The DDRR Antenna

A New Approach To Compact Antenna Design

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This unique antenna design is extremely compact, yet provides exceptionally efficient performance on frequencies from 2 through 150 mc. Developed and produced by Northrop's Ventura Division, a DDRR array will be installed by the Navy for shipboard use. This type of antenna should be of interest to radio amateurs where antenna space is restricted.

A NEW approach to compact antenna design is Northrop Corporation's DDRR (Directional Discontinuity Ring Radiator) developed and patented by J. M. Boyer, W6UYH, a member of the electro-magnetic research staff.[1]

The DDRR is a highly efficient omni-directional vertically-polarized radiator which offers a considerable height reduction over that of a full quarter-wave vertical antenna, compared to which it performs most favorably. It also may be tuned over a two-to-one frequency range with an s.w.r. within 2:1, although the efficiency drops off at the low frequency end of the range for which its dimensions are cut.

A DDRR may be built for any of the amateur bands from 160 meters down. It should be particularly attractive for use when the erection of a resonant full quarter-wave vertical antenna is impractical. In this respect, a shortened antenna often is used with resonance restored by means of lumped constants, such as a loading coil; however, the radiation efficiency of such an arrangement deteriorates considerably. The DDRR, besides being exceptionally efficient, offers a number of other advantages in regard to portable or mobile work. These will be pointed out later.

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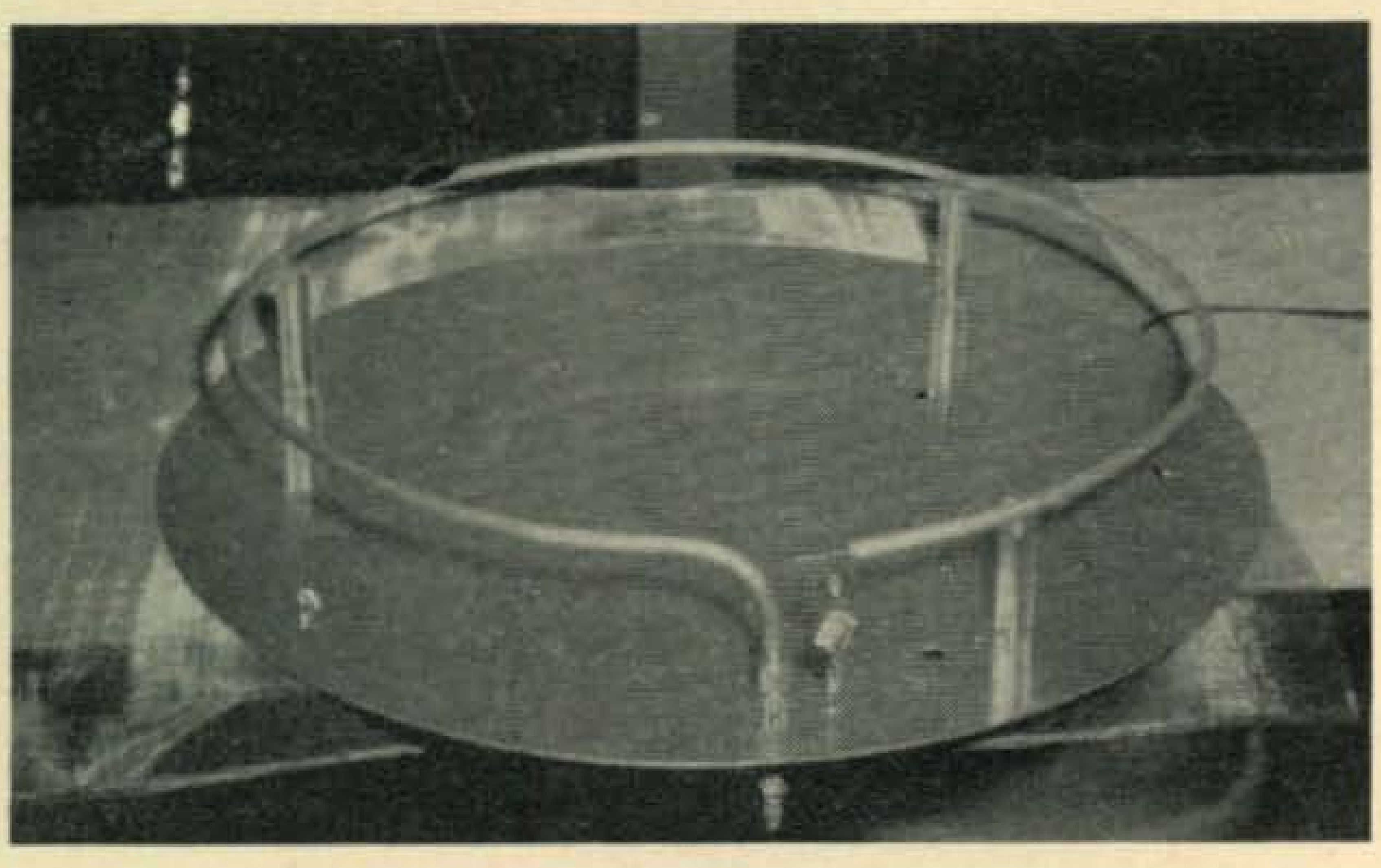
[1]J. M. Boyer, "Hula-Hoop Antennas: A Coming Trend?", *Electronics*, January 11, 1963, p. 44.

