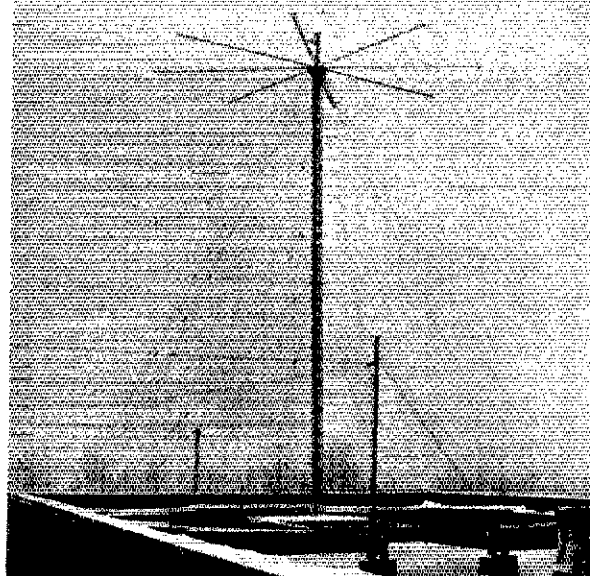


# THE HF DISCONE ANTENNA

A Frequency Independent Antenna  
For Vertical Polarization

BY JOHN S. BELROSE,\* VE2CV/VE3DRC



*The discone antenna has existed for years, but little information on this radiator has appeared in amateur publications. While the array looks like a guyed 36-foot tower having a large top hat, it offers the performance of an efficient vertical monopole but may be operated independently of any earth ground. It covers 40 through 10 meters without critical tuning, traps, or band switching, and provides an excellent match to 50-ohm coaxial line.*

**I**N 1957 Victor Rumsey explained the basic requirements for frequency-independent antennas. The concept was that if the shape of the antenna could be specified entirely by angles, its performance would be independent of frequency. This is because the shape of the antenna, when expressed in wavelengths, would be the same at every frequency. The log-periodic antenna, which is the best known of this class of antennas, was devised by DuHamel and Isbell<sup>1</sup> in 1957. In 1959 Isbell<sup>2</sup> developed the dipole arrangement currently used. The discone antenna was developed by Kandoian<sup>3</sup> in 1945, and is a radiator having an impedance that can be *directly* matched to a 50-ohm coaxial transmission line over a wide

\* 3 Tadoussac Dr., Lucerne, Quebec, and Department of Communications, Communications Research Centre, P.O. Box 490, Station A, Ottawa, Canada K1N 8T5.

<sup>1</sup> For this and all subsequent references, see the listing at the end of this article.

frequency band. The discone also belongs to the log-periodic class of antennas.

The fact that the discone antenna does belong to the log-periodic class will be made clear below. The antenna comprises a vertical cone beneath a horizontal disk (see Fig. 1). For frequencies within the range of the antenna, the radiation is due to a resonance between the fields caused by current flow over the disk and over the surface of the cone, which is established by its flare angle. The apex of the cone, which is vertical, approaches and becomes common with the outer conductor of the coaxial feeder at its extremity. The center conductor of the coaxial feeder terminates at the center of the disk, which is perpendicular to the axis of the cone and the feeding transmission line. The discone can be thought of as an upside-down conical monopole, an antenna type that was devised much earlier.

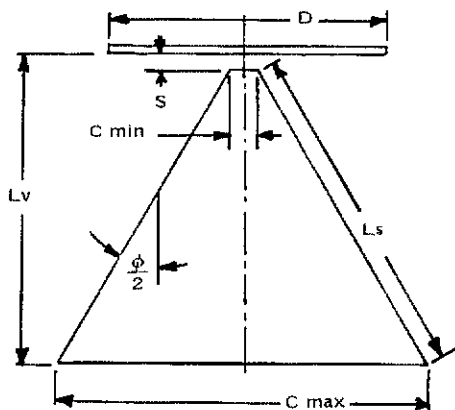


Fig. 1 — Cross-section sketch of the discone antenna. See text for definitions of terms.

