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Boulder Laboratories

OBLIQUE INCIDENCE RECEIVING ANTENNA ARRAY FOR A RELATIVE IONOSPHERIC OPACITY METER

BY

A. C. WILSON

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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November, 1960

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OBLIQUE INCIDENCE RECEIVING ANTENNA ARRAY FOR A RELATIVE IONOSPHERIC OPACITY METER

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Abstract

Experimental measurements incidental to the design of an antenna for a relative ionospheric opacity meter (RIO Meter) are described.

The frequency of operation is 50 Mc. The antenna requirements are that the main lobe of the antenna is directed at 23° above the horizon, the half-power beamwidth in the vertical plane does not exceed 10°, the minimum front-to-back ratio is at least 13 decibels, and the side-lobe levels are at least 10 decibels below the maximum response in both the E- and H-planes. Since the antenna is for use in Alaska, it is to be of simple design and physically able to withstand any anticipated wind and ice loads.

The final antenna design is an array of three stacked horizontal dipoles with two optimally spaced reflectors behind each dipole to obtain the required directivity. The narrow main lobe of the antenna directed at an angle of 23° above the horizon is obtained by properly spaced and phased dipoles above the ground. The half-power beamwidth in the vertical plane is computed to be 7-1/4°. The front-to-back ratio over the rear 180° sector is not less than 20 decibels, and the half-power beamwidth in the E-plane is 74°.

Two complete receiving antenna arrays were constructed, adjusted, and tested. These antennas were installed in Alaska where they are now in use by an auroral transmission loss project.

I. INTRODUCTION

In connection with an antenna requirement for the Auroral Transmission Loss Project of the Radio Propagation Physics Division of the National Bureau of Standards Central Radio Propagation Laboratory, a series of measurements were carried out to obtain a suitable antenna design to meet the specific requirements. The antenna is to be used as a receiving antenna at 50 Mc for a relative ionospheric opacity meter used for cosmic noise absorption measurements.[1, 2] The polarization is horizontal.

The requirements of the antenna are that the main lobe of the antenna be 23° above the horizon, the half-power beamwidth in the vertical plane not over 10°, the front-to-back ratio at least 13 decibels, and the side-lobe levels at least 10 decibels or more below the maximum response in both the E- and H-plane. The gain of the antenna is of secondary importance. The antennas are for use in Alaska, so the physical design requirements are that they be as simple a design as possible and able to withstand any anticipated wind and ice loads. It is also believed to be desirable to complete all impedance adjustments and measurements prior to installation in Alaska because of the difficult field working conditions and temperatures.

Computations were carried out to obtain the radiation pattern for an array of three dipoles stacked one above the other. Figure 1 presents the array design and Figure 2 presents the computed radiation pattern in the vertical plane. A main lobe at an elevation angle of 23° above the horizon is obtained by using a height of 0.64λ for the lowest dipole and odd multiples of 0.64λ for the other two dipoles. The center dipole is 180° out of phase with respect to the top and bottom dipoles. Other antenna arrays were considered for this application, but the stacked array of three dipoles was chosen as being the most suitable, both practically and economically.

These computations provided an array design which would fulfil the requirements for the desired 23° angle of arrival and the directivity and side-lobe levels in the vertical plane. The remaining problem then was to design an antenna utilizing dipoles with reflectors in place of the dipole used in the computations, which would give the desired directivity in the E-plane and still meet the physical requirements previously stated.

A dipole with a single reflector, with the reflector length optimized for maximum gain, has only an approximate $5\frac{1}{2}$-db. front-to-back ratio. A more complex antenna, such as a Yagi, has directivity characteristics not suitable for this application. It was necessary then to obtain a design for a reflector of simpler construction having better reflecting properties than a single reflector.

A series of measurements were carried out to obtain the design for a suitable antenna. The results of these measurements and the design configuration and parameters are described in this report.

2. EXPERIMENTAL PROCEDURE

For the purpose of determining the best reflector design, a half-wavelength folded dipole was constructed for a measuring frequency of 400 Mc (a scaling factor of 8). The dipole was then mounted on an insulated supporting structure approximately three wavelengths above the ground at the NBS Antenna Range on Table Mesa near Boulder, Colorado. The dipole with its reflector was used for receiving. The target transmitter was approximately 1000 wavelengths away.

