Reviewing The Radio Classics

Extra Wide-Band Antennas

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Number 9 of a Series

ANTENNAS are common to both the ham and the public—they simply pick up signals. But when an engineer explains that an antenna will pick up one signal well and others poorly, questions arise.

The amateur finds an easy answer to the question—the antenna is resonant. Only when person after person without technical background asks him "why", does the amateur wonder whether resonance is the entire answer. Resonance is not the whole answer; the final answer has yet to be written. Here is an area for exploration.

Space

Space is a particular form of transmission line connecting a transmitter and a receiver. It has many similarities to television twin and coaxial cable for transmitters. Let us look at these:

Twin-lead and coaxial cable are intended to be uniform from an r.f. source to a load. Each transmission line has a "design" inductance and capacitance per unit length since all conductors exhibit inductance and all conductors with a voltage difference between them exhibit capacitance.

When men design transmission lines, they work with the permeability and dielectric constants of their materials so that in terms of unit length the characteristic impedance R equals $(L/C)^{1/2}$.

When a load of impedance R is connected to this transmission line, there are no reflections of power from the load (unity s.w.r.). There are practical limitations to manufacture, but the electrical characteristics of space are the same everywhere. Space, too, has a dielectric constant and permeability giving it a certain impedance, 377 ohms per square. This is somewhat hard to understand at first, but it is this same value regardless of what unit is used; 377 ohms per square centimeter, inch, foot, or mile. Whenever we build a device that matches this impedance, we have an antenna.

The dipole is one such device—it matches space at its half-wave resonant frequency. At a *few* certain distances above ground, the antenna appears to have a resistance of 72 ohms, but its apparent resistance varies with height. As the antenna approaches ground, its apparent resistance approaches zero. At the frequency of resonance, the antenna, when looking like a pure resistance, does "match space." Thus, if we wish, we can look at an antenna as if it is a transformer matching a low impedance such as 36 ohms (¼ wave) or 72 ohms (½ wave) to the impedance of free space. It is normal to wish that this transformer action would cover a greater part of the frequency spectrum, and that is what the authors of these classics did.

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The Background

Since the early days of radio, the cage and fan antennas had been known to be less critical of tuning than those made with a single wire; they had broader bandwidth. This is only another way of saying that they had a better match over a broader frequency range. Yet there didn't seem to be a good antenna that would give a good match over the 10:1 frequency range of many amateur transmitters.

Various amateurs and manufacturers attempted to fill the need with trap antennas, cut and loaded to do a fair job of radiating a signal on several ham bands. There was always an unsatisfied few, for many hams were also interested in non-ham frequencies such as for MARS and CAP. The military was definitely unsatisfied, for they were interested in all frequencies from the broadcast band up.

The Discone

The first true space-matching antenna that this author knows of was publicly described in 1946,[1] the discone. The antenna derives its name from its two elements, one shaped like a disc, the other like a cone. The two are so proportioned that there is a gradual change of impedance from the transmission line to the impedance of free space, at which point the radio energy fully enters space and is transmitted. It is a true wide-band transformer, for it will work at any frequency in an 8:1 to 10:1 range with an s.w.r. of 2:1 or less.

[1]A. G. Kandoian, "Three New Antenna Types and their Application," *Proceedings of the I. R. E.*, v. 34, p. 70W, Feb. 1946, also *Electrical Communication*, v. 23, p. 27, Mar. 1946.