The advantages of the discone are that it can be operated remote from and independent of ground. Furthermore, since the current maximum is at the top instead of at the bottom of the antenna, and since its structural configuration lends itself to mounting on a pole or on top of a building, the radiation characteristics of a practical discone antenna can approximate an *ideal* dipole antenna in free space. The change of impedance versus frequency is, however, very much less than for any ordinary dipole, even dipoles with rather small length/diameter ratios. The same is true for the radiation characteristics of the discone. The antenna exhibits good impedance characteristics over a ten-to-one frequency range and low-angle radiation with little change in the radiation pattern over a three- or four-to-one frequency range. At the high-frequency end the pattern begins to turn upward, with a resulting decrease in the radiation at low elevation angles. The discone antenna may be visualized as a radiator intermediate between a conventional dipole and a biconical horn. A biconical horn<sup>5</sup> is essentially a conical dipole operated at frequencies for which the physical dimensions of the antenna become large compared with a wavelength. At the lower frequencies the antenna behaves very much as a dipole; at much higher frequencies it becomes essentially a horn radiator.

### Design Considerations

Refer to the sketch of the discone radiator in Fig. 1. The following nomenclature is used:

- $\phi$  = cone flare angle (total)
- $L_s$  = slant height of cone
- $L_v$  = vertical distance from the disk to the base of the cone
- $C_{max}$  = maximum diameter of cone
- $C_{min}$  = minimum diameter of cone
- $D$  = diameter of disk
- $S$  = disk-to-cone spacing

From model studies Nail has determined the optimum parameters for discone antennas to be as follows:

$$S = 0.3 C_{min}$$

$$D = 0.7 C_{max}$$

and typically, for an optimum design

$$L_s/C_{min} > 22$$

$$\phi = 60^\circ$$

The performance of the antenna is not very critical in regard to the value of flare angle,  $\phi$ , except that there is less irregularity in the SWR versus frequency if  $\phi > 50^\circ$ , although  $\phi > 90^\circ$  was not investigated. Since the bandwidth is inversely proportional to  $C_{min}$ , that dimension must be small; for a frequency range of ten to one  $L_s/C_{min}$  should be greater than 22.

From the circuit standpoint the discone antenna behaves essentially like a high-pass filter. It has an effective cutoff frequency,  $f_c$ , below which it becomes very inefficient, causing severe standing waves on the feeding coaxial line. Above the cutoff

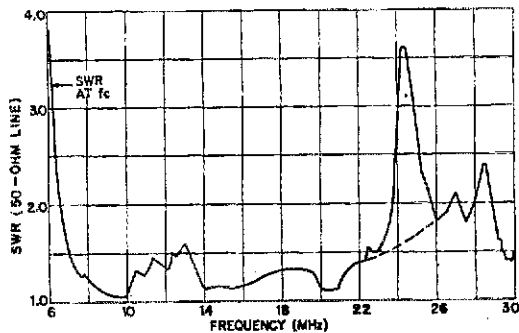


Fig. 2 — Standing-wave ratio vs. frequency for the discone antenna designed for operation on 7 MHz and above. The "spike" in the curve at approximately 24 MHz is believed to be caused by an adjacent metal structure, as explained in the text.

frequency little mismatch exists and the radiation pattern remains substantially the same over a wide range of frequencies (from some minimum frequency,  $f_{min}$ , to some maximum frequency,  $f_{max}$ ). The slant height of the cone,  $L_s$ , is approximately equal to a quarter wavelength at the cutoff frequency,  $f_c$ , and the vertical height (or altitude) of the cone is approximately a quarter wavelength at the lowest operating frequency,  $f_{min}$ .

The radiation from the discone can be viewed in this perhaps somewhat-oversimplified way. A traveling wave, excited by the antenna input between the apex of the cone and the disk, travels over the surface of the cone toward the base until it reaches a distance along the slant surface of the cone where the vertical dimension between that point and the disk is a quarter wavelength. The wave field therefore sees a resonant situation and is almost entirely radiated.

