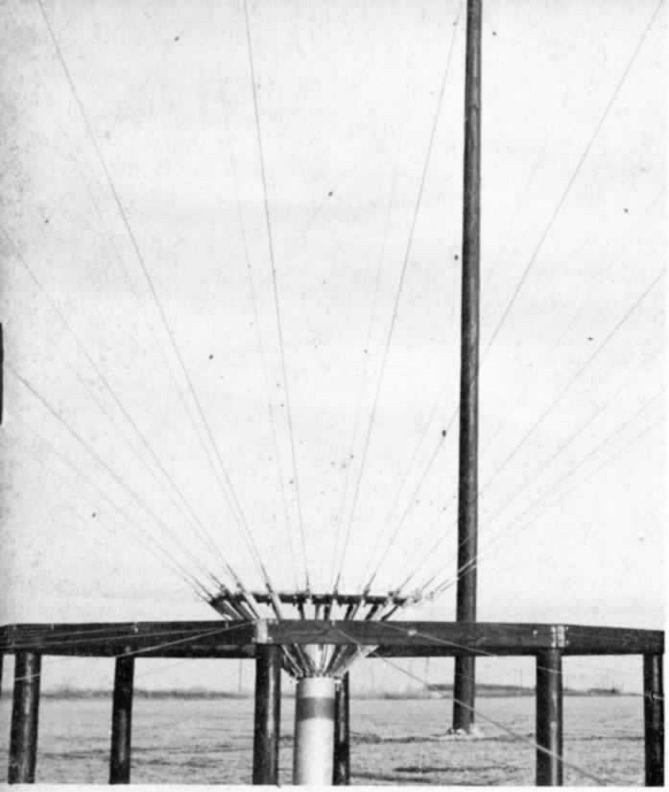
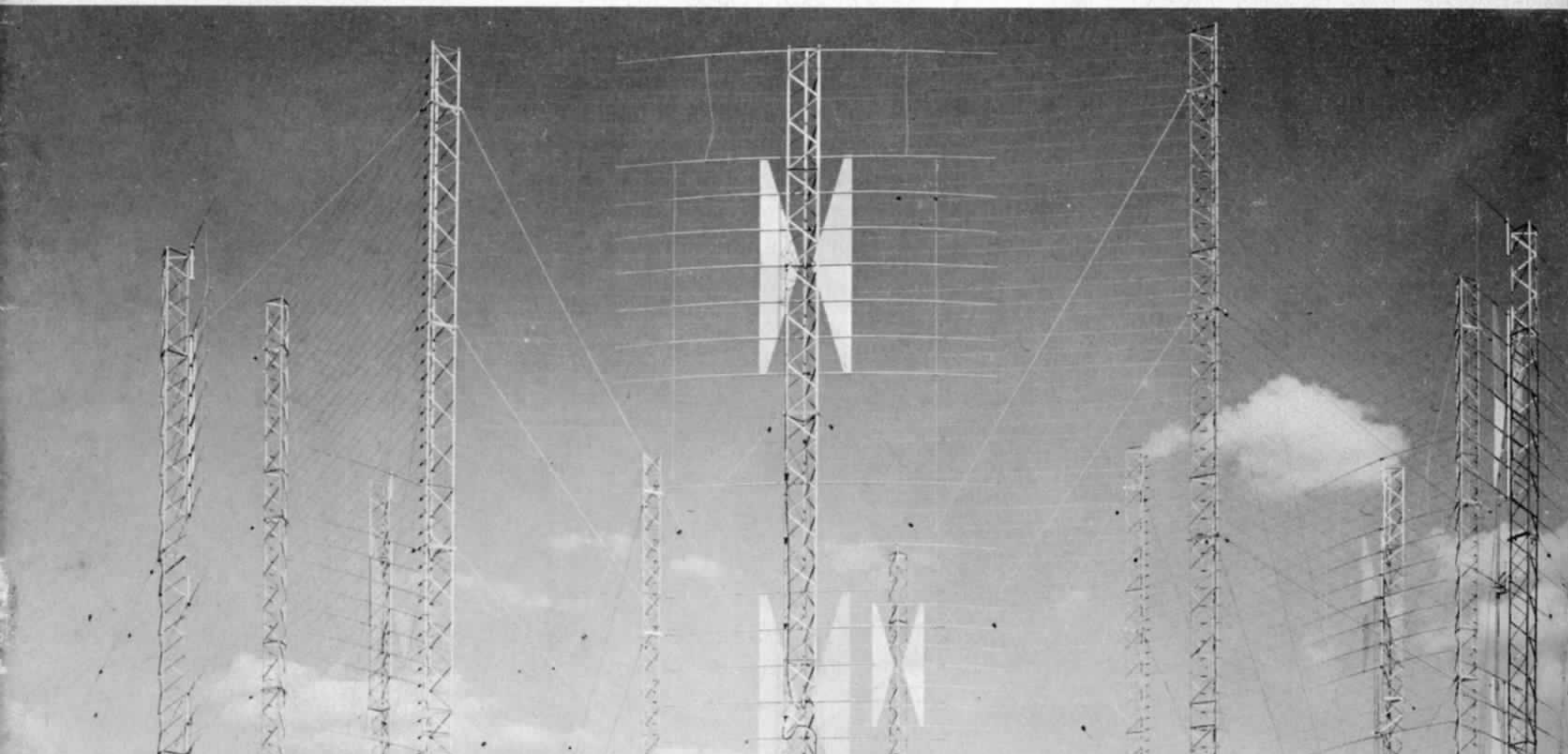


Collins

HIGH-FREQUENCY ANTENNAS



COLLINS RADIO COMPANY

A RESEARCH AND DEVELOPMENT PUBLICATION

COLLINS

CEDAR RAPIDS, IOWA, U.S.A.

261 Madison Ave.
NEW YORK 16

1930 Hi-Line Drive,
DALLAS 7

2700 W. Olive Avenue,
BURBANK

PRINTED IN THE UNITED STATES OF AMERICA

Jack Zuber
Collins Radio Co.
1961

RDP-120A

30 JULY 1959

Collins

HIGH - FREQUENCY ANTENNAS

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INTRODUCTION

The purpose of this publication is to describe some of the more recent high-frequency communications antennas that have been developed and evaluated by the Collins Radio Company. Antennas of the omnidirectional and unidirectional types designed to cover relatively wide frequency ranges are shown and discussed. Each antenna, in most cases, has been designed for a specific circuit application which dictated its electrical and mechanical characteristics. Because the operational requirements vary according to the particular circuit, it is often necessary to custom design the antenna system. This is true, for example, in the design of the antenna feed system where the power handling requirements determine the size and type of transmission line, or in a system where several antennas are employed and a customed-designed switching network is required. The antenna structure itself may require modification to alter its frequency range or directional properties.

In the following sections, the electrical and structural characteristics of various antennas are described. These are typical structures which have, in most cases, been constructed and evaluated on a full-scale basis. In all cases, they have been constructed and evaluated on a scale-model basis. The scaling technique may be used to provide antennas similar to these but designed for operation at different frequencies.

GENERAL DISCUSSION

The success of a radio communications system depends to a large degree upon the characteristics of the propagation medium. In the high-frequency region (2 to 30 megacycles) of the radio spectrum, the characteristics vary widely with time, location, and frequency. Whereas the nature of the transmitter, receiver, and antenna can be controlled within certain economic limits, the nature of the propagation medium must be accepted as it exists. The characteristics of the medium may be at times quite unfavorable. Unless the system parameters are carefully selected and varied with time and with circuit, communications may prove impossible even with a large amount of transmitter power.

The theory of ionospheric propagation is beyond the scope of this text. But in order to select an adequate high-frequency antenna system for a particular application, the nature of propagation via the ionosphere should be understood. The basic theory of ionospheric propagation is adequately covered in reference 1. Information for use in the prediction of high-frequency propagation is published monthly in references 2 and 3. On most fixed circuits, it is possible to choose and vary the system parameters with the aid of these publications so that successful communications may be maintained more than 90 per cent of the time. In some cases, it is generally necessary to have two or more frequencies available, sufficiently separated, for use at different times, and facilities for directing the electromagnetic energy as desired. These requirements depict the need for broadband unidirectional antennas.

To achieve the desired mode or modes of propagation, it is essential that the proper antenna system be employed at both the transmitting and receiving site. Their beams must also be directed at the proper vertical angle for the particular set of conditions. Generally, the vertical angle of departure will be the same as the angle of arrival. To make the best use of this effect, it is desirable to employ complementary antennas at both ends of the circuit or antennas having similar vertical plane directional characteristics.

In selecting an antenna system for a high-frequency communications circuit, absolute gain should not be the primary objective. For propagation via the ionosphere, the antenna's directional characteristics in both principal planes are of greater importance. The antenna system that is designed to utilize the optimum vertical angles and suppress others that contribute to multipath transmission is the most favorable. For long path propagation, vertical angles of 5 to 15 degrees are generally the most desirable (see reference 4). For shorter hop circuits, vertical angles up to 30° are common.

For a radiating system to possess the feature of low angle radiation, large effective vertical apertures are necessary. Consequently, the structures required are relatively high, particularly where horizontal polarization is employed. Low angle radiation is a natural characteristic of vertically polarized radiators. For a specific angle of radiation, the structure required is considerably lower than that for a horizontally polarized antenna. If, for example, a 20° radiation angle is desired from a horizontally polarized antenna operating at 4 mc, the center of the effective aperture itself would have to be about 180 feet above ground. But, the total height of a vertical monopole would not exceed 60 feet for the same vertical angle. The losses due to actual ground with vertical polarization are quite significant, however. These losses become excessive at the upper portion of the high-frequency spectrum. The actual losses due to ground depend to a large degree upon the characteristics of the ground at the antenna site and upon the directional properties of the antenna. For most practical purposes, the ground losses incurred with horizontal polarization can be neglected, and the effect of a perfect ground may be assumed. From the economic standpoint, it is generally more practical to employ horizontal polarization at frequencies where structure heights do not become unreasonable and to tolerate ground effects at the lower frequencies with vertically polarized antennas.

DETAILED ANTENNA DESCRIPTIONS

MONOPOLE BILLBOARD ANTENNA VERTICALLY POLARIZED, 4 TO 10 MC

The 4- to 10-megacycle vertically polarized "billboard" antenna structure, shown in figure 1, employs a broadband monopole radiator with a passive screen reflector. The monopole is base fed about 5 feet above the ground with standard 50-ohm coaxial transmission line. For the antenna to operate as a complete unbalanced system, and to reduce ground losses in the immediate vicinity, each vertical wire in the reflecting curtain is extended into a ground radial as shown. The radials are buried approximately 6 inches below the surface and extend to a minimum of 65 feet. If real estate permits, the losses due to the imperfect ground may be further reduced by lengthening the radials. A length of 125 feet or longer would be highly desirable, particularly for the higher operating frequencies. An extended ground system will also improve the signal strength at the lower angles of radiation.

By employing vertical polarization in this lower frequency region of the h-f spectrum, the desirable low angle of radiation is achieved with relatively low structures. Because of the increase in ground losses with increase in frequency, vertical polarization is not recommended, however, above about 10 mc in antenna systems where high overall performance is desired.

DIRECTIONAL PROPERTIES - With a single vertical radiator backed by a reflecting surface, azimuthal coverage is rather broad. The passive screen, however, provides considerable suppression of backward radiation which results in a high front-to-back ratio. Experimental patterns derived from scale-model work show that with a screen the size of that

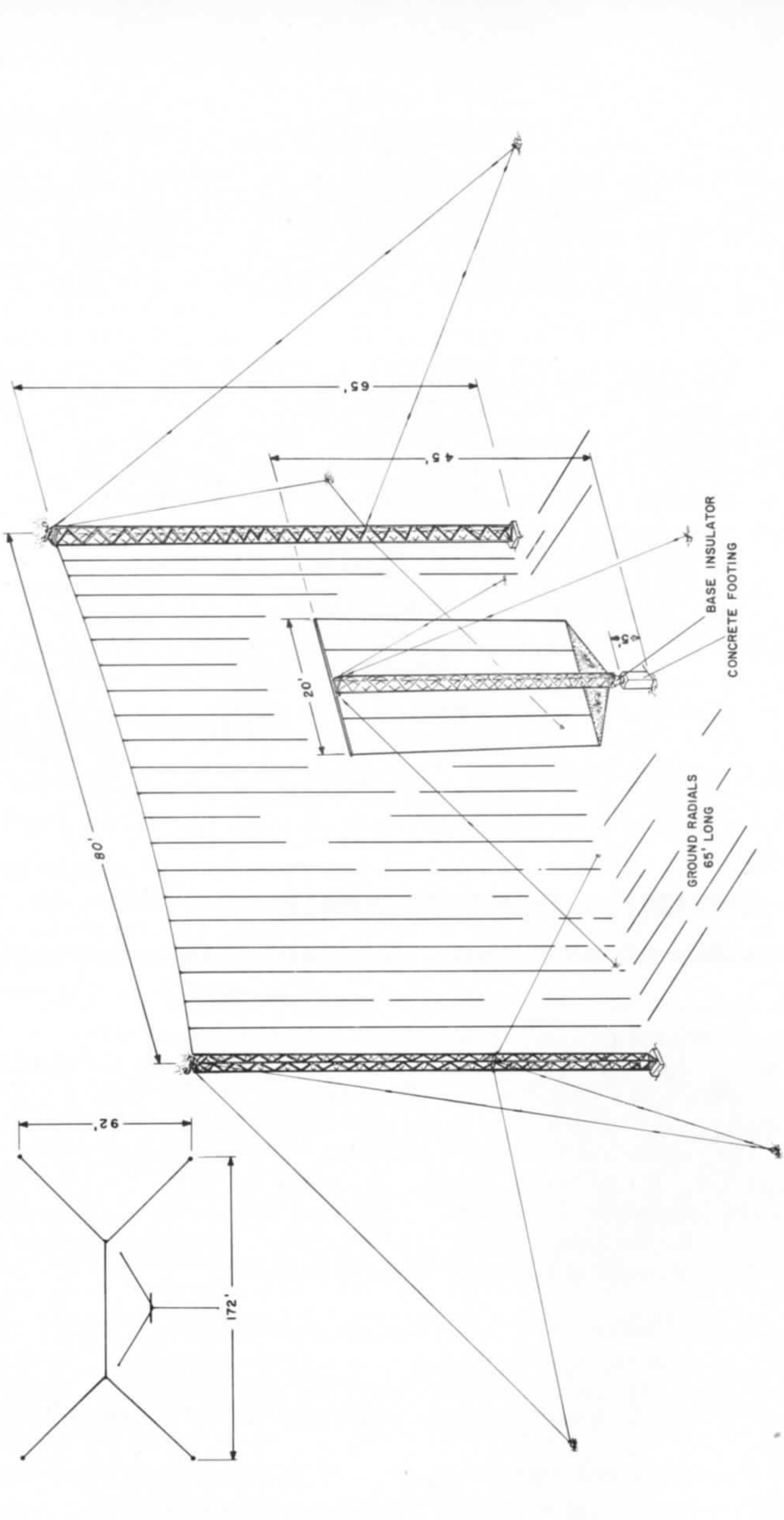

Figure 1. Outline and Dimensions, Monopole Billboard Antenna, 4 to 10 mc.

in figure 1, the f/b ranges from about 18 db to greater than 25 db over the 4- to 10-megacycle range. The f/b is the greatest somewhat above the center of the band and lowest at the two ends. This is due to the size of the screen becoming electrically smaller at the lower frequencies and to the spacing between the wires in the reflecting screen becoming wider at the higher frequencies. The f/b can be further increased by both enlarging the screen and increasing the number of vertical wires per unit length. But for most h-f applications the screen as shown is adequate.