A series of measurements was carried out using different receiving antenna reflector configurations, and repeatedly measuring the radiation patterns in the E- and H-plane in order to determine the front-to-back ratio and side-lobe levels. A 20-db front-to-back ratio was set as the design goal instead of the minimum 13-db requirement.

The first series of measurements was carried out to determine the best front-to-back ratio which could be obtained by the use of a single reflector behind the dipole. Radiation patterns were recorded for different combinations of reflector spacing from the dipole and reflector lengths. The highest front-to-back ratio was measured to be approximately 11 decibels.

Further measurements consisted of considerable experimentation with different reflector configurations and reflector lengths. The reflector spacing from the dipole was then set at 0.2λ, which seemed to be generally optimum. The reflectors were then always kept in the same vertical plane for simplicity of design. The experimentation then settled down to be a systematic check of the effect of the number of reflectors, the vertical spacing, and the length combinations.

3. RESULTS

The experimental measurements which were carried out suggested a configuration which would give the required results of a 20-db front-to-back ratio and side-lobe levels at least 20 decibels down from maximum. The design parameters are presented in Figure 3. The resultant E- and H-plane radiation patterns are shown in Figure 4. An additional 0.5 decibel was added to the front-to-back ratio by the use of two additional reflectors of the same length, one spaced 0.4 wavelength above the top reflector and one spaced 0.4 wavelength below the bottom reflector. However, the 0.5 decibel gained is considered to be worth the additional two reflectors required. An additional increase in the front-to-back ratio was obtained with some of the reflector configurations studied, but the side-lobe levels were too high.

It was found that, when an additional reflector was installed directly behind the dipole, between the two reflectors, the radiation patterns deteriorated rather than improved. It was also found that, when an aluminum sheet reflector was installed between the two reflectors, the radiation patterns deteriorated considerably.

Measurements were made to compare the front-to-back ratio obtained by use of the two-reflector configuration shown in Figure 3 with that which can be obtained by the use of an aluminum sheet reflector having a dimension of one wavelength on each side and spaced the same 0.2λ behind the dipole. The front-to-back ratio obtained by the use of the solid sheet reflector is only 16 decibels. This would indicate that a reflector sheet or grid should well exceed one wavelength in order to provide maximum suppression of signals to the rear.

The gain of the dipole with the two reflectors was not measured. However, during the measurements, a gain of at least 5 decibels over a half-wave dipole at the same height was indicated.

Of considerable importance is the frequency bandwidth of the dipole with two reflector elements. While the experimental measurements described did not have the frequency sensitivity as an important item, some measurements were made to determine the deterioration of the pattern (loss of front-to-back ratio and increase in the levels of the side lobes). If the design parameters are held constant and only the frequency changed, a ±2% change in frequency caused a maximum loss of 4 decibels in the front-to-back ratio. However, by either lengthening or shortening the length of each reflector and not changing the other dimensions, a ± 10% change in frequency causes a maximum loss of 4 decibels in the front-to-back ratio.

In order to make the model antenna more compatible with the full-scale antenna to be constructed using parameters based on the model measurements, a scaled model antenna was constructed with a 1"-wide (0.0339λ) vertical metal strap between the two reflectors and a 1"-wide (0.339λ) horizontal member to support the folded dipole. Measurements were made which indicated a required increase in the overall reflector lengths from 0.517λ to 0.529λ in order to obtain the same exact patterns as obtained previously without additional straps or supporting members.

A scaled model of one antenna array, consisting of the three dipoles and their reflectors, has been constructed for measuring the radiation pattern in the vertical plane at a frequency of 1000 Mc. It is anticipated that these measurements will be made when a planned antenna range is constructed which will provide a facility for the high-angle-of-arrival vertical pattern measurements. Figure 5 presents the computed pattern in the vertical plane for the three stacked horizontal dipole units.

