PHYSICAL SCIENCE LABORATORY

NEW MEXICO STATE UNIVERSITY

University Park, New Mexico

Spacecraft Antenna Design Study (OAO)

Scientific Report No. 1

RADIATION TESTS FOR ORBITING ASTRONOMICAL OBSERVATORY

Project Engineer: D. G. Henry
Assistant Engineer

Approved: H. W. Haas, Engineer
Supervisor, Antenna Group

May 1962

Task B-I X
NAS 5-1032

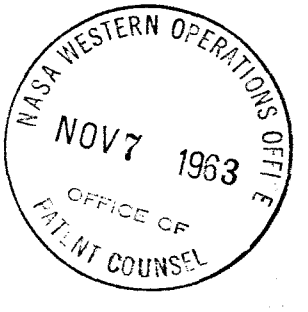

TABLE OF CONTENTS

ILLUSTRATIONS

1.0 INTRODUCTION

The National Aeronautics and Space Administration has requested the Physical Science Laboratory of New Mexico State University to conduct tests on the VHF and UHF antennas to be used on the Orbiting Astronomical Observatory (OAO). These tests are to include radiation pattern measurements, efficiency degradation of the VHF antennas due to the presence of the solar cells, and efficiency degradation of the UHF antennas when mounted on the porcelain enameled aluminum skin of the spacecraft.

These tests are to be conducted on the antennas presently designed for use on the spacecraft.

2.0 SPACECRAFT MOCKUP

The OAO spacecraft was modeled due to its large size. A one-quarter scale model mockup was made for radiation pattern measurements. (Fig. 1) The solar paddles were made of solid aluminum and the body of the spacecraft model was not enameled.

3.0 MODEL ANTENNAS

3.1 UHF Antennas

The UHF antennas consisted of a pair of "pitchfork" (double folded monopole) antennas mounted diametrically opposite on the body of the spacecraft. The antennas are mounted at right angles to the solar planes. One antenna is mounted along the axis of the mockup and the other is mounted at right angles to the axis. The mounting arrangement of the UHF antennas is shown in Fig. 2. A drawing of the "pitchfork" antenna is shown in Fig. 3. The impedance of the antennas when matched is given in Fig. 4. The frequencies shown in Fig. 4 are the scale frequencies.

3.2 VHF Antennas

The VHF antennas are resonant one-half wavelength slots cut in the solar planes. The slots are cut so that the long dimension of one is parallel to the spacecraft axis and the other is at right angles to the spacecraft axis. The location of the slots is shown in Fig. 2. The VHF antennas are used for telemetry, tracking, and command control. The telemetry and tracking frequencies are approximately 136 Mc while the command control frequency is approximately 148 Mc. Impedances are shown for both scale frequencies in Fig. 5.

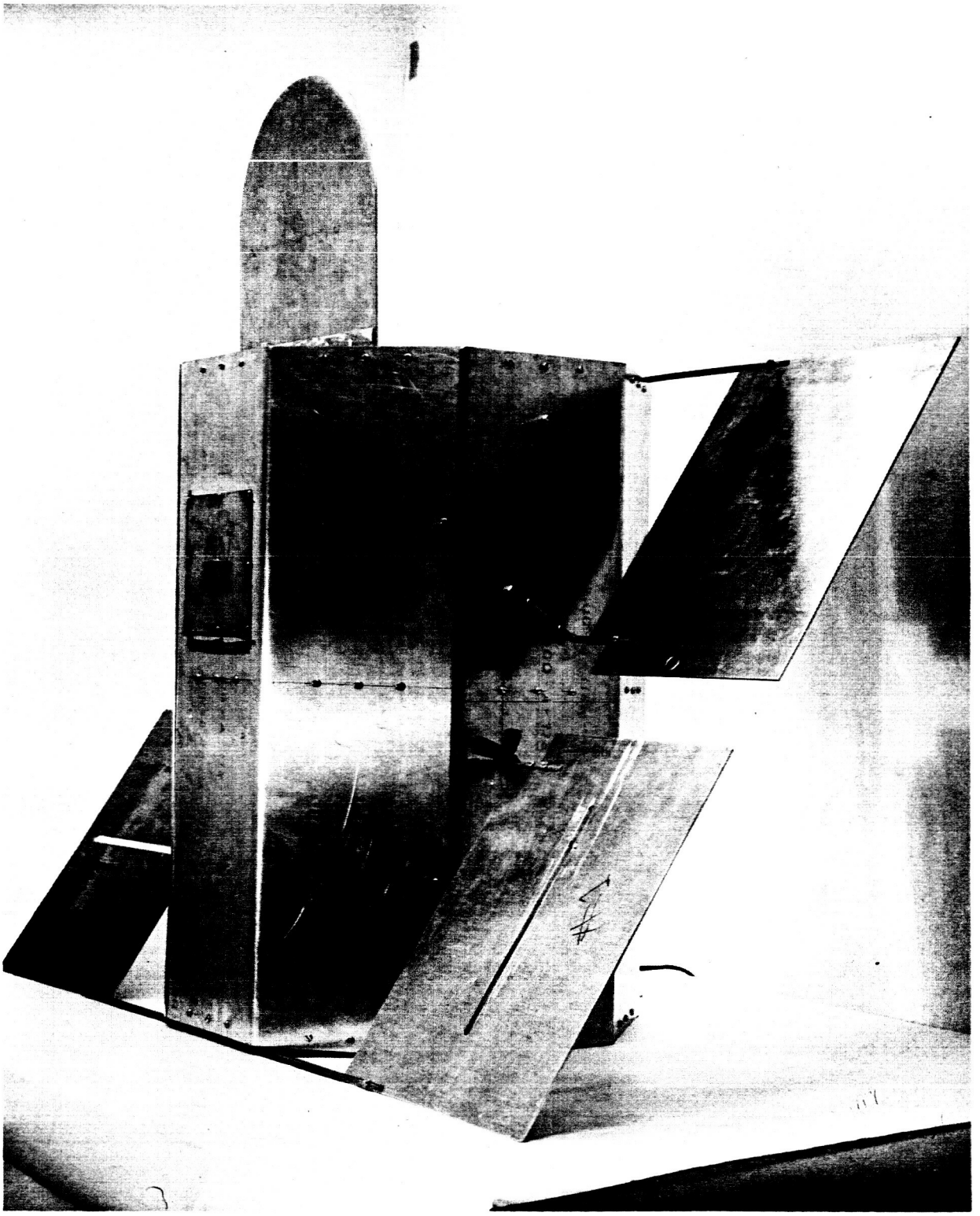

FIG. 1 - OAO 1/4 SCALE MOCKUP

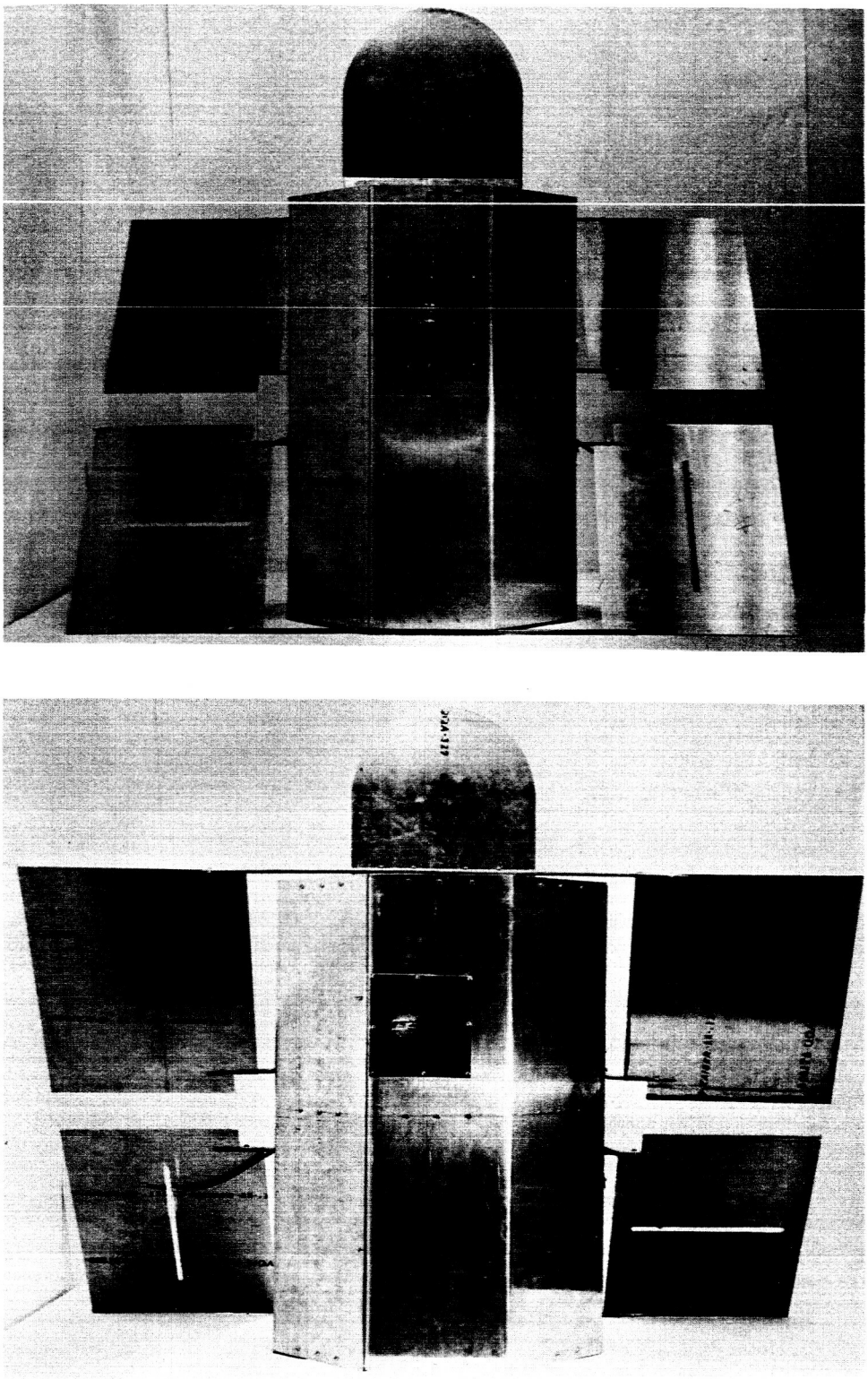

FIG. 2 - ANTENNAS ON OAO MOCKUP

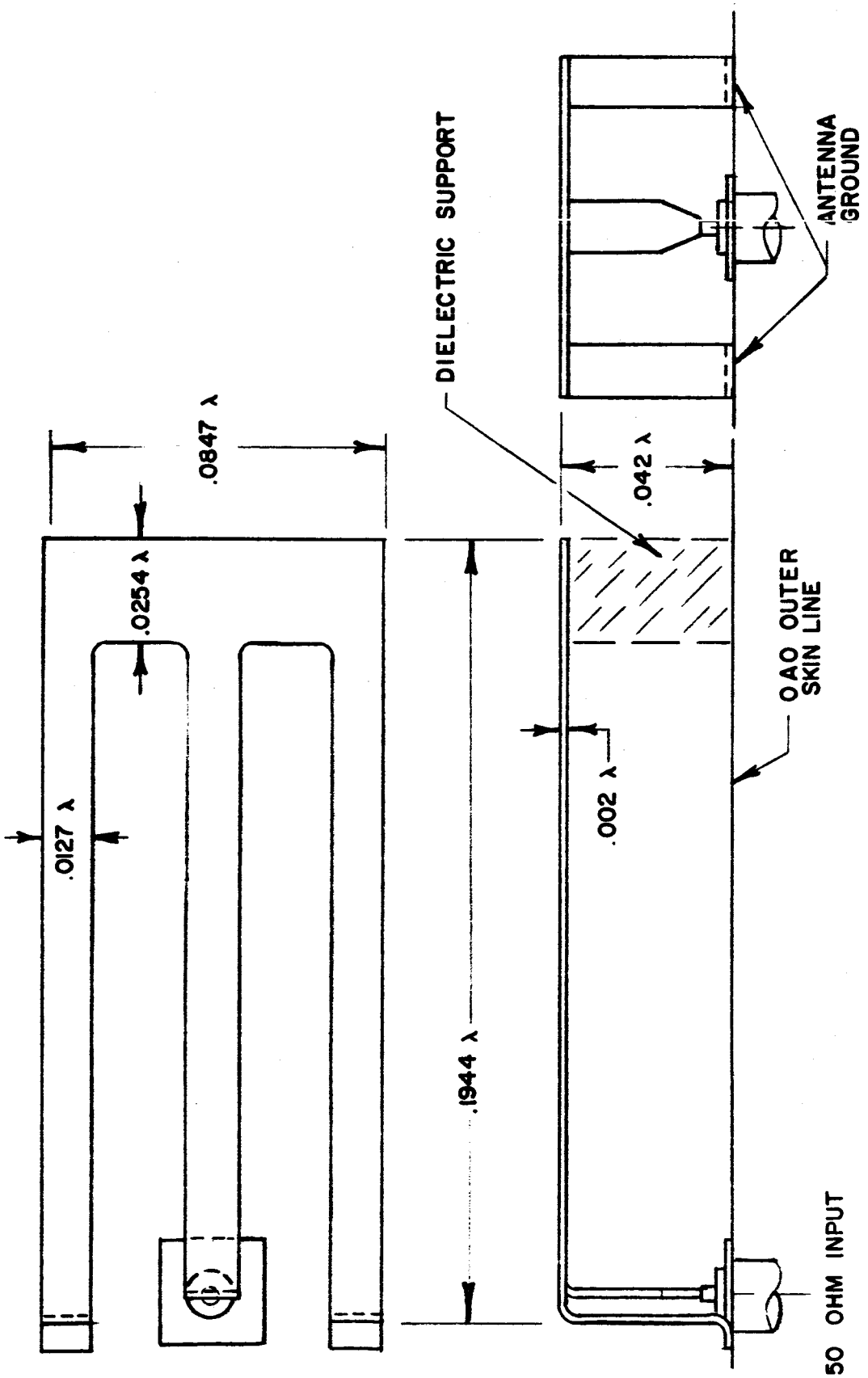

FIG. 3 - OAO UHF "PITCHFORK" ANTENNA

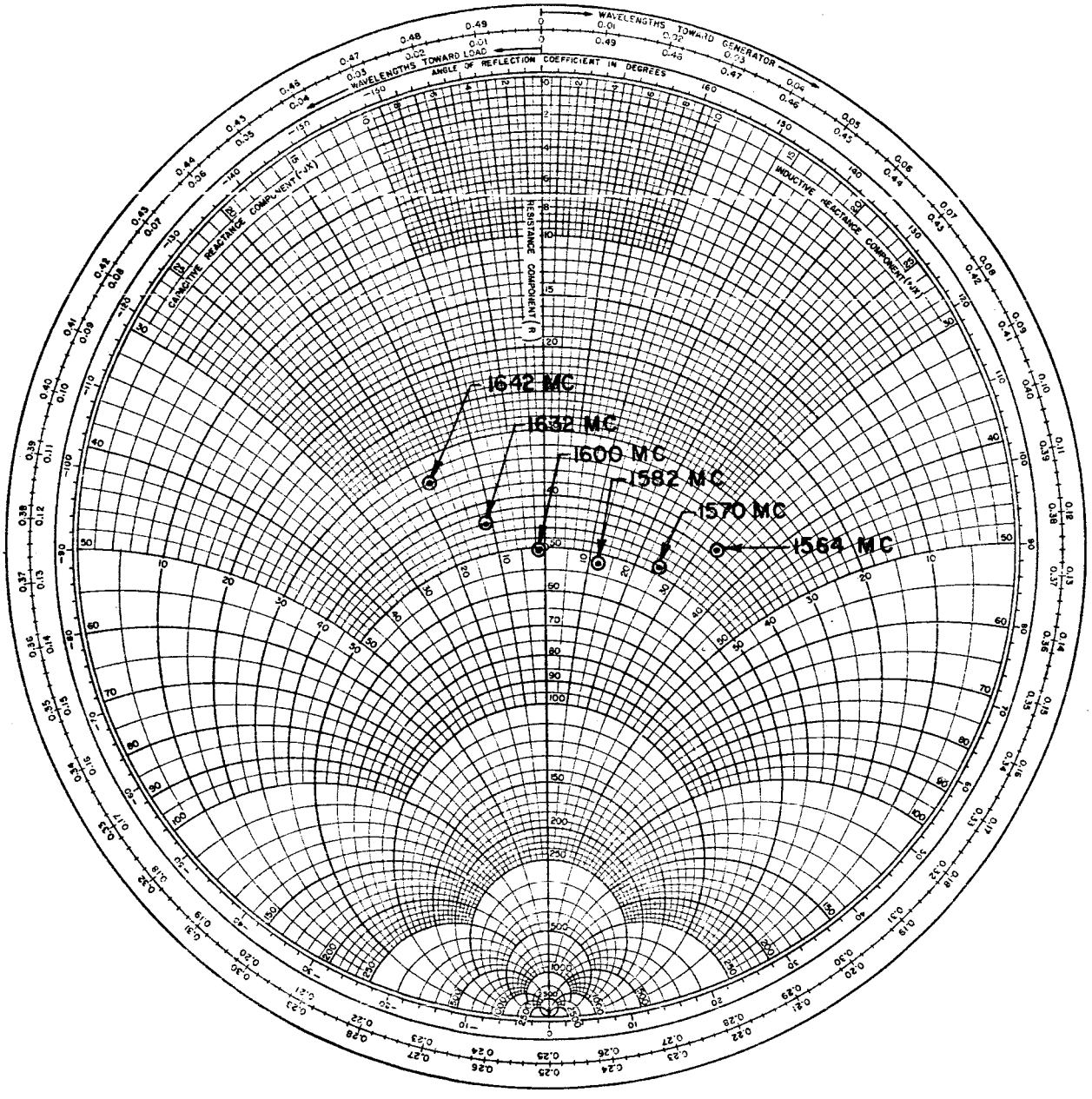

FIG. 4 - IMPEDANCE OF UHF ANTENNAS

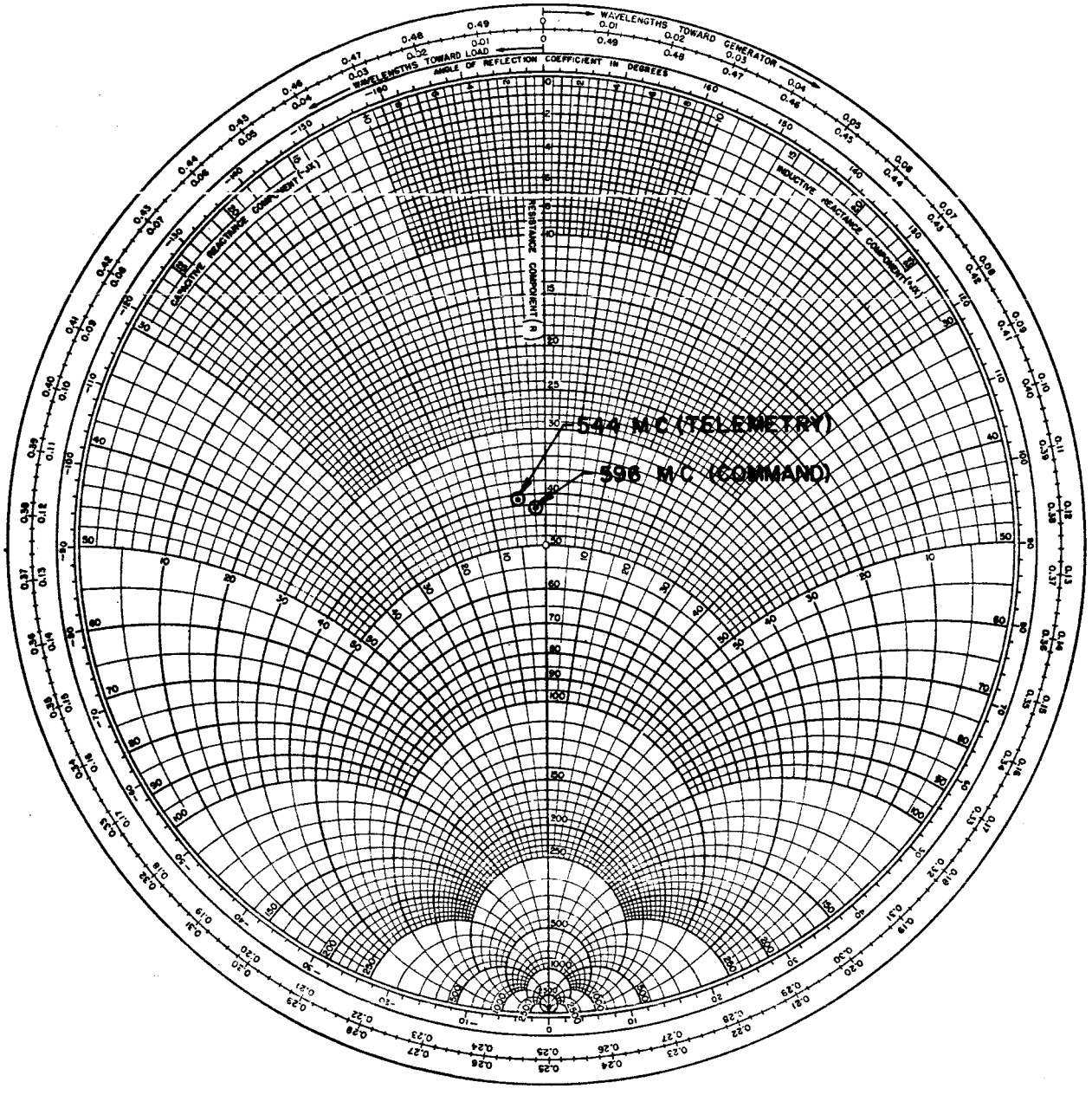

FIG. 5 - IMPEDANCE OF VHF ANTENNAS

4.0 RADIATION PATTERNS

Radiation patterns were run with linear polarization at all frequencies. Both the UHF and VHF antennas were fed with equal phase and amplitude. Check patterns were run with the antennas phased 180° apart to check the difference in the patterns. Gain checks were run at each frequency with respect to a one-half wavelength dipole. The coordinate system used for the radiation patterns is shown in Fig. 6.

