Radant Analysis Studies

Interim Report No. 4

1 June through 31 August 1966

C. T. Tai

September 1966

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Prepared for

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Research and Technology Division, AFSC
Wright-Patterson Air Force Base, Ohio 45433

FOREWORD

This report was prepared by The University of Michigan under contract No. AF 33(615)-2811, Task 416103, Project 4171. The work was administered under the direction of the Air Force Avionics Laboratory, Research and Technology Division, Air Force Systems Command: E. M. Turner, Technical Monitor; S. Pitts, Project Engineer.

This report covers the work conducted from June through August, 1966.

ABSTRACT

In this fourth interim report, the planned experimental program is discussed, and preliminary results given for the effectiveness of the radant structure as a polarization transformer. The preliminary results indicate that there are critical frequencies at which the cross-polarized field slightly exceeds the like-polarized field, and approaches to within 3 db of the incident field.

I
INTRODUCTION

The main activity during this period involved the fabrication of the 196-element radant and the supporting structure, and preliminary transmission tests of the radant. An experimental program has been outlined, and will be presented here. The purpose of the program is to determine the transmission and cross-polarization effects of the radant, which consists of two 36-inch square panels of parallel dipoles oriented perpendicular to each other, and connected by transmission lines (Fig. 1).

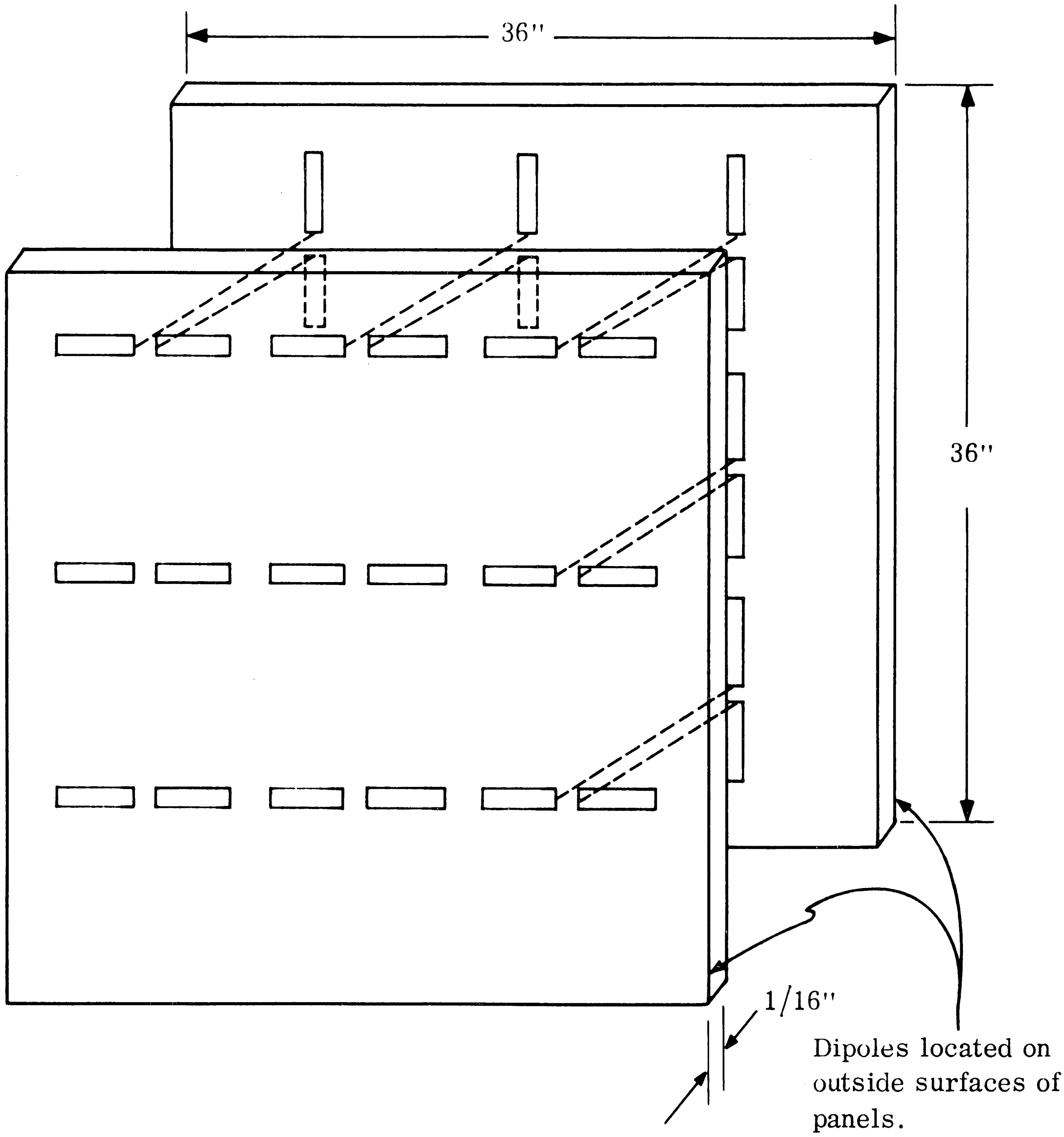

FIG. 1: ORIENTATION OF DIPOLE ARRAYS
(only 9 dipole pairs shown for clarity).

II
FABRICATION OF RADANT AND SUPPORTING STRUCTURE

The design data for the radant was given in the third interim report. It consists of two panels of 196 dipoles each, imprinted on a 36-inch square, 1/16 inch fiberglass board, shown in Fig. 2. The two panels are oriented parallel to each other but in such a way that each (vertical) dipole on one is connected by a two-wire transmission line one inch long to a (horizontal) dipole on the other. The transmission lines are made of AWG-20 wire separated by 0.06 inch, corresponding to an impedance of 160 ohms. Rather than twist the wires, it was decided to modify the feed region of the dipoles as shown in Fig. 3.

For strength, the radant has been enclosed in a wooden frame (Fig. 4). This fits snugly into a vertical supporting rack, which is free to run forward and back along a track parallel to the line joining the transmitting and receiving antennas, as shown in Fig. 5. The track allows continuous adjustment of the spacing between radant and receiving antenna. The whole system is mounted on an antenna platform and can be rotated through the azimuth plane; that is, the angle ϕ of Fig. 5 can be varied continuously.

One of the difficulties encountered in the fabrication was the practical unfeasibility of attaining a two-wire transmission line having a characteristic impedance of 50 ohms, which is the measured impedance of an individual element at the design frequency of 3.0 GHz (see Interim Report No. 3). The final design uses transmission lines having an impedance of about 160 ohms. Thus there is an inherent mismatch at the terminals, corresponding to a power reflection coefficient of 0.28. Use of folded dipole elements has been suggested to effect a better match, and impedance data taken on an individual element indicate an impedance near 140 ohms at 3.0 GHz. Future designs may incorporate these if the problem proves critical.