The horizontal plane field intensity (voltage) patterns for the extreme ends of the band are shown in figure 2. These patterns are results of calculations made on the basis of an infinitely large screen and a thin radiator. As evidenced from our scale-model work, these are fair assumptions. The azimuthal half-power beamwidths are seen to range from 95° at 4 mc to 129° at 10 mc. Widening of the azimuthal pattern with increase in frequency is a characteristic of the vertically polarized billboard antenna employing a single radiator. The small back lobe represented by the dashed line indicates the amount of backward radiation measured from the scale model having a reflecting screen the size of that shown in figure 1.

As with most h-f antennas, the directional characteristics in the vertical plane are determined largely by the effect of ground in the vicinity of the antenna. The vertical plane patterns illustrated in figure 3 indicate the antenna's performance over a typical ground at 4 and 10 mc. The ground constants chosen are those of a Nebraska antenna site, with a dielectric constant $\epsilon = 15$ and a conductivity $\sigma = 20 \times 10^{-14}$ emu. The vertical angle of beam maximum will occur at angles slightly lower than those indicated due to the effect of the ground radial system.

INPUT IMPEDANCE AND BANDWIDTH - The antenna is designed to be fed with standard 50-ohm coaxial transmission line, the size dependent on the power handling requirements. The monopole's impedance characteristics are such that the vswr on the 50-ohm line does not exceed 2:1 over the 4- to 10-mc frequency range. In general, the bandwidth of a billboard antenna is determined both by its impedance and pattern characteristics. The lower frequency

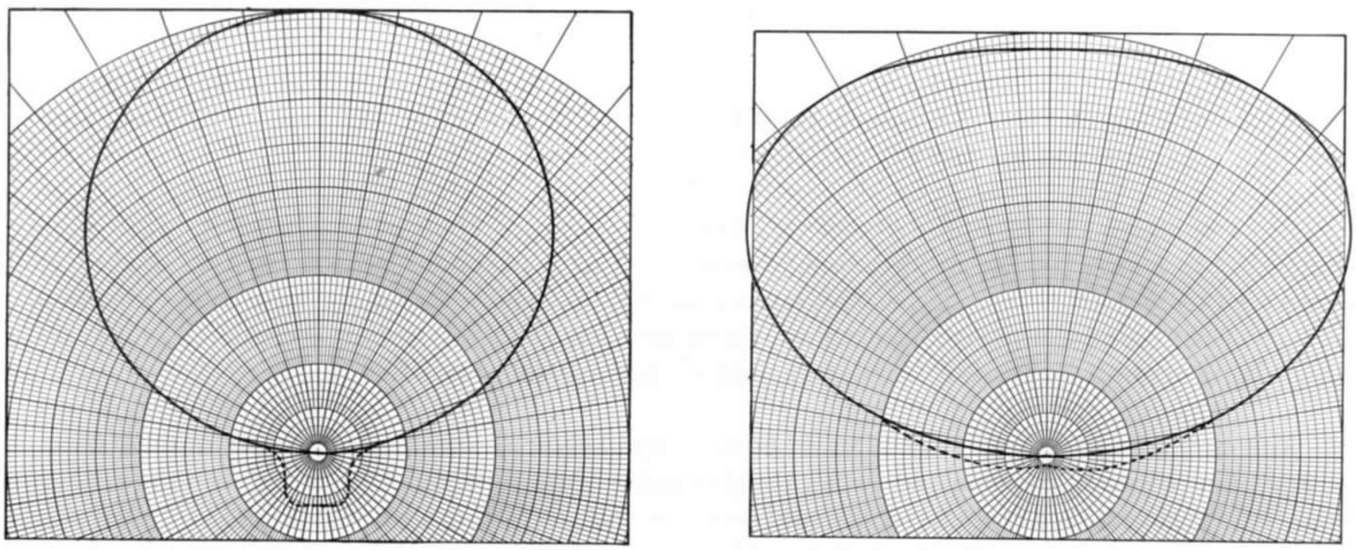

Figure 2. Azimuthal Field Intensity Patterns of 4- to 10-mc Vertically Polarized Monopole Billboard Antenna at (a.) 4 mc and (b.) 10 mc.

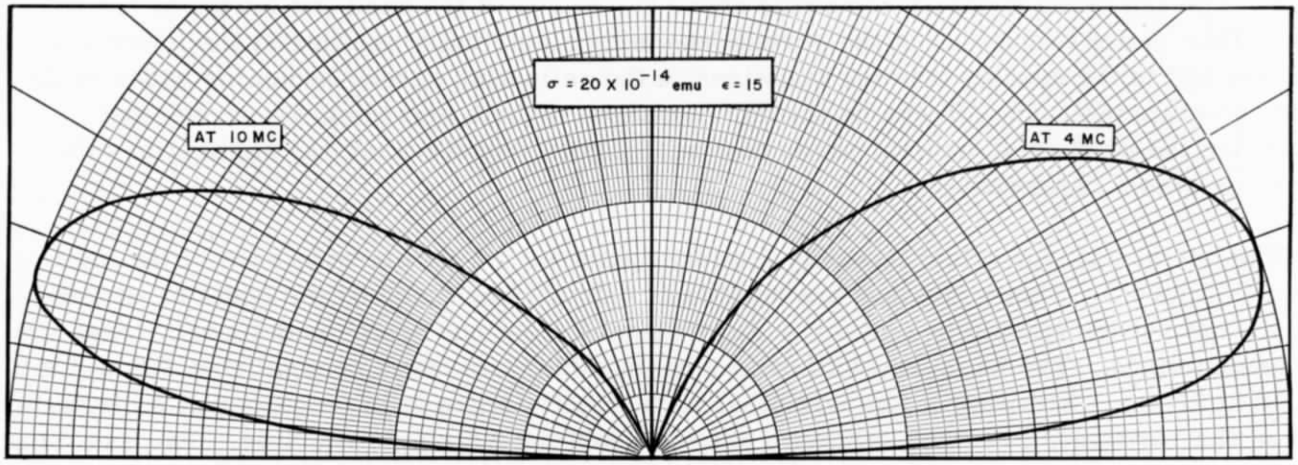

Figure 3. Vertical Plane Field Intensity Patterns of 4- to 10-mc Vertically Polarized Monopole Billboard Antenna Over Typical Ground at (a.) 10 mc and (b.) 4 mc.

is usually limited by the amount of impedance mismatch that can be tolerated, while the upper frequency is limited by pattern deterioration. On the basis of the input impedance remaining satisfactory with a resultant vswr of less than 2:1, the bandwidth here is limited chiefly by that of the antenna's impedance characteristics. For applications where a higher vswr can be tolerated, as in receiving systems for example, the bandwidth may be extended.

GAIN - This structure yields a gain at beam maximum that remains relatively constant over its operating range. With reference to a free space half-wave dipole, the calculated gain ranges from 8.5 to 9 db. These gains, although calculated, are based on analysis of the principal plane radiation patterns. Those in azimuth are experimental and those in elevation are as shown in figure 3.

STRUCTURE - The structure, shown in figure 1, is designed to withstand environmental conditions of 50-mph wind and 1-inch radial ice, 80-mph wind and 1/2" inch radial ice, and 125-mph wind with no ice.

The monopole consists of a structural tower and four vertical wire elements. The wire elements are supported by cross-arms as shown. The 3/16-inch diameter copper coated wires contain extension springs at one end to limit their load. These springs also provide a method of obtaining the proper erection tension by measuring the spring extension. The tower is insulated from its concrete foundation with an appropriate base insulator.

The reflecting screen is made up of equally spaced 3/16-inch diameter galvanized steel wires. The wires are supported by a catenary cable strung between the reflector towers, as indicated, and attached to individual steel earth anchors. From each earth anchor, the wire is extended into a 65-foot ground radial. The ground radial wire is No. 6 soft drawn copper. It is buried a minimum of 6 inches below the surface.

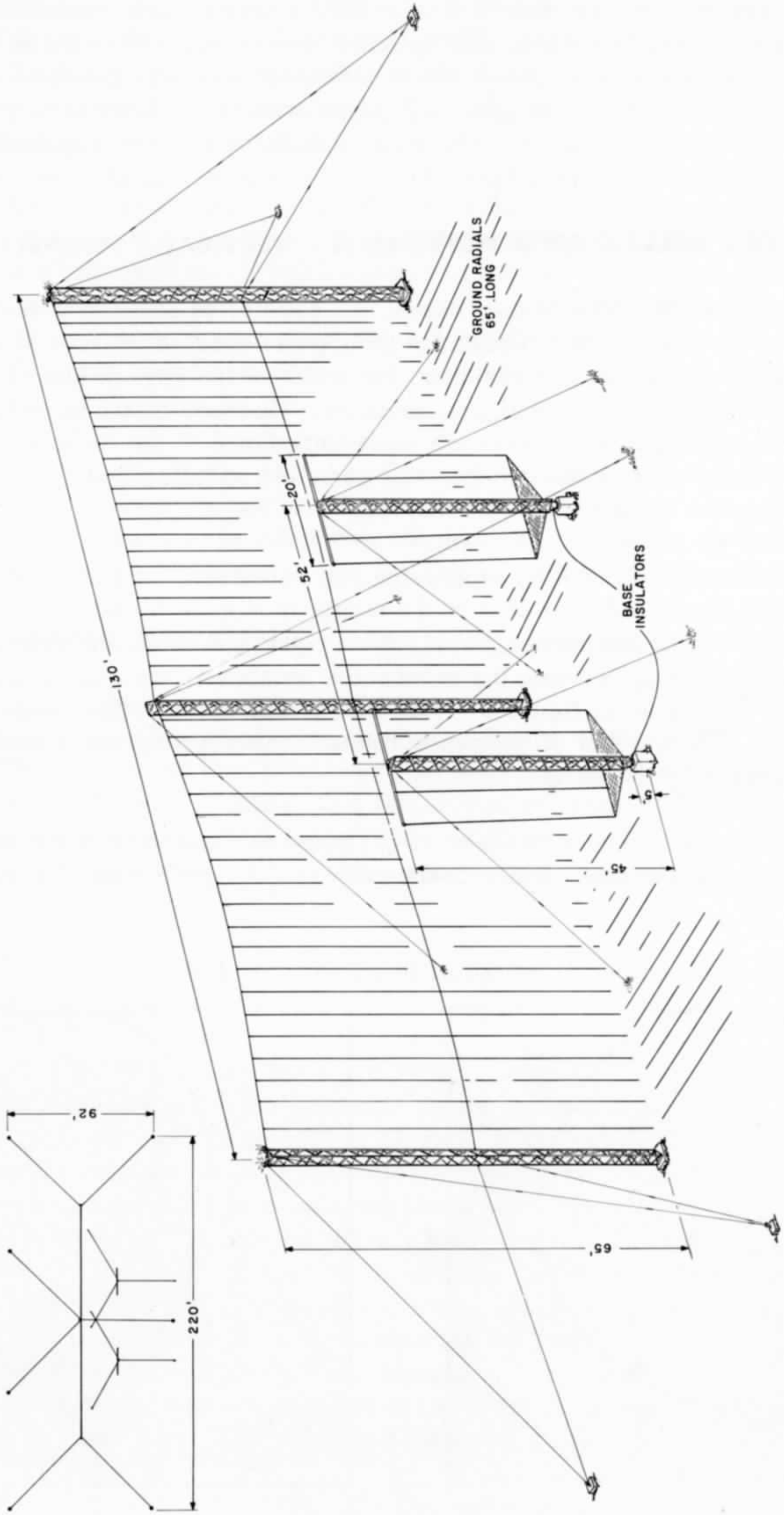

Figure 4. Outline and Dimensions, Dual Monopole Billboard Antenna, 4 to 10 mc.

The 45-foot radiator tower and the 65-foot reflector towers are commercially available triangular sections of galvanized steel. The radiator tower is guyed in three directions at its top to reinforced concrete anchors. Each of the reflector towers is guyed to reinformce concrete anchors from its top and mid-height. All guys forward of the reflecting screen are electrically broken with guy insulators. Obstruction lighting kits are supplied for installations where required. Reinforced concrete bases are used to support all the towers.

DUAL MONOPOLE BILLBOARD ANTENNA VERTICALLY POLARIZED, 4 TO 10 MC

The dual monopole billboard antenna, shown in figure 4, is similar to the monopole billboard but consists of an array of two broadband monopoles located in front of the reflecting screen. To accommodate the second radiator, the width of the screen has also been increased. Both radiators are base fed with coaxial line sections. Characteristic impedances of these sections are tapered from that of the average input impedance of the monopole to approximately 100 ohms. The 100-ohm ends of the two-line sections are paralleled and connected to the main 50-ohm feed line from the transmitter or receiver.

DIRECTIONAL PROPERTIES - By employing two radiators, as indicated, the effective azimuthal aperture is increased over that of the single monopole billboard so that much greater directivity is achieved in the horizontal plane. With equal and in-phase currents fed to each radiator, and with the spacing between the monopoles as shown, the azimuthal field intensity patterns at 4 and 10 mc are as in figure 5. The half-power beamwidths range from 59° at 10 mc to 82° at 4 mc. The amount of backward radiation measured from a scale model of this structure is represented by the dashed line.

The directional characteristics in the vertical plane are essentially the same as for the single monopole billboard antenna. Refer to the patterns of figure 3 and the accompanying discussion.

