Looking Over V-H-F Antennas

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As the frequency of operation gets higher so does the number of different types of antenna. Here is a general discussion of the many types of v-h-f antennas being employed in and out of amateur circles. The first part of this article covers vertical non-directional antennas.

THE COMING OF AGE of the v-h-f spectrum has made it economically possible for the average ham to seriously consider experimenting with antennas, a luxury previously denied all but the commercial point-to-point operators with heavy financial backing.

Of course, hams have been experimenting with antennas since the days of the flat-top and fan counterpoise, but the cost of such an antenna, or even more complex antennas such as the popular rotary beams, is insignificant compared with the complex multi-element arrays used by the long haul commercial stations.

At v.h.f., where antenna elements are so small that they can be constructed quite inexpensively from self-supporting tubing, arrays to accomplish almost any purpose can be erected for a very reasonable cost. This is especially true in the range near the microwave spectrum.

Design of v-h-f arrays on paper is usually quite simple; physical realization of the design is sometimes quite difficult. For instance, theoretically, parasitic elements can be added to a driven element indefinitely with an increase in gain accruing to each additional element. Actually, when dealing with elements of finite conductivity, a condition is rapidly reached where the ohmic resistances combine with a reduction in driving point impedance in such a manner that increasing the number of elements actually decreases the gain.

The purpose of this article, which will be presented in two parts, is to review data on proven v-h-f antennas, giving the advantages and disadvantages of each where these factors are not self-evident. Because of the necessity of drawing from commercial experience and designs, most of the data given here of necessity relates to the commercial 30-44 mc, 72-76 mc, and 152-162 mc bands; all data can be readily converted to ham band design figures, however, by formulas given.

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The first part of this article will be concerned with vertical non-directional antennas, and the second with simple horizontal antennas and both vertical and horizontal arrays.

At v.h.f., polarization of the transmitted signal is of primary importance. A station transmitting vertically polarized waves cannot normally satisfactorily work into a station using a horizontally polarized receiving antenna, and vice versa. A signal transmitted with one particular polarization will retain that polarization unless badly refracted, or reflected.

Happily, at v.h.f., an antenna with main radiating elements *vertical* produces *vertically* polarized waves, and similarly *horizontally* oriented antennas produce *horizontally* polarized waves.

Use of either polarization is dependent upon the whim of the operator more than anything, though, of course, if it is desired to work into other nearby stations, their receiving polarity must be determined. While there is some evidence that horizontally polarized waves suffer less attenuation while traveling over average earth than vertically polarized waves, this evidence is far from being conclusive. There is no evidence whatsoever that either

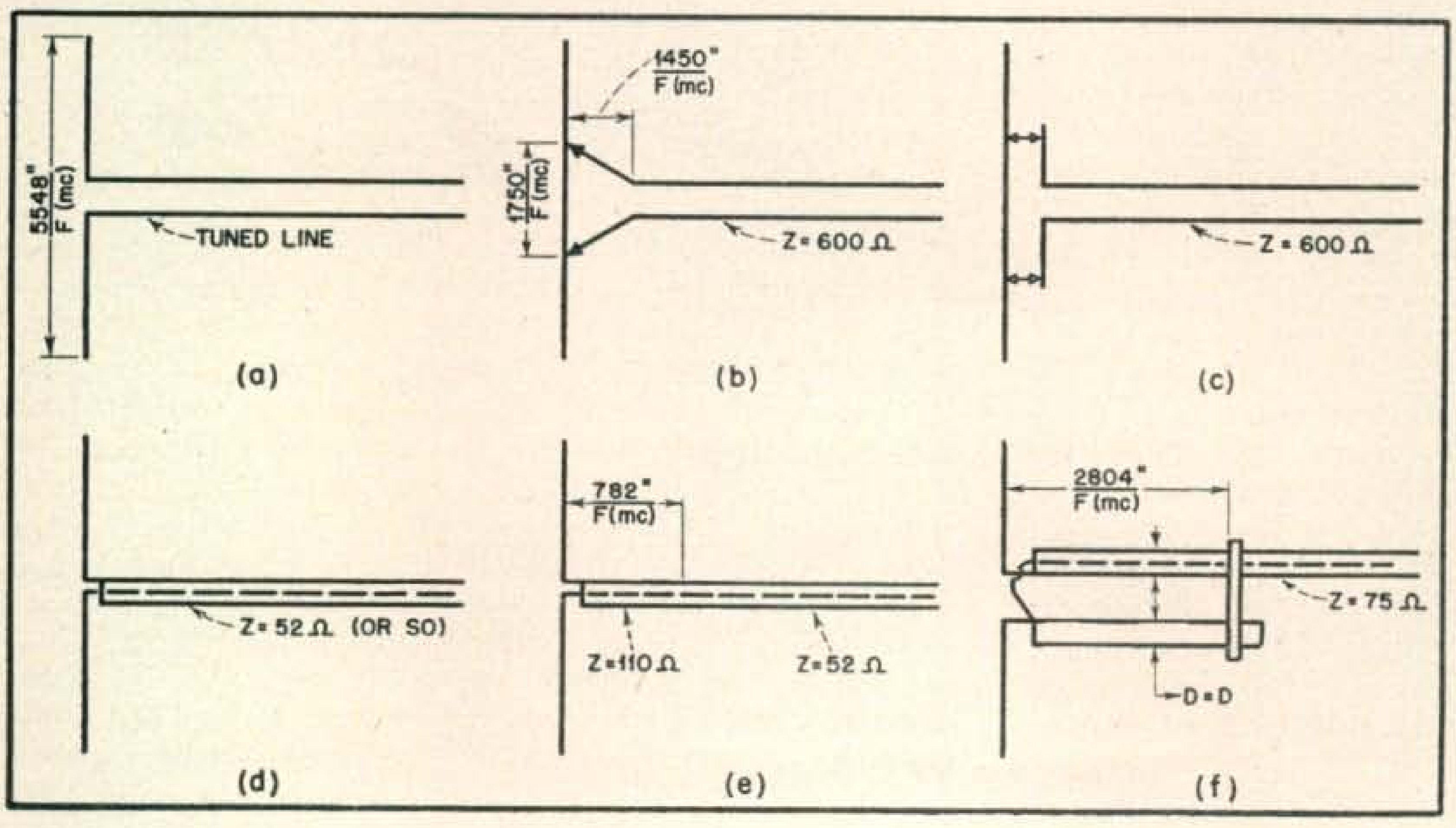

Fig. 1. Six center-fed vertical half-wave dipoles.

polarization is superior to the other on long distance communications dependent upon superrefraction or tropospheric reflections. Actually v-h-f transmissions may be reflected in such a manner that a portion of the energy of an originally horizontally polarized wave may arrive vertically polarized, so that polarization is not too important for extremely long range communications.

