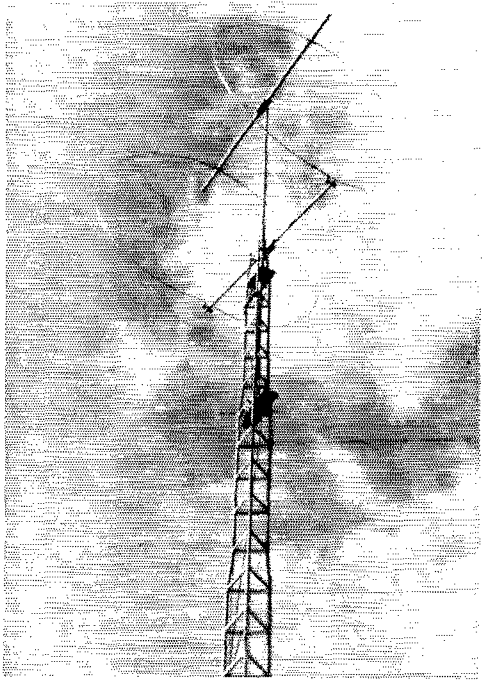

Fig. 1—Two-element circular antenna. Using the dimensions given in Fig. 2, this antenna can be fed directly with 75-ohm line.

Circular Antennas for 10 Meters

Full-Wave Loops in Two- and Three-Element Beams

BY ARCHIBALD C. DOTY, JR.,* K8CFU

We suppose these antennas could be called circular quads (if one can accept the contradiction in terms), since the general structure appears to be related to the quad family. They have given such a good account of themselves in actual operation that the author is currently engaged in extensive investigation of other antenna combinations using circular elements.

Although very few amateurs are apparently aware of the fact, loop or circular antennas having a circumference of one wavelength are neither new nor novel. They have been described in one form or another by Kraus, Rider, Noll and Mandl, and others. In addition, the *ARRL Antenna Book* has, for many years, included a summary of the properties of single-turn loops.

Since 1947 the writer has been building circular antennas for one purpose or another, and they have consistently proved to combine excellent performance with simplicity of construction.

In 1956 work was started on the design of multielement circular arrays for use on the higher amateur bands.

Experience with the antennas which have resulted has shown that they have considerably higher gain than conventional beam antennas; they provide low-angle radiation that is advantageous for DX contacts; and they produce elliptically-polarized waves, which makes them excellent for contacting mobiles or other stations using vertical polarization.

Two interesting 10-meter circulars which have been thoroughly tested are shown in Figs. 1 and 4. The first of these is a two-element circular using a 9-foot boom. It may be directly fed with coax. The s.w.r. of this antenna with 73-ohm cable is low across the entire 10-meter band. The total cost of materials was under $20.

The higher-gain three-element circular shown in Fig. 4 has a boom length of 12 feet, and is omega-matched to coax feed. The s.w.r. curve for this antenna is shown in Fig. 6. Total cost of materials was just over $30.

Element Length

If the dimensions specified are followed rather closely, excellent operating results should be obtained without making any changes from the lengths shown. These dimensions, which are those giving maximum forward gain, are derived from the following formulas:

$$\text{Driven element } L = \frac{1007}{f}$$

$$\text{Reflector } L = \frac{1078}{f}$$

$$\text{Director } L = \frac{948}{f}$$

Where L is the circumference or length of element, in feet;

f is the desired operating frequency in megacycles.

If antennas are desired which will give maximum front-to-back ratio rather than maximum forward gain, a change will have to be made in the lengths of the reflector and director. Although it is not ideal from a theoretical standpoint, the test setup shown in Fig. 8 has been used very successfully to tune the elements of circular antennas. This arrangement is convenient as it

