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Final Report

FOUR ARM CONICAL SPIRAL ANTENNA

Contract No: NAS5-11165

Prepared by

Geotronics, Inc.
5714 Columbia Pike
Falls Church, Virginia 22041

for

Goddard Space Flight Center
Greenbelt, Maryland 20771

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Final Report

FOUR ARM CONICAL SPIRAL ANTENNA

Contract No: NAS5-11165

Goddard Space Flight Center
Contracting Officer: R. D. Phillips
Technical Monitor: J. G. Guidotti, 724

Prepared by

Geotronics, Inc.
5714 Columbia Pike
Falls Church, Virginia 22041

Project Manager: Edward A. Wolff

for

Goddard Space Flight Center
Greenbelt, Maryland 20771

SUMMARY

A four arm conical spiral has been developed to operate with the IRLS system to provide optimum patterns for balloon packages when interrogated from a satellite. The antenna has a bifolium shaped pattern which minimizes the energy radiated at negative elevation angles. The antenna is circularly polarized with a relatively low axial ratio near the horizon. These two characteristics combine to give an antenna with good multipath discrimination which is important for the IRLS system.

The work performed during the antenna development is described. The results obtained are close to or exceed the design goal in all respects. The characteristics of the final production models are described.

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1.0 INTRODUCTION

This report is prepared under contract No. NAS5-11165 to document the development work undertaken to establish the electrical parameters of the four arm conical spiral which would best optimize the performance of the antenna in terms of pattern, polarization and weight.

The antenna is designed to operate suspended from a balloon and interrogated by the IRLS system on a spacecraft. The antenna operates at 401.5 MHz and 466 MHz.

It is desired to achieve the best possible impedance match to a 50 ohm coaxial input with a design goal VSWR of 1.3.

It is desired to have an antenna with a bifolium shaped pattern which minimizes the power radiated below the horizon, has maximum possible gain at low elevation angles and is circularly polarized (right hand) with good axial ratio at low elevation angles. The design goal was 3 db gain and 3 db axial ratio at 20° elevation.

It is desired to have an antenna that weighs less than one pound and is moisture proof.

The antenna developed under this contract exceeds the design goals for weight and axial ratio. The gain is within 1 db of the goal and the VSWR is slightly higher. The VSWR can be reduced for future models by slight adjustments to the balun.

This report describes the experimental work in chronological order. Patterns were measured for approximately 20 configurations. The discussion is not confined to the work which produced good results. Some things were tried which did not work, and these included for the benefit of future investigations.

This report concludes with a summary of the results obtained on the final production model antennas.

2. ELECTRICAL DEVELOPMENT

This section describes the experimental work in the order in which it was performed. Tasks which produced negative results are included with tasks which produced positive results. Patterns were measured for approximately 20 configurations as shown in Table 1.

2.1 Spiral Geometry

The first task was the determination of the spiral geometry. A computer program was written to calculate the coordinates of the spiral for various cone and spiral angles and various cone lengths. This Fortran program is given in Figure 1. The results computed for several spirals are shown in Figures 2 through 4.

Previous work at higher frequencies indicated that a spiral slant length of 40 inches and a spiral angle of 60° would give good patterns at 400 MHz, and these parameters were tried first.

2.2 Wire Spirals

At higher frequencies it is common to construct the spirals using coaxial cable for each of the four arms and using the cable of one of the arms to feed the signal from the antenna base to the cone vertex. This configuration was tried first because of the cost and weight advantage of a single small conductor for each arm. The results are shown in Figure 5 and are unsatisfactory because of the poor axial ratio and large back radiation.

It is generally believed that the currents in large spiral antennas of this type are confined to the outer edges of the conductors. Therefore an attempt was made to simulate solid arms with three wires by adding the two that would correspond to the outer edges of a solid conductor. This was done for two opposite spiral arms and the results are shown in Figure 6. This shows some (but not enough) improvement over the pattern of Figure 5.

TABLE 1 FOUR ARM CONICAL SPIRAL ANTENNA CONFIGURATIONS

No.	Cone	Spiral	Feed	Ground	Termination	Figure Number
1	40"slant length	1 wire	Cable	None	-----	5
2	" " "	1+3:3 wires 2+4:1 wire	"	None	-----	6
3	" " "	3 wires	"	None	-----	7
4	" " "	"	"	Wire	500 ⏦	8
5	" " "	2+4 wires 2+3 sheets	"	None	-----	9
6	" " "		"	Sheet	Open	10
7	" " "	"	"	Sheet	500 ⏦	11
8	" " "	1+3:sheets 2+4:1/2 sheets	"	"	"	12
9	" " "	All Sheets		None	-----	13
10	" " "	"	"	Sheet	Open	14
11	" " "	"	"	"	200 ⏦	15
12	50" slant length	"	"	None	-----	16
13	" " "	"	"	Sheet	Open	17
14	" " "	"	"	Sheet	200 ⏦	18
15	" " "	"	Balun	None	-----	19
16	" " "	"	"	Sheet	0 ⏦	20
17	" " "	"	"	"	200 ⏦	21
18	50" Truncated	"	Balun+Arms	None	-----	22
19	" " "	"	"	Sheet	Open	23
20	" " "	"	Balun+Spiral	Sheet	Open	24
21	" slant length	65° sheets	Balun	Sheet	Open	25
22	" " "	"	"	None	----	26
23	" " "	"	"	18"cone	Open	27

```
10000C      PROGRAM SPIRAL
10010C      PARAMETERS OF CONICAL SPIRAL ANTENNA.
10020C
10030       PI=3.1415926536 ; DEG=180.0/PI
10040       READ 1, ALPHAD,THOD,RO,SL
10050       ALPHA=ALPHAD/DEG ; THO=THOD/DEG
10060       A=COS(ALPHA)/SIN(ALPHA) ; B=A*SIN(THO)
10070       D=2.0*SL*SIN(THO) ; BETA=2.0*PI*SIN(THO) ; BETAD=BETA*DEG
10080       RLENGTH=(SL-RO)*SQRTF(1.0+(1.0/A↑2))
10090       PRINT 4, RLENGTH,SL,D,THOD,BETAD,ALPHAD
10100       PRINT 3
10110C
10120       DO 10  I=1,50
10130       FI=I ; FII=FI/4.0 ; PHI=FII*PI ; R=RO*EXP(B*PHI)
10140       IF(R-SL) 8,15,15
10150     8 PRINT 2, FII,R
10160    10 CONTINUE
10170    15 PHI=ALOG(SL/RO)/(B*PI) ; PRINT 2, PHI,SL
11000C
11010     1 FORMAT (6X,6F10.2)
11020     2 FORMAT (F10.2,F7.3)
11030     3 FORMAT (12X,5HSLANT/7X,10HPHI LENGTH/6X,11H(PI) INCHES/)
11040     4 FORMAT (//8X,33HCONICAL SPIRAL ANTENNA DIMENSIONS//4X,
11041      + 6HSPIRAL,5X,5HSLANT,4X,4HBASE,7X,4HCONE,5X,6HPLANAR,4X
11042      + 6HSPIRAL/2(4X,6HLENGTH),2X,8HDIAMETER,3(5X,5HANGLE)/
11043      + 3(4X,6HINCHES),3(3X,7HDEGREES)/6F10.2//)
11100C
12000       END
90000C
90010       $DATA
90020       60.0        15.0        1.0        40.0
91000       ENDFILE
```

Figure 1. Fortran Program For Spiral Coordinates

CONICAL SPIRAL ANTENNA DIMENSIONS

SPIRAL LENGTH INCHES	SLANT LENGTH INCHES	BASE DIAMETER INCHES	CONE ANGLE DEGREES	PLANAR ANGLE DEGREES	SPIRAL ANGLE DEGREES
67.99	40.00	20.71	15.00	93.17	55.00

PHI (PI)	SLANT LENGTH INCHES
.25	1.153
.50	1.329
.75	1.533
1.00	1.767
1.25	2.037
1.50	2.349
1.75	2.708
2.00	3.123
2.25	3.600
2.50	4.151
2.75	4.786
3.00	5.518
3.25	6.362
3.50	7.335
3.75	8.457
4.00	9.751
4.25	11.243
4.50	12.962
4.75	14.945
5.00	17.231
5.25	19.867
5.50	22.906
5.75	26.409
6.00	30.449
6.25	35.106
6.48	40.000

Figure 2. Spiral Coordinates for 55° Spiral Angle

CONICAL SPIRAL ANTENNA DIMENSIONS

SPIRAL LENGTH INCHES	SLANT LENGTH INCHES	BASE DIAMETER INCHES	CONE ANGLE DEGREES	PLANAR ANGLE DEGREES	SPIRAL ANGLE DEGREES
78.00	40.00	20.71	15.00	93.17	60.00

PHI (PI)	SLANT LENGTH INCHES
.25	1.125
.50	1.265
.75	1.422
1.00	1.599
1.25	1.798
1.50	2.022
1.75	2.274
2.00	2.557
2.25	2.876
2.50	3.234
2.75	3.636
3.00	4.089
3.25	4.598
3.50	5.171
3.75	5.815
4.00	6.539
4.25	7.353
4.50	8.269
4.75	9.299
5.00	10.457
5.25	11.759
5.50	13.223
5.75	14.870
6.00	16.721
6.25	18.803
6.50	21.145
6.75	23.778
7.00	26.739
7.25	30.069
7.50	33.813
7.75	38.024
7.86	40.000

Figure 3. Spiral Coordinates for 60° Spiral Angle

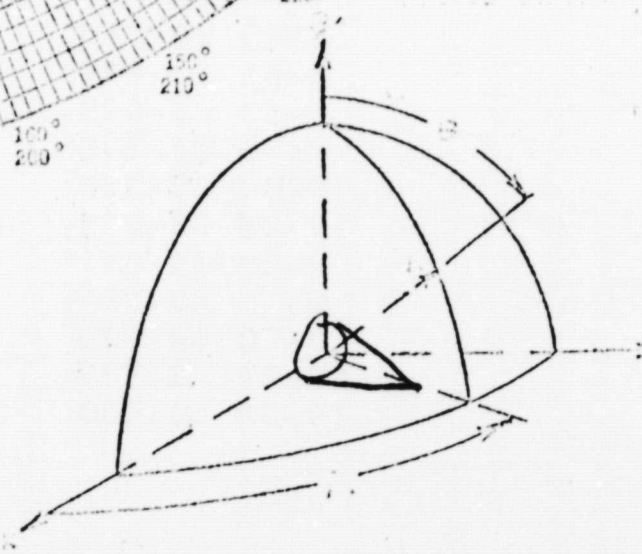
CONICAL SPIRAL ANTENNA DIMENSIONS

SPIRAL LENGTH INCHES	SLANT LENGTH INCHES	BASE DIAMETER INCHES	CONE ANGLE DEGREES	PLANAR ANGLE DEGREES	SPIRAL ANGLE DEGREES
115.94	50.00	25.88	15.00	93.17	65.00

PHI (PI)	SLANT LENGTH INCHES
.25	1.099
.50	1.209
.75	1.329
1.00	1.461
1.25	1.606
1.50	1.766
1.75	1.942
2.00	2.135
2.25	2.347
2.50	2.580
2.75	2.837
3.00	3.119
3.25	3.429
3.50	3.770
3.75	4.145
4.00	4.557
4.25	5.010
4.50	5.508
4.75	6.056
5.00	6.658
5.25	7.320
5.50	8.047
5.75	8.848
6.00	9.727
6.25	10.694
6.50	11.758
6.75	12.927
7.00	14.212
7.25	15.625
7.50	17.179
7.75	18.887
8.00	20.765
8.25	22.829
8.50	25.099
8.75	27.595
9.00	30.338
9.25	33.355
9.50	36.671
9.75	40.317
10.00	44.326
10.25	48.733
10.32	50.000

Figure 4. Spiral Coordinates for 65° Spiral Angle

Antenna: Spiral # 1	
Orientation:	
θ: 90°	Freq: 400MHz
ϕ: 0.360	Date: 1/3/69
Pol: Circ	By: OSJ
Remarks: Crystal Up	



Using Single Wire Spirals -

Figure 5. Single Wire Spiral Pattern

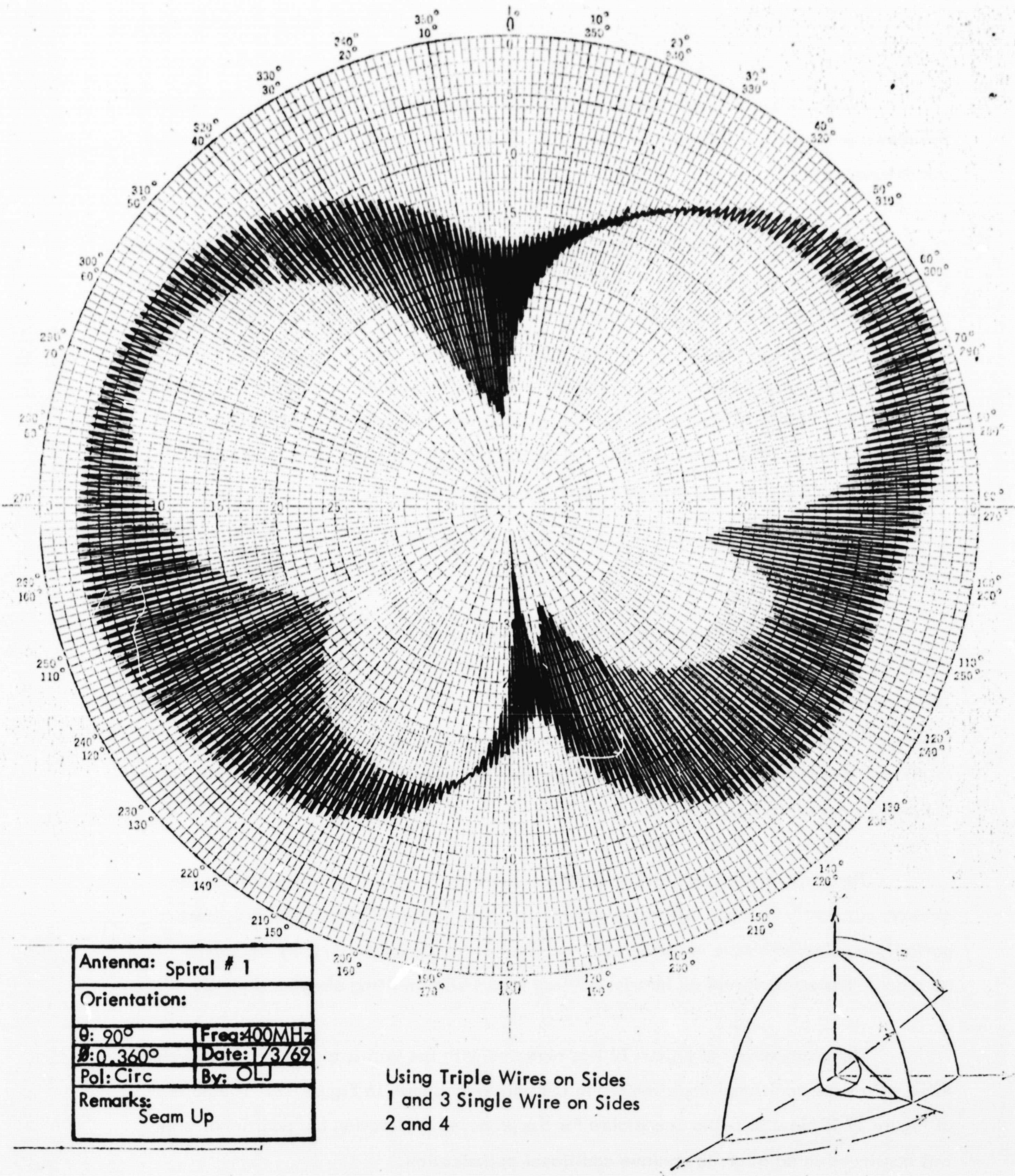


Figure 6. Pattern for Two Arms With Three Wires

Next, two wires were added to the remaining two spirals, and the results obtained are shown in Figure 7. This pattern shows some improvement over the previous pattern but the antenna is not adequate.

A 500 ohm load was then added between the ends of the spirals and a circumferential ground wire at the base to dissipate any energy that reaches the end of the antenna without radiating. If there is such non-radiated energy and no load, the energy reflects from the mismatch at the end of the spiral and returns along the spiral toward the feed. This reflected energy then radiates and produces an oppositely polarized circular radiation which has the effect of deteriorating the axial ratio. The pattern obtained from the terminated spiral is shown in Figure 8. The improvement in the axial ratio of the pattern of Figure 8 over that of Figure 7 indicates the presence of unradiated energy at the end of the antenna.

2.3 Sheet Spirals

The improved pattern obtained by using more wires for the spirals (Figure 7 versus Figure 5) led to the examination of the improvement possible by using solid sheet spiral arms made of three mil thick brass shim stock. This was avoided initially because of the greater weight of the shim stock. Initially, two opposite spiral arms were replaced with sheets. The results are shown in Figure 9. Next a flat groundplane was added at the base. This improved the pattern measurably as shown in Figure 10.