The angle θ is a variable on each pattern and the angle ϕ is fixed on a particular pattern but varies from pattern to pattern. The radiation patterns of the UHF antennas were run at 1600 Mc in 10° increments in ϕ. The VHF antennas were run at both 544 Mc and 596 Mc with the same ϕ increments. Representative patterns are shown in Fig. 7 through Fig. 30. Gain measurements are shown at the beginning of each set of radiation pattern measurements.

5.0 RADIATION COVERAGE

The antenna gain shall be no less than 12 db below isotropic for at least 90 percent of the total solid angles about the antenna (4π steradians). The polarization requirements for each usage are given below.

5.1 Radio Command Link (VHF)

The radio command link must have polarization diversity when used with two receivers. The radio command frequency is approximately 148 Mc. The 1/4 scale model antennas were run at 596 Mc. Power contour plots of the signal at 12 db below isotropic were plotted for both E_θ and E_ϕ polarization. The percent coverage for both polarizations at a level 12 db below isotropic or higher was obtained. For an E_θ polarized signal the coverage is 85% and for an E_ϕ polarized signal the coverage is 88.4%. The power plots are shown in Fig. 31 and Fig. 32.

5.2 Radio Tracking Beacon Link (VHF)

The radio tracking beacon link antenna shall be compatible with a linear polarized ground station. Both E_θ and E_ϕ polarizations were taken and a percent coverage was determined for both. The coverage for an E_θ polarized signal is 83.2% and for an E_ϕ signal the coverage is 81.4%. Figure 33 and Fig. 34 are the power plots for the radio tracking beacon.

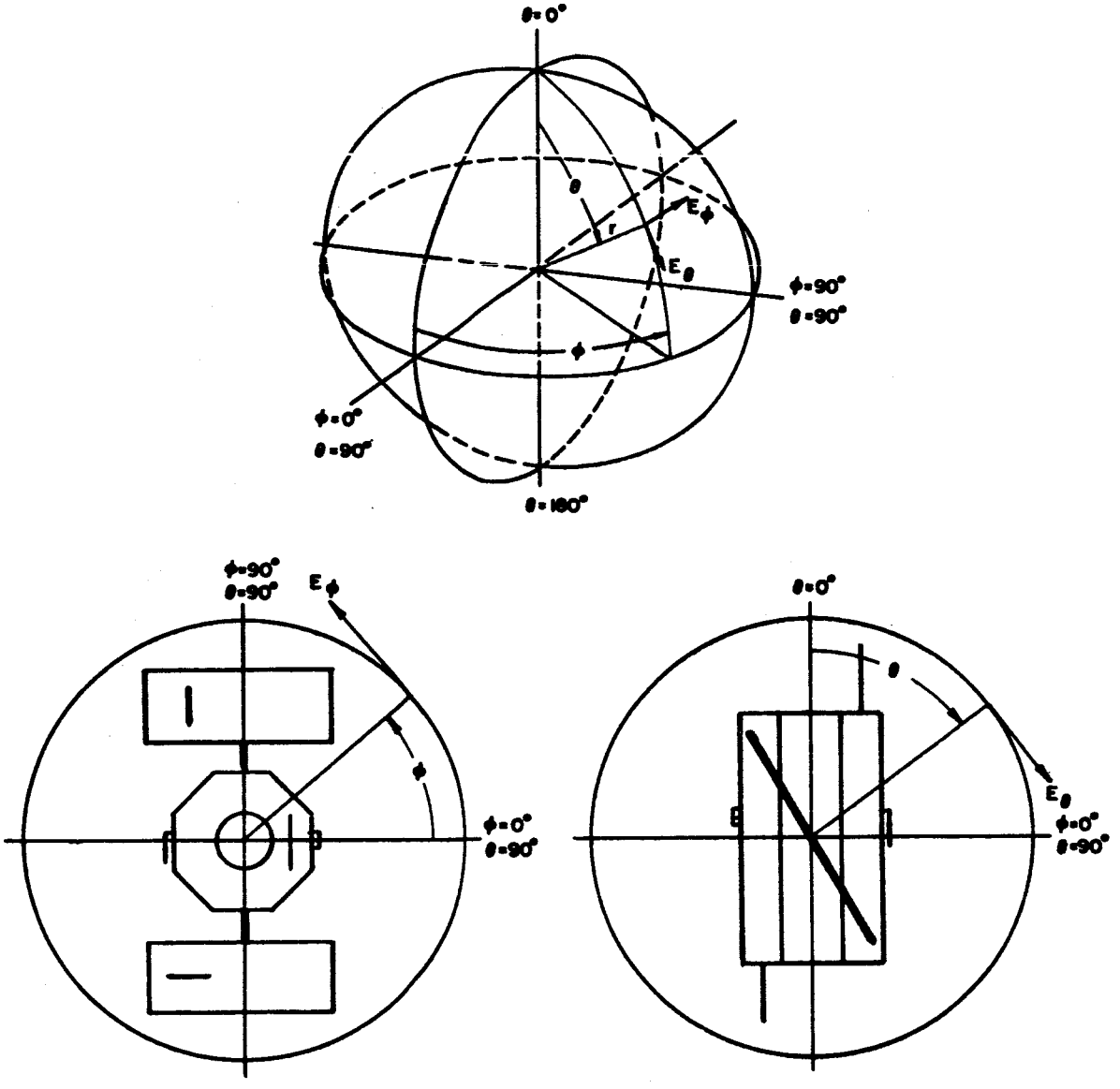

FIG. 6 - OAO COORDINATE SYSTEM

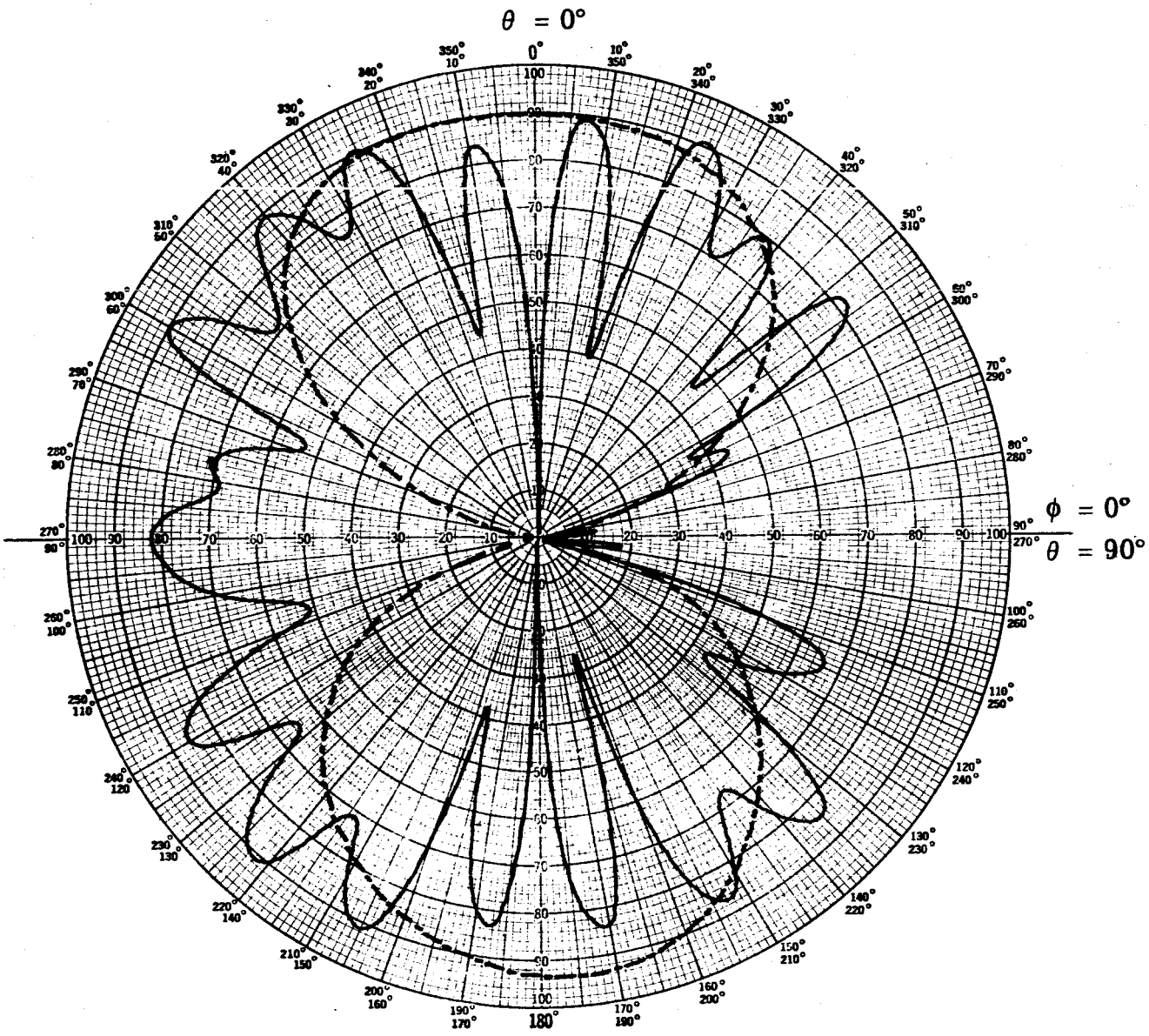

FIG. 7 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - Eθ
REMARKS - Dipole Gain Comparison
SCALE - 2 db/major division

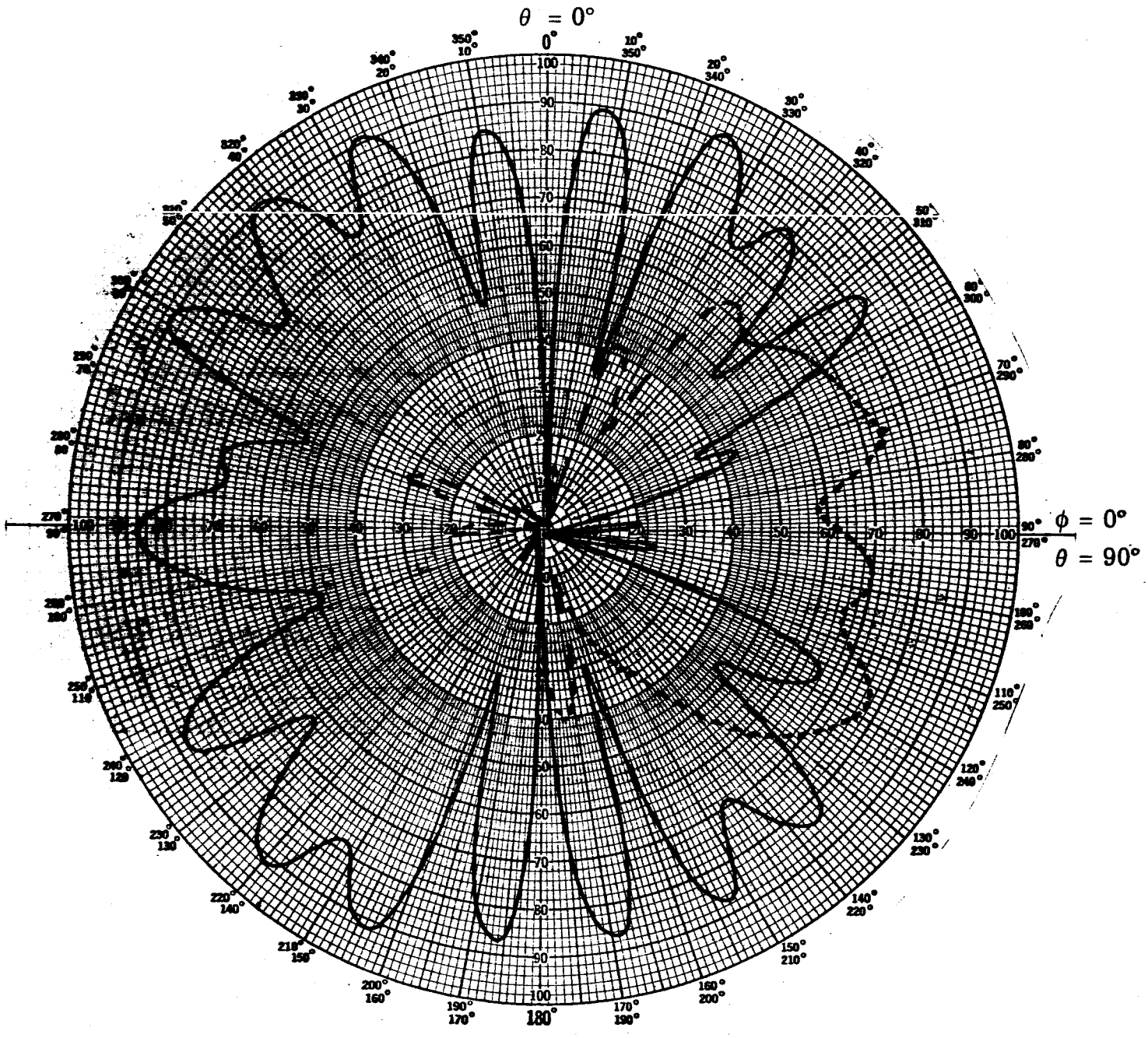

FIG. 8 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - E_θ _____
$E\phi$ ------
SCALE - 2 db/major division

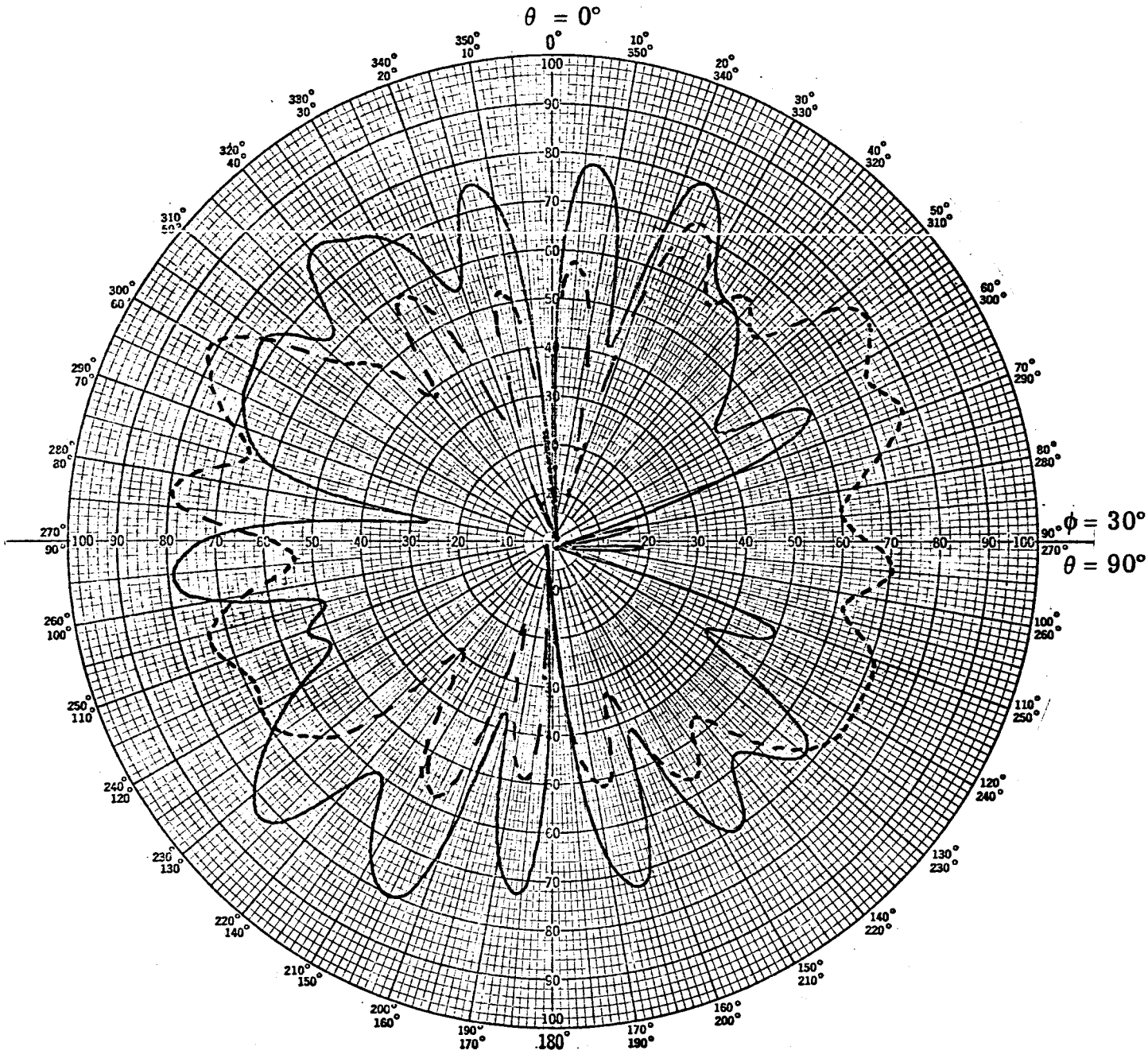

FIG. 9 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - Eθ ———
Eφ - - - - - -
SCALE - 2 db/major division

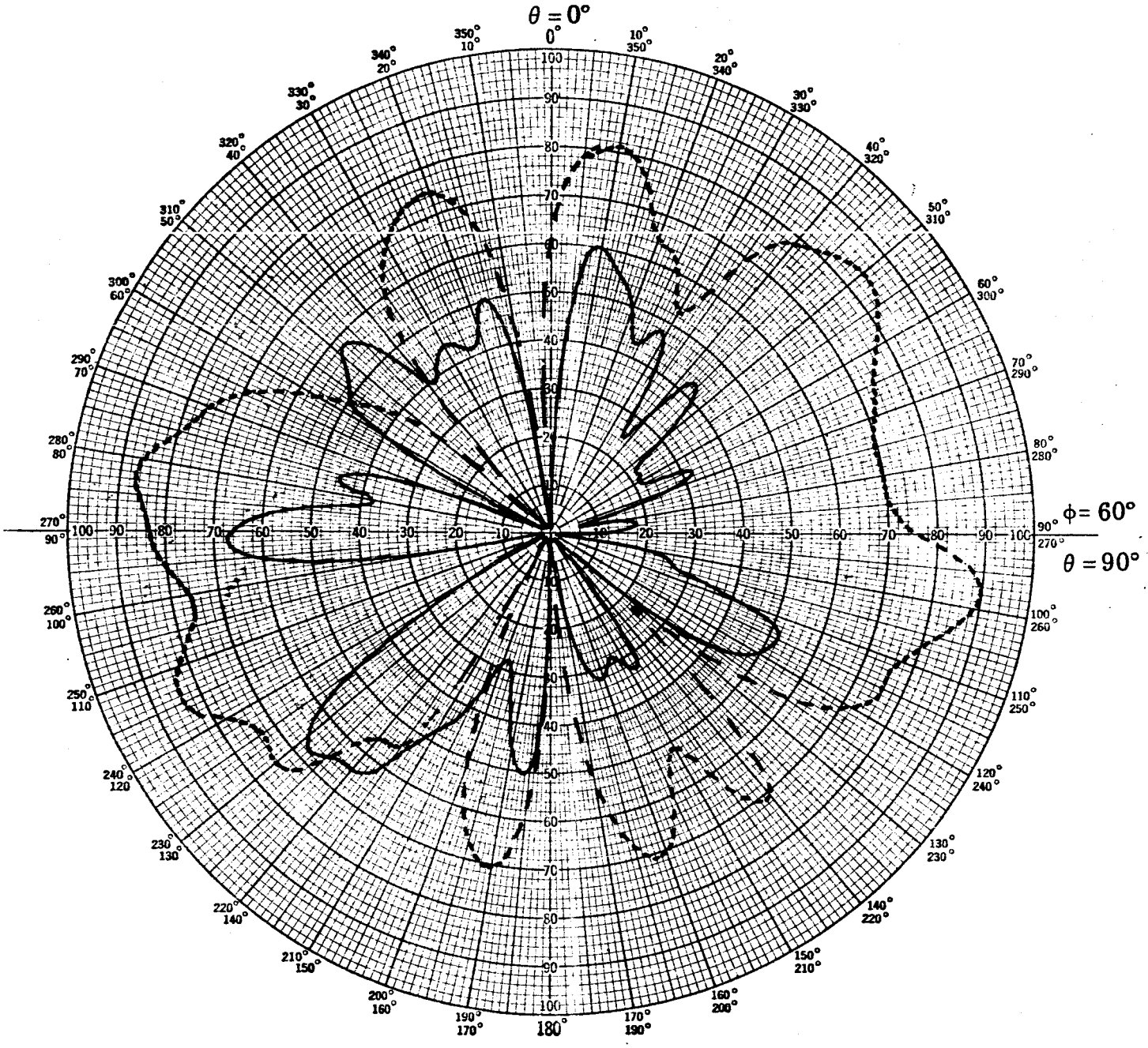

FIG. 10 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - E_θ_____
E_ϕ------
SCALE - 2 db/major division