Commercial operations involving transmitting into or out of mobile units use vertically polarized antennas of necessity since the "whips" used as antennas on mobile units are vertically polarized. Some commercial point-to-point systems use vertical polarization simply because such equipment is easily available commercially; most lower frequency (6-25 mc) point-to-point systems use horizontal polarization if mobile unit communications are not required because of the ease with which directional arrays can be set up for horizontally polarized systems.[1]

Most vertically polarized systems use non-directional antennas at the fixed stations because of the desire to talk-out to mobile units equally well in all directions. All gain in the antenna must, therefore, be produced by lowering the angle of radiation, and many designs have been worked out to accomplish this. Most designs are based on elimination of undesired radiation from antenna mounting masts and feeders and vertical stacking of radiators. If present, radiation from masts and feeders usually combines with the main signal in such a manner as to effectively increase the angle of radiation, which, of course, is tantamount to a loss in antenna gain.

The Simplest V-H-F Antenna

The simplest antenna at v.h.f. is, as at the lower frequencies, the center-fed shortened half-wave dipole. Theoretically, it has a free space driving point impedance of about 73 ohms, but this may be considerably lower at v.h.f. where the element L/D ratio, resistance, proximity to earth, and many other factors, effectively alter the theoretical value. Though center-fed half-waves are generally fed with 73-ohm coaxial or twisted-pair cable at low frequencies, at v.h.f. a better match is generally obtained with 52-ohm cable. Though this is theoretically only a fair impedance match, reasonable SWRs are obtainable and the system yields excellent results.

Six examples of center-fed (current-fed) half-wave vertical dipoles are illustrated in *Fig. 1.* Alternate *a* is tuned two-wire open line fed, and is impractical above 30 mc or so; radiation from the tuned line may be considerable, and greatly lower the efficiency of the antenna system. Alternate *b* is a delta-section matched two-wire open line feeder arrangement with the feeders untuned (non-resonant). The alternate shown in *c* approximates *b* except that a T-section matching unit is used. In general, the delta-section is the preferable design to use, but the T-section can be more easily constructed at the low frequency end of the v-h-f region.

Alternates *d*, *e*, and *f* illustrate three variations of the coaxial line fed antenna. Alternate *d* is simplest,