Dipole units for two complete antenna arrays were constructed to dimensions based on the measurements on the scaled model antennas. The dipole reflectors were mounted on their supporting members, and the impedance of each dipole unit was individually adjusted to be 52 ohms. The 180° phase shift required for the center dipole unit in the array was obtained by the method of balun and coaxial cable connection. Each set of dipoles and reflectors was then mounted at the required heights on a tower on Table Mesa for the final impedance measurements. Each dipole was connected by equal lengths of RG-17B/U coaxial cable to a junction box. The output impedance of the junction box (approximately 17 ohms) was matched to a 52-ohm coaxial lead-in cable by means of a shorted stub and impedance-matching cable length.

Figures 6 and 7 show different views of the dipole units. The construction material is entirely aluminum alloy. The method of construction of the dipole units is such that they can be conveniently packed for shipment, and assembled and installed with a minimum amount of field work. After the final impedance measurements and adjustments, the dipole units were coded for ease of reassembly and dismantled and shipped to Alaska where they have been installed and are in use for the project.

4. CONCLUSIONS

The antenna array, consisting of the dipole units with the two optimally spaced reflectors behind each dipole, provides a simple, durable and practical antenna type meeting the specific requirements previously described for this antenna. The 20-db side-lobe level and 20-db front-to-back ratio make the antenna practical for uses where these electrical characteristics are more important than gain. The dipole unit may be conveniently used as a component in an antenna array. The physical design configuration is such that it can be mounted on the face of a pole or steel tower. The compact size reduces the wind and ice load areas for weather extremes.

Other uses for this antenna design would be single-channel high-band TV reception and communication antennas where only a single frequency of transmission is used and the bandwidth is sufficient. While the antenna, as designed, is for receiving purposes only, it is also usable as a transmitting antenna type.

5. ACKNOWLEDGMENT

The experimental measurements were carried out with the assistance of Mr. W. L. Martin, the final impedance measurements and adjustments with the additional assistance of Mr. W. B. Hogwood.

6. REFERENCES

1. C. G. Little and H. Leinbach, The riometer - a device for the continuous measurement of ionospheric absorption, Proc. I. R. E., vol. 47, pp 315 - 320, Feb. 1959.

2. C. G. Little and H. Leinbach, Some measurements of high-latitude ionospheric absorption using extraterrestrial radio waves, Proc. I. R. E., vol. 46, pp 334-348, Jan. 1958.