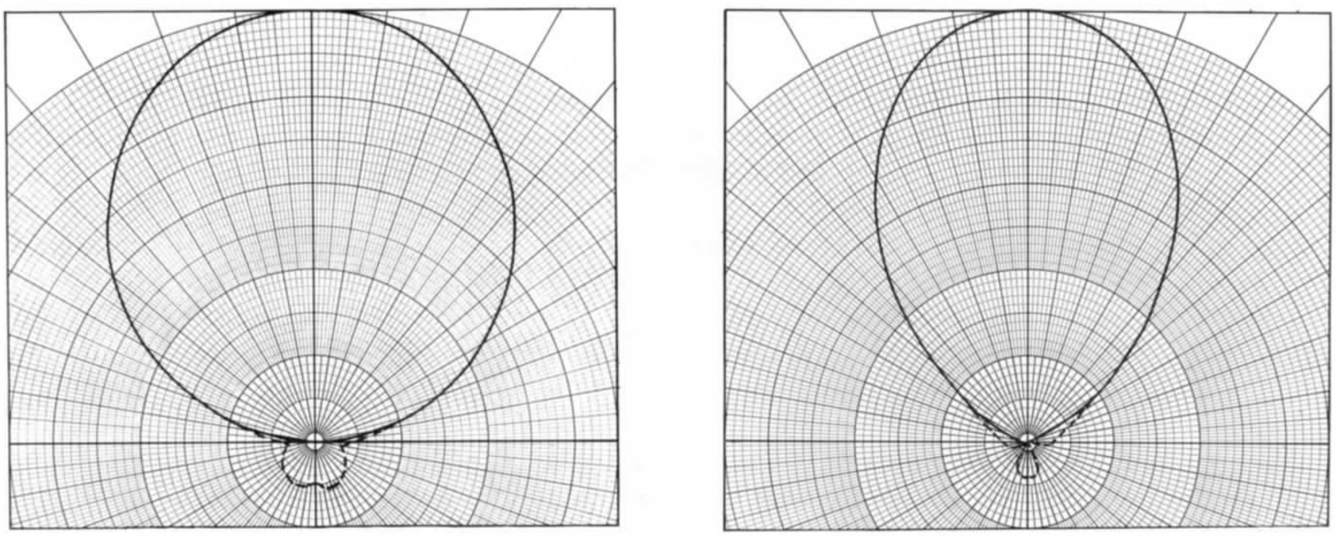

Figure 5. Azimuthal Field Intensity Patterns of 4- to 10-mc Vertically Polarized Dual Monopole Billboard Antenna at (a.) 4 mc and (b.) 10 mc.

INPUT IMPEDANCE AND BANDWIDTH - On the basis of the vswr remaining under 2:1 on the 50-ohm feed line, the monopoles maintain satisfactory impedance properties over the 4- to 10-mc band. Each monopole is fed with a section of impedance-tapered coaxial line designed to match the base impedance of the monopole to an impedance of about 100 ohms. The size of cable employed depends upon the application.

GAIN - The gain at beam maximum, relative to that of a free space, half-wave dipole, ranges from 9.5 db at 4 mc to 12 db at 10 mc. The total gain is several db greater than from the single monopole billboard due to the increase in effective azimuthal aperture. The azimuthal directivity gain can be further increased by increasing the spacing between the two radiators. This is true up to a spacing of about 85 feet where significant azimuthal side lobes appear. This, of course, would require a correspondingly wider screen and additional real estate.

STRUCTURE - The structure, shown in figure 4, is similar to that of the monopole billboard antenna. A third tower is employed in the center, however, to provide support for the 130-foot screen. The structure is otherwise mechanically the same as that of the monopole billboard antenna.

DIPOLE BILLBOARD ANTENNA VERTICALLY POLARIZED, 4 TO 10 MC

The 4-10 mc dipole billboard antenna, shown in figure 6, is another structure similar to the monopole billboard, except that a full vertical dipole is used as the radiating element. The increased radiator height also requires that the screen be made higher. The dipole is fed at its center as a balanced system from a parallel conductor type balun. The balun contains a section of an impedance-tapered coaxial line so the antenna may be operated from standard 50-ohm coaxial transmission.

Antenna performance at the lower angles of radiation is improved by using a dipole as the radiator rather than a monopole.

DIRECTIONAL PROPERTIES - But for a small change in the amount of back radiation, the azimuthal field intensity patterns, shown in figure 2, also apply here. The half-power beamwidths vary from 95° at 4 mc to 129° at 10 mc. In the vertical plane, however, there is a marked difference in the directional characteristics. Vertical plane patterns for the dipole billboard are shown in figure 7. In comparing these with figure 3, the improvement in lower angle radiation is apparent. The comparatively high magnitude secondary lobe appearing at 10 mc is due chiefly to the effect of ground in reducing the relative field intensity at extremely low angles. The effect of actual ground on vertically polarized antennas operating in this region of the h-f spectrum can be seen by comparing the pattern of figure 7b to that of figure 8, where for the latter case perfect ground was assumed. To install a ground system to simulate that of a perfect ground would be impractical at these frequencies. The partial ground system that is included with these vertically polarized structures does offer some improvement, however.

INPUT IMPEDANCE AND BANDWIDTH - The average input impedance of the dipole over the 4- to 10-mc range is approximately 90 ohms. This 90-ohm balanced load is matched to the 50-ohm unbalanced line by a balun which also incorporates an impedance taper. The resultant vswr on the 50-ohm line does not exceed 2:1 throughout the 4- to 10-mc operating range.

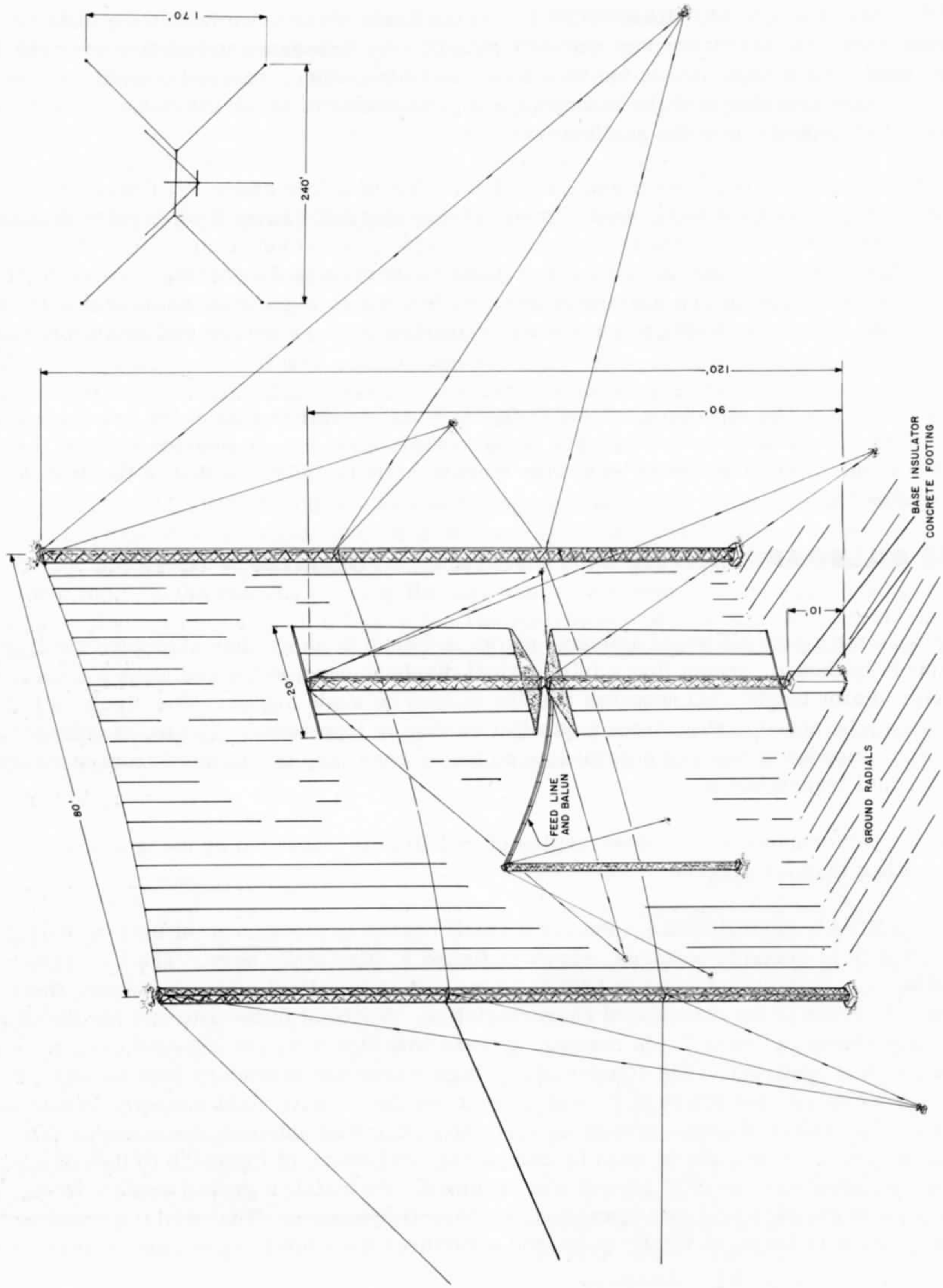

Figure 6. Outline and Dimensions, Dipole Billboard Antenna, 4 to 10 mc.

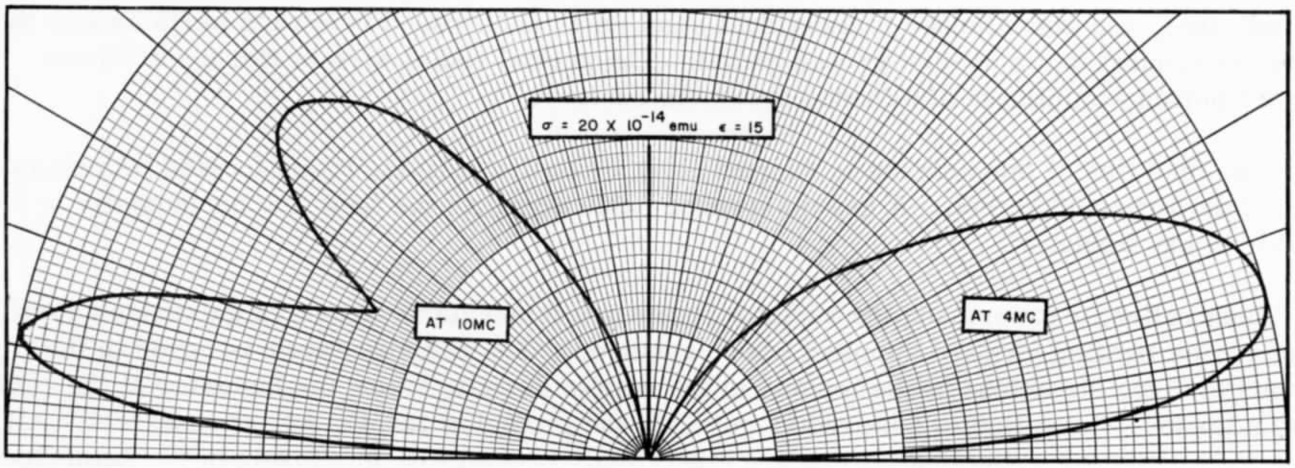

Figure 7. Vertical Plane Field Intensity Patterns of 4- to 10-mc Vertically Polarized Dipole Billboard Antenna Over Typical Ground at (a.) 10 mc and (b.) 4 mc.

GAIN - The gain for this structure, with reference to a free space, half-wave dipole, ranges from 8.5 db at 10 mc to 9.8 db at 4 mc. In comparing this total gain to that of the monopole billboard, it will be noticed that the difference is not too significant. These gains, however, are maximum gains which occur at angles of azimuth and elevation where the magnitude of the beam is maximum. When comparing the gains of two or more antennas, the comparison should be made to the same directional angles. This is particularly important for antennas operating in the h-f region where low angle radiation is most often desired. By referring to the vertical plane patterns, figures 3 and 7, it is apparent that the field intensity is significantly greater for the dipole billboard than for the monopole billboard at, for example, a 5° elevation angle.

STRUCTURE - The structure, shown in figure 6, is designed to withstand environmental conditions of 50-mph wind and 1-inch radial ice, 80-mph wind and 1/2-inch radial ice, and 125-mph wind with no ice.

The dipole consists of a structural tower and vertical wire elements supported by cross-arms. The 3/16-inch diameter copper coated wires contain springs at one end to limit their load. These springs also provide a method of obtaining the proper erection tension by measuring the spring extension. The tower is insulated at the center of the dipole, and from its concrete foundation, with appropriate insulators.

The reflecting screen is made up of equally spaced 3/16-inch diameter galvanized

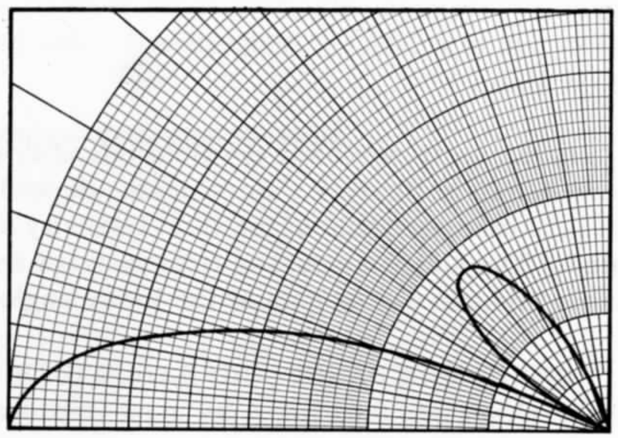

Figure 8. Vertical Plane Field Intensity Pattern of 4-mc to 10-mc Vertically Polarized Dipole Billboard Antenna at 10 mc Over Perfect Ground.

steel wires. The wires are supported by a catenary cable strung between the reflector towers as indicated, and are attached to individual steel earth anchors. From each earth anchor the wire is extended into a 65-foot ground radial. The ground radial wire is No. 6 soft drawn copper buried a minimum of 6 inches below the surface.

The feed line of this antenna is supported by a small triangular tower located immediately behind the reflector screen. A guy messenger cable supports the feed line horizontally to the center of the dipole.

Both reflector towers and the radiator tower are triangular sections of galvanized steel. Obstruction lighting kits are supplied where required. The radiator tower is guyed to the ground in three directions at the top and in the middle directly below the insulator at the center of the dipole. The reflector towers are guyed to the ground at the 40, 80, and 120 feet. All guys forward of the reflecting screen are electrically broken with guy insulators. Reinforced concrete guy anchors and tower foundations are used throughout.