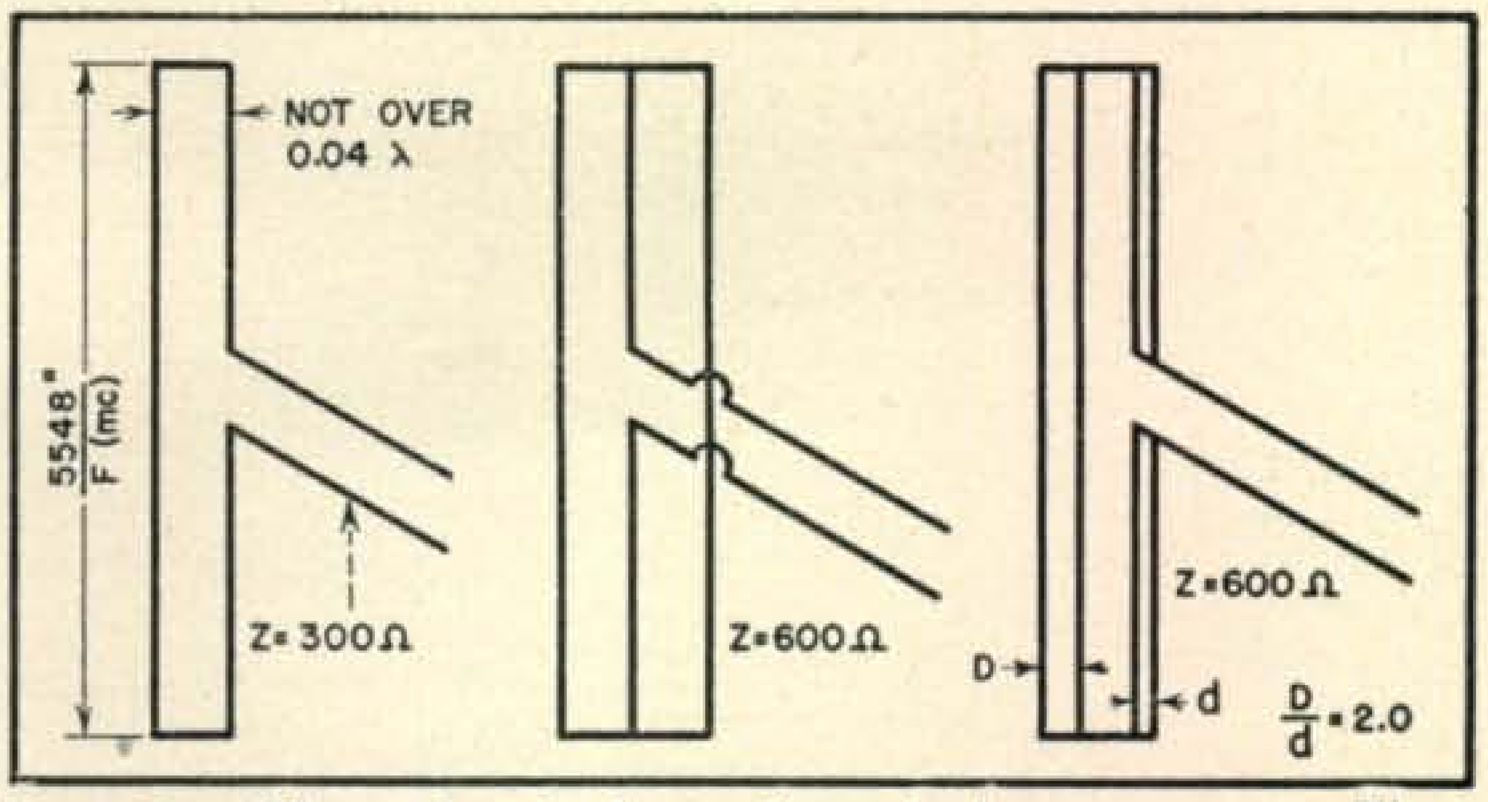

Fig. 2. Three basic broadbanded antennas. Their application is not limited to v.h.f.

of course, but will have a high SWR when required to operate over a wide frequency range. This antenna can be coupled to a receiver or transmitter by a loop (or hairpin at the top end of the v-h-f region) and a suitable condenser in series with the loop to tune out the reactance, reflected into the tank circuit.

The four alternates discussed thus far have been high-*Q* antennas, not adaptable to working over a wide range of frequencies. A fair impedance match can be obtained with an arrangement such as shown in alternate *e* which uses a modified *Q*-section to provide a fair impedance match over a frequency range as high as 1.3-1.5/1. The series *Q*-section should be about 0.1 wavelengths long at the lowest frequency desired, and will substantially compensate for variations in antenna reactance as the frequency increases.

For operations at the extreme high end of the v-h-f region, unbalanced coaxial line feeders unbalance the radiator substantially and antenna current induced on the outside conductor of the feeder is re-radiated, thus distorting both vertical and horizontal patterns. This can be almost eliminated by using a Bazooka-section to balance the line into the antenna as shown in *Fig. 1f.* Other balancing sections have been developed for this work, but the Bazooka-section is as simple as any, and as effective.

The *Q* of the average v-h-f radiator made of relatively small tubular elements is quite high, though, of course, not nearly so high as antennas for, say, 40 meters. This means that unless some sort of "broadening" arrangement is used, the tuning will be very sharp and the frequency band over which the antenna will operate satisfactorily will be quite narrow.

The half-wave center-fed dipole can be broadbanded quite simply by methods illustrated in *Fig. 2;* these methods have the added advantage of raising the driving impedance of the antenna to a point where 300-ohm Twin-Lead or 600-ohm open wire line can be used to advantage.

In *Fig. 2a* two vertical half-wave dipoles have been electrically paralleled by tieing them together at both ends. Feeding one of the elements results in a splitting of the antenna element currents in such a manner that the impedance seen looking into the terminals of the driven element is about four times that of a single vertical half-wave dipole, or approximately 300 ohms, effectively matching 300-ohm Twin-Lead. If it is desired to match a 600-ohm line, three elements can be used which re-

[1]Ed. Note: Generally speaking, high directivitity can be obtained most economically by horizontal arrays at the lower frequencies, chiefly because of decreased array height requirement.