VERTICAL ARRAY

$$E = E_o (\sin X - \sin 3X + \sin 5X)$$

Where $X = 0.64 \cdot 2\pi \sin \Delta$
$H_1 = 0.64 \lambda$

+ and - indicate current polarity

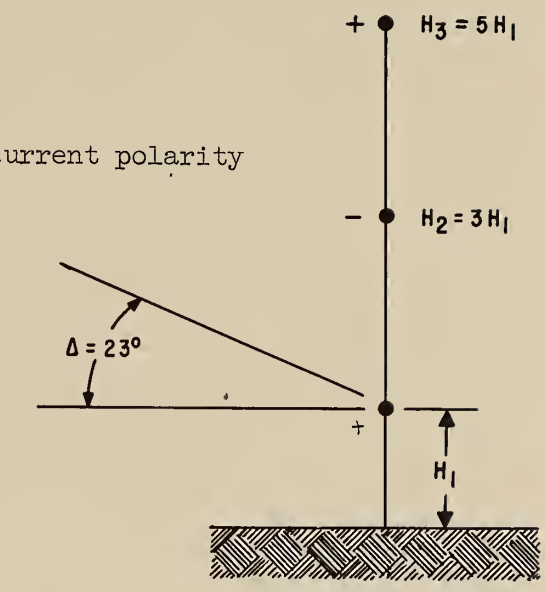

Figure 1

DESIGN DIMENSIONS AND CONFIGURATIONS FOR A VERTICAL STACKED ARRAY OF THREE DIPOLES

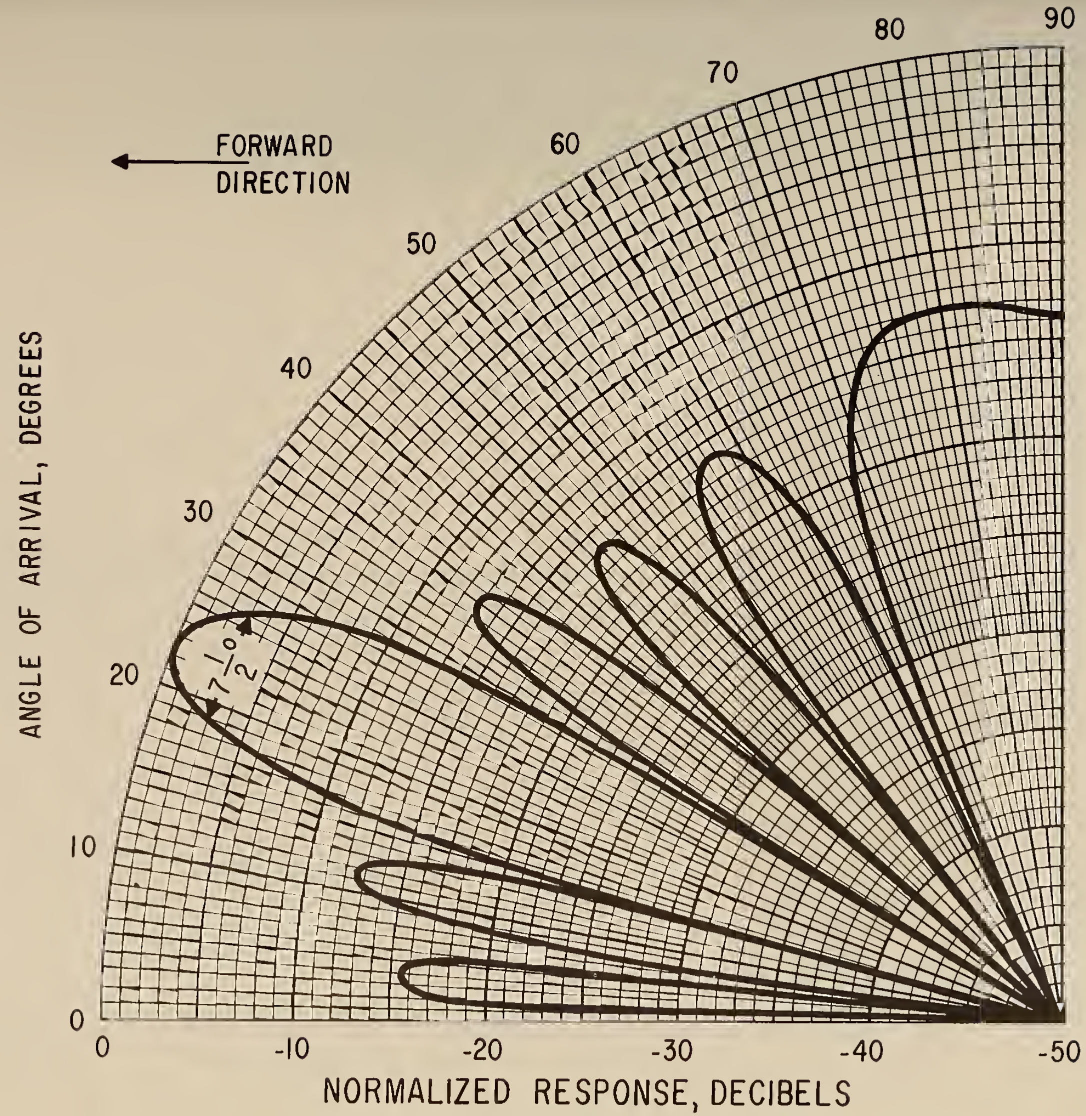

Figure 2

COMPUTED NORMALIZED RESPONSE, DECIBELS, IN THE VERTICAL PLANE IN THE FORWARD DIRECTION FOR A VERTICAL STACKED ARRAY OF THREE DIPOLES

