2

NASA CR-122511

MATCHED PAIR CONICAL SPIRAL ANTENNAS

Robert E. Metzler

GEOTRONICS, INC.
5718 Columbia Pike
Falls Church, Virginia 22041

April 1972
Final Report

(NASA-CR-122511) MATCHED PAIR CONICAL SPIRAL ANTENNAS Final Report R.E. Metzler (Geotronics, Inc.) Apr. 1972 54 p CSCL 17B G3/07

N72-28172
Unclas
36543

Prepared for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Details of illustrations in this document may be better studied on microfiche

NAS 5-23053

54p.

Preface

The contract objective was to design, fabricate, test, and calibrate a matched pair of VHF (220-260 MHz) conical spiral antennas for use in a rocket-tracking interferometer array. While gain, bandwidth, impedance, and pattern measurements met specifications, the phase match between antennas at low elevations was not equal to the design goal. Future work in this area might point toward patterns with more gain at low elevation angles plus construction techniques to produce pairs more nearly identical.

Table of Contents

List of Illustrations

List of Tables

1.0 Summary of Requirements

The application for the matched pair of conical spiral antennas is an rf interferometer array used in missile tracking at the White Sands facility. The cones are to be mounted with axes vertical and pointed toward the zenith. In this orientation, it is desired that maximum gain and circularity, if they vary with azimuth angle, should be maintained through an azimuth sector of 150° minimum. The axial ratio (polarization is right hand circular) through this sector and between 25° and 85° elevation is to be 3 dB maximum with a 1.5 dB design goal. Maximum gain is to fall at 80° to 90° elevation (referred to the ground plane) and is anticipated to be +4dBi. The required frequency range is 220-260 MHz and the VSWR 1.5:1 maximum referred to 50 ohms. Calibration and fiducial markings are required for each antenna of the pair such that they can be installed to produce equiphase far field planes (design goal ± 30 minutes of arc); this calibration is to be accomplished at three frequencies and every 36° of azimuth.

Mechanically, the antennas are designed for a wide outdoor temperature range (-55° to +150°F), winds up to 100 mph and humid, salt-corrosive environments.

2.0 Design

Geotronics had previously designed and constructed 4-arm conical spiral antennas in several physical configurations. These antennas produced patterns with an overhead null and maximum gain 30° to 50° above the horizon and were used for communication with satellites. This interferometer application, however, required a 2-arm spiral to produce maximum gain at the zenith.

Geotronics' previously-developed computer program for conical spirals is usable for either 2 or 4 arm models. From previous experience, it was felt that a base diamter of approximately 24 inches would be required for operation at 220 MHz. A spiral angle, α, of 84° degrees was selected. A prototype antenna was constructed to these dimensions and rotating-dipole patterns were taken across the band. Pattern shape and circularity were as anticipated, so detailed design of the deliverable matched pair commenced.

Since any appreciable tooling would have been prohibitively expensive for two units on a small fixed-price contract, the antennas were designed for hand construction. Three circular discs were machined for horizontal members, with oak ribs set into the discs to form the remainder of the underlying structure. This ribbed structure was covered with thin plastic sheet and the seams filled to form a smooth, continuous skin. The cone was truncated at the top at the 4 inch diameter point to provide space for the top of the feed balun. The conductive arms were pattern cut from aluminum sheet stock, formed onto the skin, and held in place with rivets and screws. The various sections of arms were spliced at the joints with aluminum plates,Devcon aluminum epoxy,and fasteners. The completed antennas were 24 inches in base diameter with a 27 inch diameter mounting plate, 50 inches high, and weighed 32 pounds each.

The balun is a choke at 240 MHz, open at the feed point and shorted one quarter wave below it. Impedance transformation is accomplished by a quarter-wave section of high impedance (82 ohm) transmission line.

The completed assembly was covered with 4 coats of Latex white paint. Following calibration, four fiducial marking strips and a top cap marker were affixed as an aid to installation and alignment with surveying equipment.

3.0 Test and Calibration

Four types of testing were performed on the completed antennas. Impedance (VSWR) measurements, elevation patterns with rotating linear source dipole, and gain measurements with a circularly polarized source antenna were all done on Geotronics roof-top antenna range. Phase versus azimuth measurements were made in a Government anechoic chamber at NASA-GSFC.

Table 3-1 shows VSWR measurements for both antennas. Table 3-2 lists gain, referred to a right-hand circularly polarized isotropic antenna, of both antennas at three frequencies.

Table 3-3 through 3-14 are the results of phase versus azimuth measurements on the antennas. The various tables represent measurements at three frequencies, two elevation angles, and with both vertically and horizontally polarized linear source antenna.

Figures 3-1 through 3-24 are elevation patterns of the antennas. The first eight patterns were taken at 220 MHz, the second eight at 240 MHz, and the final eight at 260 MHz. In each group of eight, the first four patterns are of antenna number one and the last four of antenna two. Each group of four patterns represents a complete 360 elevation cut (Θ) at four different azimuth angles (ϕ = 45°, 135°, 225°, and 315°) as measured clockwise from the "north" foot of each antenna.

Table 3-1

Antenna VSWR (ref. 50 ohms)

Freq. MHz	VSWR, Ant.#1	VSWR, Ant.#2
220	1.40	1.34
225	1.30	1.22
230	1.18	1.11
235	1.10	1.11
240	1.08	1.17
245	1.13	1.23
250	1.16	1.23
255	1.15	1.18
260	1.15	1.14

Table 3-2

Antenna Gain

(ref. RHCP isotropic)

Freq.MHz	Gain dB, Ant. #1 Range	Avg	Gain dB, Ant. #2 Range	Avg
220	7.9-8.3	8.1	7.9-8.2	8.0
240	8.0-8.2	8.1	8.0-8.3	8.2
260	8.1-8.2	8.2	8.0-8.2	8.1

Table 3-3

Frequency: 220 MHz Elevation Angle: 28° Source Antenna Polarization Vertical

Positioner Azimuth Angle, Deg.	Phase, Deg. Ant. #1	Phase, Deg. Ant, #2	Phase Difference, Deg. #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	39.1	36.8	-2.3
72.0	77.0	75.0	-2.0
108.0	115.1	112.8	-2.3
144.0	151.2	148.3	-2.9
180.0	-176.5	-178.0	-1.5
216.0	-141.6	-142.7	-1.1
252.0	-101.9	-104.4	-2.5
288.0	- 67.6	- 68.1	-0.5
324.0	- 36.1	- 34.4	+1.7
360.0	- 0.3	- 0.2	+0.1

Table 3-4

Frequency: 220 MHz   Elevation Angle: 28°   Source Antenna Polarization Horizontal

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	36.5	36.3	-0.2
72.0	72.1	71.3	-0.8
108.0	106.7	106.2	-0.5
144.0	143.9	142.9	-1.0
180.0	-176.9	-178.9	-2.0
216.0	-141.5	-142.5	-1.0
252.0	-108.4	-108.2	+0.2
288.0	- 72.7	- 73.3	-0.6
324.0	- 35.9	- 36.8	-0.9
360.0	0.2	0.2	0.0

Table 3-5

Frequency: 220 MHz Elevation Angle: 10° Source Antenna Polarization Vertical

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	33.7	33.5	-0.2
72.0	67.8	66.7	-1.1
108.0	110.4	104.6	-5.8
144.0	149.0	143.9	-5.1
180.0	-179.8	179.8	-0.4
216.0	-144.6	-146.0	-1.4
252.0	-104.8	-110.2	-5.4
288.0	- 73.7	- 75.8	-2.1
324.0	- 40.6	- 39.0	+1.6
360.0	0.2	- 0.1	-0.3

Table 3-6

Frequency: 220 MHz   Elevation Angle: 10°   Source Antenna Polarization Horizontal

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	38.5	36.8	-1.7
72.0	72.2	72.0	-0.2
108.0	106.8	107.4	+0.6
144.0	145.9	144.2	-1.7
180.0	-175.9	-178.7	-2.8
216.0	-140.5	-142.4	-1.9
252.0	-103.9	-106.1	-2.2
288.0	- 68.5	- 69.8	-1.3
324.0	- 35.8	- 35.0	+0.8
360.0	0.2	0.3	+0.1

Table 3-7

Frequency: 240 MHz   Elevation Angle: 28°   Source Antenna Polarization Vertical

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	34.9	36.8	+1.9
72.0	70.2	72.4	+2.2
108.0	106.7	108.4	+1.7
144.0	144.1	146.3	+2.2
180.0	-177.2	-176.4	+0.8
216.0	-139.9	-142.0	-2.1
252.0	-105.8	-107.9	-2.1
288.0	- 71.9	- 72.5	-0.6
324.0	- 36.1	- 36.4	-0.3
360.0	0.0	0.1	+0.1

Table 3-8

Frequency: 240 MHz   Elevation Angle: 28°   Source Antenna Polarization Horizontal

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.2	0.1	-0.1
36.0	35.8	36.3	+0.5
72.0	72.6	74.8	+2.2
108.0	109.5	111.6	+2.1
144.0	144.9	146.0	+1.1
180.0	179.5	-179.9	+0.6
216.0	-144.3	-143.8	+0.5
252.0	-106.2	-106.3	-0.1
288.0	- 69.4	- 69.6	-0.2
324.0	- 34.7	- 34.4	+0.3
360.0	- 0.2	0.1	+0.3

Table 3-9

Frequency: 240 MHz   Elevation Angle: 10°   Source Antenna Polarization Vertical

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	40.4	45.0	+4.6
72.0	74.9	79.9	+5.0
108.0	102.2	109.6	+7.4
144.0	129.1	142.1	+13.0
180.0	172.5	-177.3	+10.2
216.0	-132.3	-133.3	- 1.0
252.0	- 95.6	- 96.5	- 0.9
288.0	- 66.3	- 66.3	- 0.0
324.0	- 35.9	- 37.6	- 1.7
360.0	0.2	0.2	0.0

Table 3-10

Frequency: 240 MHz Elevation Angle: 10° Source Antenna Polarization Horizontal

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.0	0.1	+0.1
36.0	35.5	35.8	+0.3
72.0	72.5	74.3	+1.8
108.0	108.8	111.5	+2.7
144.0	143.3	147.8	+4.5
180.0	177.8	-177.2	+5.0
216.0	-145.8	-142.0	+3.8
252.0	-108.5	-104.7	+3.8
288.0	- 72.2	- 67.6	+4.6
324.0	- 35.4	- 32.8	+2.6
360.0	0.0	- 0.1	-0.1

Table 3-11

Frequency: 260 MHz Elevation Angle: 28° Source Antenna Polarization Vertical

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	34.7	35.3	+0.6
72.0	70.5	71.9	+1.4
108.0	106.5	108.4	+1.9
144.0	143.2	144.7	+1.5
180.0	-179.6	-178.9	+0.7
216.0	-143.9	-143.3	+0.6
252.0	-109.5	-108.5	+1.0
288.0	- 72.8	- 72.1	+0.7
324.0	- 35.6	- 35.4	+0.2
360.0	0.0	0.2	+0.2

Table 3-12

Frequency: 260 MHz   Elevation Angle: 28°   Source Antenna Polarization Horizontal

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.2	0.1	-0.1
36.0	36.0	35.7	-0.3
72.0	73.4	73.1	-0.3
108.0	110.6	110.1	-0.5
144.0	144.7	144.4	-0.3
180.0	178.4	178.3	-0.1
216.0	-145.7	-145.6	+0.1
252.0	-107.7	-107.2	+0.5
288.0	- 70.6	- 69.9	+0.7
324.0	- 35.2	- 35.1	+0.1
360.0	0.4	- 0.1	-0.5

Table 3- 13

Frequency: 260 MHz Elevation Angle: 10° Source Antenna Polarization Vertical

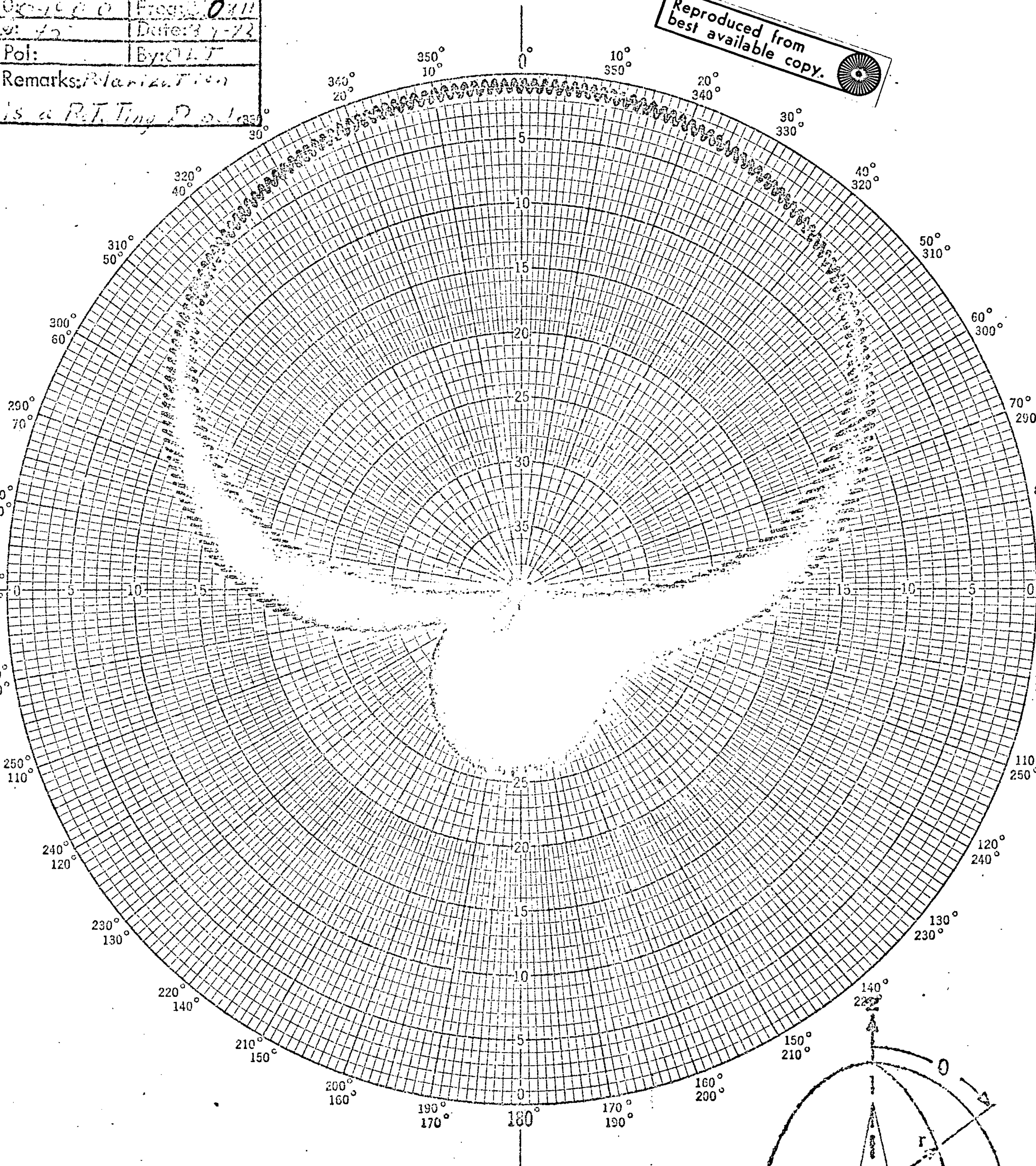
Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.1
36.0	34.5	32.9	-1.6
72.0	66.5	67.1	+0.6
108.0	98.3	102.8	+4.5
144.0	139.6	145.8	+6.2
180.0	-176.6	-173.4	+3.2
216.0	-144.5	-142.1	+2.4
252.0	-113.5	-110.0	+3.5
288.0	- 78.1	- 73.8	+4.3
324.0	- 37.7	- 35.2	+2.5
360.0	0.1	- 0.1	-0.2

Table 3-14

Frequency: 260 MHz Elevation Angle: 10° Source Antenna Polarization Horizontal

Positioner Azimuth Angle,	Phase, Ant. #1	Phase, Ant, #2	Phase Difference #2 rel. to #1
0.0	0.1	0.1	0.0
36.0	36.6	36.4	-0.2
72.0	75.5	75.3	-0.2
108.0	112.5	112.3	-0.2
144.0	146.3	145.7	-0.6
180.0	180.0	179.2	-0.8
216.0	-143.5	-144.1	-0.6
252.0	-107.1	-106.4	+0.7
288.0	- 69.8	- 68.3	+1.5
324.0	- 33.8	- 33.0	+0.8
360.0	0.1	0.0	-0.1