For  $f_{min} = 7.0$  MHz and a velocity factor for propagation along the surface of the cone equal to

$$0.96, \quad L_v = \frac{2834}{f_{min}} = 405 \text{ inches.}$$

If  $\phi = 60^\circ$ , then  $L_s = 456$  inches and  $f_c = \frac{2834}{L_s} = 6.22$  MHz. The disk diameter is  $D = 0.7$

$C_{max} = 0.7 (456) = 319.2$  inches, and for  $C_{min} = 13.5$  inches (a practical dimension which we shall

see later),  $S = 0.3 C_{min} = 0.3 (13.5) = 4$  inches.

The ratio  $L_s/C_{min} = \frac{456}{13.5} = 33.7$ .

The frequency response of a discone antenna constructed with these dimensions is shown in Fig. 2. Here we see that the SWR is 3.25 at  $f_c$  and decreases rapidly with increasing frequency, being about 1.5 at  $f_{min}$ . The SWR is  $< 1.5$  over the frequency range 7 to 23 MHz, and while this ratio

increases for frequencies  $> 23$  MHz, the SWR, except for the irregularity for frequencies 23.5 to 25.5 MHz, is  $< 2.5$  over the frequency range 6.5 to 30 MHz. The SWR peak in the frequency range 23.5 to 25.5 MHz is thought to be due to a resonance in the metal structure of a nearby part of the building on which the discone antenna is mounted. It was mounted on a flat roof 70 feet from a penthouse which is 21.25 feet in height (including the grounded metal rail around the top). This height is a resonant half wave at 24.4 MHz.

### Practical Construction

At hf the discone can be built using closely spaced wires to simulate the surface of the cone. The disk can be simulated by a structure consisting of eight spreaders with wires connected between them. It is important that a skirt wire connect the bottom ends of all slant wires simulating the cone, and another the outer ends of the spreaders which simulate the disk. These wires have the effect of increasing the effectiveness of the wire structures