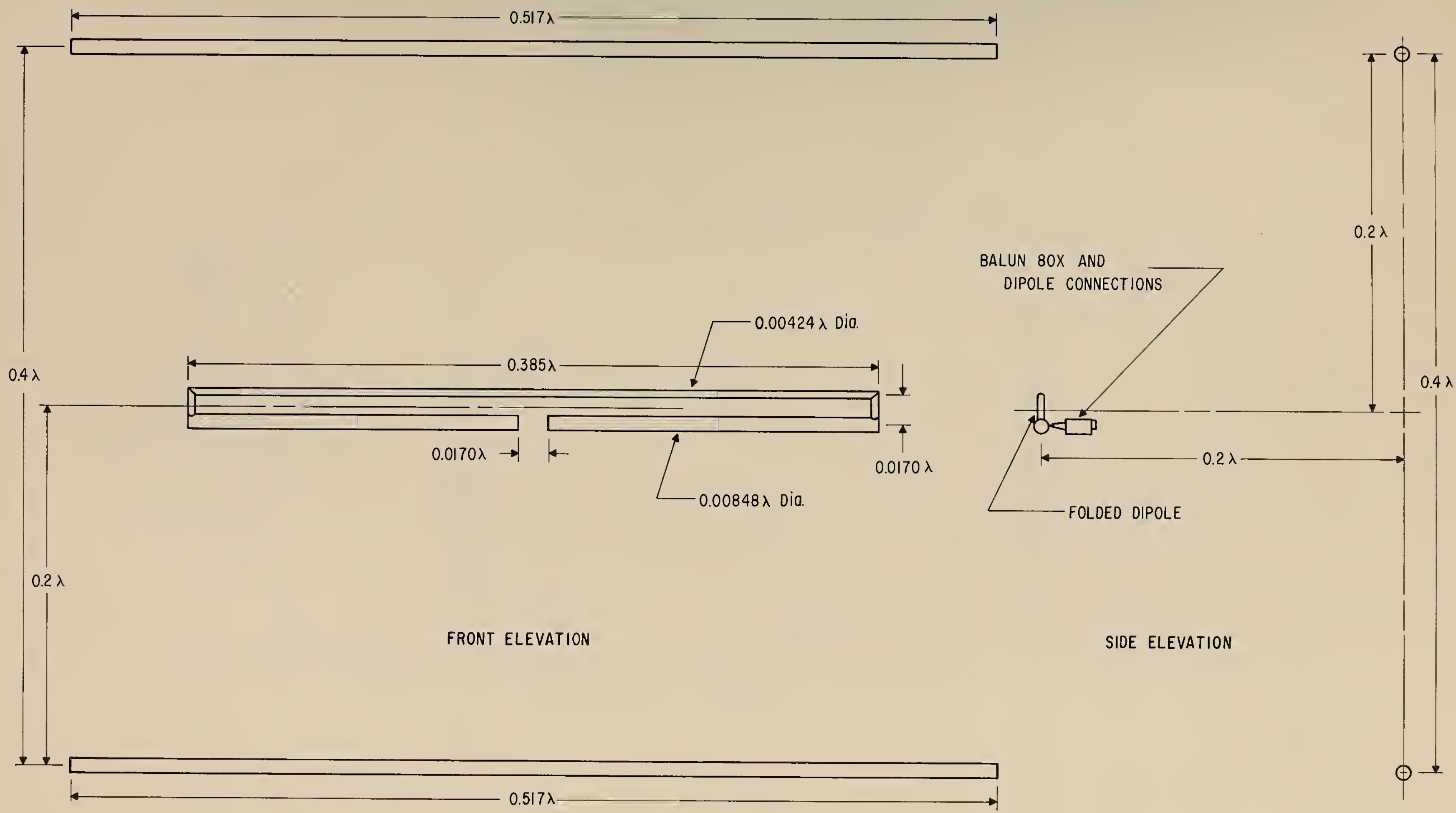

Figure 3

DESIGN DIMENSIONS OF THE BASIC DIPOLE UNIT WITH TWO REFLECTORS

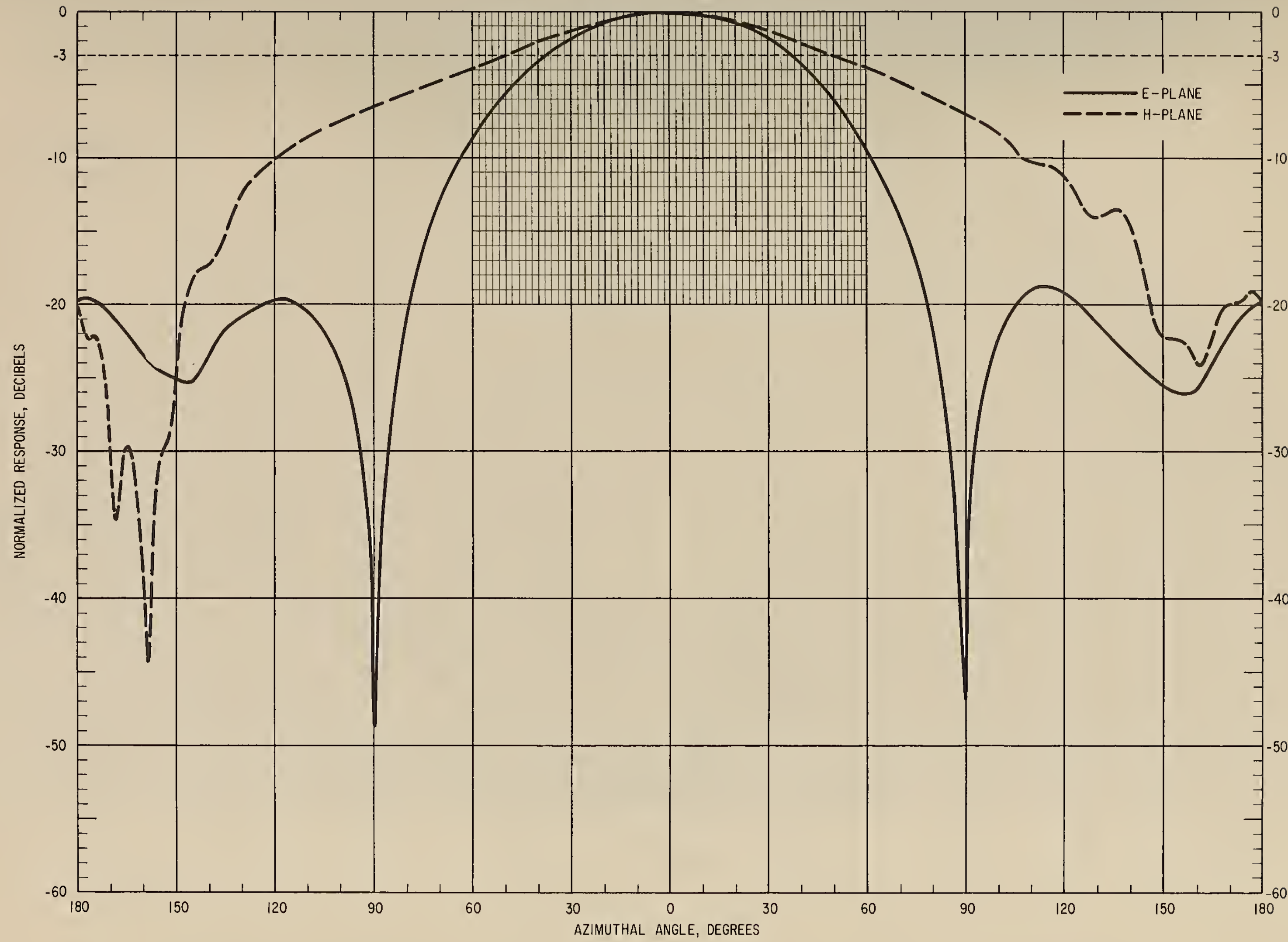

Figure 4

RADIATION PATTERNS IN THE E- AND H-PLANE OF THE BASIC DIPOLE WITH TWO REFLECTORS