Antenna:
Orientation:
Freq:
Date:
Pol:
By:
Remarks:



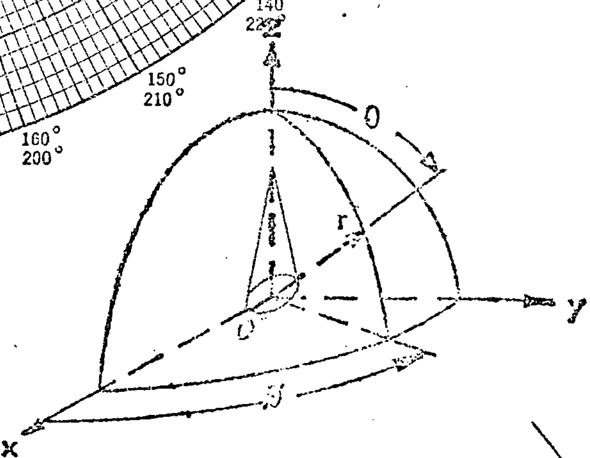


Figure No. 3-1

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#1 220 MH

Antenna: 136-CS-2 SN-1

Orientation:

θ: 0-180-0	Freq: 220MH
ø: 135°	Date: 3-4-72
Pol:	By: OLJ

Remarks: Polarization is by a Rotating Dipole

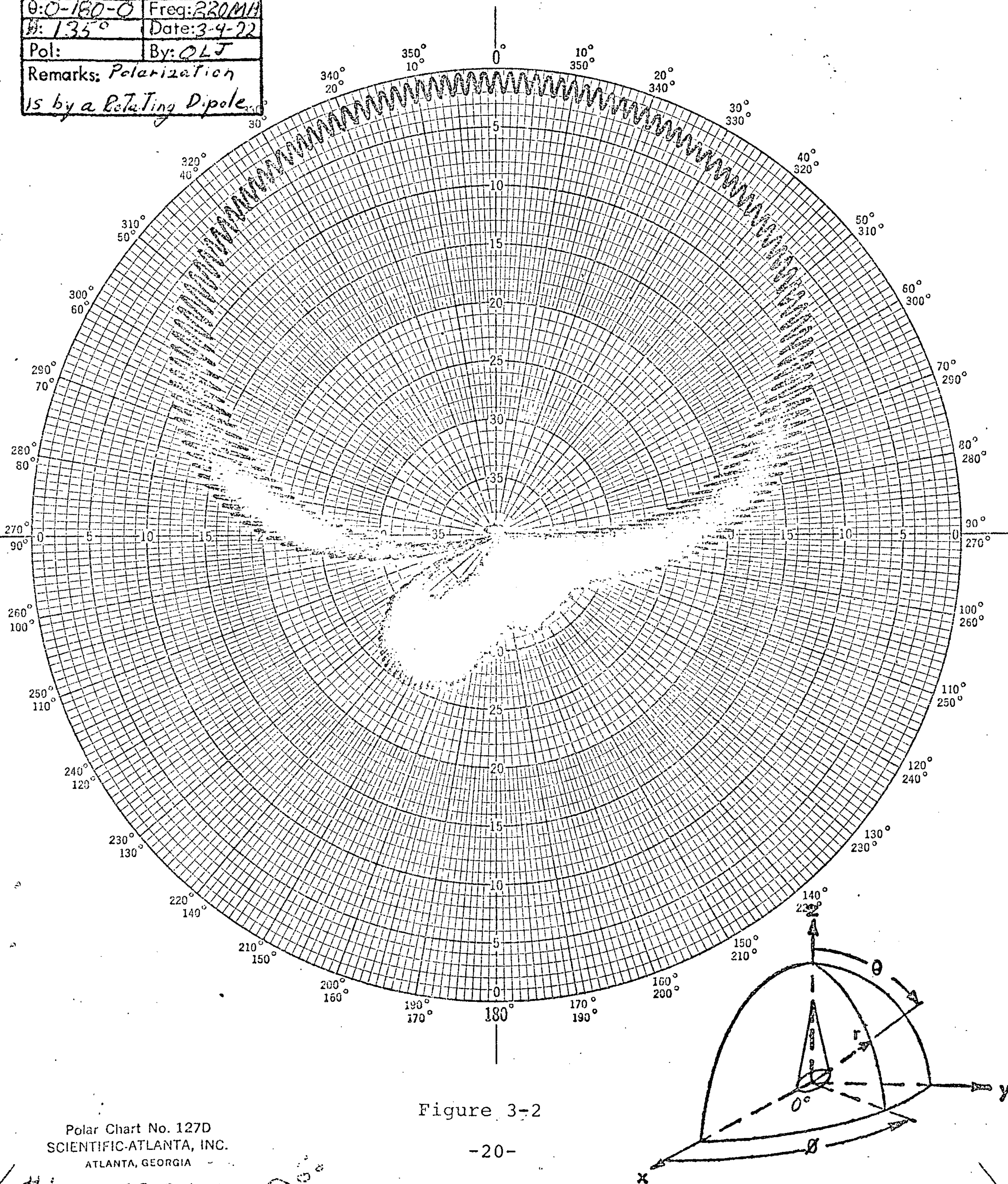


Figure 3-2

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#1 220 MH

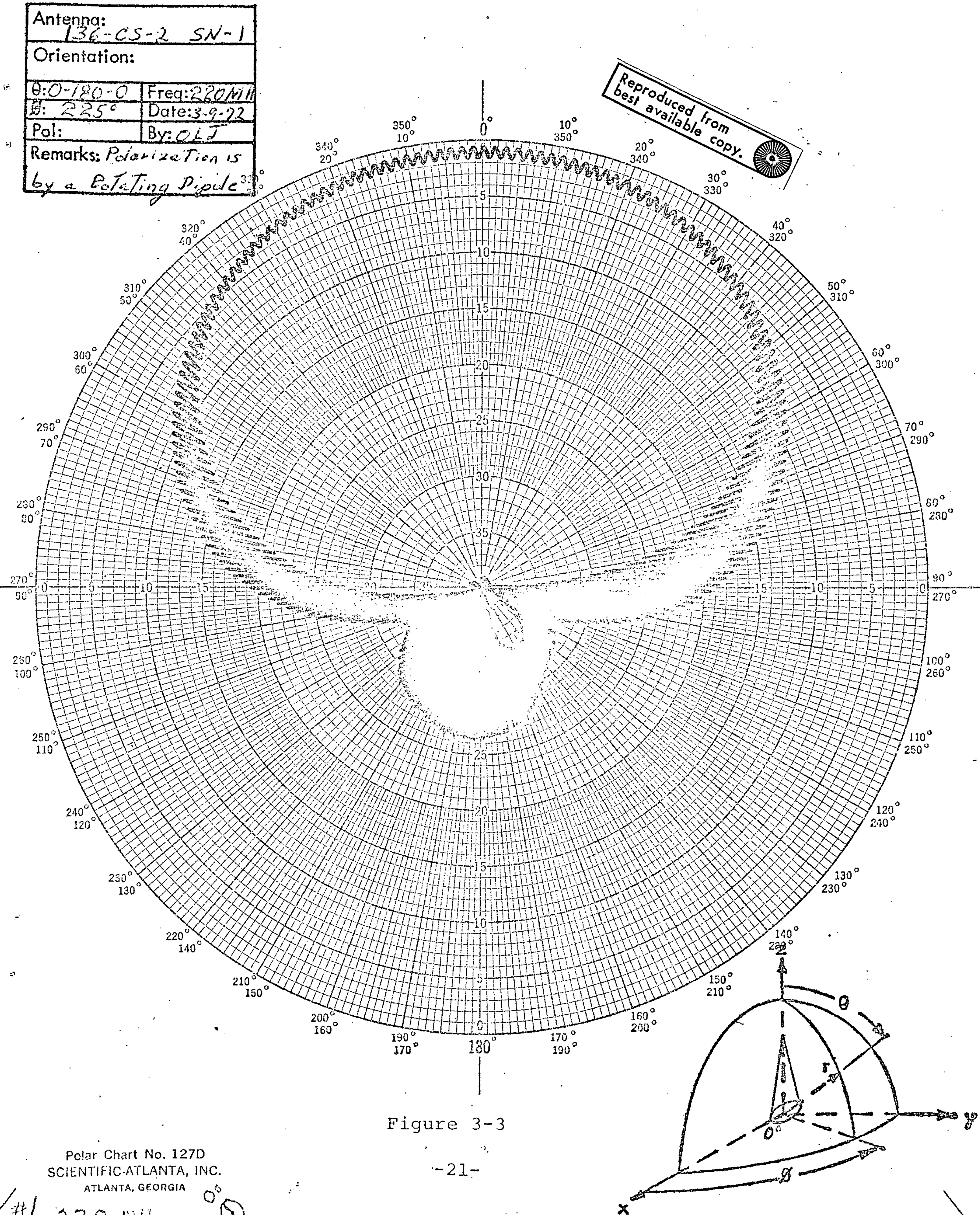
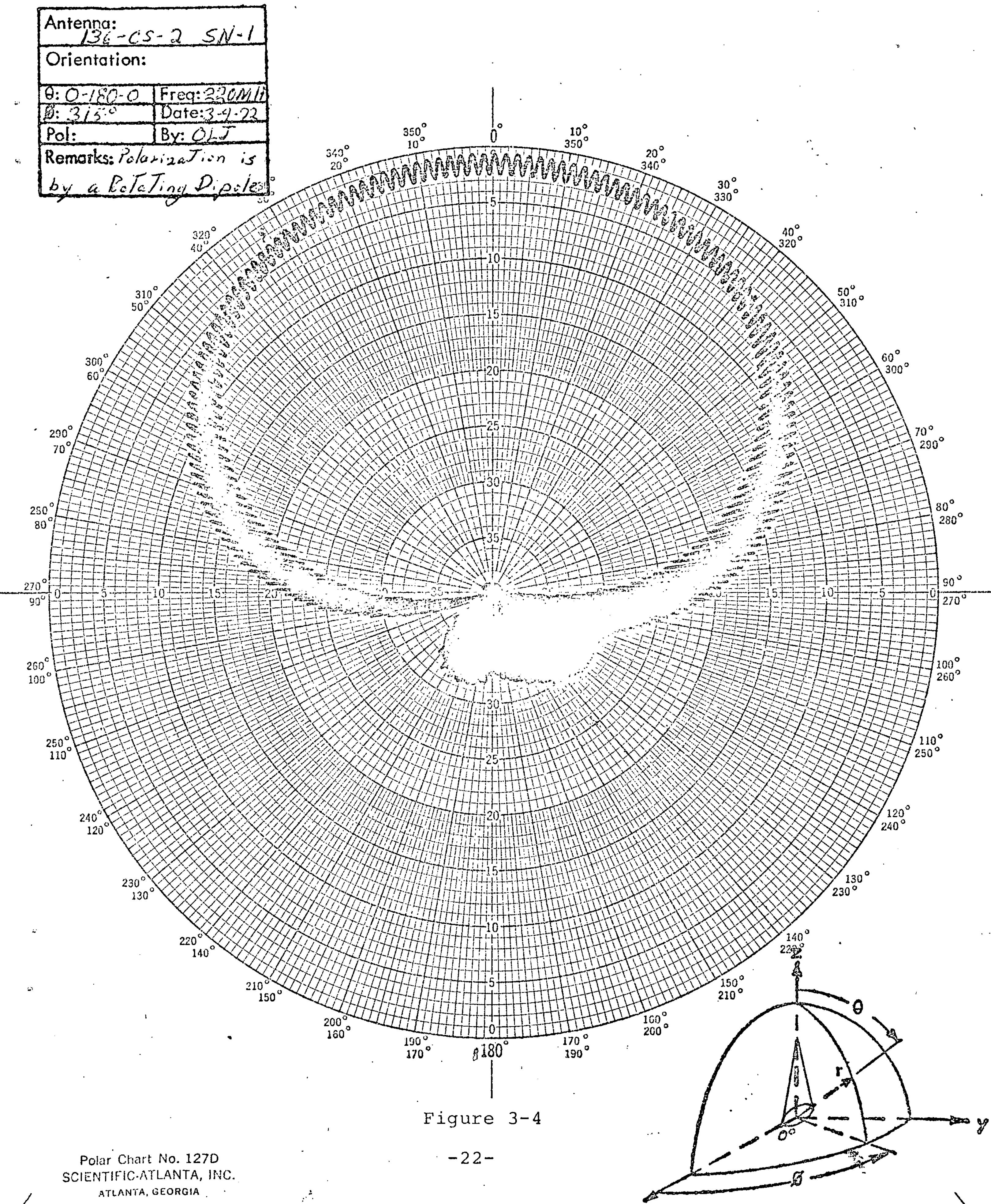


Figure 3-3

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#1 220 MH 0°



Antenna: 136-CS-2 SN-1
Orientation:
θ: 0-180-0
Freq: 220MHz
ϕ: 315°
Date: 3-9-72
Pol:
By: OLJ
Remarks: Polarization is by a Rotating Dipole
z
θ
r
y
x
ϕ
0°
Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA
#1 220 MH ①

Figure 3-4

Antenna: 132-CS-2 SN-2	
Orientation:	
	Freq: 220 MH
	Date:
Pol:	By:
Remarks: Polarization	