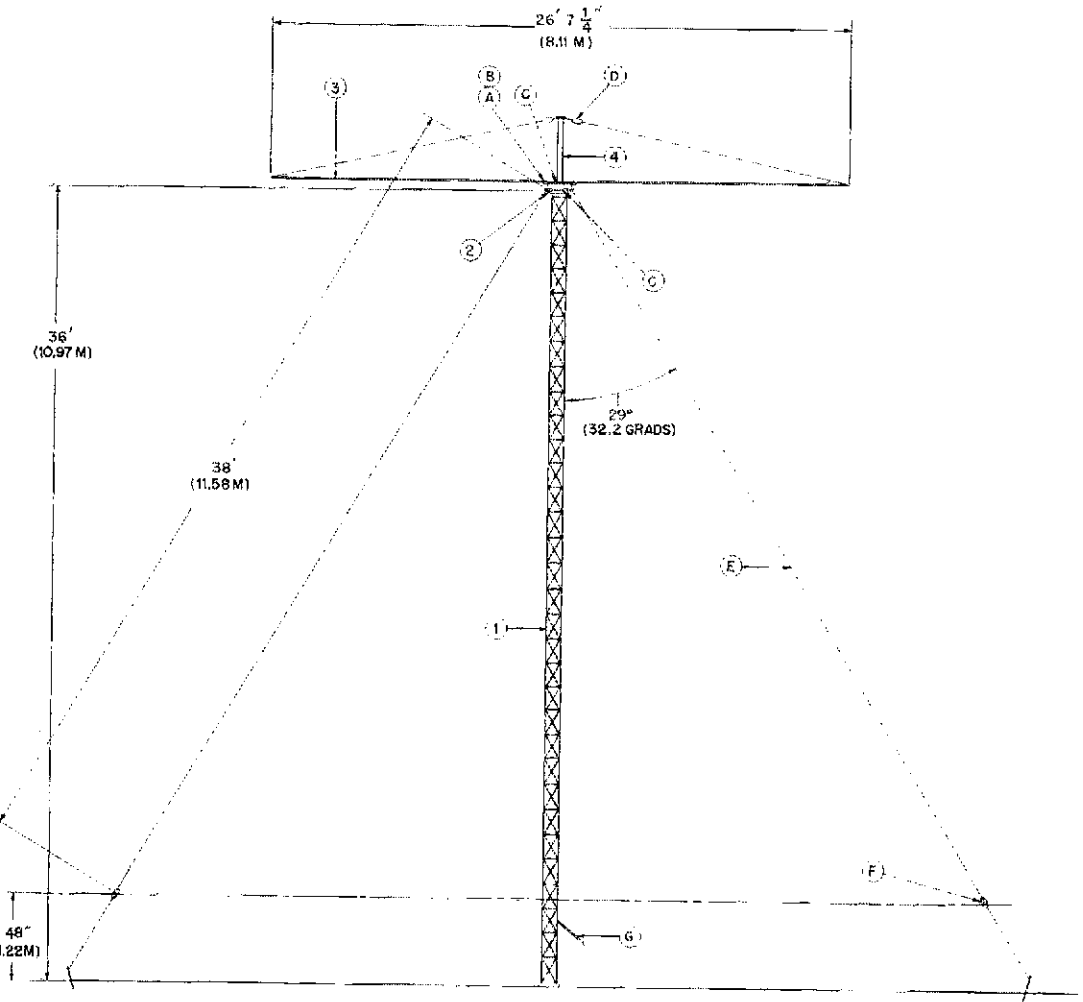


Fig. 3 — Construction details for the hf discone antenna.

- A — Hex-head screw, 1/4-20  $\times$  2-in. long, 16 req'd.
- B — Hex nut, 1/4-20 thread, 16 req'd.
- C — Hex-head screw, 3/8-16  $\times$  1-in. long, 8 req'd.
- D — 6-in. turnbuckle, 8 req'd.
- E — No. 12 Copperweld wire, 1400 feet req'd.
- F — Porcelain or ceramic insulators, 24 req'd.

- G — 50-ohm coaxial feed line, length as required. Line is secured to mast and connected at feed point shown in Fig. 4.
- 1 — Antenna mast with cap.
- 2 — Insulator subassembly. See Fig. 4.
- 3 — Spreaders, made from 1-in. aluminum tubing, 8 req'd.
- 4 — Spreader support, 3-ft. length of steel or aluminum pipe or tubing, flange mounted.

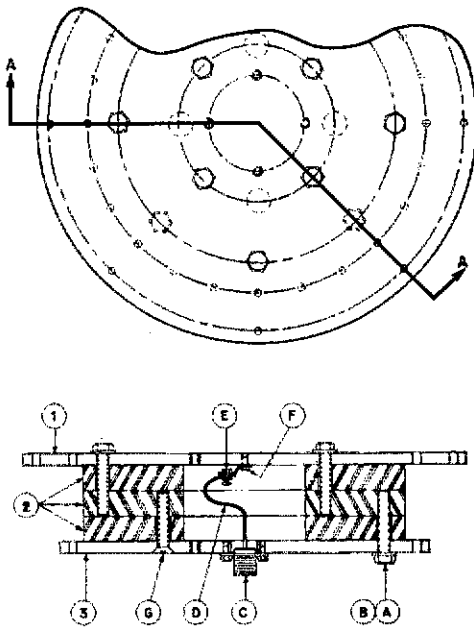


Fig. 4 - Construction details of insulator sub-assembly.

- A - Hex-head screw, 1/2-13 x 2-1/2-in. long, 12 req'd.
- B - Flat washers, 1/2-in. 12 req'd.
- C - Rf connector, as required.
- D - 6-in. length of copper wire.
- E - Wire lug, Emco 14-6 or equiv.
- F - Round-head screw, 10-32 x 3/8-in. long.
- G - Flat-head screw, 1/2-13 x 2-1/2-in. long, 4 req'd.
- 1 - Aluminum mounting plate for disk spreaders.
- 2 - Phenolic insulator rings.
- 3 - Guy mounting plate.

to a considerable extent. An antenna constructed in this way closely approximates the performance of a solid disk and a cone over the frequency range of the antenna.