The assymetry in the previous patterns is due partly to a slight assymetry in the antenna but mostly to range reflection problems. These range reflection problems were partially eliminated by the use of screens and significantly reduced later by the use of absorber. The screens were an interim measure used while awaiting absorber delivery.

The arrangement of Figure 10 was repeated with the spirals terminated in 500 ohm loads with some additional improvement in the pattern as shown in Figure 11. The pattern of Figure 11 is close to being acceptable for the proposed application but additional work was continued in an effort to achieve additional optimization.

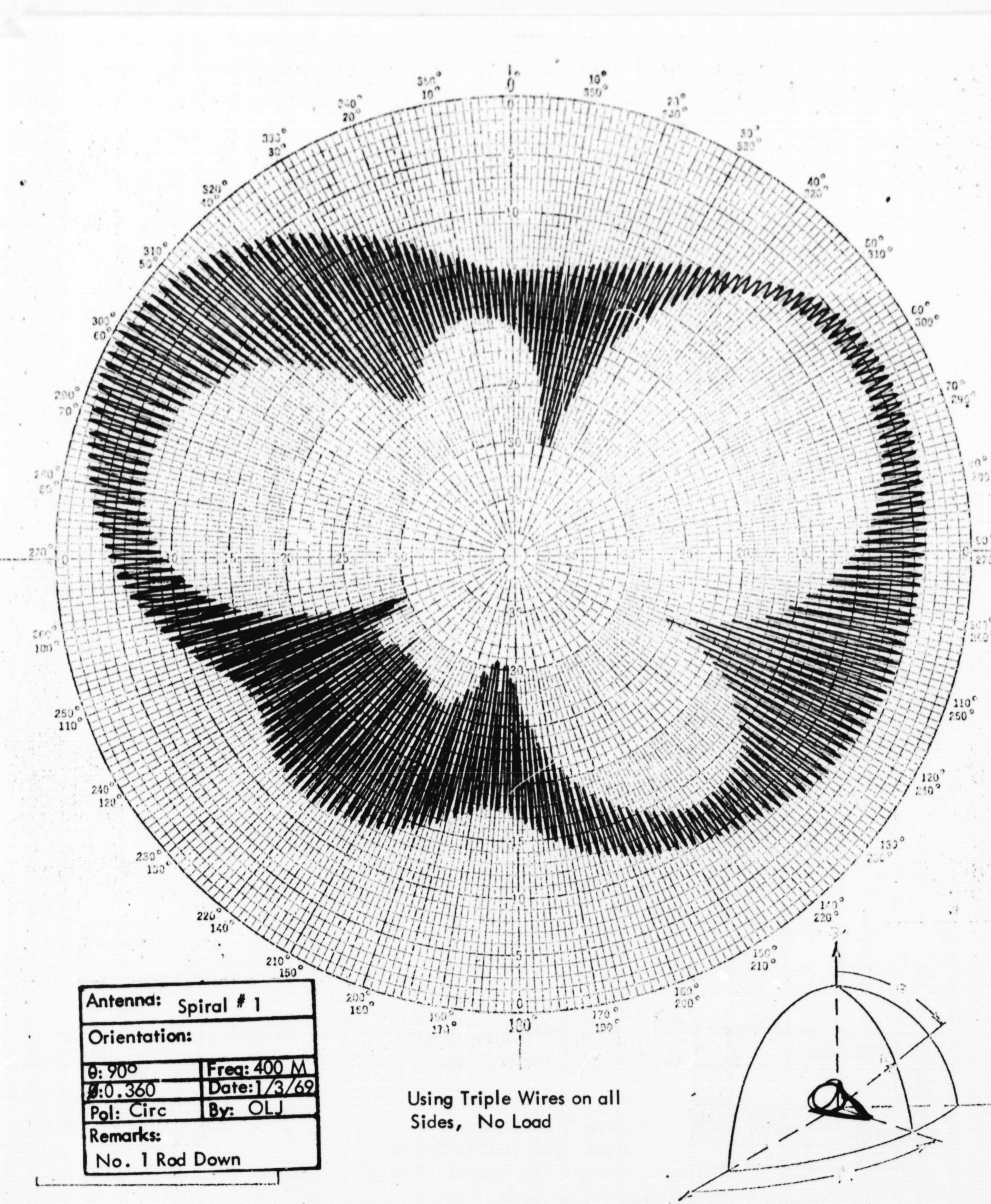


Figure 7. Pattern for Three-wire Spirals

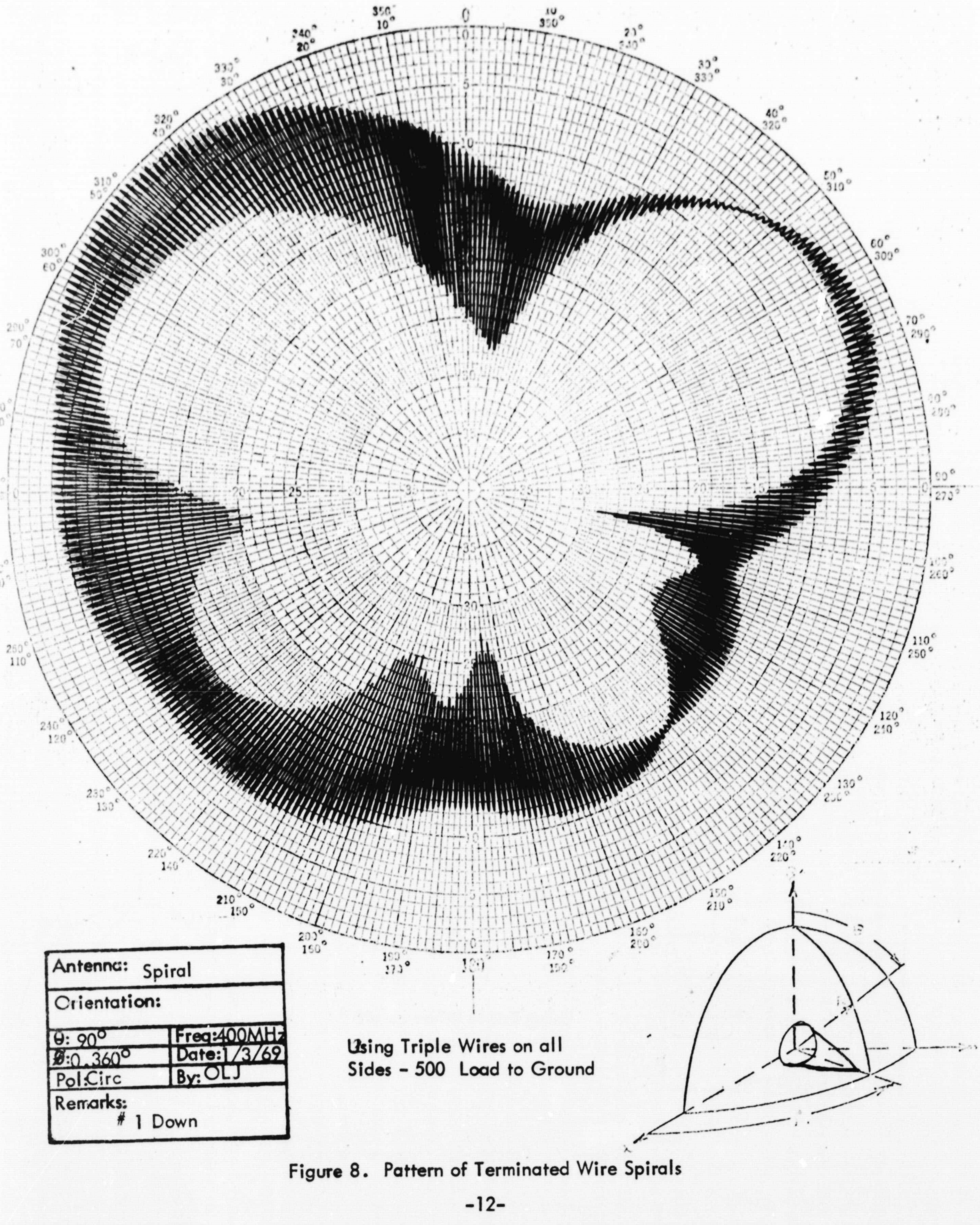


Figure 8. Pattern of Terminated Wire Spirals

Antenna: Spiral	
Orientation:	
θ: 90°	Freq: 400MHz
∅: 0.360	Date: 1/6/69
Pol: Circ	By: OLJ
Remarks: No. 1 Down	

Sides 2 and 4 Have Triple Wires

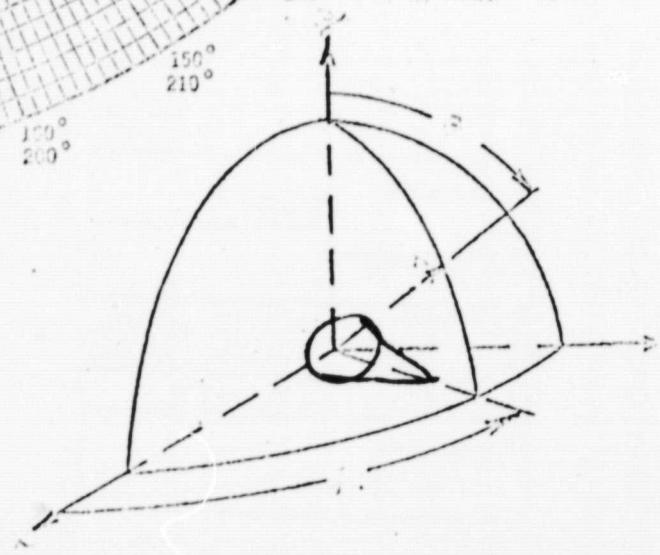


Figure 9. Pattern for Two Sheet Spirals

Antenna: Spiral	
Orientation:	
θ: 90°	Freq: 400M
∅: 0.360°	Date: 1/6/69
Pol: Circ	By: QLJ
Remarks: # 1 Down	

Sides 2 and 4 have Triple Wires Brass Reflector on Bottom of Ant

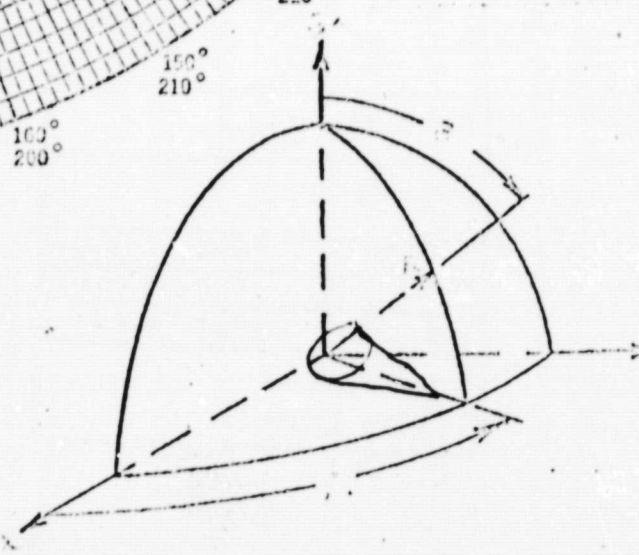


Figure 10. Pattern for Two Sheets and Groundplane

Antenna:	Spiral
Orientation:	No. 1 Side down
θ: 90°	Freq: 400MHz
ϕ: variable	Date: 1/8/69
Pol: rotating	By: OLJ
Remarks:	3 wires on sides 2 & 4 tapered brass on 1 & 3 500 load

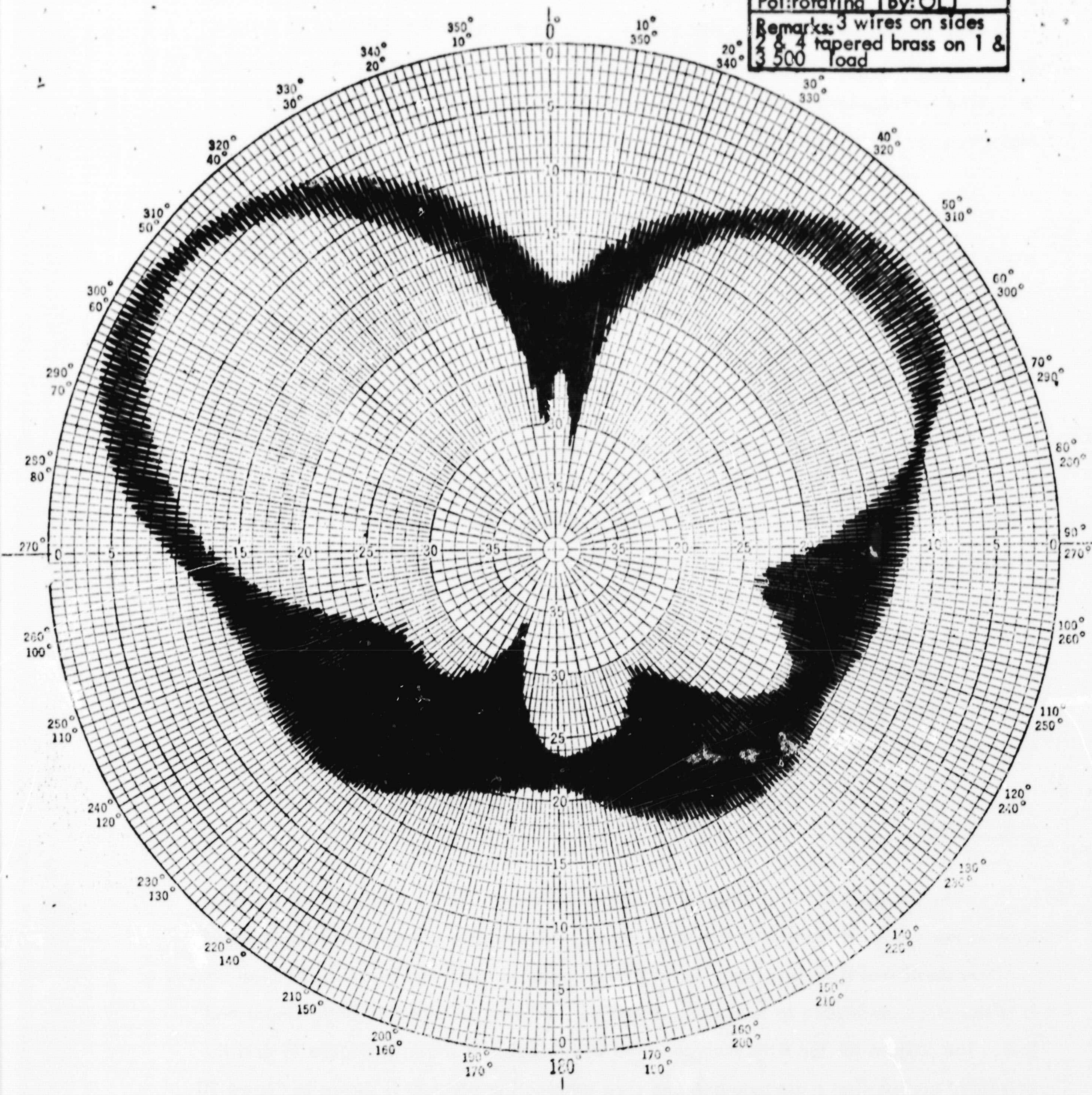


Figure 11. Pattern for Two Terminated Sheets

Figure 12 shows the effect of replacing the wires with sheets on the lower half of the remaining two wire arms, that portion which radiates at 400 MHz. The pattern for the full shim stock arms is shown in Figure 13. This pattern was taken on the newly delivered rectangular recorder which expands the amplitude (db) scale by a factor of about two for better analysis.

Figure 14 shows the results of adding a groundplane to the antenna and Figure 15 shows the effects of terminating the spirals in 200 ohm loads. The assymetry of this pattern is due partly to the range and partly to the antenna.

2.4 Fifty Inch Cone

The improved pattern obtained by terminating the antenna (Figure 15 versus Figure 13) indicated the desirability of using a slightly larger cone to achieve a more efficient antenna. Accordingly a cone with a fifty inch slant length was built with increased care taken to achieve circular symmetry. The pattern for the basic antenna without a groundplane is shown in Figure 16. A comparison of Figures 13 and 16 illustrates some improvement in the performance of the large antenna. The effect of adding a groundplane to the fifty inch antenna is shown in Figure 17 and the effect of terminating the spirals is shown in Figure 18. This latter pattern is the one included with the monthly progress letter for February.

2.5 Balun Feed

The previous patterns were taken with the antenna fed by a cable from the cone base to the vertex along one of the spiral arms. This requires an eight foot cable which is either small and light and has a high attenuation or is large and less lossy but too heavy. It is therefore preferable to feed the antenna with a balun to minimize both weight and loss. The pattern for the fifty inch cone fed with a balun is shown in Figure 19 and the effects of adding first a groundplane and then terminating resistors is shown in Figure 20 and 21. A sketch of the balun is shown in Figure 22.