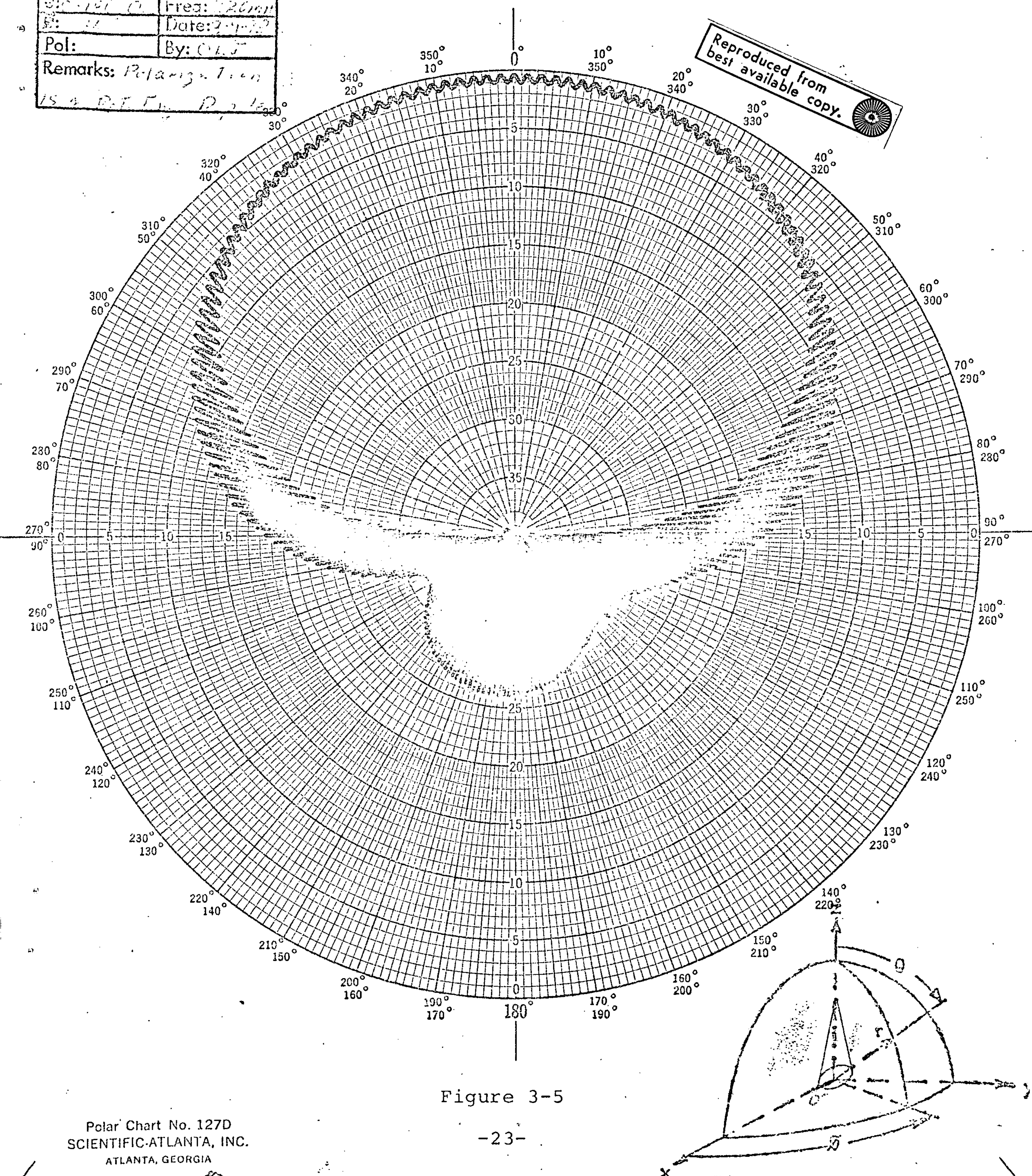
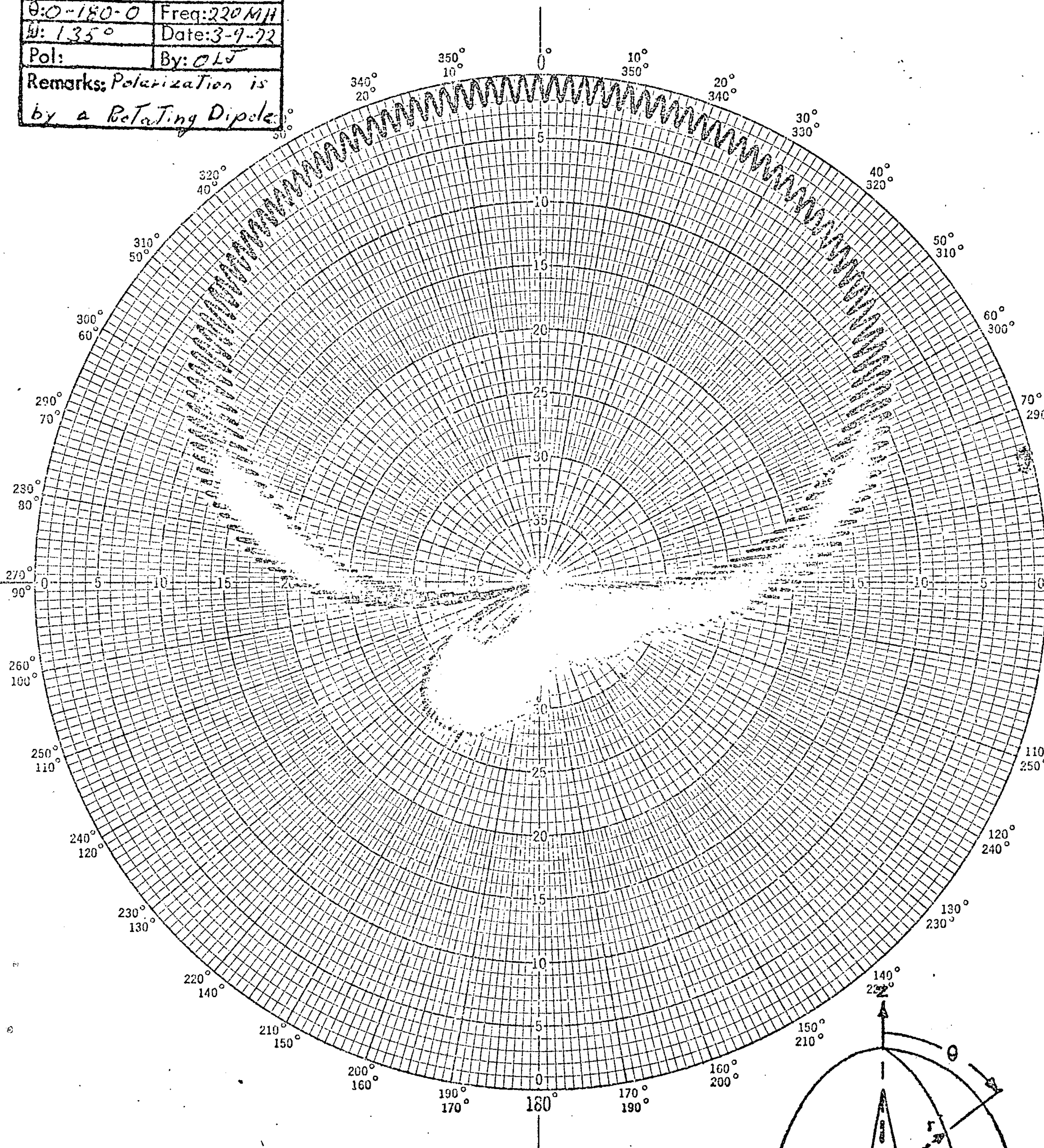


Figure 3-5

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 220 MH

Antenna: 136-CS-2 SN-2	
Orientation:	
θ: 0-180-0	Freq: 220 MH
Ø: 135°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	



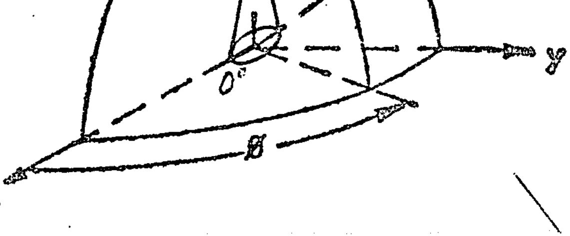
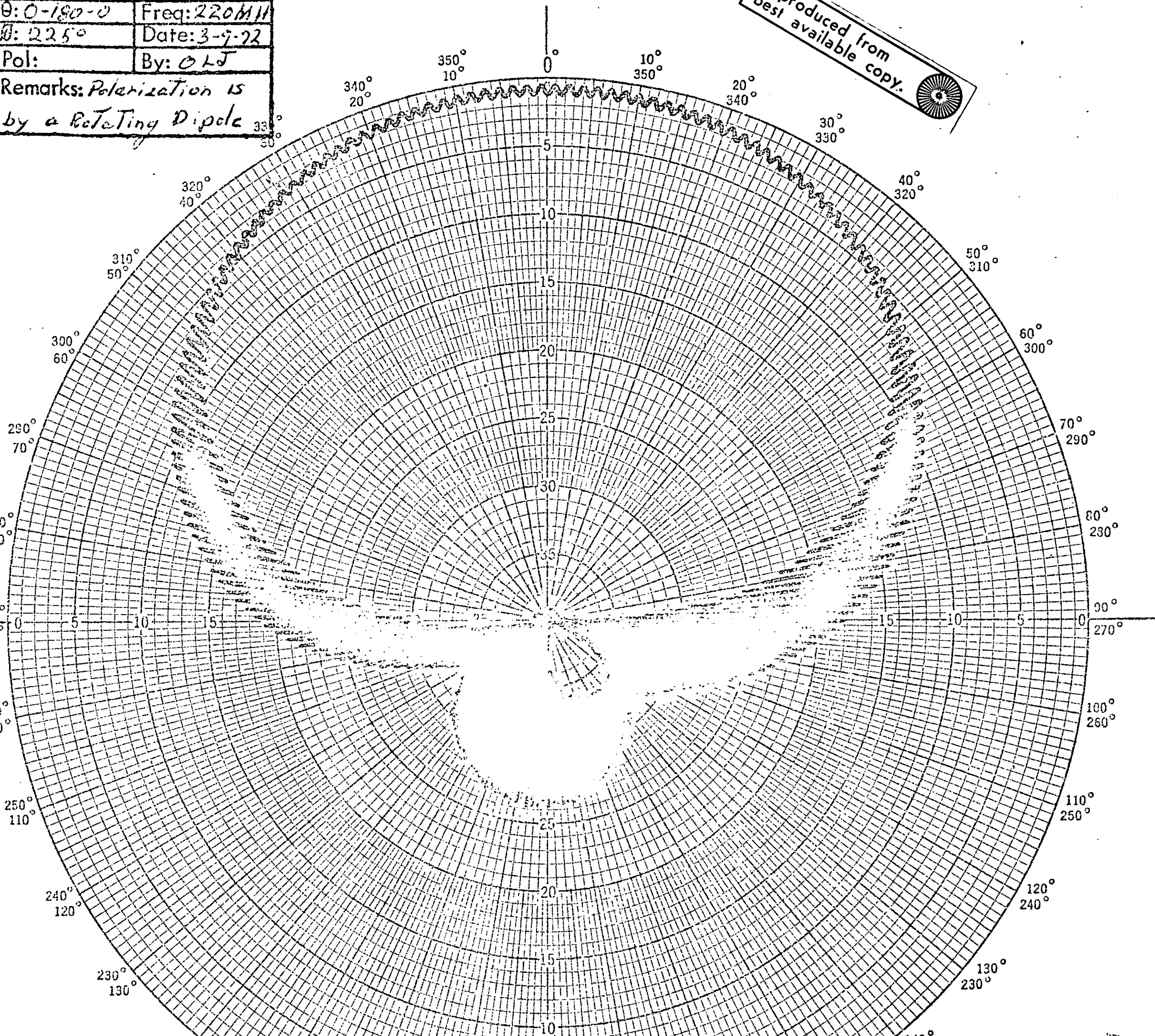


Figure 3-6

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 220 MH

Antenna: 136-CS-2- SN-2	
Orientation:	
θ: 0-180-0	Freq: 220MH
Ø: 225°	Date: 3-7-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	



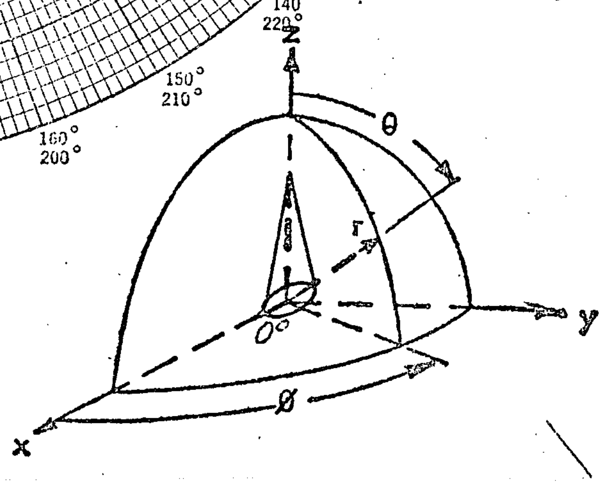
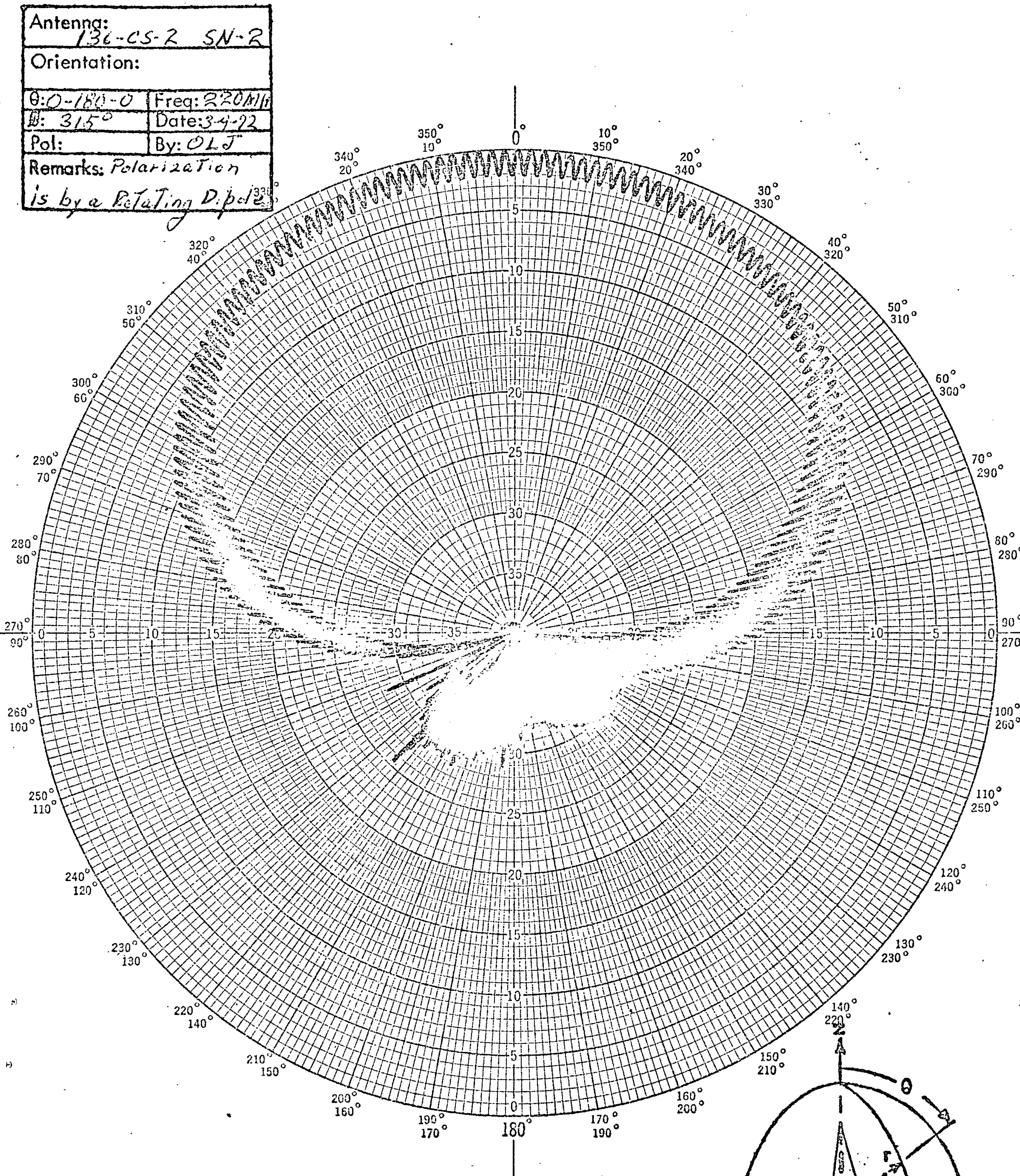