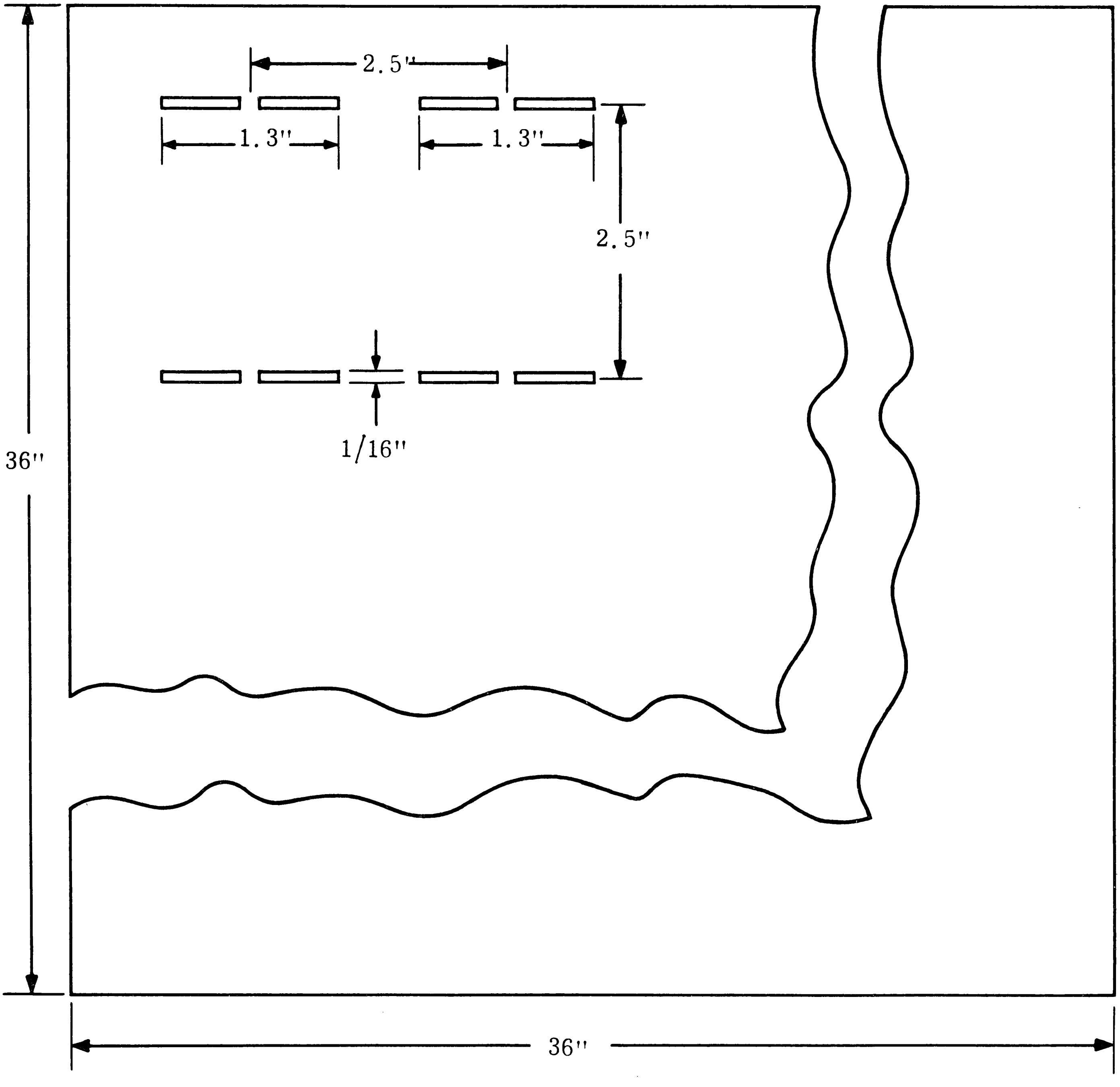

FIG. 2: ARRANGEMENT OF DIPOLE ELEMENTS OF FIBERGLASS PANEL.

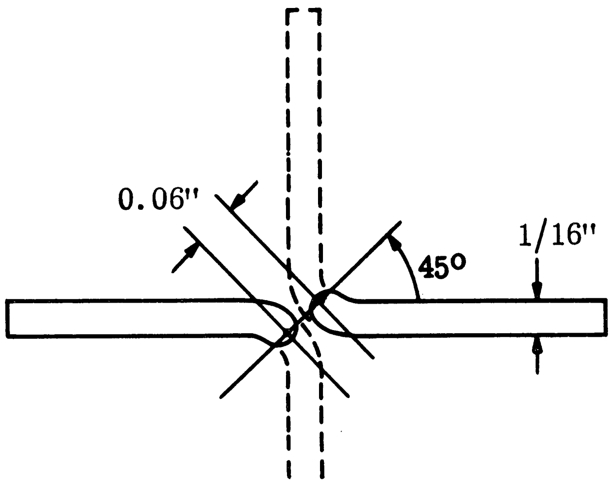

FIG. 3: RADANT DIPOLE ELEMENT

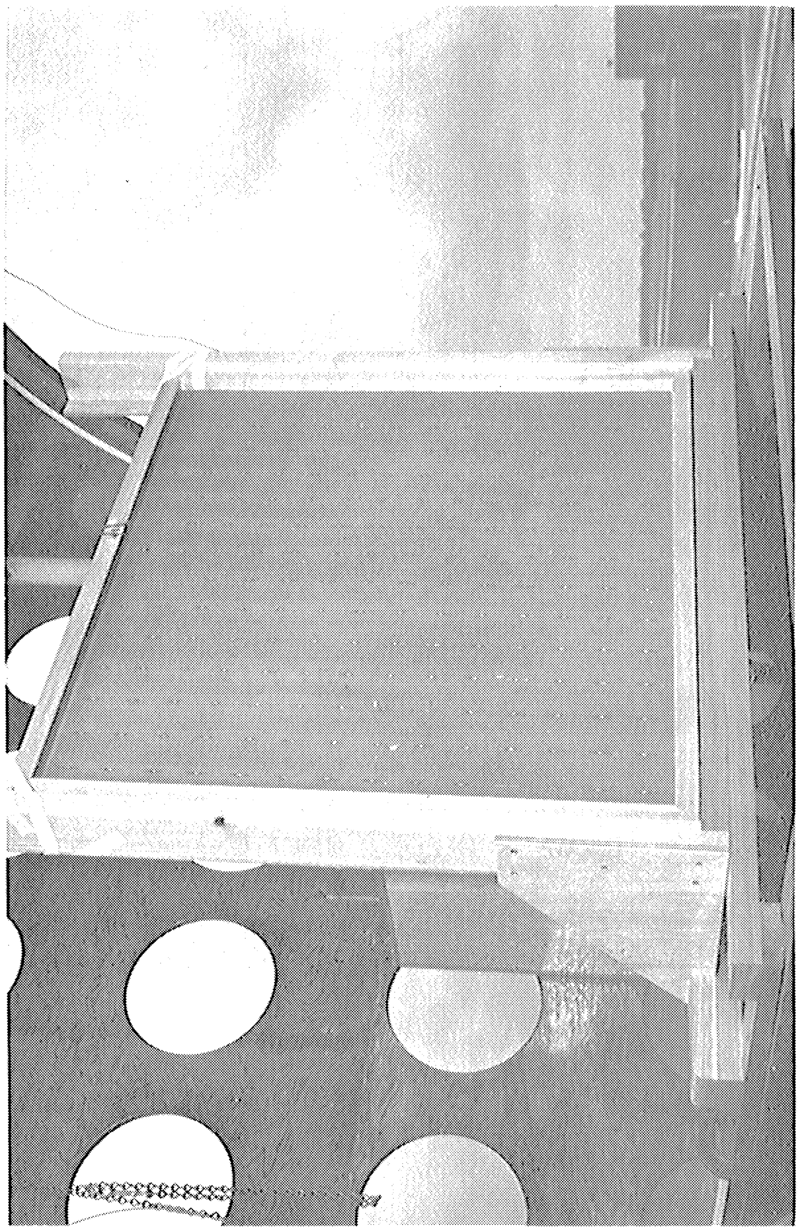

FIG. 4: RADANT IN WOODEN FRAME.