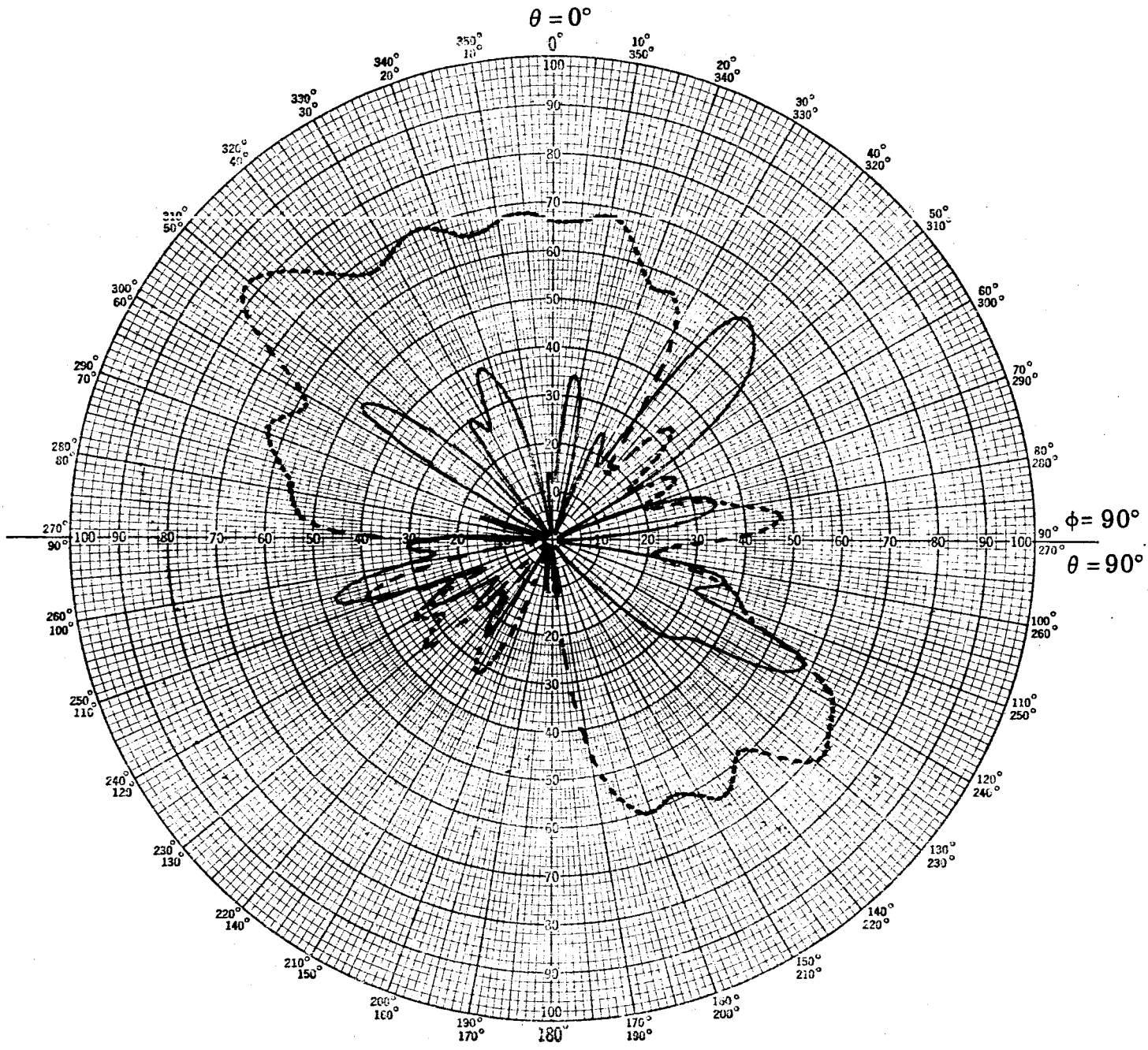

FIG. 11 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - E_θ _____
E_ϕ - - - - - - -
SCALE - 2 db/major division

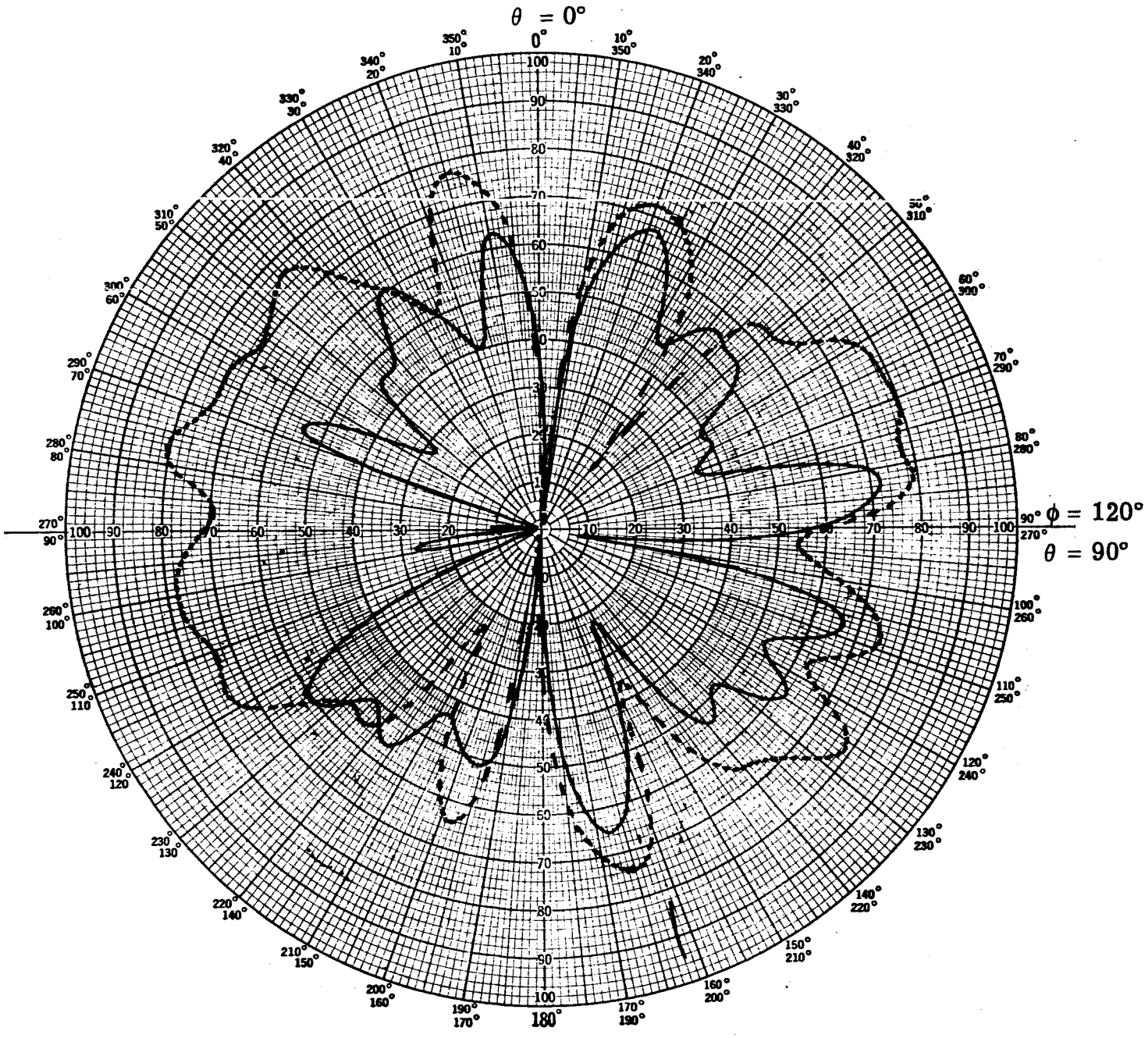

FIG. 12 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

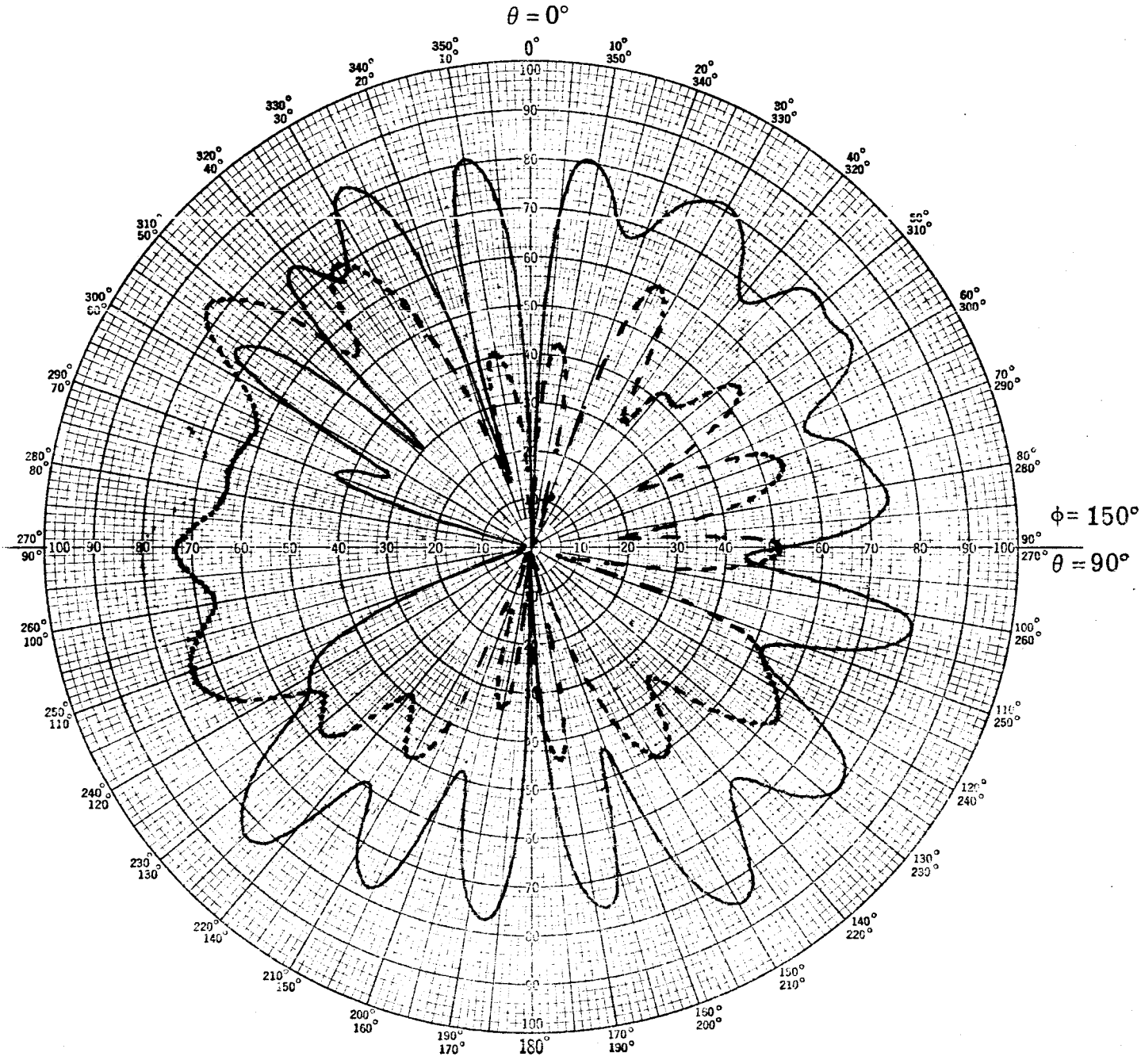

FIG. 13 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

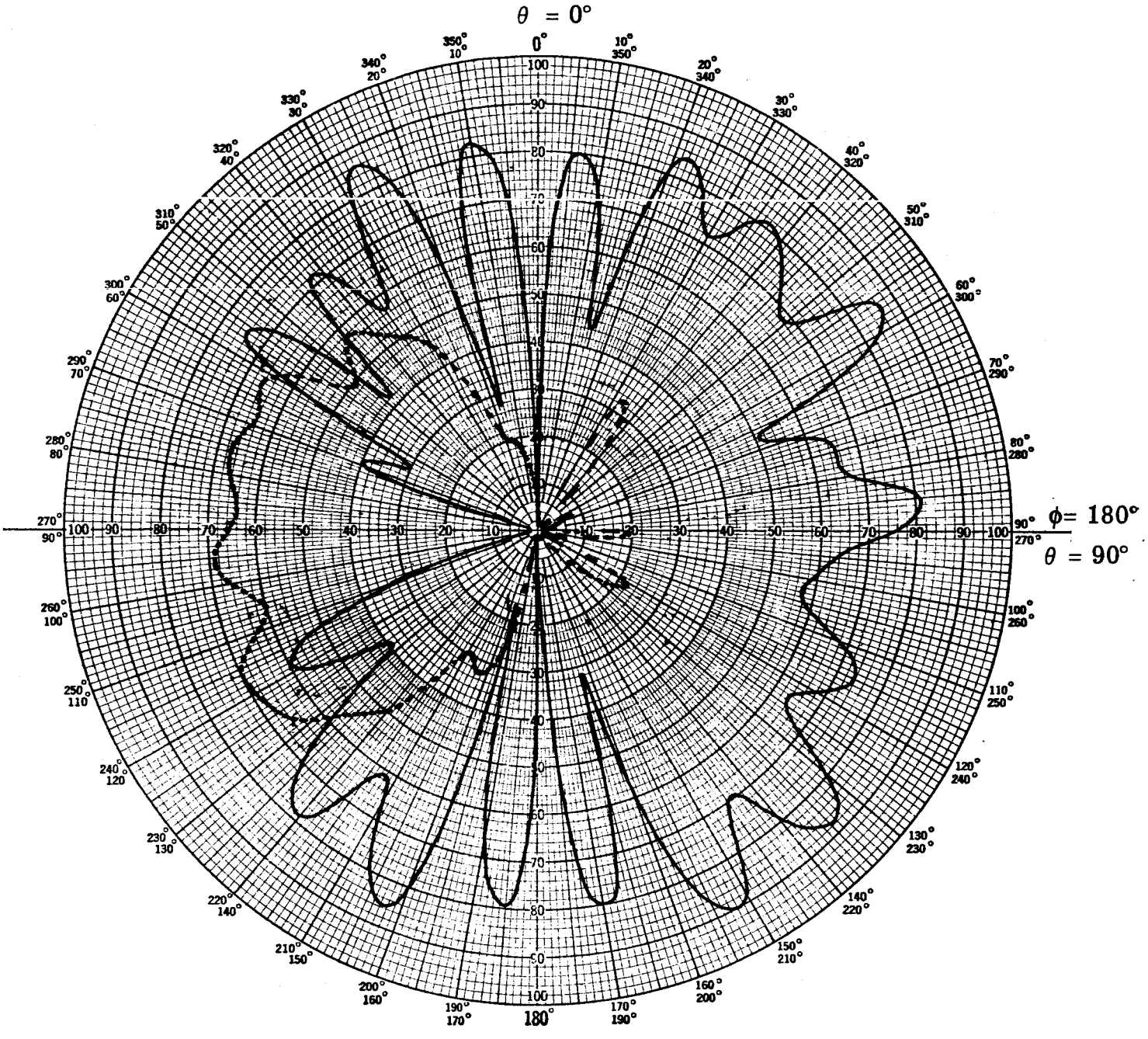

FIG. 14 - UHF RADIATION PATTERNS

ANTENNA - UHF Pitchforks on OAO
POLARIZATION - $E\theta$ _____
$E\phi$ - - - - - -
SCALE - 2 db/major division

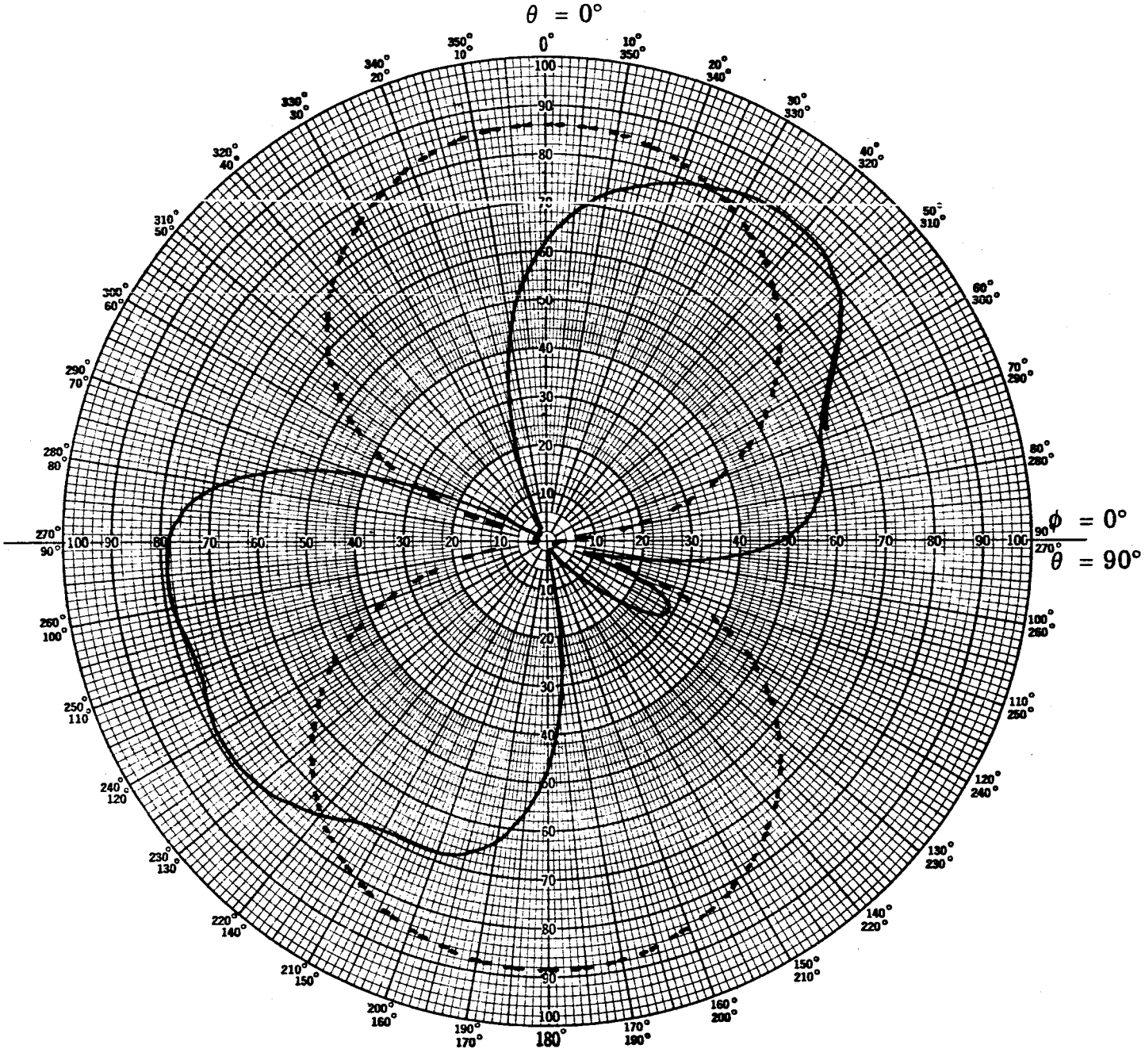

FIG. 15 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
REMARKS - Dipole gain comparison
SCALE - 2 db/major division

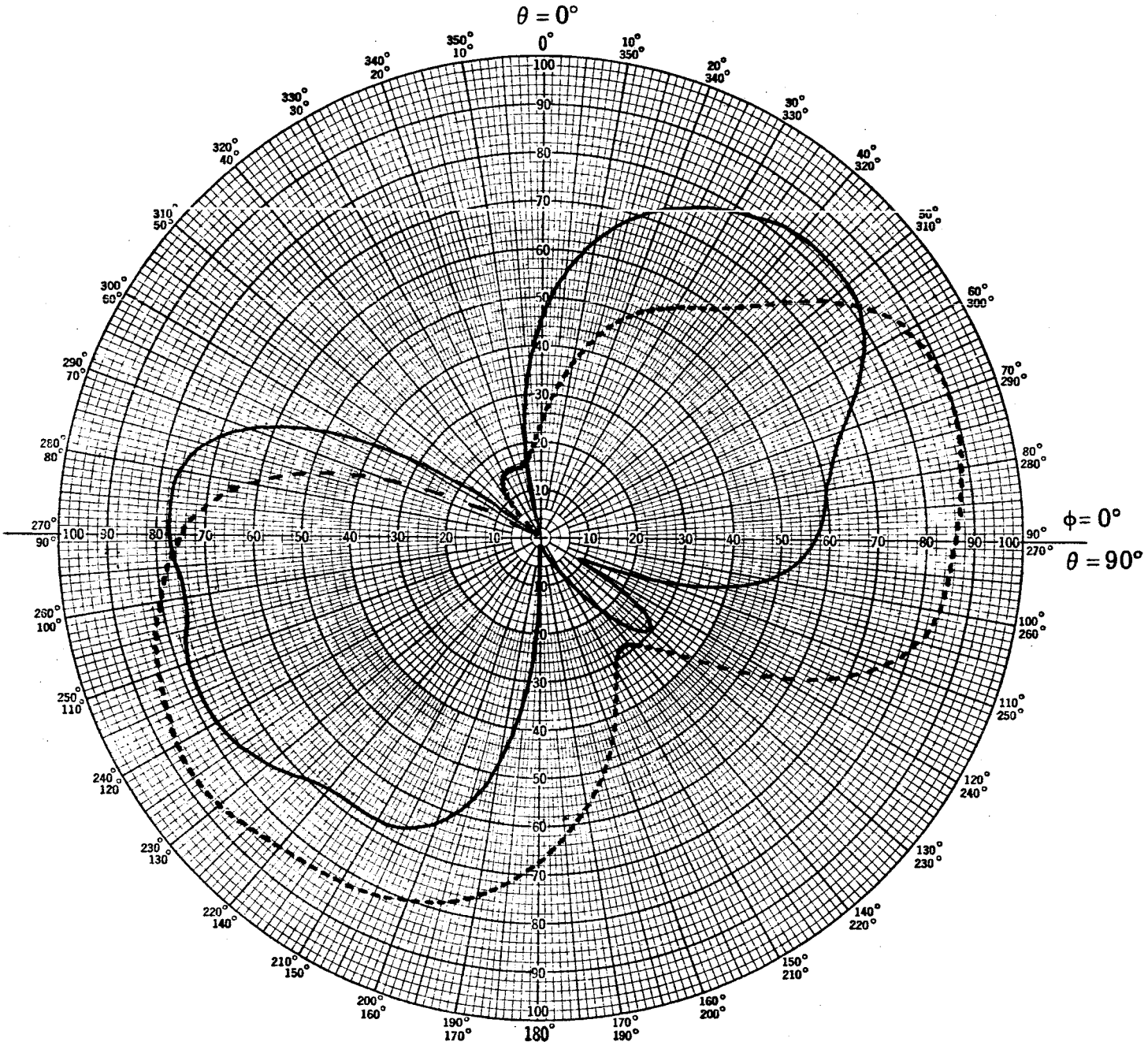

FIG. 16 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division
REMARKS - Fig. 15 through 22 are for the radio tracking beacon and radio telemetry links.