The discone assembly and construction details are given in Fig. 3. The antenna is supported by an eight-inch triangular aluminum mast (item 1) which is 36 feet high. The insulator separating the disk and the cone (item 2) is detailed in Fig. 4. Basically it is two metal plates separated by an insulating section. The lower plate has a coaxial feedthrough connector mounted at its center, and the outer edge is drilled with 24 equally spaced holes, 5/32-inch diameter, on a 13.5-inch diameter circle for the guy wires that simulate the cone. The end of each wire is soldered to a spade lug that is attached by a self-tapping machine screw to the plate. This plate is bolted to the top of the mast. Eight 1-inch diameter disk spreaders (item 3) are bolted to the top plate. A short 3-foot supporting rod (item 4) is flange mounted at the center of the upper plate to hold the cables for supporting the far ends of the spreaders. The center conductor of the coaxial feed line is attached to the center of the top plate, as shown in Fig. 4.

The antenna is mounted on the flat roof of a three-story building. The height of the lower edge of the cone is 4 feet above the roof. The 24 guy wires simulating the cone are broken by 12-inch porcelain insulators (item F) at their bottom ends, and, as previously mentioned, the ends of each wire are joined by a skirt wire, as shown in the figure.

### Performance

The discone antenna shown in the photograph was constructed in 1968, and it is still in use. It has survived more than one freezing-rain ice storm. The entire antenna and all supporting wires on at least one occasion were covered with 1/2-inch radial thickness of ice. A 3-element triband amateur beam covered with this thickness of ice also survived the ice storm but it was unusable; it was detuned too much by the ice sheath. The performance of the discone was unaffected by the ice. In fact at an operating frequency of about 14 MHz, paradoxically, the SWR was marginally lower when the antenna was covered with ice compared to normal. The antenna has no sharp corners or ends, and it is operated at dc ground (the cone is grounded and the disk is grounded through the input coil of the receiver). Because of this the antenna is essentially immune to precipitation static due to electrically charged rain, such as frequently falls in the Ottawa Valley during summer months. A log-periodic antenna is normally used for hf communications at the Communications Research Centre Amateur Radio Station, VE3DRC. Under conditions of precipitation static this antenna frequently builds up static-charge noise levels equal to a signal strength of S4 to S9 on a Drake R4C receiver, even though the antenna is operated at dc ground. By contrast, there is apparently no static buildup on the discone antenna. The noise levels are essentially that of the atmospheric noise intensity of the distant or nearby thunderstorm.

The antenna exhibits most of the usual characteristics of a vertical monopole. It is certainly and not surprisingly much superior in performance to the horizontal log-periodic antenna for communications over ground-wave ranges with a mobile station using a short vertical whip. The usual vertical monopole antennas have a characteristic overhead null in the radiation pattern, and for short-distance sky-wave communications a horizontal dipole is in general the best antenna. In our experience, however, communication was always possible with the discone, to distances beyond that over which the ground wave could be received, provided of course that the ionosphere would reflect a frequency of 7 MHz (the lowest frequency for which the antenna could be used). While there is certainly a null overhead, it is not a very deep one, and with a linear amplifier at the base station the mobile could always copy the base station if the base station could copy the mobile.

The antenna has been used for many hundreds of contacts on four amateur bands, 40, 20, 15 and

(Continued on page 56)

license at the entry level which would be more attractive to prospective amateurs. The main objection to the FCC-proposed Communicator is that it is a "something-for-nothing" license; it grants so many desirable privileges that few people will want to upgrade. Also, because it requires no familiarity at all with the Morse code, Communicator licensees might not be encouraged to upgrade. The League's proposed alternative, called the Basic Amateur license, provides reasonable privileges as compared with requirements for the license. A novel feature of the Basic Amateur exam is the inclusion of basic questions on the broad range of opportunities available to amateurs with higher classes of license, to ensure that new amateurs are aware of the desirability of upgrading. We feel that this approach will attract large numbers of the kind of new amateurs who will be encouraged to seek the more fertile fields of the higher grades of amateur license.

