Journal of Research of the National Bureau of Standards Vol. 46, No. 2, February 1951 Research Paper 2182

Effect of a Metal Mast and Guy Wires on the Performance of the 600-Ohm Multiple-Wire Delta Antenna

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This report describes the results of measurements made to determine the effect of a metal mast and guy wires on the radiation pattern and the effect of guy wires on the terminal impedance and the radiation efficiency of the 600-ohm multiple-wire delta antenna. Model techniques were used to obtain radiation patterns of identical antennas supported in various ways. Curves are presented showing the terminal impedance over the frequency range 1 to 25 megacycles of full-scale antennas with and without guy wires. A graph of the quasi-radiation efficiency of the antenna as a function of frequency is shown.

I. Introduction

The 600-ohm multiple-wire delta antenna [1] (fig. 1) used in ionosphere studies requires only a single large wooden mast. This mast, which is less than 80 ft. long, can ordinarily be procured and erected in most locations. However, in some locations it may be desirable to use a sectionalized metal mast. As the mast lies in a neutral plane of the antenna, it would appear that if the antenna was electrically and mechanically symmetrical and was fed by a balanced transmitter there would be no radiation from a metal supporting mast. It is quite improbable however that such a completely balanced condition will prevail. Any unbalance in the system will cause a residual current flow in the mast, which at resonance could become quite large causing appreciable radiation. It would also seem desirable to use guy wires to help support either a wooden or metal mast. Because the effects of a metal mast and guy wires on the radiation pattern and impedance of the delta antenna are difficult to predict analytically, experimental measurements were made to determine these effects. This report describes the results of these measurements.

II. Instrumentation

Radiation pattern measurements were made by using model techniques. That is, all dimensions of the antenna were scaled down by a certain factor, in this case 30, and the frequency was scaled up by the same factor. The model antennas were supported by nonconducting or metal masts of a diameter corresponding to 1 ft. in diameter on a full-scale antenna. Since ordinarily a single mast supports one transmitting and one receiving delta antenna mounted at right angles to each other, guy wires when used were spaced as shown in figure 2. In all cases the guy wires were insulated from the pole and from ground. When continuous guy wires were used these were the only insulators. The sectionalized guy wires had insulators at a spacing equivalent to every 7½ ft., or about 0.2 wavelength at 25 Mc. Pattern measurements were made over a ground mat of metallic mesh. When the model was supported by a metal mast, this mast was electrically connected to the ground mat.

The model antenna was used as a receiving antenna. A battery-operated high-frequency transmitter modulated at an audio frequency was mounted at the apex of an A-frame and moved about the model in a semicircular arc of 13 ft. in radius. The angular displacement of the transmitter with respect to ground was transferred to the turntable of a recorder by means of a selsyn system. The signal received by the model was rectified and the resulting audio-frequency voltage passed through a series of selective amplifiers and servomechanisms to cause a radial displacement of a pen on the recorder turntable. Thus as the transmitter was moved through an arc of 180 deg., the vertical radiation pattern of the antenna was automatically plotted.

Figure 3 is a diagram of the model range showing the paths of the target transmitter with reference to the antenna under test. The model antenna was located in the X-Z plane. Radiation patterns were measured in the X-Z and Y-Z planes. In measuring patterns in the X-Z plane the polarization of the transmitting antenna was always such that the electric vector was tangent to the meridian arc XZX'. In measuring patterns in the Y-Z plane, the electric vector was always parallel to the X axis.

The patterns obtained show the relative power that would be radiated by the antenna at different vertical angles in a given plane for a given frequency. The patterns were normalized, that is, the gain of the pattern plotter was adjusted for each frequency to give a full-scale deflection at the point of maximum gain. Pattern measurements were made only for the frequencies equivalent to 14 through 25 Mc because, with the scale factor of 30 which was used, the model range was too small for measurements at lower frequencies.

Impedance measurements of full-scale antennas were made with a balanced recording impedance meter that automatically plots the absolute magnitude of input impedance of an antenna over the frequency range 1 to 25 Mc. A block diagram and brief description of this instrument have been

[1] H. N. Cones, H. V. Cottony, and J. M. Watts, A 600-ohm multiple-wire delta antenna for ionosphere studies, J. Research NBS **44**, 475 (1950) RP2094.

published.[2] Basically, it consists of a sweep frequency generator with a constant-current output, the voltage across the output terminals being, therefore, directly proportional to the impedance impressed across the output terminals. The instrument is calibrated by substituting noninductive resistors for the unknown impedance. The absolute magnitude of the unknown impedance at any frequency can be determined by interpolating between the calibrating lines.

