

A single antenna has a definite gain. Duplicating this antenna and feed from the same source will provide 3dB more gain. Duplicating again will add 3dB more. The collinear antenna is one example of *phased array*. In the classic *broadside phased array* as shown in Figure 7 on the next page, eight dipole antennas are connected to a transmission line. Note that the transmission line is transposed. To have the antenna appear as one large antenna, all elements need to be fed with the exact same phase. For example, assume all elements will have the left side instantaneously positive. Each antenna is spaced halfwave apart, therefore the transmission line is transposed because the energy is shifted 180° in the halfwave transmission line. The center transmission line, however, is not transposed because the energy being fed in the center arrives at each antenna at the same time. If the antenna array were fed from the bottom, the center phasing harness would have a transposition.

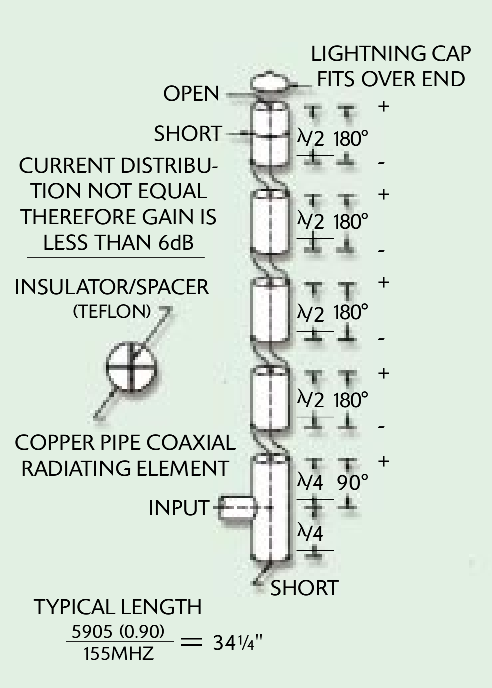


Figure 4. End fire collinear antenna.

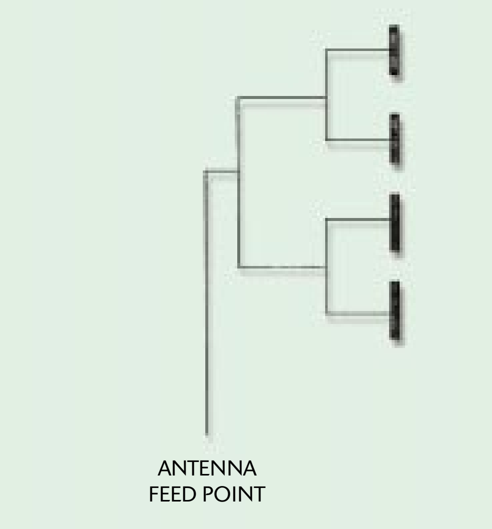


Figure 5. The collinear.

The key in any phased array is keeping all elements in the correct phase relationship. Antenna patterns can also be shaped by changing the spacing of antenna elements and different feed phase angles.

Log periodic antennas

A log-periodic antenna, (as

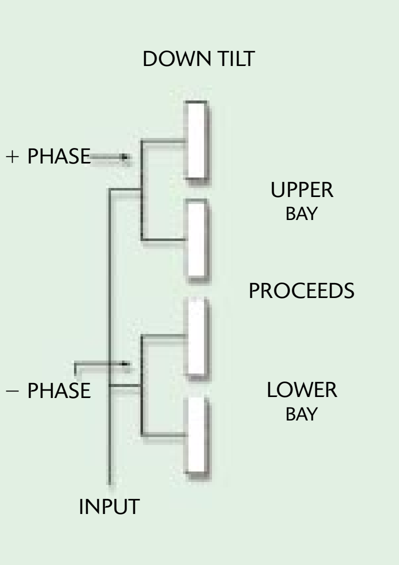


Figure 6. Downtilt.

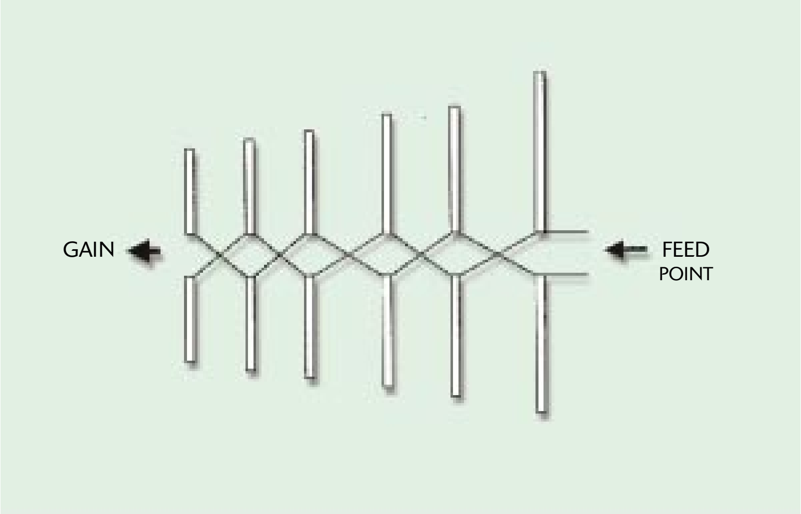


Figure 8. Log periodic antenna.