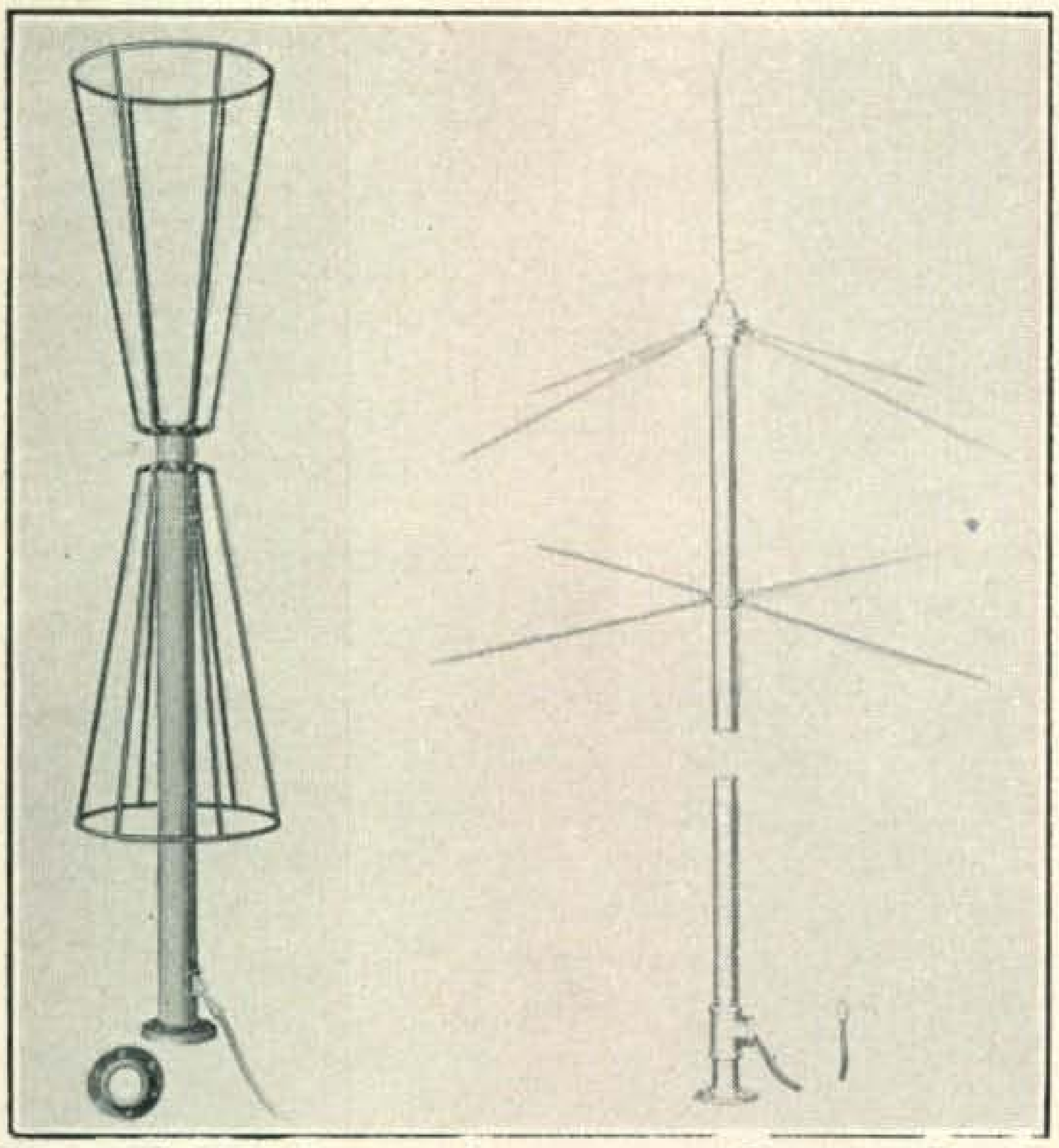

Fig. 3 (left). Biconical antenna. (Courtesy Bendix Company). Fig. 6 (right). Isoplane antenna. (Courtesy Motorola, Inc.)

sult in an increase in impedance of nine times, or slightly more than 600 ohms. In both of these antennas, the elements should not be separated by more than 4% of a wavelength, and preferably should be spaced even closer.

A broad-band antenna matching a 600-ohm line can also be produced as shown in *Fig. 2c* wherein one element is made twice the diameter of the other, resulting in an unequal split in element current.†

Due to the use of conductors having appreciable cross section thickness with respect to length, these "broad banded" dipoles have a very broad tuning characteristic and can be used over an entire amateur band without retuning.

One point should be noted concerning center-fed dipoles. A moderate amount of horizontal pattern distortion can usually be tolerated, and distortion due to bringing in the feeders will not be appreciable if the horizontal section of line between the antenna and the beginning of the down-run is kept at least a half-wave long or greater; if less than a half-wave length is used, severe pattern distortion will usually result.

One other point should be considered—lightning protection. Since it does not affect the antenna's transmitting or receiving characteristics, the element tied to the coaxial line shield should be uppermost, thus providing a direct path to ground for the highest point in the antenna system.

†Ed. Note: The impedance at the feed point is a function of the spacing between and diameter of the conductors. Roberts, *RCA Review*, 1947.

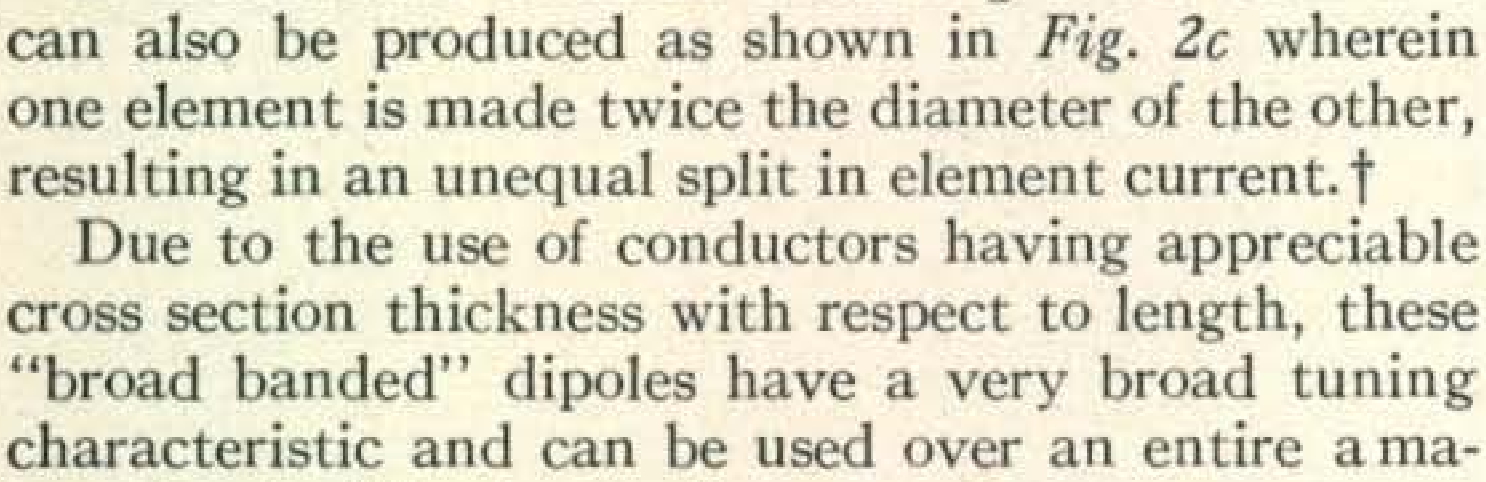

Fig. 4. Three end-fed half-wave dipoles. The "J" is one of the most popular in use.

Conical Antennas

There is one group of center-fed broad-band antennas which eliminated feeder pattern distortion by bringing the feeder to the antenna inside the antenna itself, thus keeping it out of the radiation field. These antennas, known generally as conical antennas, are used commercially in some fixed station-to-mobile unit systems with excellent results.

A commercial model of an antenna of this type known as the biconical antenna is illustrated in *Fig. 3*. This particular antenna, designed to be fed by a 52-ohm cable, will operate over the entire 152-162 mc band with a SWR of less than 1.5/1, and over the range 135-180 mc with a SWR less than 2.0/1. A good power gain is claimed over a half-wave vertical dipole because of lowered angle of radiation.

A good design figure for ham biconicals would be about 0.70-0.75 wavelengths over-all, with an angle of revolution of 20°-30°. Actually, the dimensions are not too critical because of the broad-band characteristics of the antenna itself.