DUAL DIPOLE BILLBOARD ANTENNA — VERTICALLY POLARIZED, 4 TO 10 MC

The dual dipole billboard antenna for 4- to 10-mc operation, shown in figure 9, employs an array of two broadband vertical dipoles. Except for the wider screen, the structure is similar to that of the single dipole billboard antenna. The dual dipole antenna is recommended for applications where greater azimuthal directivity at very low angles of radiation is required.

The two dipoles are center fed as a balanced load, each with its own balun. The unbalanced ends of the two baluns are of the proper impedance so that when paralleled a standard 50-ohm coaxial input is provided.

DIRECTIONAL PROPERTIES - With the dipole spacing indicated in figure 9 and with each fed equal and in-phase currents, the azimuthal patterns will be essentially those shown in figure 5. Experimental data shows a small difference in the back lobe characteristic, but this difference is relatively insignificant. The half-power beamwidths vary from 59° at 10 mc to 82° at 4 mc.

In the vertical plane, the field intensity patterns over actual ground at 4 and 10 mc will be those shown in figure 7. Here again, depending upon the length of the ground system employed, the relative magnitude of the field intensity at the lower angles will be greater than that indicated. The actual amount of improvement from a partial ground system in decreasing ground losses and increasing gain at the lower angle is difficult to predict.

INPUT IMPEDANCE AND BANDWIDTH - On the basis of the vswr not exceeding 2:1 on the 50-ohm main feed line, the input impedance of the two dipoles remains satisfactory over the 4- to 10-mc operating band.

GAIN - Relative to a half-wave dipole in free space, the calculated gain at beam maximum ranges from 10.5 db at 4 mc to 11.8 db at 10 mc. Here, as with the single dipole billboard antenna, gains must be compared at specific elevation angles in order to realize the improvement in gain at the lower angles with the higher antenna structures.

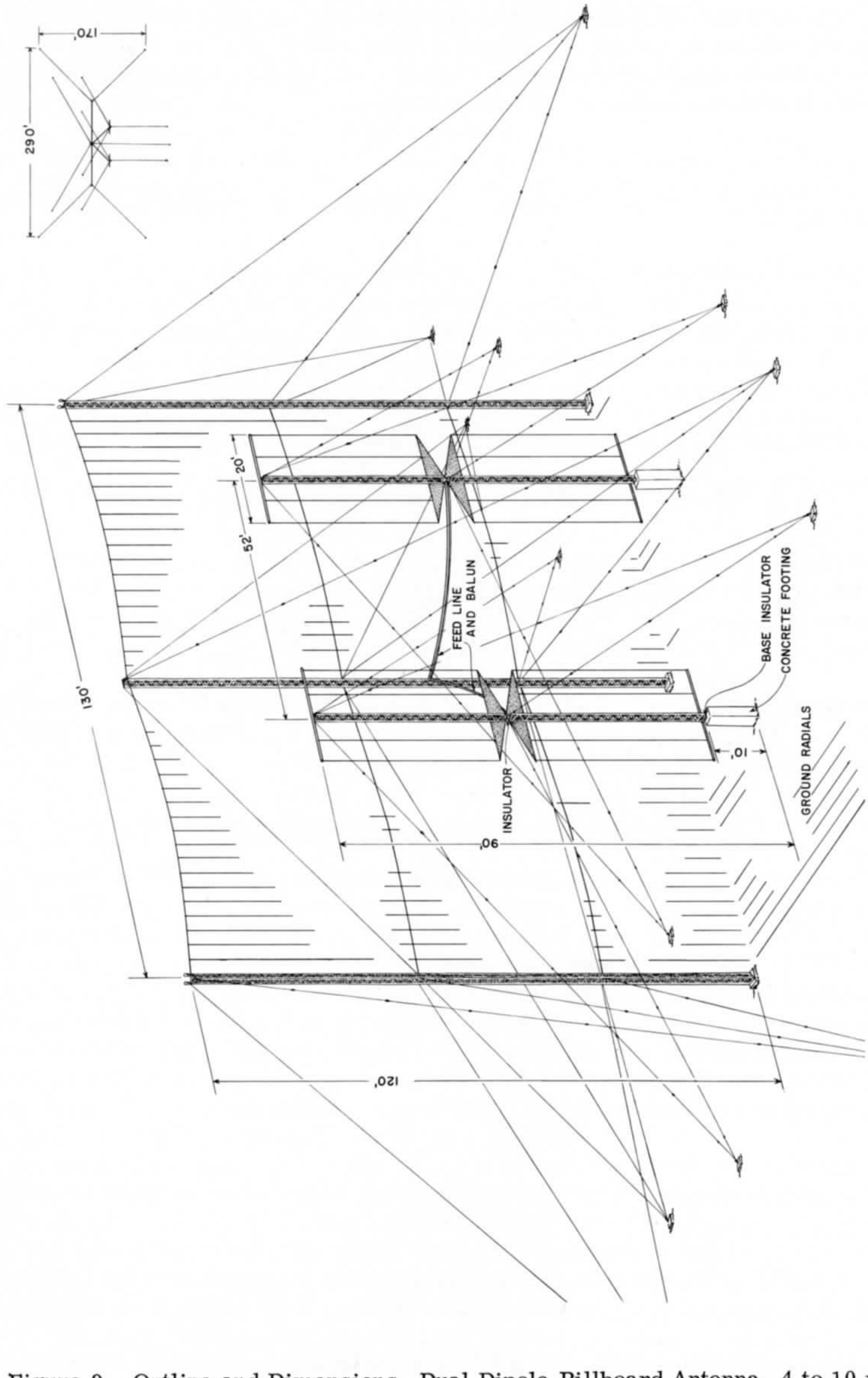

Figure 9. Outline and Dimensions, Dual Dipole Billboard Antenna, 4 to 10 mc.

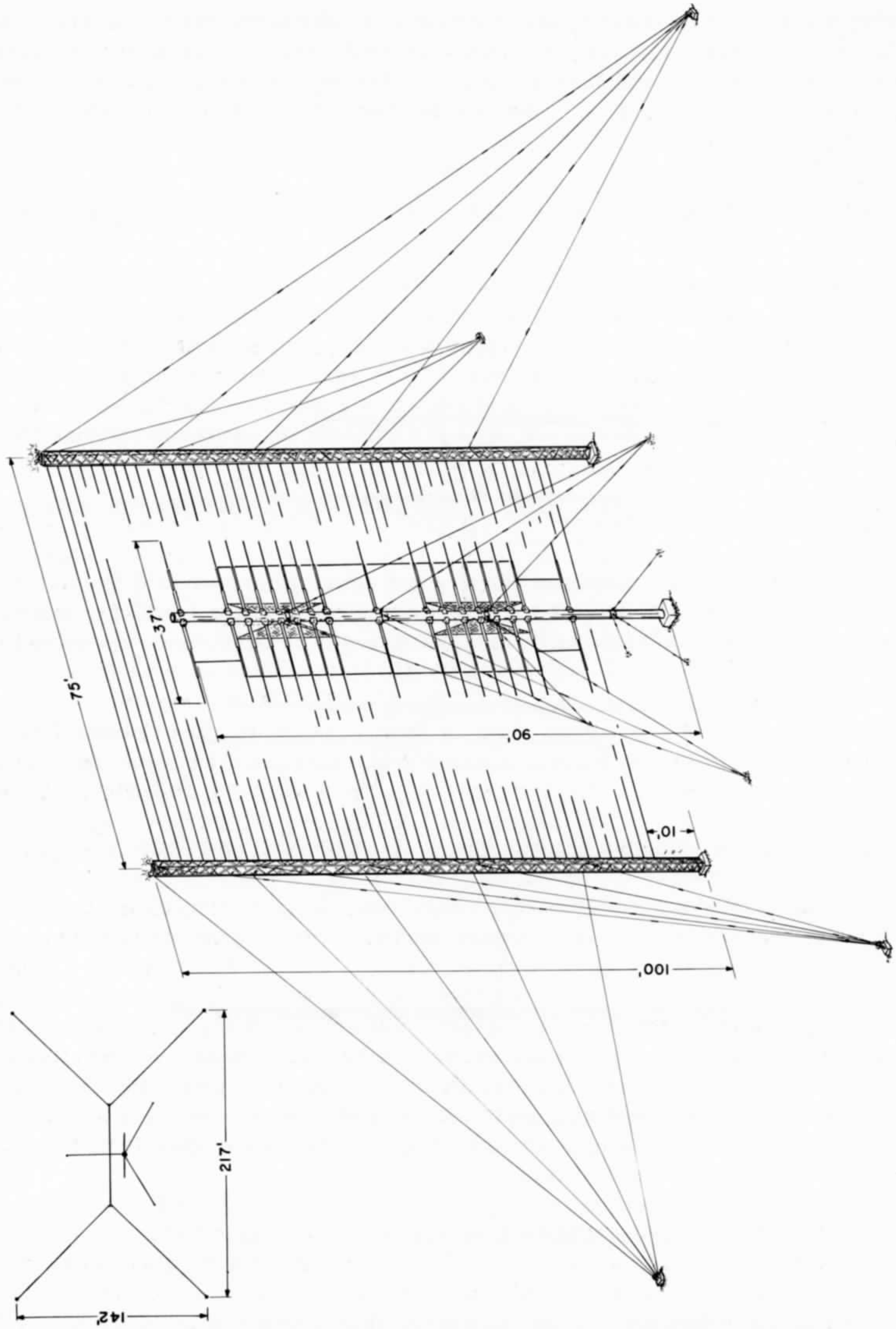

Figure 10. Outline and Dimensions, Horizontally Polarized Dual Dipole Billboard Antenna 237F-1, 9 to 27 mc.

STRUCTURE - The structure, shown in figure 9, is similar to that of the dipole billboard antenna. A third tower is employed to provide support for the 130-foot wide reflecting screen. This tower also supports the feed lines to the two radiators. Messenger cables support the feed lines horizontally to the centers of the dipoles. The structure is otherwise mechanically the same as that of the single dipole billboard antenna.

DUAL DIPOLE BILLBOARD ANTENNA HORIZONTALLY POLARIZED, 9 TO 27 MC

The horizontally polarized billboard antenna for 9- to 27-mc operation, shown in figure 10, employs a radiator in front of a passive reflecting screen. The radiator consists of two vertically stacked broadband dipoles that simulate a continuous current sheet. The current sheet is fed as a balanced system at the dipole centers by two separate baluns. The two unbalanced ends of the baluns are of the proper input impedance so that they will match directly into standard 50-ohm coaxial line when paralleled. The size of the coaxial transmission line is dependent chiefly on the power handling requirements of the antenna.

DIRECTIONAL PROPERTIES - One of the features of the horizontally polarized billboard antenna is its relatively constant azimuthal directional properties. The half-power beamwidth remains within ±5° of about 60° over its operating range and below. This, together with the small amount of backward radiation, is evident from the experimental field intensity (voltage) patterns shown in figure 11. These are polar recordings measured on a scale model of the structure.

The vertical plane field intensity patterns at 10 and 25 mc are illustrated in figure 12. For the structure illustrated, the vertical angle of beam maximum ranges from 8° at 27 mc to 24° at 9 mc. Since the angle of radiation is chiefly a function of antenna height, the angle at which beam maximum occurs can be lowered with an increase in radiator height. For long path propagation circuits, an additional overall height of 20 to 40 feet may be desirable.

The directional properties, particularly in azimuth, remain satisfactory down to frequencies where the width of the reflecting screen becomes comparable to a half wavelength. For the structure with dimensions as in figure 10, this is about 7 mc. At this frequency, the pattern in the vertical plane becomes rather broad with beam maximum occurring at an elevation angle of about 38°. An angle such as this is desirable for relatively short hop propagation. The half-power beamwidth in azimuth at 7 mc remains at about 60° with a backward radiation as indicated in figure 11a. The upper frequency limit is a function of the screen-to-radiator spacing and also the spacing between the horizontal wires which constitute the reflecting screen. Scale model measurements indicate satisfactory azimuthal directivity up to about 29 mc where the pattern begins to show a slight dip in the forward direction.

INPUT IMPEDANCE AND BANDWIDTH - Each of the two dipoles has an average input impedance of approximately 100 ohms. The two baluns which feed the dipoles are designed so that they will have a single 50-ohm coaxial input when paralleled. On the basis of the vswr on the 50-ohm line not exceeding 2:1, the impedance characteristics are satisfactory from 9 to 27 mc. Up to 28 mc and down to 8.8 mc, the maximum vswr is 2.5:1.