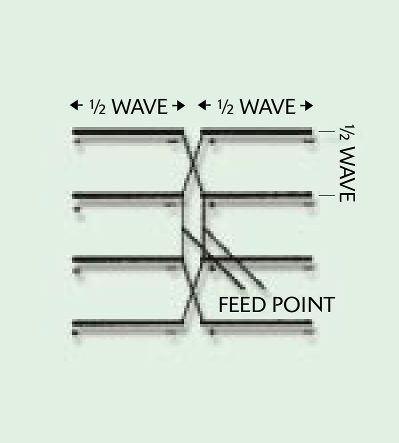


Figure 7. Broadside array.

shown in Figure 8 above right) is a variation of the broadside antenna. The radiating elements decrease in length according to the logarithmic function. The design is based on antenna characteristics that are periodic with the logarithm of the frequency. The variation of the characteristics is small over a single time period, allowing the antenna to operate frequency-independent. In other words, it has an acceptable VSWR over a 2:1 frequency change—the detracting feature is that it has less gain than a Yagi-Uda antenna having the same number of elements, but it is less susceptible to ice buildup. Note the phase reversal of the feed line at each element.

Parasitic array

The multi-element Yagi-Uda antenna was described by S. Uda in Japanese and subsequently in English by H. Yagi. It became first known in the United States as the yagi antenna. A three-element antenna is shown in Figure 9 at the right with optimum spacing for forward gain. The longer element is the reflector, and the driven element (that takes power) and the director are shorter. The driven element is the base where all elements are derived from. Its length is found by 492(K)/F(MHz), where K is the ratio of diameter to wavelength. The reflector is 5% longer and the director is 5% shorter than the driven element. Optimum spacing is 0.2 wavelengths from reflector to driven element and 0.1 to 0.15 wavelengths between the driven element and the director. A single reflector is all that is required, but additional directors can be added for more gain. Some antennas may have as many as 48 directors, but the contribution of any more than a dozen is so small, it is best to add another full antenna and feed it in phase. The exception would be when insufficient real estate exists to add antennas side by side.

The operation of a Yagi-Uda antenna is based on all elements accepting energy from the driven element and re-radiating in the correct time relationship. Consider a single wave radiating from the driven element. The reflector receives this energy, and it begins to radiate. It does so in the correct time relationship to be in phase with the next wave produced by the driven element. The same contribution is experienced for the directors. They all add in-phase in the forward direction but add out-of-phase in the reverse direction. Anything that modifies the phase relationship directly affects the forward gain and its *front-to-back ratio*. Front-to-back ratio is the energy sent in the forward direction compared to that measured at 180°, and it is expressed in decibels. Ice buildup is one of many factors that alters the performance of the antenna. To make a Yagi-Uda antenna broadband, use large diameter elements, and no more than five. The more directors used, the higher the antenna Q is, resulting in less bandwidth.