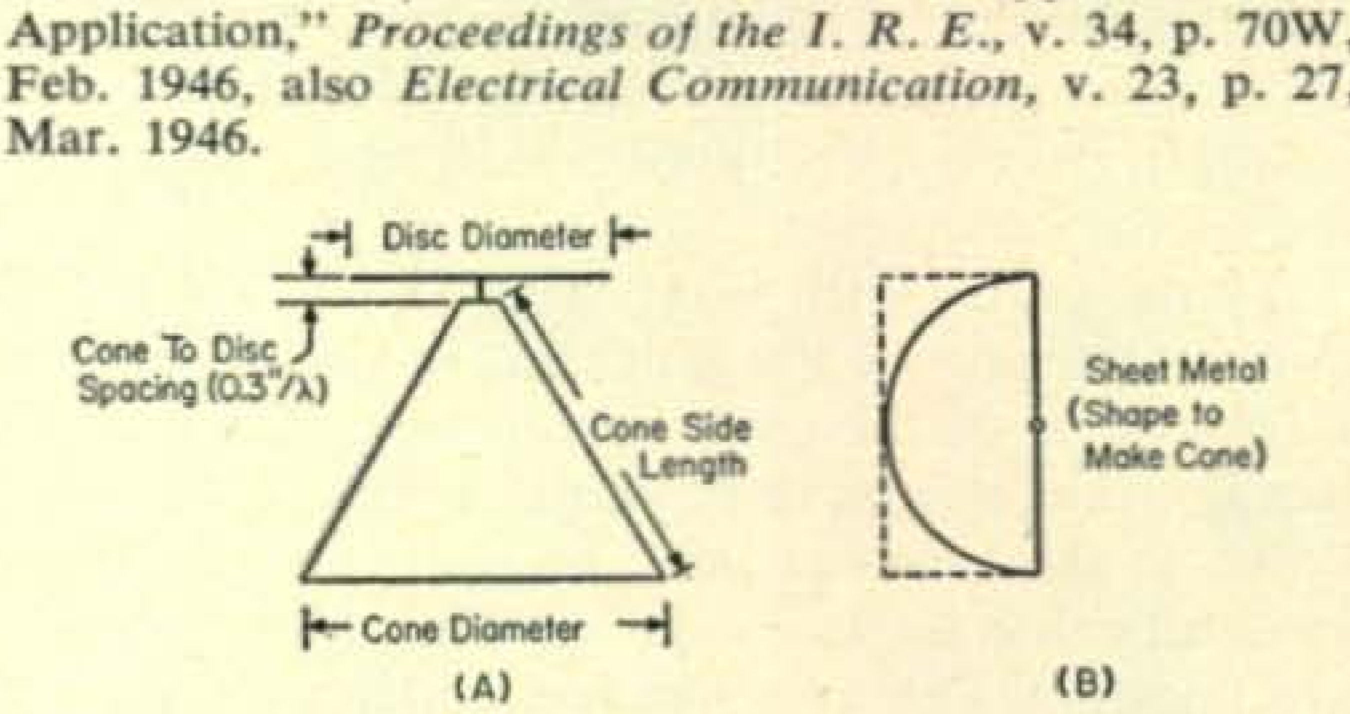

Fig. 1—(A) The discone antenna is named for its two primary elements: the disc and the cone, which together form a broadband antenna usable over a 10:1 frequency range. (B) The cone for a v.h.f. discone may easily be cut from a single rectangle of sheetmetal as described in the text.

