Fig. 1. W6UYH inspects a vertically polarized temporary test installation of the 40 to 500-mc discone.

JOSEPH M. BOYER, W6UYH, ex-W8PVL*

A single efficient antenna for operation on any frequency from 40 to 500 mc that requires no tuning stubs or matching transformers, has an s.w.r. under 2:1 and provides gain over a dipole throughout its spectrum.

Discone—40 to 500 Mc Skywire!

ONE ANTENNA CAPABLE of highly efficient performance from six to three-quarter meters—period! No tuning stubs or matching transformers needed. Voltage standing wave ratio in the transmission line under 2:1 over the entire stretch of r.f. territory quoted. Once up you can forget it, come gale or high water. That, ham brethren, is the discone.

The writer decided upon the discone for v.h.f. work when the XYL made it clear she didn't want the brand new QTH looking like a radar development laboratory. Now visiting hams say, "Yeah, that's a nice ultra-modernistic weathervane up there but where's the skywire?" A few minutes of listening on 2 meters, however, with the OM using a coaxial switch to cut from a well matched ground plane antenna to the "weather vane" and they climb up on the roof for a closer look.

While not too familiar to the ham fraternity,[1] the discone was developed and used during World War II. Some designs now in the patent files of this and other countries show some similarity in theory of operation and appearance to the discone, but the exact configuration of top disk and cone is the brain child of Armig G. Kandonian.[2]

The discone consists of a metal cone which is a continuation of the shield of a coaxial cable, and a top disk which is connected to the inner conductor of the same coaxial line. The slant height of the cone (shown in *Fig. 2* as dimension *d*) is equal to an electrical quarter wavelength at the lowest frequency for which operation is desired. The flare angle at the apex of the cone has a first order effect upon the input impedance of the discone antenna. The exact diameter of the top disk is only critical if the discone is to be operated over the first few megacycles of its low frequency design point; otherwise its effect upon input impedance is secondary.

Physical dimensions are given in *Fig. 2* for the three models of the discone to be described. Model A is designed to cover the frequency range 40—500 mc; model B, 400-1,200 mc; and model C (800—5,000 mc) is a scale replica of the 40—500 mc version whose purpose was to provide a means of measuring the radiation pattern of the discone using the model antenna range technique. This technique will be described later in the article.

Theory of Operation

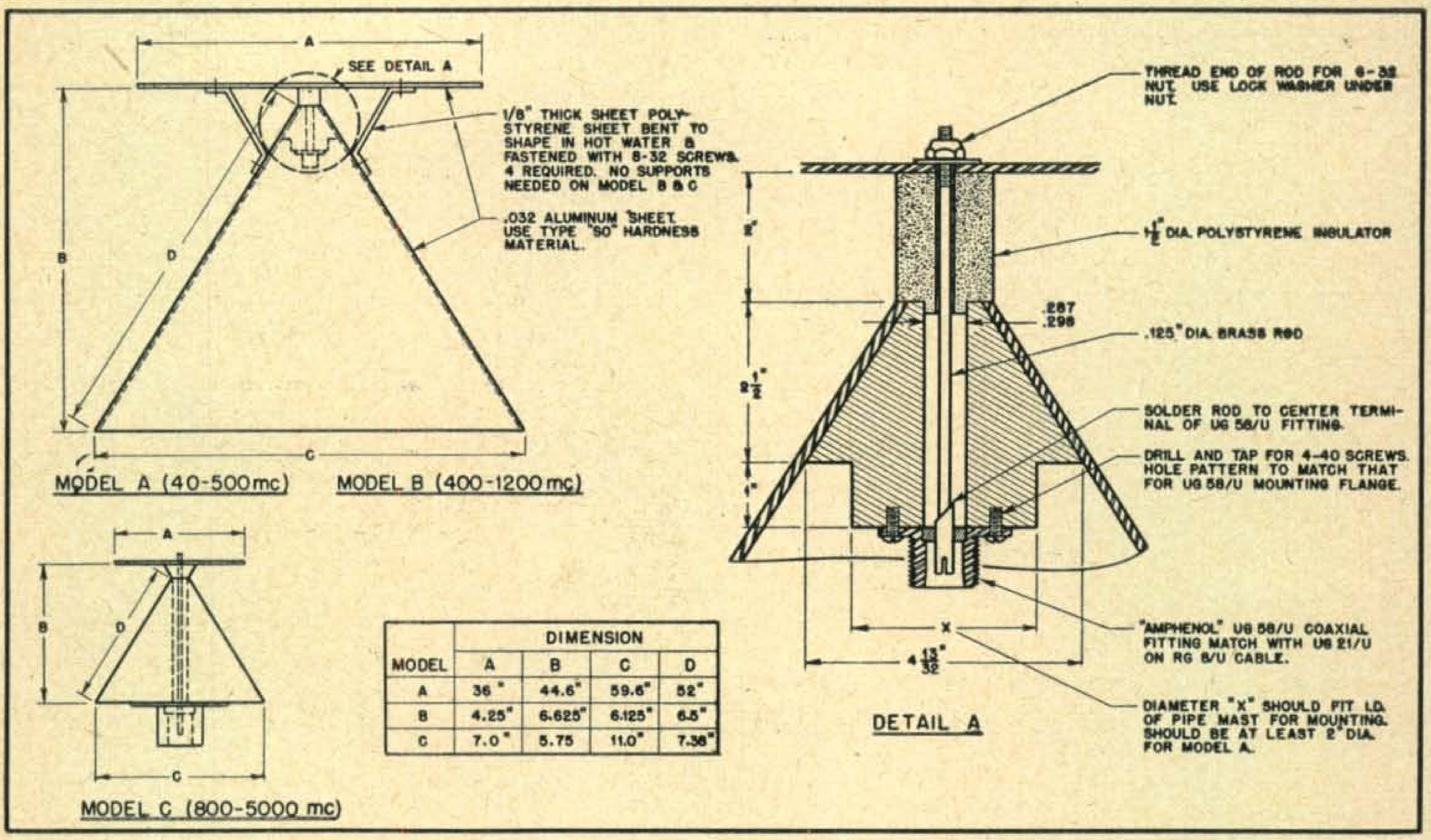
While a rigorous analysis of the discone would result in an unwieldy mass of boundary equations, a brief non-mathematical description should be of value particularly to those desiring to modify the basic design for their own special needs.