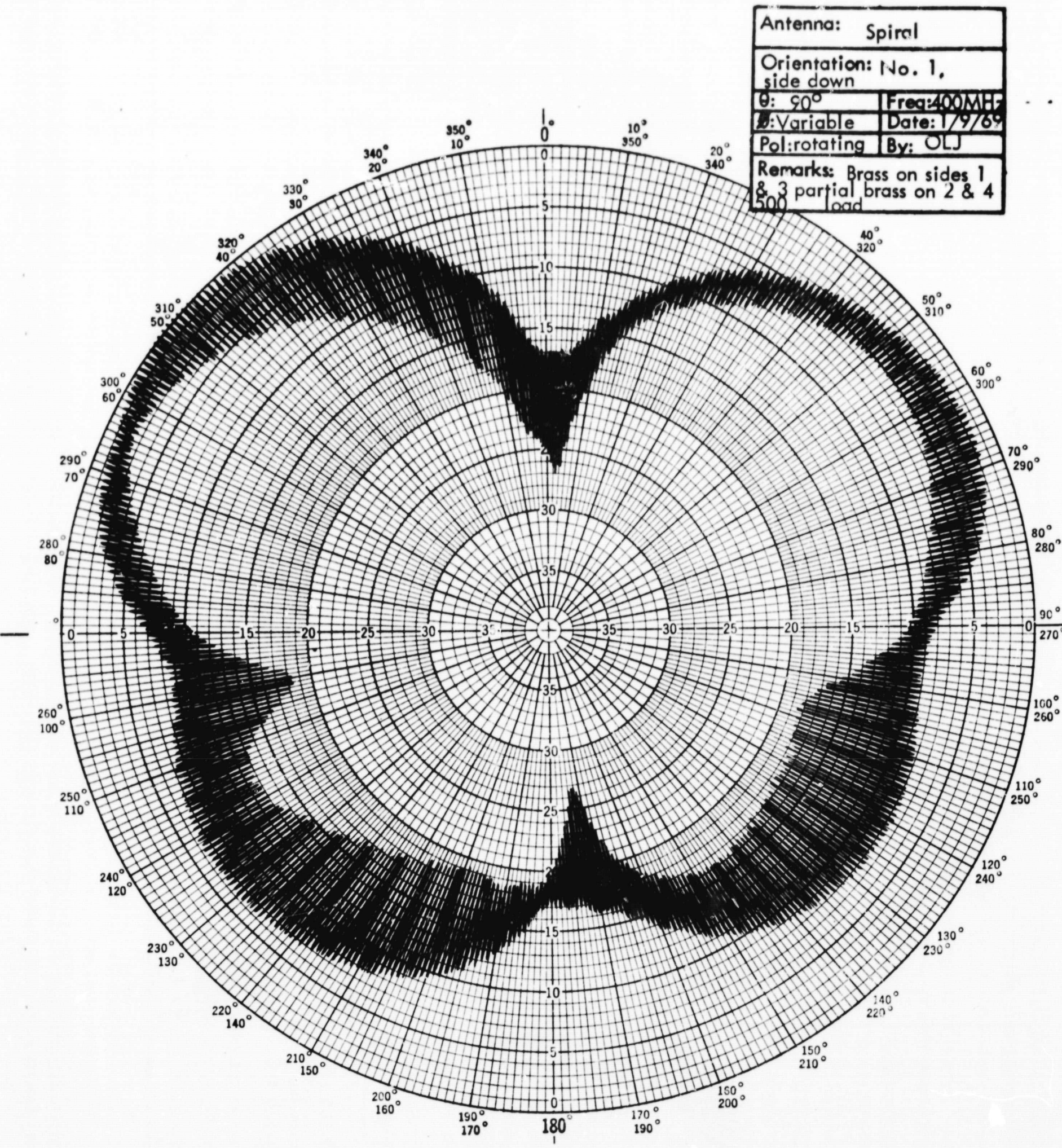


Figure 12. Pattern for Two Full and Two Half Sheets

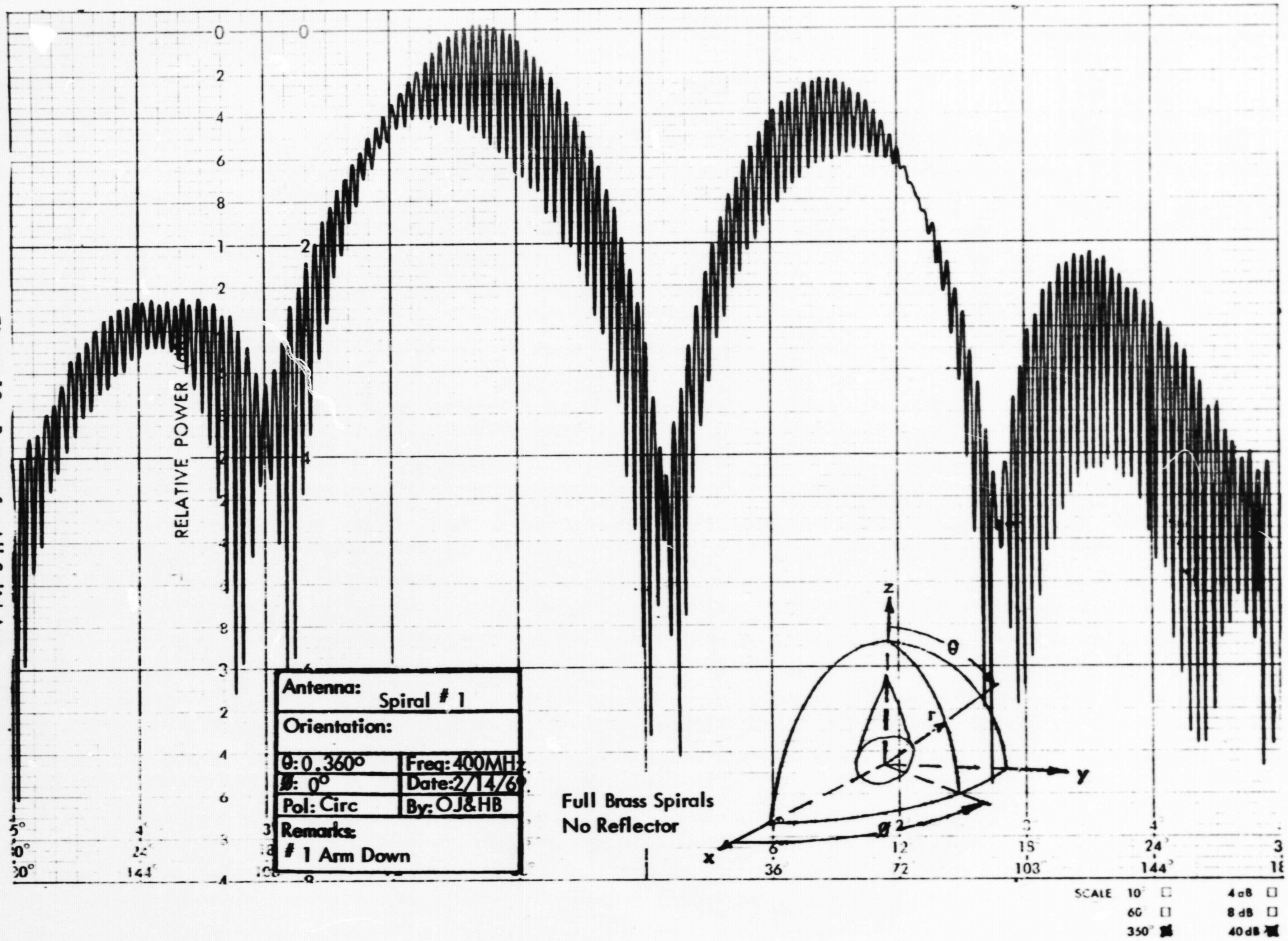


Figure 13. Pattern for All Solid Arms

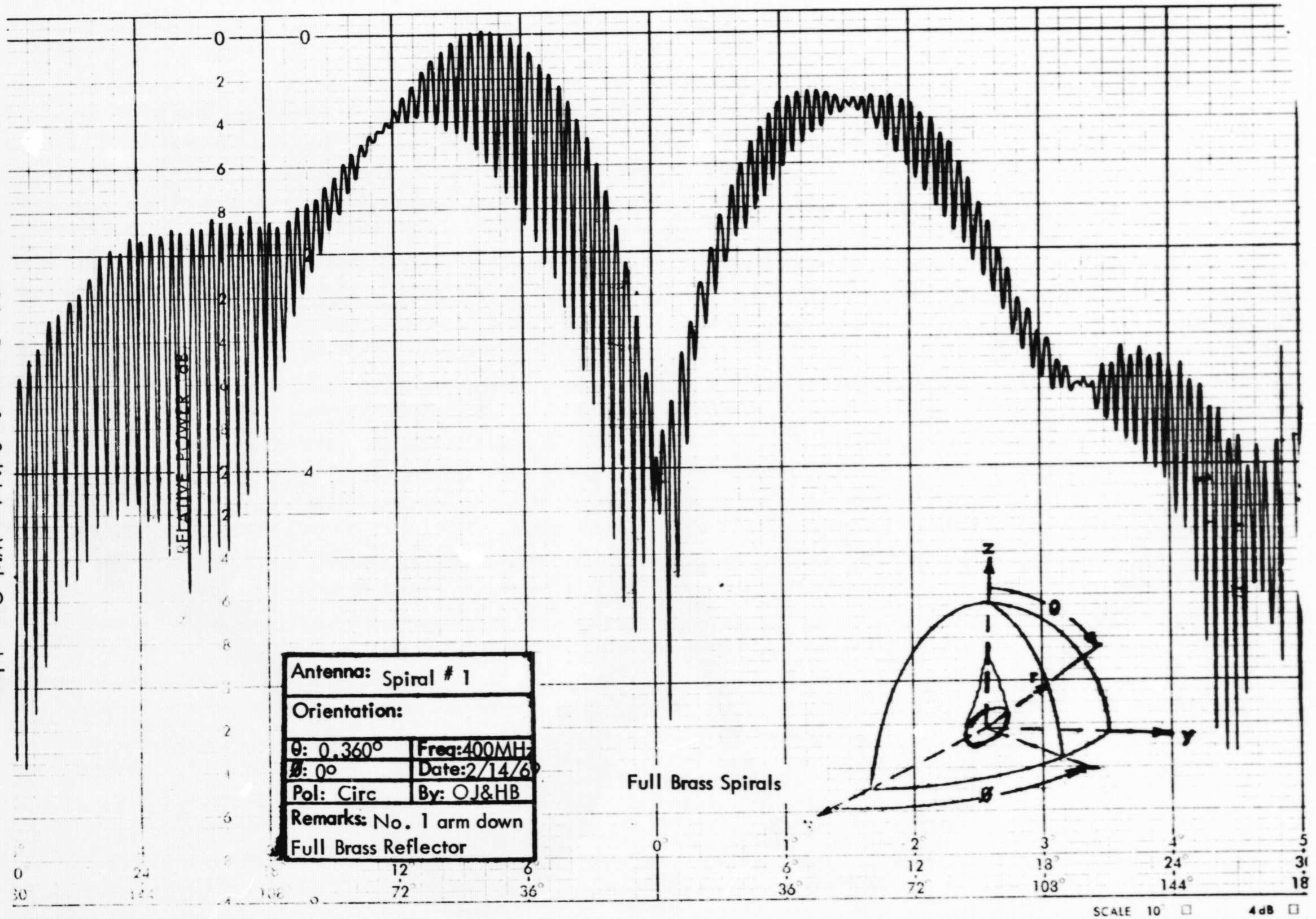


Figure 14. Pattern for Solid Arm With Groundplane

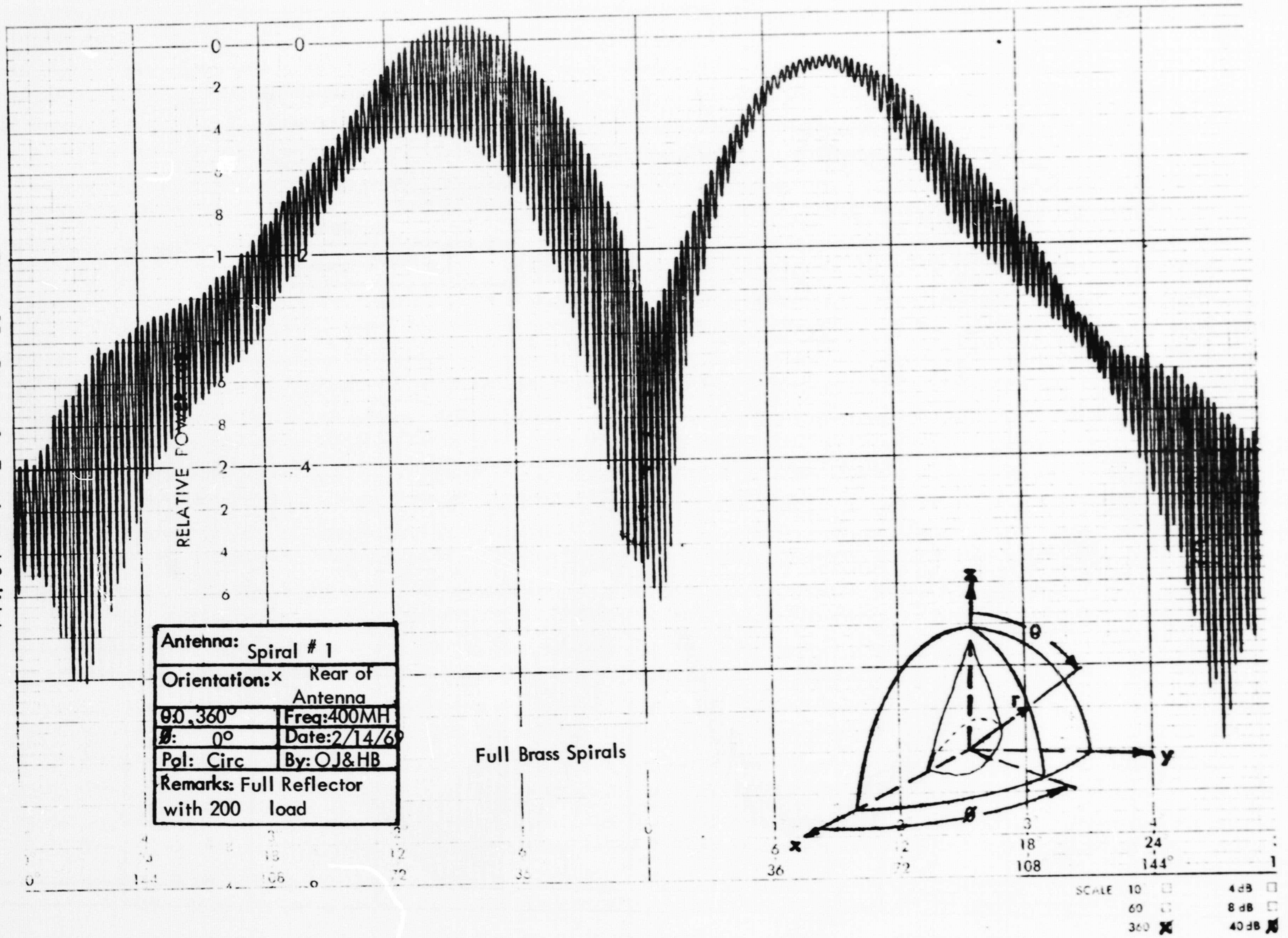


Figure 15. Pattern for Terminated Solid Arms

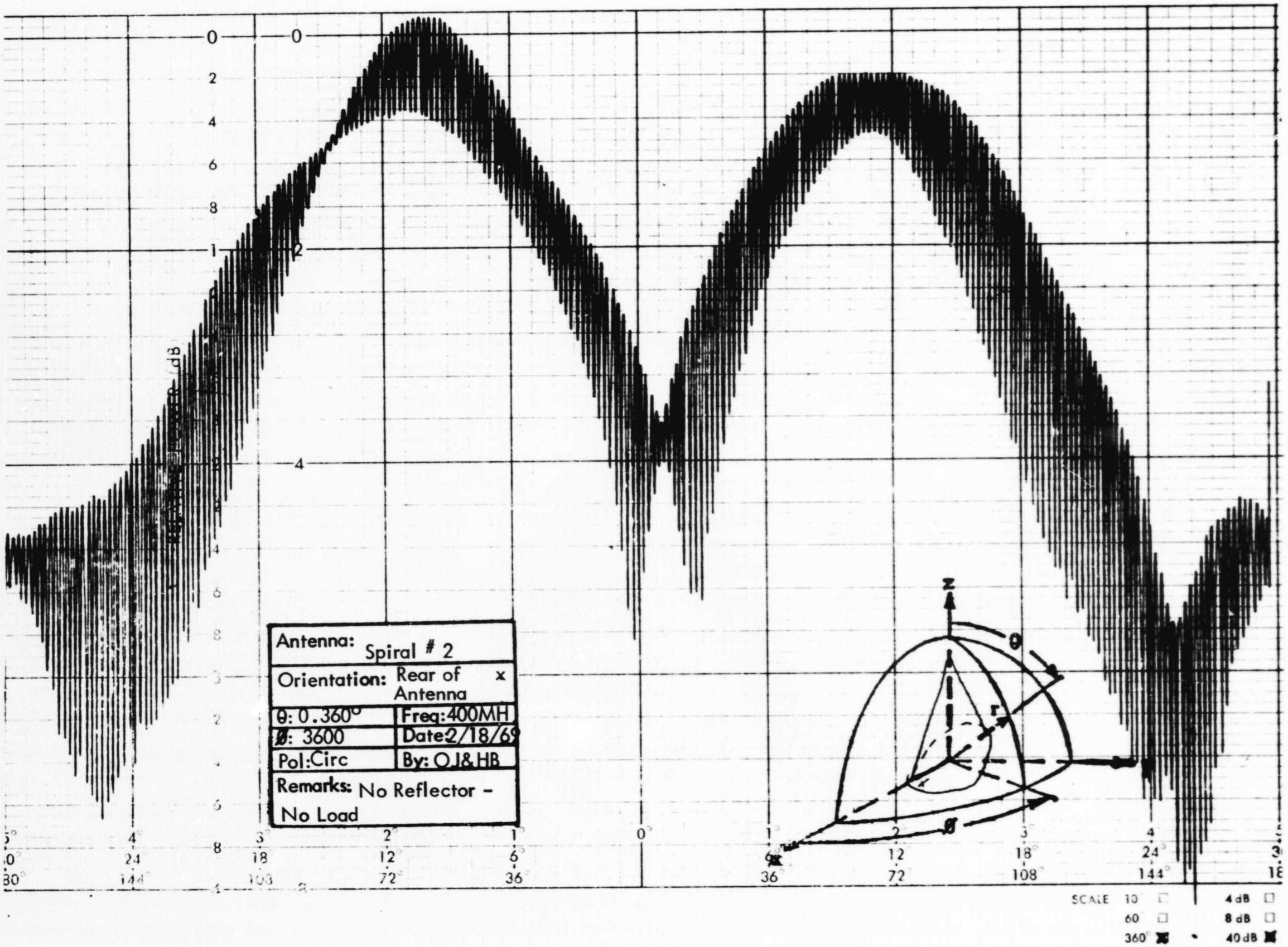


Figure 16. Pattern for Fifty Inch Cone

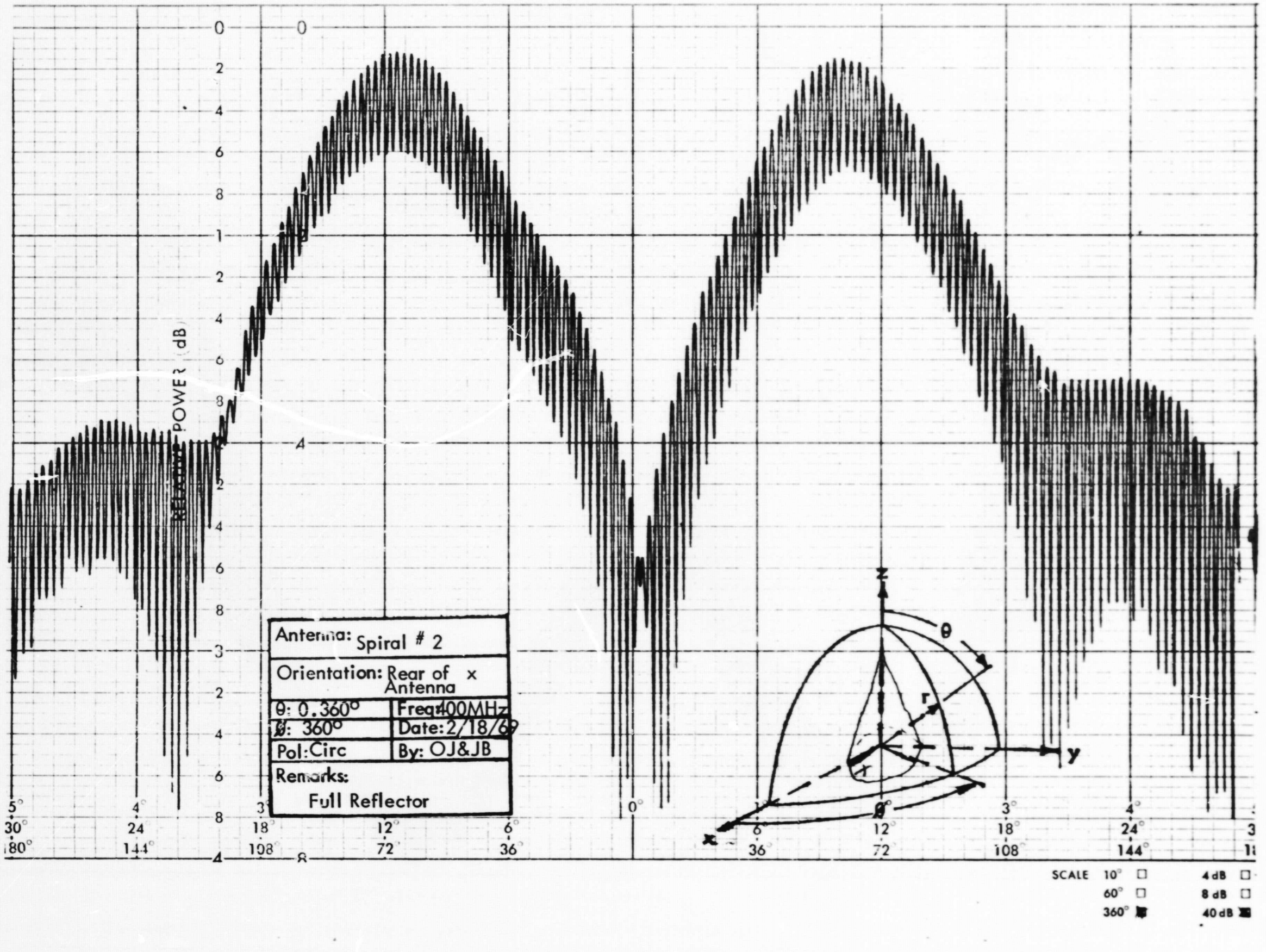


Figure 17. Pattern for Fifty Inch Cone With Groundplane

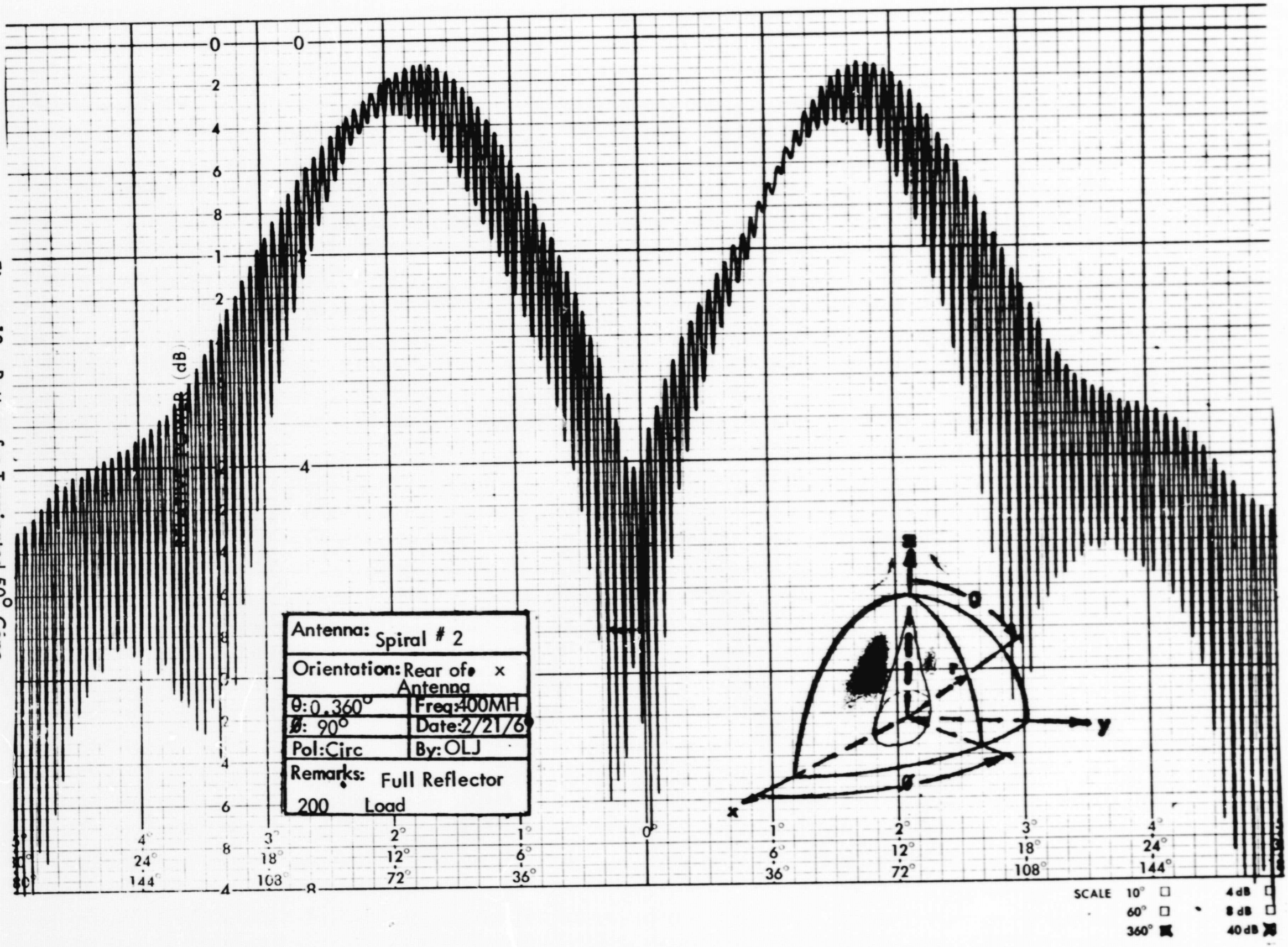


Figure 18. Pattern for Terminated 50° Cone

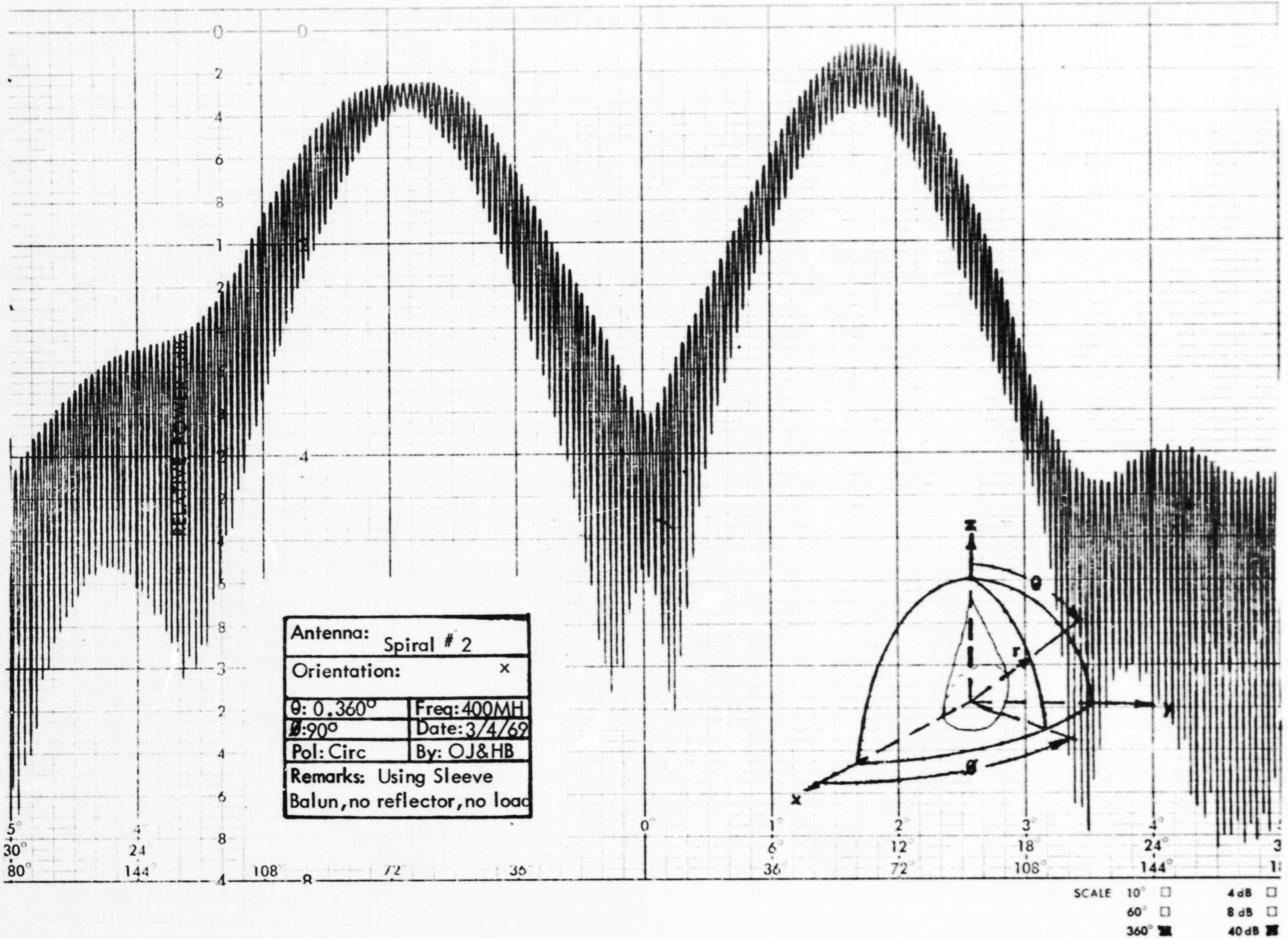


Figure 19. Pattern for 50" Cone With Balun

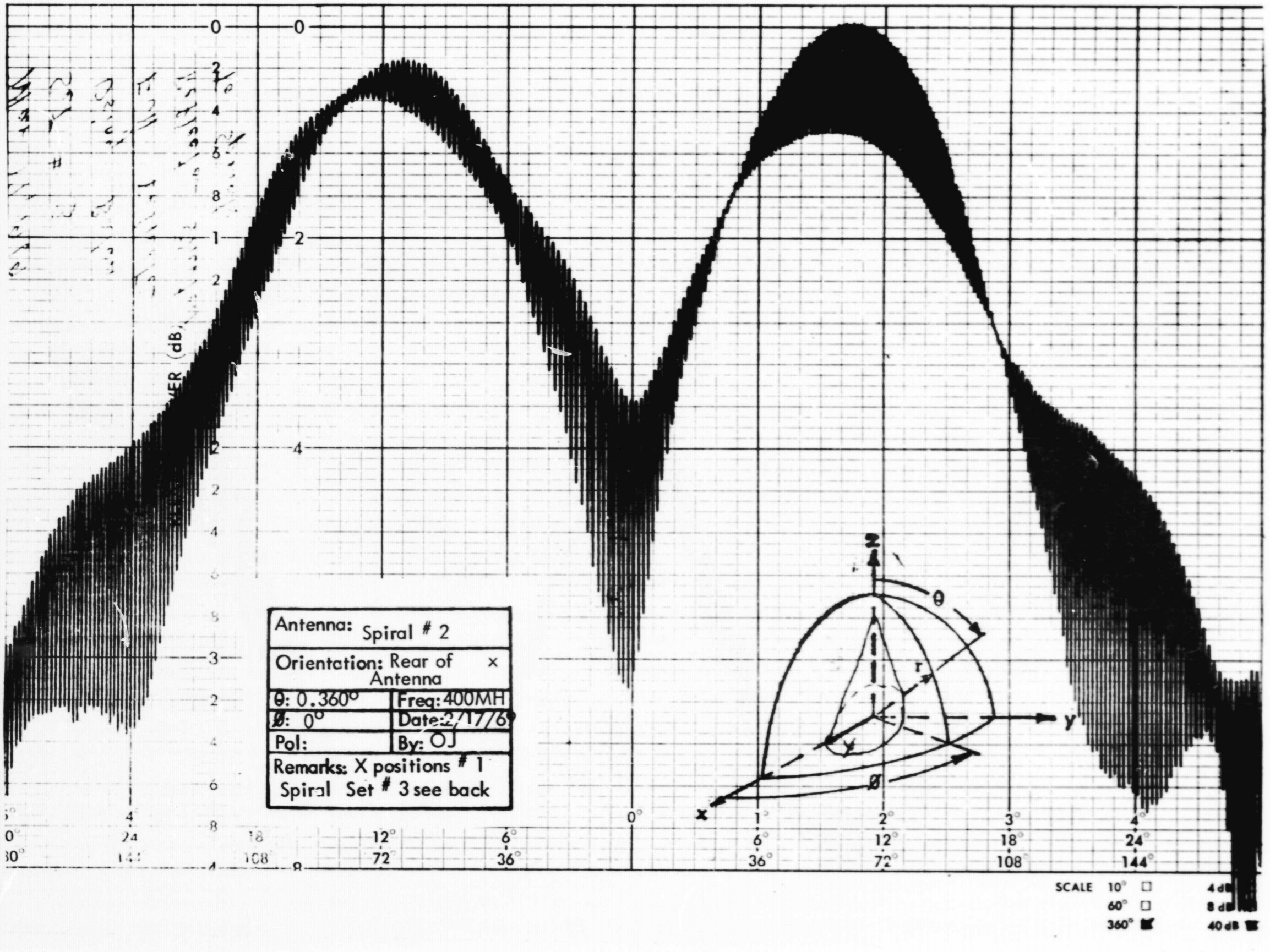


Figure 20. Pattern for 50" Cone With Balun and Groundplane

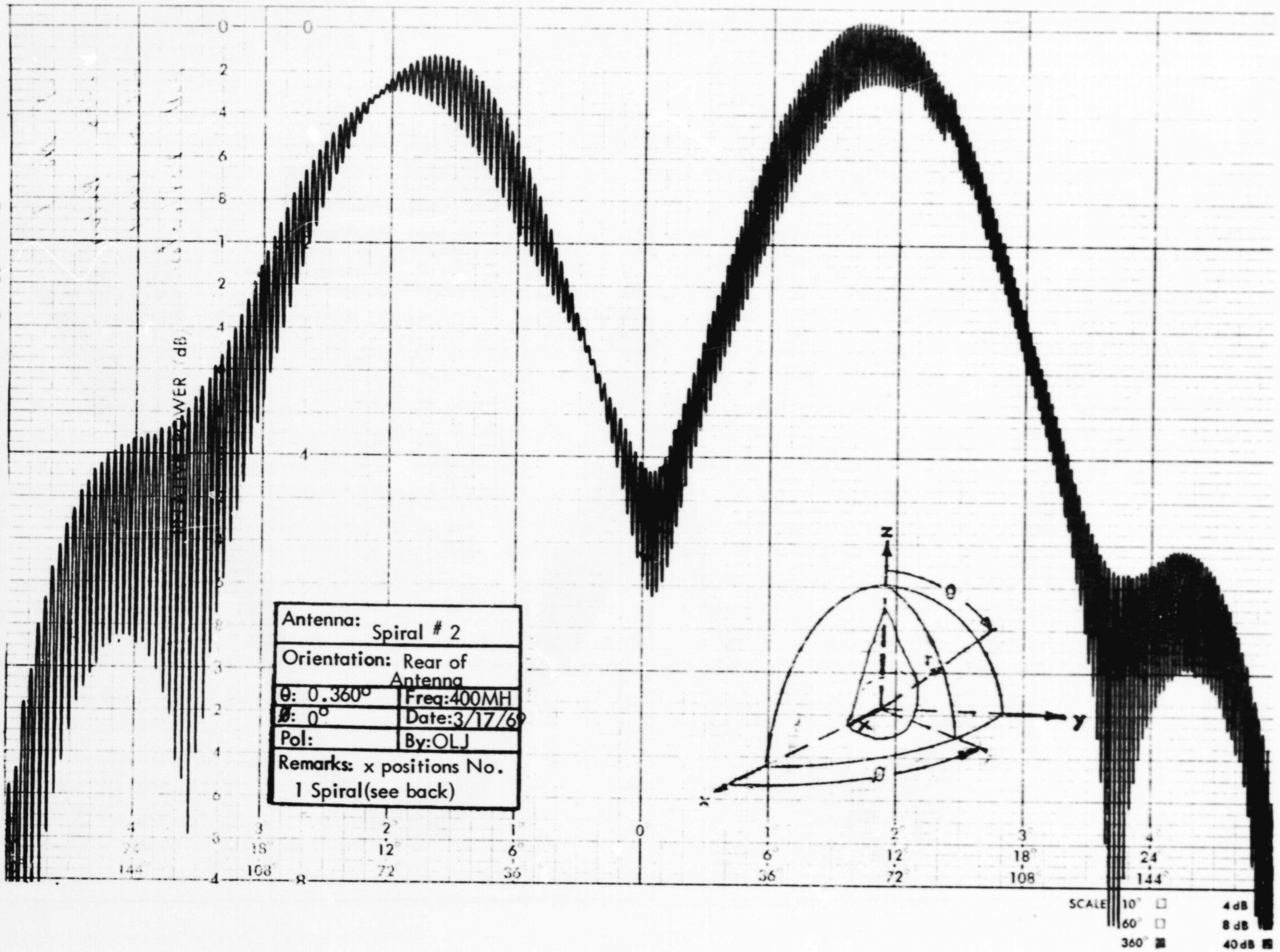


Figure 21. Pattern for Terminated 50" Cone With Balun

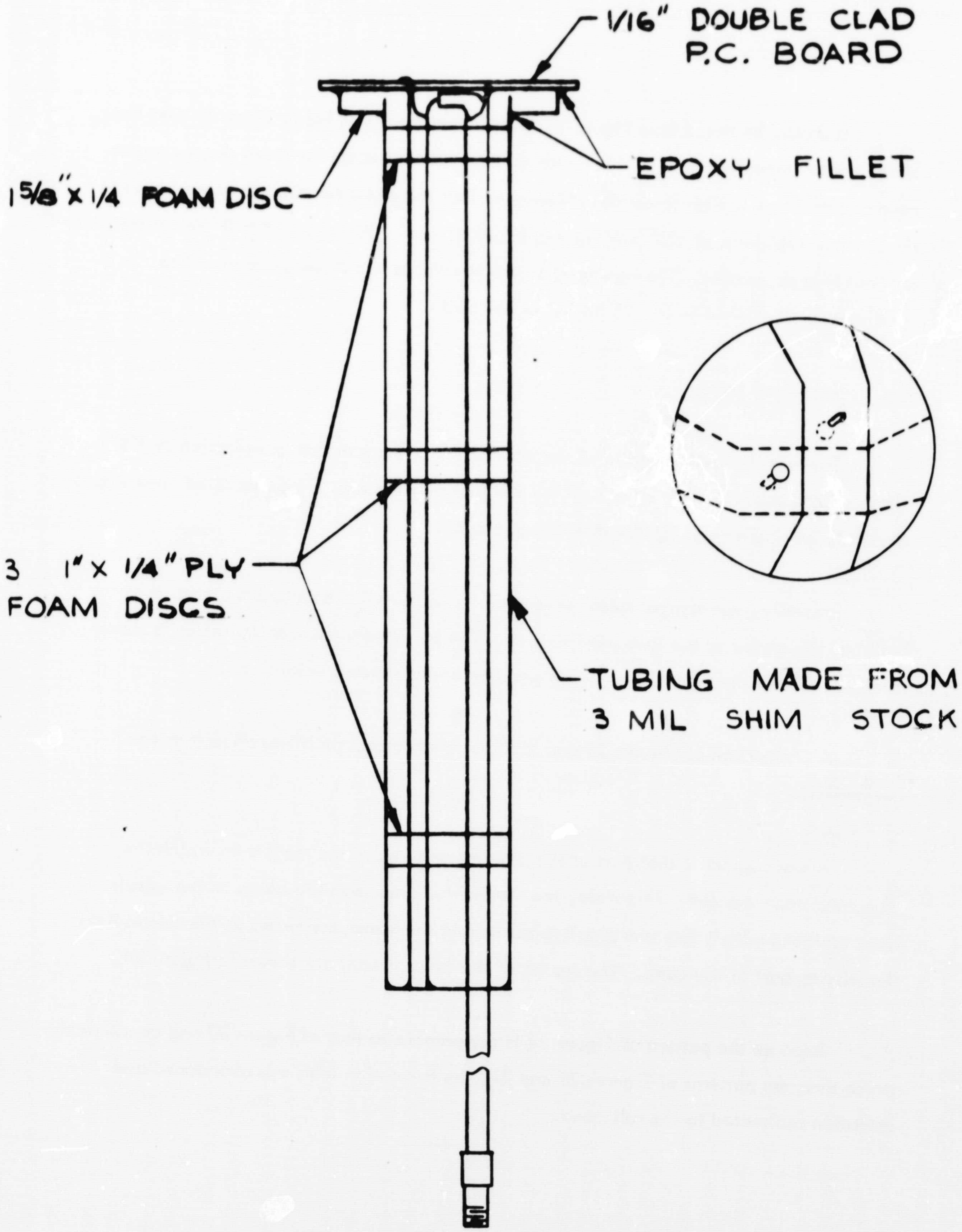


Figure 22. Sketch of Balun

It should be noted from Figure 21 that the axial ratio is below three db over most of the upper hemisphere and is below four db everywhere except for a ten degree region near zenith where it rises to six db. Note also that there is a ten db difference between the pattern amplitude at $+20^{\circ}$ and the amplitude at -20°. At angles of $\pm 30^{\circ}$ this difference is about five db greater. The assymetry in the backlobes is a range problem. The backlobes are believed to be 25 db below the peaks.

2.6 Truncated Cone

Because the lower portion of the cone is the primary region of radiation at 400 MHz, an attempt was made to cut off the top half of the cone. This truncated cone would obviously be smaller and lighter than the full cone.

Initially, the conical spiral arms were fed from radial conductors attached to the balun at the center of the truncated surface. The pattern for this configuration is shown in Figure 22 and the effect of adding a groundplane is shown in Figure 23.

A comparison of Figures 21 and 23 shows that serious problems arise from the truncation.

It was suspected that part of the problem was due to the manner in which the truncated cone was fed. Therefore, the radial fed arms from the balun to the spirals were replaced with a four arm plane spiral having the same parameters as the spirals from the missing part of the cone. The results of this arrangement are shown in Figure 24.

Because the pattern of Figure 24 is comparable to that of Figure 23 and considerably worse than the patterns of Figures 20 and 21, the truncation idea was abondoned and attention redirected to the full cone.