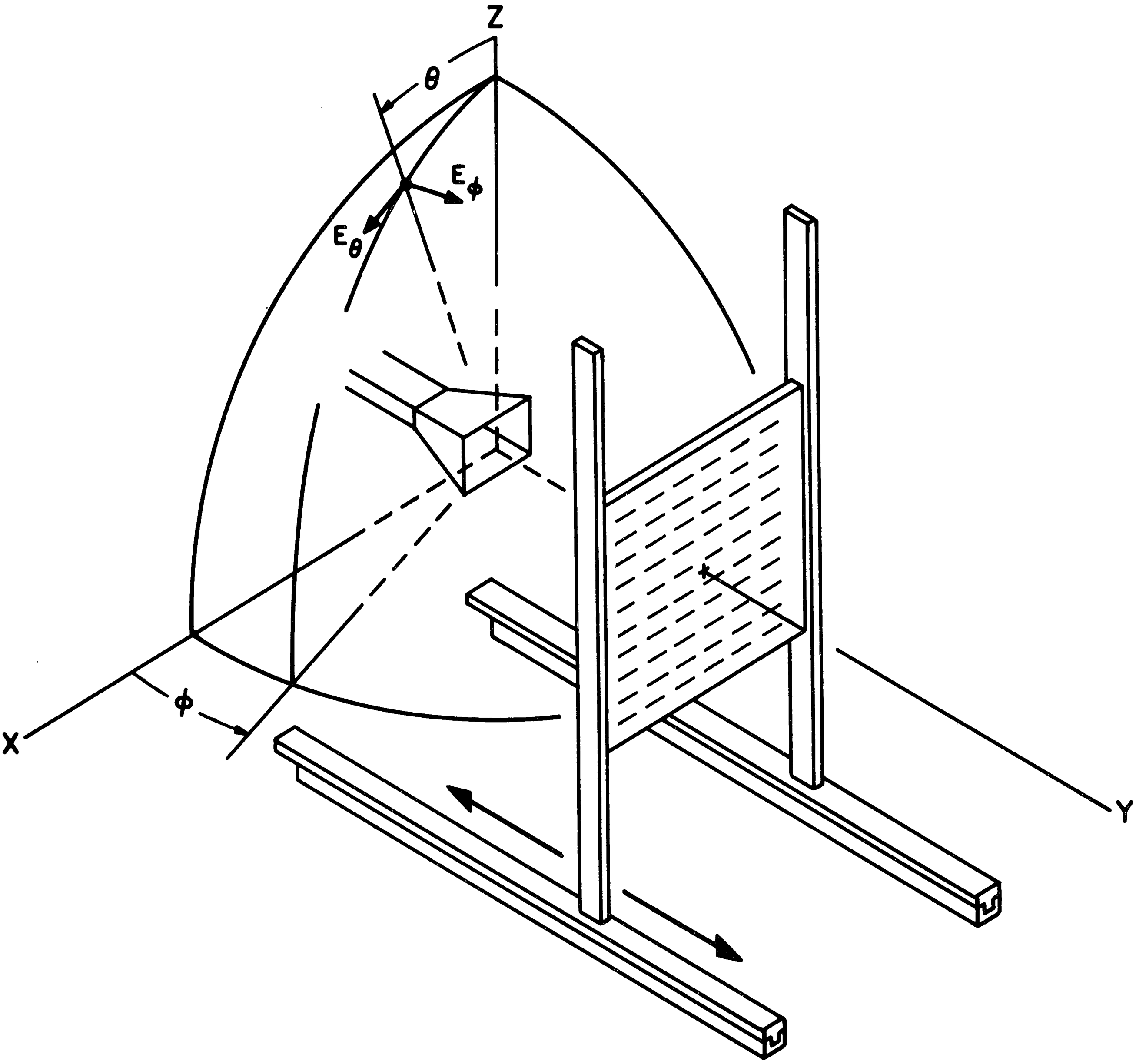

FIG. 5: SPHERICAL COORDINATE SYSTEM FOR RADANT STUDY

III
EXPERIMENTAL PROGRAM

The frequency of the transmitting source is to be varied over the band 100-3000 MHz to determine the frequency bands at which the radant produces a large cross-polarized component. Initially the spacing between the radant and receiving horn is to be 15 inches. Data is to be taken with the transmitting antenna vertically polarized, and the receiving antenna both vertically and horizontally polarized. Sweep equipment is available between the frequencies of 1000 MHz and 4000 MHz and can be instrumental in determining critical frequencies. Pattern data is to be obtained at least every 100 MHz over the band.

Once critical frequency bands are established, additional information will be sought: the effect of spacing variations between radant and receiving antenna, and the effect of rotation of the transmitting and/or the receiving antennas. If it is possible, other designs of radants will be considered, involving other spacings and elements.

IV
PRELIMINARY RESULTS

Patterns taken at the design frequency of 3.0 GHz are shown in Figs. 6 and 7, using Table I. Figure 6a shows that the cross-polarized component of the field with the radant removed is well down into the noise, so that the cross-polarized signals observed in Figs. 6b and 6c are indeed caused by the radant. The difference between the conditions of Fig. 6b and 6c is that the radant has been rotated by 90°. The marked difference in the patterns indicates an appreciable effect due to the dielectric sheets. Comparison of the signals in Figs. 6b and 6c at nose-on incidence, or 0° with the nose-on levels of Fig. 7a indicates that the cross-polarized component is 17-20 db below the incident signal, much lower than had been anticipated in the discussion in Interim Report No. 3. (Note that the two patterns cannot be directly compared since they represent different pattern cuts of the receiving antenna.) Figures 7b and 7c have the same order of magnitude and pattern beamwidth (24°) as the incident pattern of 7a, confirming that little energy has been transferred to the cross-polarized field.

Sweep-frequency data was taken from 2.2 GHz to 4.0 GHz and indicated that strong polarization transformation takes place at 3.63 GHz and to a lesser extent at 2.55 GHz, but not around 3.0 GHz. Patterns were then taken at 3.63 GHz, and are shown in Figs. 8a-8c. At nose-on incidence the cross-polarized component comes to within 3 db of the incident power, and slightly exceeds that of the like-polarized component. Patterns taken at close frequencies indicate a bandwidth of 0.11 GHz, or about 3 percent. These results are very close to what had been anticipated, and indicate that a large part, about half, of the power incident on the radant is reradiated via the transmission lines.

A possible explanation for the shift in frequency is that since the actual transmission lines are not well matched to the dipole elements, there are probably other frequencies at which the match is good. Impedance data on the individual elements reported in Interim Report No. 3, suggests that this may be the case. The frequency band of that data was only from 2.2 GHz to 3.3 GHz, and so is not sufficient to verify this. Impedance data over a wider frequency range will be taken in the next period.

TABLE I: CONFIGURATION DESIGNATION

V	V	H	H
Polarization of Transmitting Antenna.	Polarization of Radant Dipoles Nearest Transmitter.	Polarization of Radant Dipoles Nearest Receiver.	Polarization of Receiving Antenna.