Dimensions

First, let us take a look at the physical and electrical properties of one type of DDRR. It consists of a single circular open-ended radiating element mounted in a horizontal plane a short distance above an electrical ground plane. See fig. 1. Best performance from this type of DDRR is obtained when the diameter, *D*, of the circular radiator is 0.078 wavelength (28 electrical degrees), in which case the electrical circumferential length will be a quarter wave and the element will be naturally resonant. The ring is mounted on insulators at a distance of approximately 0.007 wavelength (2.5 degrees) above the ground plane and it is left open for a short distance at point *A*. One end of this gap is connected to the ground plane at *B*.

In practice, where operation is at more than one frequency, the diameter of the ring is made slightly less than the aforementioned dimension (reducing the circumferential length) so that a variable capacitor, connected between the other end of the gap and the ground base, may be used to tune the system *exactly* to quarter-wave resonance.

A shunt-feed arrangement is used with the shield of the coaxial line connected to the ground plane and the inner conductor connected to an appropriate tap on the ring to provide the correct impedance match.



Overall bench-view of the 10 Meter DDRR antenna constructed by the author. Series feed is used directly to the ring radiator which is made of rigid coax. The small trimmer capacitor, used for tuning at the end of the ring, was eventually changed to a high-voltage type as it went up in smoke. Rigid coax may not be readily available, so it is recommended that ½ or ¾ inch copper tubing be used instead together with shunt feeding of the transmission line as shown in fig. 1.