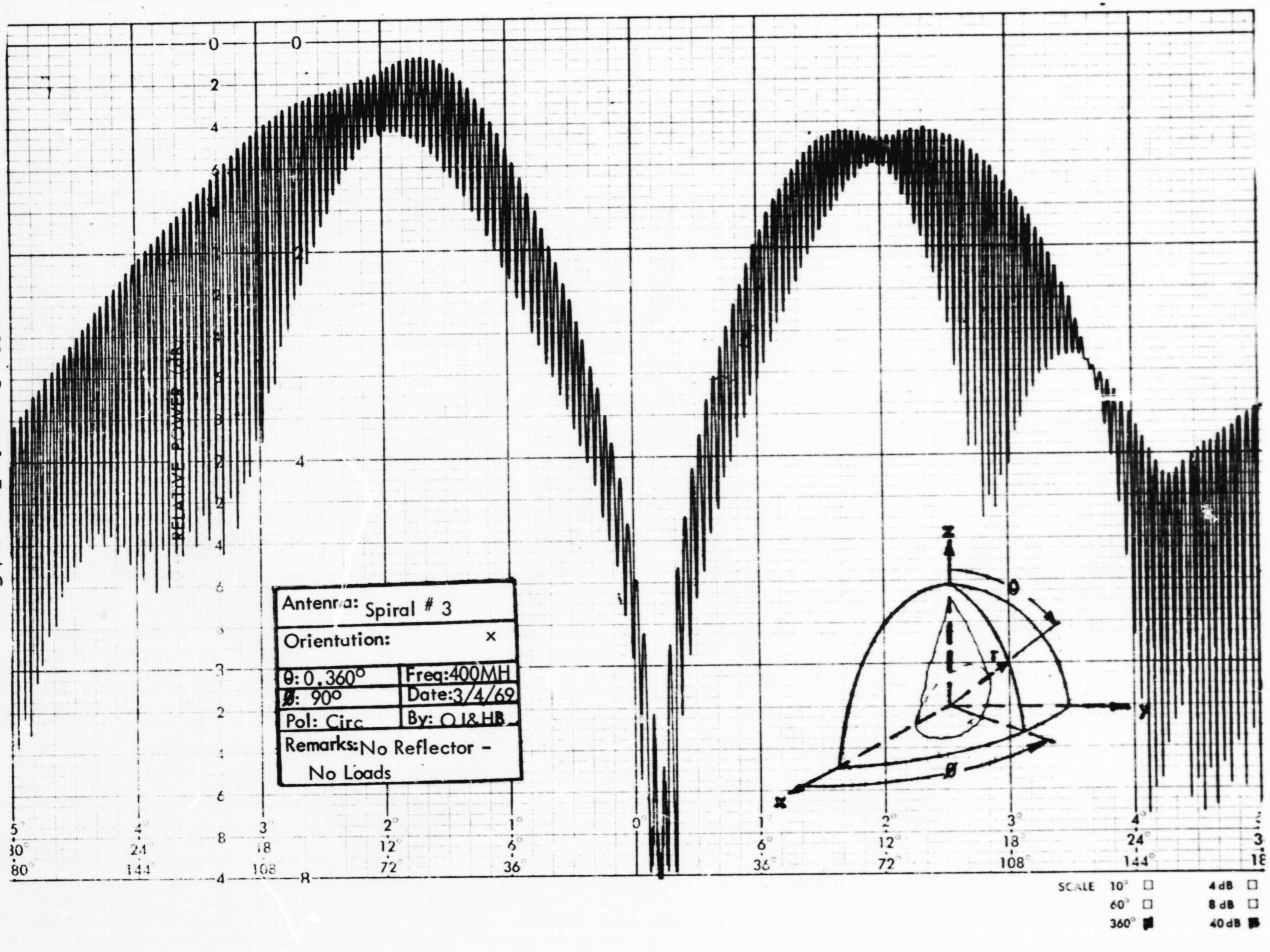


Figure 23. Pattern for Truncated Cone

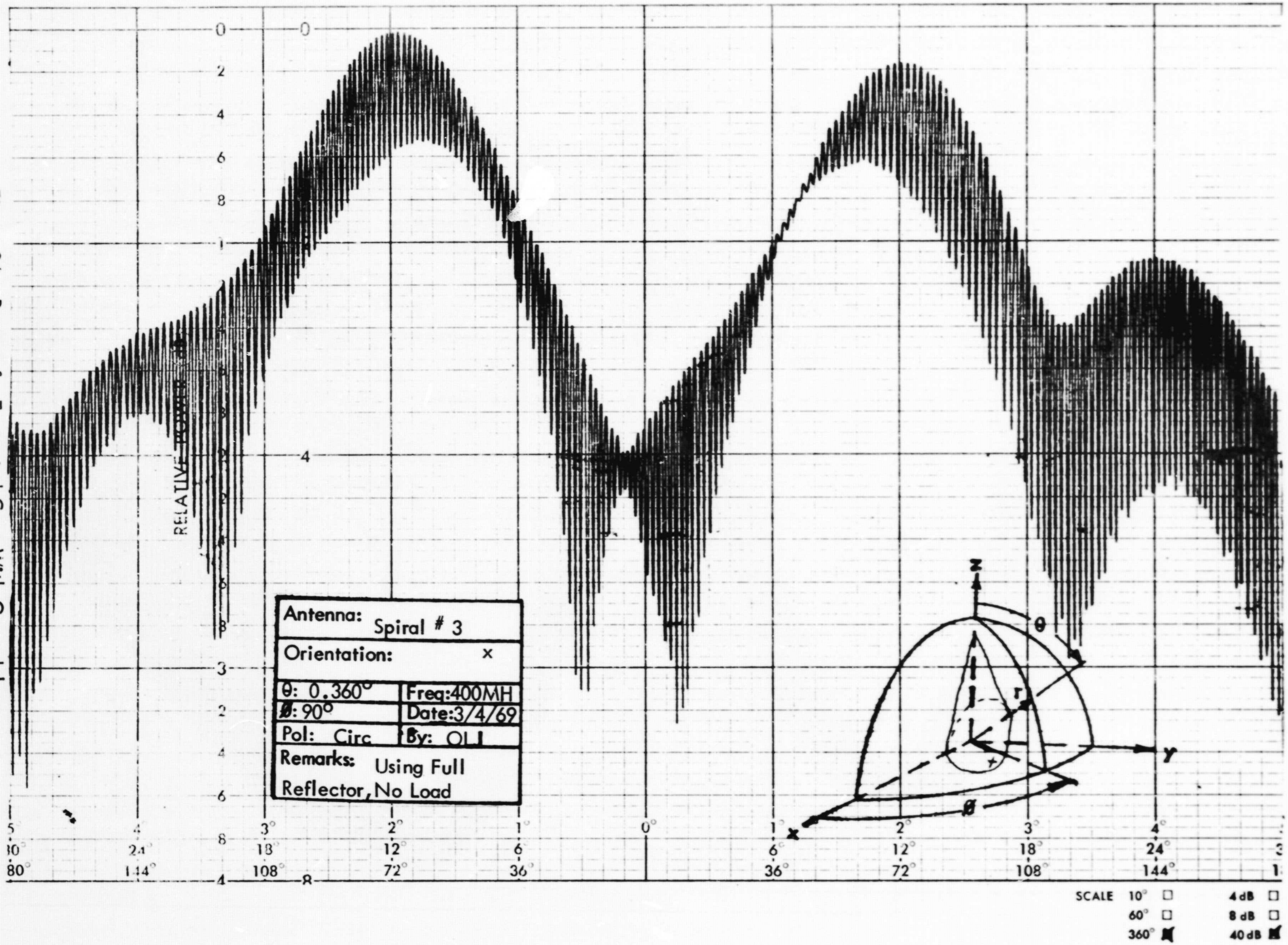


Figure 24. Pattern for Truncated Cone With Groundplane

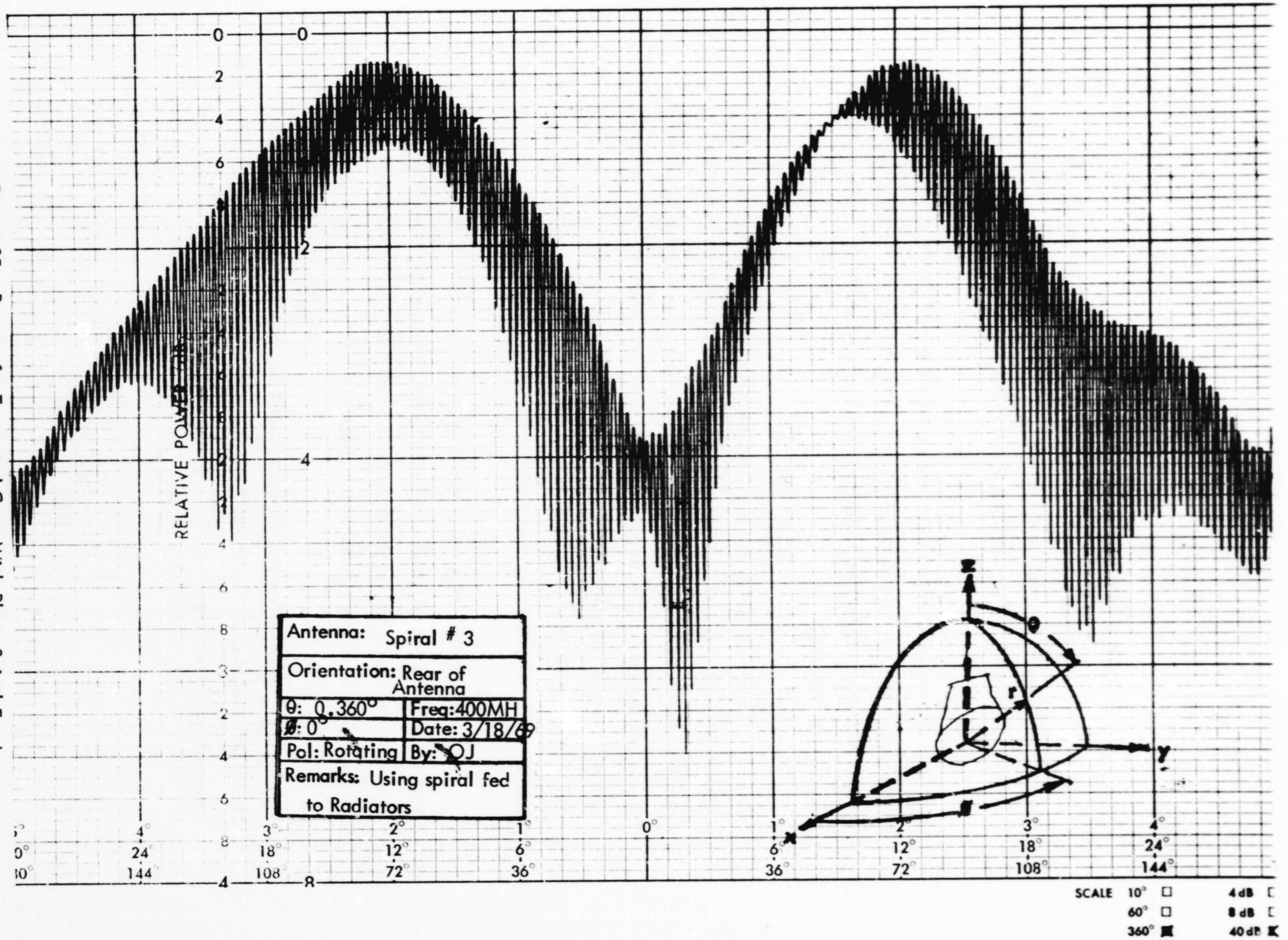


Figure 25. Pattern for Truncated Cone With Plane Spiral Feed

2.7 Prototype Antenna

The next cone was made with a 65° spiral angle. This antenna was fed with a balun and was measured with and without a groundplane. The patterns with and without the groundplane are shown in Figures 25 and 26 respectively.

Finally, the effect of a metallic reflector inside the cone was examined. An 18" high cone was mounted on the base so that its sides were approximately a quarter wavelength inside the radiating surface. The results of this experiment are shown in Figure 27.

A review of all of the measured data led to the adoption of the 65° spiral without reflectors as the final prototype design. Complete patterns at both operating frequencies with rotating linear and circular polarization are shown in Figures 28 through 31. Figures 28 and 29 are patterns taken at 401 MHz and Figures 30 and 31 are patterns taken at 466 MHz. Figures 28 and 30 show the results when the antenna is illuminated with a rotating linearly polarized field and Figures 29 and 31 are for a circularly polarized field.

The results of Figures 29 and 31 are redrawn on polar coordinates in Figures 32 and 33 respectively. The design goal pattern from the original proposal is included in Figures 32 and 33 for comparison purposes. The measured pattern is very close to the desired pattern at both frequencies.

The axial ratio obtained from Figures 28 and 30 is plotted in Figures 34 and 35 respectively. Note that the axial ratio is relatively low over most of the region above the horizon.