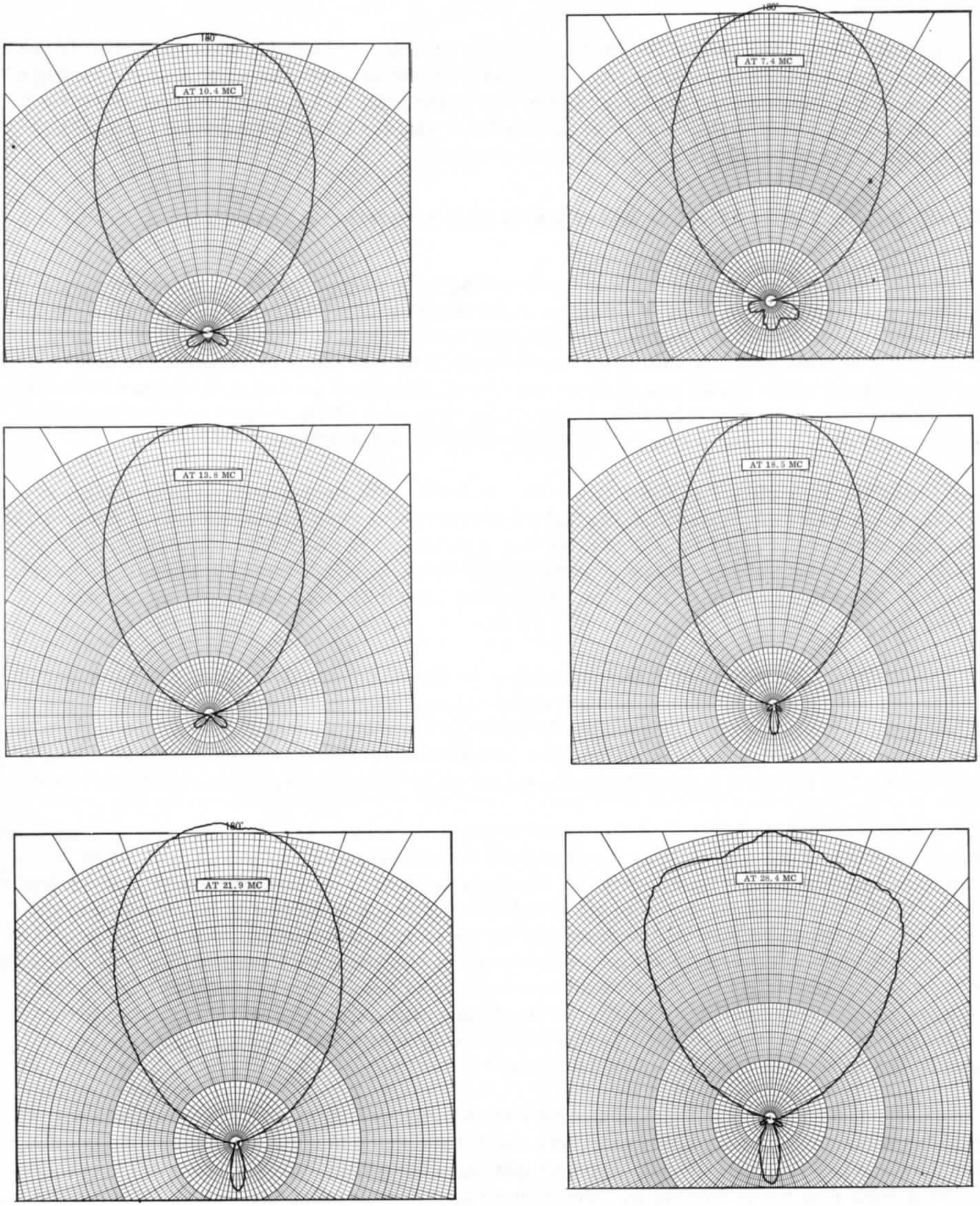

Figure 11. Experimental Azimuthal Field Intensity Patterns Taken on Scale Model of Horizontally Polarized Billboard Antenna at (a.) 7.4 mc, (b.) 10.4 mc, (c.) 13.8 mc, (d.) 18.5 mc, (e.) 21.9 mc, and (f.) 28.4 mc.

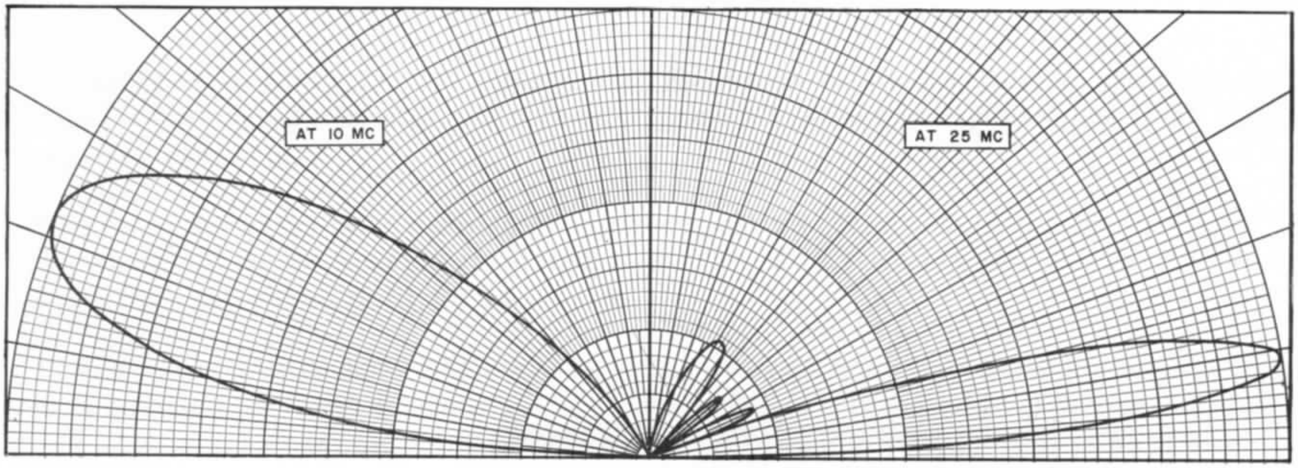

Figure 12. Vertical Plane Field Intensity Patterns of 10- to 25-mc Horizontally Polarized Dual Dipole Billboard Antenna at (a.) 10 mc and (b.) 25 mc.

GAIN - Antenna gains based on analysis of experimental azimuthal patterns and theoretical elevation plane patterns range from 12.1 db at 9 mc to 15.7 db at 27 mc. This is with reference to a free space, half-wave dipole and includes the effect of ground.

STRUCTURE - The 237F-1 antenna is a rugged structure designed to withstand the following wind and ice conditions: 125-mph winds with no ice, 80-mph winds with 1/2-inch of radial ice or 50-mph winds with 1-inch of radial ice.

The horizontal elements in the radiator are constructed of galvanized tubular steel sections. Each element is self-supporting and is mounted to the steel support column by structural stand-off insulators. The screen reflector is made up of equally spaced wires strung between two guyed towers. Each wire contains an extension spring at one end to limit the load. The towers are constructed of triangular sections of galvanized steel and guyed at 20-foot intervals to reinforced concrete ground anchors. All guys forward of the screen reflector are electrically broken with guy insulators. Reinforced concrete foundations are employed to support the column and towers. Obstruction lighting kits are available for installations where required.

DIPOLE BILLBOARD ANTENNA HORIZONTALLY POLARIZED, 10 TO 25 MC

The horizontally polarized dipole billboard antenna for 10- to 25-mc operation, shown in figure 13, is similar to the dual dipole billboard antenna, figure 10, but is of less overall height. It is intended for installations where the height of the structure is limited and where somewhat less vertical directivity is required. The current sheet consists of a single broadband dipole with a balanced feed at its center. The antenna and balun are designed to be fed with standard 50-ohm coaxial line.

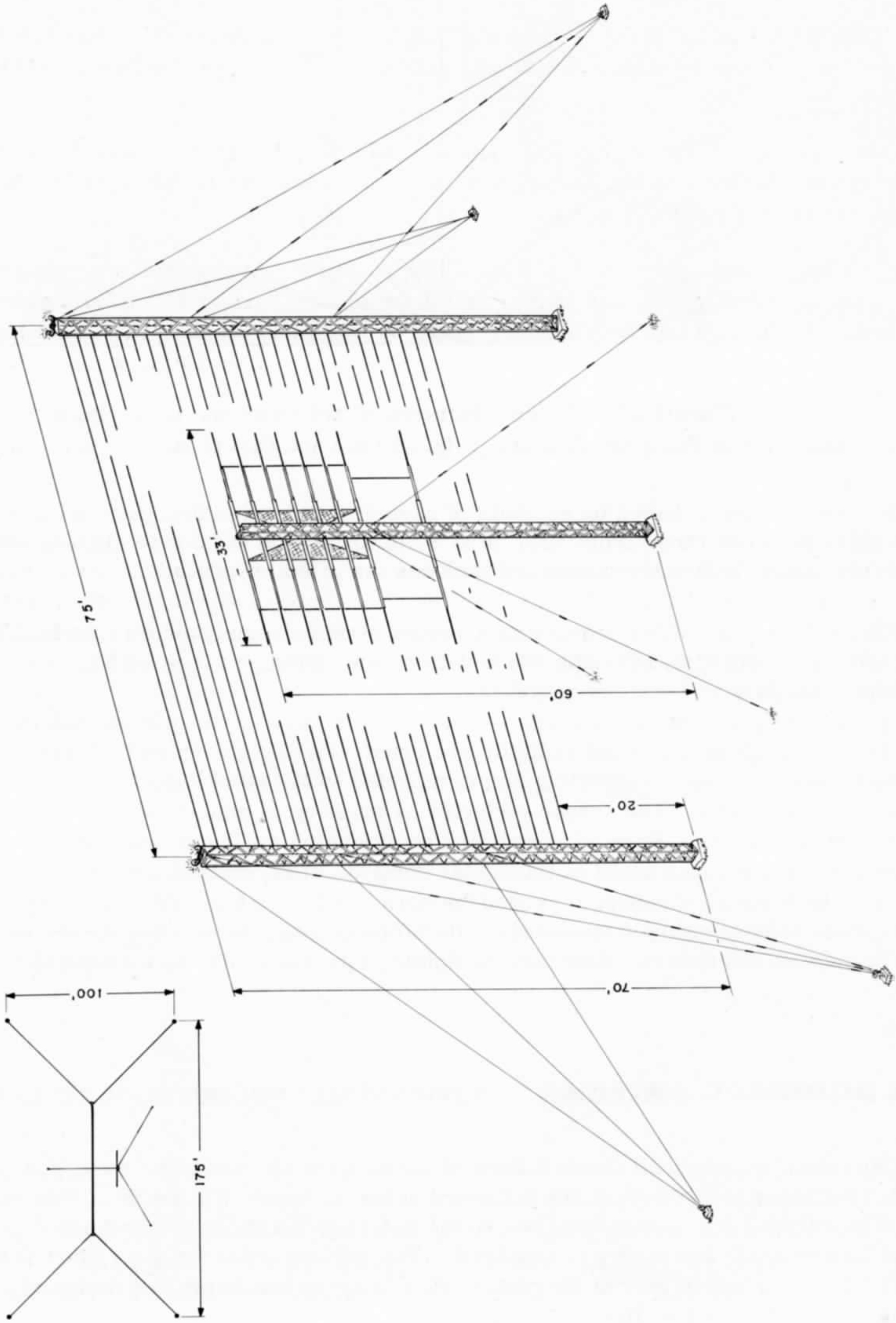

Figure 13. Outline and Dimensions, Horizontally Polarized Dipole Billboard Antenna, 10 to 25 mc.

DIRECTIONAL PROPERTIES - The directional properties in the azimuth plane are the same as for the dual dipole billboard antenna, figure 10. The experimental patterns, shown in figure 11, also apply.

The lower structure with decreased vertical aperture exhibits less directivity in the vertical plane than did the antenna shown in figure 10. The field intensity patterns in this plane at 10- and 25-mc are shown in figure 14.

INPUT IMPEDANCE AND BANDWIDTH - The average input impedance of the broadband dipole is adjusted for about 50 ohms. The dipole is fed as a balanced load through a balun having a standard 50-ohm input. The vswr on the 50-ohm line remains under 2:1 over the 10- to 25-mc band. For operation at frequencies below the normal operating range of the antenna, a tuning unit is available.

GAIN - The antenna yields a gain relative to a free space, half-wave dipole ranging from 11.6 db at 10 mc to 12.9 db at 25 mc.

STRUCTURE - The structure, illustrated in figure 13, is similar to the horizontally polarized dual dipole billboard antenna. The towers are reduced in height, however, and have fewer elements in the radiator. The lower end of the screen is at a height of 20 feet. The radiator tower is guyed in three directions from the 40-foot height to the ground. The reflector towers are guyed to the ground at 30, 50, and 70-foot heights.

The structure is otherwise mechanically the same as that of the antenna shown in figure 10.

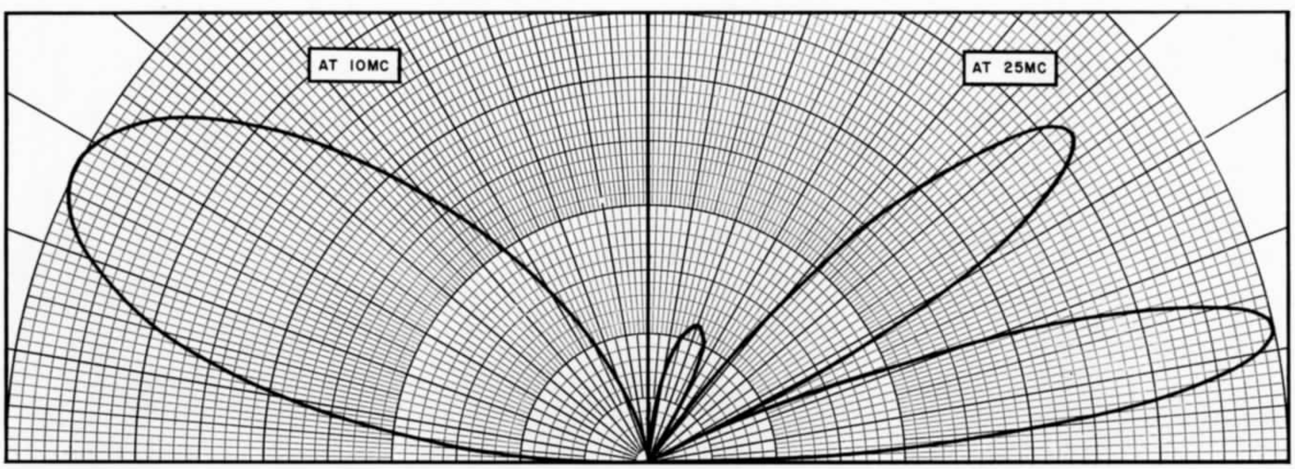

Figure 14. Vertical Plane Field Intensity Patterns of 10- to 25-mc Horizontally Polarized Dipole Billboard Antenna at (a.) 10 mc and (b.) 25 mc.