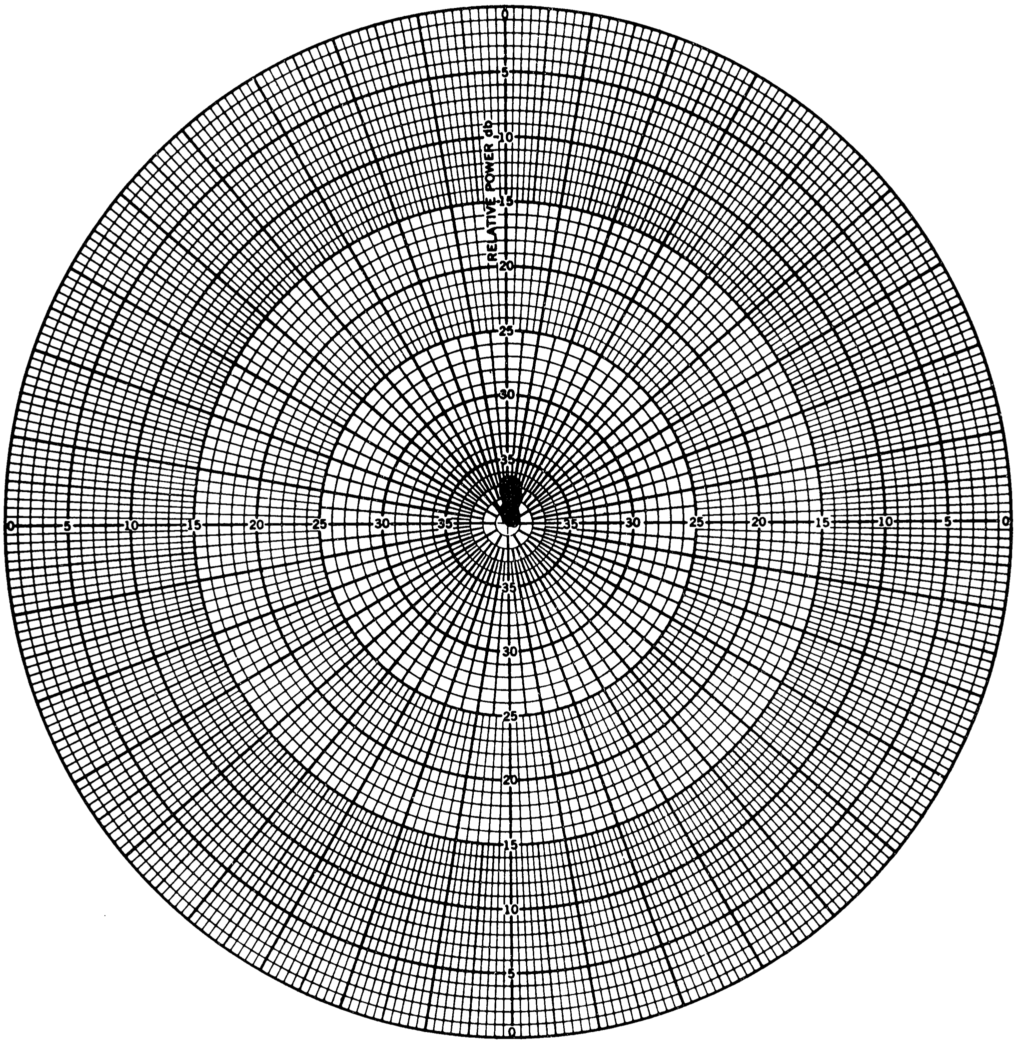

FIG. 6a: CROSS-POLARIZED INCIDENT PATTERN.

Freq. 3.0 GHz. Radant Support to Antenna Spacing: 15 inches. Configuration Designation: V--H. Antenna to Antenna Spacing: 290 Ft. Pattern Description: E-Plane Cut. Transmitting Antenna: 6' Parabolic Dish, Splash Plate Feed. Receiving Antenna: Scientific Atlanta Type 2.6, 10 cm Gain Standard Horn.

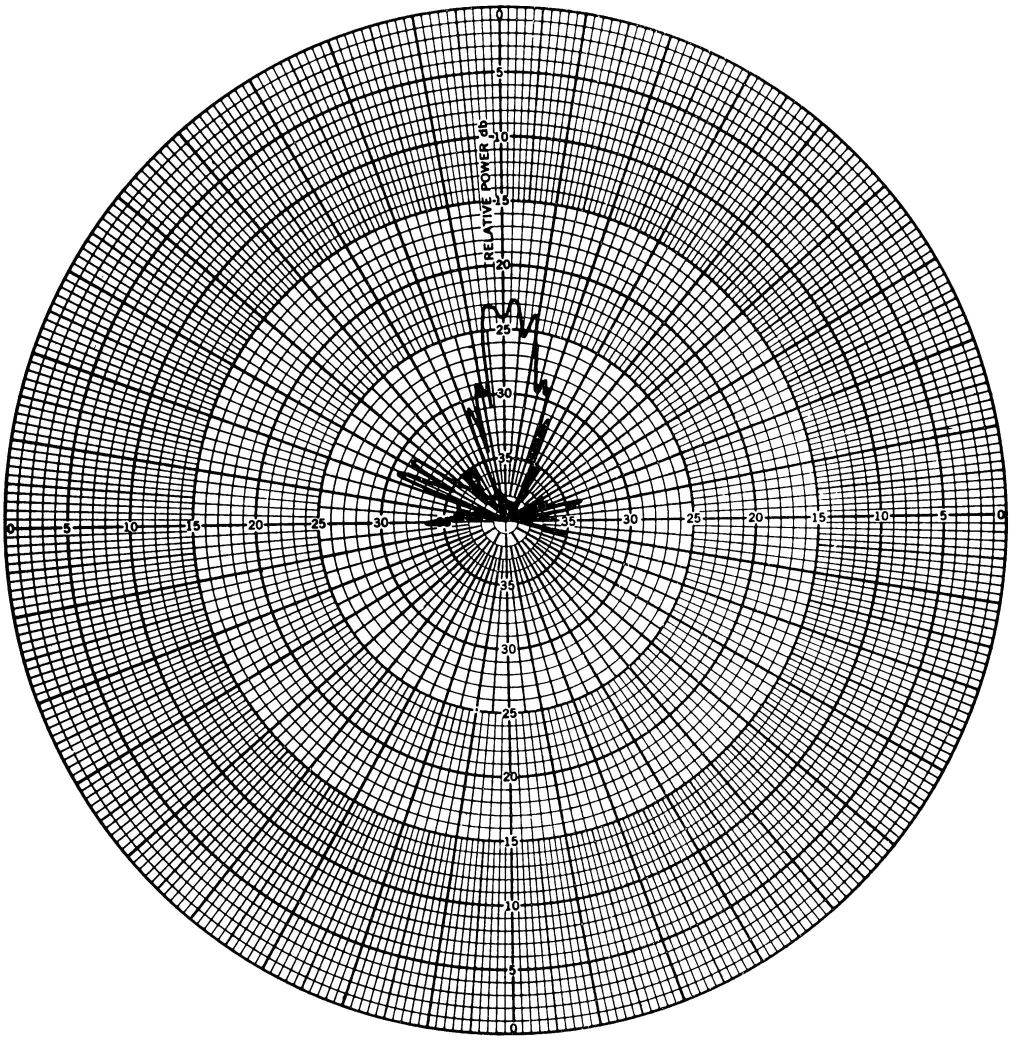

FIG. 6b: CROSS-POLARIZED RADANT PATTERN.