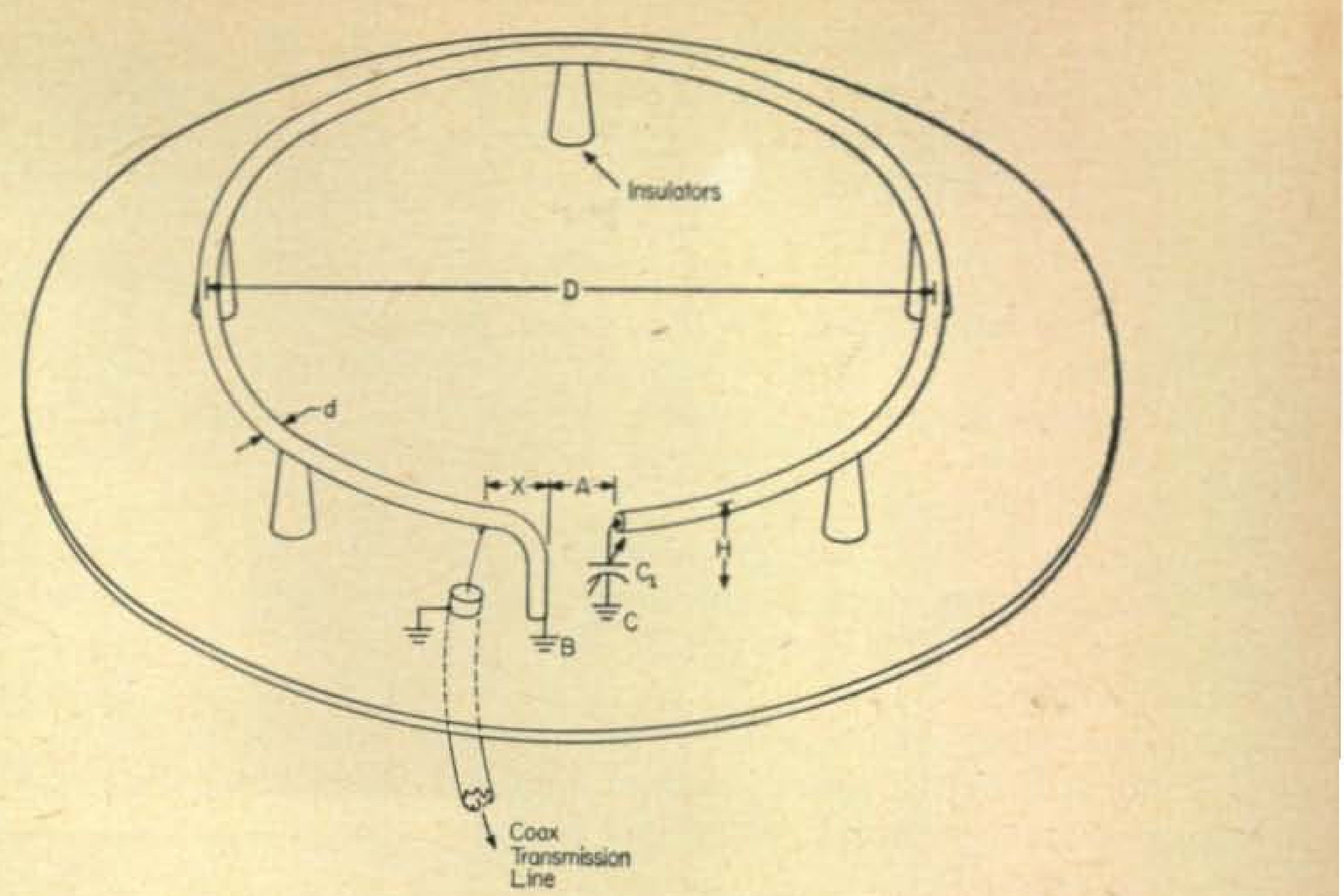


Fig. 1—Basic construction of the DDRR antenna. The critical dimensions illustrated are enumerated on a band-by-band basis in Table I.

Better performance and lower angle of radiation may be obtained when the ground plane is extended beyond the boundaries of the ring. This can be done by means of a large number of quarter-wave length radials; however, good performance was obtained with the high-frequency model, as shown here, using only a sheetmetal disc slightly larger than the radiator.

Operation

There appear to be some differences of opinion regarding the theory of operation for the DDRR, so no attempt to go into the matter will be made at this point; however, a version is given in the addenda. The important thing is that the antenna does work. The radiation is vertically polarized and an omni-directional field pattern is obtained from it.

By comparing the dimensions shown at fig. 1 with a quarter-wave antenna height of 68 feet for 4 mc operation, it can be seen that a height reduction of over 30 to 1 is attained. On the other hand, the dimension in the horizontal plane is increased, but not to impractical proportions.

The relative sizes of a DDRR and a quarter-wave vertical ground plane antenna also are indicated in the photographs of the two-meter models of both types which were built in *CQ*'s laboratory for comparative performance tests. A six-meter model is also shown with metal strips extended from the base to effect a better ground plane surface.

Efficiency

Radiation efficiency at 4 mc, measured by the originators of the DDRR, indicated it to be only 2.5 db less than that of a 68 foot quarter wave vertical antenna. When operated over a 2 to 1 frequency range, the efficiency dropped off gradually and at 2 mc was −15 db compared to a 110 foot quarter wave vertical for this frequency. The same DDRR was used in both cases. At 4 mc its diameter was 0.073 wavelength and its height was 0.008 wavelength, while at 2 mc its diameter was 0.036 wavelength and height was 0.004 wavelength. Thus, the efficiency is highest when the ring diameter approaches 0.078 wavelength and the natural circumferential electrical dimension nears a full quarter wave.

Portable and Mobile Applications

No doubt the major interest in the DDRR will probably pertain to low frequency fixed station operation, but its potentialities for portable and mobile work should not be overlooked.