Figure 3-7

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 220 MH



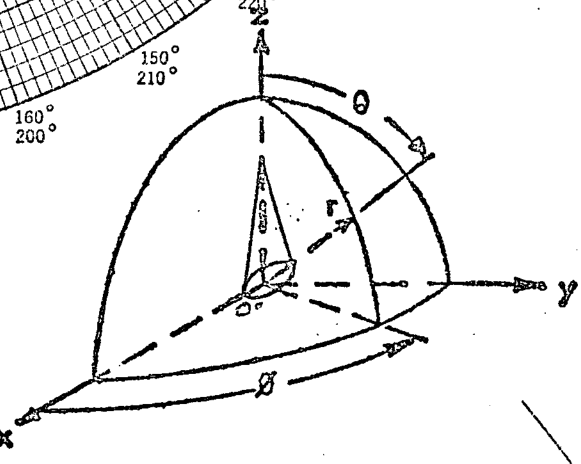
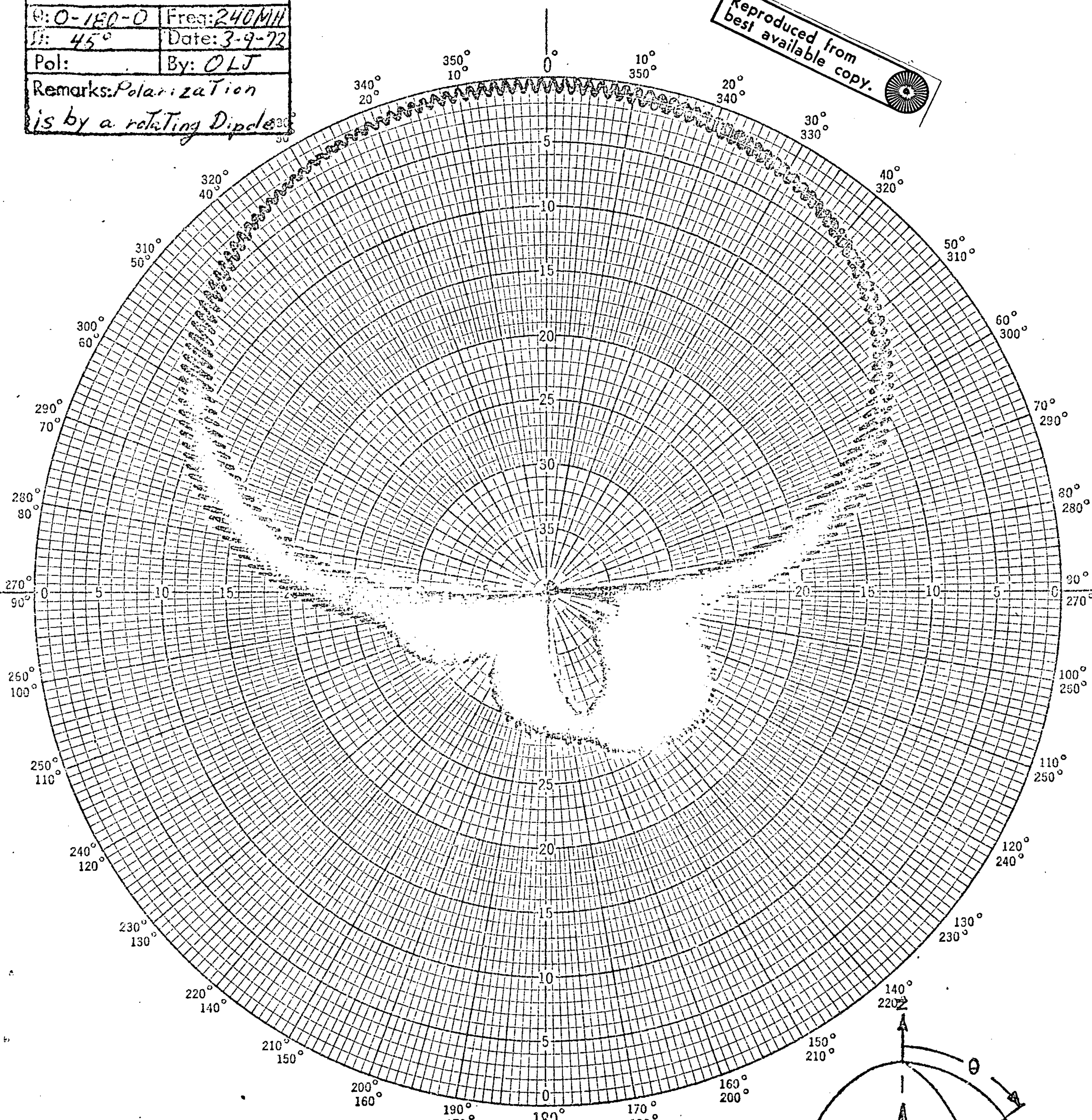


Figure 3-8

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 220MH

Antenna: 136-CS-2 SN-1	
Orientation:	
θ: 0-180-0	Freq: 240MH
Φ: 45°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a rotating Dipole	



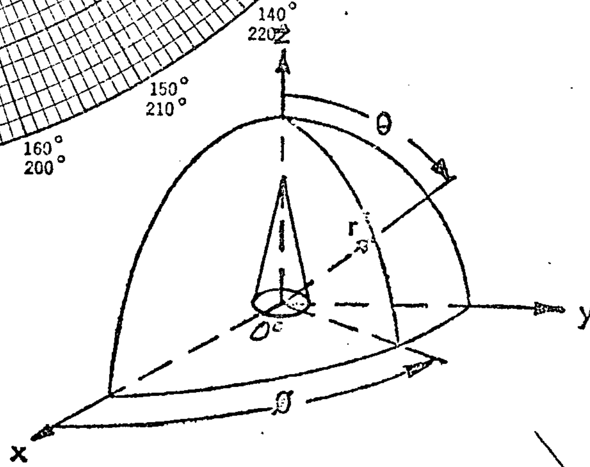


Figure 3-9

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#1 240 MH

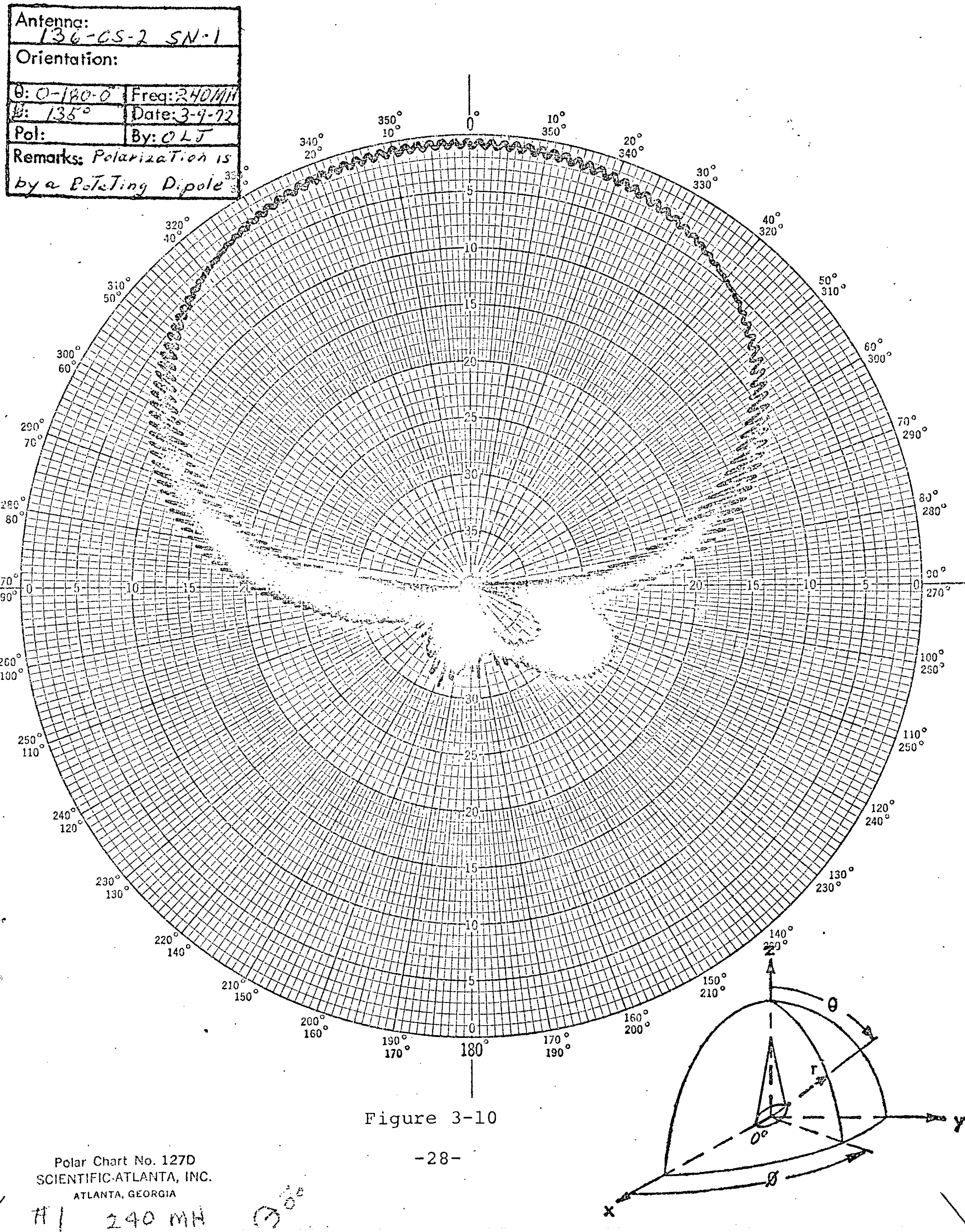
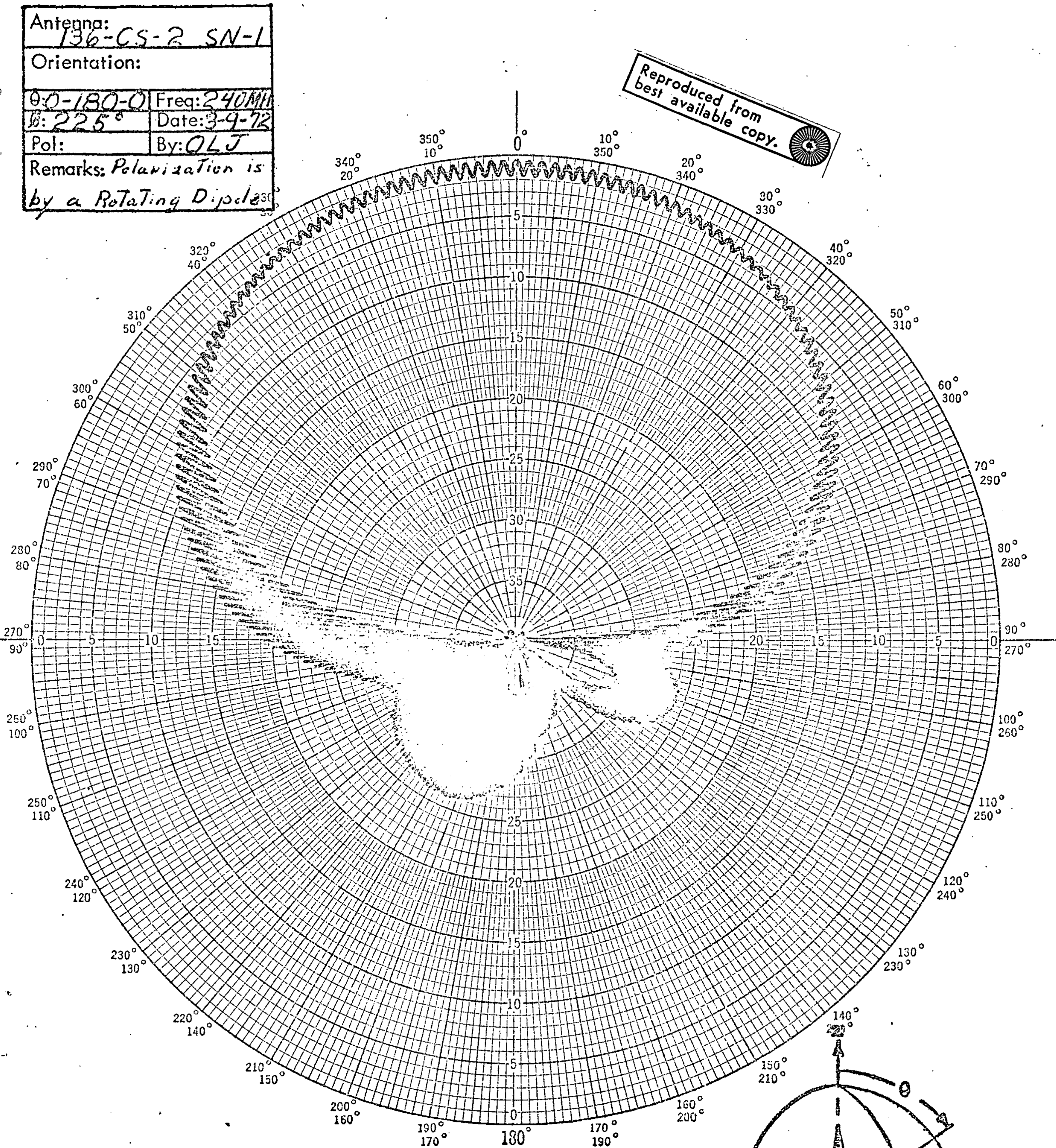

Antenna: 136-CS-2 SN-1
Orientation:
θ: 0-180-0 Freq: 240MH
Ø: 135° Date: 3-9-72
Pol:
By: OLJ
Remarks: Polarization is by a Rotating Dipole
Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA
H | 240 MH
z
θ
r
y
0°
Ø
x

Figure 3-10



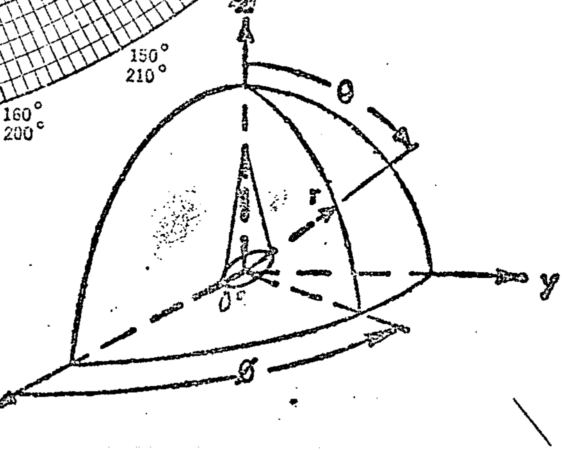
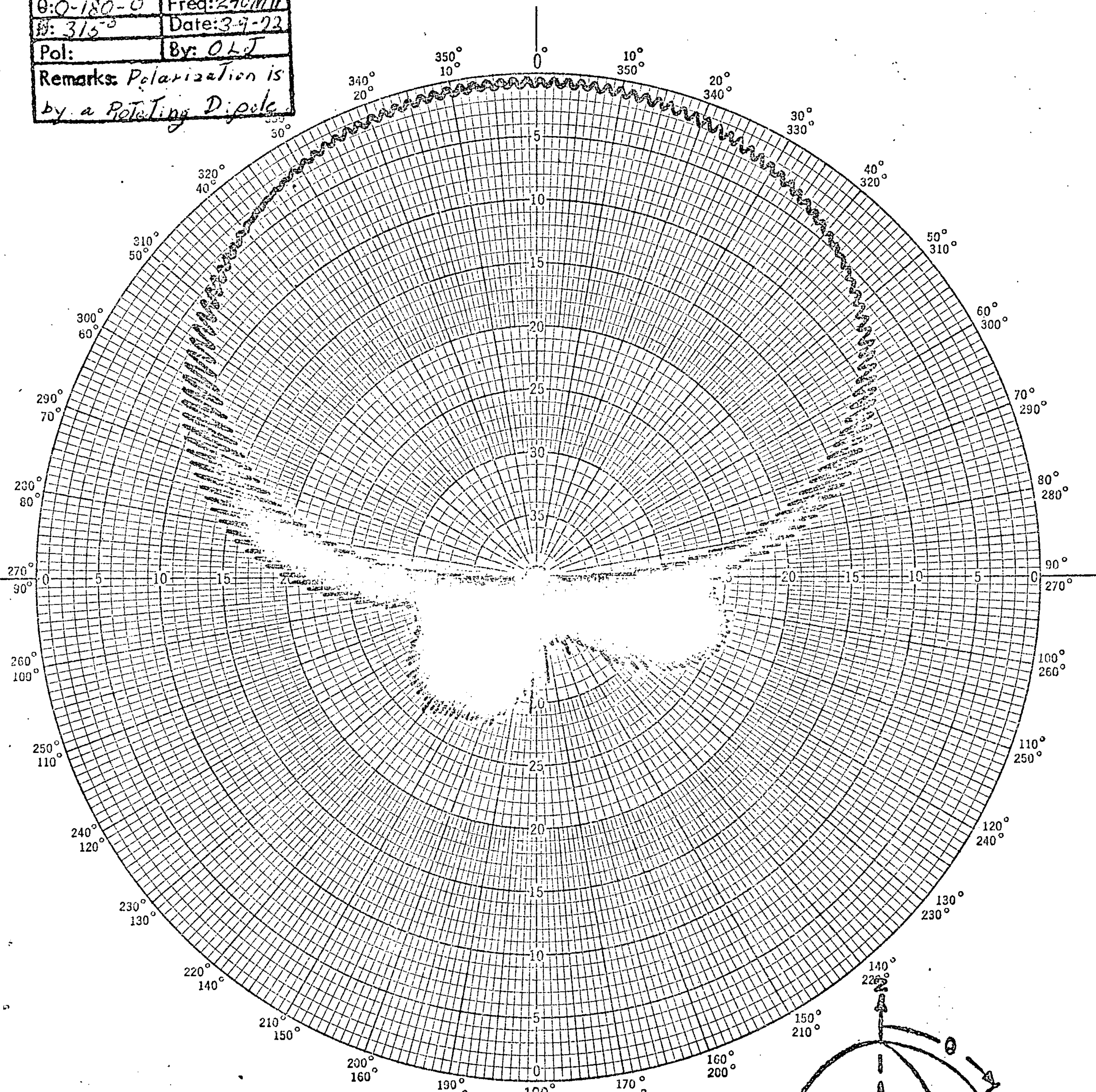