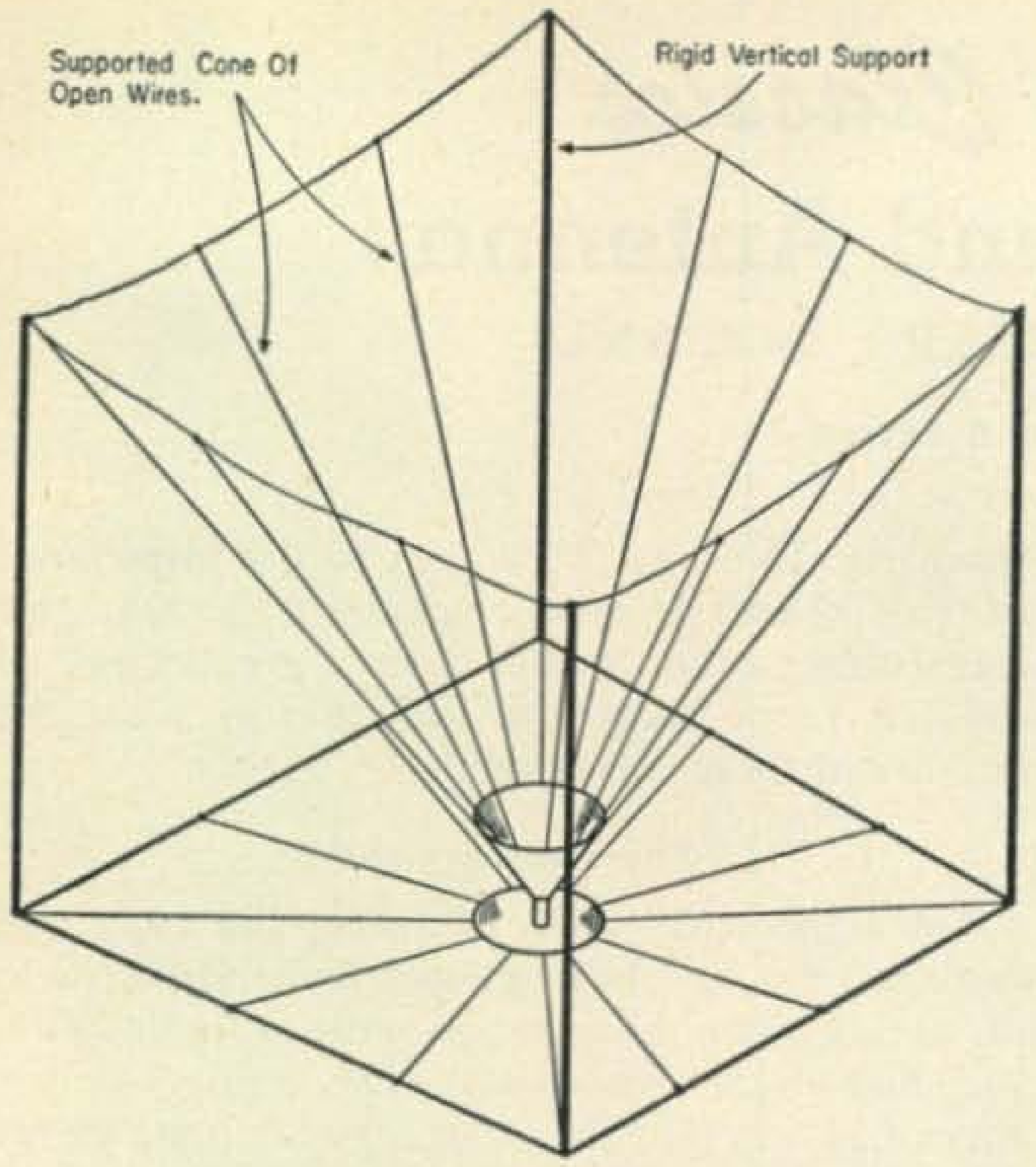

Fig. 2—A low frequency version of the discone may be inverted as shown and may be constructed of wires rather than sheetmetal.

Its radiation pattern is like a ¼ wave vertical antenna.[2]

The design of the antenna (fig. 1) is mathematically simple. For a 50-ohm feed the following proportions are used:

CONE SIDE LENGTH: ¼ wave at lowest freq. plus 10%.

CONE DIAMETER: same.

DISC DIAMETER: ⅔ cone side length.

CONE TO DISC SPACING: 0.3 inch/meter wavelength at lowest freq.

One of the easiest ways to make such an antenna for two meters and higher frequencies is to make it out of sheet metal. To do this with the given dimensions, procure a sheet of metal twice the side-length long by the side-length wide, and scribe a half circle on it. This will make a 60° cone when the curved edge is formed into a circle. A strip riveted or soldered to make a seam will hold the cone in shape. If you wish, metal legs or brackets may be attached to the open end of the cone for attachment to an automobile or roof.

The point of the cone (if formed from sheet metal) should be sawed off to permit mounting of a coax connector within the cone. If the disc is small, it may be directly soldered to the center pin of the connector.

Many hams will want to make a lower-frequency version of the antenna. In this case, only a foot or so of the cone should be made of sheet metal, the remainder being wires continuing down at the same angle. The sheet metal will be structure that looks "pure" at v.h.f. and the wires are good enough at lower frequencies if 12 to 20 are used. Also, the sheet metal cone tip offers a good cover for the husky hardware needed to support the large disc. The l.f. disc need not be

[2]J. M. Boyer, "Discone—40 to 500 Mc Skywire," *CQ*, July 1949. M. Seybold, "The Low-Frequency Discone," *CQ*, July 1950.