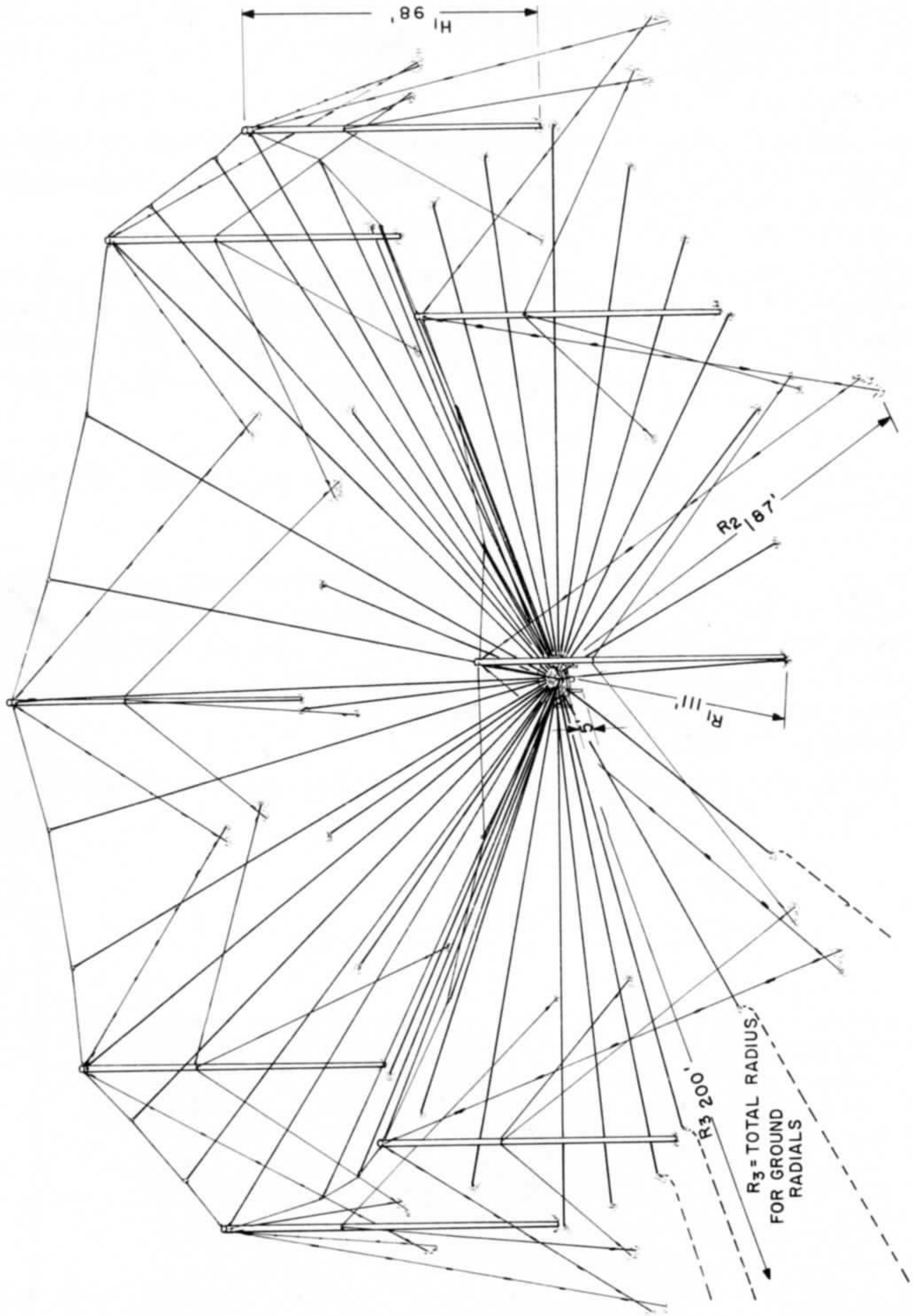

Figure 15. Outline and Dimensions, Inverted Discone Antenna, 2 to 11 mc.

INVERTED DISCONE ANTENNA 2 TO 11 MC

The inverted discone type radiator designed for 2- to 11-mc operation is illustrated in figures 15 and 16. The discone antenna is intended for use primarily where performance similar to that of a vertical dipole is desired but over a considerably wider frequency range.

The cone of this structure consists of wire elements supported by a messenger cable which is strung between eight wooden poles. The ground radials which constitute the disk, or hat, run from an elevated platform at the center of the hat to the ground at a gradual taper. The antenna is fed unbalanced at the top of the five-foot high platform with standard 50-ohm coaxial transmission line.

For installations not requiring operation at frequencies as low as 2 mc, the structure may be reduced in size accordingly. The heights required for 3- and 4-mc coverage are indicated in figure 15.

Figure 16. Typical Installation of a 2- to 11-mc Inverted Discone Antenna.

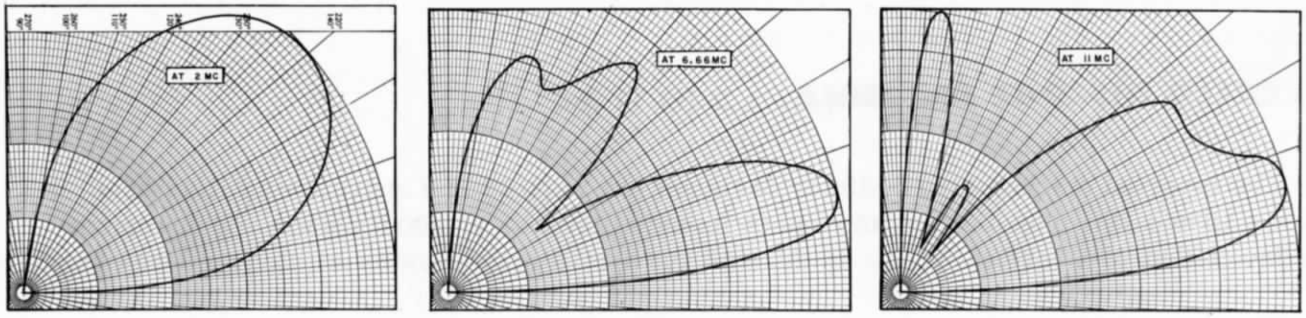

Figure 17. Vertical Plane Field Intensity Patterns of 2- to 11-mc Inverted Discone Antenna Over Typical Ground at (a.) 2 mc, (b.) 6.66 mc, and (c.) 11 mc.

DIRECTIONAL PROPERTIES - Azimuthal coverage is essentially omnidirectional from 2 through 11 mc. Scale model investigation into the effect of the octagonally shaped cone indicates that the pattern remains omnidirectional to within ±0.5 db over this frequency range. The directional performance in the vertical plane depends to a large extent upon the characteristics of the ground in the vicinity of the antenna. Figure 17 shows the vertical plane directivity at several representative frequencies over a ground with a dielectric constant $\epsilon = 10$ and a conductivity $\sigma = 5 \times 10^{-14}$ emu. These field intensity (voltage) patterns are derived by applying a ground factor to free space patterns measured on a scale model.

INPUT IMPEDANCE AND BANDWIDTH - The average input impedance of the inverted discone from 2 through 11 mc is approximately 50 ohms. The vswr on the 50-ohm line does not exceed 2:1 over this frequency band. On the basis of the input impedance remaining satisfactory, the antenna may be operated at frequencies well above the 11-mc limit. Beyond about 11 mc, however, the patterns in the vertical plane deteriorate quite rapidly, resulting in a large number of high angle secondary lobes.

GAIN - The gain is comparable to that of a vertical half-wave dipole at the same height above ground.

STRUCTURE - The structure, shown in figure 15, consists of a cone of wire elements centered over a screen of ground radials. The structure is designed to withstand environmental conditions of 50-mph wind and 1-inch radial ice, 80-mph wind and 1/2-inch radial ice, and 125-mph wind with no ice. The structure is shown with dimensions for 2- to 11-mc operation. Dimensions for higher frequency bands are also indicated.

Eight 110-foot wood poles, equally spaced on a 111-foot radius, are used to support 24 cone wires. These wires are copper coated and are 3/16-inch in diameter. Eight of the wires are attached directly to the poles. The remaining 16 are supported from catenary cables strung between the tops of the poles. The cone has a nominal included angle of 100 degrees. The apex, and feed point, of the inverted cone is 5 feet above the ground. It is supported on a steel pipe that is anchored in a reinforced concrete footing. This foundation is designed to resist the uplift from the tension in the cone wires, in addition to providing the required shear resistance. The feed line for the antenna is brought up the inside of the steel pipe, which is 10 inches in diameter.

A lightly creosoted wood framework, 15 feet in diameter and also 5 feet high, supports 48 equally spaced ground wires that are anchored to concrete anchors placed on a 116-foot radial distance. These wires are copper coated and are 3/16-inch in diameter. From each concrete anchor, a No. 6 soft drawn copper wire is extended at a depth of 6 inches below the surface on a radial line for an additional distance of 84 feet.

The wood poles used are creosoted Douglas fir, Class 2 size. These poles are 110-feet long and are set approximately 12 feet deep in the ground. In addition to the wire element and the support catenaries at the top of each pole, there are two guys to the ground. Each pole is also guyed at its 60-foot height. All guys are attached to steel earth anchors and are broken electrically with guy insulators.

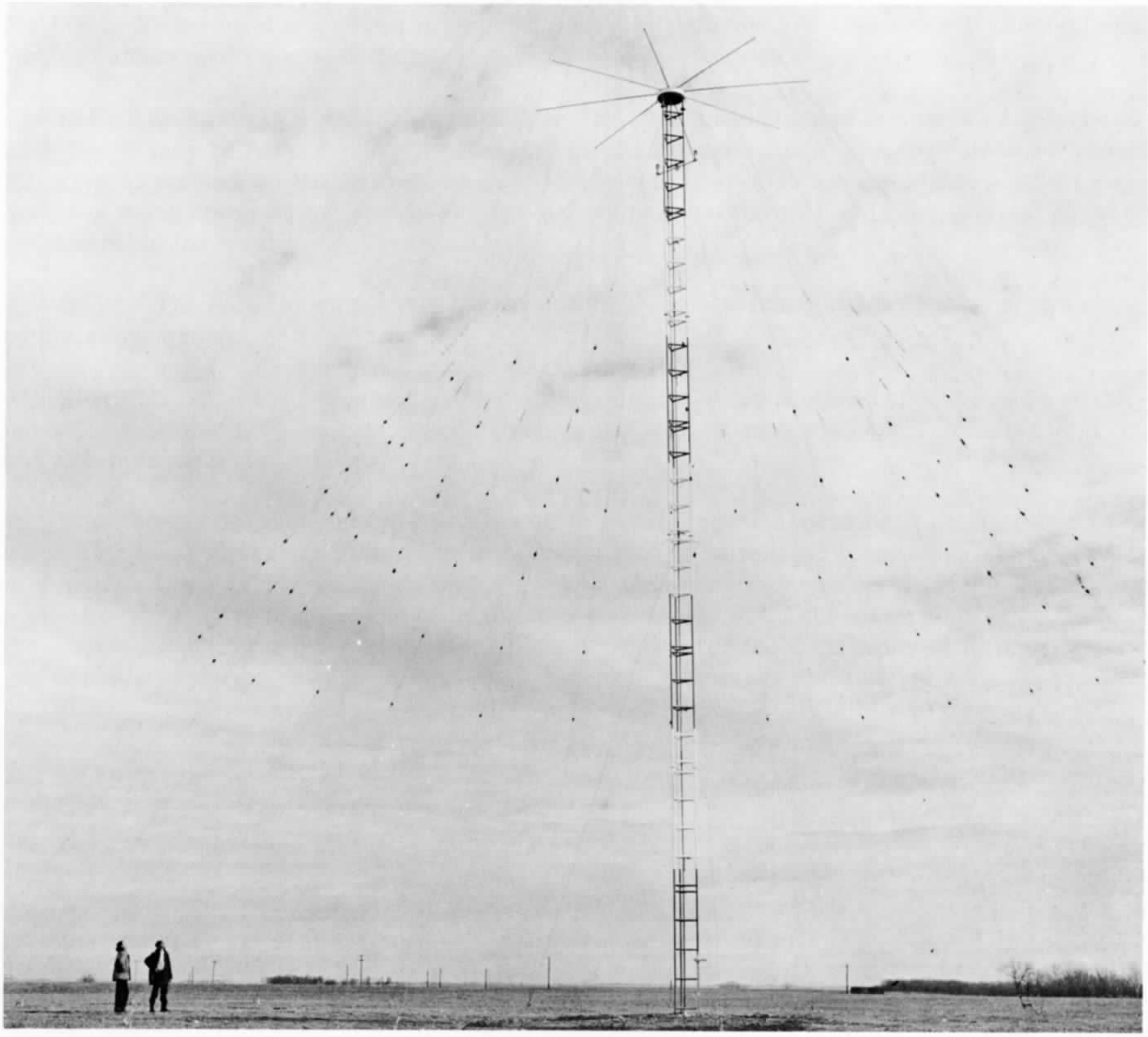

Figure 18. Typical Installation of a 11- to 30-mc Elevated Discone Antenna.

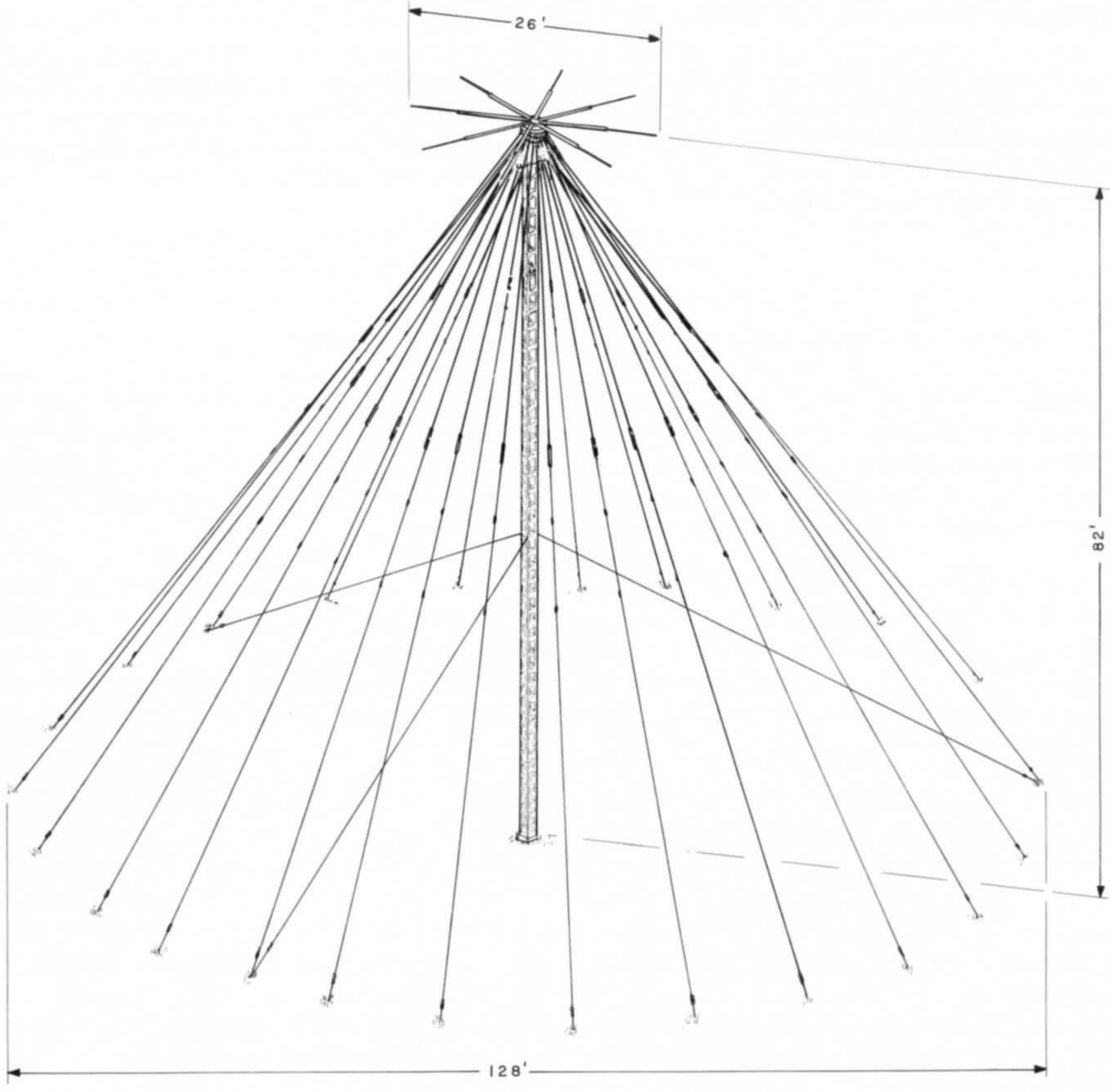

Figure 19. Outline and Dimensions, Elevated Discone Antenna 237H-1, 11 to 30 mc.

