Directional Antennas with Closely-Spaced Elements

By John D. Kraus,* W8JK

ONE of the simplest and most efficient radiators used on short waves is the horizontal half-wave antenna.[1] Offhand it might not appear that two such antennas would make a good radiating system, if placed parallel to each other a small fraction of a wavelength apart and fed with currents 180 degrees out of phase. It is true, however, that this arrangement forms a simple and very compact directional antenna.

Fig. 1 is a sketch of two half-wave radiators oriented in the horizontal plane as described and placed high above the ground. The spacing may be a small fraction of a wavelength. If the wires

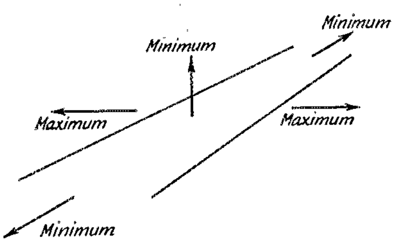

FIG. 1—TWO HALF-WAVE ANTENNAS CLOSELY SPACED AND WITH CURRENTS 180 DEGREES OUT OF PHASE

The arrows indicate the directions in which radiation is a maximum and a minimum.

are not placed too close together, the pair will radiate the same power as would a single half-wave antenna with the same input. But, because of the close-spacing and out-of-phase currents, the direction in which the radiation takes place is profoundly altered. G. H. Brown[2] was the first to point out the advantages of using such close spacing.

As indicated by the arrows in Fig. 1, the radiation from the pair is very small—theoretically zero—off the ends and also vertically. The radiation horizontally broadside is a maximum and is considerably greater than from a single half-wave antenna fed with the same power.

Fig. 2 shows the close spacing idea applied to a number of practical directive antenna systems. The type of Fig. 2-A is 32 feet long. It has two half-wave radiators spaced one-eighth wavelength and fed at the center. The cross-over feeds the two radiators 180 degrees out of phase. The feeders connect on at the middle of the cross-over. The radiation from the antenna is maximum in both directions broadside and minimum off the ends. The gain in both directions broadside is as much as or more than in the one preferred direction when a half-wave radiator is used with a reflector one-quarter wavelength behind. Dimensions are given for fundamental operation in the 14-Mc. band. The antenna is actually a multiband affair, giving approximately the same horizontal bi-directional pattern on 28 Mc. as on 14 Mc., or on any frequency between these two bands. When used on 56 Mc. the horizontal pattern has four lobes. For fundamental operation on 28 Mc. the dimensions of Fig. 2-A should be halved. This smaller array would have about the same bi-directional pattern on both 28 and 56 Mc.

An antenna of about the same size as the one of Fig. 2-A is shown in Fig. 2-B. This antenna is end-, instead of center-fed. An array having two sections, which uses four half-wave elements, is shown in Fig. 2-C. It is 62 feet long. The array of Fig. 2-D has 4 sections or 8 half-wave elements and is 112 feet long. The antennas of Fig. 2-B, C, and D have the bi-directional pattern only on their fundamental frequency—14 Mc. in this case. When operated on 28 Mc. their horizontal patterns will have four main lobes. For fundamental operation on 28 Mc. the dimensions should, of course, be halved.

CONSTRUCTION

To make one of these antennas as a unit so that it may be supported between two poles it is convenient to use spreaders, which, for a 14-Mc. antenna, are about 9 feet long. These may be either of bamboo or 1- by 1-inch strips of wood. A suggested arrangement for a two-section antenna is given in Fig. 3. Since the antenna bears a striking resemblance to one of the "T" or flat-top types popular a decade or two ago, it is called a "flat-top beam."[3]

The cross-over at the middle of the flat-top is made by using two 6-inch feeder-spreader insulators, one placed horizontally at the center and the other vertically half-way between the center and one end of the wooden spreader. The two-wire feed line comes up from below and con-

* Arlington Blvd., Ann Arbor, Mich.

[1] An excellent treatment of the characteristics of horizontal antennas has been given by George Grammer, *QST*, Nov., 1936, and March, 1937.

[2] G. H. Brown, "Directional Antennas," *Proc. I.R.E.*, Jan., 1937.

[3] J. D. Kraus, "Small But Effective Flat-top Beam," *Radio*, March and June, 1937.

nects on to the cross-over at the horizontal center insulator. In order to get greater separation at the cross-over, the insulators may be made longer by fastening two 6-inch feeder spreaders end-to-end. The wire length at the cross-over is of necessity a few inches more than the spacing. Thus, the wire length at the cross-over of a 14-Mc. antenna (8 feet 8 inches spacing) may be about 8 feet 11 inches.