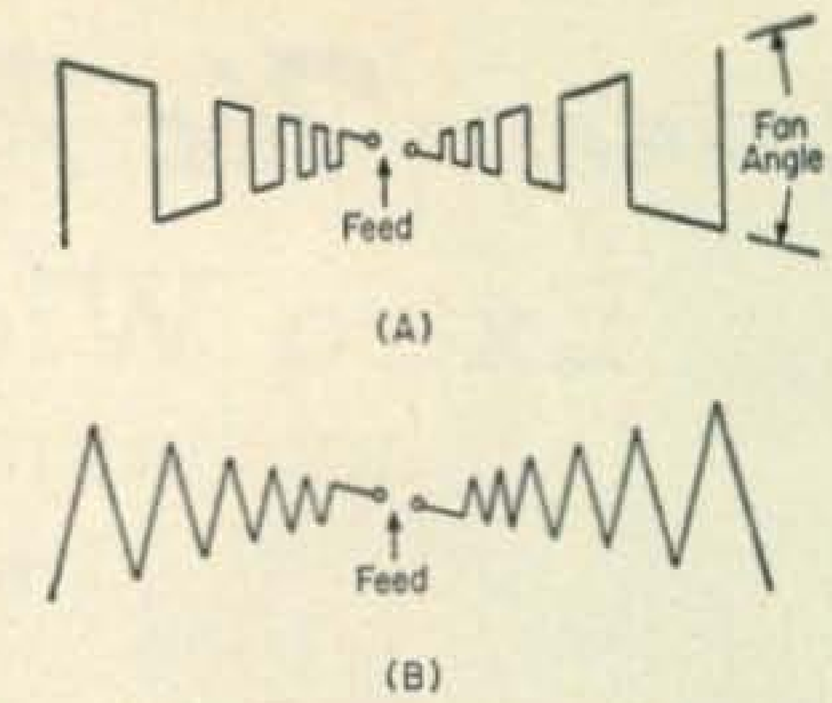

Fig. 3—Two versions of the log periodic antenna prior to "folding." Radiation is into and away from the page.

solid for more than a foot or so, aluminum angle making good radials that look sufficiently like a disc. It is important, however, to have plenty of strong insulation to support the disc away from the cone.

The discone may be turned upside-down, with the disc slightly above ground level and the open end of the cone up (fig. 2). This has an advantage with 3-30 mc discones, or even higher frequencies, for the supporting poles around the cone perimeter are less than a ¼ wave high and have only to support the weight of conically descending wires. There is no awkward disc to balance.

The discone is a decent vertical antenna that does not require tuning, it is omnidirectional, and may be stacked or put in a parabolic reflector for higher gain.[3] It does, however, have the major disadvantage that it is not capable of directional characteristics as is a rotary beam without considerable awkwardness. This is the primary reason for the invention of the log-periodic antenna.

The Log-Periodic Antenna

Apparently, about 1957 it was realized that antennas that made solid angles in space could possess extremely wide bandwidths. Thus, antennas like the discone could be extended infinitely without real change in characteristics. However, refinement of the theory seemed to indicate that for best bandwidth, the two elements of the antenna should have the same shape but have corresponding irregularities extending in opposite directions. An example of such an antenna is shown in each fig. 3(A) and (B).[4] Antennas of these shapes in the positions shown would

[*Continued on page 83*]

[3]Kandoian, *et al*, "High Gain With Discone Antennas, *Electrical Communication*, v. 25, p. 139, June 1948.

[4]DuHamel and Isbell, "Broadband Logarithmically Periodic Antenna Structures," *1957 I. R. E. Convention Record*, Part I, p. 119.