There are several non-mathematical analogies which permit a visualization of the operation of the discone, but two are particularly valuable. First, the discone antenna may be looked upon as a "hi-pass" filter network. Imagine such a network hooked between two transmission lines, one labeled "Communications Network" and the other "Space Network." If we add an energy source in the form

*Design Engineer, Douglas Aircraft Co., 208 Calle de Madrid, Hollywood Riviera, Redondo Beach, Calif.

1 Lester, "Looking Over V-H-F Antennas," *CQ*, November, 1948.

2 Federal Radio and Telegraph Company.



MODEL	DIMENSION A	B	C	D
A	36"	44.6"	59.6"	52"
B	4.25"	6.625"	6.125"	6.5"
C	7.0"	5.75	11.0"	7.38"

Fig. 2. Constructional details and dimensions of discone models A, B, and C. Each of the three antennas shown, spanning the frequency band 40 to 7,500 mc, will offer almost constant input impedance to a coax feed line.

of a very high frequency signal generator to the "Communications Network" it will be found that for all frequencies below some critical value the filter will pass little energy from the generator to the "Space Network." High magnitude voltage standing waves will exist on the line connecting the generator to the filter.

However, once the critical frequency is exceeded the voltage standing wave magnitude will quickly drop to a very low value and energy will pass smoothly from the "Communications Network" to the "Space Network." We might call such a "hi-pass" filter a "broad band" network. From theory such a network, after the critical low frequency limit is passed, will offer little attenuation to all frequencies on up to light waves. Practical networks fail to achieve this performance either because lumped elements such as coils begin acting like condensers after a certain frequency range is covered; or if distributed elements such as transmission line sections are used in its construction a frequency region is reached where minute defects in fabrication and surface pits and "bumps" present discontinuities—that is, begin to act like lumped elements and the network design fails.

The discone, then, may be visualized as a "hi-pass" network with the above limitations. The familiar dipole, on the other hand, acts like a "band-pass" network. Over only a very narrow band of frequencies does it pass energy from the "Communications Network" to the "Space Network." The objection may be raised that a dipole will radiate first as a half-wave antenna, then as a full wave, and so on. Its input impedance, however, at each of these resonance points changes radically and consequently, unless the generator's impedance is matched to the antenna impedance at each of these points, high standing waves will still exist with poor energy transfer. This change of input impedance with frequency, relatively speaking, does not occur with such an antenna as the discone.

Intrinsic Impedance

The question then arises: what sort of radiation characteristics does an antenna have to possess in order to function like a "hi-pass filter network"? The first step in this direction is to define the term *intrinsic* or *wave impedance*. There is nothing formidable about this term, and as ham radio moves into the region beyond 2,000 megacycles on a large scale its use in the hobby's jargon will become common. Today most amateurs are familiar with the picture of radio energy being merely *guided between* the conductors or boundaries of a transmission line. (The earth, for example, serves as a rather leaky waveguide wall or boundary for vertically polarized "ground" waves on most ham frequencies.)

The *intrinsic* or *wave impedance* is simply the ratio of the electric to magnetic fields existing between a particular pair or set of such wave boundaries. It is the wave equivalent of the familiar law of Ohm, $R = E/I$. This concept permits assigning a value of impedance to the empty space existing between all the transmitting and receiving skywires in the universe. The assigned value is 377 ohms and space is then looked upon as a mammoth transmission line with this value of intrinsic impedance.

The job of any antenna is to act as an impedance matching transformer between the impedance of the communications networks connected to them and the above mentioned space transmission line. The sharply tuned transformer represented by the dipole is one way of doing this job, but its characteristics are not suited for operation over a wide band of frequencies.

The discone goes about its space matching duties in a slightly different manner. Assume a very high frequency signal generator connected to a long coaxial line of convenient characteristic impedance, say 52 ohms. At a frequency of 300 mc, for example, energy passing down the line and reaching the open end reflects back and sets up high magnitude voltage standing waves. Little power can leak out of the open end and propagate into space. If, however, over a distance of 10 feet or more the spacing between the inner conductor and the shield of the coaxial line is gradually increased so that at the open end the shield is now a tube several feet in diameter—then it will be found that almost *all* energy supplied to the line is being radiated. The standing waves along the line will, for practical purposes, have vanished. Radiation will continue to occur even when the signal generator is tuned to higher and much higher frequencies. What we have done is build a wide band antenna known as a form of anular slot, which in its way is a brother to the discone.