This instrument can also be used to obtain an indication of the radiation efficiency of a nonresonant antenna. The curve plotted by the impedance meter when an antenna is connected to its output terminals shows in arbitrary units the voltage across the antenna imput terminals. The curve also shows the impedance of the antenna, as the voltage is directly proportional to impedance. Since the input voltage and the input impedance of the antenna are known, the input power (in arbitrary units) can be computed for frequencies at which the antenna is purely resistive. These are, for all practical purposes, the frequencies at which the impedance is either a maximum or a minimum. If measurements are made of the voltage across the terminating resistor, the power dissipated in the resistor (in the same arbitrary units) can be determined. Knowing the power input to the antenna and the power dissipated in the terminating resistor, a quasi-radiation efficiency of the antenna (taken as the quotient of the power input less the power dissipated in the terminating resistor and the power input) can be evaluated. This quasi-radiation efficiency always exceeds the true radiation efficency, since it includes the copper, ground, and dielectric losses as power radiated.

III. Results of Radiation Pattern Measurements

Radiation pattern measurements were made of four identical antennas supported by a nonconducting mast, by a metal mast, by a metal mast and continuous guy wires, and by a metal mast and guy wires that were broken up by insulators spaced at distances equivalent to 7½ ft.

Figure 4 shows the radiation patterns obtained in the *X-Z* plane for these four antennas. Referring to the figures, it is seen that at 14 Mc the side lobes that are characteristic of the multiple-wire delta antenna at this frequency are effectively suppressed, at least in this plane, by the continuous guy wires. At 15 Mc, the metal mast causes a marked change in the usual pattern. Here again the continous guy wires suppress the side lobes in this plane. From 16 through 20 Mc, the method of support does not appear to affect the pattern appreciably, although continuous guy wires slightly increase the amount of low angle radiation at 16 Mc and slightly decrease it at 17, 18, 19, and 20 Mc. At 21 Mc, side lobes appear for the antenna with the continuous guy wires. At this frequency the long guy wires are 2 wavelengths long and the short guy wires are 1 wavelength long. Also at this frequency, the metal mast is approximately 1½ wavelengths long. From 22 through 25 Mc the patterns are very nearly alike, although the use of the sectionalized guy wires results in a slight change in the radiation pattern at 24 and 25 Mc.

The difference in the radiation patterns observed at 15 Mc between antennas employing nonconducting and metal masts (both without guy wires) is attributed to the resonance of the mast close to this frequency. This effect would not be observed except for the existence of an exciting voltage that would have to arise from an unbalance incidental to the model antenna system under test. Therefore, as the unbalance is likely to vary in different installations it may be expected that the resonance effects discussed above will likewise vary in magnitude.

Figure 5 shows comparative radiation patterns in the *Y-Z* plane for all four methods of support. At any one frequency the patterns are substantially alike.

It is seen that the use of continuous guy wires is very effective in suppressing side lobes in the *X-Z* plane at 14 and 15 Mc and to some extent effective in reducing low-angle radiation at other frequencies. They do not appear to affect the pattern in the *Y-Z* plane.

IV. Results of Impedance Measurements

Impedance measurements were made of full-scale antennas. As no metal mast was available, tests were limited to determining the effect of continuous guy wires on the terminal impedance of the antenna.

The following impedance measurements were made: 1. Measurements of an antenna without guy wires; 2. measurements of an antenna with long continuous guy wires, that is, guy wires fastened to the top of the mast; 3. measurement of an antenna with long and short continuous guy wires, that is, guy wires fastened to the top of the mast and guy wires fastened to the mast 35 ft above the ground.

Figure 6 shows the results of these measurements. The long guy wires affected the impedance only near the frequency where the guy wires were a half wavelength long. No change is noted at any multiple of a half wavelength. The short guy wires did not appear to have any effect on the impedance.

V. Results of Measurements of Quasi-Radiation Efficiency

Figure 7 shows the results of measurements of the quasi-radiation efficiency of an antenna with continuous guy wires and of an antenna without guy wires. As noted previously the quasi-radiation efficiency always exceeds the true radiation efficiency, as the copper, ground, and dielectric losses are included as power radiated. Although the true radiation efficiency is not known, the lower curve of figure 7 indicates the manner in which the quasi-

[2] H. N. Cones, Impedance characteristics of some experimental broad-band antennas for vertical-incidence ionosphere sounding, J. Research NBS **43**, 71 (1949) RP2006; see also reference listed in footnote 1.

radiation efficiency changes with frequency. The effects of guy wires are apparently very small.

It was shown in a previous paper (see footnote 2) that the value of the terminating resistor was not particularly critical for frequencies above 8 Mc. Figure 7 shows that only a relatively small amount of energy is dissipated in the terminating resistor at frequencies above 8 Mc.