Although the FCC proposal has been promoted as one having little negative impact on present licensees, in fact the present holders of all classes of license (except Advanced and Novice) stand to lose privileges if it is enacted without change. The League is firmly opposed to further erosion of privileges already earned, including the renewability of the licenses.

Further details on the League's response to Docket 20282 will be found elsewhere in this issue, including the cover. The important fact to note here is that the position adopted by the Board was worked out on the basis of detailed reference to the membership opinion survey. A strong spirit of cooperation enabled individual members of the Board to adjust their positions and response so that the overall position taken by the Board was unanimous. We feel it is truly representative of the majority opinion of League membership. We believe that amateur radio has spoken so clearly in this matter that there can be little reason for a delay in its conclusion along the lines proposed by the League.

And when the final report and order is announced, the League is ready to proceed with strong support of this unified approach to licensing and amateur privileges. We are committed to the adoption of League programs which will encourage the revitalization and growth of the amateur radio service.

- WIRU

10 meters, as well as on a number of frequencies outside amateur bands. The performance of the antenna is difficult to assess quantitatively. Compared to a log-periodic antenna, which has a theoretical gain of 13.5 dB above isotropic (dBi), we should anticipate a change of two to three S units when switching from one antenna to the other. This is assuming that the gain of the discone is not going to be greater than 2.14 dBi (the gain of a dipole antenna) and that an S unit is equal to 5 dB of signal change. At frequencies near the low end of the range, 7 MHz, the signal change is usually greater, being 3 to 4 S units. This seems reasonable. At 7 MHz the angle of maximum radiation for the log-periodic antenna occurs at 32° above the horizon, whereas low-angle radiation from the discone is optimum at this frequency. At 14 MHz the angle of maximum radiation for the log periodic decreases to 10° above the horizon, whereas the discone radiates somewhat less efficiently at low angles. The relative gain between the two antennas is therefore a function of frequency and distance and more particularly the elevation angle of the downcoming sky wave and the relative response of the antenna at that angle.

In an article in a recent issue of *QST*, Wintzer<sup>7</sup> discusses experiments with simplified wire discones. While none of the experimental arrangements utilized a sufficient number of wires to simulate a discone very well, nevertheless a reasonable performance was achieved on spot frequencies in some amateur bands. The advantages of a true discone antenna can be obtained without constructing the "unwieldy monster" that Wintzer suggests it must be, and one can certainly claim that the discone is a sensible alternative for a monopole. The 4-band broadband frequency range with low standing-wave ratio and no critical tuning of traps and inter-trap spacing should appeal to many. In the eyes of the antenna man, the discone is a beauty to behold; birds also love it as rows of them are usually seen sitting of the disk spreaders.

#### References

1. DuHamel and Isbell, "Broadband Logarithmically Periodic Antenna Structures," 1957 *IRE National Convention Records*, Pt. 1, pp. 119-128.
2. Isbell, "Log-Periodic Dipole Arrays," *IRE Transactions on Antennas and Propagation*, Vol. AP-8, No. 3, May, 1960, pp. 260-267.
3. Kandoian, "Three New Antenna Types and Their Applications," *Proc. IRE*, Vol. 34, Feb. 1946, pp. 70W-75W.
4. U.S. Radio Research Lab. Staff, Harvard University, *Very High Frequency Techniques*, McGraw-Hill, 1947.
5. Barrow, Chu, and Jansen, "Biconical Electromagnetic Horns," *Proc. IRE*, Vol. 27, Dec., 1939, pp. 769-780.
6. Nail, "Designing Discone Antennas," *Electronics*, Vol. 26, Aug. 1953, pp. 167-169.
7. Wintzer, "Dipole Passe," *QST*, Oct., 1974, pp. 15-21.

**QST**