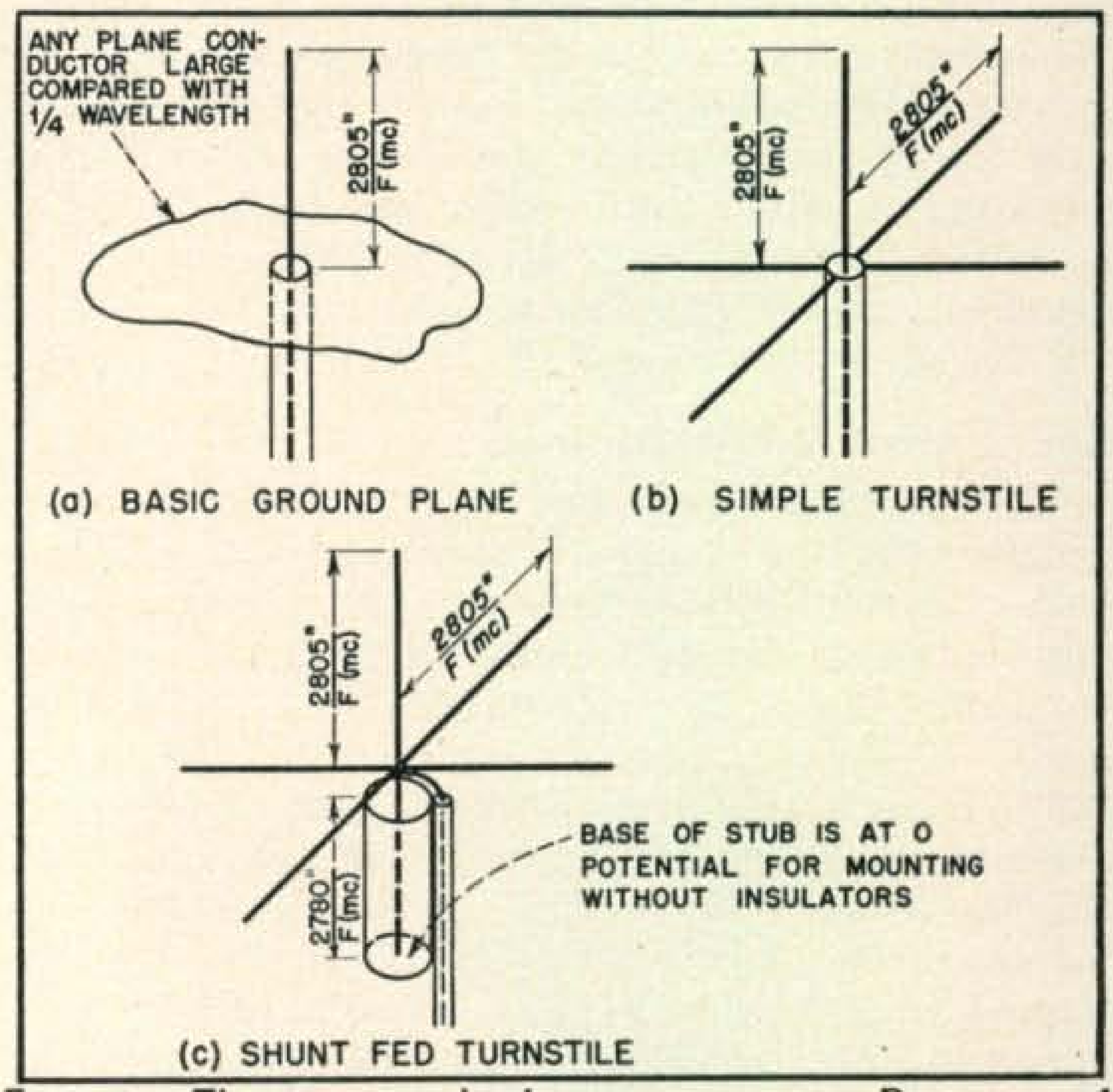

Fig. 5. Three ground plane antennas. Because of their dimensions application is largely confined to the v.h.f.

If the lower element is removed and replaced with a ground plane in the form of a metal sheet, or several radial rods slightly over a quarter wave long, the driving impedance will be approximately 37 ohms, and can be fed with two 75-ohm cables in parallel. Such an arrangement will operate with fair characteristics over a frequency range of 3/1. At least 10 splines should be used for the cone, or it can be made of sheet metal if desired.

Hams have favored the two-wire open line because it is considerably less expensive than most coaxial cables. One of the most popular v-h-f antennas ever designed is shown in *Fig. 4a*. This antenna is known as the "J" because of its con-