VI. Conclusions

1. The use of a metal mast to support the multiple-wire delta antenna causes little change in the vertical radiation pattern in the frequency range 14 through 25 Mc, except at 15 Mc where large side lobes were observed in the particular model on which measurements were made. (See fig. 4.)
2. In general the use of continuous guy wires appears to improve the vertical radiation pattern of the antenna.
3. Guy wires that are broken up at short intervals by insulators have no measurable effects on the vertical radiation pattern of the antenna except at the highest frequencies in the operating range. Even here the effects are minor.
4. In the case of wooden masts continuous guy wires have no measurable effect on the input impedance of the antenna except near the frequency where the long guy wires are a half wavelength long.
5. In the case of wooden masts the use of guy wires does not appear to affect the efficiency of the antenna as a radiator.

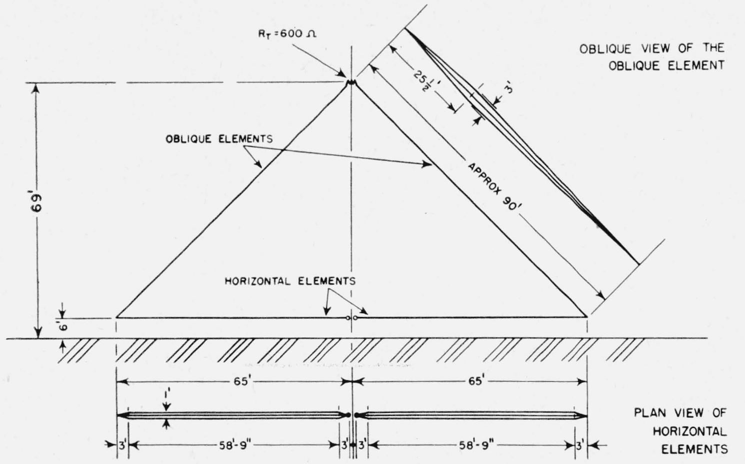

FIGURE 1. *Simplified diagram of the 600-ohm multiple-wire delta antenna.*

No. 12 wire used for all elements.

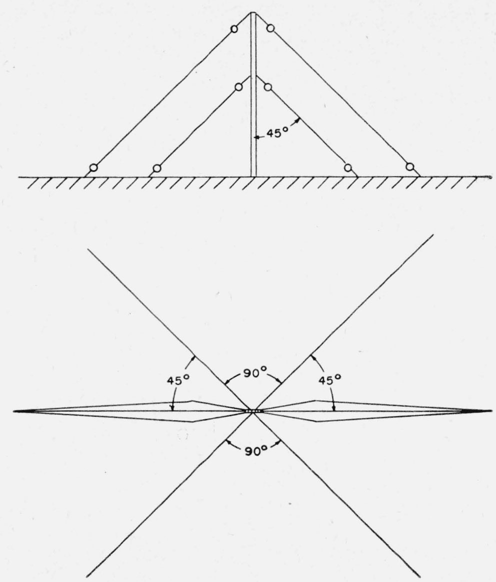

FIGURE 2. *Arrangement of guy wires used with multiple-wire delta antenna.*

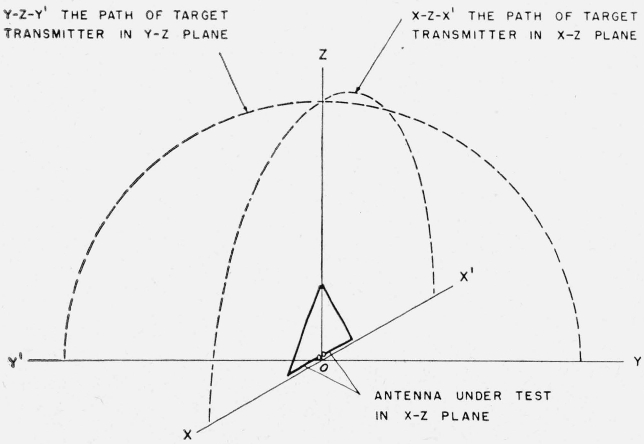

FIGURE 3. *Diagram of the model range showing the paths of the target transmitter with reference to the antenna under test.*