Freq. 3.0 GHz. Radant to Antenna Spacing: 15 inches. Configuration Designation: VVHH. Antenna to Antenna Spacing: 290 Ft. Pattern Description: E-Plane Cut. Transmitting Antenna: 6' Parabolic Dish, Splash Plate Feed. Receiving Antenna: Scientific-Atlanta Type 2.6, 10 cm Gain Standard Horn.

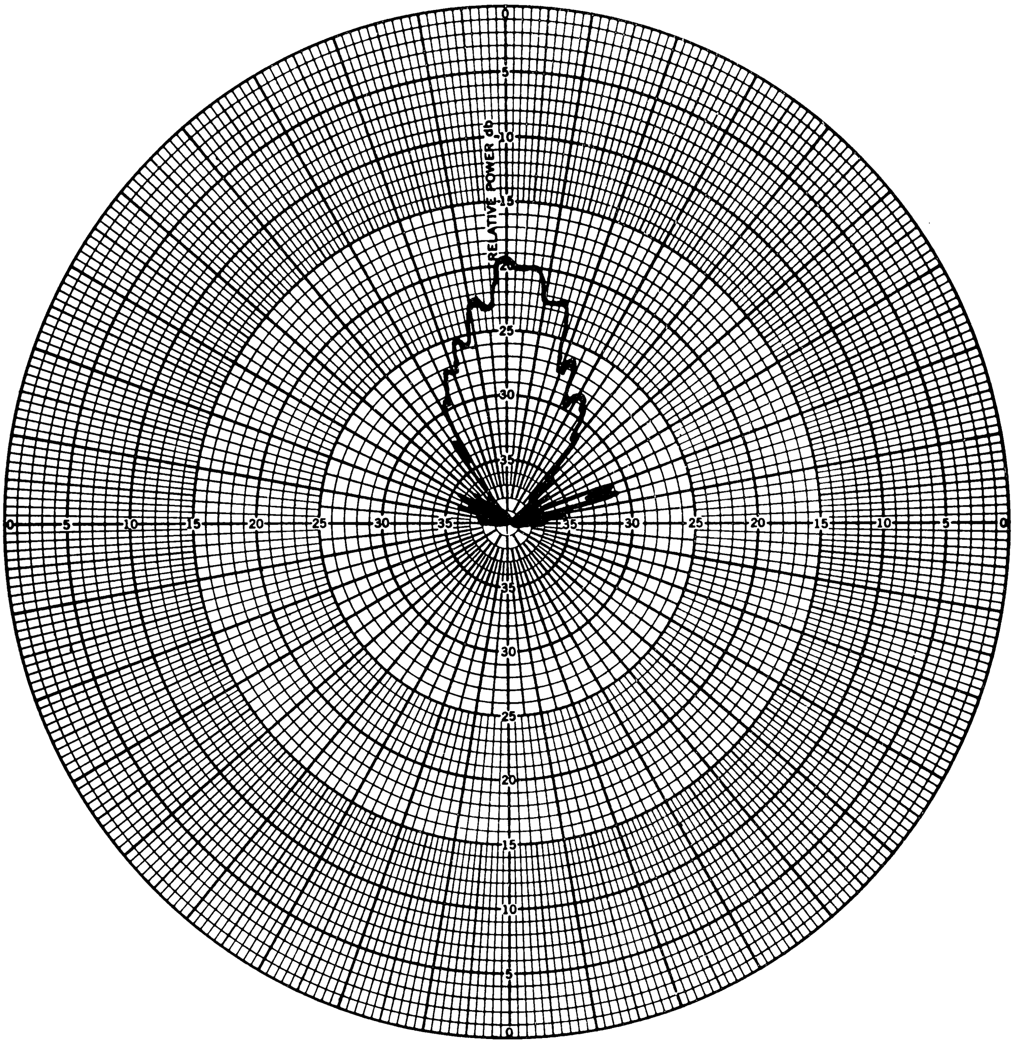

FIG. 6c: CROSS-POLARIZED RADANT PATTERN.

Freq. 3.0 GHz. Radant to Antenna Spacing: 15 inches. Configuration Designation: VHVH. Antenna to Antenna Spacing: 290 Ft. Pattern Description: E-Plane Cut. Transmitting Antenna: 6' Parabolic Dish, Splash Plate Feed. Receiving Antenna: Scientific Atlanta Type 2.6, 10 cm Gain Standard Horn.

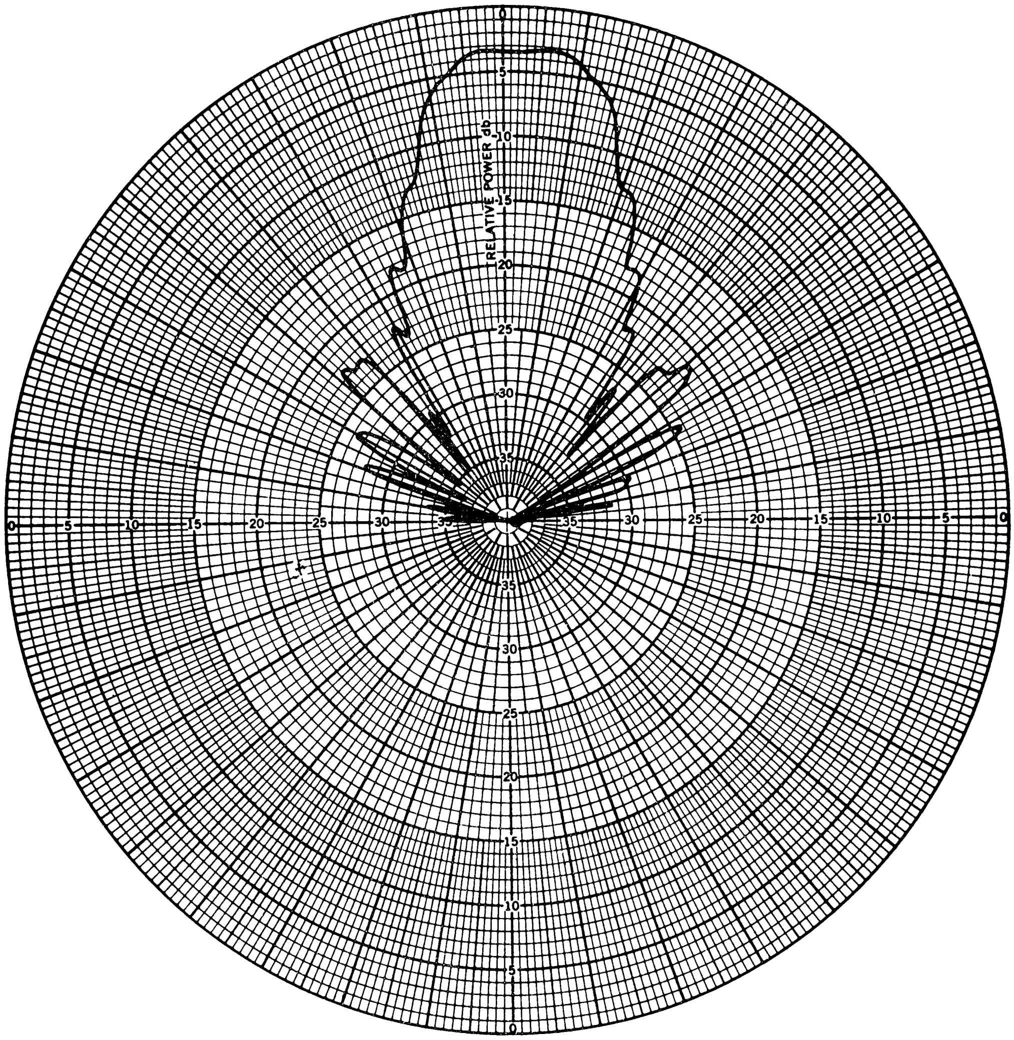

FIG. 7a: LIKE-POLARIZED INCIDENT PATTERN.