To see the similarity attention is directed not to the open end of the line but to the gradually tapering section between the signal generator and the slot radiator at the open end. This section is known as a *taper transformer*. Such a configuration of

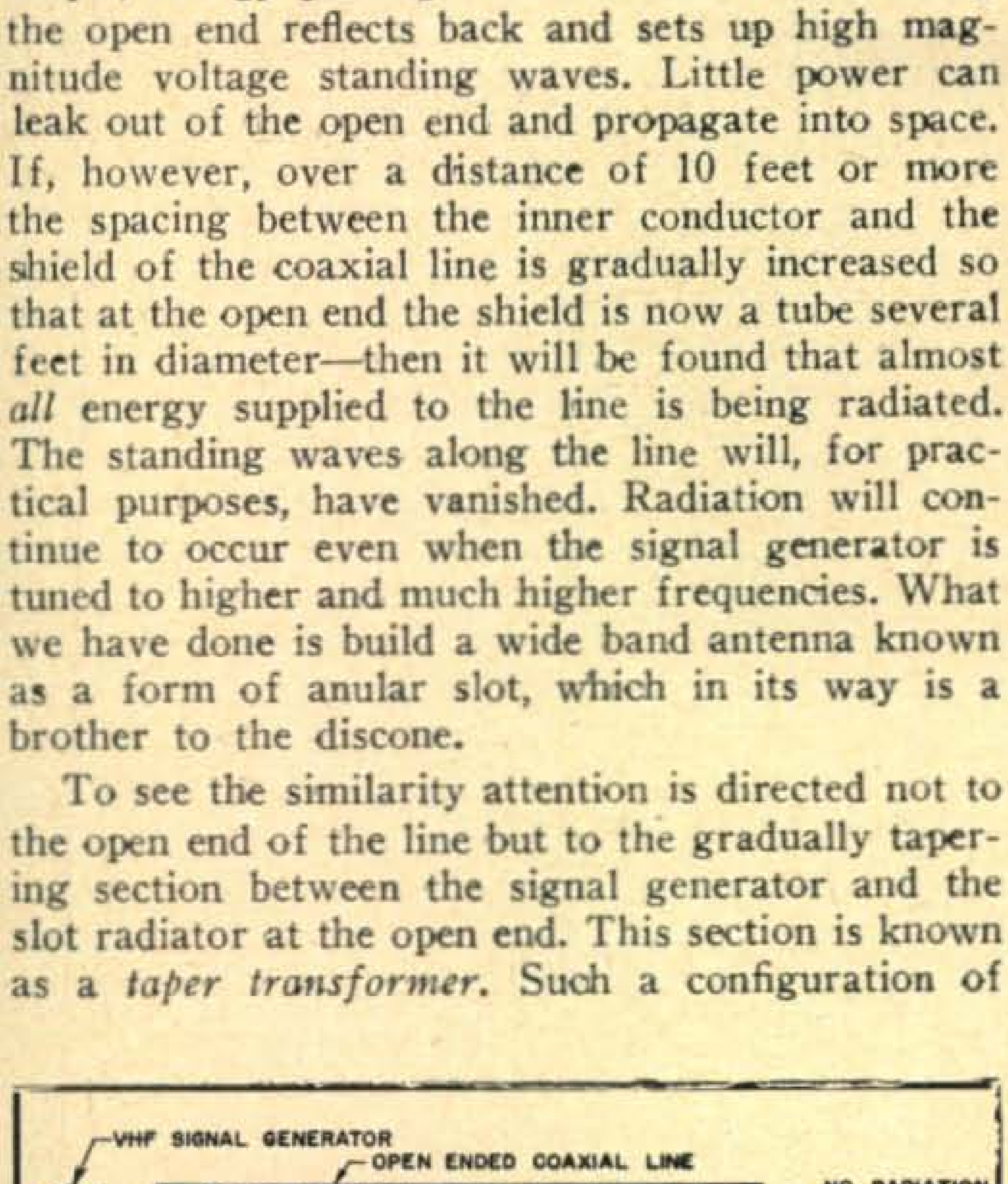


Fig. 3. Evolution of the discone antenna from an open-ended coaxial line. The relationship shown is true only when the discone is operating at least a half octave above its low frequency cutoff point.