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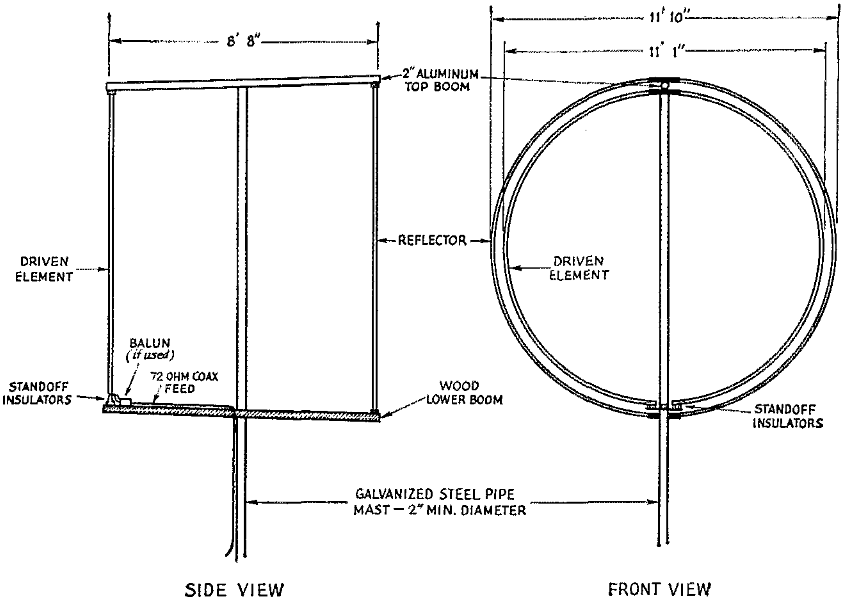
Fig. 2—Principal details and dimensions of the two-element circular. Note that the two booms are slightly off parallel to compensate for the different diameters of the driven element and reflector.



allows element length or spacing changes to be made on the antenna under test without having to turn off the transmitter. Also, the effect of changes made can be immediately observed on the field-strength meter.

Element Diameter

In order to give both structural rigidity and broad-band characteristics to the antenna, a length-to-diameter (L/D) ratio of approximately 650 has been used.

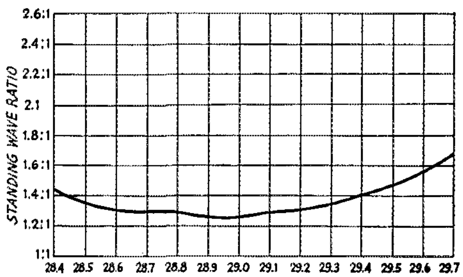


Fig. 3—Standing-wave ratio vs. frequency; two-element antenna fed directly with RG-59/U coax line.

Element Spacing

Spacing of one-quarter wavelength, or 8 feet 8 inches, between elements is used for the two-element circular. This provides wide band width as well as a convenient impedance match to 73-ohm coaxial cable or transmitting type Twin-Lead.

On the three-element circular the spacing is that which will give maximum forward gain with a boom length of 12 feet. The dimensions are given in Fig. 5.

Impedance Matching

If desired, the two-element circular may be directly fed with RG-11/U or RG-59/U coaxial cable. However, when such an arrangement is used (feeding a balanced antenna with unbal-

Fig. 4—The three-element circular is also coax fed, but uses an omega matching section to transform the low antenna input impedance up to the coax line impedance. The antenna dimensions are given in Fig. 5.

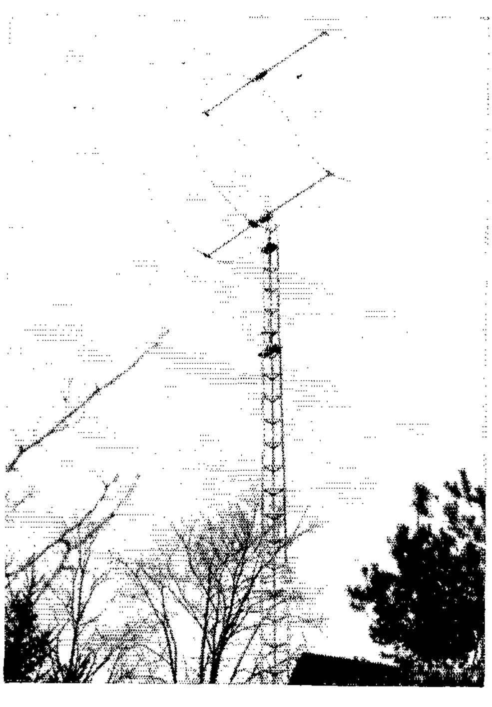
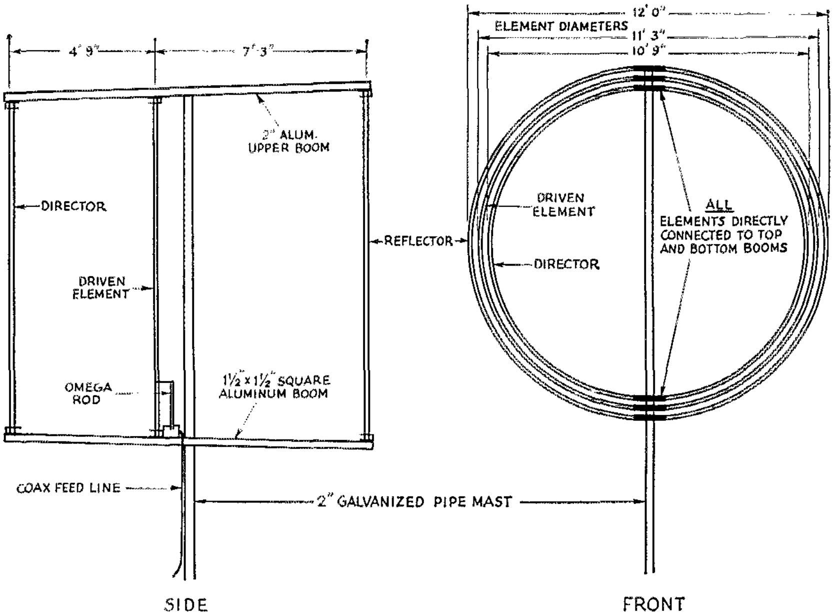