Freq. 3.0 GHz. Radant Support to Antenna Spacing: 15 inches. Configuration Designation: V--V. Antenna to Antenna Spacing: 290 Ft. Pattern Description: H-Plane Cut. Transmitting Antenna: 6' Parabolic Dish, Splash Plate Feed. Receiving Antenna: Scientific-Atlanta Type 2.6, 10 cm Gain Standard Horn.

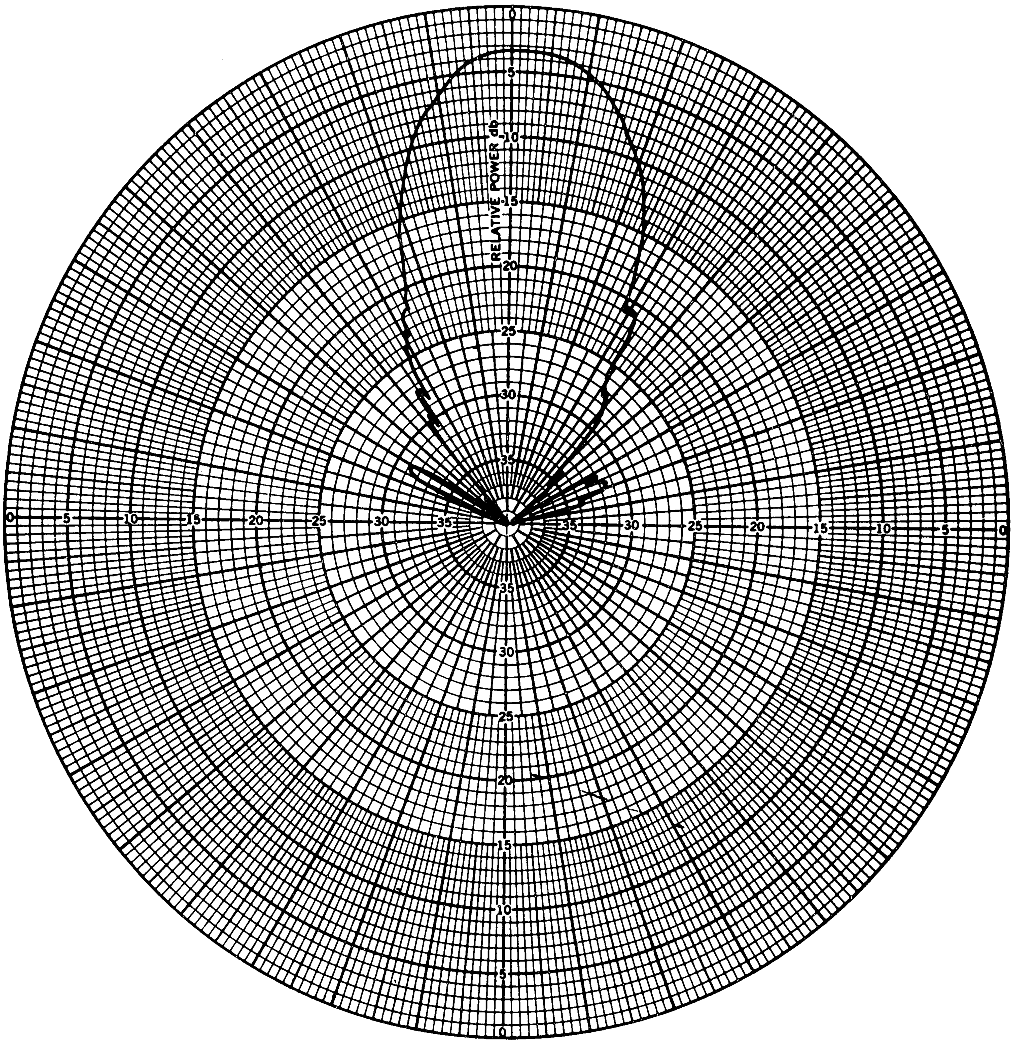

FIG. 7b: LIKE-POLARIZED RADANT PATTERN

Freq. 3.0GHz. Radant to Antenna Spacing: 15 inches. Configuration Designation: VVHV. Antenna to Antenna Spacing: 290 Ft. Pattern Description: H-Plane Cut. Transmitting Antenna: 6' Parabolic Dish, Splash Plate Feed. Receiving Antenna: Scientific Atlanta Type 2.6, 10cm Gain Standard Horn.

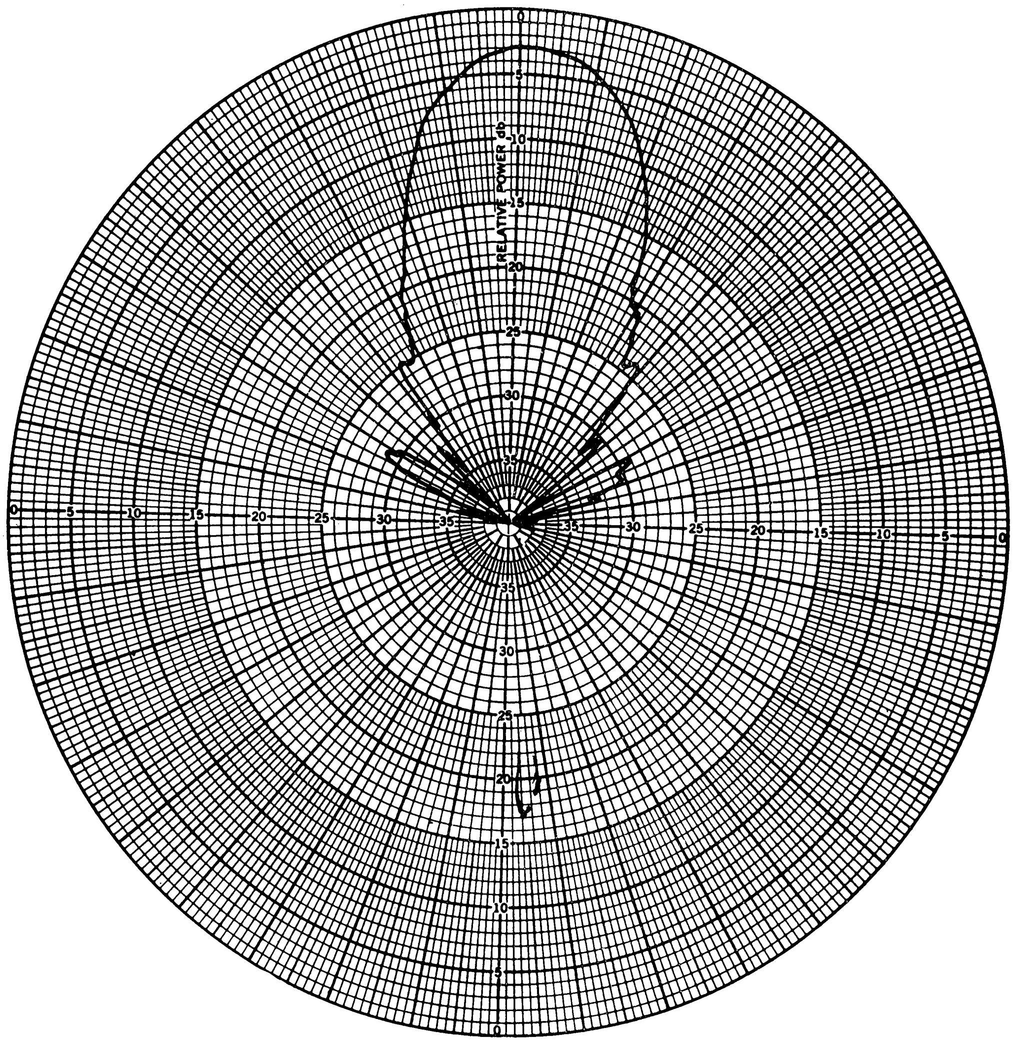

FIG. 7c: LIKE-POLARIZED RADANT PATTERN.