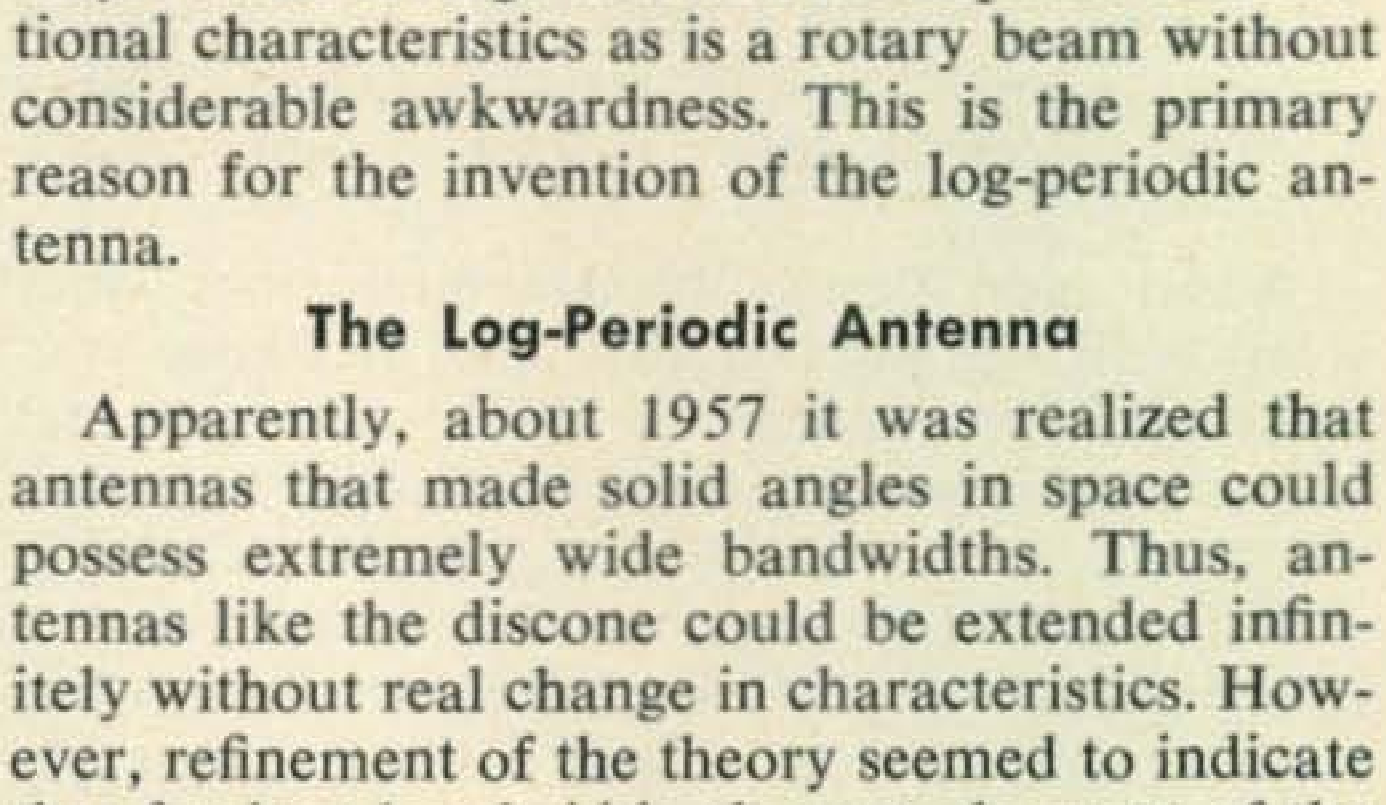

Fig. 4—A log periodic antenna showing the bend angle and the transmitting and receiving direction.

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radiate a horizontally polarized signal. Ideally, the elements would become progressively thicker as they were further from the center of the array. If all angles in such an array converge to the center point, the ideal feed-point impedance is about 190 ohms. These arrays are bidirectional, into and out of the page.

If the array suffers a sharp bend at the center (fig. 4), the signal strength in the direction of the center-point is increased and that toward the larger elements is decreased.[5] It is not particularly difficult to get 30:1 power ratios (15 db) in the front-to-back directions.

Forward gain of 6 to 10 db is not hard to get if fan angles and bend angles less than 60° are used. A minimum of 30° each seems to be a good practical limit, though fan angles as low as 15° have been reported. Reducing these angles increases both the gain and the front-to-back ratio.

The name log periodic comes from the idea that the elements show a slight but continuous change electrically with frequency. As the frequency continues to change, the characteristics will repeat themselves over and over. As these "repeating" frequency characteristics occur at fixed multiples of the previous frequency, the element lengths have a constant logarithmic (or "log") spacing, hence the name "log periodic."