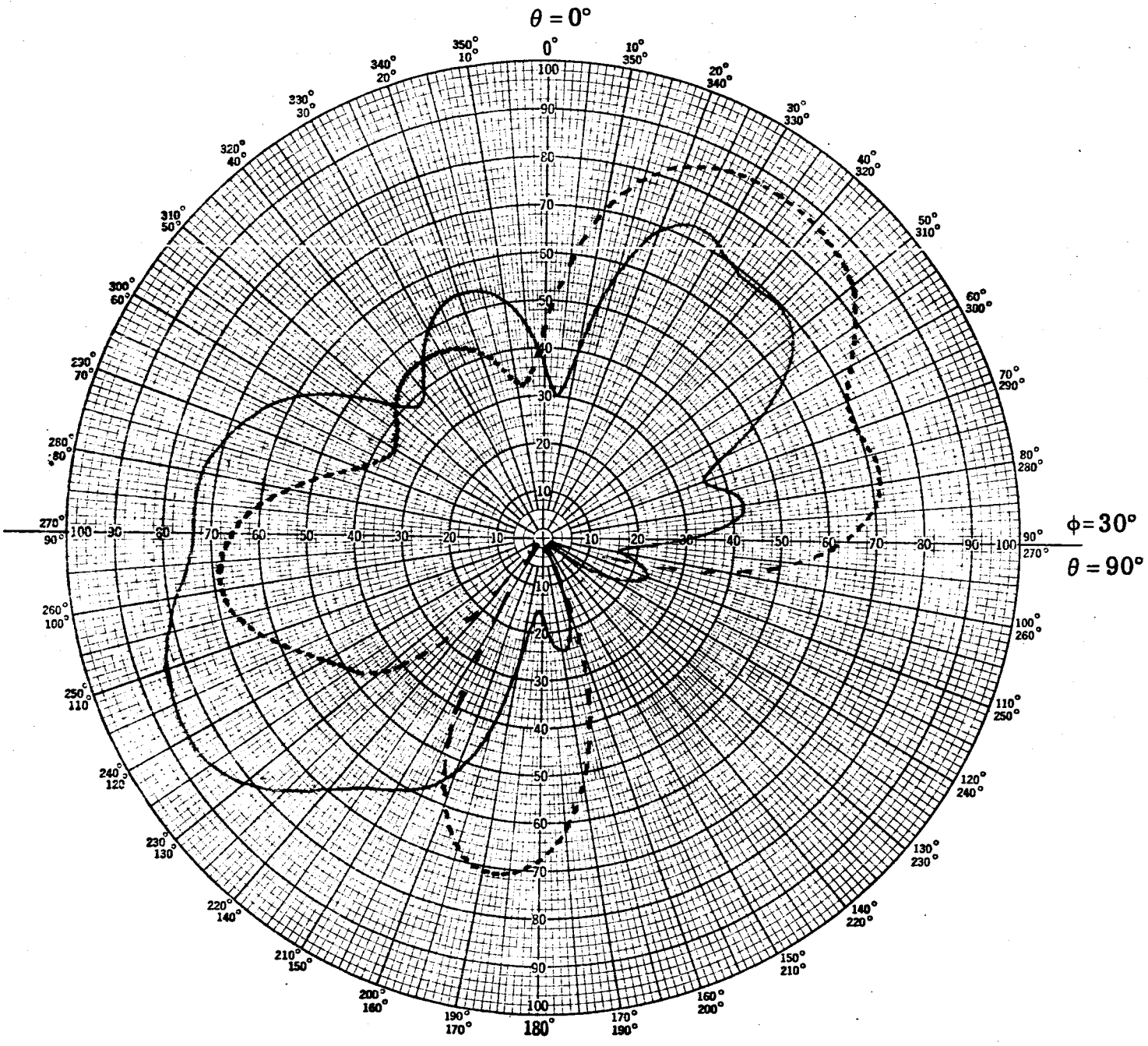

FIG. 17 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

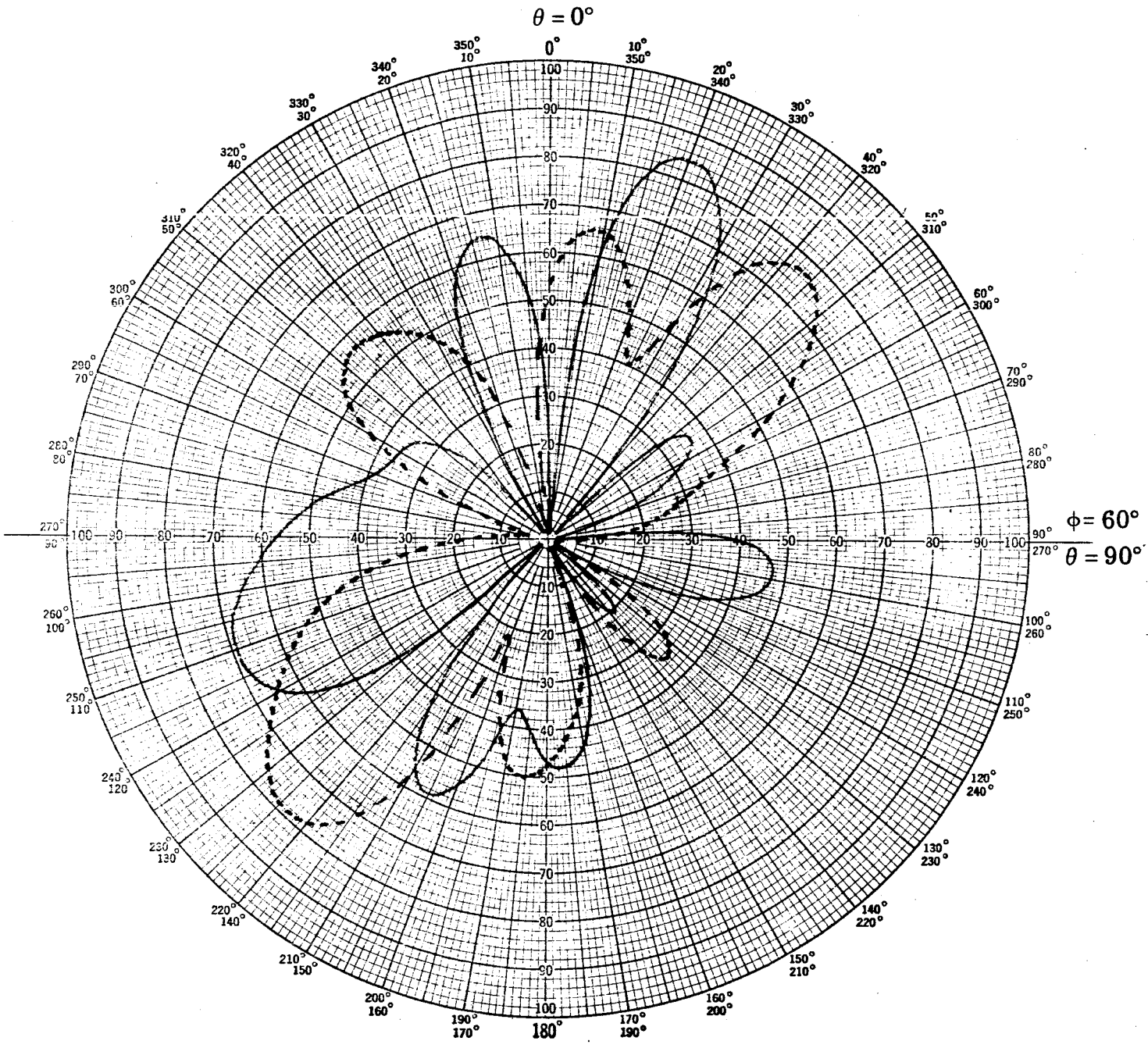

FIG. 18 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

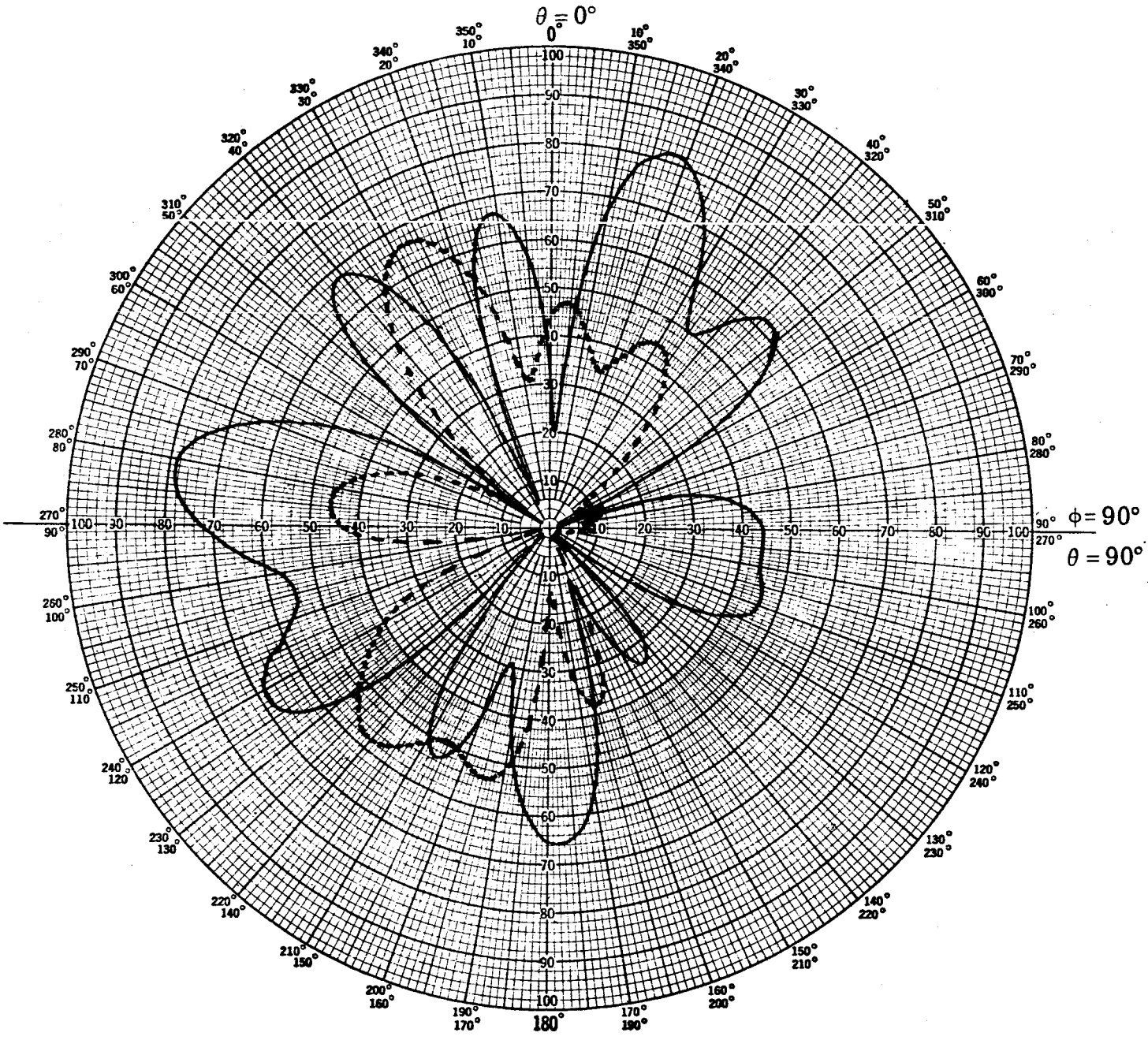

FIG. 19 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

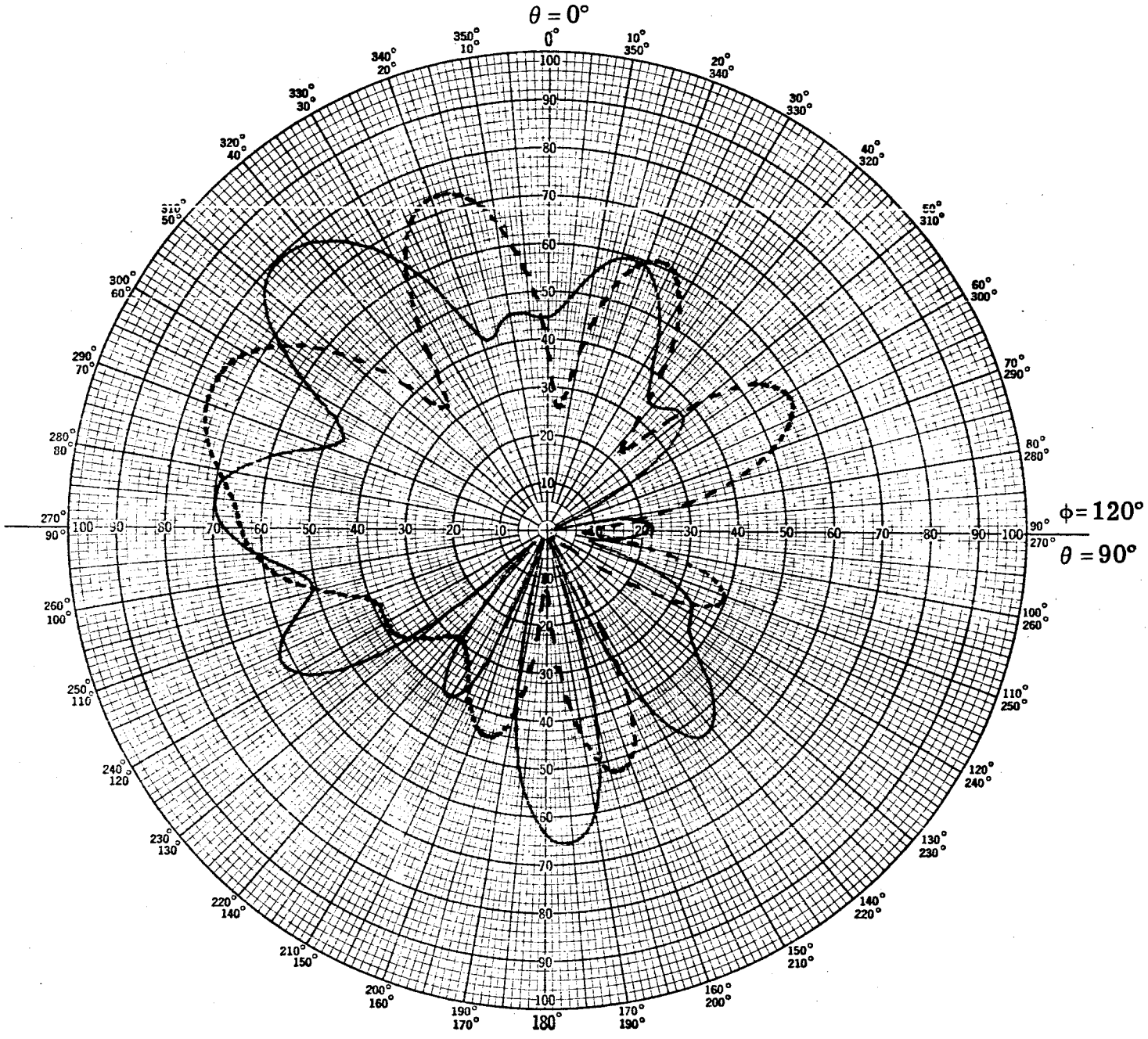

FIG. 20 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

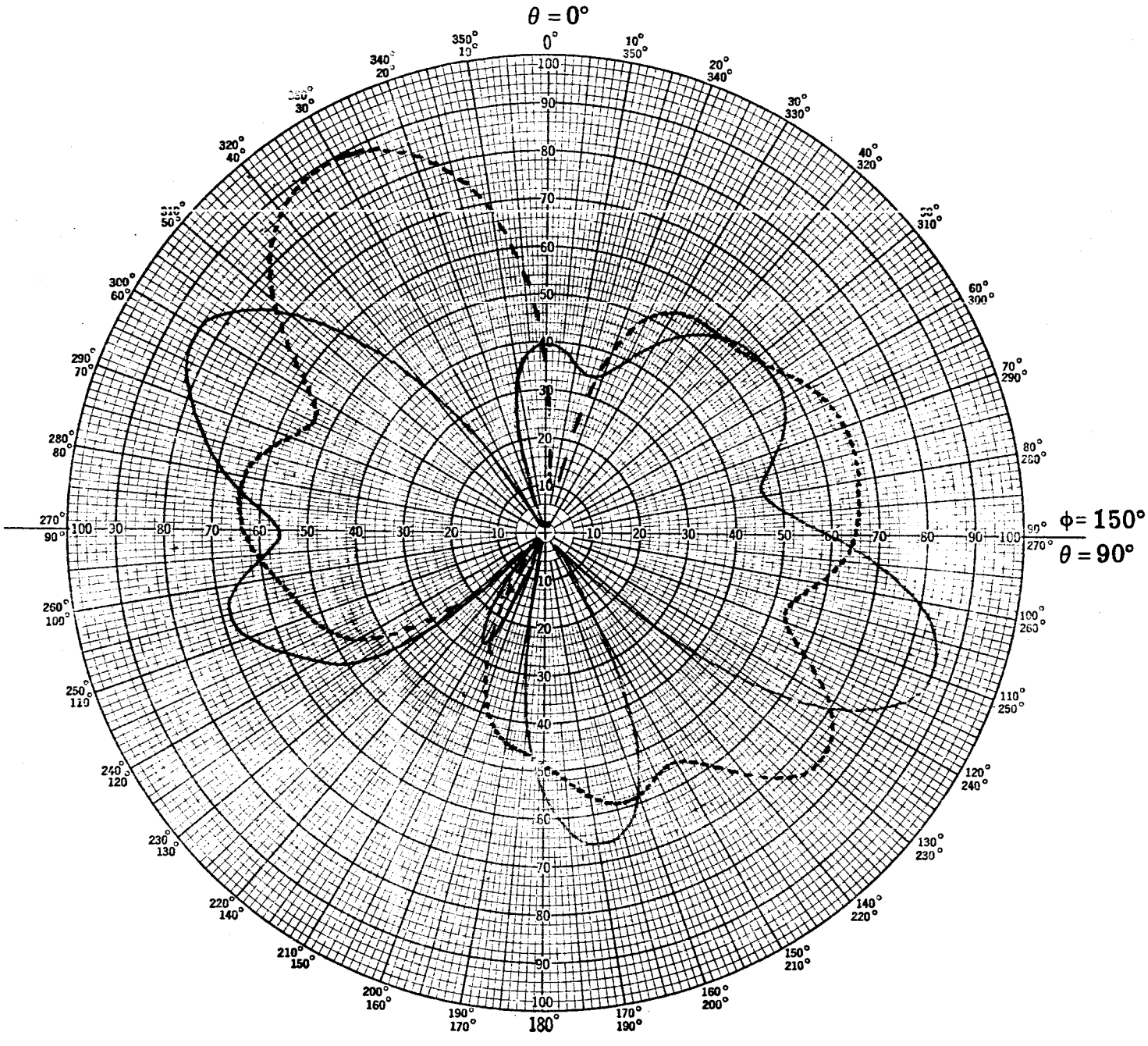

FIG. 21 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

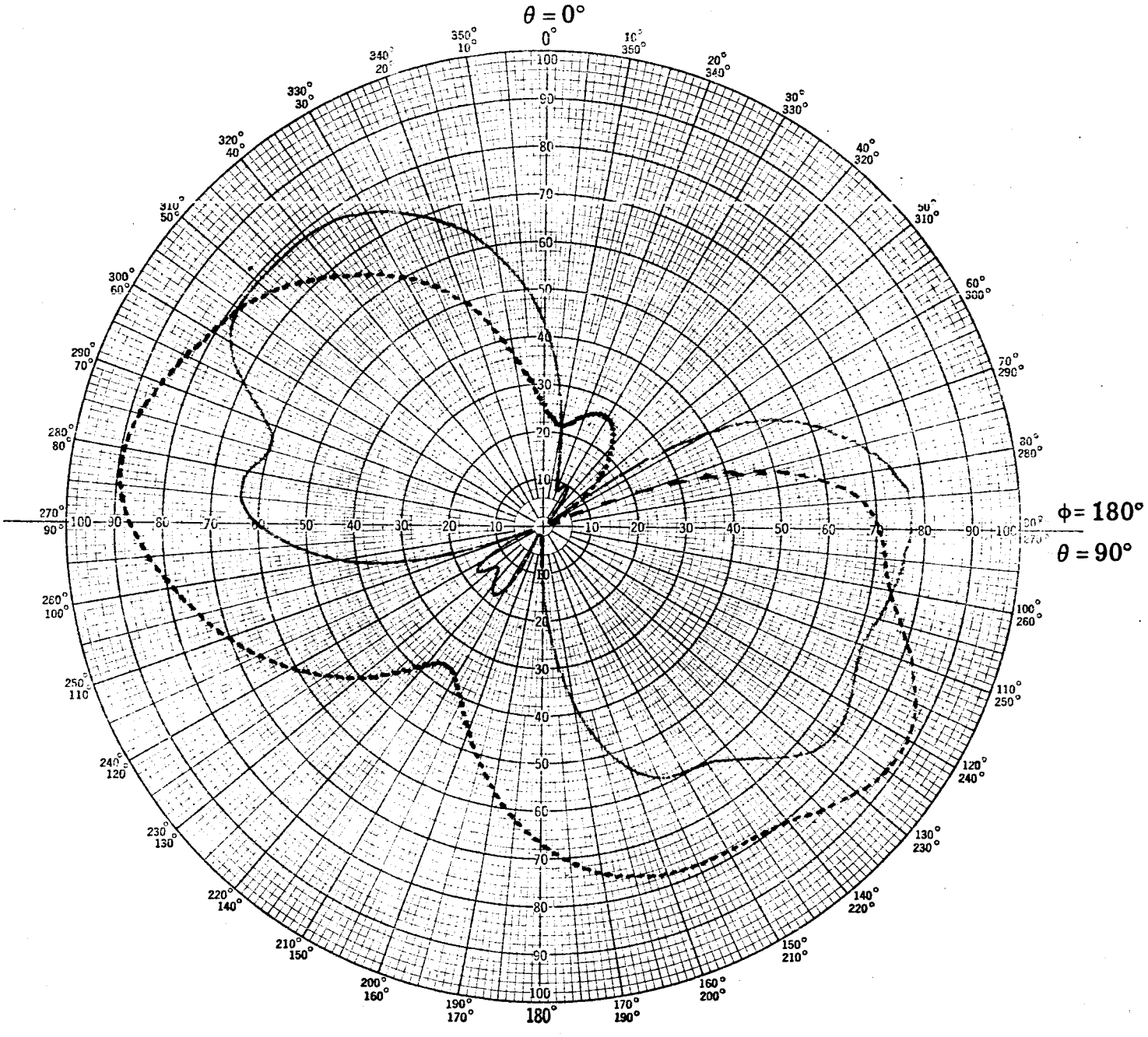

FIG. 22 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ - - - - - - -
SCALE - 2 db/major division