Freq. 3.0 GHz. Radant to Antenna Spacing: 15 inches. Configuration Designation: VHVV. Antenna to Antenna Spacing: 290 Ft. Pattern Description: H-Plane Cut. Transmitting Antenna: 6' Parabolic Dish, Splash Plate Feed. Receiving Antenna: Scientific Atlanta Type 2.6, 10 cm Gain Standard Horn.

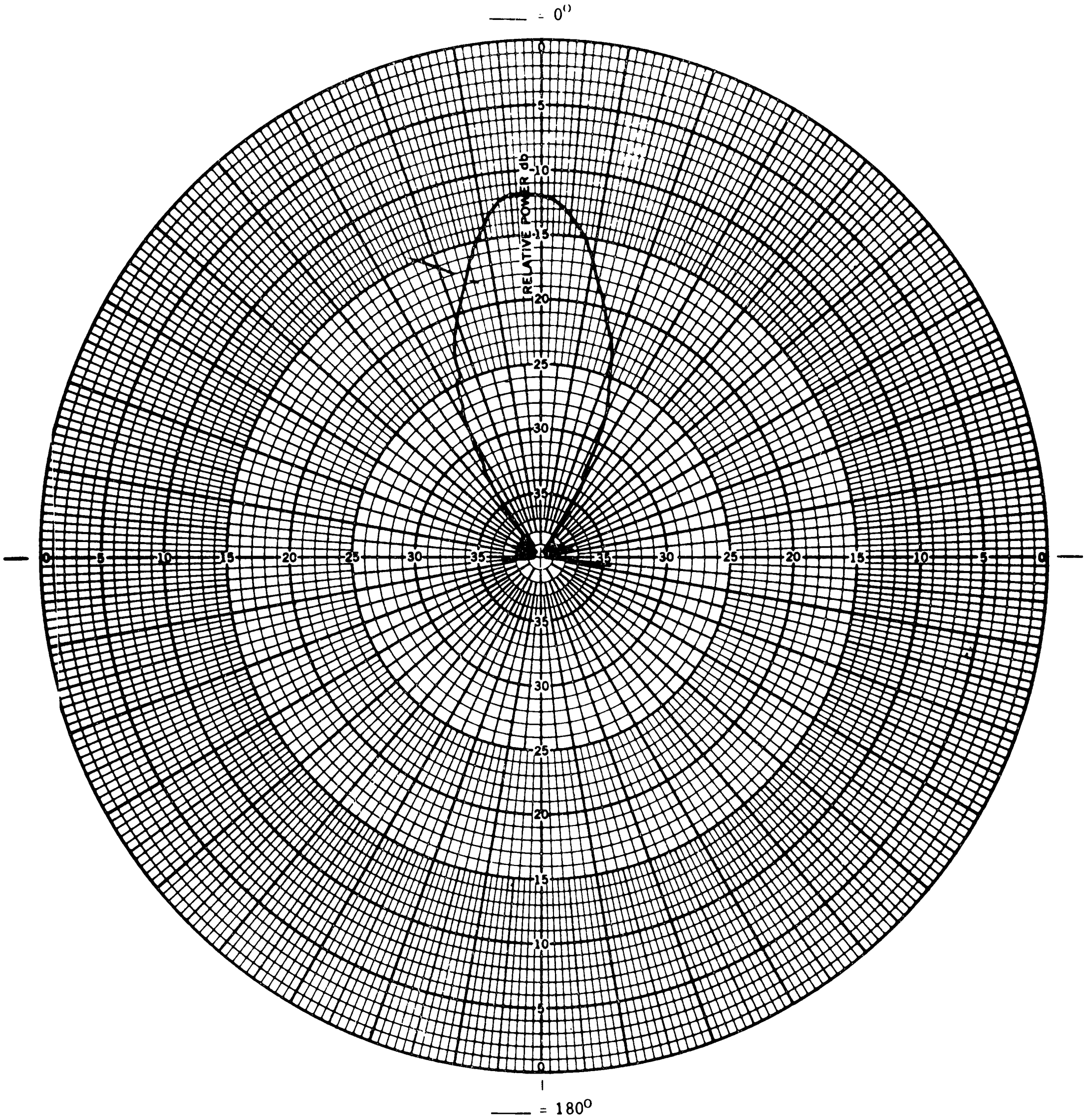

FIG. 8a: LIKE-POLARIZED INCIDENT PATTERN

Freq. 3.625 GHz. Radant to Antenna Spacing: 15 inches. Configuration Designation: V--V. Antenna to Antenna Spacing: 70 Ft. Pattern Description: H-Plane Cut. Transmitting Antenna: Narda Type 644 Horn. Receiving Antenna: Scientific- Atlanta Type 2.6, 10 cm Gain Standard Horn.