The line used to support the long wooden spreaders at each end of the flat-top should preferably be of rope. In case a 4-section flat-top is used, a method of accomplishing the additional cross-overs is indicated by dotted lines in Fig. 3. One vertical feeder-spreader insulator is used at the middle of the long wooden spreader. The recommended spacing lengthwise between the sections of the flat-top is about 2 feet.

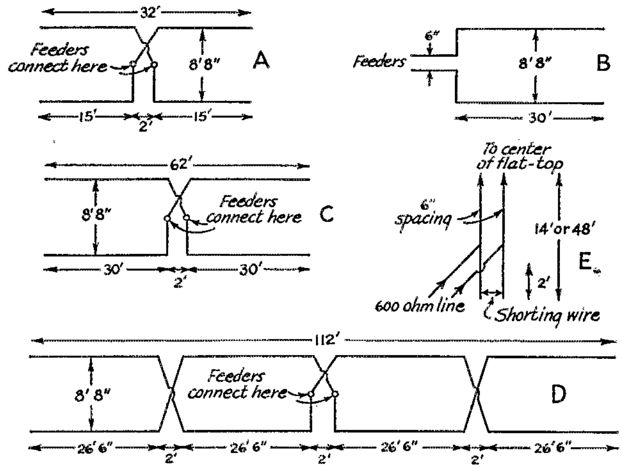

FIG. 2—FOUR TYPES FOR USE IN THE 14-MC. BAND

A and B are single-section types, C a 2-section, and D a 4-section. For fundamental operation on 28 Mc. the dimensions should be halved. Approximate dimensions for a matching stub to feed the 2-section antenna of C are given in E.

FEEDING

The main characteristics of a flat-top directional antenna are the closely-spaced elements, about one-eighth wavelength apart, and currents 180 degrees out of phase. All the elements are driven. The spacing is not critical but one-eighth wavelength seems to be about optimum when 180-degree phasing is used, and is recommended. The mutual coupling between closely spaced out-of-phase wires is such that the impedance at the center of the half-wave elements becomes quite small and, inversely, quite large at the ends. Accordingly, the current flowing at voltage nodes is very high.

The dimensions are not critical and the values of Fig. 2 are recommended for use on any frequency in the 14-Mc. band. Compensation is made for any small variations when the antenna is tuned up.

Either Zepp feeders or a matching stub and 600-ohm line can be used to feed the antennas. The Zepp feeders or the stub connect at the center of the cross-over in the flat-top as shown in Fig. 3. The approximate dimensions for a stub to feed the antenna of Fig. 2-C is indicated in Fig. 2-E. With more sections the 600-ohm line will connect farther from, and with fewer sections closer to, the shorting wire on the stub.

Where the line is not over a wavelength or two long, the Zepp type of feed is very practical. It is also convenient if one expects to use the same flat-top beam on a number of bands. For example, the antenna of Fig. 2-A may be series fed at the transmitter on 14 Mc. and parallel fed on 28 Mc. The feeders in this case would be either one-half or one wavelength long, approximately, since this antenna is fed at a current loop (voltage node) on 14 Mc. A matching stub for this antenna would also be either one-half or one wavelength long on 14 Mc. and about 8 feet either longer or shorter on 28 Mc. The other antennas, Figs. 2-B, C, and D, are all fed close to current nodes as used on 14 Mc. so that matching stubs to feed them should be either one-quarter or three-quarter wavelengths long. It is often convenient to use a three-quarter wavelength stub as one may be able to adjust it from the ground after the antenna has been pulled up into place. It is advisable to use good 6-inch spreader-insulators throughout the stub and 600-ohm line.

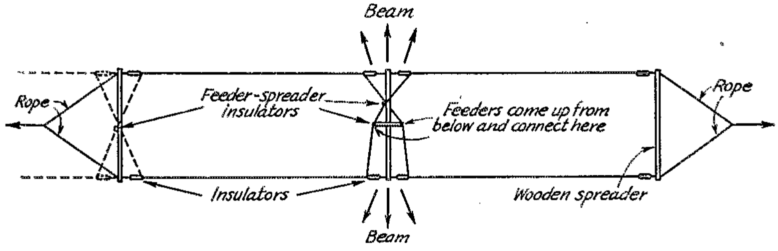

FIG. 3—TOP VIEW SHOWING CONSTRUCTION OF A 2-SECTION ANTENNA WHICH IS POPULARLY TERMED A "FLAT-TOP" BEAM

Method of making cross-over if extra sections are added is shown by dotted lines at left.