A designer does not have to be able to "work" logarithms or trigonometry to lay out a log periodic antenna.[6] The procedure is: lay out the fan angle on a piece of paper with one inch standing for a couple of feet. Draw a line bisecting the fan angle. Draw a line ¼ wavelength long at the design or lowest frequency at right angles to the bisector to just touch one side of the fan angle (fig. 5). This determines all other dimensions of the fan. The design frequency for fans like those of fig. 3(A) is the lowest operating frequency, but for (B) should be about 82% of the lowest operating frequency. The place where the ¼ wavelength line touches the angle is the end of the outermost element.

Now a fraction must be chosen that will de-

[5] DuHamel and Ore, "Logarithmically Periodic Antenna Designs," *1958 I. R. E. Convention Record,* Part I, p. 139.

[6] C. T. Milner, "Log Periodic Antennas," *QST,* Nov, 1959, p. 11. G. J. Monser, "Design for an All-Purpose TV-FM Antenna," *Electronics World,* Nov. 1962, p. 36.

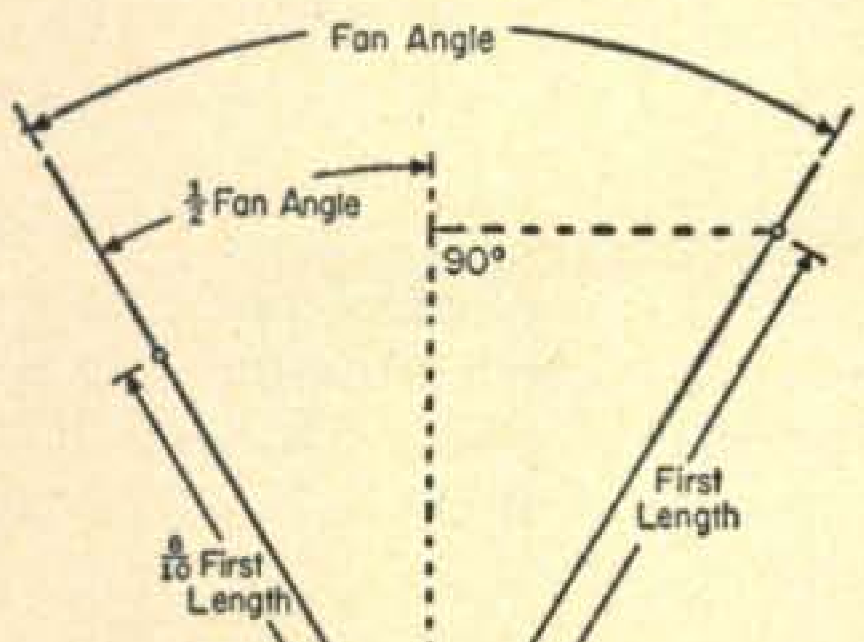
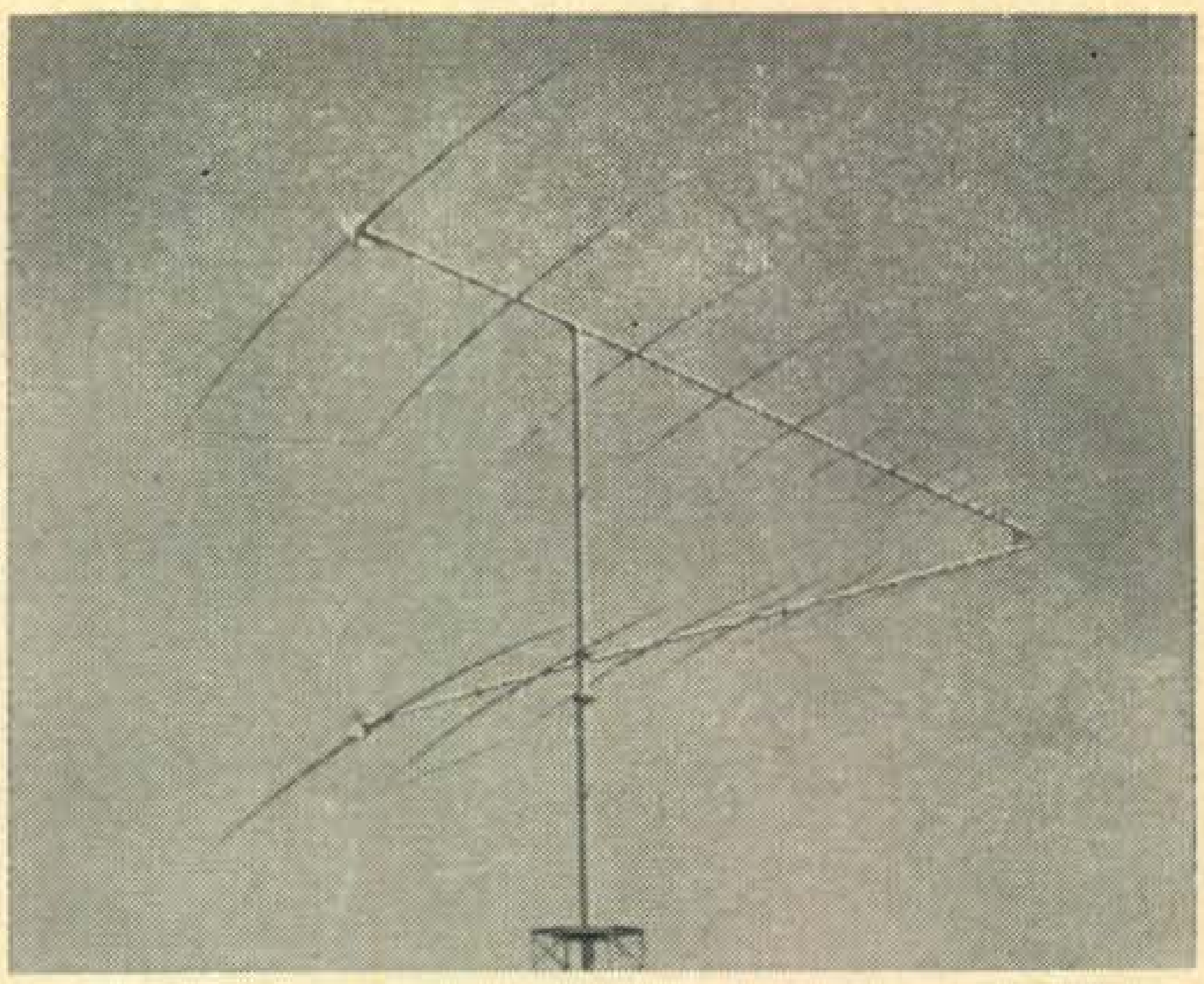