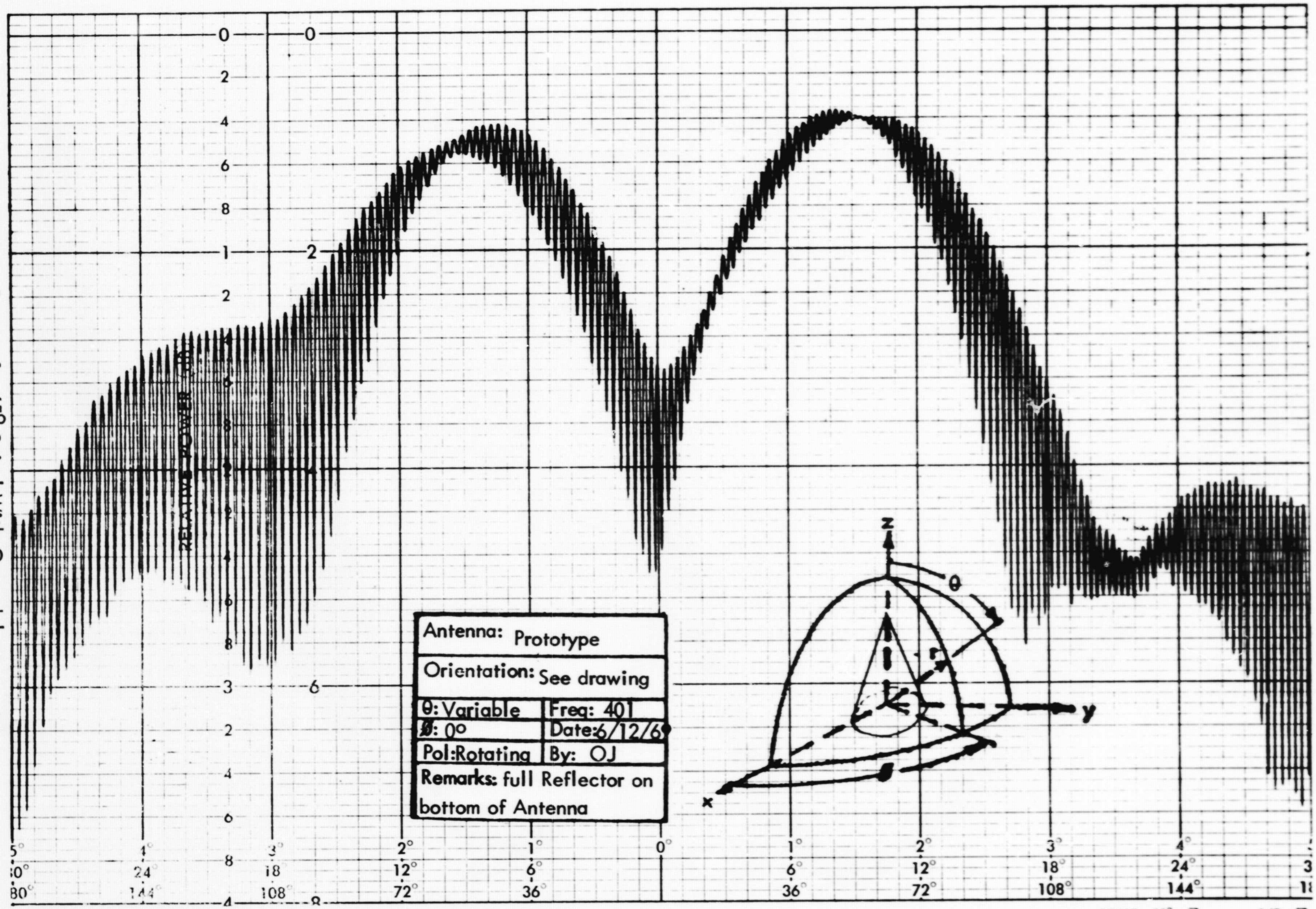


Figure 26. Pattern for 65° Spiral With Groundplane

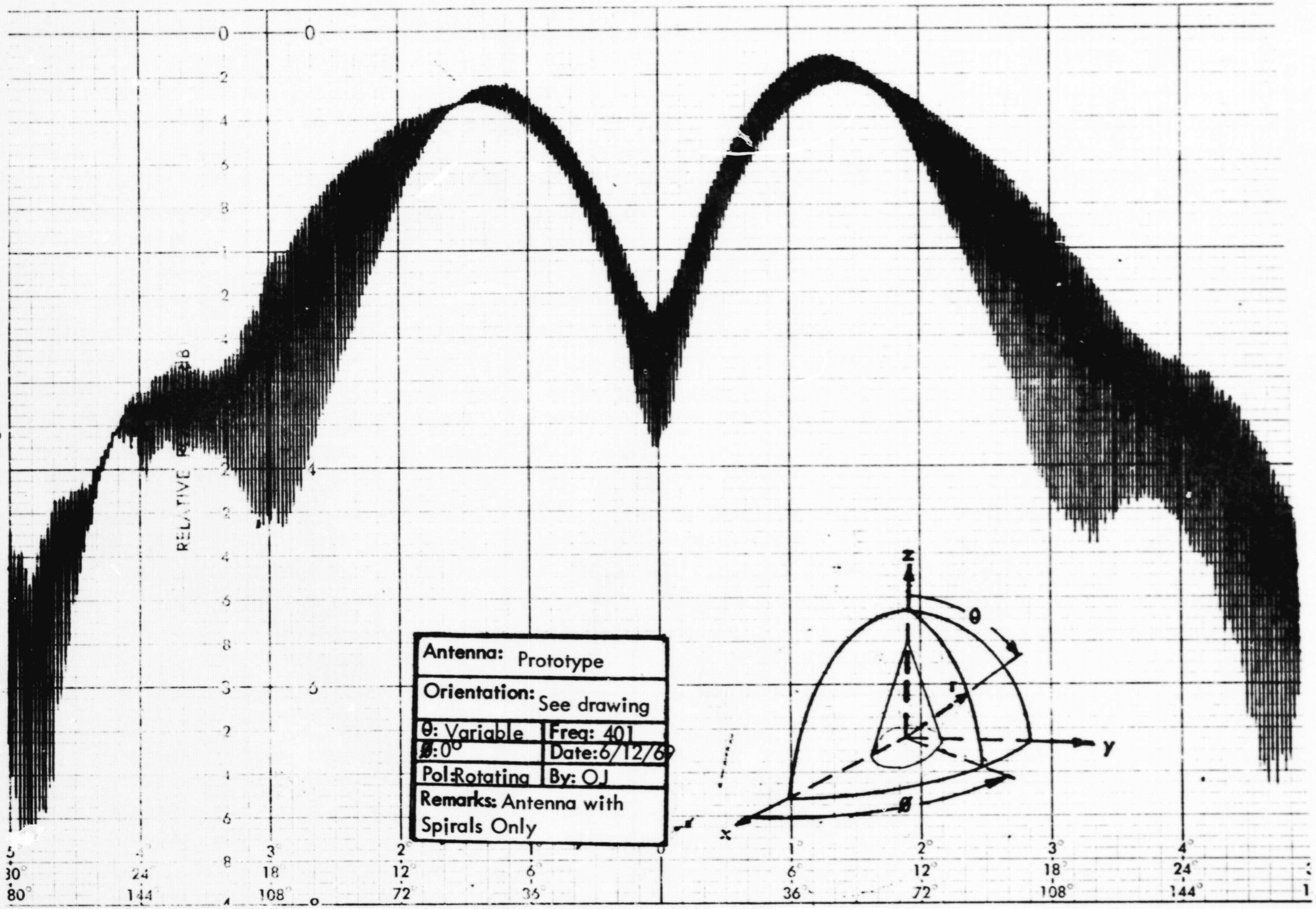


Figure 27. Pattern for 65° Spiral Without Groundplane

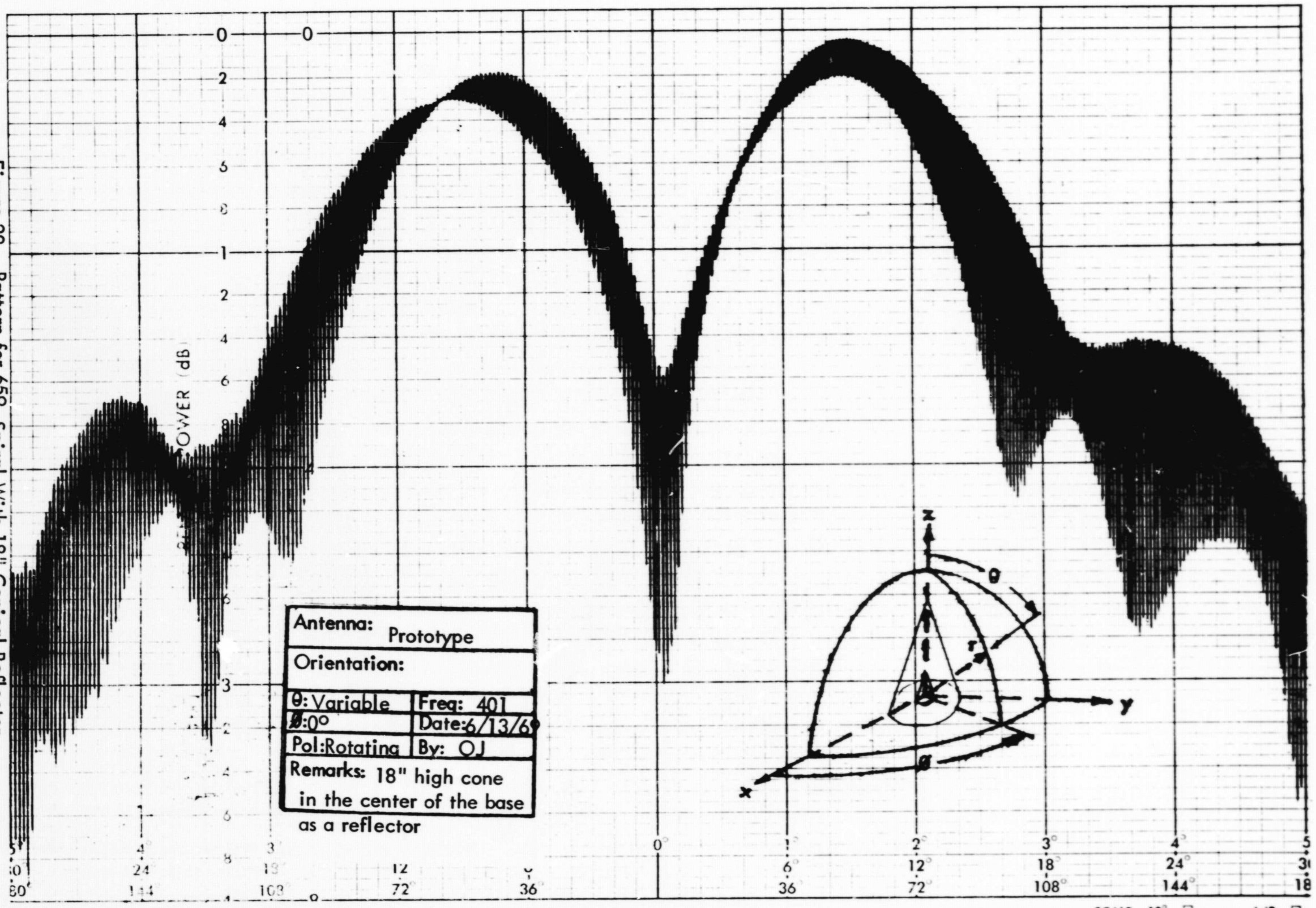


Figure 28. Pattern for 65° Spiral With 18" Conical Reflector

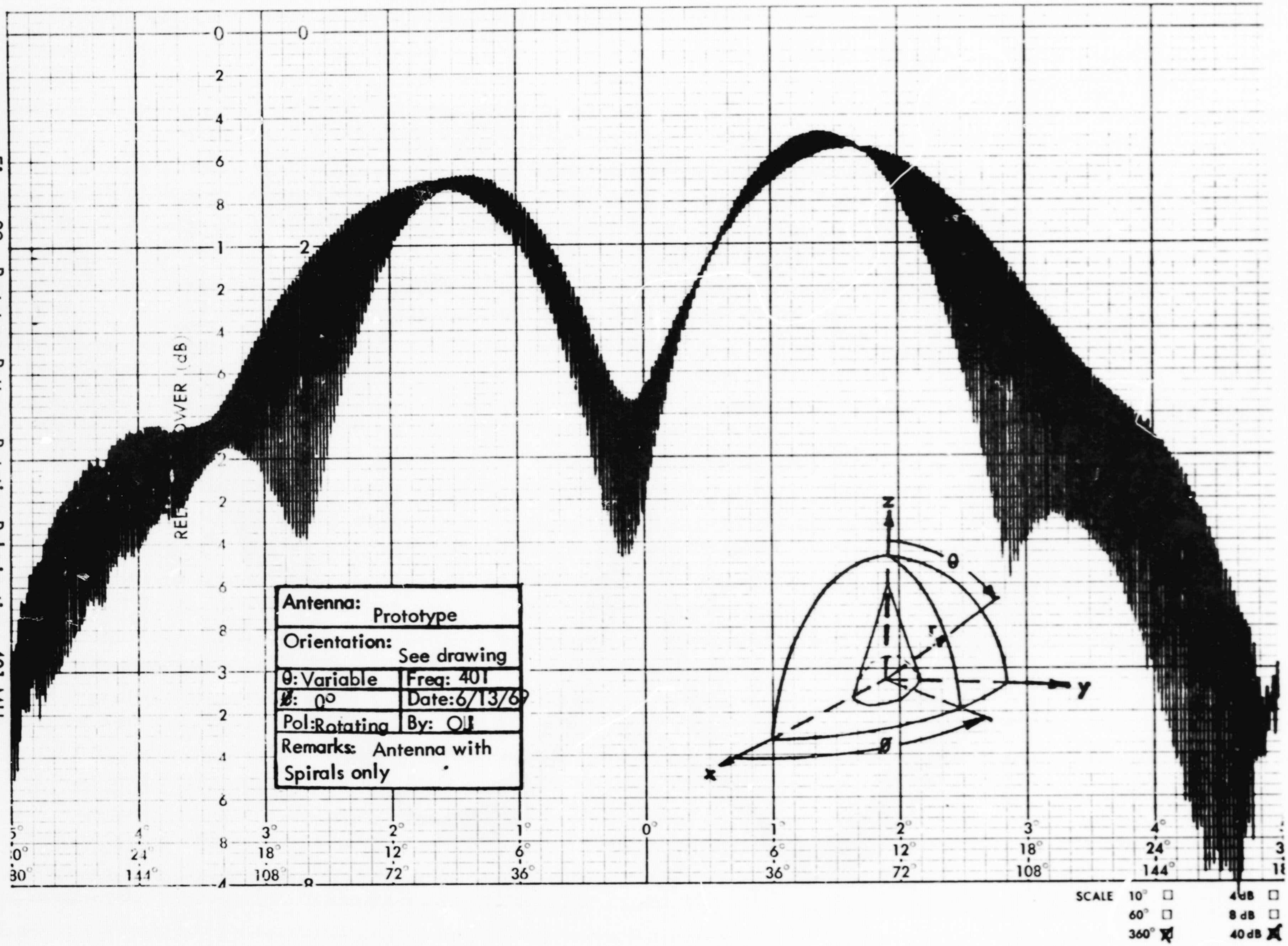


Figure 29. Prototype Pattern, Rotating Polarization, 401 MHz

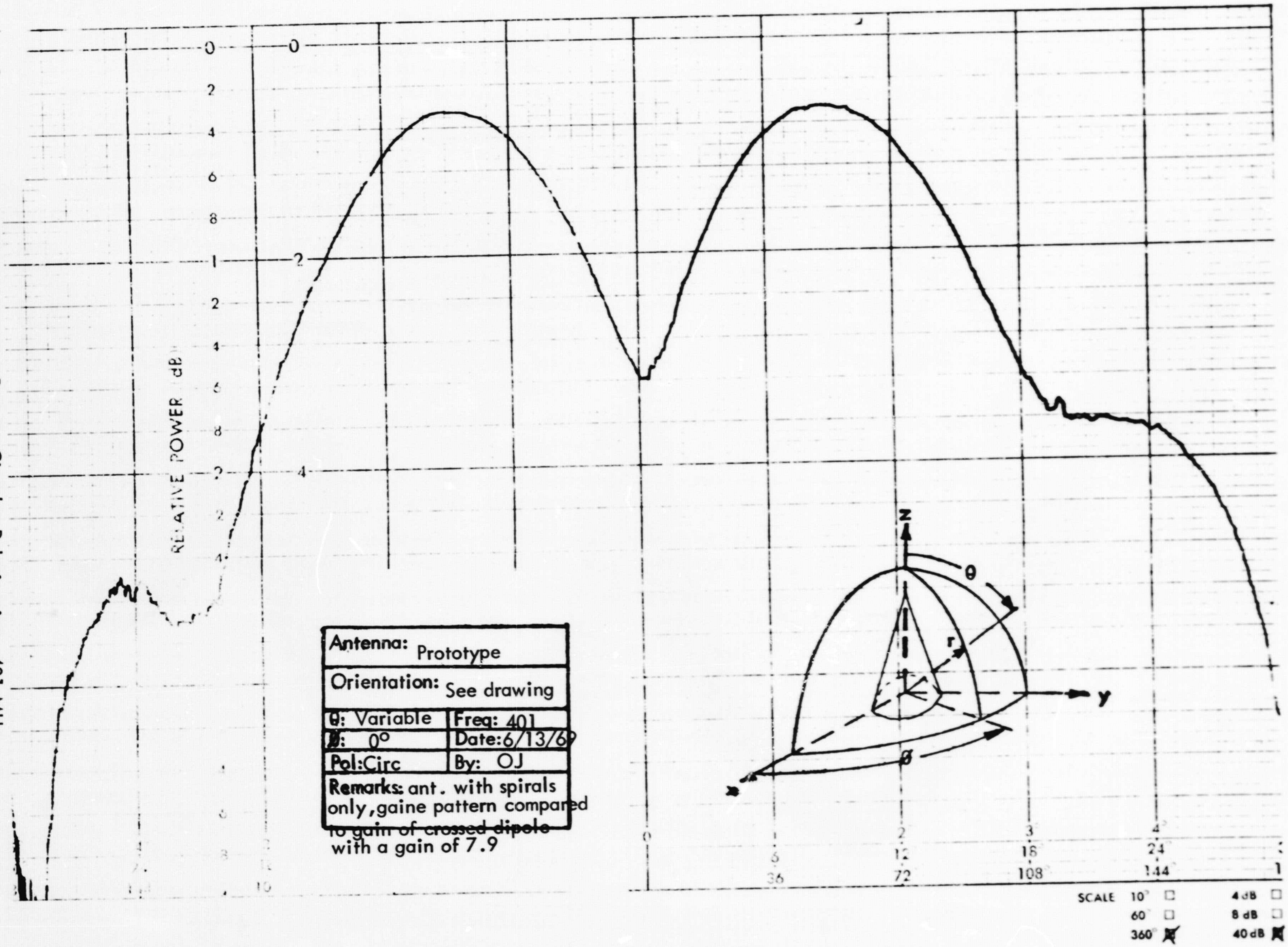


Figure 30. Prototype Pattern, Circular Polarization, 401 MHz

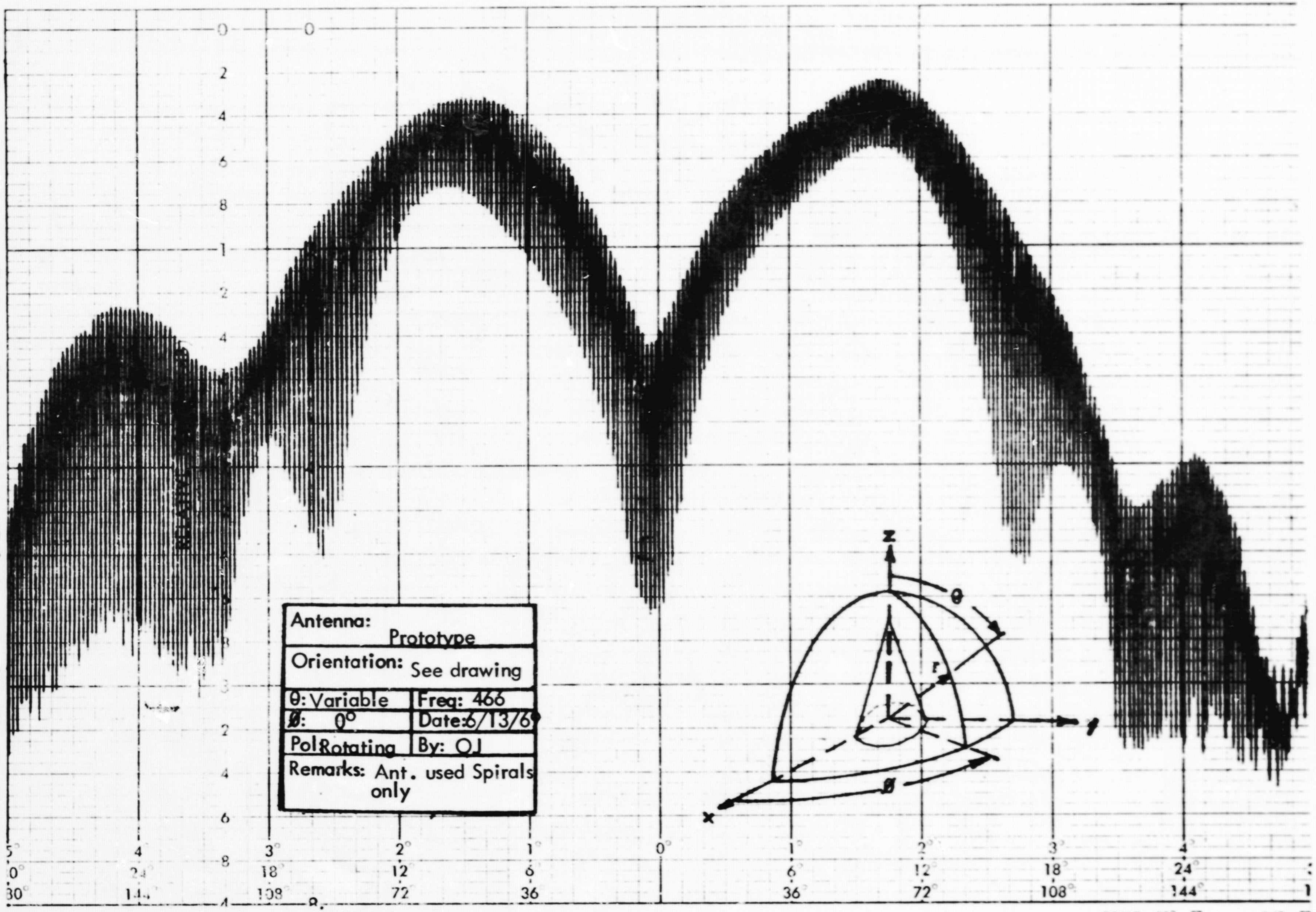