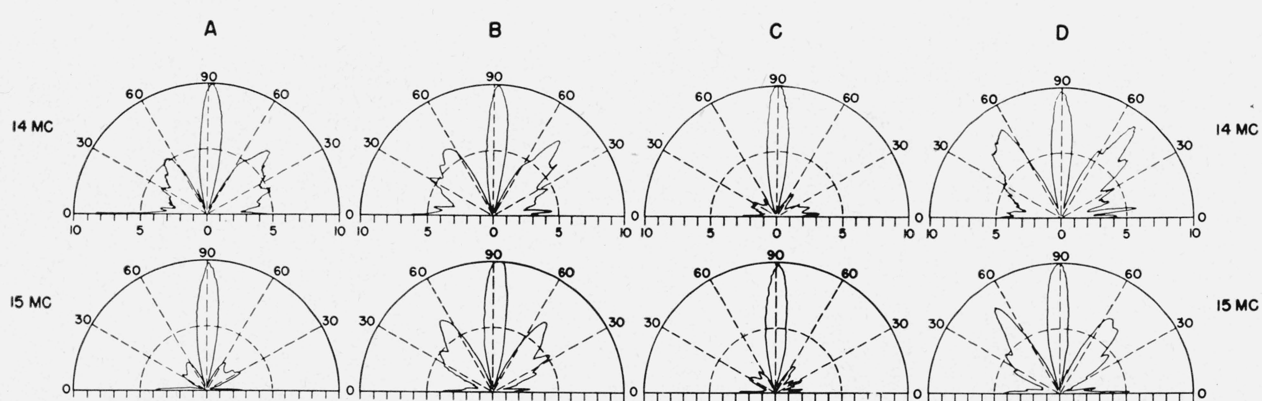

FIGURE 4. *Normalized radiation patterns in space for a multiple-wire delta antenna supported by an insulated mast and for a multiple-wire delta antenna supported by a metal mast with and without guy wires.*

The patterns are taken in the X-Z plane, and the antenna is in the X-Z plane. The radial displacement is proportional to power. A, Nonconducting mast; B, metal mast; C, metal mast with continuous guy wires; D, metal mast with guy wires that have insulators inserted every 7½ ft.