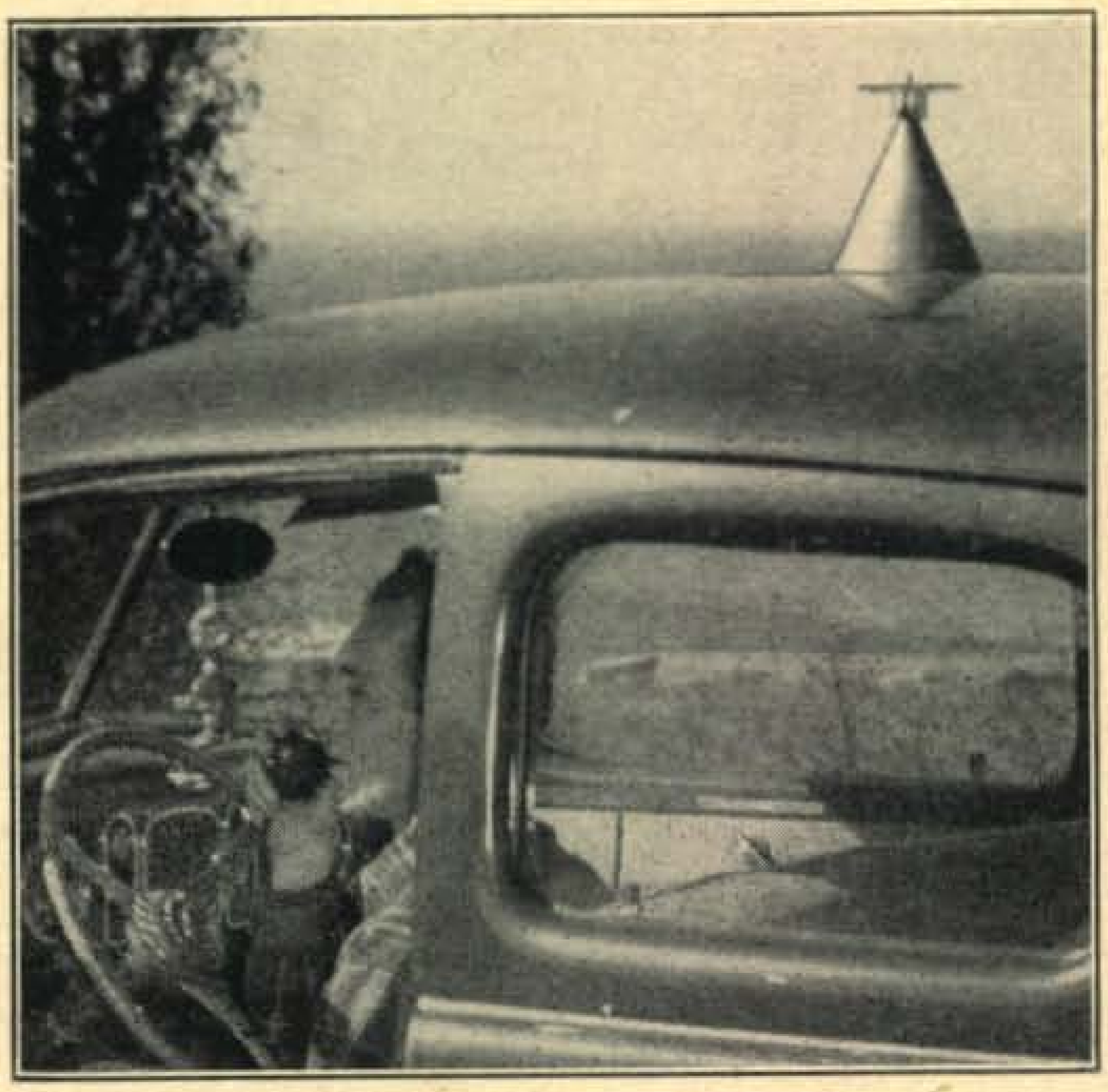


Fig. 5. The model B discone, shown mounted on the metal roof of the test car, proved to be very efficient in tests over a 12-mile path on the amateur 420-mc band. Transmitter used had a power output of 2½ watts.

boundaries starts out with a low value of wave impedance because of the electrical dimensions between the shield and inner conductor. As these spread apart the wave impedance changes gradually until somewhere along its length it "looks" like the value for space. The location of this point will change with a change in frequency, either moving further back down the throat of the taper transformer or out toward the open end. But in either case from this point forward in the taper transformer the radiated waves will find themselves in an environment which has the electrical "feel" of space and from there on out into actual space electromagnetic waves will propagate with little loss.

Tapering boundary transformers are the theory basis for many types of microwave radiators such as the electromagnetic sectorial horn used in radio city-to-city links, and they also explain the operation of the discone.

Coaxial Taper Transformer

All the foregoing ground had to be covered in order that we might finally see that the discone is a *coaxial taper transformer* in which the shield of the transmission line has been folded back on itself at the beginning of the taper and flared out into a cone (*Fig. 3*). The top disk is provided for two good reasons. One, it provides a continuous boundary, symmetrical in all directions from the center of the system, upon which the electric field lines of force extend themselves as they advance out along the cone into space. Two, at the low frequency limit point (where the electrical diameter of the open end of the taper is barely sufficient in size to support radiation) the top disk acts as a capacitive plate to permit the discone to function quite like a top loaded dipole. This low limit point occurs at a frequency for which the slant height of the cone is equal to an electrical quarter wave.