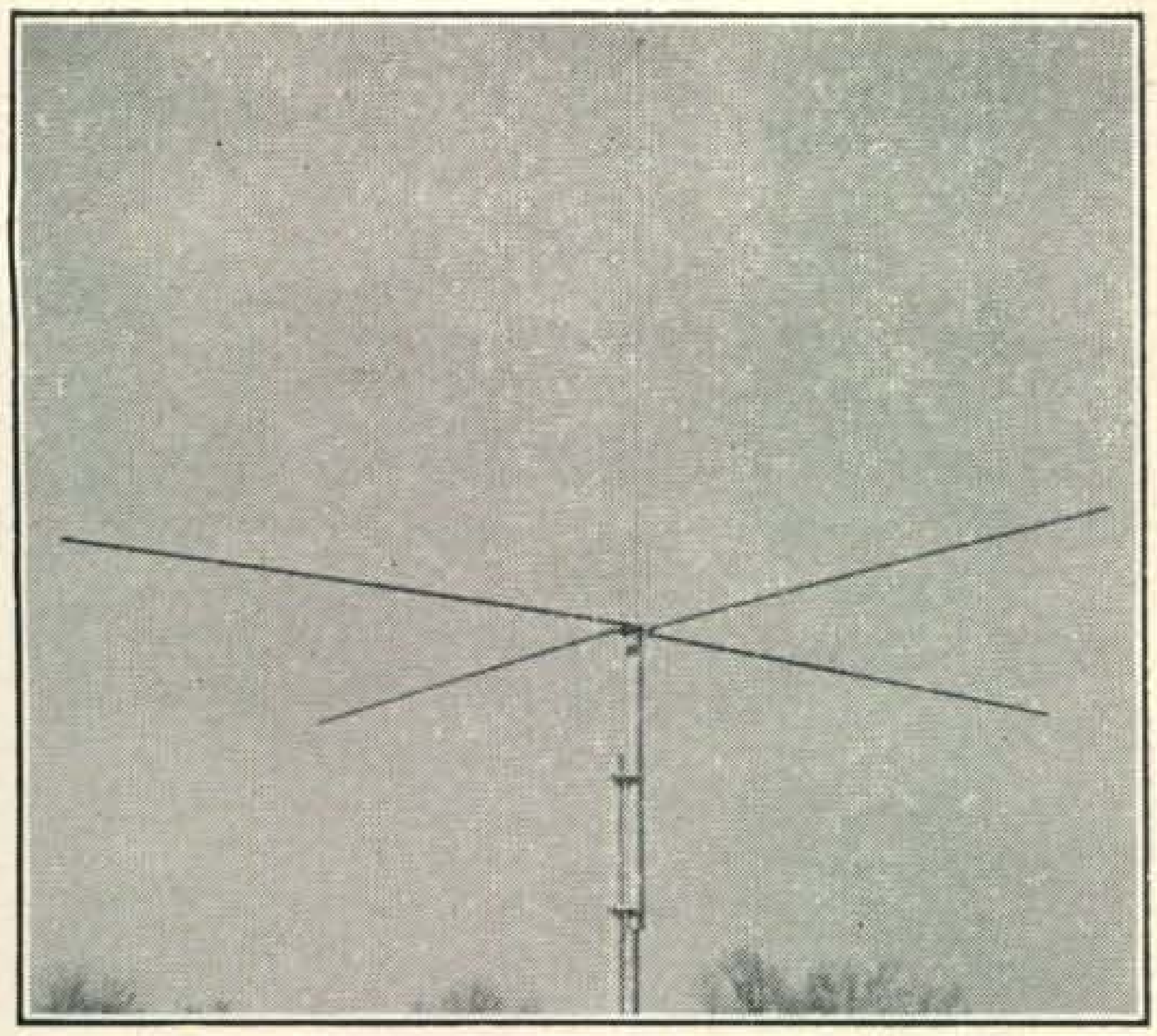

Fig. 7. Folded unipole for 30-44 mc. (Courtesy Andrew Corporation).

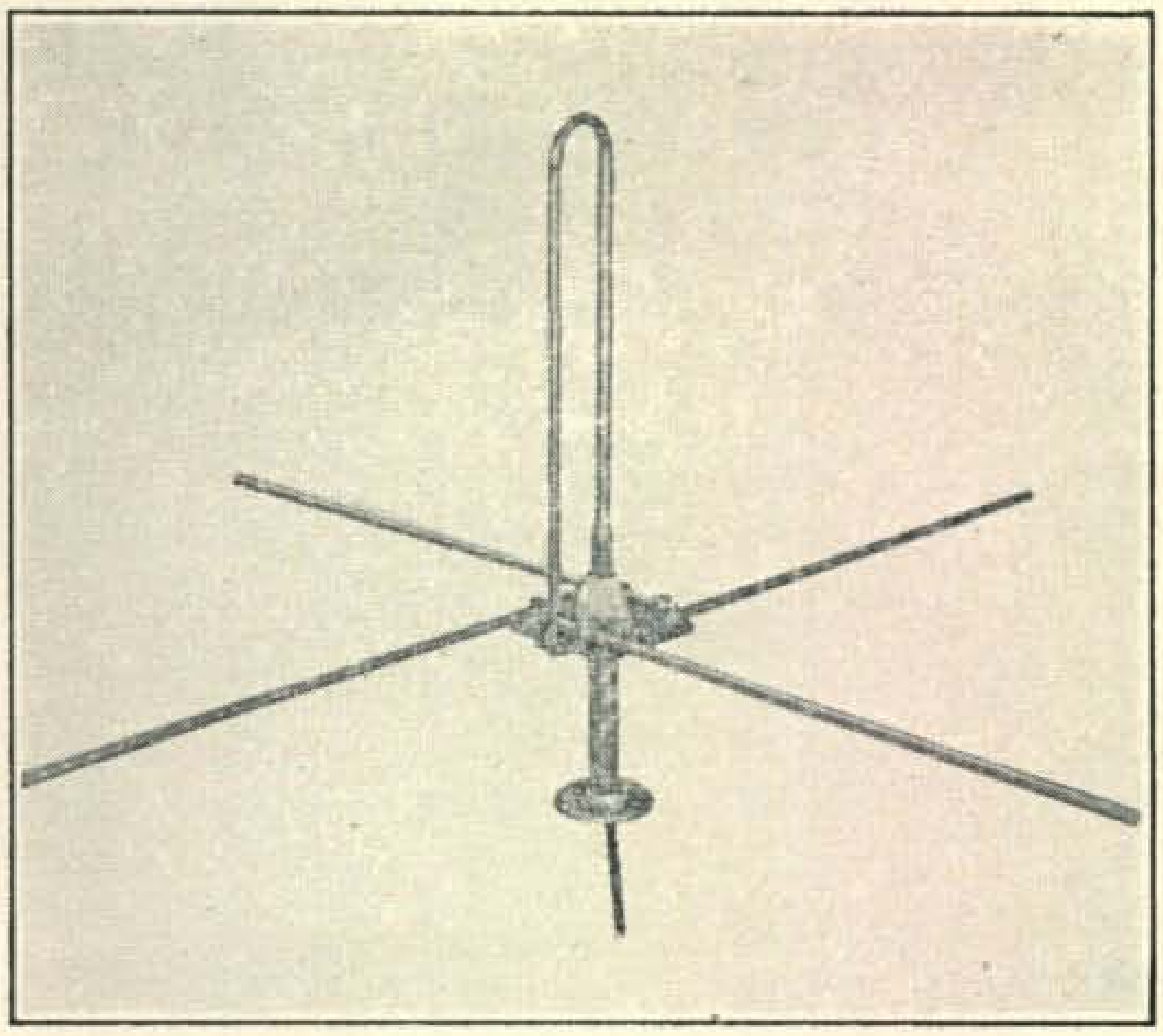

Fig. 8. Folded unipole for 152-162 mc. (Courtesy Andrew Corporation).

figuration. The bottom end of the J-section is at ground potential and can be mounted directly to the support without insulators.