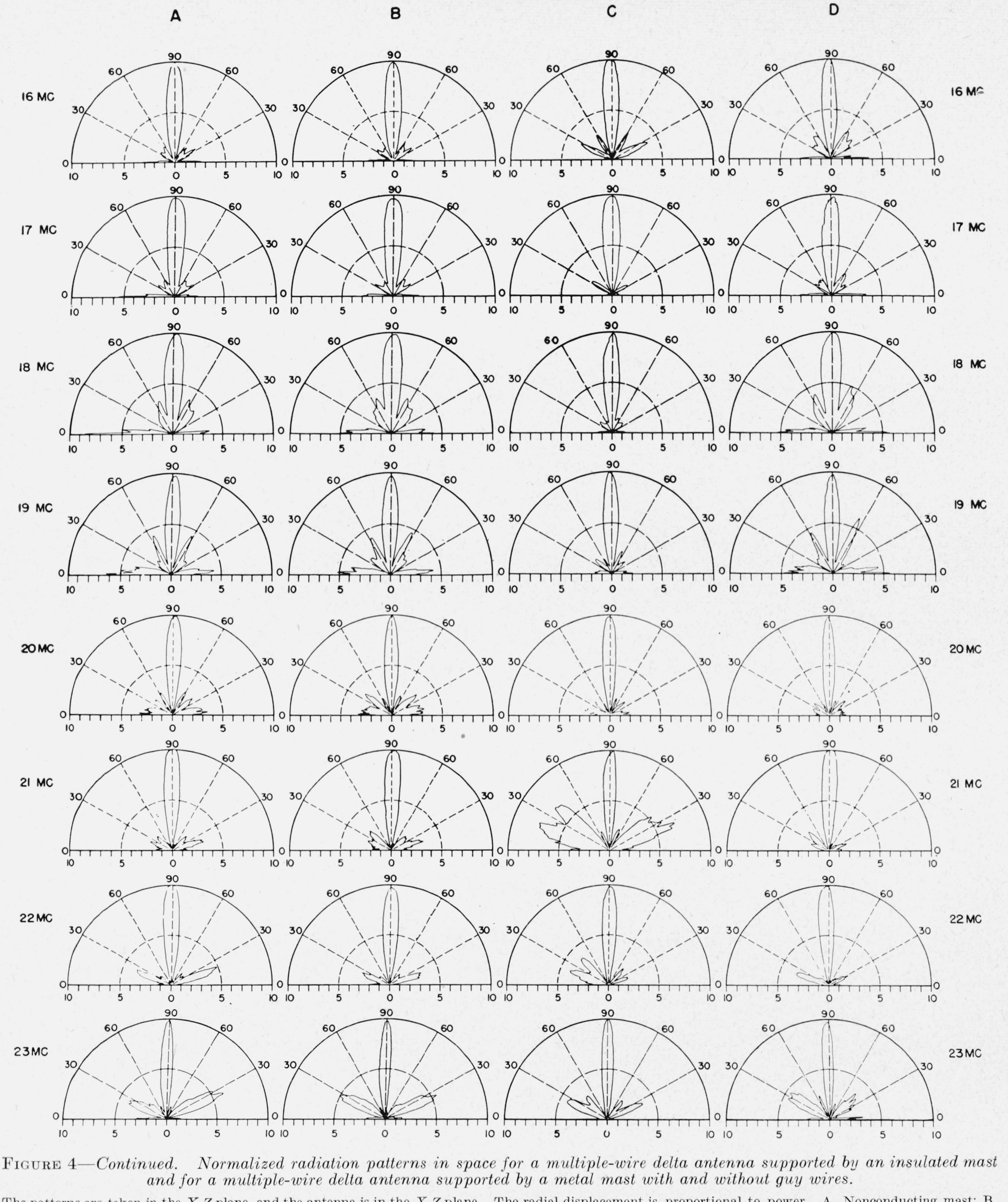

FIGURE 4—*Continued. Normalized radiation patterns in space for a multiple-wire delta antenna supported by an insulated mast and for a multiple-wire delta antenna supported by a metal mast with and without guy wires.*

The patterns are taken in the X-Z plane, and the antenna is in the X-Z plane. The radial displacement is proportional to power. A, Nonconducting mast; B, metal mast; C, metal mast with continuous guy wires; D, metal mast with guy wires that have insulators inserted every 7½ ft.

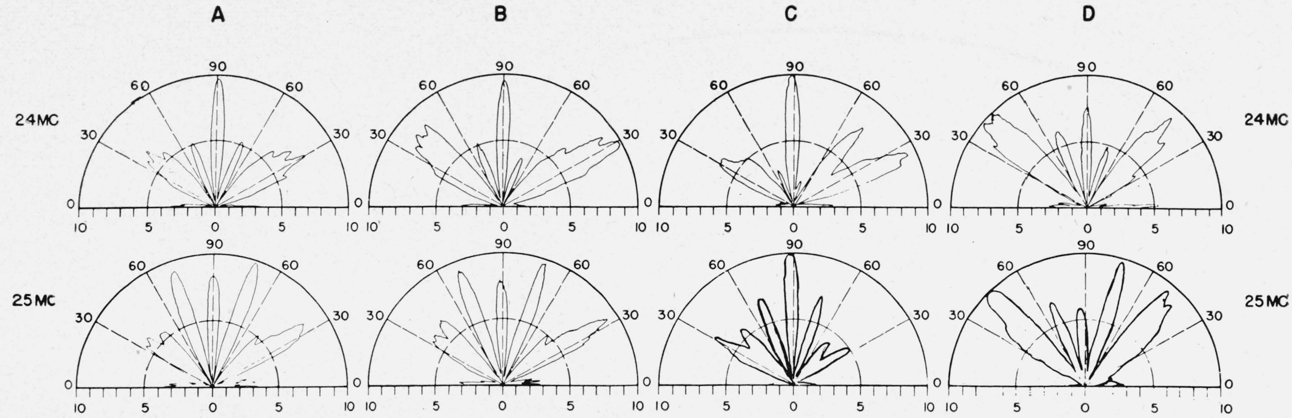

FIGURE 4—*Continued. Normalized radiation patterns in space for a multiple-wire delta antenna supported by an insulated mast and for a multiple-wire delta antenna supported by a metal mast with and without guy wires.*

The patterns are taken in the *X-Z* plane, and the antenna is in the *X-Z* plane. The radial displacement is proportional to power. A, Nonconducting mast; B, metal mast; C, metal mast with continuous guy wires; D, metal mast with guy wires that have insulators inserted every 7½ ft.