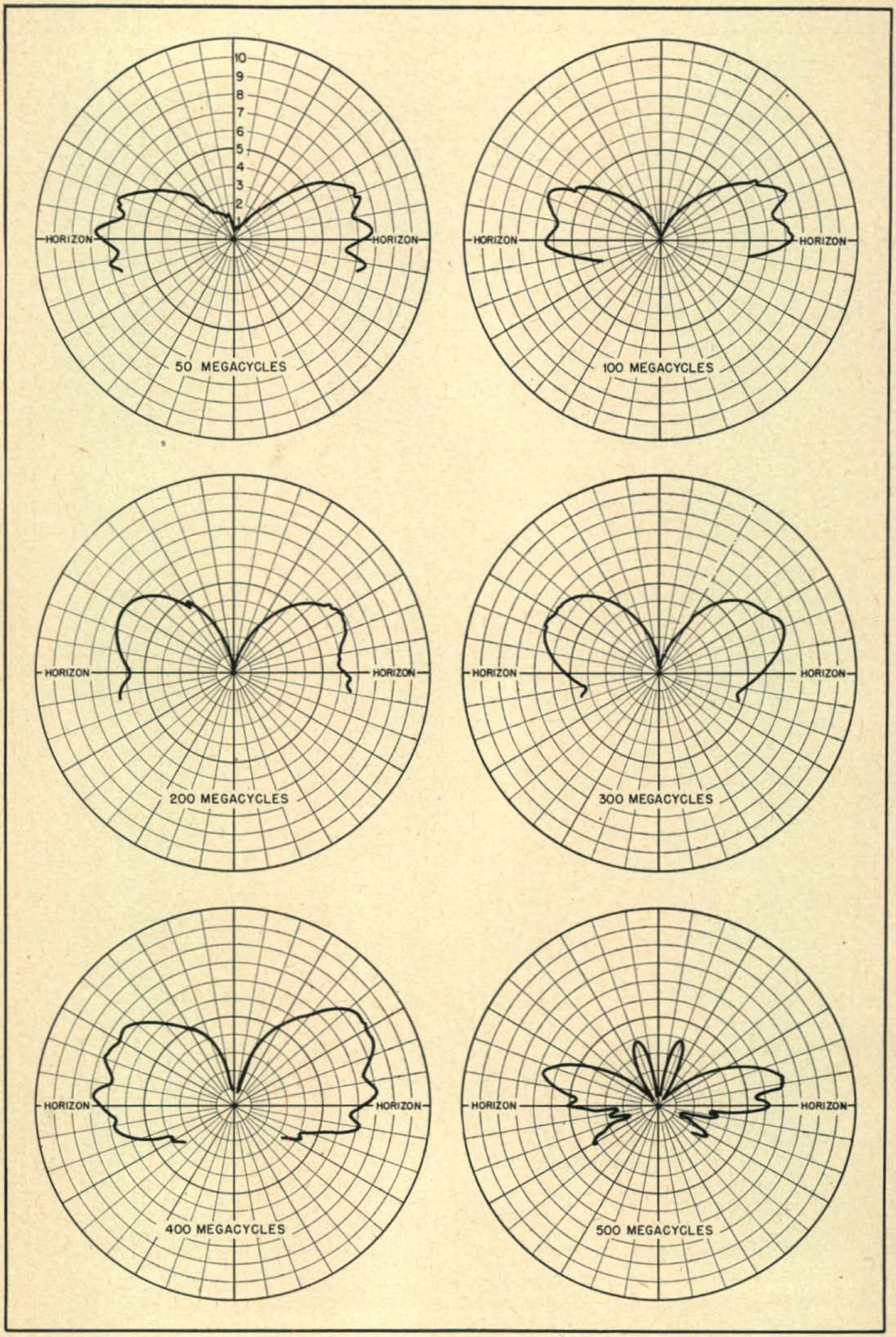


Fig. 4. Asymmetry of scale model C radiation patterns is caused by reaction of objects within the antenna fields.

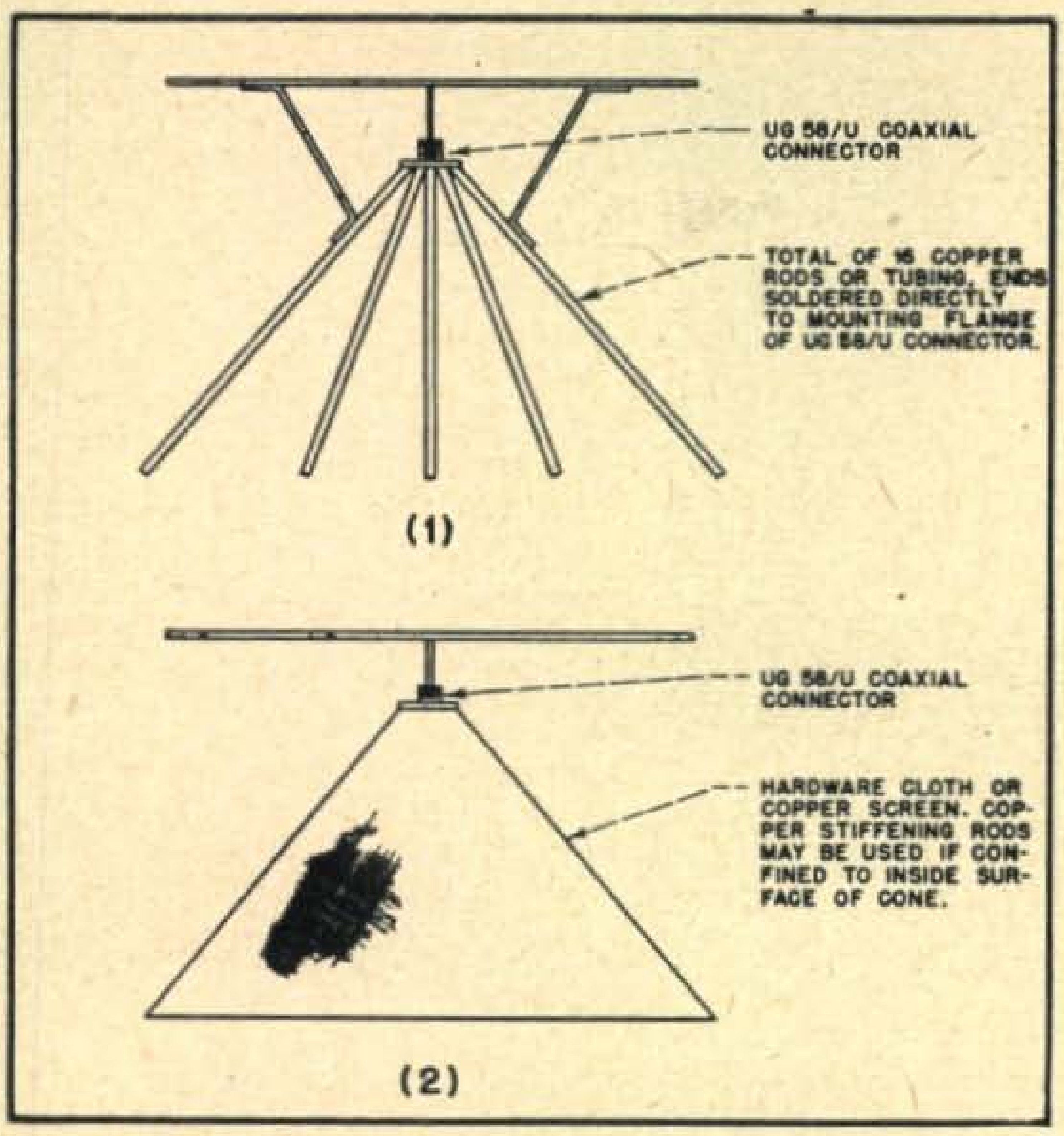


Fig. 6. Two alternate methods of constructing simple discone antennas.