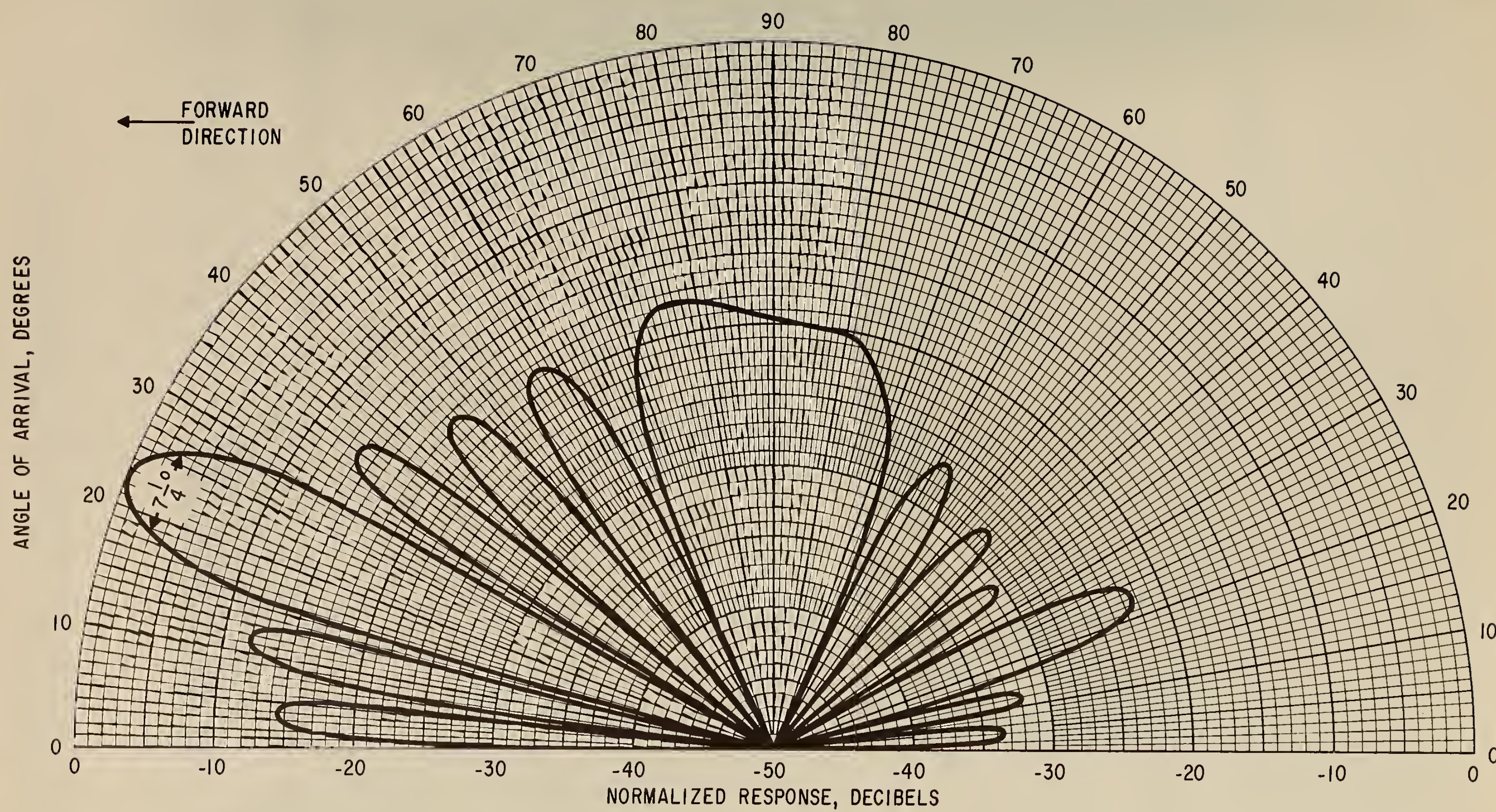

Figure 5

COMPUTED NORMALIZED RESPONSE, DECIBELS, IN THE VERTICAL PLANE FOR THE VERTICAL ARRAY OF THREE DIPOLE UNITS WITH THEIR REFLECTORS

Figure 6

A VIEW OF THE THREE DIPOLE UNITS MOUNTED ON A TOWER FOR IMPEDANCE MEASUREMENTS AND ADJUSTMENTS

Figure 7

A VIEW OF THE THREE DIPOLE UNITS MOUNTED ON A TOWER FOR IMPEDANCE MEASUREMENTS AND ADJUSTMENTS

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