First of all, its physical size is such that a DDRR, built for as low a band as 20 meters (diameter approximately 4½ feet) can easily be moved about and quickly set up for portable use, while one designed for mobile use may be mounted on top of the vehicle roof. Such a mobile setup will be more efficient than the usually used whip antenna. Also, the latter generally is quite directional, depending on just where it is mounted on the vehicle; the roof mounted DDRR is omni-directional.

Too, the wind resistance is low; there is no whipping around of the antenna and no signal-fluttering effect at high speeds and since the DDRR is grounded to the vehicle by direct connection, picked-up static charges are drained off to ground. Signal to noise ratio can thereby be improved. The DDRR is physically low, eliminating entanglement with tree limbs and simplifying garaging of the vehicle, as the antenna need not be lowered or removed.

Another advantage of the DDRR, for all types of service, is that it is a high *Q* tunable device

Table I—DDRR Antenna Dimensions

Band	*D*	*H*	*d*	*A*	*X*	C_1 (in mmf)
160	36′	48″	5″	18″	12″	100
80	18′	24″	5″	12″	6″	100
40	9′	12″	2.5″	6″	3″	75
20	4′6″	6″	1″	3″	1½″	50
15	3′4″	4½″	½″	2″	1″	35
10	2′3″	3″	½″	2″	¾″	25

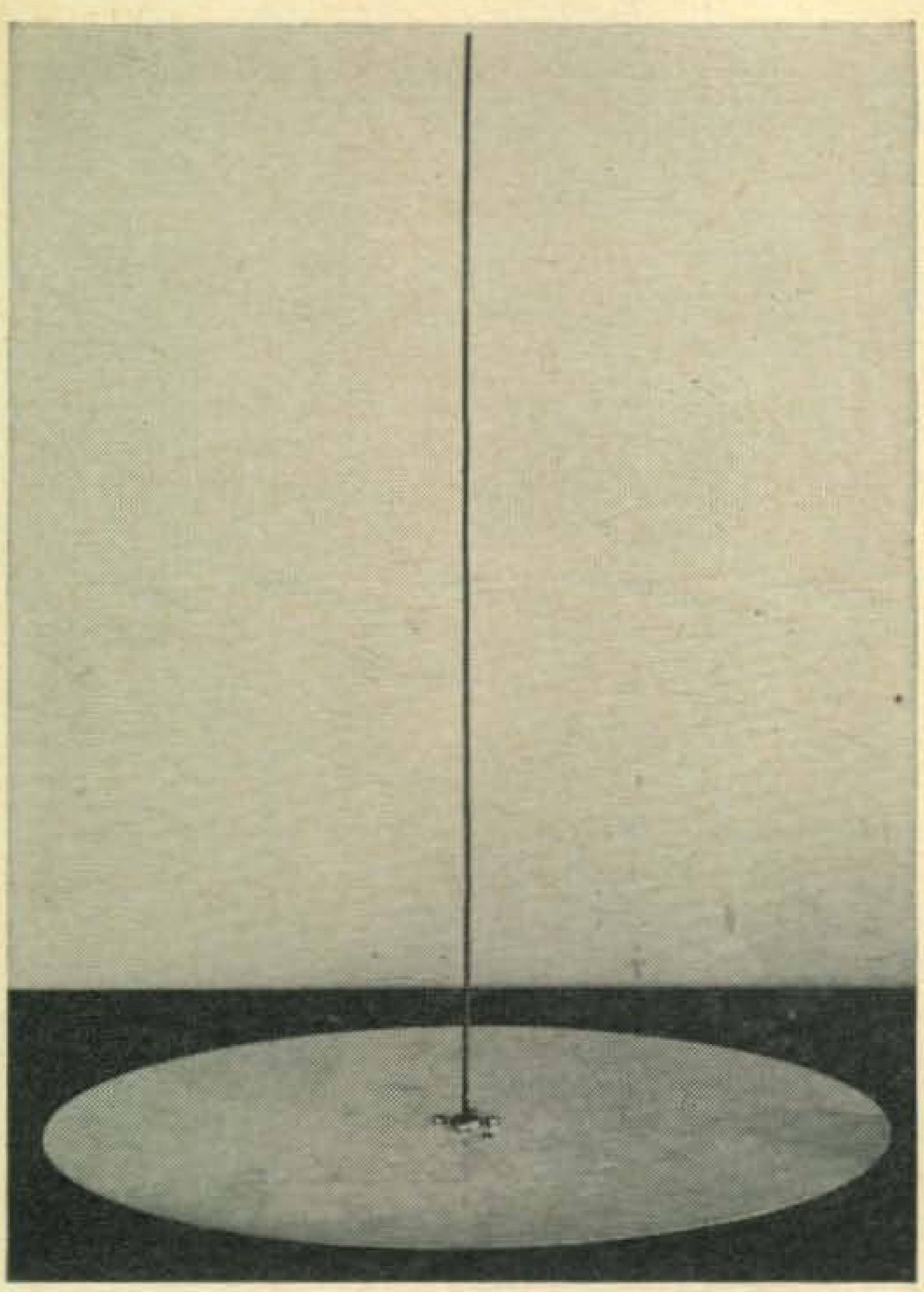
which thus provides increased selectivity during reception, resulting in a minimization of adjacent-channel interference, image response and cross modulation.