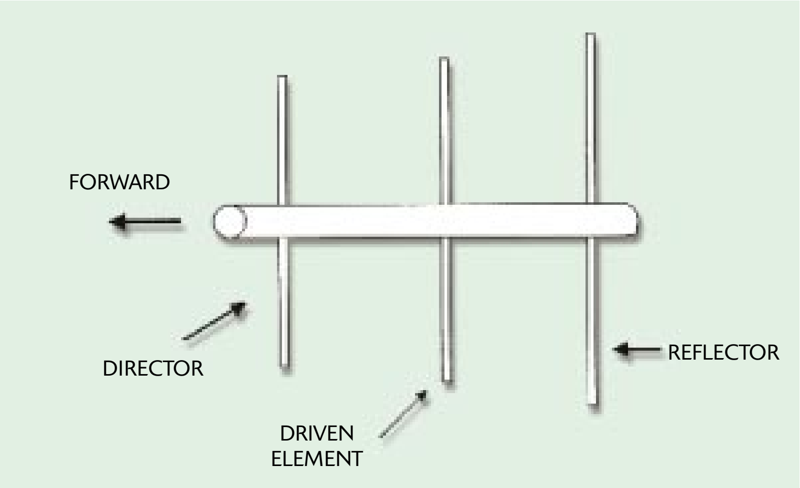
Slot antennas

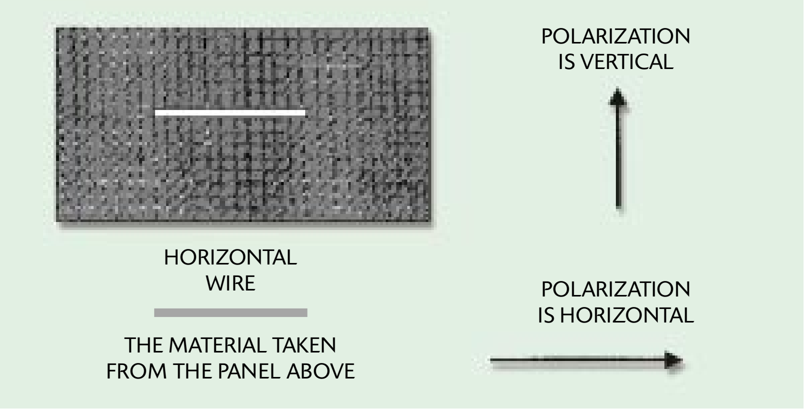
A *slot antenna* is the conjugate of a wire antenna. Figure 10 at the right shows a large conductive sheet where a halfwavelength section of material is cut out. The material removed is a half-dipole antenna. The slot, then, is a halfwave antenna, but with reverse properties. Its high impedance point is in the center compared to the dipole with the lowest impedance at the center. Polarization is vertical, and it is a balanced antenna.

When the antenna is rotated to where the slot is vertical, it is now radiating horizontal. Gain is achieved by stacking several in the vertical plane, one above the other. This antenna is the workhorse for the TV broadcast band. It is immune to lightning because its feed point is inside a grounded structure. Another use for the slot antenna is with guided missiles, aircraft and counterintelligence operations where the metal skin of the vehicle is used as the antenna. The slot is filled in with non-conductive resin, painted and completely camouflaged. If the slot antenna is backed with a cavity, it becomes highly directional and does not radiate inside the vehicle. Some texts incorrectly refer to this product as a "pylon antenna."

Parabolic antennas

Figure 11 at the right shows a parabolic antenna. It behaves identical to the flashlight. A source of energy at the focal point is re-radiated in the forward direction. The focal point can consist of a simple two-element Yagi-Uda antenna, a horn or an inverse parabolic antenna fed from the center of the larger antenna. The latter is common in space research antennas. For point-to-point microwave, the first two "illuminators" are common. Gain is calculated as $G=20\log D + 20\log F - 52.5$, where D is diameter in feet and F is in megahertz. The industry classifies this antenna at 55% efficiency. If a radome is installed, then the gain figure must be reduced to account for the radome loss.





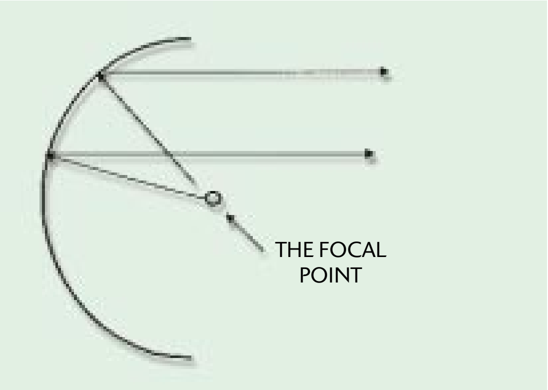


Figure 9 (top). Yagi-Uda antenna. Figure 10 (middle). The slot antenna has polarity opposite that of the wire. Figure 11 (right). The focal point is where all energy is reflected to. It is a narrow area and is easily missed by damage, often caused by leverage on the rear of the antenna such as waveguide.

If high-performance antennas are required, a shroud with RF absorbing material is added around the dish to attenuate most of the sidelobe energy and to improve the front-to-back ratio. To the observer, the feed horn is further shielded except for the front of the dish. The reflector can be either solid, grid or mesh screen, depending on the frequency used. The higher the frequency, the tighter the tolerance must be in dish construction. As long as the opening in the material is less than 0.01 wavelengths, it appears as a solid. Vandalism can be a problem because parabolics present attractive targets. At 6GHz, bullet holes contribute little distortion. It's when the feed horn or waveguide is hit that the problem becomes serious. An example is a shipboard radar antenna. Most are constructed of metal screen to reduce wind loading with little reduction in either gain or beam width. Along that line, most navigational radar antennas have little material vertical but large in the horizontal. The large horizontal focuses the beam to be narrow in the horizontal and large in the vertical. This not only allows accurate bearing measurements but also allows the vessel to rock about vertically and not lose its target. A pencil beam is required for pinpoint accuracy such as fire control radar or speed measuring devices. ■