Radiation Patterns

As mentioned previously, the radiation patterns of the discone were secured by the model antenna range technique.[3] A one-twentieth scale model of the discone was constructed to operate over a frequency range of 800 to 5000 mc. An Army surplus APT-5 transmitter unit was used from 800 to 1,500 mc to excite a large pyramidal horn radiator used to "illuminate" the model antenna under test. From 1,500 mc up a Klystron transmitter was available.

The model discone was mounted upon a specially constructed dielectric tower. This tower, in turn, was fixed upon a motor driven circular table which permitted the model antenna to slowly rotate about its central axis either in the vertical or horizontal planes. As the model turned at approximately 1 r.p.m. it was "illuminated" by the uniform wave front beam of the horn radiator mounted upon the laboratory building. All signals to the model were square-wave modulated to avoid danger of frequency modulating the Klystron.

A bolometer detector (10 ma Littelfuse in a special holder) connected to the model discone demodulated the received signal, passing the audio component back to tuned amplifiers in the laboratory. To record this signal graphically in the form of a polar plot of field strength a specially designed cathode ray oscilloscope with servo-driven deflection coils was provided. The oscilloscope screen is photographed during the process of rotating the antenna through 180 or 360 degrees to secure a permanent record. The plots shown in *Fig. 4* were projected and traced from such films.

As can be seen, the vertical pattern changes relatively little over the large span of frequencies covered, which are equivalent to the range 40 to 500 mc for the model A discone. Wasteful high angle lobes are noticed at the frequency equivalent to 500 mc. The model range technique permits measuring patterns with great accuracy under realistic conditions and the results differ in many respects from the idealized patterns usually encountered in textbook literature.

3 Sinclair, Jordon, Vaughan, "Measurement of Aircraft Radiation Patterns Using Models," Proc. I.R.E., Dec., 1947.

If a more narrow beam is desired near the horizon while retaining the 360 degree horizontal coverage, several discones may be stacked one above the other. While the band, over which the input impedance of such an array remains essentially constant, is narrowed by this procedure it is still enormous when compared with the useful bandwidth of arrays such as the stacked Franklin or the loop type radiators used in FM broadcasting.[4]

Operating Tests

The discone has a theoretical gain of about 1.8 over a dipole in its first half octave of frequency coverage. It was the purpose of the operating tests to determine what superiority, if any, could be noticed on the various ham bands within the model A discone's territory. A rig ending in a 4E27 with 200 watts input was used on the 6-meter band. An SCR 522 was put on 144 and 220 mc, with an APT 5 employed on 420. A 3-watt mobile unit for 420 was used for the mobile tests.

With regard to actual air contacts it is only fair to comment that ham radio in general is not set up as a research project. Hence the results to follow, because they are based on many "R" meter readings—each with its own peculiar characteristics of calibration and law characteristic—are necessarily qualitative instead of quantitative.

Comparison between the performance of the discone and four individual ground plane antennas cut for the middle of each band and carefully matched

(*Continued on page 69*)

4 Longitudinal and transverse arrays of discones as well as an "array" consisting of a discone feeding a hollow paper tube with a half power beam width of only 5 degrees cannot be described here but may be the subject of a later article.