In adjusting the stub the antenna is shock-excited from another antenna or from an r.f. line coupled loosely to it. The shorting wire on the stub is then adjusted for a maximum of current through the short. The transmission line is next connected on the stub a foot or two above the short and adjusted up or down the stub until the

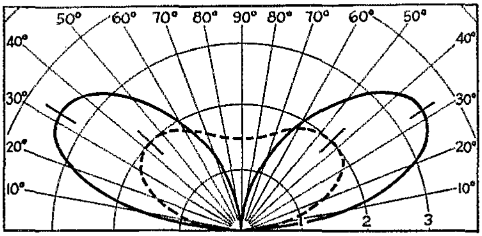

FIG. 4—COMPUTED RADIATION CHARACTERISTICS IN THE VERTICAL PLANE FOR A SINGLE HALF-WAVE ANTENNA (DASHED) AND A 2-SECTION FLAT-TOP (SOLID) BOTH AT A HEIGHT OF THREE-EIGHTHS WAVELENGTH ABOVE GROUND

standing waves along the transmission line are a minimum. A sensitive r.f. current meter (0-200 ma.) equipped with a single turn loop and an insulated hook can be used to slide along one side of the transmission line, so that readings may be made quickly at four or five points along the line spaced about an eighth wavelength apart. Insulation of the antenna and feeders from the transmitter plate supply voltages is, of course, important in any installation.

PERFORMANCE

Because of the out-of-phase currents, the vertical radiation from the flat-top antenna approaches zero. As a result, the maximum radiation in the vertical plane is lowered to a smaller vertical angle. In Fig. 4 the vertical radiation characteristics of a single half-wave antenna (dashed curve) and a 2-section or 4-element flat-top antenna (solid curve) are compared for a height in both cases of three-eighths wavelength above ground. The plane in which the radiation is shown is at right angles to the antennas. The relative field strength is plotted in arbitrary units, and the curves are calculated on the basis of the same power to both antennas. Perfectly conducting ground is assumed, but with horizontal antennas and the height being considered the patterns for ordinary ground would probably be quite similar.

It is apparent from Fig. 4 that the radiation maximum is lowered from about 43 degrees in the case of the half-wave antenna to about 32 degrees for the flat-top. The maximum gain of the flat-top over the half-wave does not occur at these angles, however, but rather at lower ones—15 degrees and less. It is these low angles which are frequently the most effective in long distance communication. The effect of lowering the vertical angle of maximum radiation from a flat-top beam is most pronounced at heights up to a half wavelength or so above ground. At greater heights the angle of the lowest lobe becomes nearly the same as that for a single half-wave antenna. For 14-Mc. DX a height of three-quarters to one wavelength above ground seems worth while.

Although much of the gain comes through vertical directivity, the horizontal gain is also important. This depends mainly on the number of sections used. Fig. 5 shows the measured horizontal radiation pattern for a single-section antenna (see Fig. 2-A). The maximum radiation is broadside and the minimum is off the ends of the antenna. The radiation is 3 db down at an angle of about 35 degrees off the center line of the beam (broadside). At 70 degrees the signal is over 20 db down, representing a front-to-side signal power ratio of well over 100 to 1. The relative field strength is plotted in decibels, the minimum signal observed being taken as 0 db.

The power gain of a single-section flat-top compared to a single half-wave antenna is over 4 db. When used on its second harmonic the gain

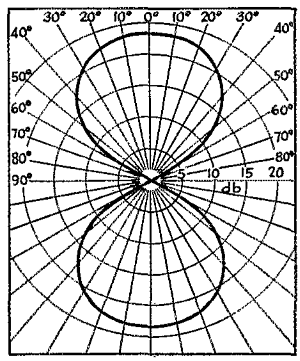

FIG. 5—MEASURED HORIZONTAL RADIATION PATTERN OF SINGLE-SECTION FLAT-TOP ANTENNA

The relative field strength is plotted in decibels.

is about 6 db. The horizontal radiation as measured from a 2-section flat-top (Fig. 2-C) is only slightly narrower, the signal being 3 db down at about 30 degrees off the center. Thus, a 2-section flat-top puts out a very satisfactory signal over an angle of about 60 degrees in each direction broadside, and a usable signal over an even wider angle. The null off the ends, however, is very pronounced. Three 2-section antennas arranged at angles of 120 degrees with respect to each other should give good coverage over 360 degrees. The gain of a 2-section flat-top is over 6 db. A 4-section array would have over 8 db gain and a still narrower pattern than the 2-section type.