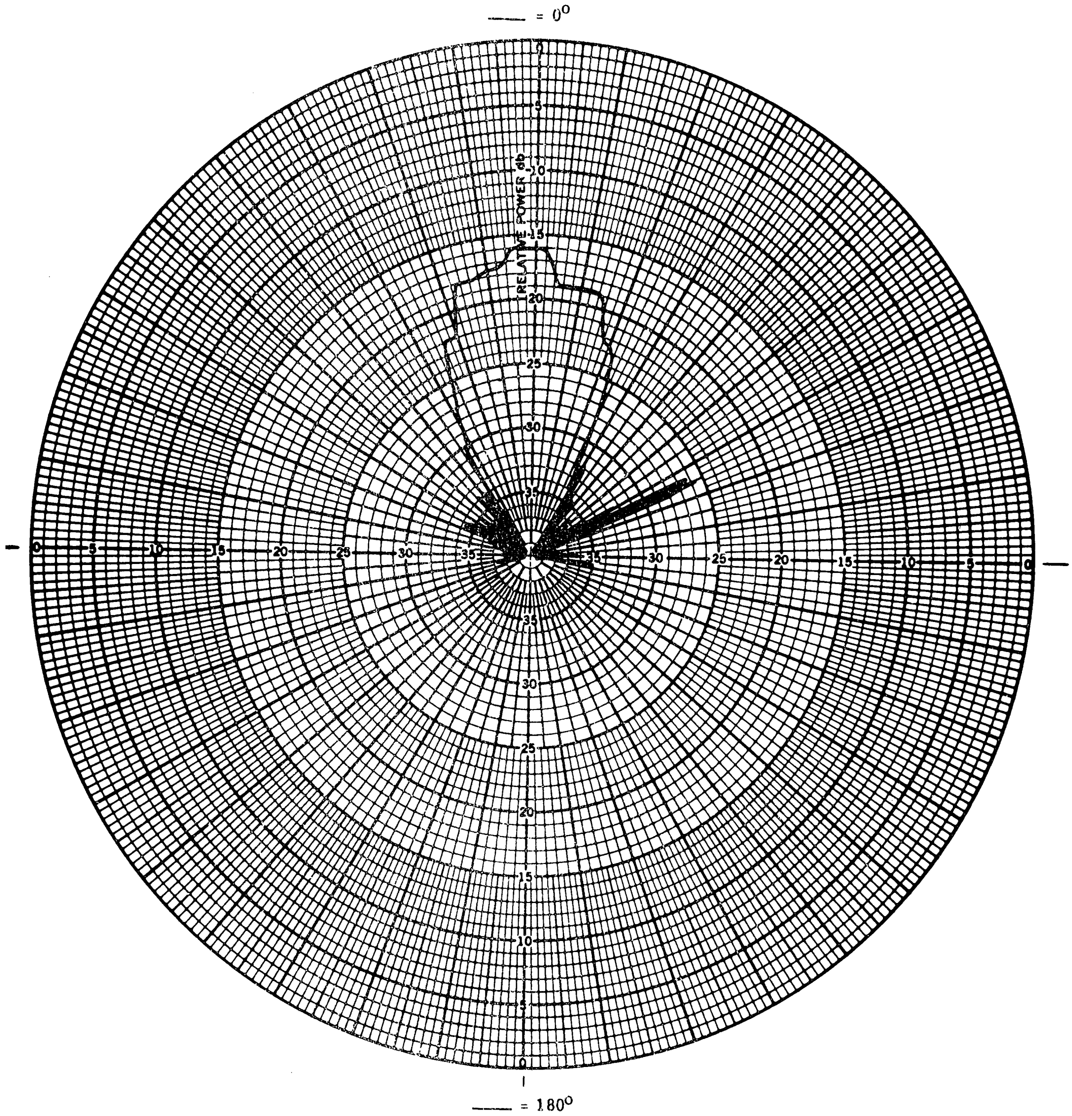

FIG. 8b: LIKE-POLARIZED RADANT PATTERN

Freq. 3.625 GHz. Radant to Antenna Spacing: 15 inches. Configuration Designation: VVHV. Antenna to Antenna Spacing: 70 Ft. Pattern Description: H-Plane Cut. Transmitting Antenna: Narda Type 644 Horn. Receiving Antenna: Scientific-Atlanta Type 2.6, 10 cm Gain Standard Horn.

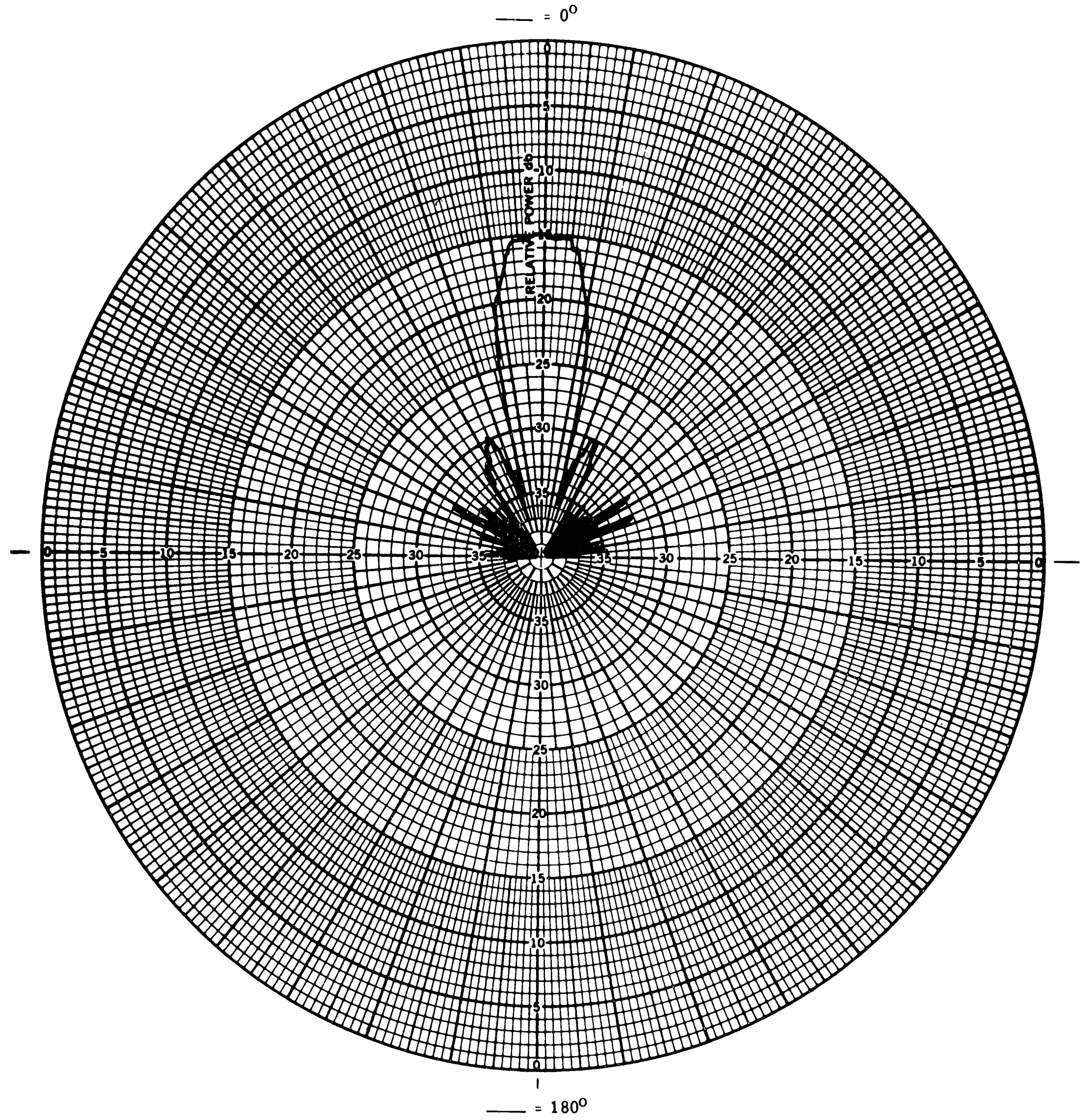

FIG. 8c: CROSS-POLARIZED RADANT PATTERN.

Freq. 3.625 GHz. Radant to Antenna Spacing: 15 inches. Configuration Designation: VVHH. Antenna to Antenna Spacing: 70 Ft. Pattern Description: E-Plane Cut. Transmitting Antenna: Narda Type 644 Horn. Receiving Antenna: Scientific-Atlanta Type 2.6, 10 cm Gain Standard Horn.

V
FUTURE WORK

During the next period, experimental work will proceed as outlined in Section III, covering frequency ranges above and below those reported here. The theoretical model developed in Interim Report No. 3 is presently being extended and applied to the scattering properties of a pair or dipoles joined by a transmission line. Calculations, not reported here, have yielded figures in approximate agreement with the observed behavior. The more refined model, which uses measured impedance data, is expected to determine the extent to which the two-dipole configuration is related to the radant panel and provide design criteria. Further impedance data will be taken on individual elements to supplement this effort.

VI
ACKNOWLEDGMENTS

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13. ABSTRACT

In this fourth interim report, the planned experimental program is discussed, and preliminary results given for the effectiveness of the radant structure as a polarization transformer. The preliminary results indicate that there are critical frequencies at which the cross-polarized field slightly exceeds the like-polarized field, and approaches to within 3 db of the incident field.

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