Figure 3-11

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

Antenna: 136-CS-2 SN-1	
Orientation:	
θ: 0-180-0	Freq: 240 MH
Ø: 315°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	



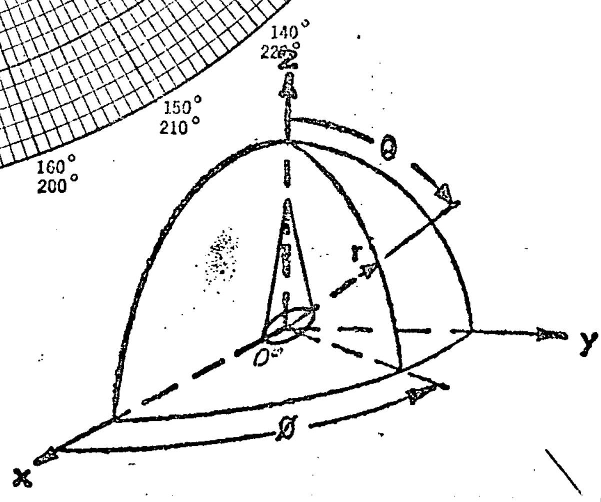
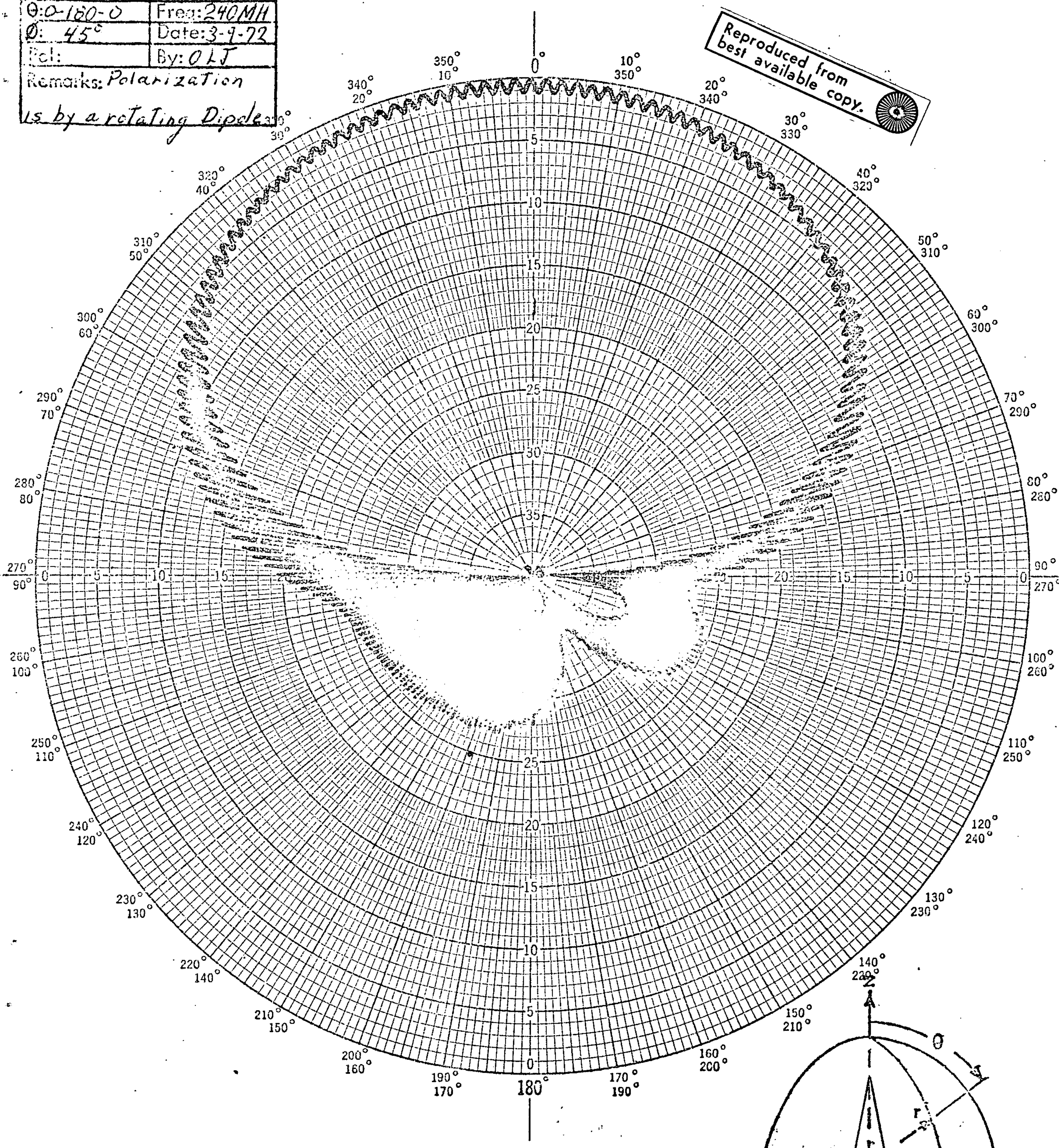


Figure 3-12

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#1 240 MH (1)

Antenna: 136-CS-2-SN-2	
Orientation:	
Θ: 0-180-0	Freq: 240MH
Ø: 45°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a rotating Dipole	



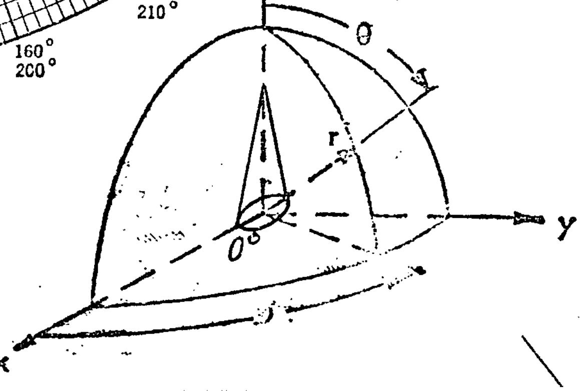


Figure 3-13

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#? 240 MH

Antenna: 136-CS-2 SN-2	
Orientation:	
θ: 0-180-0	Freq: 240 MH
Ø: 135°	Date: 3-4-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	

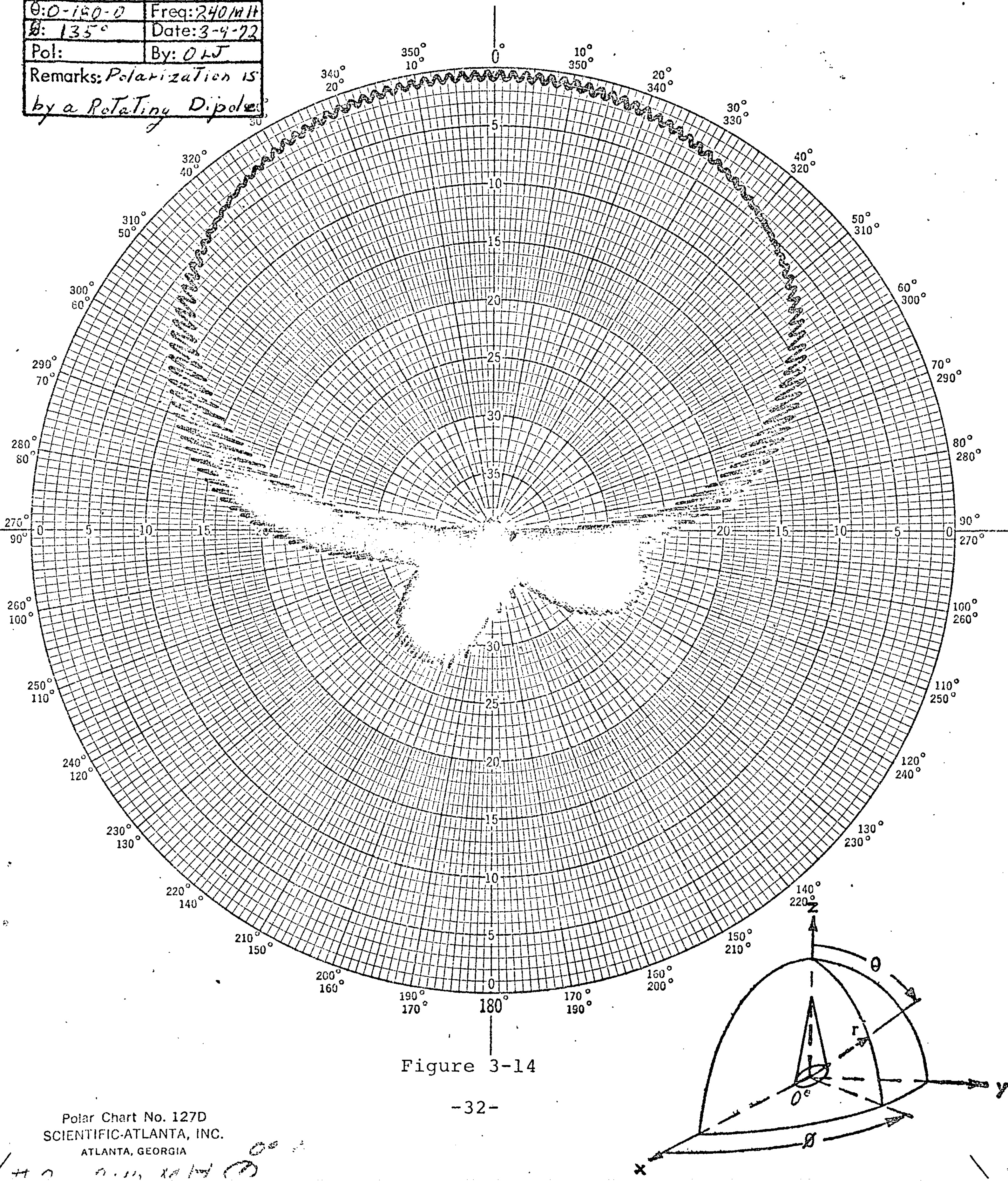


Figure 3-14

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

Antenna: 136-CS-2 SN-2	
Orientation:	
θ: 0-180-0	Freq: 240 MHz
∅: 225°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	

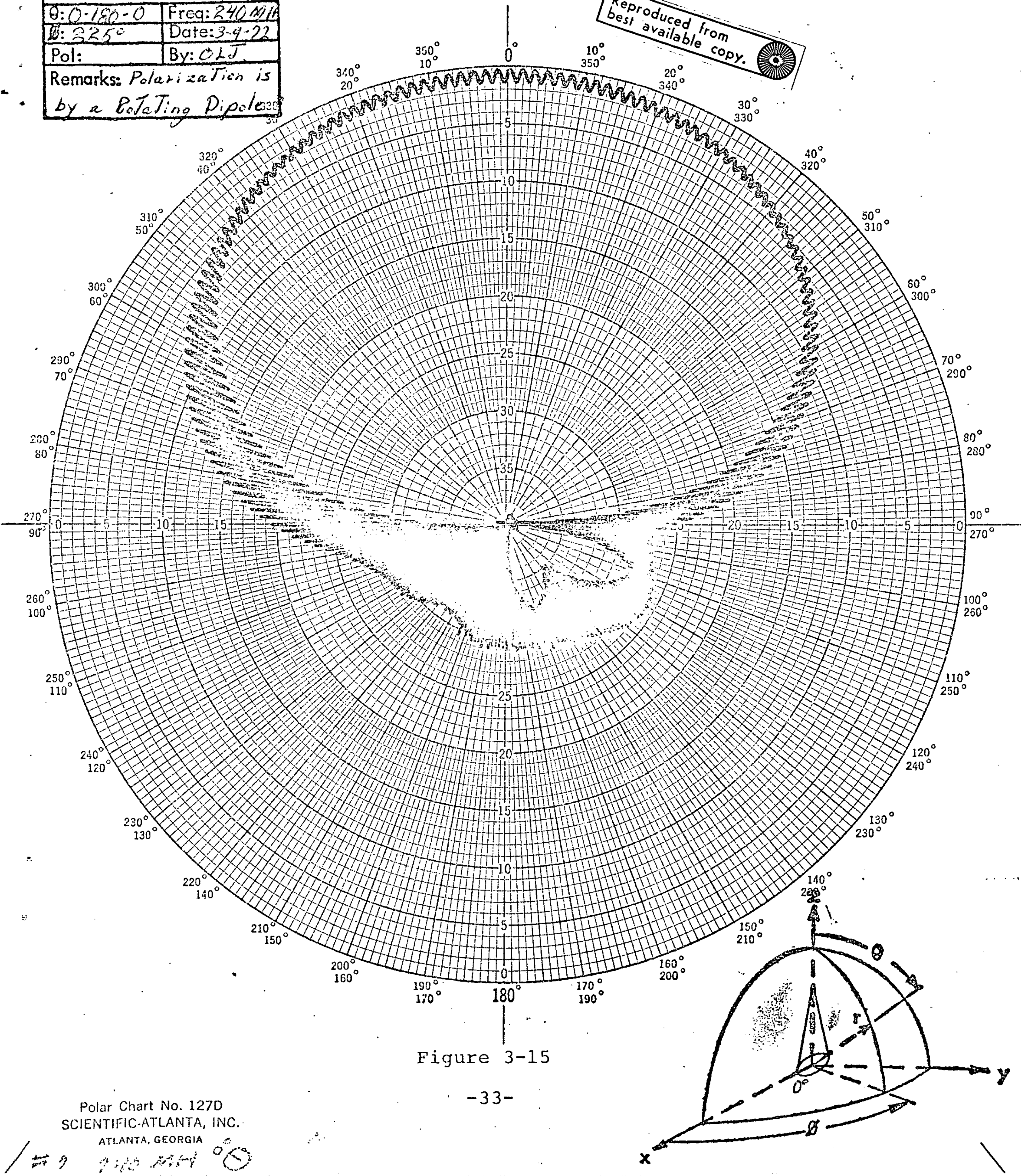


Figure 3-15

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

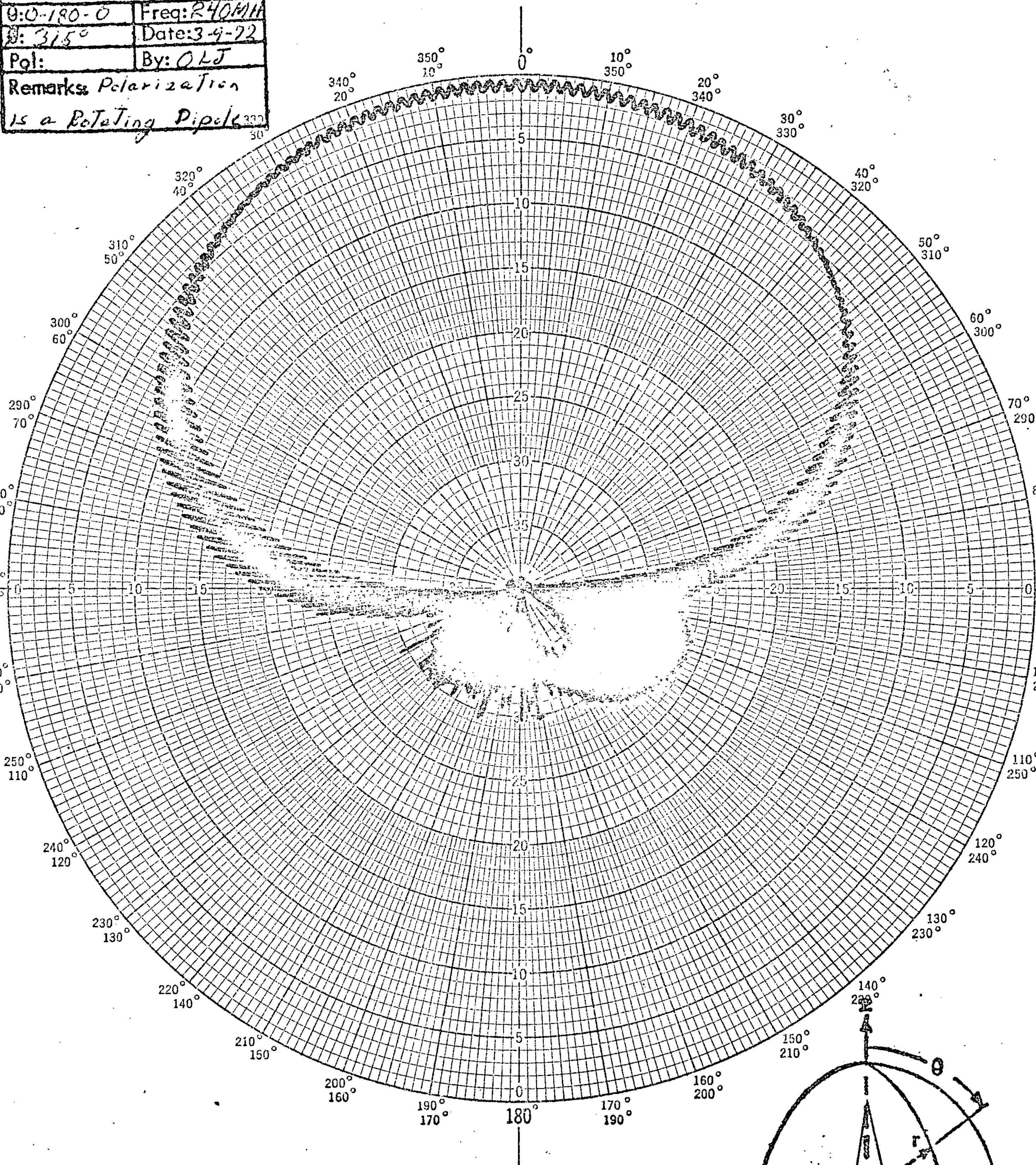
#9 240 MHz 0°

Antenna: 136-CS-2 SN-2

Orientation:

θ: 0-180-0	Freq: 240MH
Ø: 315°	Date: 3-9-72
Pol:	By: OLJ

Remarks: Polarization is a Rotating Dipole



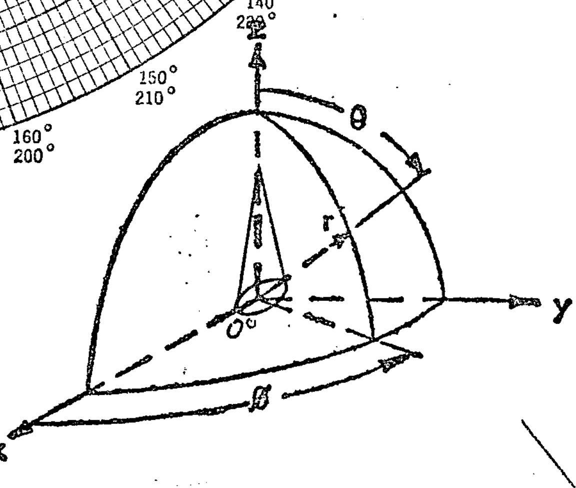
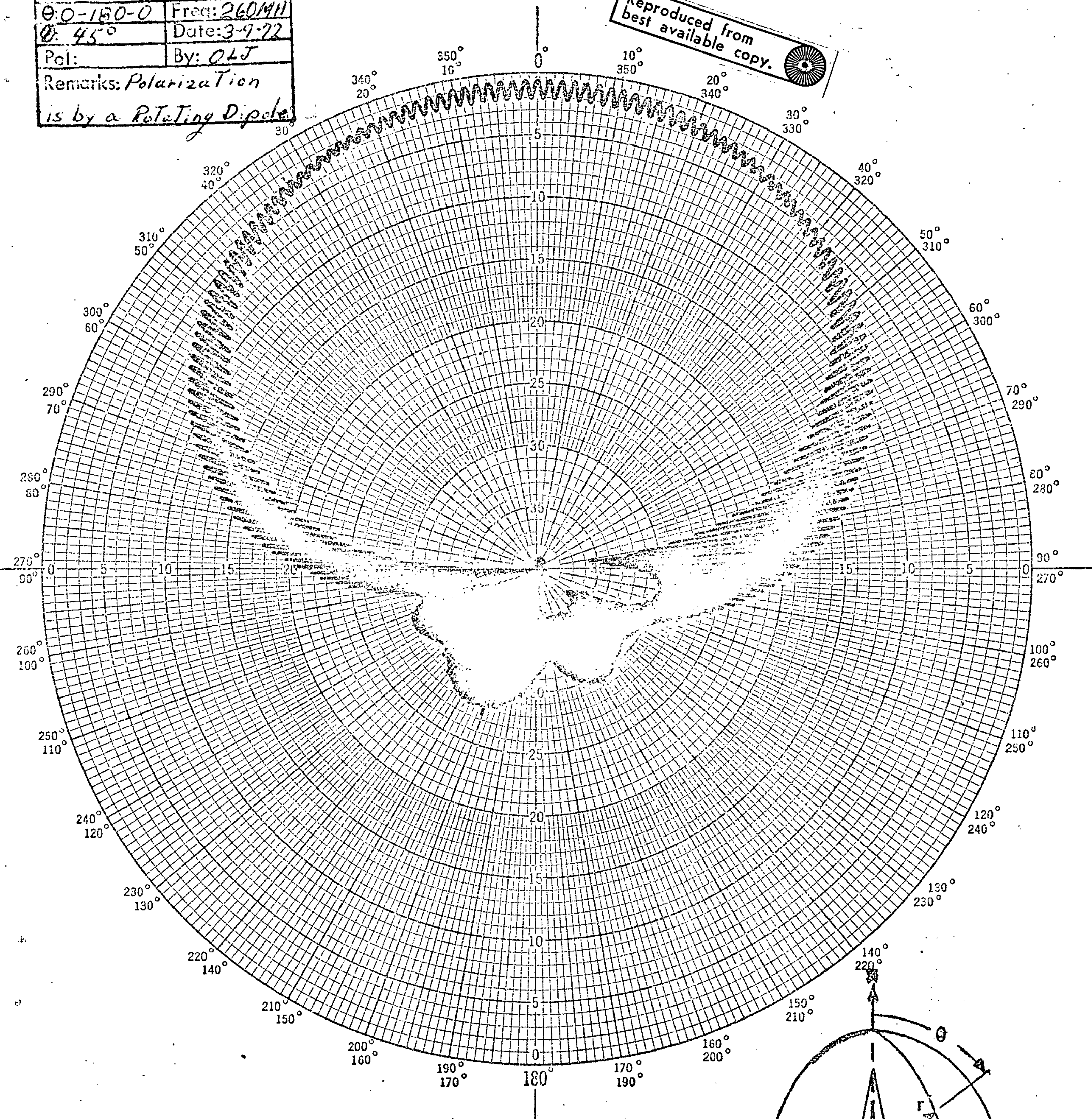


Figure 3-16

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 240 MH ①

Antenna: 136-CS-2 SN-1
Orientation:
θ: 0-180-0 | Freq: 260MH
Ø: 45° | Date: 3-9-72
Pol: | By: OLJ
Remarks: Polarization is by a Rotating Dipole



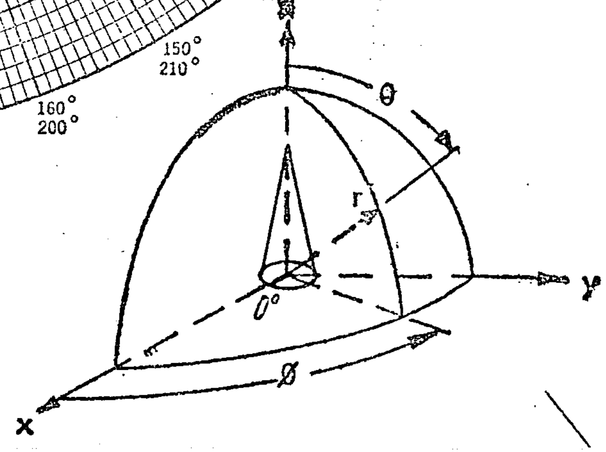


Figure 3-17

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#1 260MH (V)

Antenna: 136-CS-2 SN-1	
Orientation:	
θ: 0-180-0	Freq: 260MH
Ø: 135°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a RoTaTing Dipole	

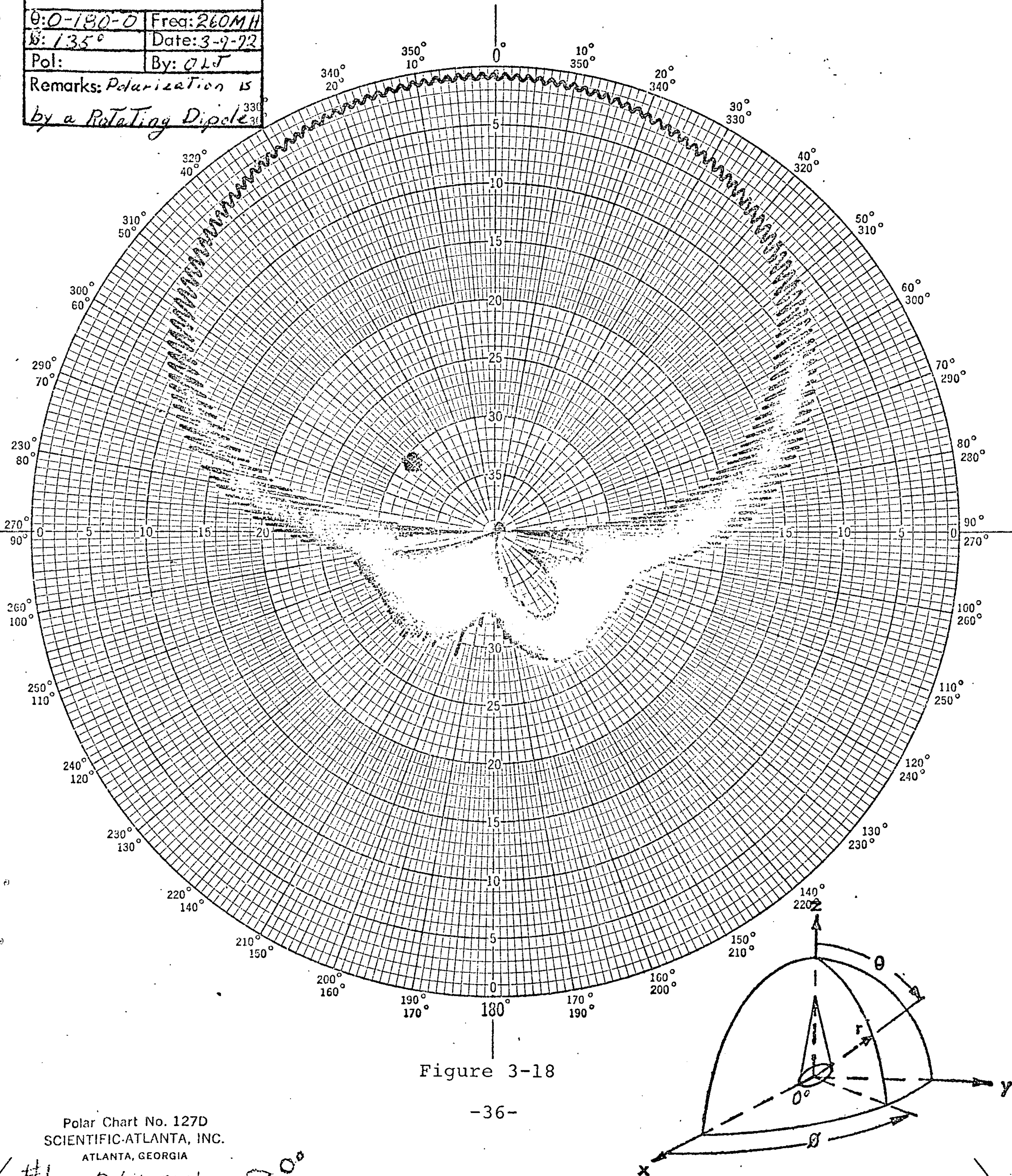
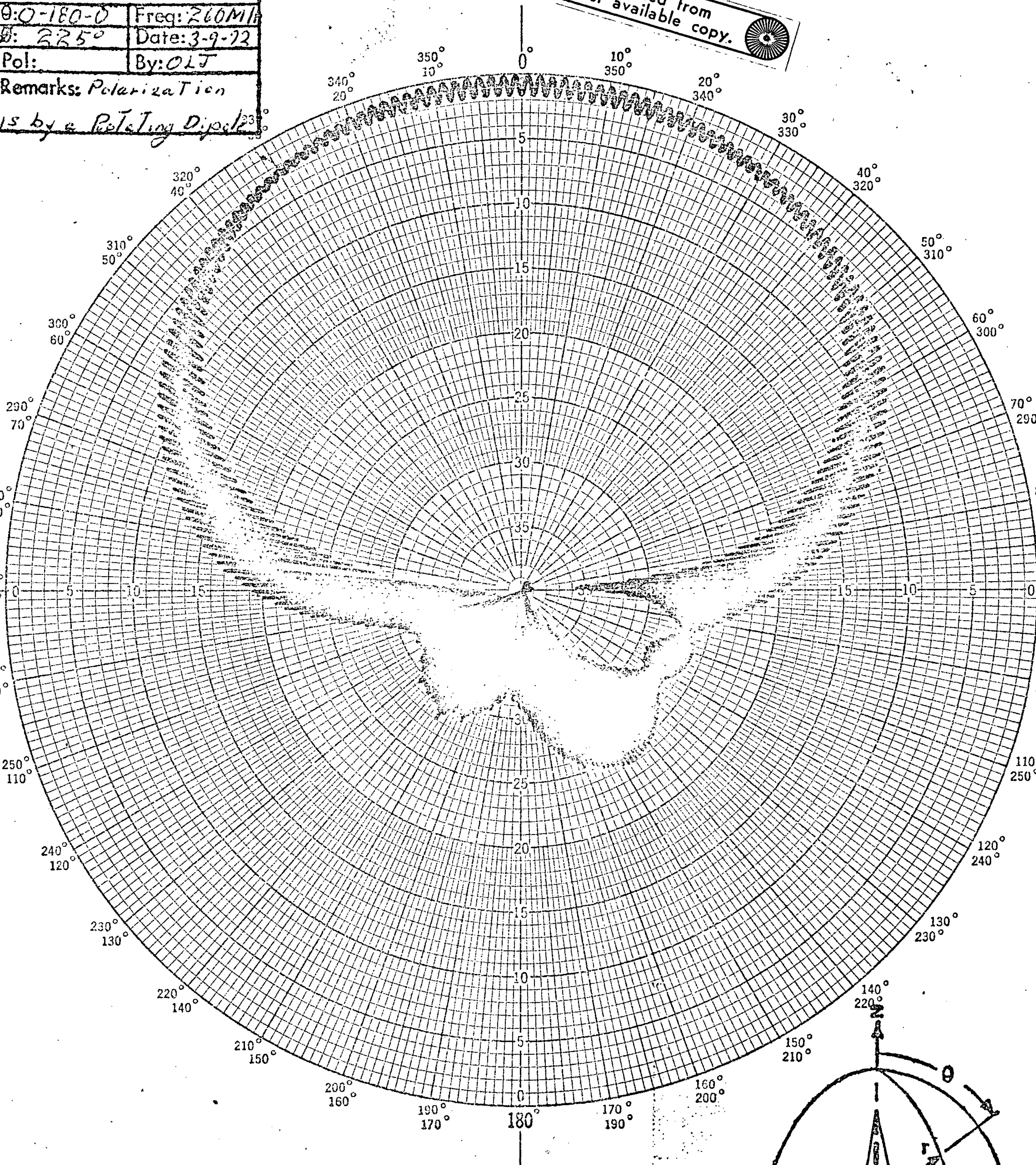


Figure 3-18

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#1 260 MH 0°

Antenna: 136-CS-2 SN-1	
Orientation:	
θ: 0-180-0	Freq: 260MHz
Ø: 225°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	