This same antenna can be coaxial fed as shown in *Fig. 4b* and *c* which are identical except *c*, with the highest point grounded for lightning, is slightly unbalanced near the microwave region.

This class of antenna has been largely replaced commercially by the ground plane and coaxial antennas to be discussed.

The Ground Plane Antenna

The ground plane group of antennas is one of the most popular now in use in non-directional vertically polarized systems. It has many variations, all of which claim some improvement over the simple ground plane design. The basic ground plane in *Fig. 5a* has a driving impedance half that of its equivalent dipole, or about 37 ohms. When four quarter-wave long radials are used for the "plane," the impedance drops to about 20-25 ohms, and the coaxial line feed should be matched with a "*Q*-section" a quarter-wave long with a characteristic impedance equal to the geometrical mean of the antenna and line impedance.

It can also be shunt fed as in *Fig. 5c*, the length of the stub and the radiator being varied to produce a match.

For low power installations, it is sometimes possible to allow rather high SWRs on the feed line if the transmitter can be loaded properly. It is common practice in mobile installations to ignore the line match to the antenna proper and produce the power transfer match at the transmitter by tuning the loop.

An exact match to any standard transmission line can be accomplished in two ways, however. In one method, the ground plane radials are pointed downward so that the entire assembly begins to approach a semi-conical antenna, with a consequent rise in driving impedance. One particular example of this antenna is the "isoplane," illustrated in *Fig. 6*. Here the radials are bent downward to match the transmission line, and another set of ground plane elements is mounted one quarter wave below the base of the first set to eliminate vertical pattern distortion due to mounting staff radiation. This antenna, shown for the 152-162 mc band, may be obtained for other frequency ranges also. It is usually shipped pre-cut for the desired frequency. All elements are one-quarter wavelength long electrically, or 2805 inches/F(mc).

Another method to increase the driving impedance of the ground plane antenna is to fold or "trombone" the vertical element. A commercial design for the 30-44 mc band known as the "folded unipole" is shown in *Fig. 7;* another antenna for the 152-162 mc band made by the same company, is shown in *Fig. 8*.

With the vertical element cut to an electrical quarter wave, variation in ground plane radial length from 0.25 to 0.31 wavelengths has little or no effect on the driving impedance. Also, increasing the number of ground plane radials beyond four has practically no effect on performance.

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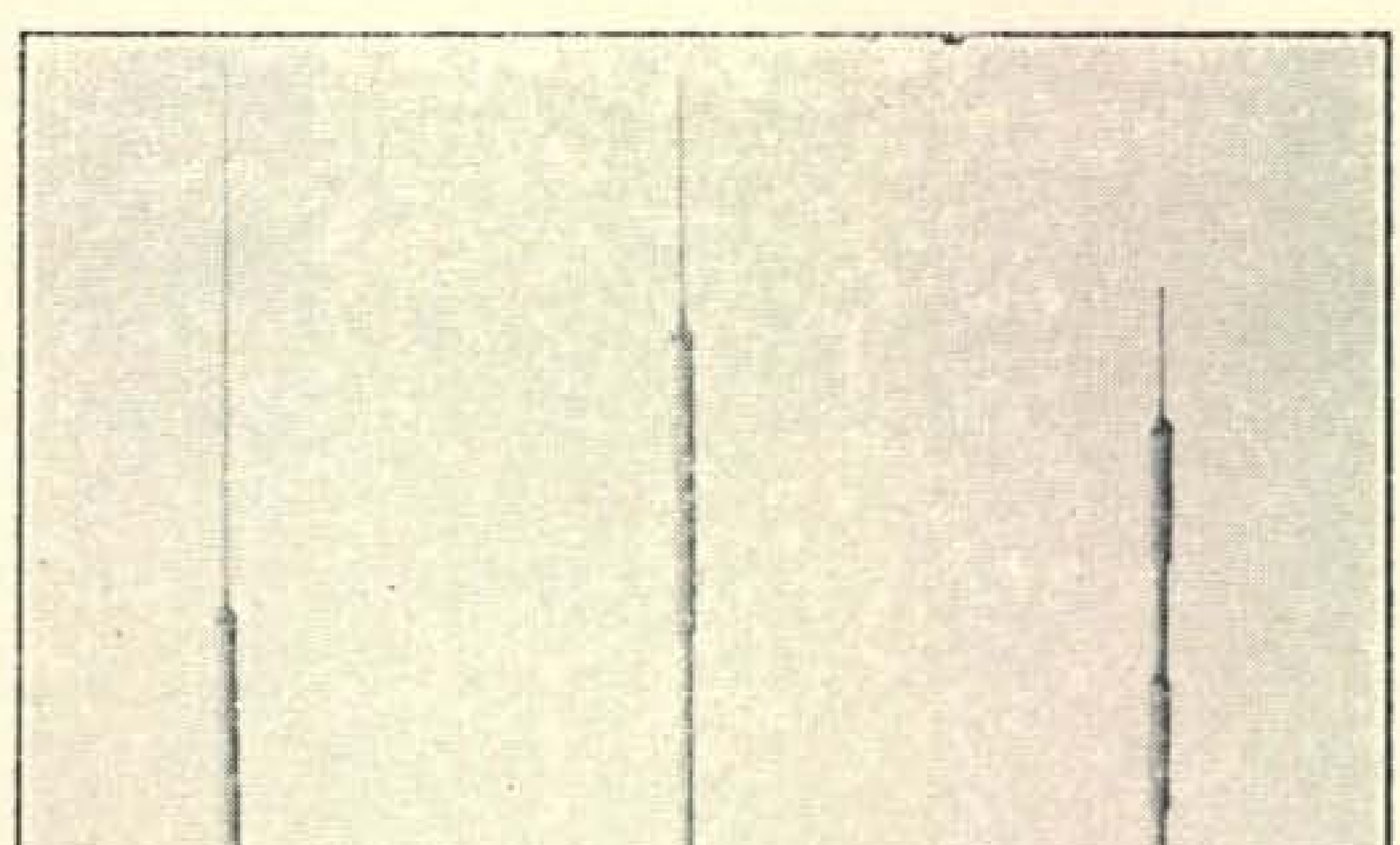