Figure 31. Prototype Pattern, Rotating Polarization, 466 MHz

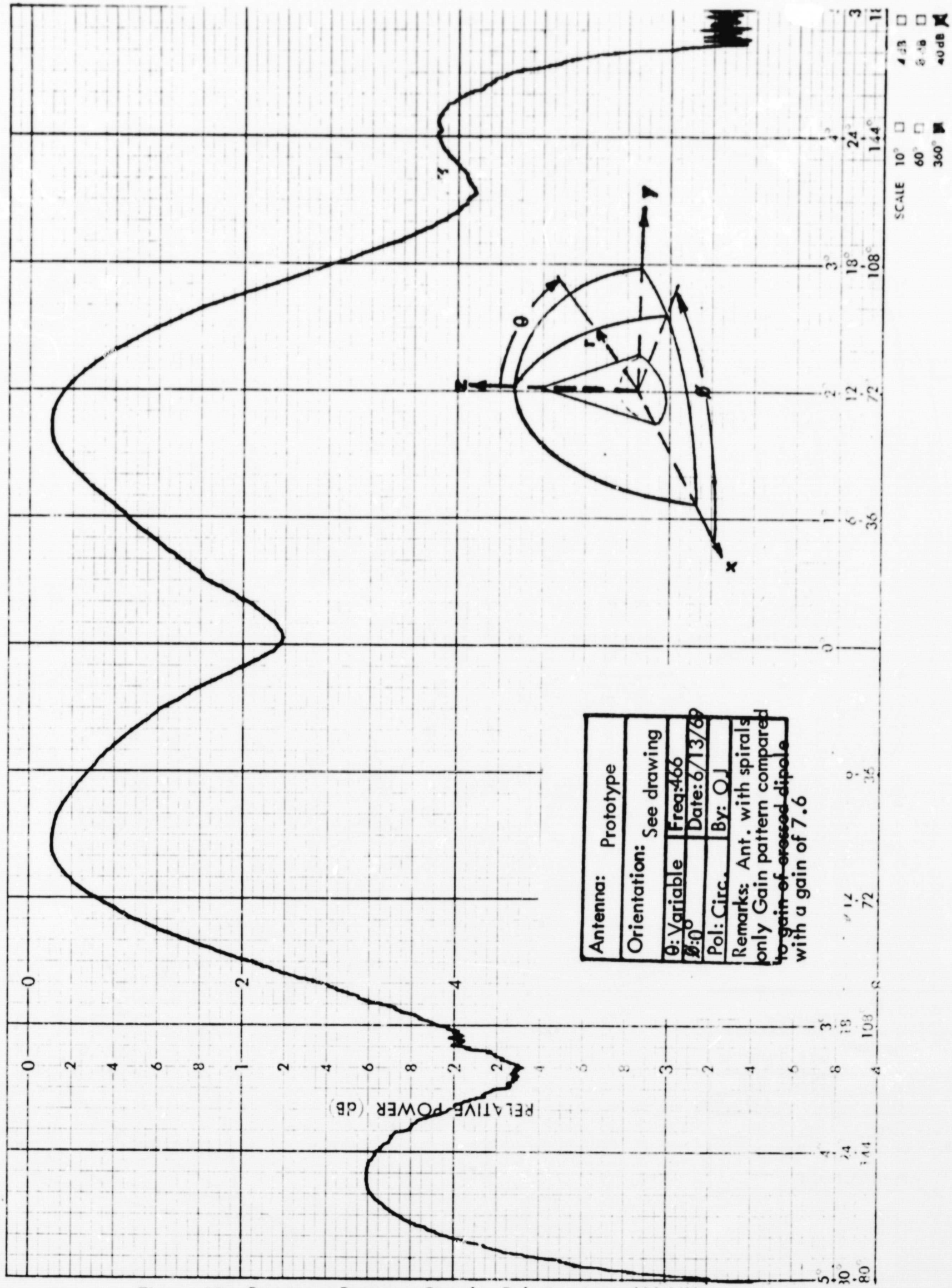


Figure 32. Prototype Pattern, Circular Polarization, 466 MHz

Antenna: Prototype	
Orientation: See drawing	
θ: Variable	Freq: 401
Ø: 0°	Date: 6/13/69
Pol: Circ	By: OJ
Remarks: Actual Pattern Proposed Pattern	

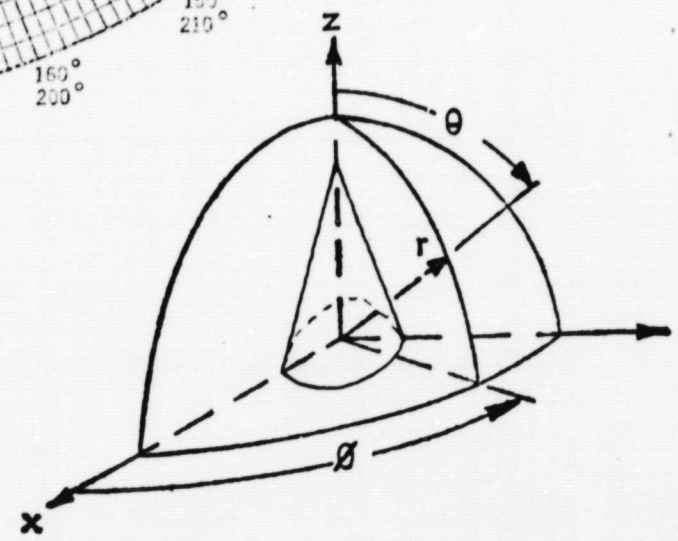


Figure 33. Prototype Pattern In Polar Coordinates, 401 MHz

Antenna: Prototype	
Orientation: See drawing	
θ: Variable	Freq: 466
ø: 0°	Date: 6/13/69
Pol: Circ	By: OJ
Remarks: Actual Pattern Proposed Pattern	