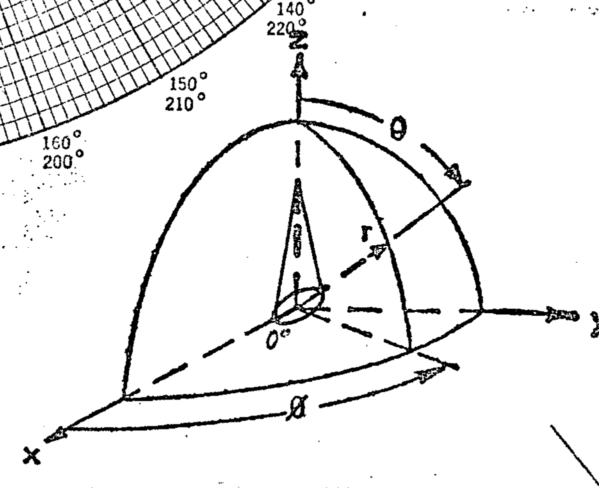


Figure 3-19

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

FF1 260 MH

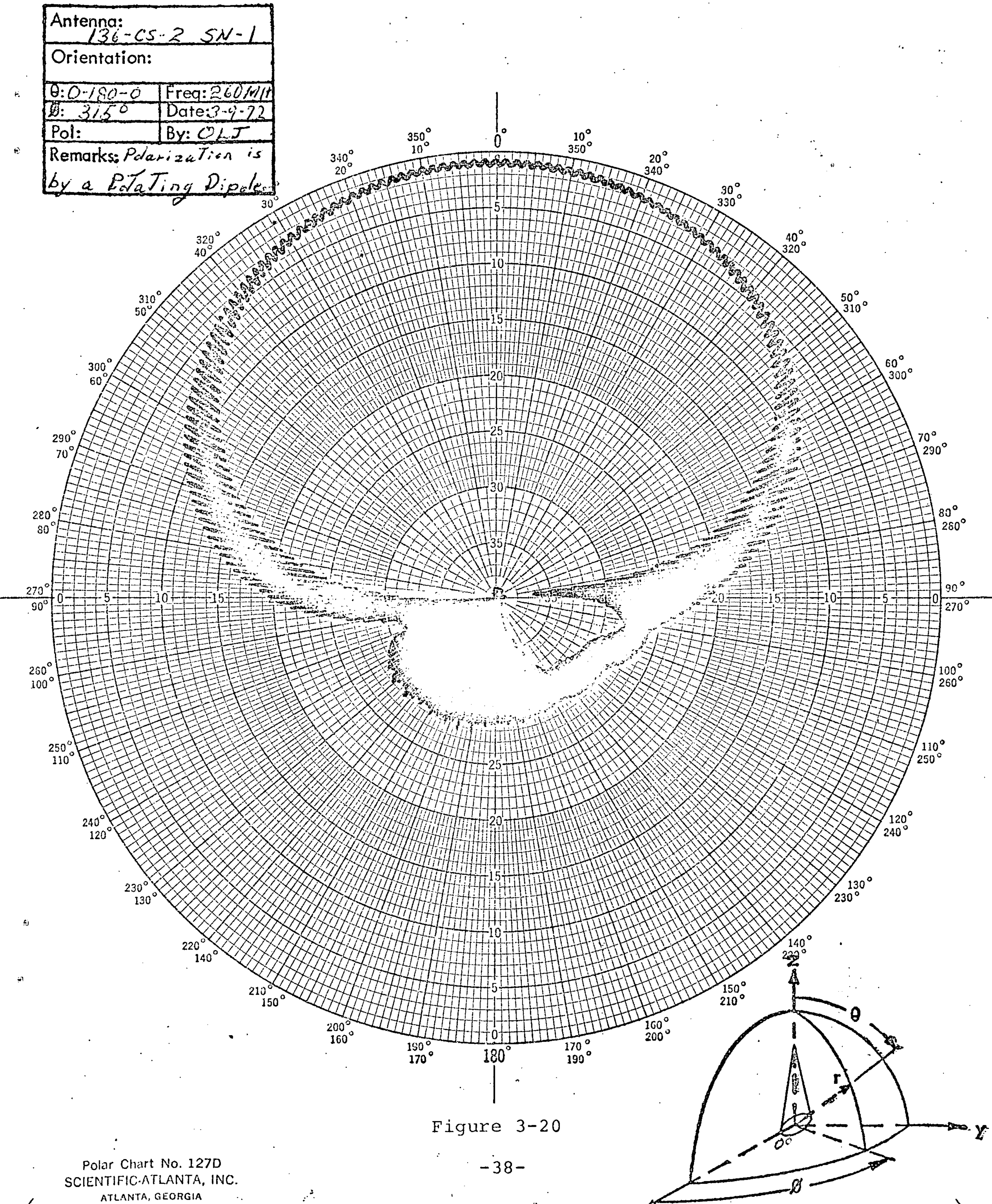
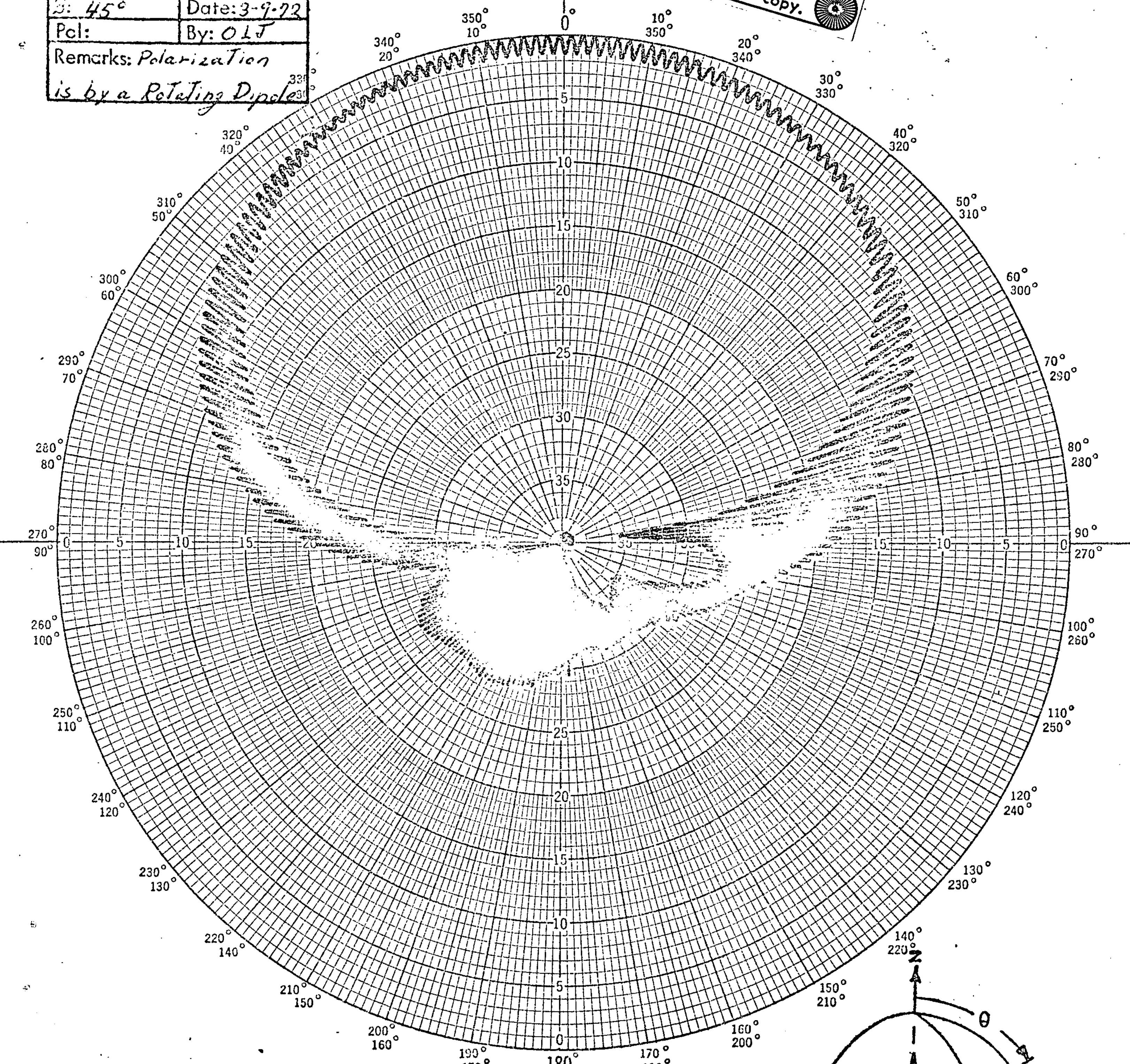


Figure 3-20

#1 210MH (1)

Antenna: 136-CS-2 SN-2	
Orientation:	
θ: 0-180-0	Freq: 260MH
φ: 45°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	



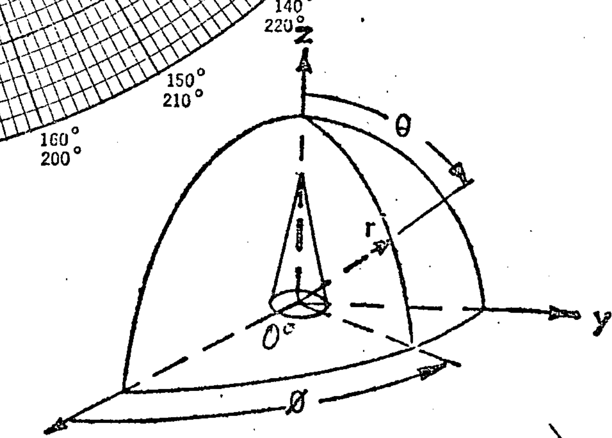
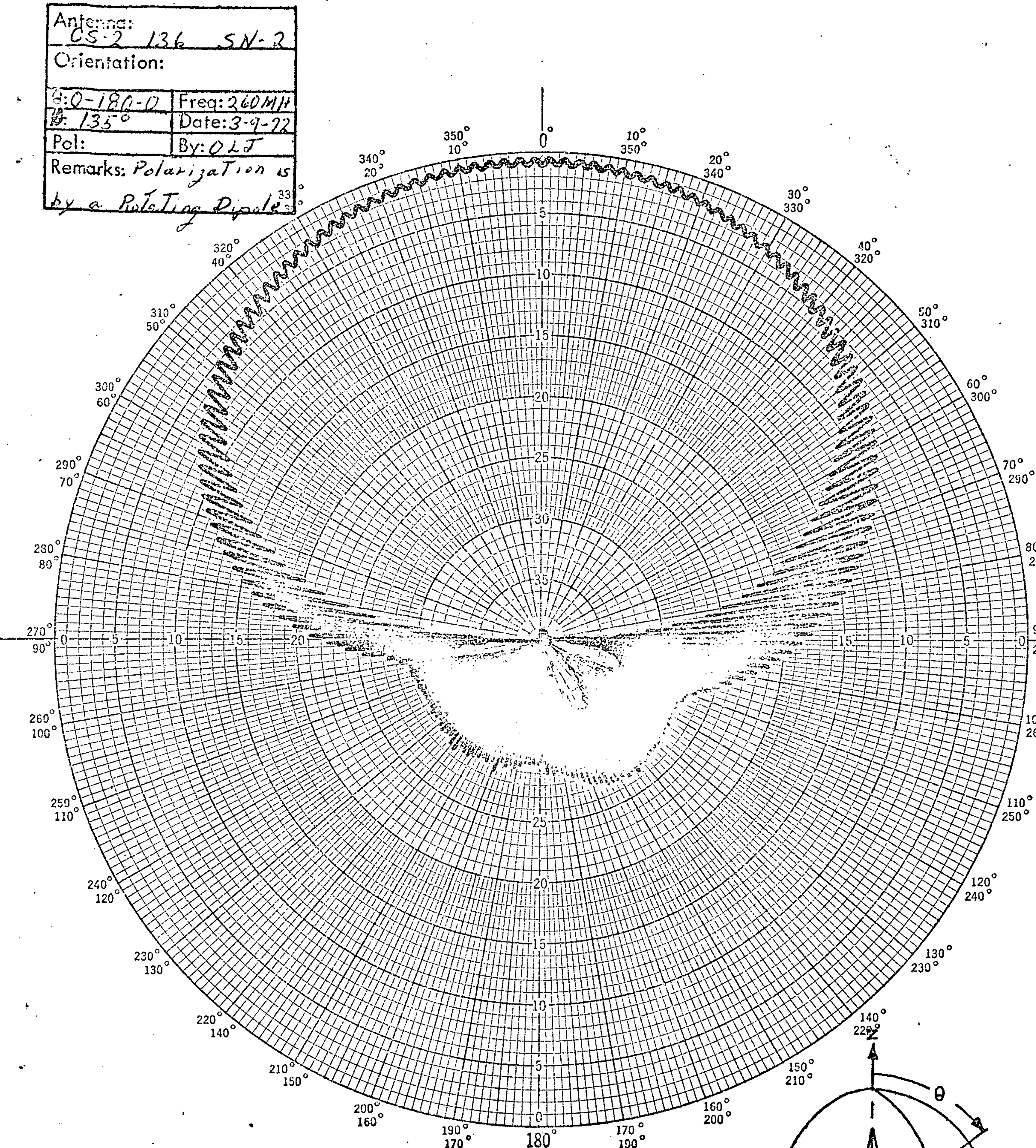


Figure 3-21

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 260MH @00



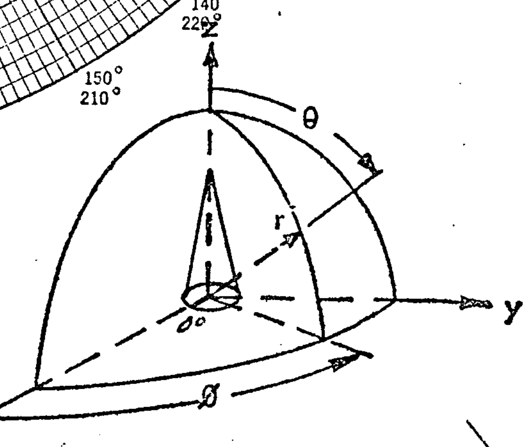
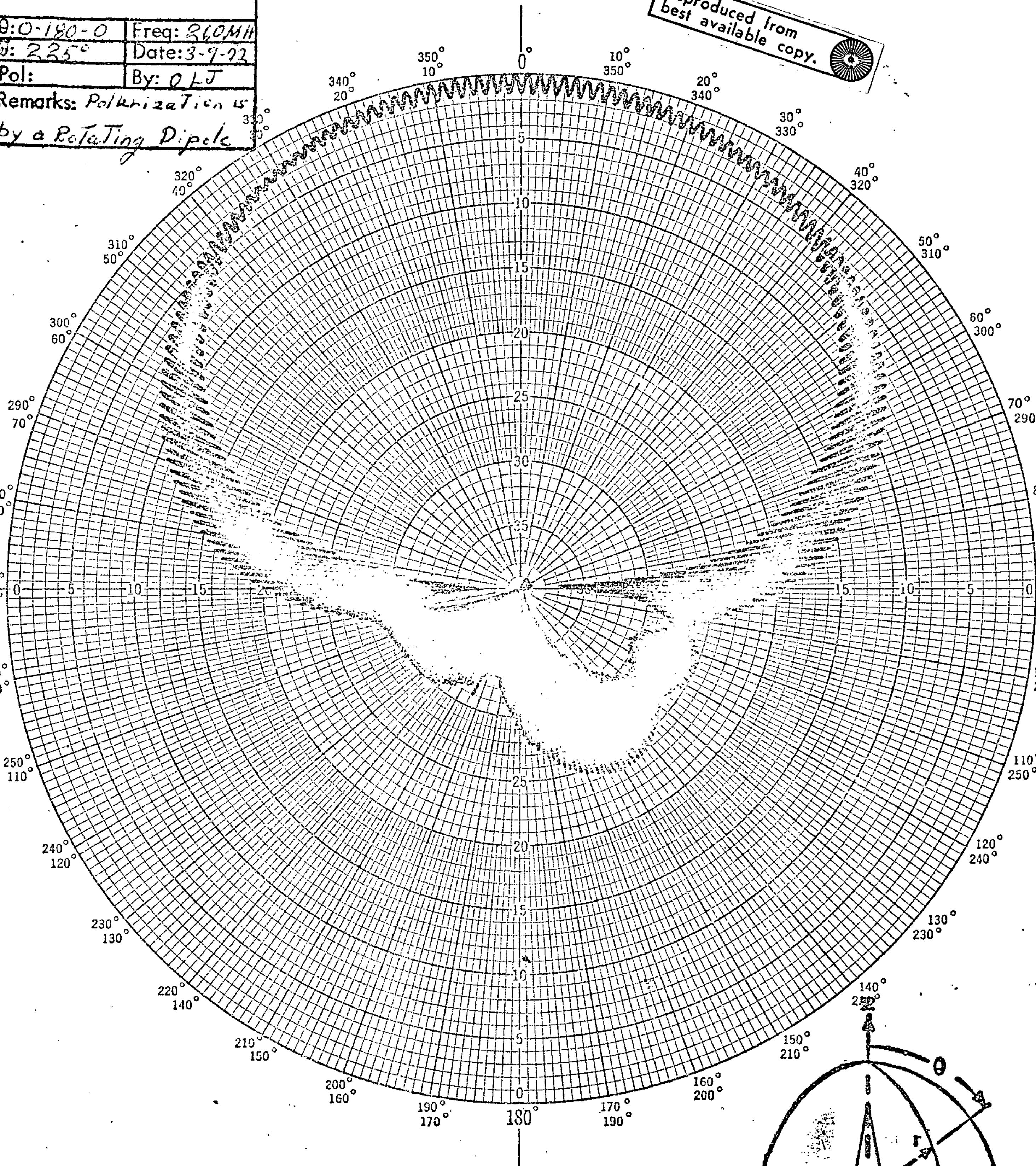