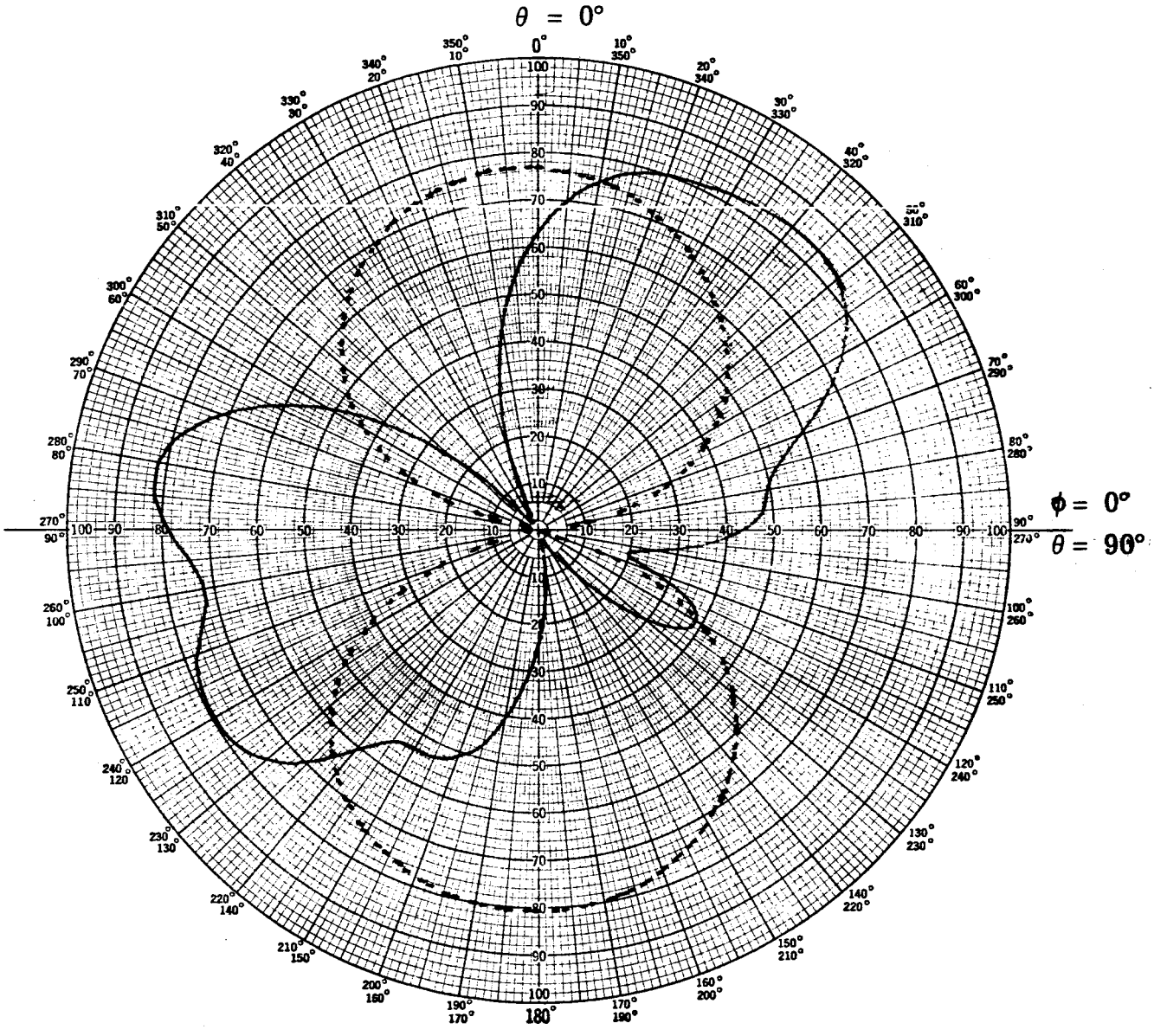

FIG. 23 - VHF RADIATION PATTERNS

ANTENNA - VHF Slots on OAO
POLARIZATION - E_θ _____
SCALE - 2 db/major division
REMARKS - Dipole Gain Comparison
Fig. 23 to 30 are for the
Radio Command Line.

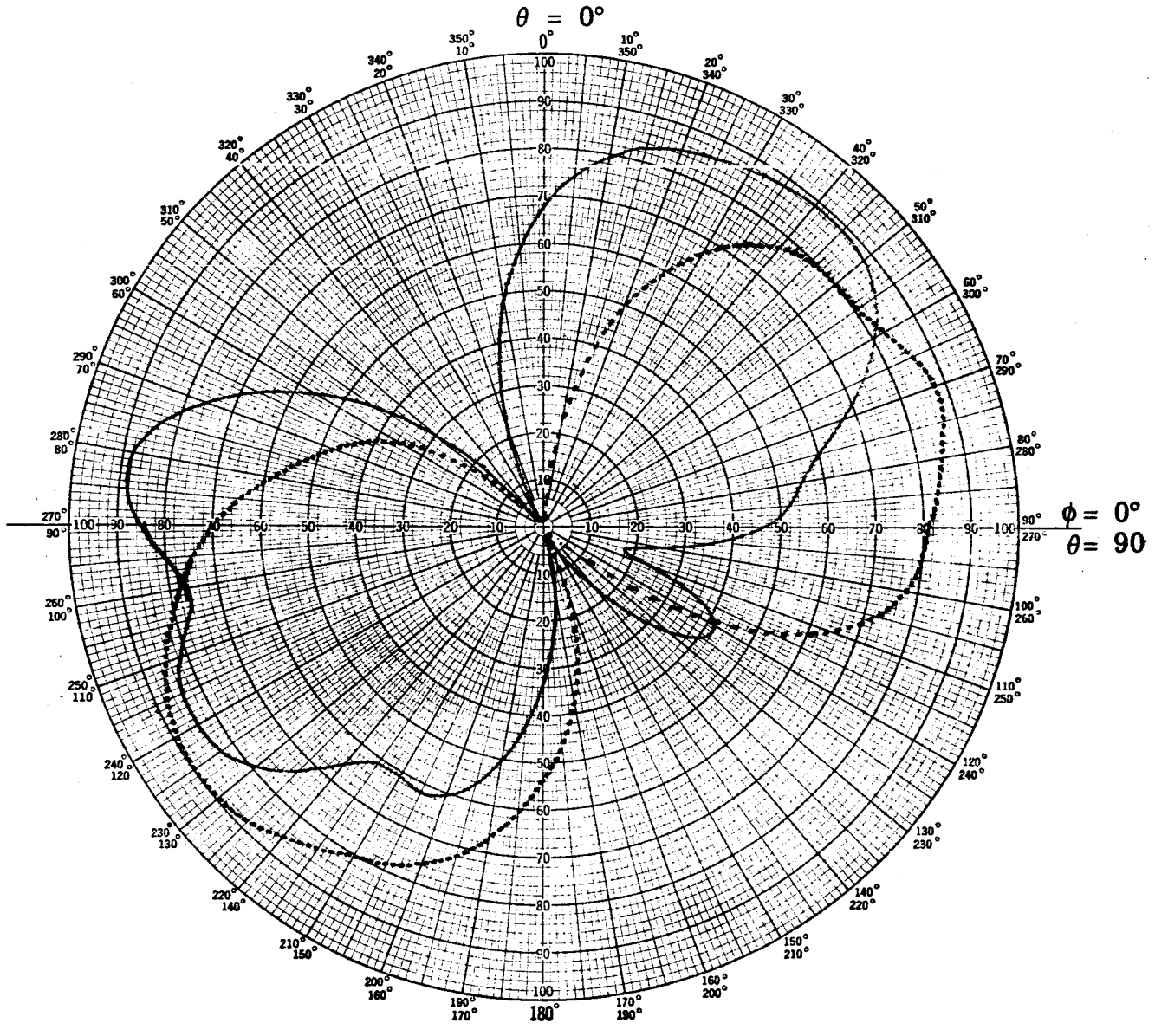

FIG. 24 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - $E\theta$ _____
$E\phi$ - - - - - -
SCALE - 2 db/major division

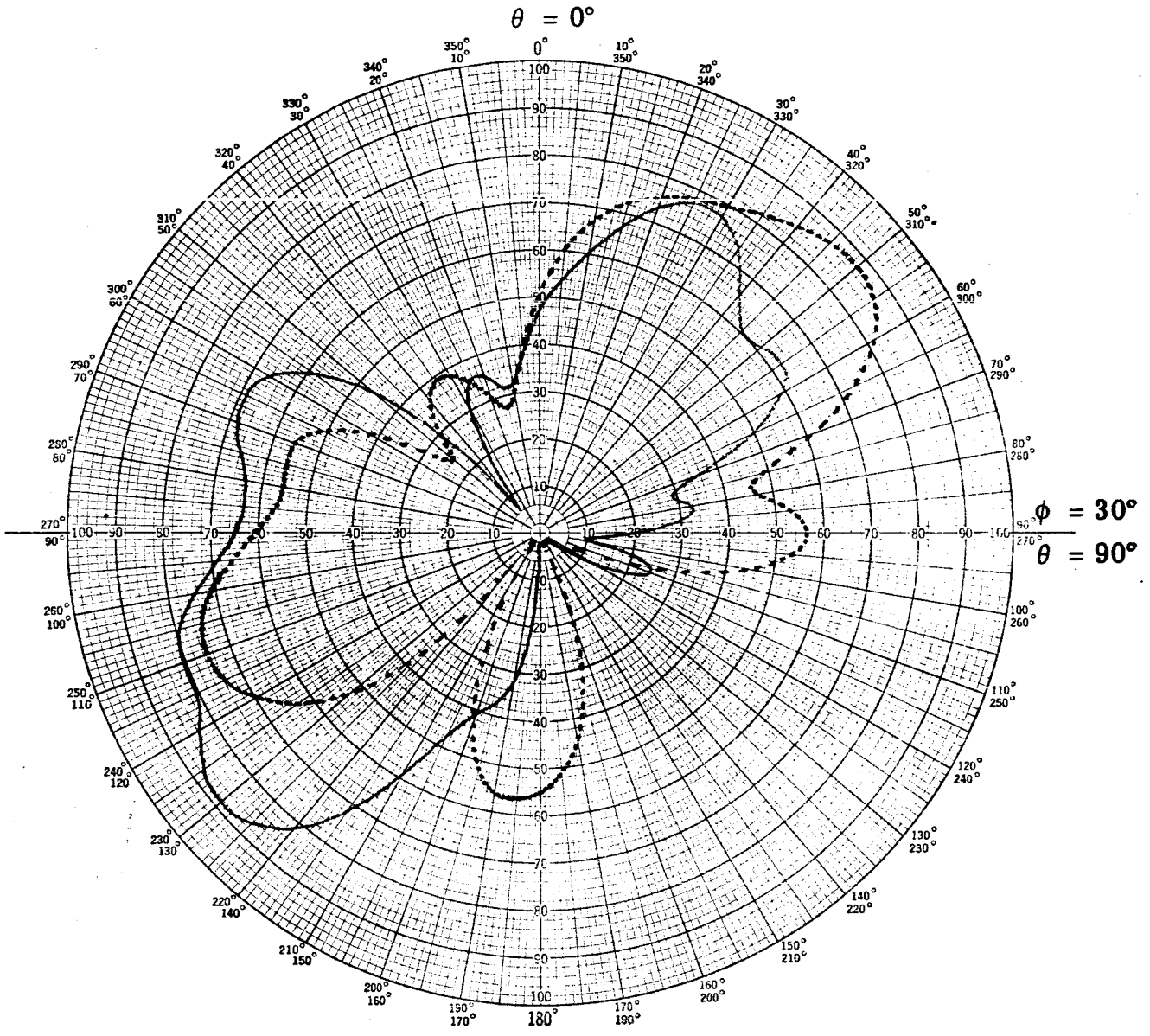

FIG. 25 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ - - - - - - -
SCALE - 2 db/major division

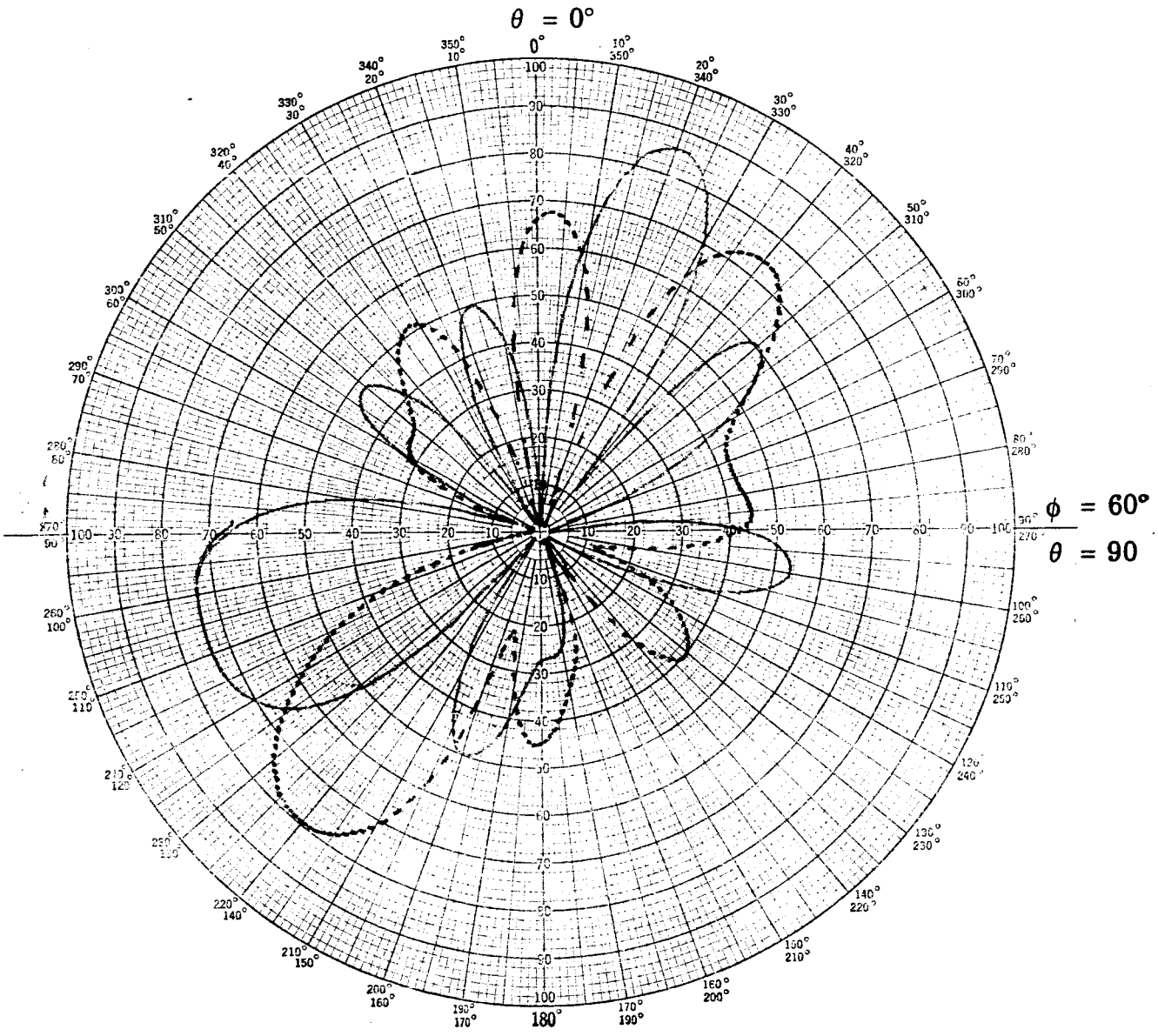

FIG. 26 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

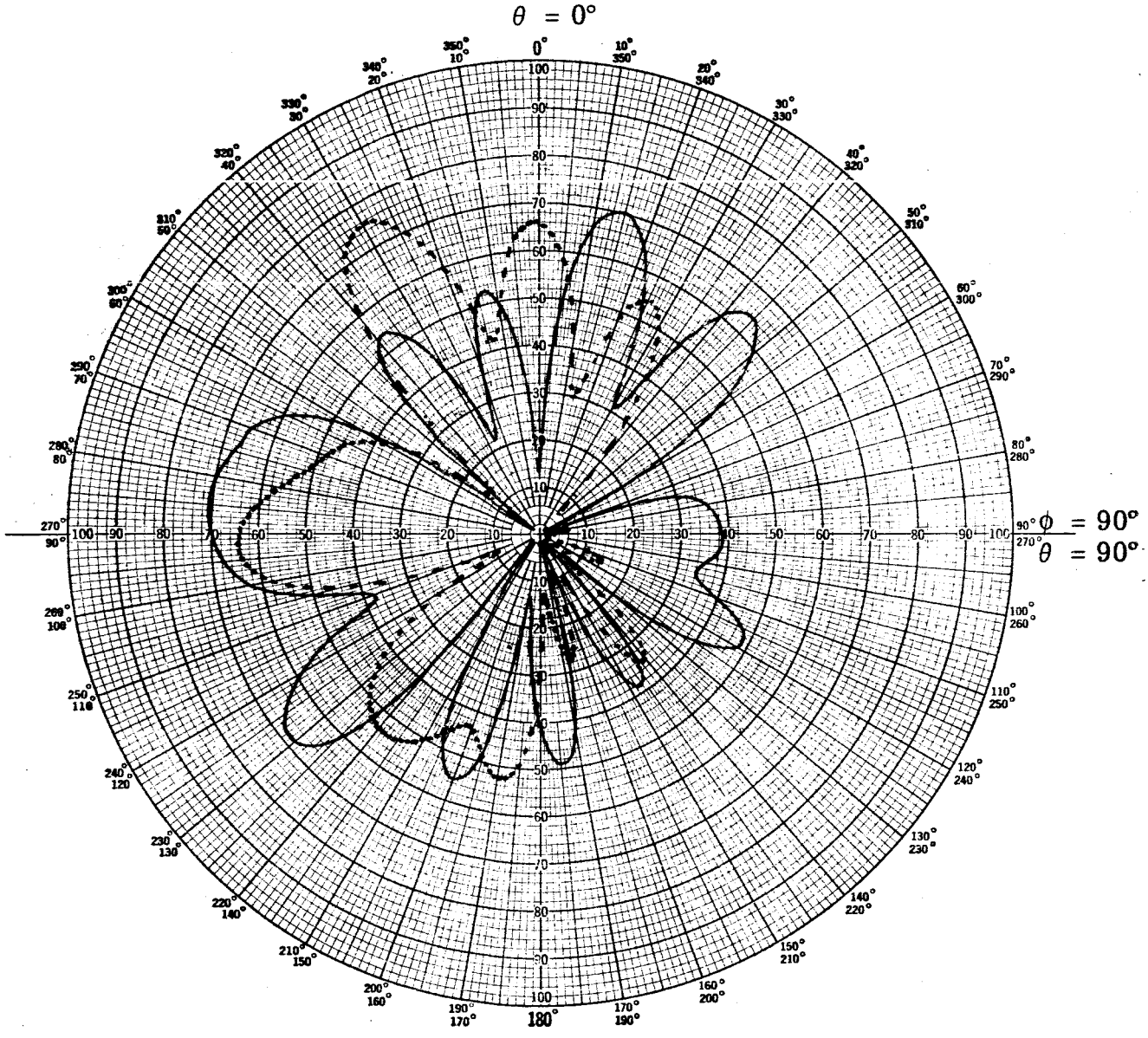

FIG. 27 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION E_θ _____
E_ϕ ------
SCALE - 2 db/major division