10 Meter Model

The model built by the writer provided excellent results with 10 meter operation. The dimensions are as follows: ½ inch rigid coax line with a ring diameter of 30 inches and mounted on 6 inch high 1 inch round polystyrene pillars. The metal ground plane is one-quarter inch thick aluminum 35 inches in diameter. See Table I. Series feed, with a 52 ohm coax line, is used in this model instead of the shunt-feed arrangement. No feedline tap is needed, as the inner conductor of the transmission line is connected directly to that of the ring radiator.

The tuning capacitor, which is also connected to the inner conductor of the ring, but at the far end, is a modified Johnson 12G7 with all plates removed except two stators and one rotor. Maximum capacitance is about 6 mmf. Note that the spacing between the plates of the capacitor is quite large since the potential at this end of the ring is very high. (One of the photos shows a ceramic trimmer which quickly went up in smoke!) For 100 watts transmitter input, the capacitor should be rated up to about 4000 volts. A kw input would require a rating up to about 15 kv.

This model is not intended for mobile use, but when such installation is required, insulators on suction cups may be used to mount the ring on the vehicle roof, the latter then serving as the ground plane. If this is done, the ground connections for the ring, feedline and the tuning capacitor should be securely made. Paint should be removed at these points and connections soldered, if possible. Any resistance at these points can be fatal to DDRR efficiency.



The shaft of the tuning capacitor can pass through the top of the vehicle in order that the antenna may be tuned by the operator when the operating frequency is changed. A suitable non-metallic housing (polystyrene or plexiglass) also should cover the capacitor to protect it against various weather conditions.

Tune Up

Tune-up simply involves the adjustment of the capacitor for a minimum standing wave ratio as indicated by an s.w.r. meter inserted in the transmission line. It should be possible to obtain an s.w.r. near 1.2 to 1; however, a ratio of up to 2 to 1 will still provide satisfactory results.

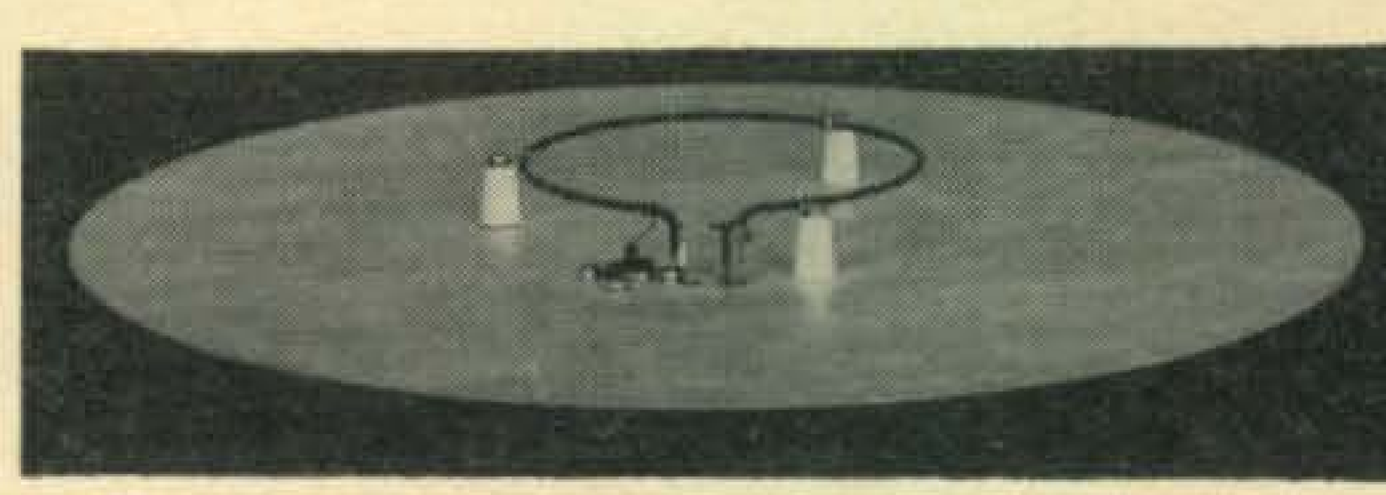
In the event a shunt fed DDRR is used, both the capacitor and the feedline tap should be adjusted for a minimum s.w.r. at the operating frequency. It may be found best to first adjust the capacitor for antenna resonance (no feedline connected) as indicated by a grid-dipper held inside the corner where the ring turns down for the ground connection.