Figure 3-22

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 260 MH

Antenna: 136-CS-2 SN-2	
Orientation:	
θ: 0-180-0	Freq: 260MH
ø: 225°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	



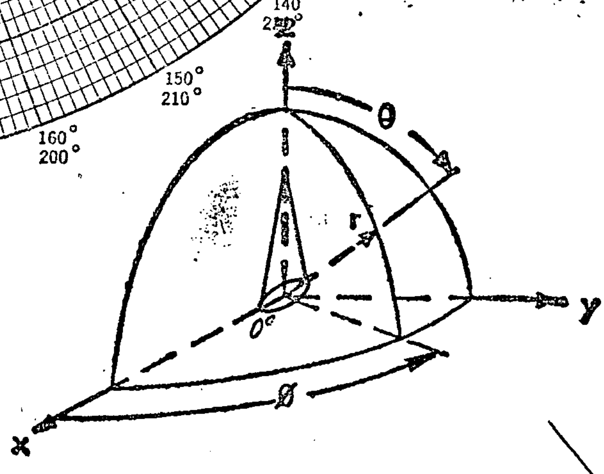
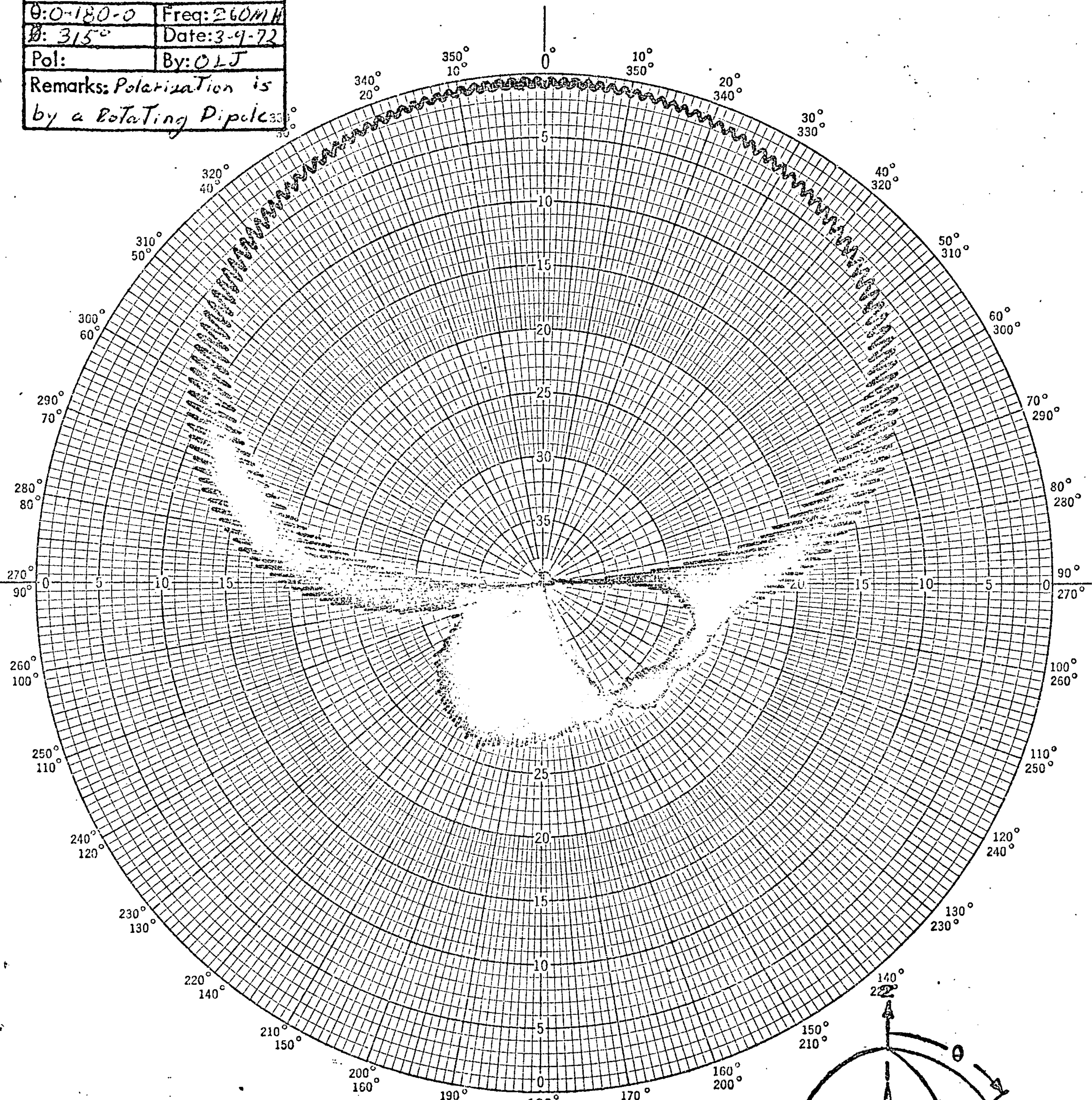


Figure 3-23

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 260 MH 0° (1)

Antenna: 136-CS-2 SN-2	
Orientation:	
θ: 0-180-0	Freq: 260MH
Ø: 315°	Date: 3-9-72
Pol:	By: OLJ
Remarks: Polarization is by a Rotating Dipole	



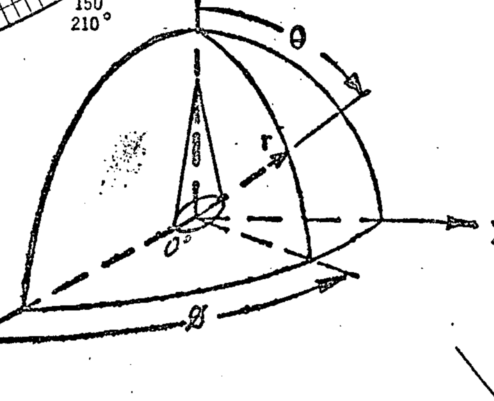


Figure 3-24

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

#2 260MH (1)

4.0 Conclusions

4.1 Gain

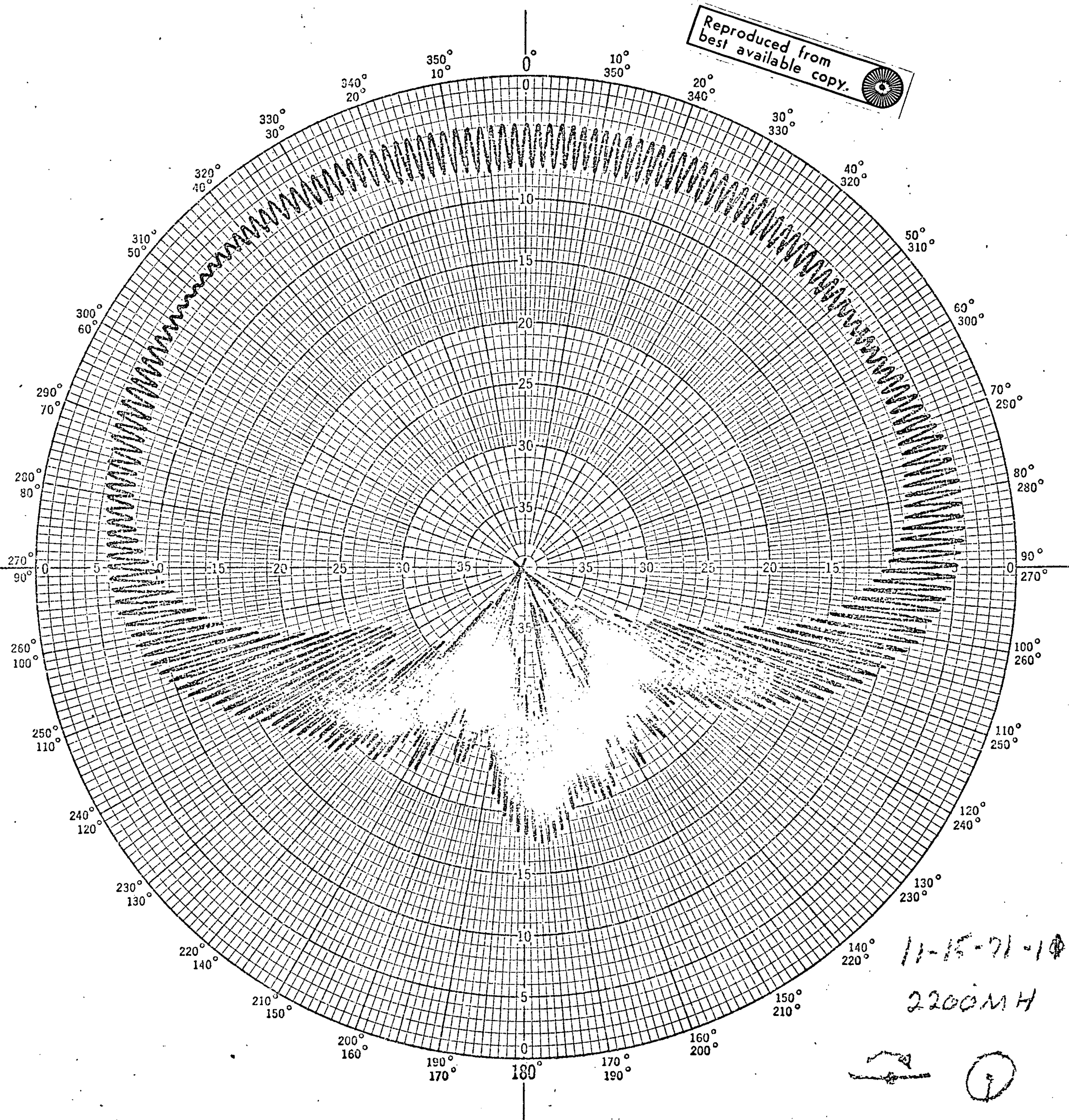
Measured gain, at the only point specified (zenith), exceeded the requirement by 4 dB. Table 4-1 shows the typical gain variation with elevation angle from one of the patterns in paragraph 3. With Geotronics' present understanding that the ability to track missiles to impact is a requirement, a serious question is raised as to the total suitability of this pattern. The pattern of a conical spiral is directly controllable by means of spiral angle; for example, Figure 4-1 is the pattern of a prototype antenna designed by Geotronics for another application. Although the gain at the zenith is only (approximately) +2dBi, this gain holds within approximately 2 dB down to the horizon. Such a spiral would therefore provide more gain than the matched pair delivered under this contract at elevation angles between about 40° and the horizon. It is not known, however, what impact this faster spiral rate would have on the ability to match two antennas in their phase versus azimuth characteristics. Dyson and Mayes[1] indicate that a more linear relationship between phase and azimuth results from slower spiral rates, but since match rather than linearity is the requirement, the faster spiral for broader pattern may be worth investigation.

1. Dyson, J.D., and Mayes, P.E., "New Circulary Polarized Frequency - Independent Antennas with Conical Beam or Omnidirectional Patterns", IRE Transactions on Antennas and Propagation, July, 1961.

Table 4-1

Absolute gain vs. el. angle

Elevation Angle, Deg.	Gain dB, ref r.h.c.p. isotropic
90 (zenith)	8.1
80	7.9
70	7.5
60	6.3
50	4.7
40	2.5
30	-0.4
20	-4.1
10	-8.4
0 (horizon)	-12.4



11-15-71-10
2200MH
Sec #10

Elevation Pattern, Fast-Spiral Antenna

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

Figure 4-1

4.2 Bandwidth.

In general, characteristics of the antennas varied only slightly with frequency from 220 to 260 MHz. Impedance match was optimum at 235 to 240 MHz, while pattern,gain, axial ratio, and phase match characteristics show no significant systematic variation across the band.

4.3 Impedance and VSWR.

The matching technique used met the specified requirements.

4.4 Circularity.

Axial ratio can be read directly from any of the elevation patterns. Table 4-2 summarizes the axial ratio at elevations from horizon to zenith for antenna number one at all frequencies and two orthogonal azimuth angles. The average of the two azimuth readings is generally 1.5 dB or less above 50° elevation and 3 dB or less above approximately 35° elevation.

4.5 Equiphase Characteristics

Table 4-3 summarizes the worst excursions from phase match for each of the twelve measurement conditions detailed in Tables 3-3 through 3-14. Examination of the data shows better match at 28° elevation than at 10°; it was not possible to make measurements at higher angles in the facility available. With the patterns showing axial ratios on the

Table 4-2

Axial Ratio vs. elevation (SN 1)

Elevation Angle, Deg.	Ratio,dB at 220 MHz $\phi=45°$	$\phi=135°$	avg.	Ratio, dB, at 240 MHz $\phi=45°$	$\phi=135°$	avg.	Ratio, dB, at 260 MHz $\phi=45°$	$\phi=136°$	avg.
90 (zenith)	0.9	1.8	1.4	1.1	0.8	1.0	1.5	0.6	1.0
80	1.0	1.8	1.4	1.0	1.0	1.0	1.4	0.5	1.0
70	1.2	1.9	1.6	0.9	1.0	1.0	0.8	0.7	0.8
60	1.0	2.0	1.5	0.5	0.8	0.6	0.9	0.7	0.8
50	1.1	2.2	1.6	1.1	0.3	0.7	1.8	1.2	1.5
40	1.5	3.2	2.4	2.0	1.3	1.6	2.8	1.8	2.3
30	3.2	4.9	4.0	3.0	3.0	3.0	4.2	2.8	3.5
20	5.4	6.5	6.0	4.7	5.1	4.9	5.0	4.5	4.8
10	8.5	8.0	8.2	6.2	8.5	7.4	7.5	8.0	7.8
0 (horizon)	13.5	9.0	11.2	13.0	16.5	14.8	14.0	17.0	15.5

Table 4-3

Summary - Worst Excursion from Phase Match

Freq.-MHz	Elev.,Deg.	Source Polarization	Excursion Phase Angle	@	Az. Angle
220	28	Vert.	-2.9°	@	144°
240	28	Vert.	+2.2°	@	72° and 144°
260	28	Vert.	+1.9°	@	108°
220	28	Horiz.	-2.0°	@	180°
240	28	Horiz.	+2.2°	@	72°
260	28	Horiz.	+0.7°	@	288°
220	10	Vert.	-5.8°	@	108°
240	10	Vert.	+13.0°	@	144°
260	10	Vert.	+6.2°	@	144°
220	10	Horiz.	-2.8°	@	180°
240	10	Horiz.	+5.0°	@	180°
260	10	Horiz.	+1.5°	@	288°

order of 7 to 9 dB at the 10° elevation and gain some 16 dB down from peak, it should not be too surprising that the phase match is relatively poor. In general, antenna characteristics are difficult to control and, in fact, difficult to measure near nulls in the pattern. It is believed that the design goal phase match specifications probably would be met within the 3 dB beamwidth, had the facility permitted measurement at those elevation angles. It is possible that a fast spiral with better control of gain and axial ratio down to the horizon (see Figure 4-1) would permit the goal to be achieved. It is not known how the results would have been affected by use of a circularly polarized source antenna.

As described in paragraph two, the antennas were hand-built and include splices and fasteners. If facilities existed for manufacture of this size and type antennas with automatically controlled machinery or photographically-based techniques (chemical etching, etc.), a better phase match might be obtained.

4.6 New Technology

No new technology was developed in the course of performance of this contract.