Fig. 5—Principal dimensions of three-element antenna.



anced feed) "antenna currents" are induced on the outside braid of the coax, and a 1:1 standing-wave ratio can not be achieved at any frequency.[1]

If this feed arrangement is used it is important that the effective feed-line length be a multiple of one-half wavelength at the operating frequency. The correct length of line for minimum s.w.r. can be determined most conveniently through the use of an s.w.r. bridge inserted in the line at the transmitter. With this arrangement the original feed-line length should be made at least 6 feet longer than required, and then "pruned" approximately 6 inches at a time until minimum s.w.r. is achieved.

If the two-element circular is fed through a balun located at the antenna, or by a balanced line, no feed-line "trimming" will be necessary, of course.

[1] Lest there be any misunderstanding of this point, as well as the line pruning mentioned in the subsequent paragraph, it should be emphasized that what the author is discussing does not in any way contradict the fact that the s.w.r. on a transmission line is determined only by conditions existing at the load end and (except for the effects of normal line losses) is *not* affected by the line length. When terminated in a balanced antenna, the cable sees a load consisting of the actual antenna plus the *outside* of the coax. The component of the load impedance contributed by the latter depends on the length of the coax, in terms of wavelength, and the relationship of the cable to nearby objects. To minimize this "antenna effect" it is necessary to detune the outside of the line at the operating frequency, and one method of detuning is to adjust the line length by pruning. Decoupling through a balun at the antenna is also effective. — *Ed.*

The three-element circular has relatively low impedance, which makes it necessary to use some type of impedance-matching device between the

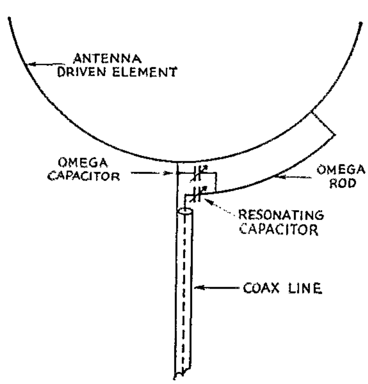


Fig. 7—Omega matching section for driven element of three-element antenna.

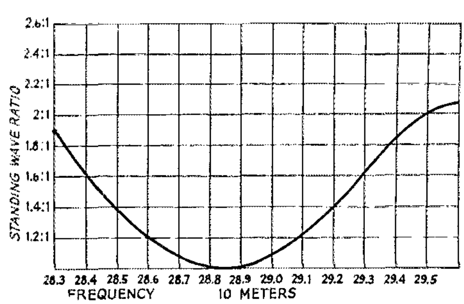


Fig. 6—Standing-wave ratio vs. frequency; three-element antenna with matching section.