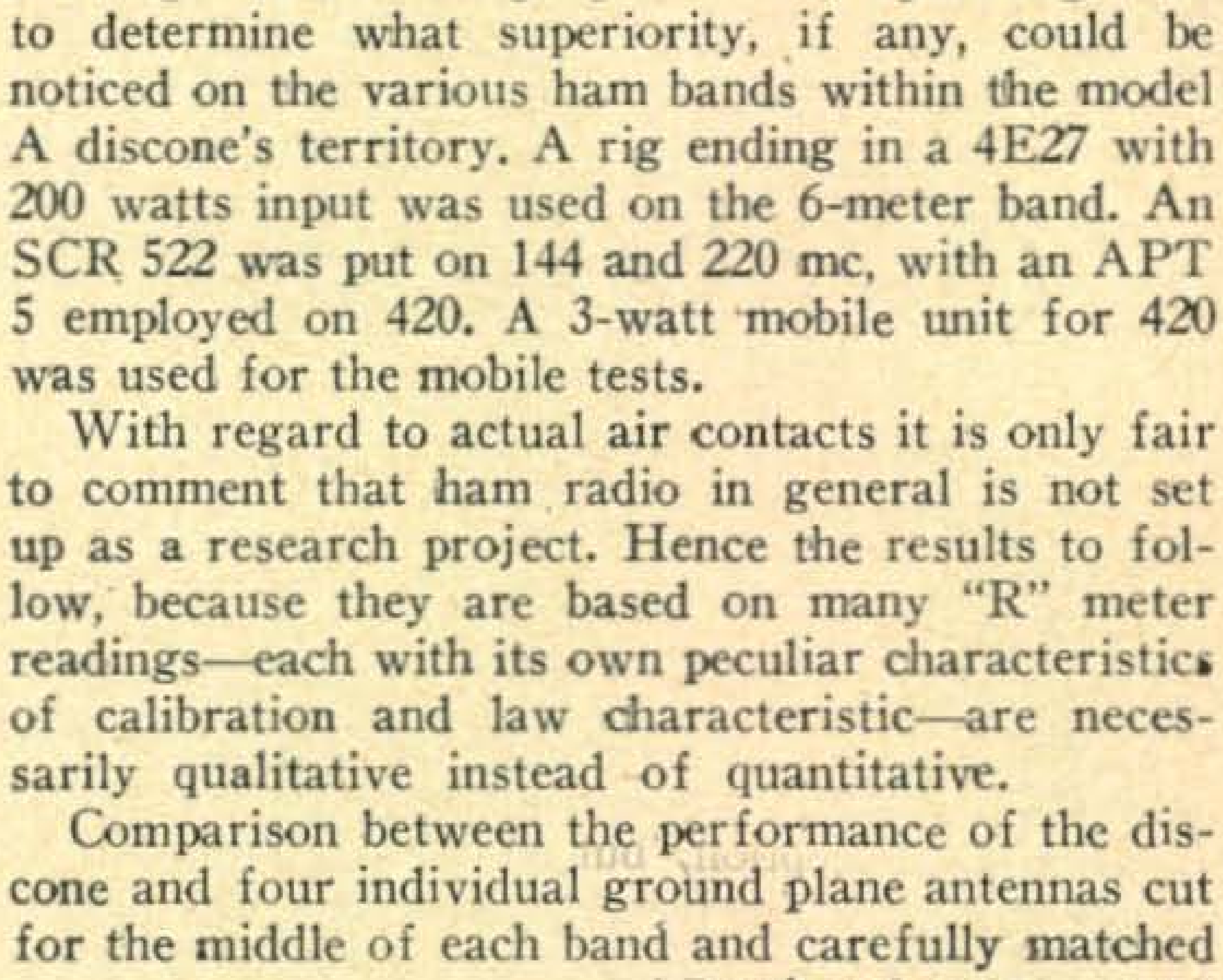


Fig. 8. An "exploded' view of the model B discone illustrating the simplicity of construction. A special flange, not shown, was welded to the base of the antenna for ease in mounting to an automobile roof.

wild look in eye about to detune scared old Scratchi. Before he are getting any ideas like cutting off legs I are thinking fast and asking him why not bypassing me to ground.

He are evidentally liking idea, as he are wrapping me well with wire, and connecting condenser to this and then to radiator. Then he turn on rig and go downstairs. This are working ok, I guess, as he are coming back and untying me. Needless to say, I am leaving hurriedly with instructions not to coming back until have grown cupple more inches.

I are sorry to be leaving so soon, as were about to try out antenna idea. Being he so high in air on top of building, couldn't Scratchi using metal framework of building for vertical antenna?

Respectively yours,
Hashafisti Scratchi

BC-624 NOISE LIMITER

[*from page 25*]

noise. Resistors need not be more accurate than 10% because a little clipping on occasional voice peaks is not objectionable in amateur communications. Distortion is so low that no provision has been made for cutting the limiter out of the circuit, or for adjusting the limiting level.

The 18,000-ohm resistor (R6) in the cathode lead from the 6B8 has no effect on detector and noise limiter performance. Its function is to provide a bias which delays the a.v.c. so that it does not act on weak signals. The amount of delay can be varied by changing the size of this resistor. In some receivers the a.v.c. diode load resistor, R8, is returned to ground rather than to the cathode. This more conventional connection should be retained. No changes were made in the audio amplifier other than adding a 6800-$\mu\mu$f condenser from the plate of the 6J5 (or 12J5) to ground. This serves to bypass the higher-pitched audio components of input noise which previously had been attenuated by the audio transformer.

DISCONE

[*from page 15*]

with shunt coaxial transformers to the RG 8/U line were requested from stations worked. By "carefully matched," we mean actually measuring the voltage standing wave ratio with a laboratory slotted line and matching until the line to the ground plane was as flat as it could be made. No matching of any kind was used on the discone at any of the frequencies used.

Out of twenty-two contacts made, nineteen reports gave the discone a 2 to 3 "R" advantage; one station called it a draw, and two other reports (on the three-quarter meter band) gave the discone anywhere from 3 to 5 R-units greater signal strength but had to be reluctantly discarded because the stations concerned were estimating by ear, not meter.

The smaller version of the discone shown mounted on an automobile top (model B, *Fig. 5*) was