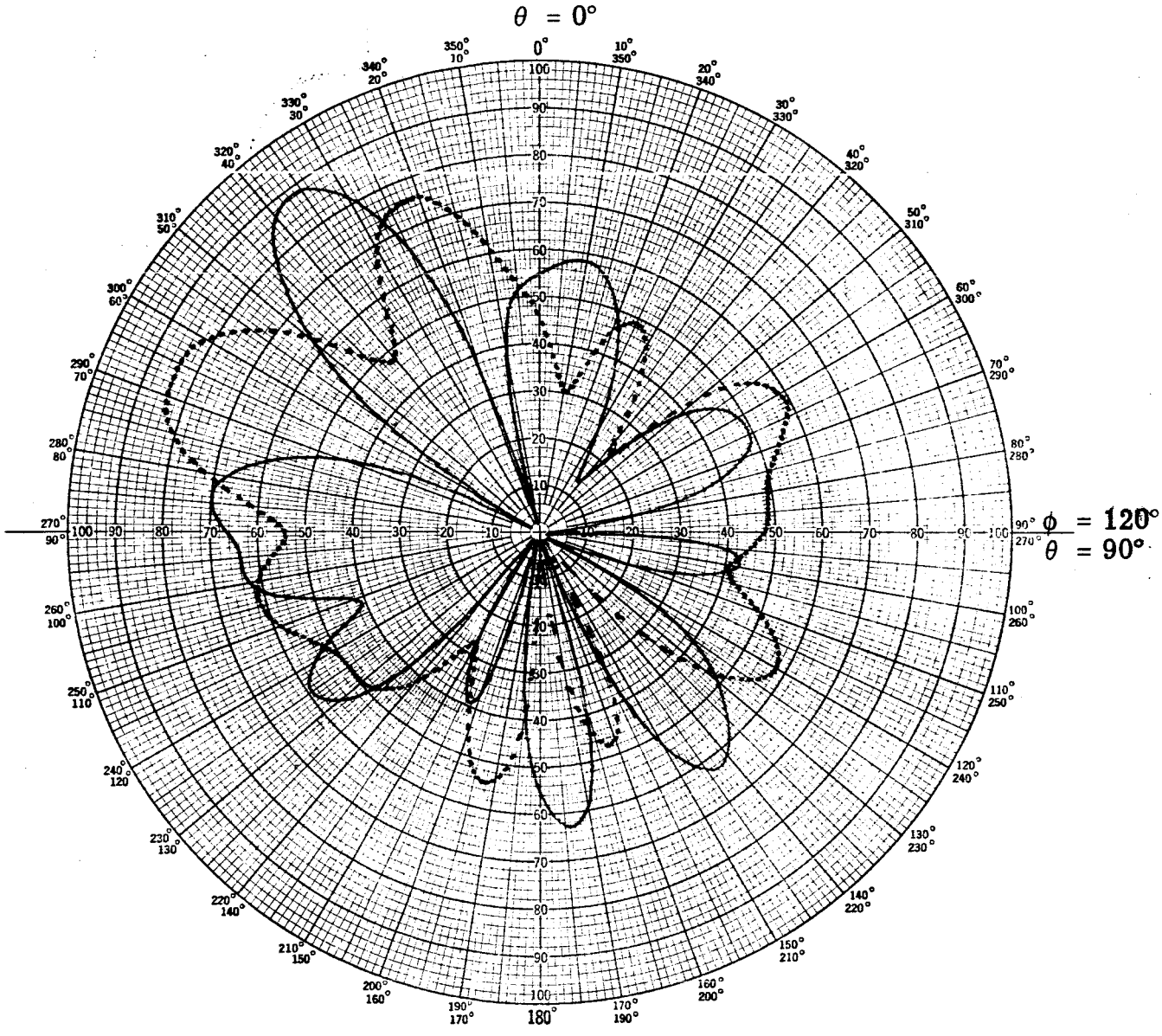

FIG. 28 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION E_θ _____
E_ϕ ------
SCALE - 2 db/major division

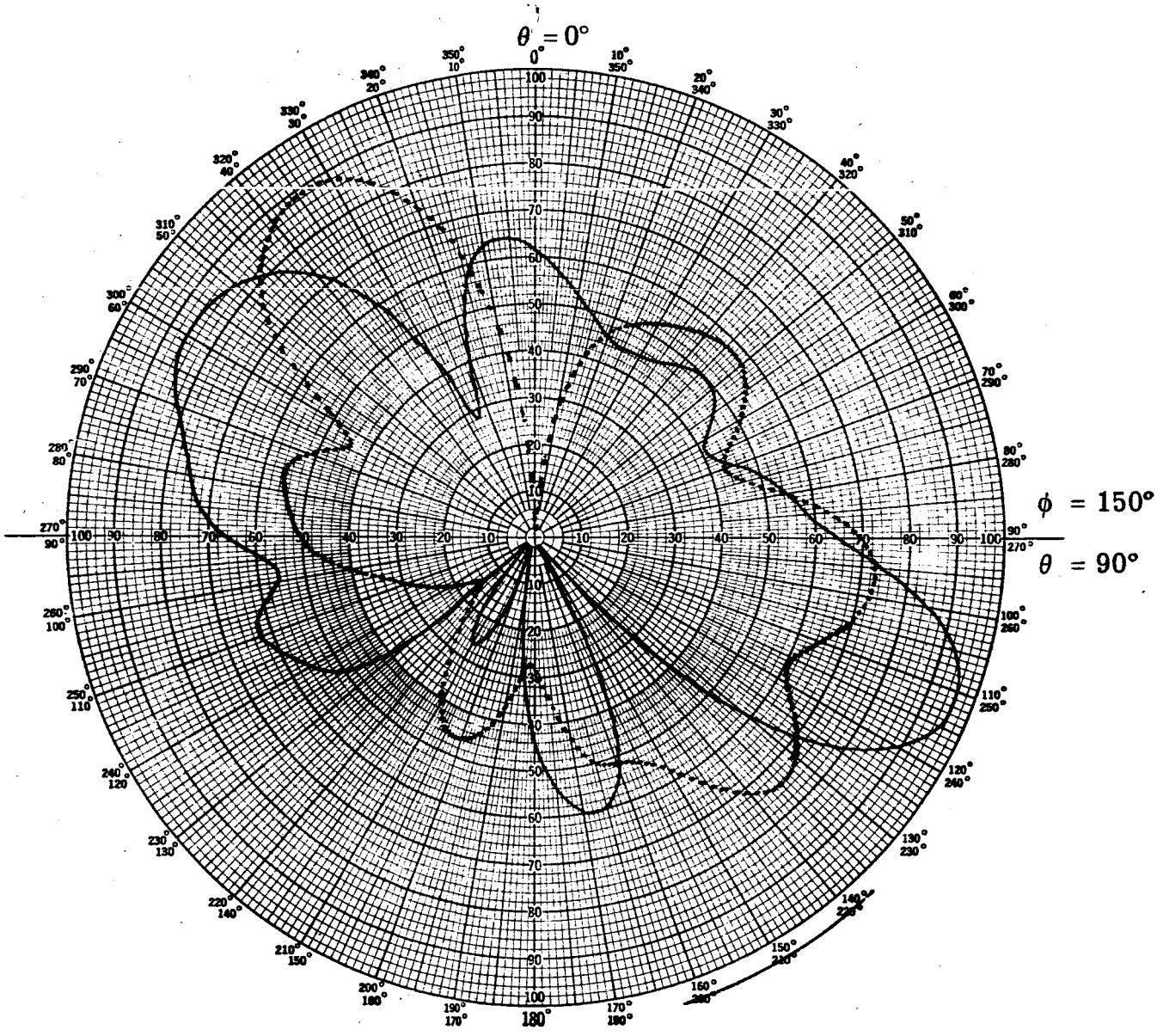

FIG. 29 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

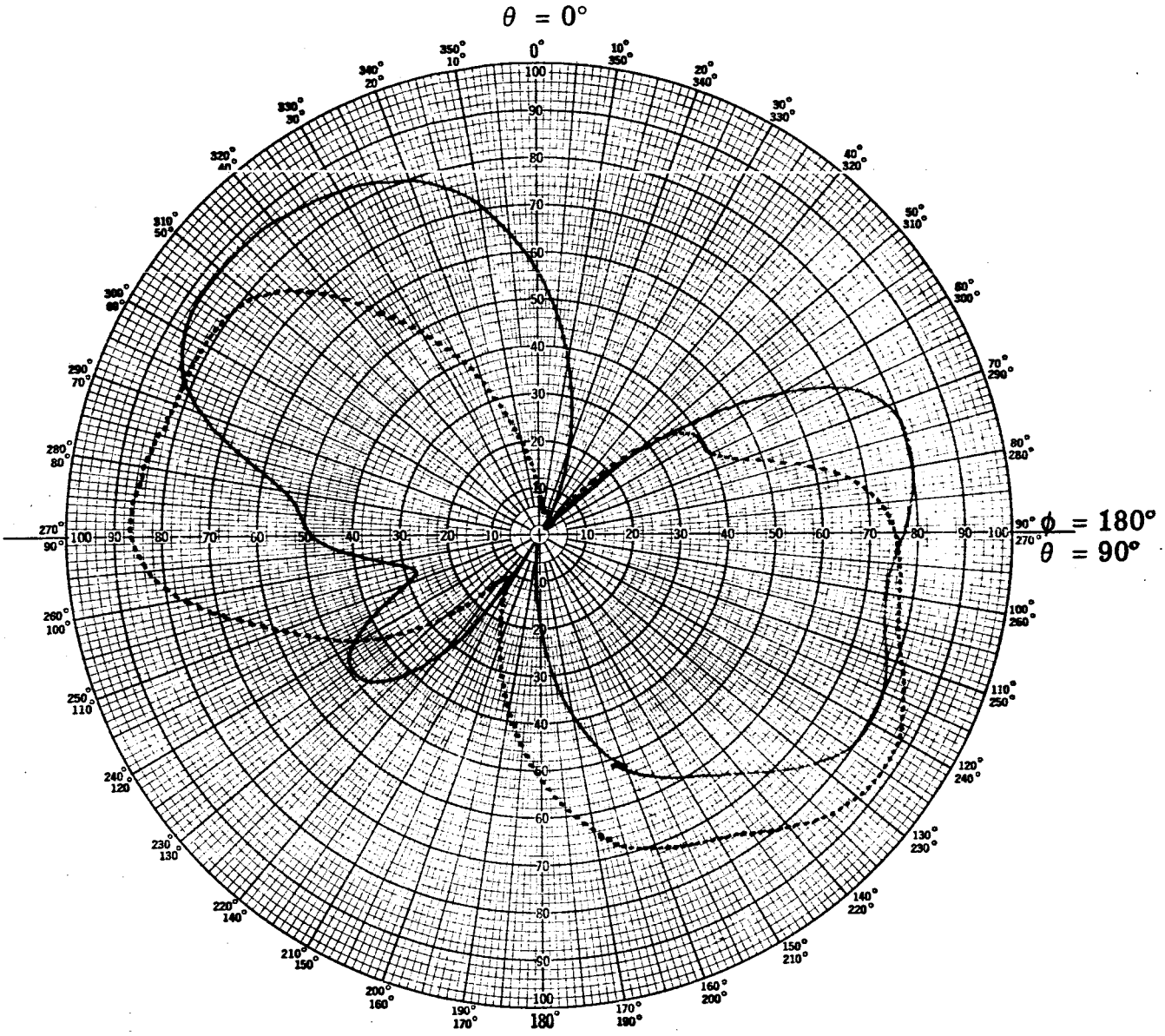

FIG. 30 - VHF RADIATION PATTERNS

ANTENNA - VHF slots on OAO
POLARIZATION - E_θ _____
E_ϕ ------
SCALE - 2 db/major division