Fig. 9 (left). 30-40 mc coaxial antenna. Fig. 10 (center). Twin-skirted colinear coaxial antenna for 72-76 mc. Fig. 11 (right). Triple-skirted colinear coaxial antenna for 152-162 mc. (All courtesy Motorola, Inc.)

V-H-F ANTENNAS

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The antenna shown in *Fig. 7* has vertical members made of 61ST seamless aluminum tubes and horizontal members made of tapered steel tubes ¾" diameter at the large end tapering to ⅜" at the small end. The support tube is 2½" aluminum.

This antenna can operate over a 1.1-1.2 frequency range with a SWR of less than 2.0.

The Coaxial "Sleeve"

One of the most popular types of vertically polarized antennas in use is the coaxial or "sleeve" antenna, and its colinear coaxial modifications. A simple coaxial antenna for the commercial 30-44 mc band is shown in *Fig. 9*.

This class of antennas is very sensitive to frequency and requires very careful construction. The whip should be a quarter-wave long, or 2805 inches $/F$(mc). If fed with a 52-ohm cable, the skirt should be $2775/F$(mc) inches long, or $2920/F$(mc) inches long if fed with 72-ohm cable.

The dimensions of the whip are not too critical, plus or minus 1% being sufficiently accurate; the dimensions of the skirt are extremely critical, and should be set using a slotted line in the feeder between the antenna and the transmitter so that the skirt length can be cut for a minimum standing wave ratio.

This type of antenna is entirely symmetrical, and there are essentially no support mast radiation effects to raise the naturally low angle of radiation. However, in an effort to further lower the angle of radiation, the antennas illustrated in *Fig. 10* and *11* have been developed. *Figure 10* shows a twin-skirted colinear coaxial antenna for the 72-76 mc band and *Fig. 11* a triple-skirted colinear coaxial antenna for the 152-162 mc band. The additional skirts are parasitically driven, and it is claimed that a lower angle of radiation is obtained; surely better isolation from the mast is obtained.

Both the twin-skirted and triple-skirted colinear coaxial designs are extremely difficult to adjust, and their construction should not be undertaken unless good instruments are available. A slotted line is almost a necessity.

These antennas should also be adjusted in conjunction with a field strength meter some distance away because the minimum SWR does not always coincide with the lowest angle of radiation.

A controversy has been going on for some time as to the merits of a properly constructed coaxial (or colinear coaxial) antenna as compared to a properly adjusted ground plane type, such as the isoplane of folded unipole. In all probability, these antennas are approximately equal when properly adjusted. Theoretically, the multi-skirted coaxial antenna should have a lower angle of radiation, but, since the parasitic elements are out of the main radiation field of the driven element, it is doubtful that full use is made of the additional elements. All in all, either type will be entirely satisfactory for general purpose omni-directional coverage.

A word is in order as to the merits of the other types of antennas discussed. Purposely, this article has presented antennas in order of their physical complexity. The half-wave dipoles, whether center-fed, end-fed, folded or coned, are all capable of good results. The center-fed folded and coned antennas will be less expensive generally than any of the ground plane or coaxial antennas, but are more difficult to mount and usually have a higher angle of radiation than the more complicated antennas.

If the maximum non-directional coverage is required, one of the coaxial or ground plane antennas should be used. These antennas have the economic disadvantage that they must be fed with coaxial cable which is relatively expensive in long runs. Further, in long runs the power losses in coaxial cable on the v.h.f.s becomes considerable.

The second part of this article will cover simple horizontally polarized antennas, and both vertically and horizontally polarized arrays.

INSURANCE FOR AMATEURS

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protection offered to equipment in an automobile may be more limited than in other policies with "away from home" coverage.

Theft Insurance: Theft Insurance protects against Theft, Larceny, Burglary, "Mysterious Disappearance," Vandalism, Malicious Mischief, Robbery, and Damage incurred during attempted robbery. As with all "residence" policies, it covers the property of all members of the household up to the policy limit. For an additional premium the coverage can be extended to anywhere in the Western Hemisphere. A typical "All Protection" Theft policy costs about $18.00 per $1,000.

The easiest way to buy Theft Insurance is in an All Protection policy. However the premium can be reduced by itemizing the property to be insured. A typical list would include your most valuable jewelry, watches and rings, with a value assigned to each piece. Next a lump sum value would be assigned to the less valuable jewelry and table silver, etc., and another lump sum value would be placed on your furniture and radio equipment. These amounts would then be totalled, and 20% or so added to cover damages suffered in an attempted robbery, plus $100.00 for cash on hand, and $500.00 for securities, plus the desired amount of away-from-home protection.

Theft Insurance can be written to cover only your radio equipment. However the premium on an itemized policy covering most of your valuables may cost little more than an all protection policy on only your radio equipment.

Being an amateur does not affect the advisability of carrying Health and Accident, or Life Insurance. The same is true of most automobile insurance; although mobile equipment mounted permanently in an automobile would be considered part of it. And the value of such equipment should be computed in buying applicable insurance.

Certain Inland Marine Companies sell an All Protection Policy on commercial radio towers. It is