After the DDRR has initially been tuned and adjusted for a given frequency, a change in the frequency will require retuning. This may be facilitated by leaving an s.w.r. indicator (reflectometer type) in the line at all times for tuning to minimum s.w.r. as needed.

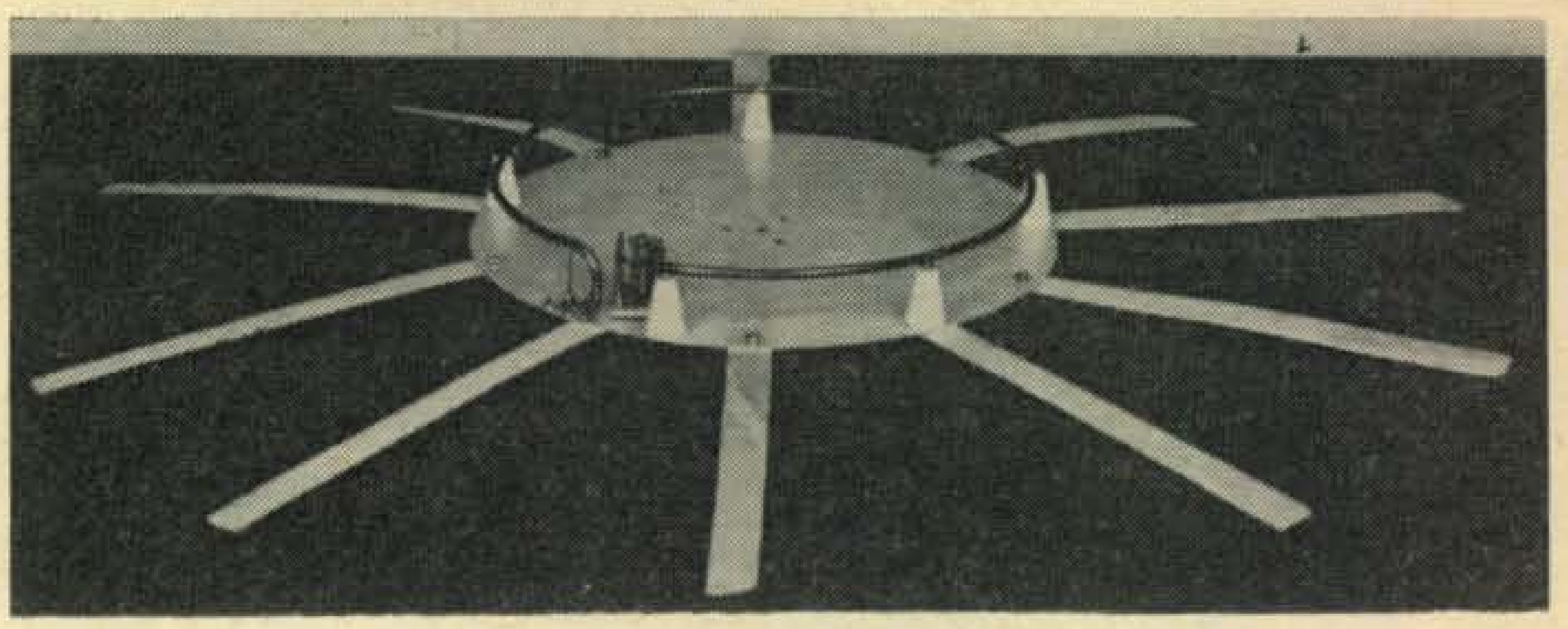
Another method is to peak up received signals with the tuning capacitor, after which the system will be tuned closely enough. If the DDRR is located where the capacitor cannot be conveniently reached for retuning, a remote control system using flexible shafting or a servo mechanism may be employed.