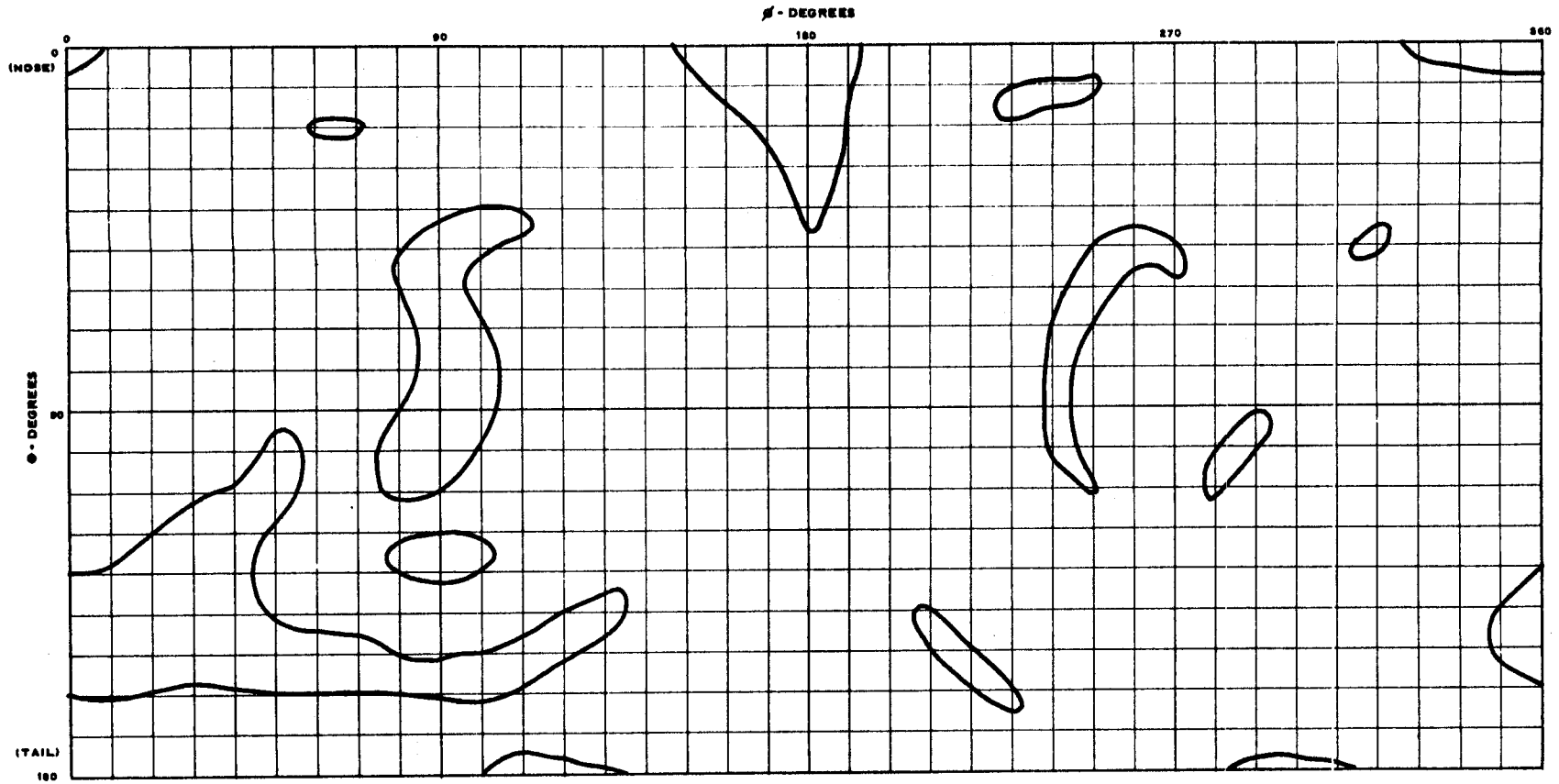

FIG. 31 - RADIO COMMAND LINK RADIATION POWER PLOT AT -12 db WITH RESPECT TO ISOTROPIC FOR E_ϕ POLARIZATION

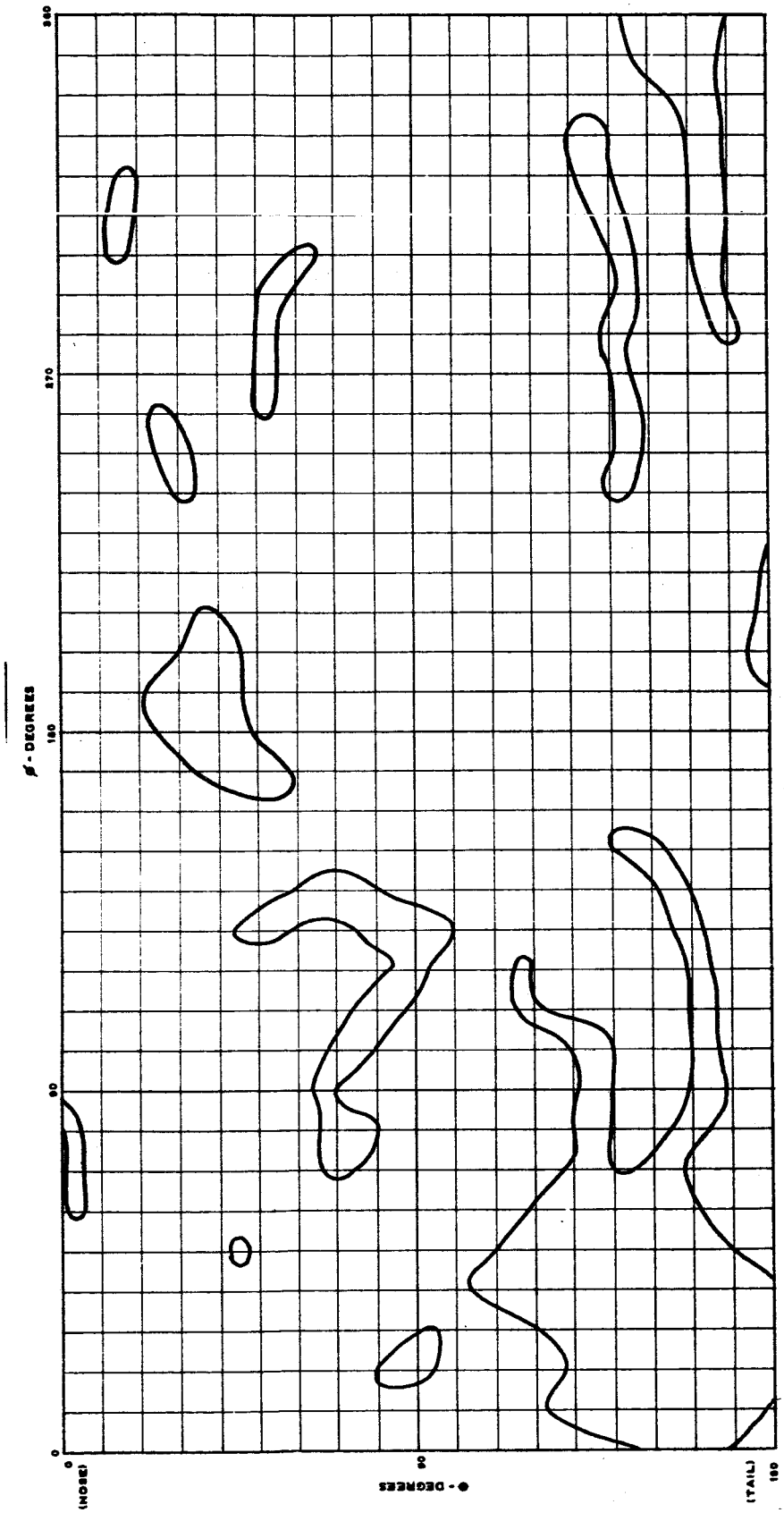

FIG. 32 - RADIO COMMAND LINK RADIATION POWER PLOT AT -12 db
WITH RESPECT TO ISOTROPIC FOR E_θ POLARIZATION

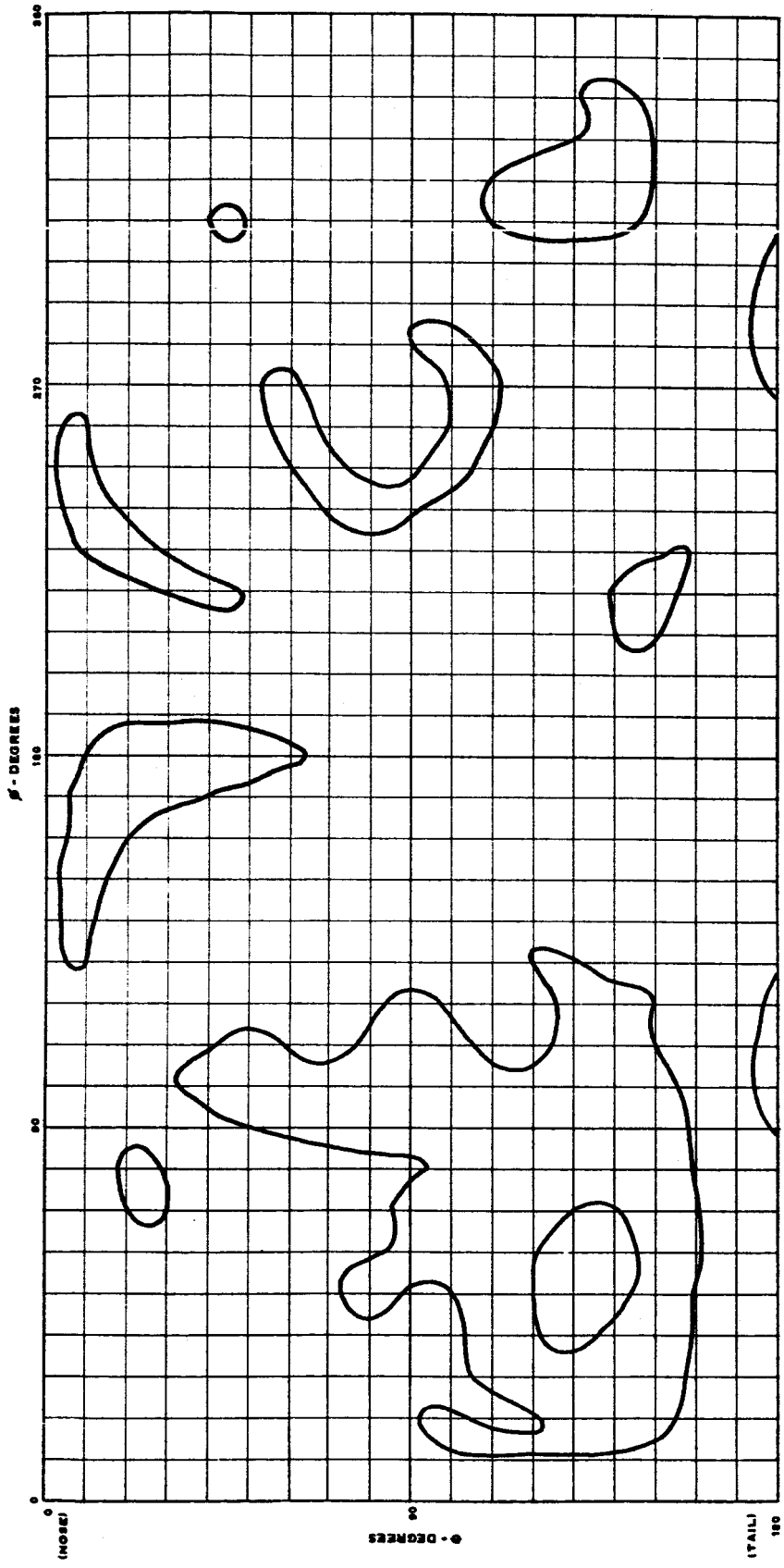

FIG. 33 - RADIO TRACKING BEACON LINK RADIATION POWER PLOT AT -12 db WITH RESPECT TO ISOTROPIC FOR E_ϕ POLARIZATION

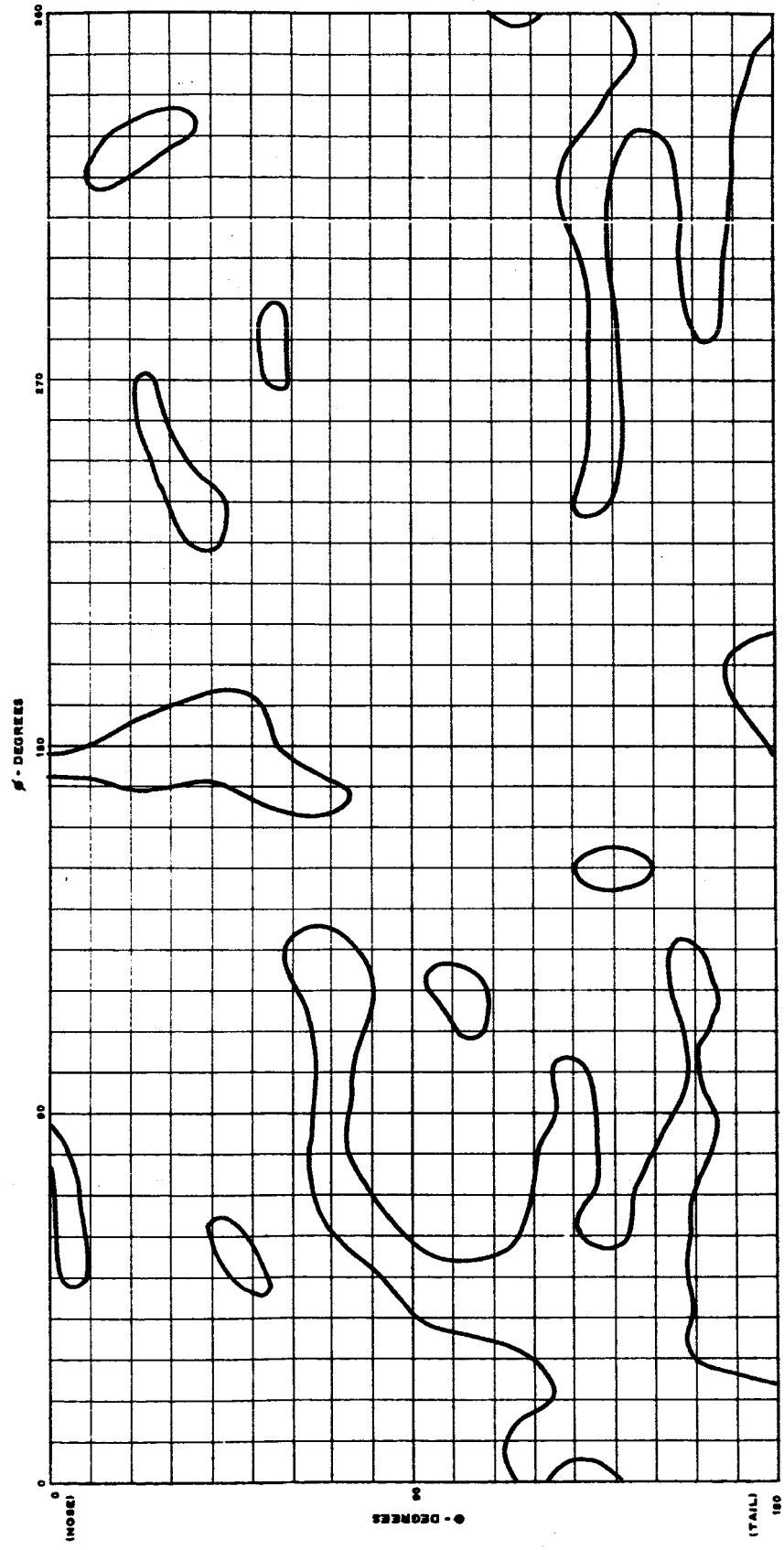

FIG. 34 - RADIO TRACKING BEACON LINK RADIATION POWER PLOT AT -12 db WITH RESPECT TO ISOTROPIC FOR E[redacted] POLARIZATION

5.3 Narrowband Telemetry Link (VHF)

The narrowband telemetry spacecraft antenna shall be compatible with a linear polarization diversity ground station. The parallel operation of the slots yields a radiated signal which has coverage in both E_θ and E_ϕ polarizations. Since the ground station can receive both polarizations the percent coverage of the narrowband telemetry is dependent on signal strength only and not on the polarization in a given direction. From the pattern data it was found that the coverage at a level 12 db below isotropic was 95.4% for the narrowband telemetry system. Figure 35 shows the power plot from which the percent coverage was obtained.

5.4 Wideband Telemetry Link (UHF)

The wideband telemetry system must meet the same requirements as the narrowband. The wideband telemetry coverage was obtained in exactly the same way as the narrowband telemetry coverage. The coverage is 95% at a level 10 db below isotropic for the wideband telemetry. The power plot for this system is shown in Fig. 36.

6.0 SOLAR CELL EFFICIENCY TEST

The slot antennas on the OAO spacecraft are cut directly in the solar planes. The effects of the solar cells on the antenna impedance and gain are desired. To obtain these effects two identical slot antennas were constructed. One antenna was constructed on a plain aluminum ground plane and one was cut in a ground plane covered with solar cells. (Fig. 37) The impedance of the two antennas before the addition of solar cells to one was the same. The antennas are both backed by a one-quarter wavelength cavity. This confines the radiation to only one side (the side with the solar cells) of the ground plane.

From the impedance plot in Fig. 38 it can be seen that the addition of the solar cells to antenna number two had no effect. The patterns of both antennas are compared in Fig. 39. The patterns of the antenna on the plain ground plane is almost identical to the one with the solar cells mounted on the ground plane. From these two tests it was concluded that the solar cells had no effect on the gain or impedance of the VHF slot antennas on the OAO spacecraft.

7.0 PORCELAIN ENAMELED ALUMINUM TEST

The skin of the OAO spacecraft is porcelain enameled aluminum. The UHF antennas are mounted directly on this surface. The effect of this surface on impedance and gain of an antenna mounted on the porcelain was investigated.

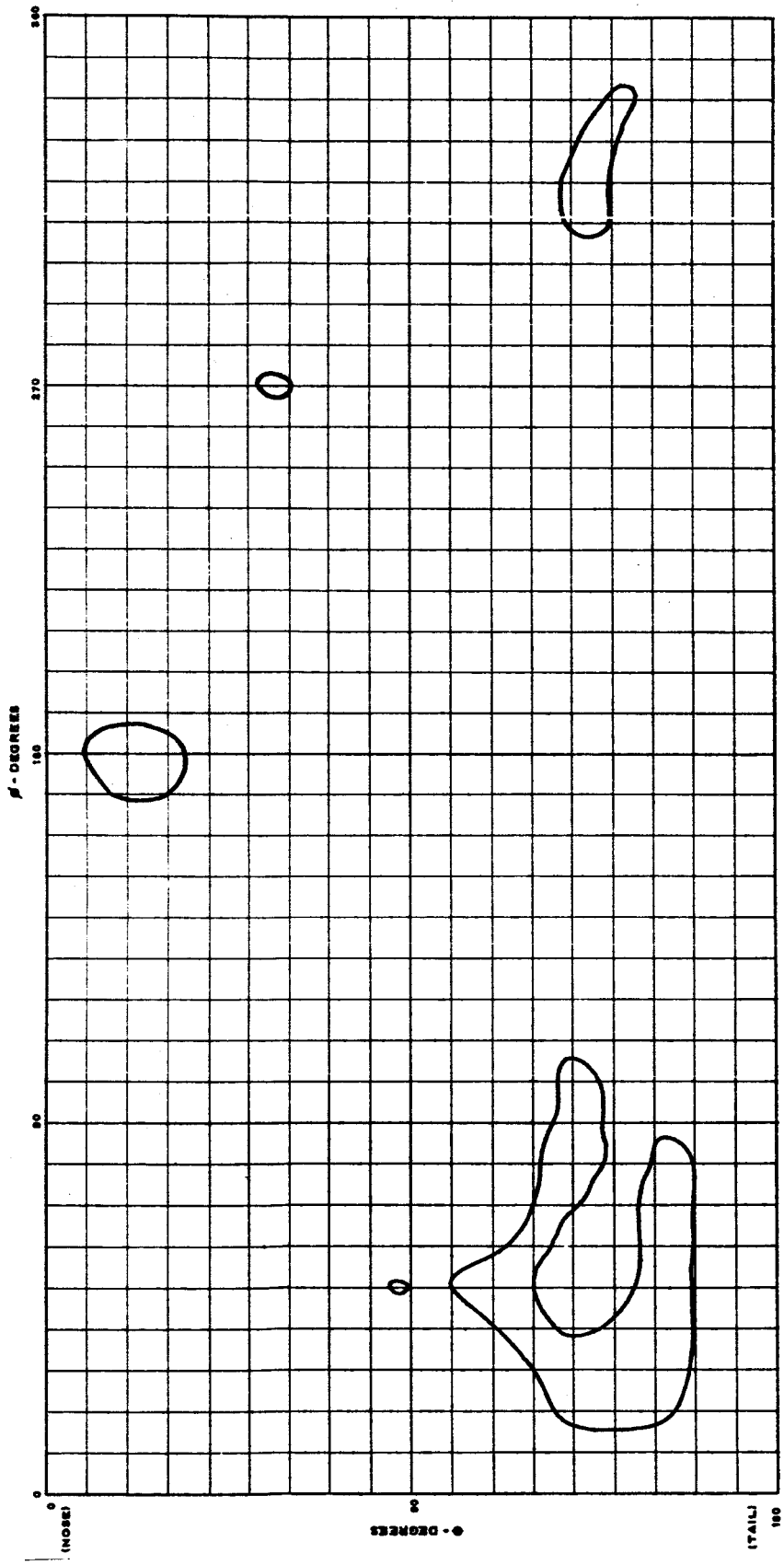

FIG. 35 - NARROW BAND TELEMETRY LINK RADIATION POWER PLOT AT -12 db WITH RESPECT TO ISOTROPIC FOR E_ϕ OR E_θ POLARIZATION