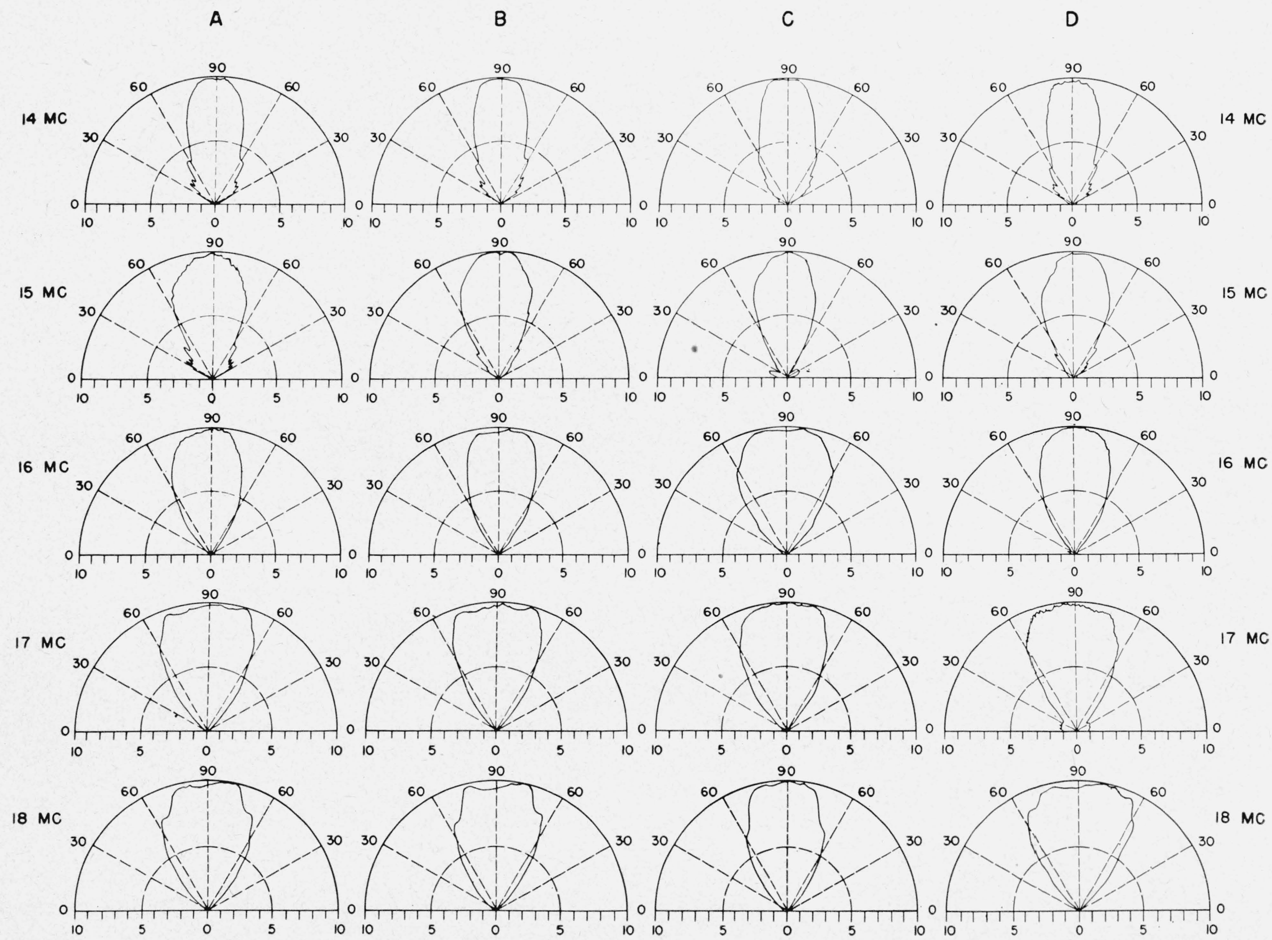

FIGURE 5. *Normalized radiation patterns in space for a multiple-wire delta antenna supported by an insulated mast and for a multiple-wire delta antenna supported by a metal mast with and without guy wires.*

The patterns are taken in the *Y-Z* plane, and the antenna is in the *X-Z* plane. The radial displacement is proportional to power. A, Nonconducting mast; B, metal mast; C, metal mast with continuous guy wires; D, metal mast with guy wires that have insulators inserted every 7½ ft.