If two band operation is desired, the feedline tap must be selected for the lowest average s.w.r. This will be a compromise ratio to about 2:1 on both bands.

Size comparison of a typical DDRR antenna and ground plane for the same frequency. Both antennas are for the two meter band and are built on 16" aluminum recording discs.



A six meter DDRR built on a 16" recording disc with "spider web" extensions added to increase the effective ground plane area.



Construction

The dimensions for any one band given in the above table may be used for two-band operation with the next higher-meter band for a 2:1 frequency range. For instance, an 80 meter DDRR may be used on 160 meters also. In addition, a 10 meter antenna may be used for 15 and 20 meters too.

For maximum efficiency, the ring diameter, D, should be 0.078 wavelength at the highest frequency used; however, the given dimensions are slightly shorter than this in order that C_1 may be added to permit simple tuning to exact resonance whenever the operating frequency is changed.

The ring may be made from any good conductor such as copper tubing, aluminum conduit or copper leader pipe. If the latter is used, the ring element may be made with short lengths of the pipe, mitered and soldered together at the ends, to form a multi-sided polygon.

The ground plane may be made of copper, aluminum[2], galvanized sheet metal or hardware cloth. The diameter should be at least 25% larger than that of the ring. If the ground conductivity is poor, it will be best to enlarge the ground plane by soldering quarter-wave radials, made of copper wire, to the edges of the metal sheet.

The height, H, is not critical, as long as the minimum is that indicated. An increase in height will raise the efficiency slightly.

If single band operation is contemplated, the conductor diameter, d, may be reduced. When this is done, the bandpass over which a low s.w.r. may be maintained is decreased, so a reduction in d is not recommended for two band operation.

Dimension X is approximate. It must be determined experimentally, since the proper matching point will depend on a number of variables, including conductor diameter, ring height, transmission-line impedance and ground-plane configuration and conductivity.

Dual-band operation will require an increase in the value of C_1 of approximately five times.

[2]Aluminum is satisfactory but must not be permitted to oxidize or performance will deteriorate seriously.

Results

The performance of the 10 meter DDRR was found to be most gratifying. It also functions nicely on 27,575 kc which is the operating frequency for this Army Post. With a transmitter power of 30 watts, on-the-air reports from other base stations located in Phoenix, Arizona and in Seattle, Washington indicated reception of transmissions from the DDRR to be as good as that from a vertical quarter-wave ground plane antenna mounted 30 feet high. During these transmissions, the DDRR was located 2 feet above the floor of a cement-block building!

A larger model for low frequency work was not constructed, but from the information obtained thus far, the DDRR looks like a "natural" for restricted space use on the lower bands. ■

Addenda

The new DDRR may be regarded as a form of slot antenna. In the conventional slot antenna or magnetic dipole, a rectangular aperture is cut into a metal sheet and the resulting gap shunt fed.[3] In such conventional slot antennas, excitation of the slot sets up currents on the metal sheet which actually accomplish the radiation of fields into space. In the DDRR the "slot" is formed in the space between the ring and the ground plane immediately below. From figure 1 it can be seen that the feed launches a wave into the curved "transmission line" or slot, the wave moving toward the open end at the speed of light. When such wave reaches the open end of the ring it is reflected and now on the return trip interferes with the outgoing wave producing standing waves in the slot gap. On both the outgoing and return trip the wave radiates a part of itself to space. At the same time the ground post functions as a "second antenna" in the form of a short height, electrically loaded monopole. The combination of fields from both these sources form the effective radiation from a DDRR antenna. A horizontally polarized field, radiated directly by current flowing around the ring, is cancelled out by an equal and opposite field radiated by the image of the ring in the ground plane. Hence, what looks to us like a horizontally polarized loop antenna actually functions like a vertical dipole antenna.

[3]Kraus, J. D., *Antennas*, McGraw Hill, page 354.