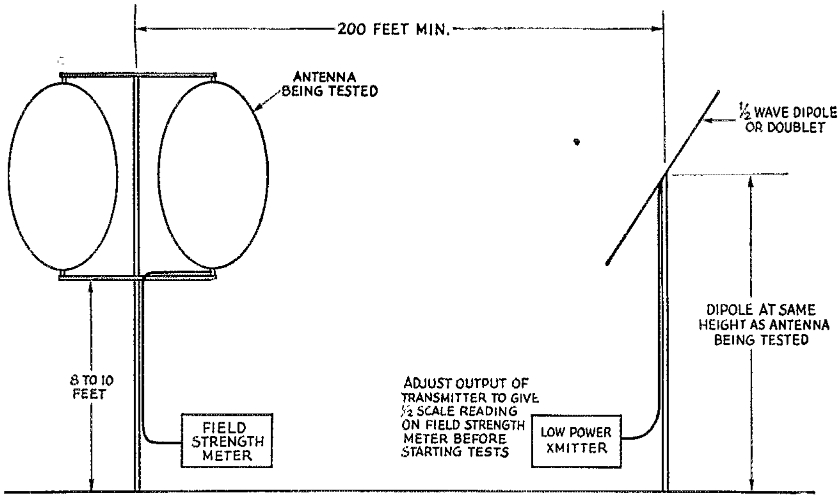


Fig. 8—Setup for antenna adjustment.

driven element and the feed line. The antenna shown uses an omega match,[2] which is simple to construct and easy to tune. Specifications of this omega match, which is built in a 4 × 5 × 6-inch aluminum box, are:

Omega capacitor — 15 μμf. max.
Resonating capacitor — 45 μμf. max.
Omega rod length — 23 inches
Omega rod diameter — ¼ inch
Spacing from omega rod to driven element — 4 inches.

Once the antenna has been constructed, tuning of the omega match will take only a few minutes. With an s.w.r. bridge in the feed line at the transmitter, the omega and resonating capacitors are successively tuned for minimum s.w.r.

Experience has shown that circular antennas can be tuned with the lower boom 8 to 10 feet from the ground and will remain substantially in tune when raised to operating height.

Construction Details

Soft aluminum tubing has been found ideal for use in the construction of the circular elements, as it is light in weight and easy to form into shape.

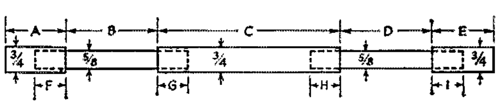
If you are lazy, and don't mind spending a few extra dollars on materials, the elements can be made of one-piece construction from continuous lengths of tubing of the type stocked by aluminum warehouses. Tubing of this type (Alcoa "Utilitube", for example) is available in 50- and 100-foot lengths in ⅝- or ¾-inch outside diameters.

The industrious but thrifty can make their elements from standard 12-foot lengths of soft-temper tubing available from any surplus metal supplier. Five-eighths-inch tubing telescoped into ¾-inch tubing results in excellent light but rigid elements. One circular antenna using ½-inch and ⅝-inch tubing stood up in winds in excess of 60 miles per hour, but the larger diameters are much easier to handle during construction.

Table I gives the sizes and lengths of tubing needed for the two- and three-element circulars. To assemble the elements, the individual pieces of tubing are first laid out in a straight line as shown in Fig. 9. The sections of tubing are then telescoped together to the dimensions indicated, and fastened at each joint with a sheet-metal screw. *Note:* Make sure that the elements are of the correct length at this point, as it is very difficult to change the length once they have been formed into circles.

After assembly the elements are formed into their circular shape. This can be done in a few minutes by first preparing a circle of stakes or nails around which the tubing can be formed. Wooden stakes driven into the ground work well,

[2] Orr, *Beam Antenna Handbook*, Radio Publications, Wilton, Conn.

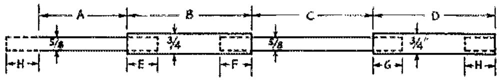


ANTENNA ELEMENT	DIMENSIONS A, E	B, D	C	F, G, H, I	OVERALL LENGTH
DRIVEN ELEMENT	4′	9′ 5″	8′	1′ 3½″	34′ 10″
REFLECTOR	4′	10′ 7″	8′	8½″	37′ 2″

Fig. 9—Element construction detail for two-element antenna.