Fig. 5—Typical design layout for one fan of a log periodic antenna.



Commercial version of a log periodic antenna. *(Photo courtesy Collins Radio Co.).*

termine the number of elements needed and the variation of s.w.r. with frequency. The fraction will best be between 0.8 and 0.95. As the fraction increases, the number of elements goes up and s.w.r. changes become less. Let's assume 0.8 is picked. We then pick a spot on the other side of the fan angle 0.8 of the first distance from the corner angle. This is where the next crossing element begins. Then go back to the first side of the fan angle, and measure from the apex 0.8 of the last distance or 0.64 of the original (0.8 × 0.8). We continue this effort, zig-zagging back and forth with elements until the end of one is less than ¼ wave from the bisector at the highest operating frequency. Count the number of lines that represent elements to see how many you need. Measure the lines to see the element lengths. Remember, this is for one fan, and two are needed. Should you wonder how you are going to hold those elements in place, the bisector is at ground potential and makes a very logical boom.

Feedpoint impedance will probably be over 100 ohms, so high impedance coax may be desirable—at least 72 ohms, unless a balun is used. Twin-lead (150 ohms) would seem about ideal from an impedance standpoint. A common form of feed is to poke coax cable through part of the lower boom, with the shield connected to the lower set of elements and the center conductor connected to the upper.

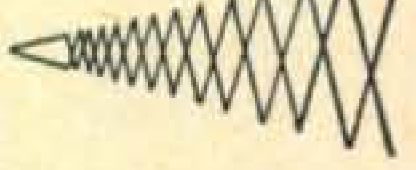


Fig. 6—Two identical fans are reversed and mounted one above the other to form the antenna shown in fig. 4.

After construction of the two fans, lay the upper over the lower to check for differences (there should be none), and then lift and rotate one fan so that the open sides of its elements are over the closed sides of the other fan (fig. 6). Install hardware to give the desired bend angle, add feedline connections, and raise into position.

Watch out for harmonics—the log-periodic will happily radiate them with the same gain it gives your desired signal. ■