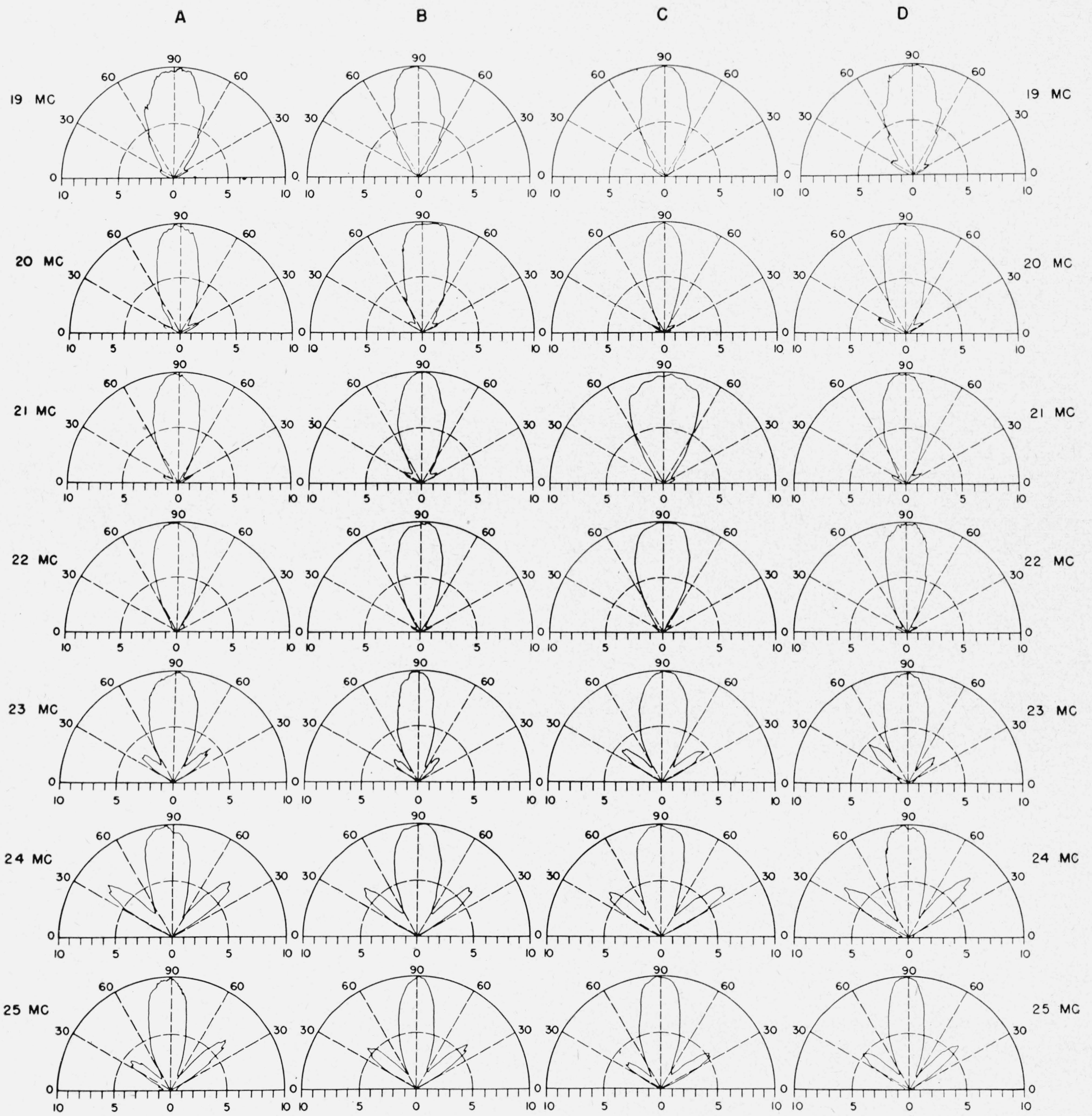

FIGURE 5—*Continued. Normalized radiation paterns in space for a multiple-wire delta antenna supported by an insulated mast and for a multiple-wire delta antenna supported by a metal mast with and without guy wires.*

The patterns are taken in the *Y-Z* plane, and the antenna is in the *X-Z* plane. The radial displacement is proportional to power. A, Nonconducting mast; B, metal mast; C, metal mast with continuous guy wires; D, metal mast with guy wires that have insulators inserted every 7½ ft.

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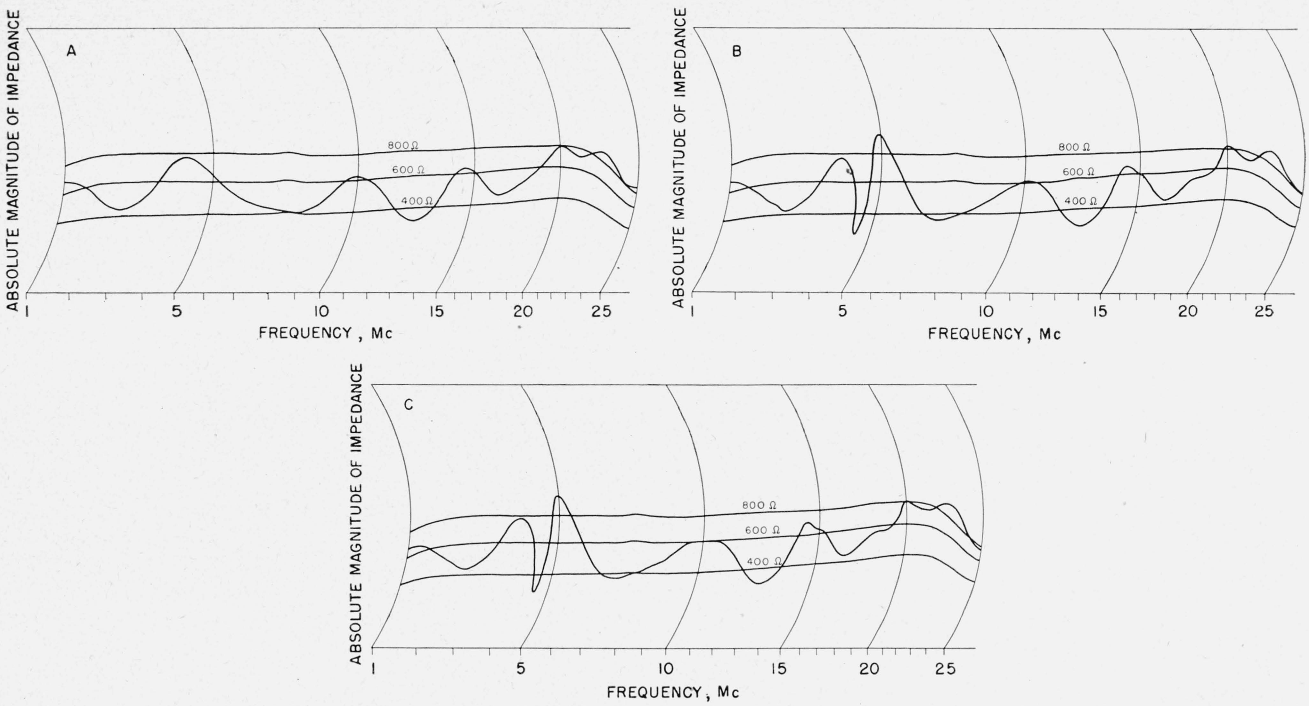