A pair of double-Zepp antennas, one stacked one-half wavelength above the other, is a familiar

(Continued on page 37)

messages. Unfortunately the printer didn't do a very good job of following the rules. We are reproducing the example in its proper form and repeating the description and hints for copying messages on a typewriter.

First line: write the number, station of origin, operator's sign and check.

Third line: place of origin, filing time (if any), and date.

Fifth line: the name of the addressee.

Seventh line: one space after the last word of the addressee's name, the address, giving number and street.

Eighth line: name of the city immediately under street and number.

The body of the message starts at the left on the tenth line. Copy ten words to the line. At the end of the fifth, fifteenth, twenty-fifth, etc., word, a double space should be left to aid in counting the check. New York is written NEWYORK, as are all the names of places, and counted one word.

Two lines under the last word of the body appears the signature. If the last word of the body is too far to the right, start the signature two lines down and in the center of the blank. The message is serviced by the receiving operator by placing the call letters of the transmitting station two lines under the signature, followed by the time of receipt and day of the month.

As the message is being copied between the fifth and tenth lines, a new blank may be placed in the typewriter so that upon the removal of the completed message the new blank appears in approximately the right position for the next message. If carbon copies are made, considerable practice is required to get the new blanks in at the proper time.

The Strongheart Boys

(Continued from page 35)

The plane roars low over the island, drops a message, and flies on. Horace races to the spot where the note falls and, picking it up, reads. Clarence comes to a stop behind him, trying vainly to read over his shoulder.

"What does it say, Horace? Does it say that he is sending help? Maybe the U. S. Navy is on its way." (See "Strongheart Boys with Uncle Sam.")

Horace reads aloud.

"Dear OM. Heard you calling at 11:52 E.S.T. Your frequency was 7301. Would appreciate a note saying you will be in the band in the future. Yours for amateur radio. W1 glub glub."

—*Robert J. Black, W1EEK*

Directional Antennas

(Continued from page 13)

bi-directional array of 4 elements. In many cases, especially where the lower double-Zepp is not very high off the ground, a 2-section flat-top should give somewhat improved performance, that is, if the flat-top is placed at the same height as the upper double-Zepp of the pair. A 2-section flat-top should also give more gain over a much wider horizontal angle than 4 co-linear half-wave antennas in phase and at the same height above ground.

The small dimensions of the flat-top antenna make it suitable for use in many locations. Through the use of close-spacing the gain is exceptionally good for an array of its size.

The Cover

MODERN television receiving gear may seem simple once you understand the general idea, but it must be admitted that the apparatus doesn't *look* simple. The mess of aluminumware in the photograph belongs to an experimental vision receiver built a couple of weeks ago by Ross Hull. His objects in building the affair were: To discover if a picture could be had in Hartford from New York (about 105 miles); to see if a haywire rig, built in a hurry from standard parts, could be made to function without breaking any blood vessels, and, to find out whether the whole business of building the set and fiddling with it could be described in ham language as fun. The outcome was a definite "yes" on all counts. Quite fair pictures were received from New York; the receiver functioned after a couple of hours of bug hunting; it was plenty fun. Naturally, the pictures were far from "commercial" quality since the band-width of the receiver had to be sacrificed severely in order to allow enough gain. But at that, they were a bunch of good-looking ghosts walking around the kinescope.

A New Transmitting Tube—the 809

ANEW high-μ, 25-watt plate-dissipation tube, to be known as the 809, has been added to RCA's line of transmitting tubes for amateurs. It can be used at maximum ratings at frequencies up to 60 megacycles in r.f. service, and is designed to operate with good plate efficiency at relatively low plate voltage and driving power. The 809 also is suitable for Class-B audio service.

Tentative characteristics and ratings are given below:

Filament voltage	6.3 volts
Filament current	2.5 amp.
Amplification factor	50
Interelectrode capacitances:	
Grid-plate	6.7 $\mu\mu$fd.
Grid-filament	5.7 $\mu\mu$fd.
Plate-filament	0.9 $\mu\mu$fd.
Max. plate dissipation	25 watts
Max. plate input	75 watts

In Class-B audio service, two tubes are capable of delivering 100 watts output at 750 volts, using

(Continued on page 106)