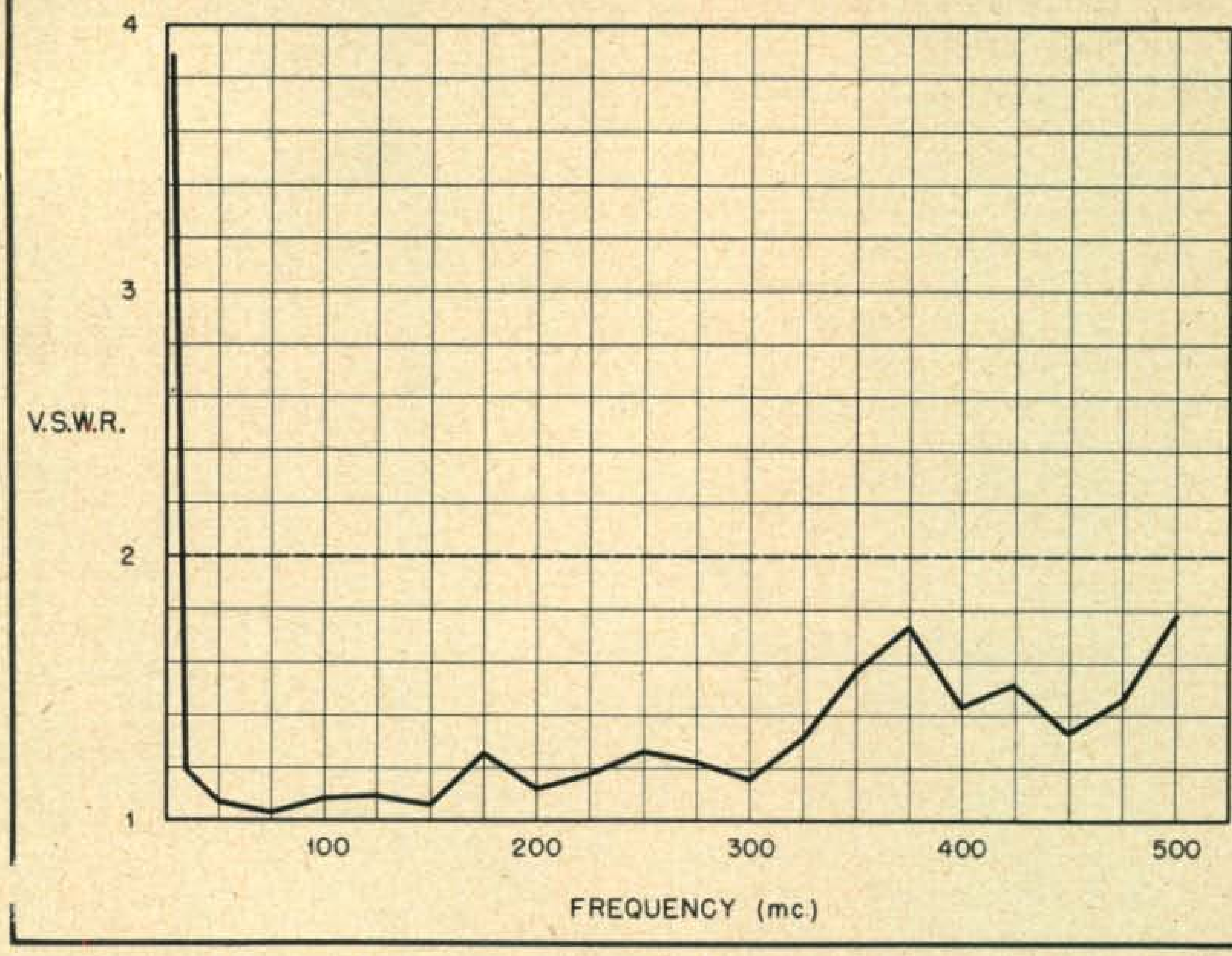


Fig. 7. Voltage standing wave ratio existing in a 52-ohm coaxial line for model A discone. A v.s.w.r. magnitude of 2 represents only 3 per cent power loss due to impedance mismatch. Measurements were made on a laboratory slotted line.

necessary in order to test the antenna for suitability under mobile conditions. Operation was in the 420-mc band. Only two schedules could be arranged between the mobile unit and the home station in the time allotted for mobile operation. In both instances contact over a 12 mile path could not be established with ground plane antennas being used at both ends of the circuit. After a five minute call the home station switched to the model A discone and was heard about Q3 R3 by the car. The mobile unit then tied in its discone and the signal was Q5 R4. The least that can be said from the above results is that the discone looks like a good, efficient antenna for members of the fraternity who do not desire a roof bedecked with an antenna for each v.h.f. band they operate in. For the experimenter who wishes to work with combinations of discones, possibilities appear extremely bright.

A point of interest about the mobile installation is that the base of the discone is welded to a flat ring of .064 brass. This ring is drilled and tapped for 12 type 10-32 screws which go directly into the car top which then acts as an excellent ground plane. Little change in the input impedance results when this is done, but the radiation pattern changes slightly. In this case a lowering of the major lobe was noticed. No attempt was made to secure permission for transmissions in the Citizens Band, although voltage standing wave measurements were carried out to 500 mc and, as can be seen from the curve, *Fig. 7*, predict excellent results for a band many hams will probably be tempted to try.

Construction Notes

Several suggestions for construction of a discone are given in *Figs. 2* and *6*. Due to the fact that the alternative designs in *Fig. 6* are only approximations of a solid surface they will not perform as efficiently over the higher range of frequencies as the models shown in *Fig. 2*. These sketches show, however, how simply the antenna can be made. In one case a "jury rigged" discone (*Fig. 6*) was constructed and put on the air in less than twenty minutes. It is recommended that if a permanent installation is contemplated that the builder pay the slight charge for having the inner support cone machined by a local shop. The author's model A antenna cost a total of $25.00; this cost covered all raw materials from surplus sheet aluminum and bar stock to the machining fee. Wind loading is considerable on a structure offering as much surface as the discone, therefore a very rigid guying system or tower is suggested when mounting the antenna permanently more than a few feet above the roof.

DUAL CONVERSION SUPER

[*from page 23*]

capacity can be used across the coil for the same purpose, if desired.

The pitch control is an air trimmer of approximately 35 $\mu\mu$f maximum capacity. Actually, it is a standard 50-$\mu\mu$f air trimmer from which two stator and three rotor plates were removed, leaving nine plates in all. In order to avoid trouble from b-f-o harmonics, the pitch control condenser is mounted directly under the b-f-o coil so that its stator lead can be made as short as possible. A ¼ inch brass shaft and a pair of flexible couplers are used to couple the trimmer shaft to a bearing assembly mounted on the panel. In wiring the second i-f and detector circuits, be sure to keep all components close to the chassis to allow clearance for this shaft.

The send-receive switch, SW_4, is a double-pole-double-throw toggle switch, one pole of which is used to apply 117 volts a.c. to a pair of terminals on the rear of the chassis to operate antenna and transmitter relays in the "send" position. The other pole grounds the proper terminals of the gain control potentiometers in the "receive" position, and