FIGURE 6. *Impedance of 600-ohm multiple-wire delta antenna with and without guy wires.*

A, Impedance of multiple-wire delta antenna without guy wires; B, impedance of multiple-wire delta antenna with long continuous guy wires; C, impedance of multiple-wire delta antenna with long and short continuous guy wires.

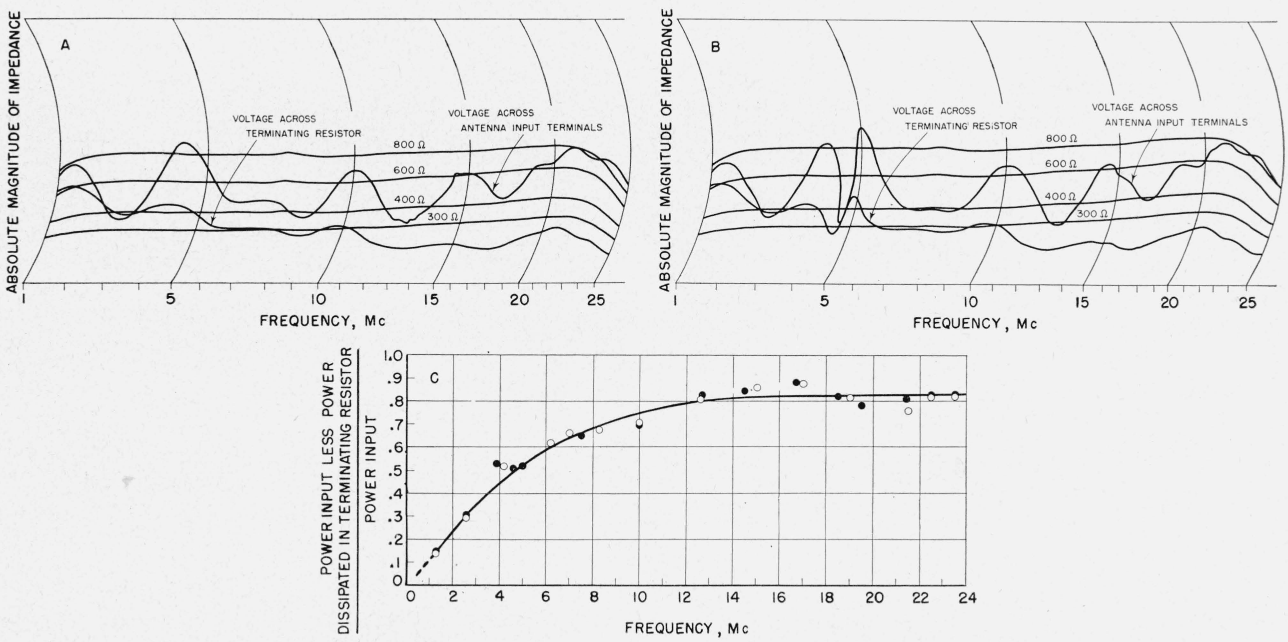

FIGURE 7. *Measurements of the quasi-radiation efficiency of a multiple-wire delta antenna with and without guy wires.*

A, 600-ohm multiple-wire delta antenna supported by a wooden mast, no guy wires used; B, 600-ohm multiple-wire delta antenna supported by a wooden mast, continuous guy wires used; C, ○, without guy wires; ●, with continuous guy wires.

WASHINGTON, October 16, 1950.