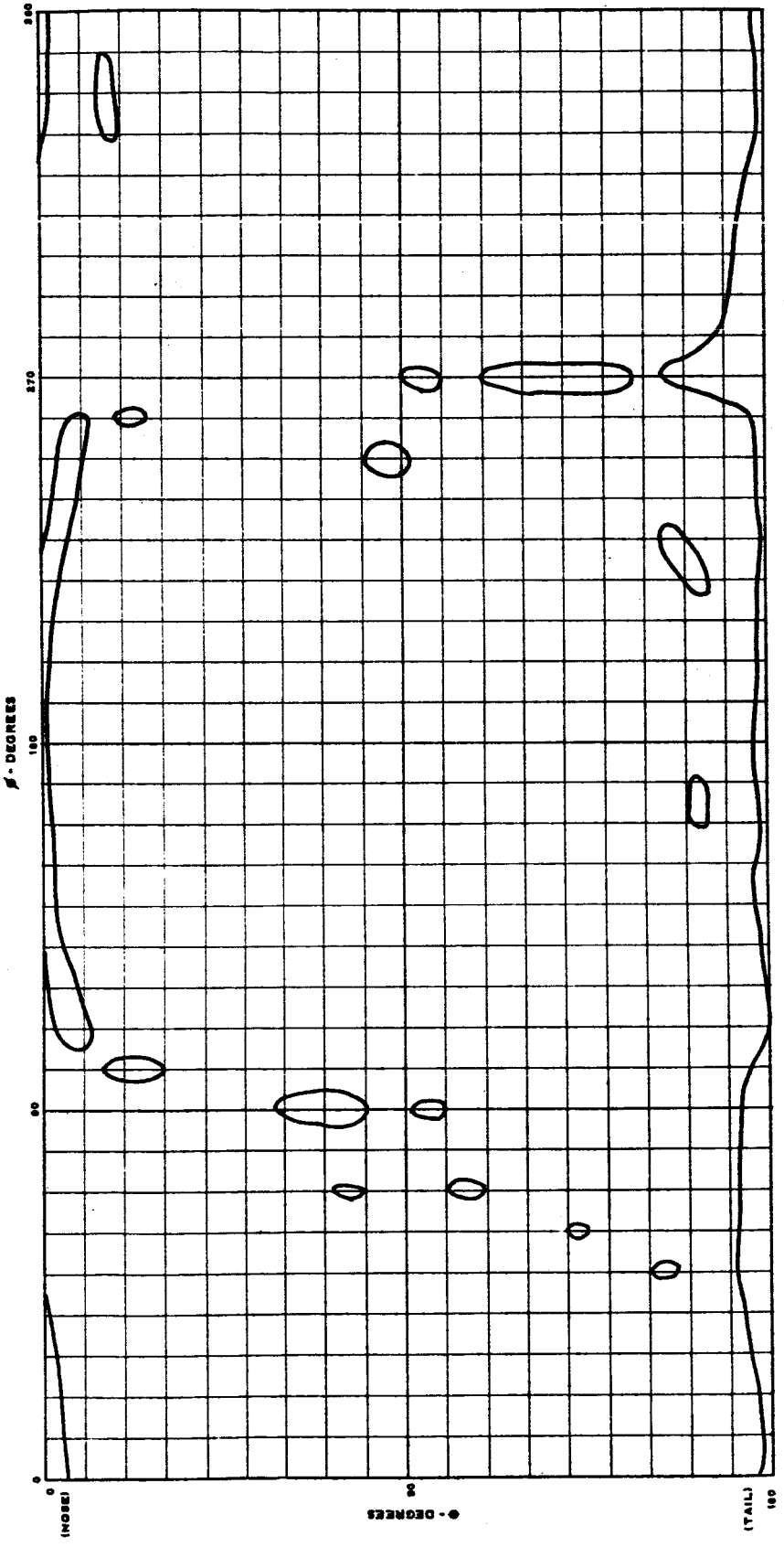

FIG. 36 - WIDE BAND TELEMETRY LINK RADIATION POWER PLOT AT -10 db
WITH RESPECT TO ISOTROPIC FOR E_ϕ OR E_θ POLARIZATION

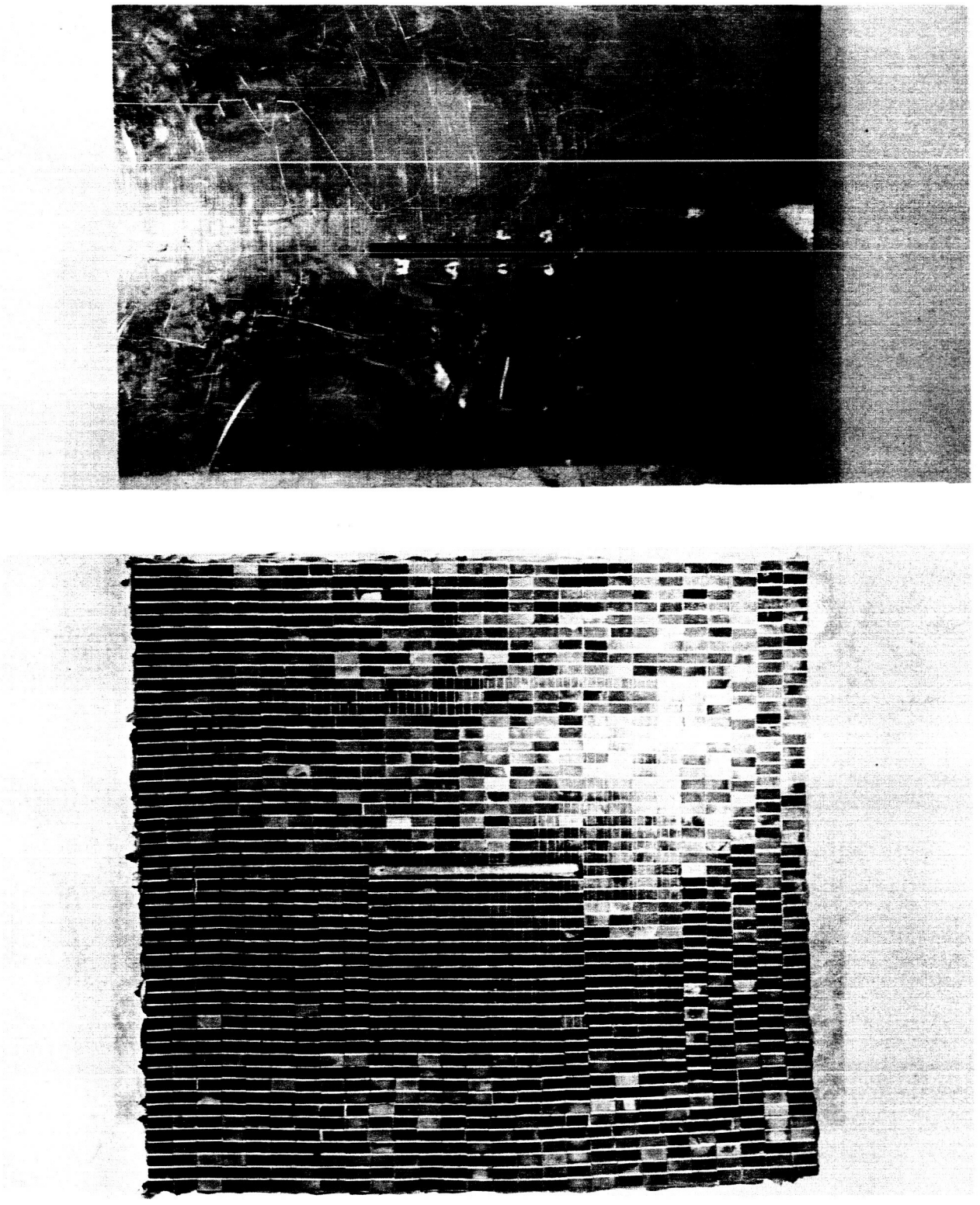

FIG. 37 - SLOT ANTENNAS USED FOR SOLAR CELL EFFICIENCY TEST

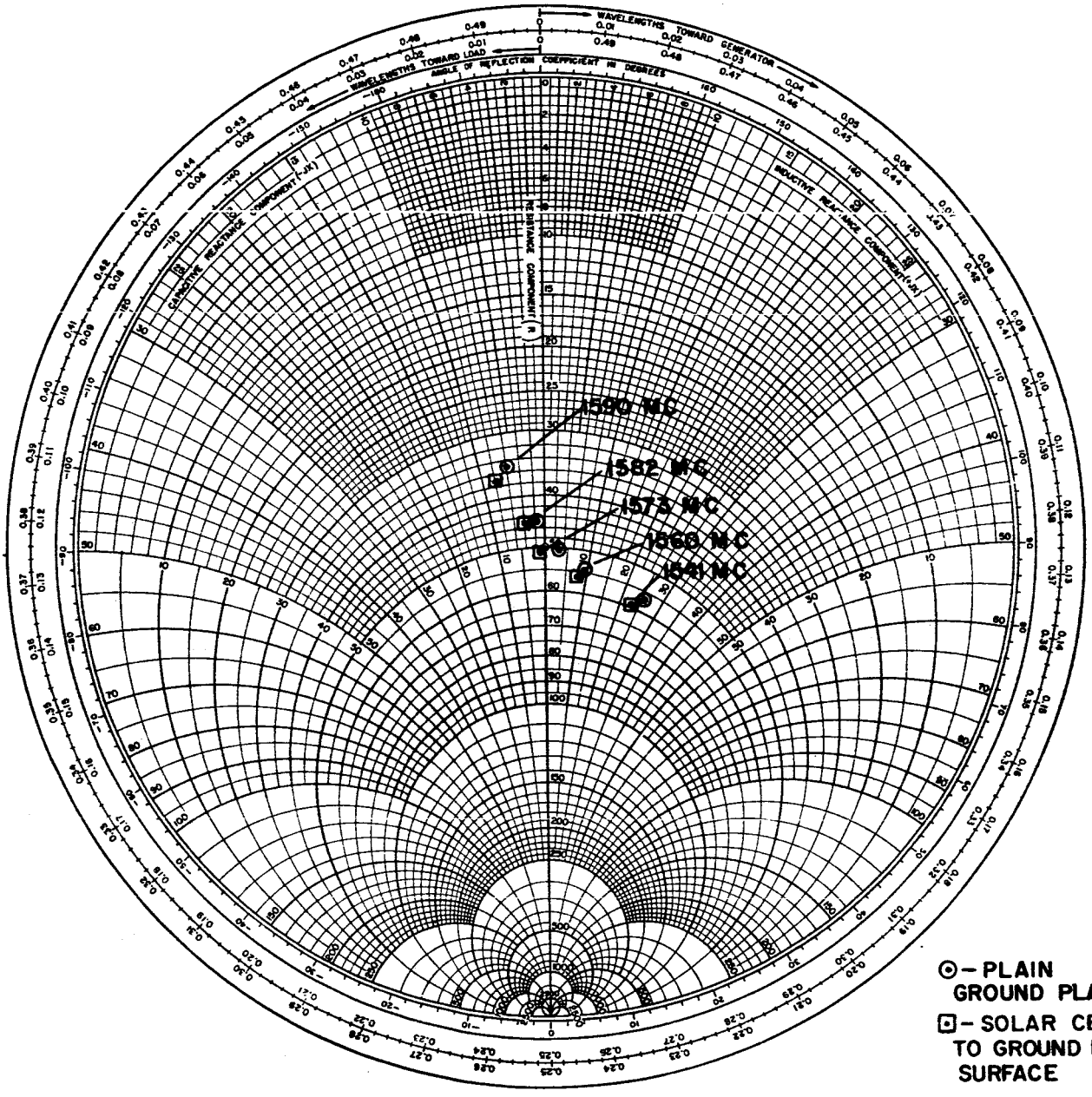

FIG. 38 - IMPEDANCE OF SOLAR CELL EFFICIENCY TEST ANTENNAS

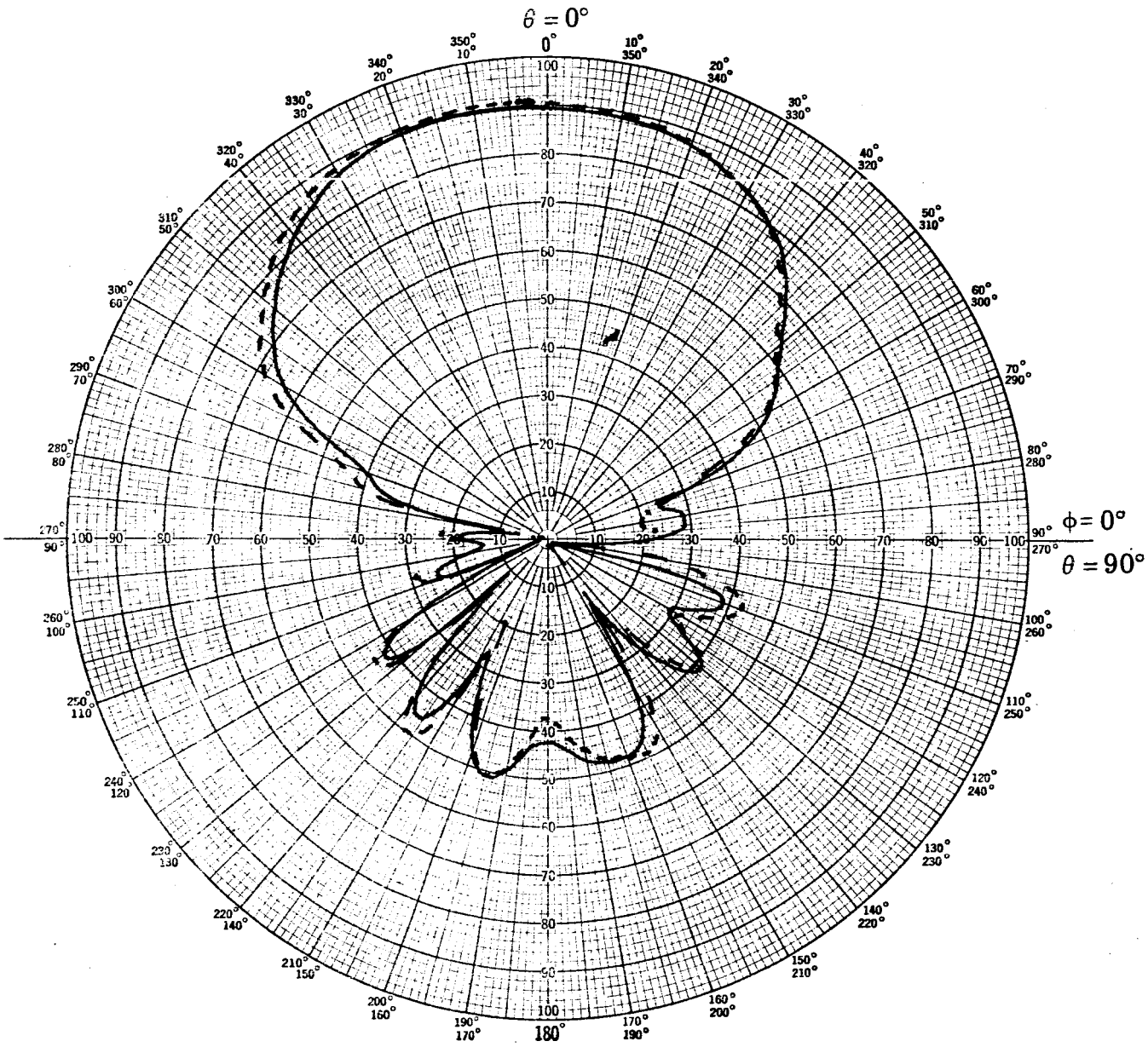

FIG. 39 - RADIATION PATTERNS OF SOLAR CELL EFFICIENCY TEST ANTENNAS

Radiation patterns of slot antenna with and without solar cells on the groundplane.
Dotted Pattern - with solar cells
Solid Pattern - without solar cells
E_ϕ Polarization

A quadraloop antenna tuned to approximately 400 Mc was checked first on a plain aluminum ground plane and then on the porcelain enameled surface. (Fig. 40) The impedance of the antenna on each ground plane was compared. Radiation patterns were taken of both configurations and the gain was compared to a half-wave dipole. There was some change in the impedance as shown in Fig. 41, but the change was slight. The radiation patterns showed no change and the gain of the two different cases was the same. (Fig. 42 and Fig. 43)

From the above tests it seems that no trouble will be encountered in the antenna tuning when the porcelain enameled aluminum ground plane is used.

8.0 CONCLUSIONS

The pattern and coverage checks were made to evaluate the data taken by the OAO spacecraft contractor. The coverage in all cases is adequate and the coverage figures obtained by the Physical Science Laboratory agree very well with those of the OAO prime contractor.

The tests of the effects of the solar cells and the porcelain enameled aluminum body were conducted to answer the question of antenna efficiency. These tests showed that the antennas are not affected by these physical parameters.

The tests run on the 1/4 scale OAO spacecraft indicate that the antenna system, both UHF and VHF, will do the job required.

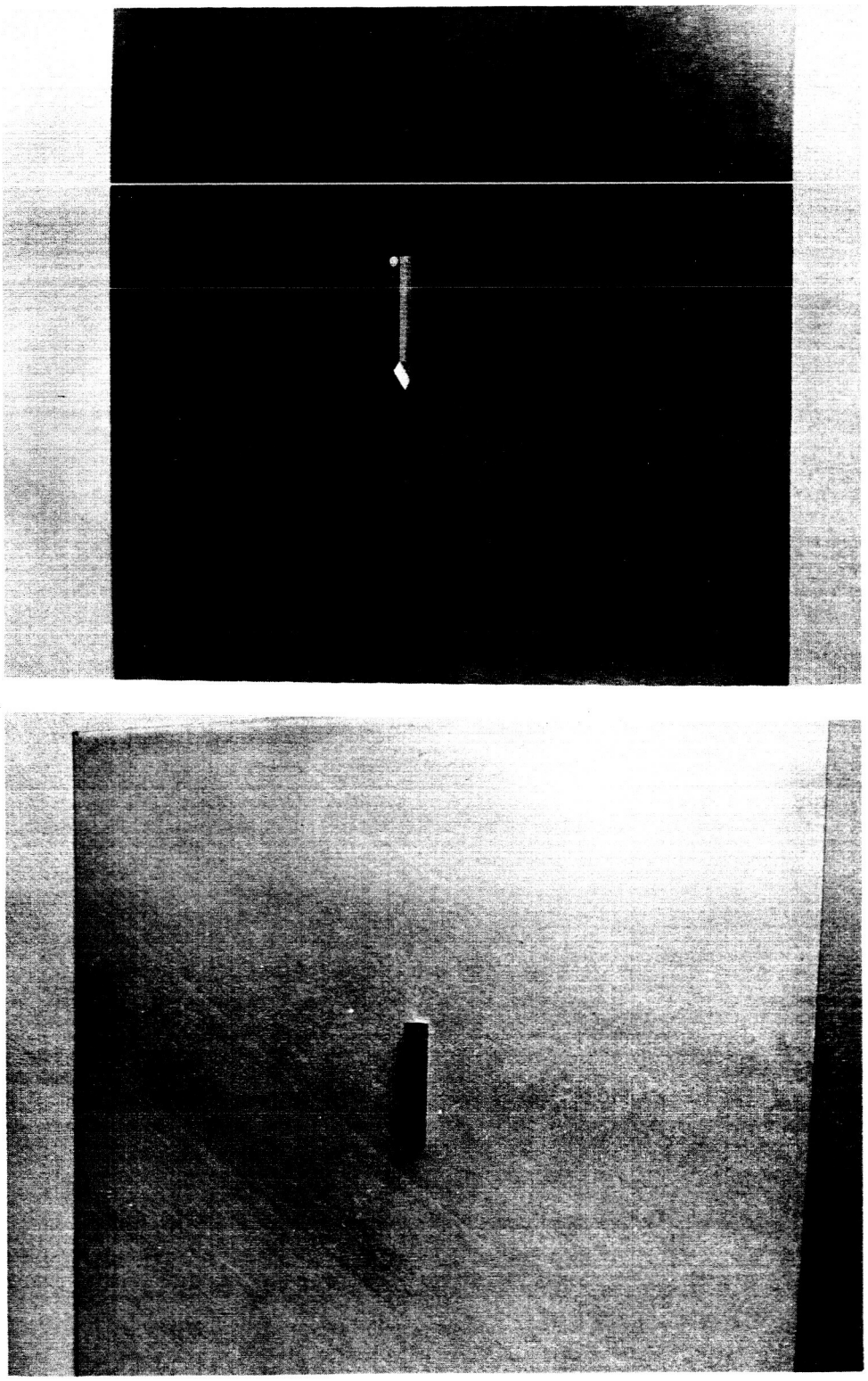

FIG. 40 - ANTENNA USED TO TEST PORCELAIN ENAMELED ALUMINUM

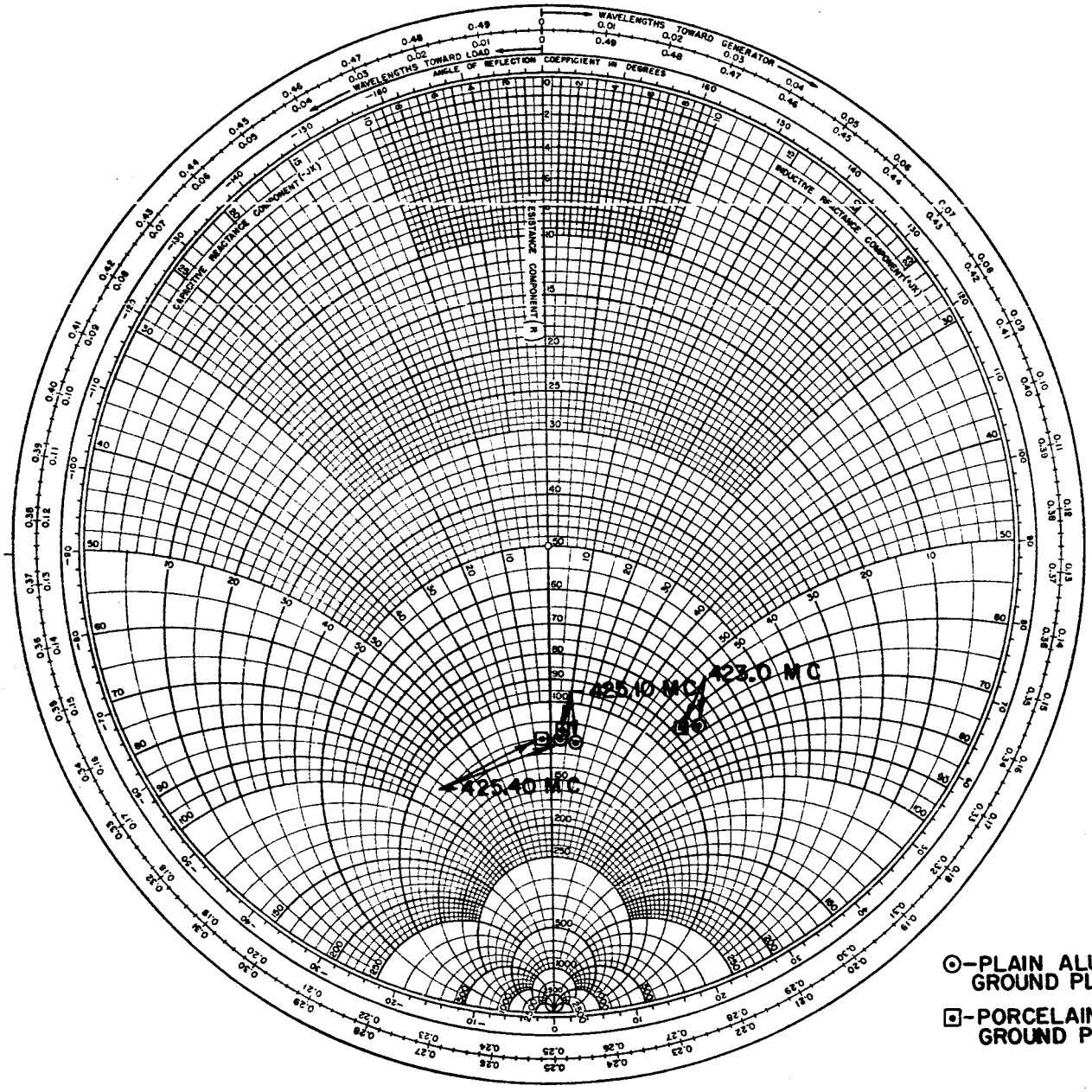

FIG. 41 - IMPEDANCE OF QUADRALOOP ON ALUMINUM AND PORCELAIN ENAMELED GROUND PLANES

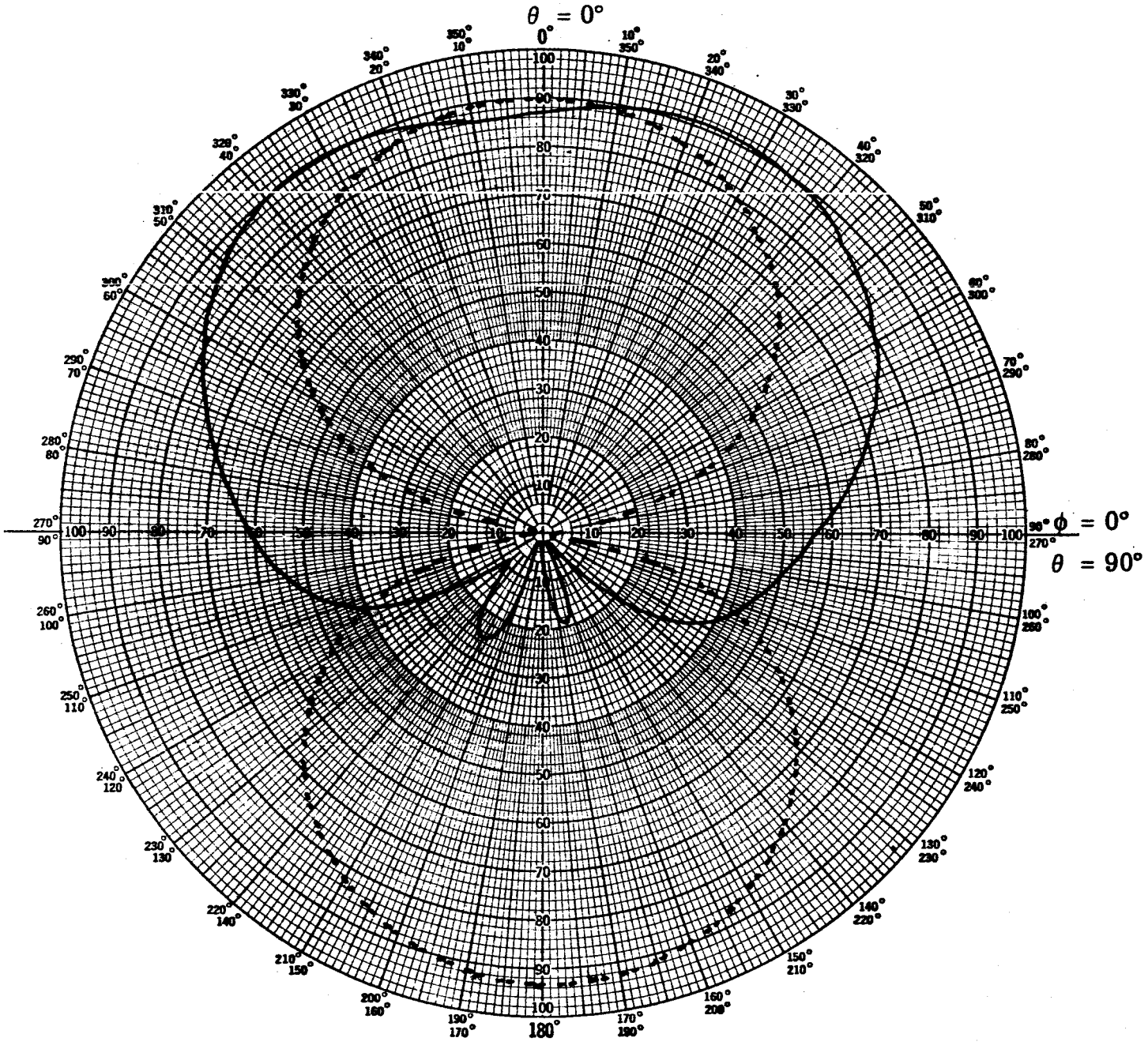

FIG. 42 - GAIN COMPARISON OF QUADRALOOP ON ALUMINUM GROUND PLANE

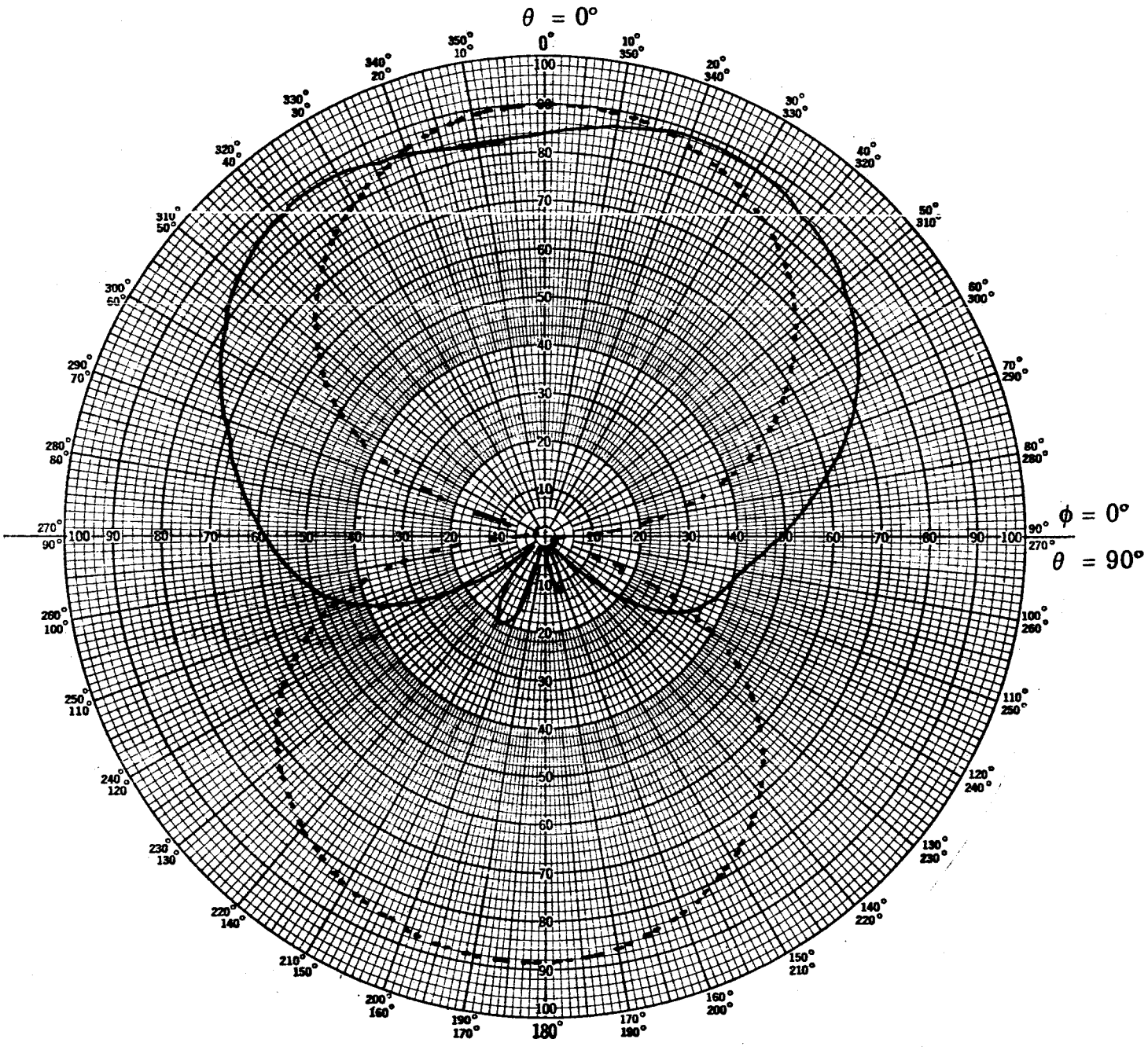

FIG. 43 - DIPOLE GAIN COMPARISON OF QUADRALOOP ON PORCELAIN ENAMELED GROUND PLANE

DISTRIBUTION LIST

1 - 4	National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland Attention: Joseph Purcell, 621
5 - 8	National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland Attention: August H. Wessels, 241
9 - 15	PSL/Antenna Section
16	PSL/RO