Table I

Antenna Model	Tubing Required: Quantity	Length	O.D.	Wall Thickness
2-element	4	12′	⅝″	.049 or thicker
	3	12′	¾″	.049 or .058
3-element	6	12′	⅝″	.049 or thicker
	4	12′	¾″	.049 or .058



ANTENNA ELEMENT	DIMENSIONS				OVERALL* LENGTH
	A, C	B	D	E, F, G	
DRIVEN ELEMENT	9' 8"	12' 0"	4' 0"	1' 2"	36' 6"
REFLECTOR	10' 8"	8' 0"	8' 0"	8"	38' 0"
DIRECTOR	9' 0"	12' 0"	4' 0"	1' 6"	35' 6"

*NOTE: *Overall length is not the same as final element length, as it includes "H" which is telescoped into "D" after the element has been formed into circular shape.*

Fig. 10—Element construction detail for three-element antenna.

as do nails hammered into an asphalt driveway surface. The diameter of the circle should be approximately 10 feet 6 inches. To form an element, simply fasten one end in a fixed position (get your wife to stand on it) and bend the tubing around the stakes until the two ends meet.

If the element being made is the driven element for the two-element antenna, the two free ends should be temporarily taped together until the element has been attached to the top boom.

The reflector of the two-element, and all of the elements of the three-element antenna, are complete, unbroken circles. Thus the two free ends can be slipped together after forming, and the joint fastened with a sheet-metal screw.

Booms

Two-inch diameter hard-temper aluminum is used for the top boom, which actually supports virtually the entire weight of the elements. The lower boom acts mainly as a sway brace, and to carry the feed line.

All elements are connected directly to the top boom with automobile muffler clamps or pipe clamps. Fig. 11 shows two simple methods of attachment which have proved satisfactory.

The lower boom may be of wood (for the two-element circular only) or of metal. However, as the driven element of the two-element circular is split to accept coax or balun feed, it is necessary to insulate the two ends from the lower boom if it is metal.

The two-element circular shown in Fig. 2 used a 2 × 2-inch wooden lower boom, while that of the three-element antenna is 1½ × 1½-inch square aluminum.

Note that all elements of the three-element model are directly connected to the lower boom as well as to the upper boom.

Performance

No gain figures are included in this article, because accurate data of this type can only be obtained through elaborate tests conducted on model antennas operating in the microwave spectrum. However, the following *operating* results will give a pretty good idea as to what can be expected from a circular antenna operating in a fairly good location:

When operated with its lower boom only 7 feet above ground level the two-element circular outperformed a well-tuned three-element close-spaced conventional beam immediately adjacent, but at a height of 50 feet.

All continents were easily worked using the three-element circular operating with its lower boom 7 feet above ground level.

The gain of the three-element circular is of a sufficiently high order to allow solid contacts from the Detroit area with many stations throughout the eastern half of the country using back scatter. One interesting 11-meter evening roundtable (before operating privileges in this band were withdrawn — *Ed.*), in which both back scatter and normal forward propagation were used at K8CFU, included stations in Australia, Ohio, Marshall Islands, California and Pennsylvania.

Operating in less than one third of the 1958 ARRL DX Competition resulted in contacts with 55 countries on 10 meters, and 15 countries on 11 meters. Only one country called (Estonia) was not worked.

The transmitter used for all operations was a DX-100 operating with an input of 130 watts.

In spite of the excellent results from the circular antennas built to date, there are undoubtedly many ways in which the performance and versatility of this type antenna may be increased.

Want to be a pioneer?

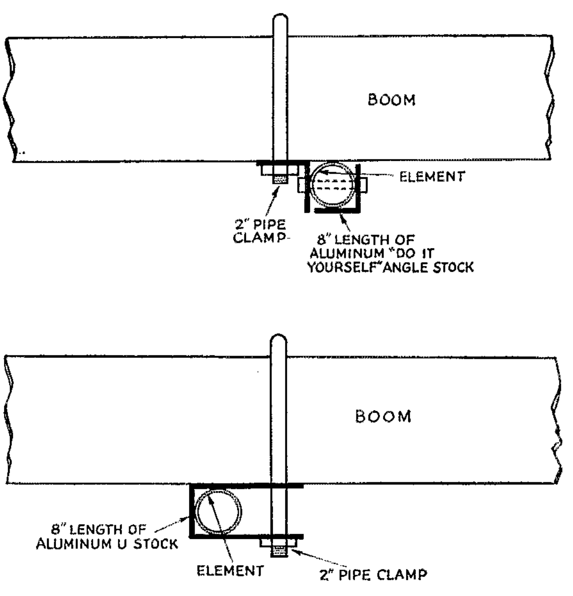


Fig. 11—Alternative methods for attaching elements to booms.