ELEVATED DISCONE ANTENNA 11 TO 30 MC

Another discone type radiator, the elevated discone antenna, is somewhat more conventional than the inverted discone type. This antenna, shown in figures 18 and 19, covers the 11- to 30-mc band with performance similar to that of an elevated vertical dipole. The cone consists of wire elements which also serve as guys for the supporting tower. The guy wires are broken electrically with insulators so that normal behavior of the antenna is not affected. The "hat" is made up of self-supporting tubular elements insulated from the tower and guys. The actual radiator is, therefore, at an appreciable height above ground.

DIRECTIONAL PROPERTIES - Azimuthal coverage from 11 through 30 mc is omnidirectional. Vertical plane field intensity (voltage) patterns at several frequencies throughout the 11- to 30-mc band are shown in figure 20. These patterns are also a result of modifying the free space scale model patterns by an actual ground factor.

INPUT IMPEDANCE AND BANDWIDTH - The input impedance of the elevated discone is such that it may be fed directly with standard 50-ohm coaxial line. The vswr does not exceed 2:1 from 11 through 30 mc and remains satisfactory to frequencies much higher. At frequencies much above 30 mc, however, the directional characteristics in the vertical plane are not desirable for most h-f applications.

GAIN - The gain is comparable to that of a half-wave vertical dipole located at the same height above ground.

STRUCTURE - The structure, illustrated in figure 19, is designed to withstand environmental conditions of 50-mph wind and 1-inch radial ice, 80-mph wind and 1/2-inch radial ice, and 125-mph wind with no ice.

Eight horizontal elements are positioned as equally spaced spokes and cantilevered from a circular steel plate. The elements are constructed of galvanized steel pipe, which is reduced in diameter towards the end of the element. The circular attachment plate is separated from a similar plate by vertical stand-off insulators 6 inches long. This lower plate is attached directly to the top of an 82-foot tower and has provision for the attachment of 24 equally spaced guy wires. These guy wires, of 3/16-inch diameter galvanized steel, form a cone around the

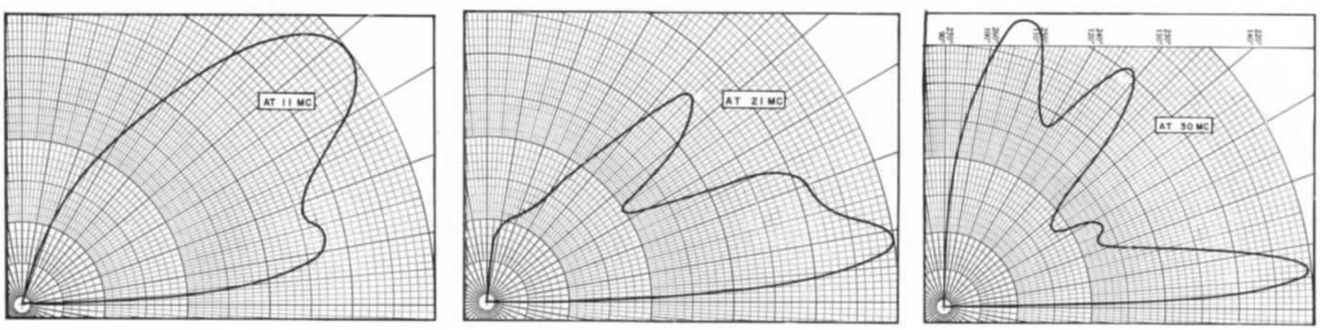

Figure 20. Vertical Plane Field Intensity Patterns of 11- to 30-mc Elevated Discone Antenna Over Typical Ground at (a.) 11 mc, (b.) 21 mc, and (c.) 30 mc.

tower of 75° included angle. The guy wires have an electrical function for the antenna in addition to providing the support for the top of the tower. The feed line is brought up the inside of the supporting tower.

The tower is a commercially available triangular section. Obstruction lighting kits are supplied for installations where required. In addition to the guys at the top of the tower, there are guys in three directions to the ground at the mid-height. All guys are attached to steel earth anchors and are broken electrically where required with guy insulators. The tower is supported on a reinforced concrete foundation.

SLEEVE ANTENNA 4 TO 10 MC

A sleeve type vertical polarized radiator, designed for 4- to 10-mc operation, is shown in figure 22. It is most commonly used for applications requiring performance similar to that of a vertical monopole and where a bandwidth up to three octaves is desired.

The inner radiating element is composed of a cylinder of vertical wires and the tower that supports them. The sleeve also consists of wire elements that are supported by the guys to the tower. The guys are broken electrically with insulators so as not to interfere with the performance of the antenna. The inner cylinder is base fed about 5 feet above ground with standard 50-ohm coaxial line. A ground radial system is included as part of the structure.

For applications requiring operation at lower frequencies, the structure is increased in size accordingly. The dimensions required for 2- and 3-mc coverage are indicated in figure 22.

DIRECTIONAL PROPERTIES - Directional characteristics in the two principal planes are similar to those of a ground based vertical monopole. Azimuthal coverage is omnidirectional. Coverage in the vertical plane is a function of antenna height and the condition of the ground. Vertical plane patterns at 4 and 10 mc, for the ground constants indicated, are shown in figure 21.

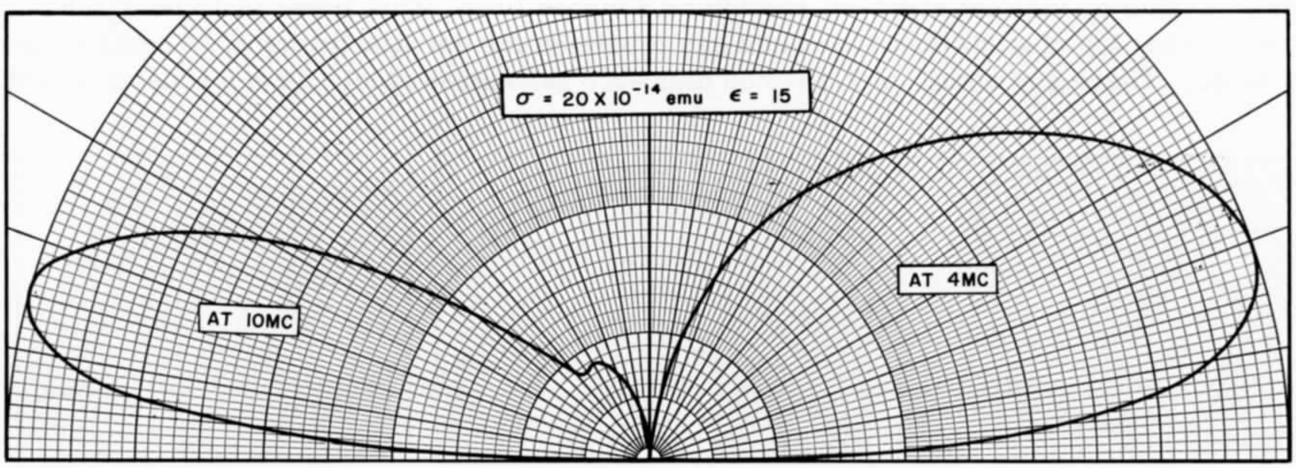

Figure 21. Vertical Plane Field Intensity Patterns of 4- to 10-mc Sleeve Antenna Over Typical Ground at (a.) 10 mc and (b.) 4 mc.

FREQ. RANGE	DIMENSIONS				
	H_1	H_2	D_1	D_2	D_3
2 - 5 MC	115'	54'	10'	31'	84'
3 - 7.5 MC	78'	38'	7'	21'	60'
4 - 10 MC	AS SHOWN				

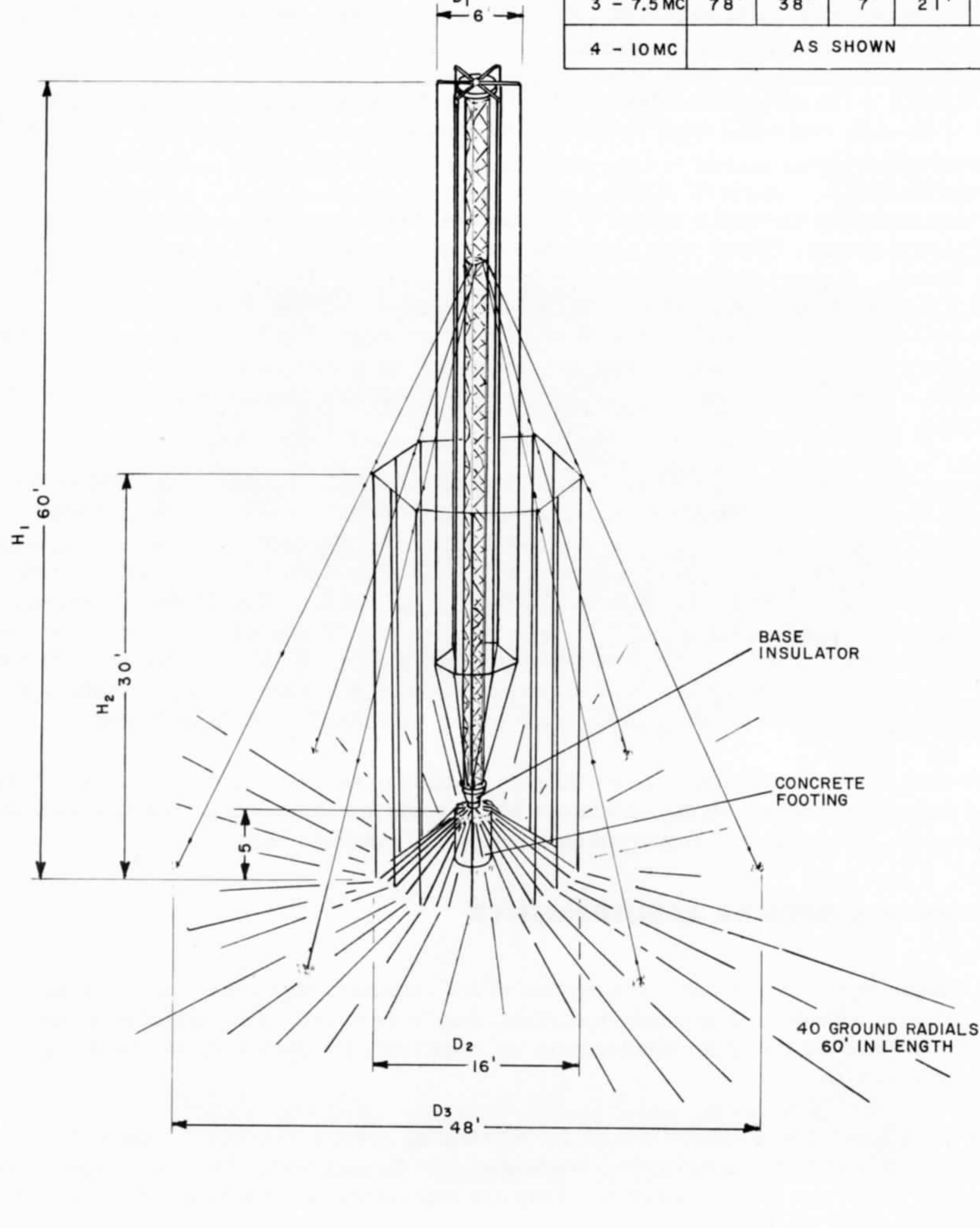

Figure 22. Outline and Dimensions, Sleeve Antenna, 4 to 10 mc.

INPUT IMPEDANCE AND BANDWIDTH - The sleeve radiator has an average input impedance of about 50 ohms. It is an unbalanced load and may therefore be fed directly with 50-ohm coaxial transmission line. The vswr on the 50-ohm line does not exceed 2:1 over the 4- to 10-mc operating band.

GAIN - The gain is similar to that of a vertical monopole with the same height above ground.

STRUCTURE - The structure, illustrated in figure 22, is designed for environmental conditions of 50-mph wind and 1-inch radial ice, 80-mph wind and 1/2-inch radial ice, and 125-mph wind and no ice.

The inner radiating element consists of a structural tower surrounded concentrically by 8 vertical wire elements. These wire elements are supported off the top of the tower by cantilever spokes. A short distance above the base of the tower, the wires are horizontally restrained by spokes so that they can be attached to a point at the base of the tower. The wire elements, copper coated and 3/16-inch in diameter, contain extension springs at one end which limit their load. These springs also provide a method of obtaining the proper initial tension for the element. The tower is insulated from its concrete foundation by an appropriate base insulator.

The tower is guyed to the ground at its 3/4-height by 6 equally spaced guys. Thirty feet above ground these guys are connected by horizontal catenary cables which form a circle approximately 16 feet in diameter. Twelve vertical sleeve wires, copper coated and 3/16-inch in diameter, are supported from these catenaries. At the ground the wires are attached to steel earth anchors and electrically connected to the ground radials. The 40 equally spaced ground radials are copper coated wires 3/16-inch in diameter. These wires are supported on the concrete foundation of the tower and attached to earth anchors placed on a circle 16 feet in diameter. From each anchor a No. 6 soft drawn copper wire is extended along a radial line at a minimum depth of 6 inches below the surface for an additional distance of 44 feet.

The 60-foot tower is a commercially available triangular section of galvanized steel. All guys are electrically broken with guy insulators where required and are attached to reinforced concrete anchors. The tower is supported on a reinforced concrete base.

ANTENNAS FOR SPECIAL REQUIREMENTS

Often a high-frequency antenna, or a system of h-f antennas, with characteristics not entirely consistent with those previously described, may be required. Because of economic limits or limited real estate or for applications not requiring high performance, the simple dipole may be adequate.

On the other hand, there may be a need for a radiating system to cover the entire h-f range with high gain and with an azimuthal beam steerable through 360°. The specialized antenna structures that follow are in this category. They are representative of antennas now in operation or currently being installed.

BROADBAND DIPOLE ANTENNA HORIZONTALLY POLARIZED, 10 TO 25 MC

For installations not requiring a great deal of gain or directivity, the horizontally polarized broadband dipole, shown in figure 23, may be employed. This dipole is designed for 10- to 25-mc operation with an average input impedance of 50 ohms over this range. The dipole is fed balanced at its center through a balun with a standard 50-ohm coaxial input. The antenna exhibits azimuthal directivity similar to that of a horizontal dipole whose length ranges from about 0.3 to 0.75 wavelengths. As with any horizontal dipole, its vertical plane directional properties depend on its height above ground.

The dipole shown is mounted on a 100-foot guyed tower. At this height the vertical angle of beam maximum ranges from 18° at 10 mc to 7° at 25 mc, with some significant secondary lobes at the higher frequencies.

Figure 23. Typical Installation of a 10- to 25-mc Horizontally Polarized Broadband Dipole Antenna.

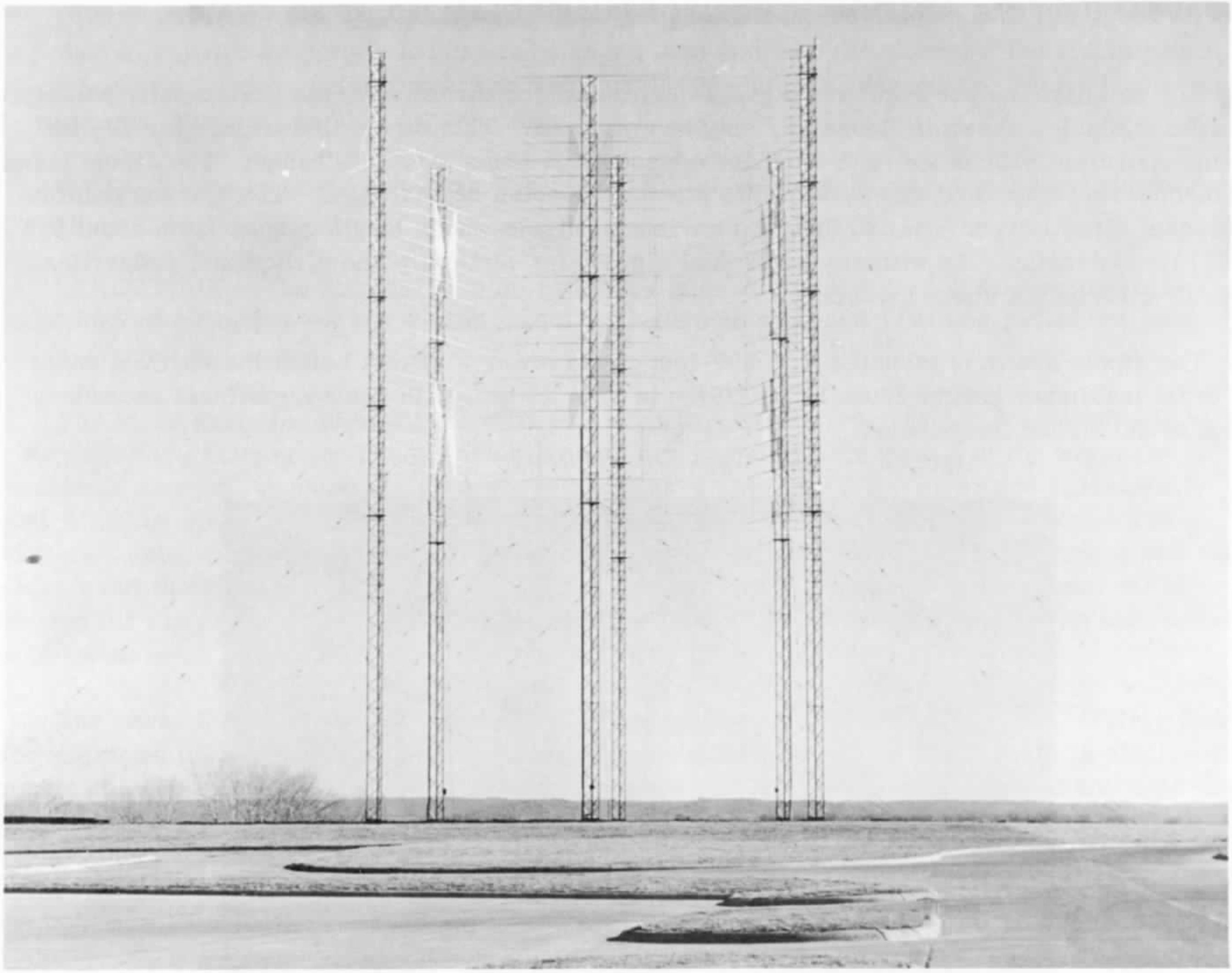

Figure 24. Typical Installation of a Three-Directional Billboard Antenna Combination, Horizontally Polarized, 10 to 25 mc.

BILLBOARD ANTENNA COMBINATION HORIZONTALLY POLARIZED, 10 TO 25 MC

The billboard antenna structure, pictured in figure 24, consists of three horizontally polarized dual dipole billboard antennas arranged in a triangle. The electrical characteristics are essentially the same as for the dual dipole billboard antenna, figure 10, but three distinct azimuthal directions are covered. Because of the geometry of the structure, the front-to-back ratio is greater than that indicated in the experimental patterns, figure 11. The three panels may be operated separately or simultaneously and at the same or a different frequency. A tuning unit is available to permit operation at frequencies down to 7 mc.

A similar installation, shown in figure 25, also employs the horizontally polarized structure of figure 10 but covers six distinct azimuthal directions with six billboard antennas arranged in a hexagon. With this arrangement, 360° azimuthal coverage is provided with the signal strength about 3 db down at the beam crossover points. Electrical characteristics are otherwise the same as for the antennas in figures 10 and 24.

H-F STEERABLE BEAM ANTENNA SYSTEM

The structure, illustrated in figure 26, is one of several of its type designed for long distance communications in the 3.5- to 30-mc frequency range. The structure shown covers the 3.5- to 14-mc range with electrical characteristics desirable for long path ionospheric propagation, providing high gain at low angles of radiation with patterns containing a minimum of secondary lobes. An additional feature is its provision for steering the azimuthal beam through 360°.

The steerable system is of the Wullenweber type. But the nature by which two separate and independent arrays are combined in one supporting structure is of interest. The lower frequency array, 3.5 to 7 mc, is vertically polarized, while the higher frequency array, 7 to 14 mc, is horizontally polarized. The system maintains a gain comparable to that of a class A rhombic antenna. On the basis of the vswr on the main 50-ohm feed line not exceeding 2:1, the input impedance characteristics remain satisfactory over the respective operating bands. For a detailed description of this system, see reference 7.

Additional structures of this type are designed for both transmitting and receiving applications for frequencies up to 30 mc.

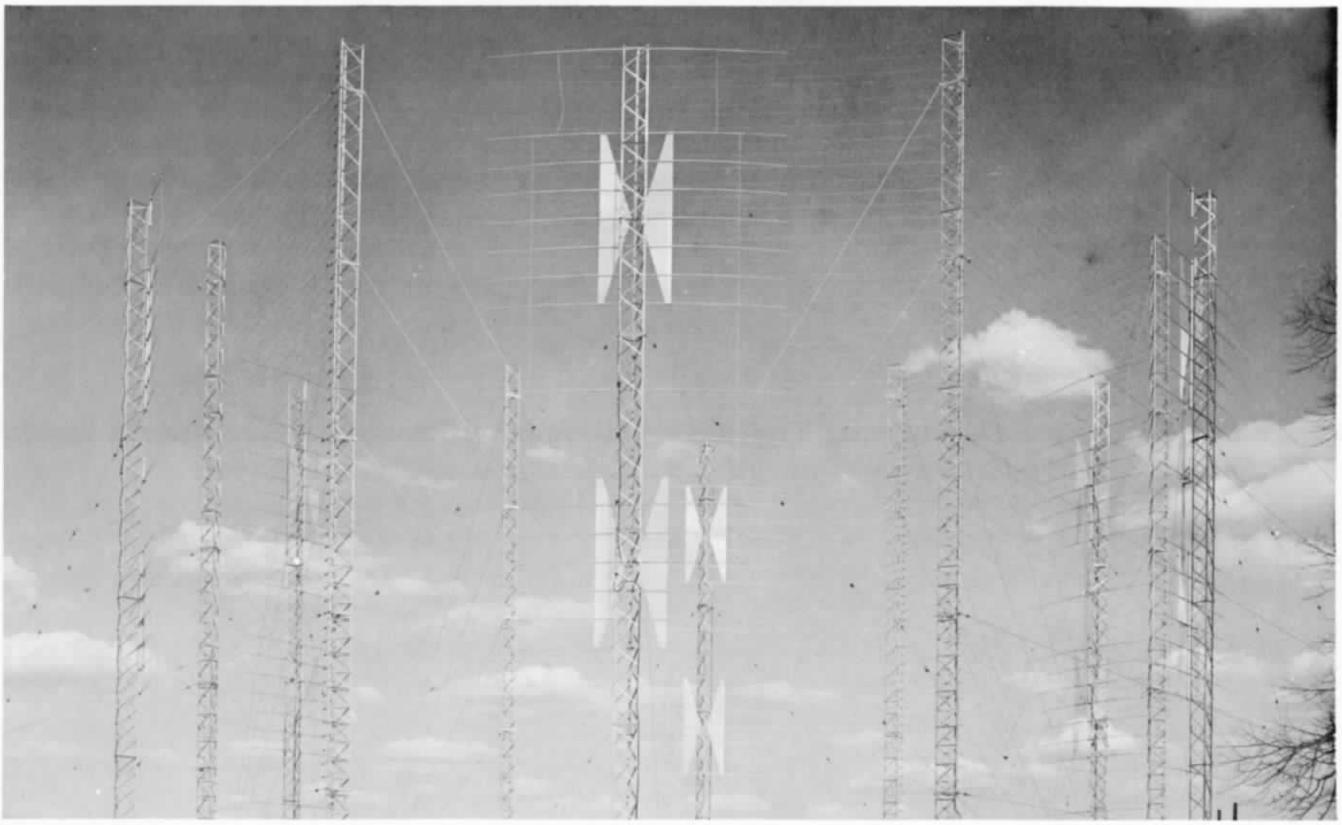

Figure 25. Typical Installation of a Six-Directional Billboard Antenna Combination, Horizontally Polarized, 10 to 25 mc.

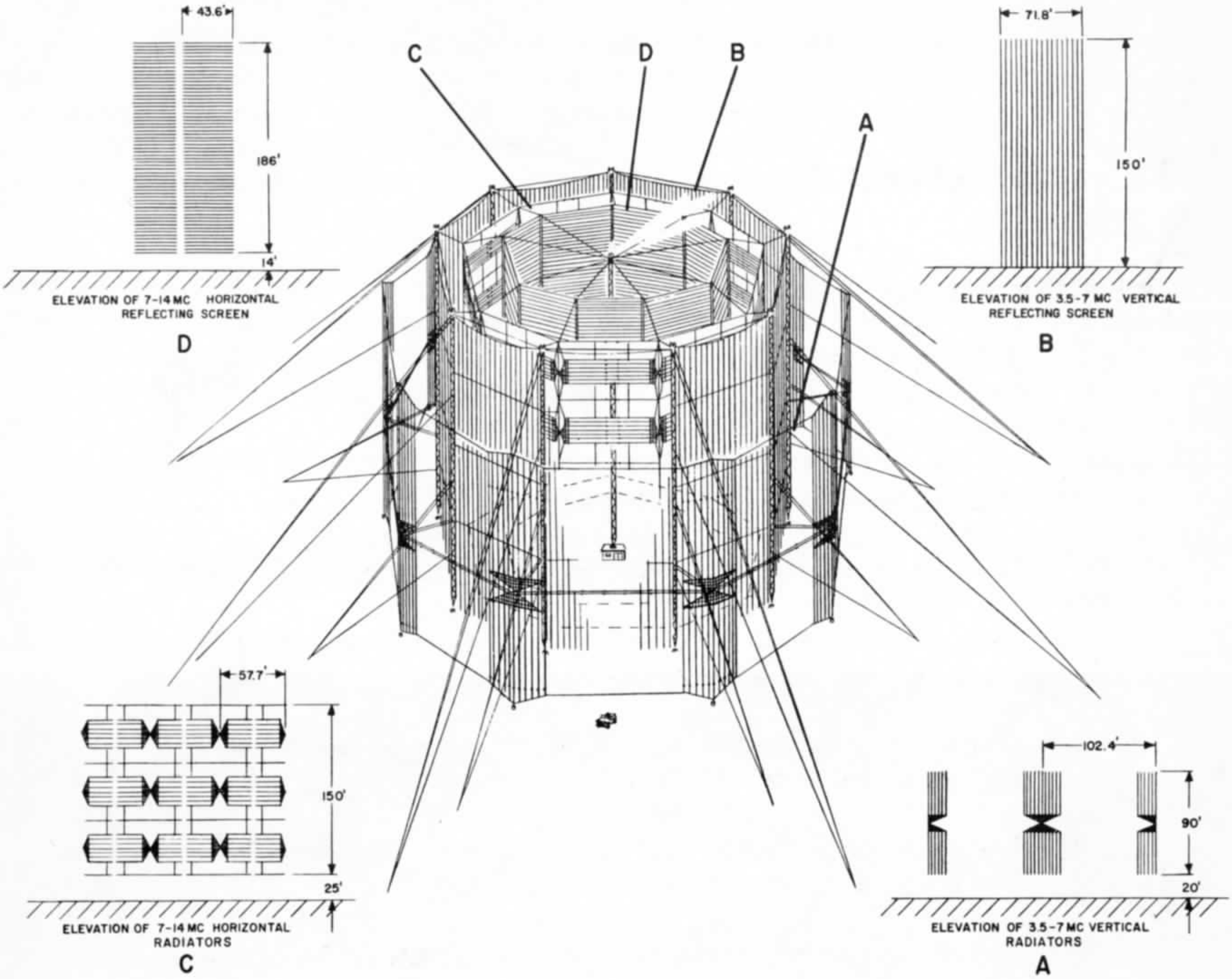

Figure 26. Outline and Dimensions, Typical High-Frequency Steerable Beam Antenna System.

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