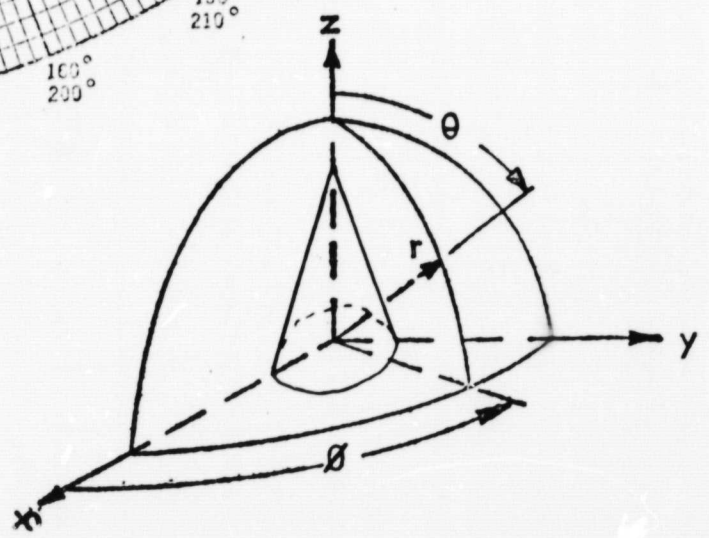


Figure 34. Prototype Pattern in Polar Coordinates, 466 MHz

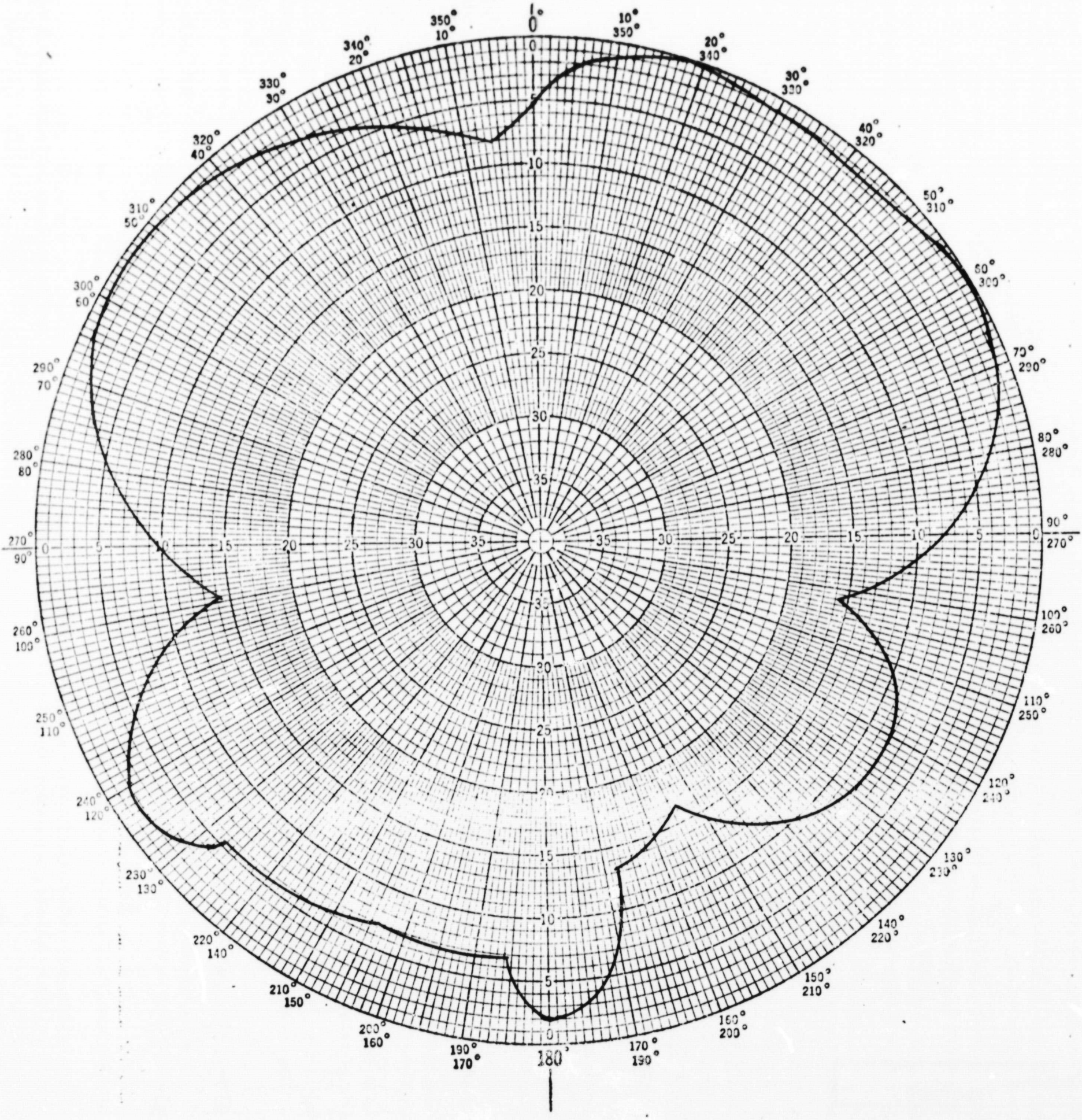


Figure 35. Axial Ratio at 401 MHz

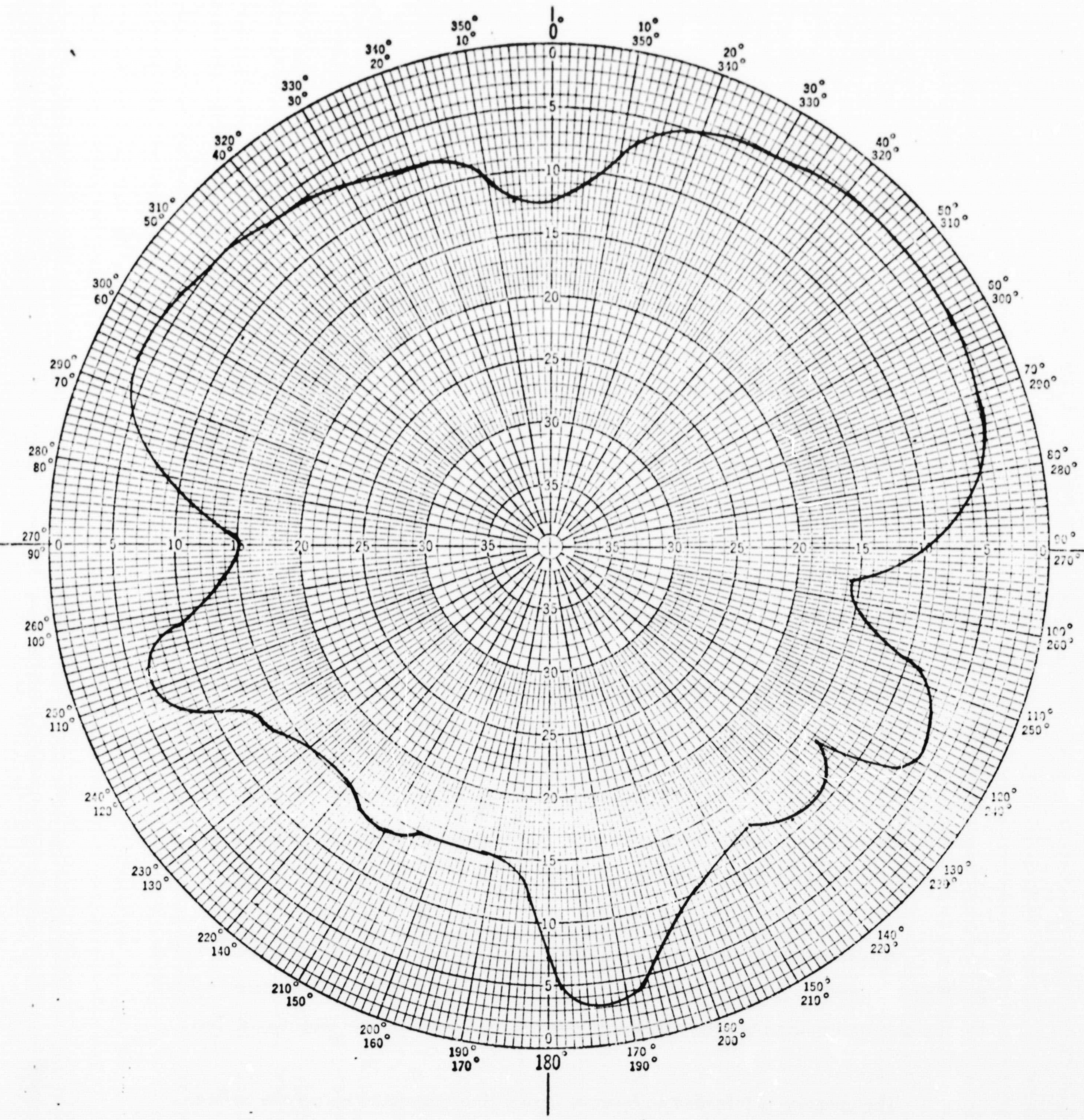


Figure 36. Axial Ratio at 466 MHz

3.0 MECHANICAL DEVELOPMENT

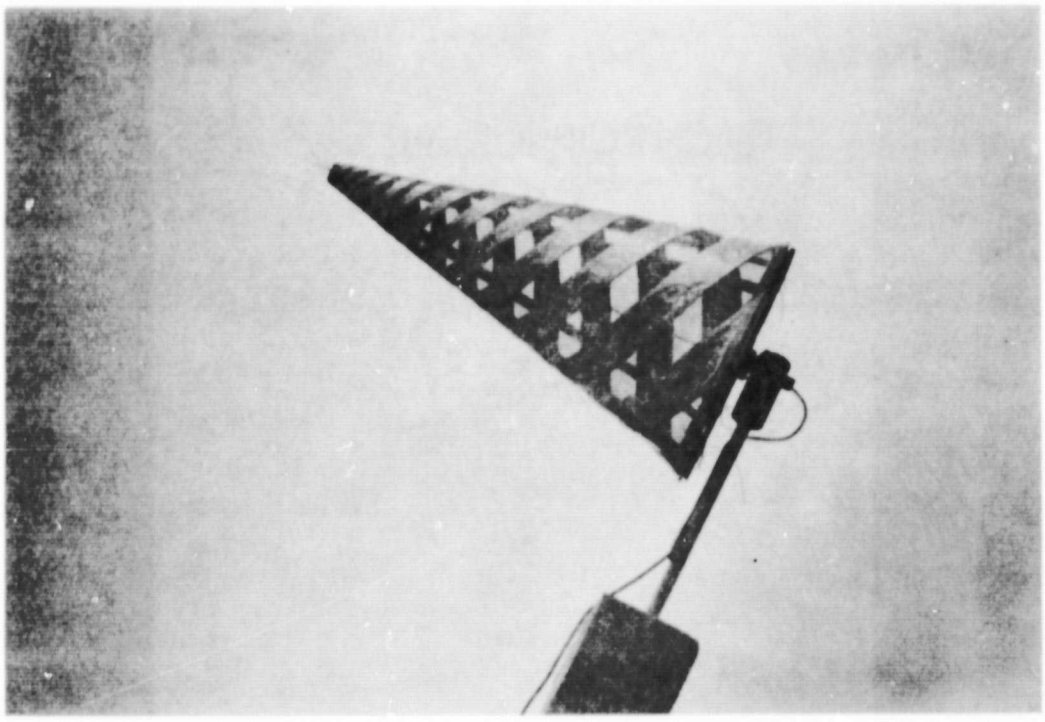
The original electrical design was performed with a solid plastic cone and brass shim stock spiral arms. These units were rugged and offered flexibility in adaptation to changing electrical parameters, but they were heavy and unsuitable for balloon use.

Once the electrical design was firm, a prototype antenna was fabricated using polyvinylchloride foam for the cone and aluminum foil for the conducting arms. This antenna with balun and a length of rigid coaxial cable to extend the input to the antenna base weighs 330 grams (0.726 pounds). The cone is cut out after fabrication to eliminate as much material as practical to reduce the antenna weight. A sample of the foam was soaked in water for several hours and then placed in a carbon dioxide cooled box at -50°F for several hours without damage. The sample was not unduly brittle when removed from the temperature chamber.

The balun is made from thin shim stock and foam spacers to minimize weight. The foam cone is covered with a thin mylar sheet before the radiators are added and another mylar sheet is placed over the radiators. These mylar sheets provide some strength, water repellance, and protection from damage in handling. They add 30 grams each to the weight and give the cone more wind resistance. They can be eliminated if handling is not excessive or careless.

A photograph of the antenna is shown in Figure 36. The test data taken on the prototype antenna is given in Figure 37. An attempt was made to use aluminzed mylar for the conducting arms but the resistivity was too high and the gain was two db less.

The antenna is intended to operate from a line suspended below the balloon. A solar cell array and a balloon cut-down device are mounted above the antenna and the IRLS transceiver is mounted below the antenna. Provision must therefore be made to suspend the antenna and the package below it and to pass electrical signals through the antenna from the transceiver to the upper equipment. The antenna is therefore designed with an 80 pound test fish line and four wires passing through the cone along



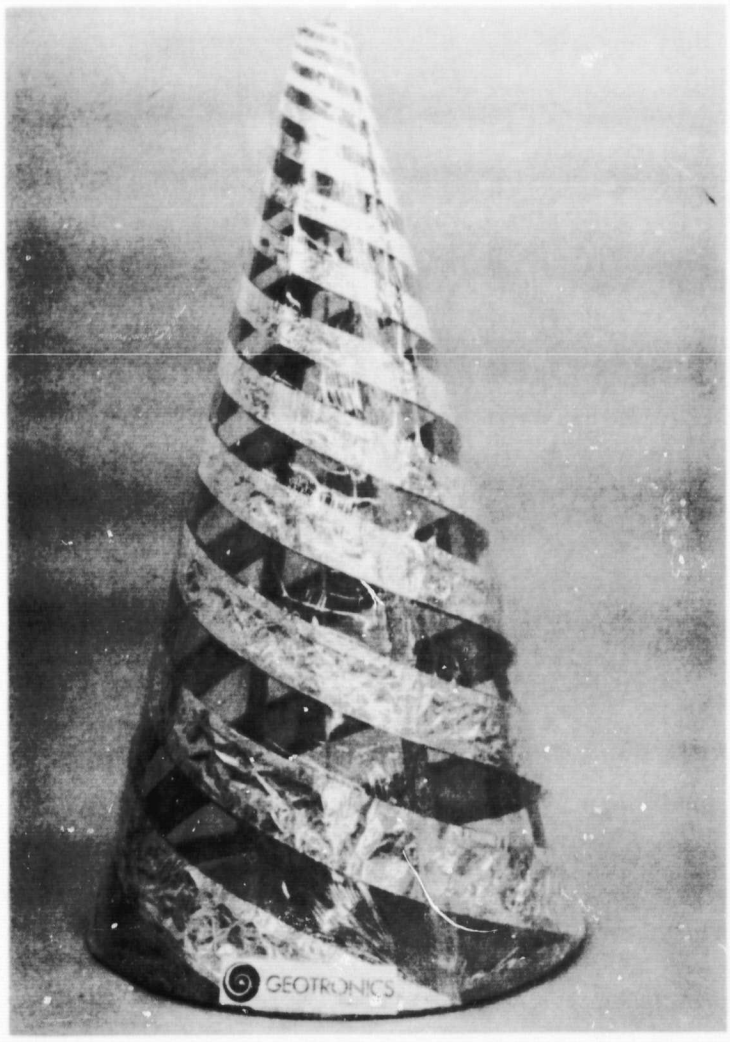


Figure 37. Antenna Photographs

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Antenna Model 075-CS Serial Number Prototype

Test Data

1. Weight (Grams)		330
Frequency (MHz)	401	466
2. VSWR (at 50 ohms)	1.7	1.55
3. Elevation Angle of Beam Max (degrees)	37	32
4. Gain at Peak (DB)	4.2	5.0
5. Gain at 20° Elevation (DB)	2.7	3.9
6. Axial ratio at 20° Elevation (DB)	1.6	3.8

By Oswald T. Jewell

Date July 2, 1969

Figure 38. Prototype Antenna Test Data

the axis with the RF cable. The wire and fish line pass through the balun.

A foam disk with spokes is used to hold the circular shape of the antenna at the base and a similar smaller disk is used to anchor the bottom end of the balun. The balun itself and the various foam pieces are held together with epoxy cement. Eastman 910 cement is used to fasten the mylar to the cone and the foil to the mylar.

The prototype antenna was accidentally caught by a gust of wind and blown off the roof to the asphalt drive twenty feet below without damage. This demonstrates the sturdiness of the design.

4.0 RESULTS AND CONCLUSIONS

Following successful test of the prototype antenna, four "production" model antennas were fabricated and tested. Figure 36 shows one antenna on the pattern measurement range. The results for the four final models are shown in Figures 38 through 57. The performance of antenna serial numbers 1, 2, 3 and 4 are given in Figures 38 through 42, 43 through 47, 48 through 52 and 53 through 57 respectively. The patterns for the four at 401 MHz are given in Figures 39-40, 44-45, 49-59 and 54-55 respectively and the patterns at 466 MHz are given in Figures 41-42, 46-47, 51-52 and 56-57 respectively.

It should be noticed that the antenna performance is close to the design goal in all respects. The VSWR of serial number 4 is slightly higher due to a difference in the construction of the balun. The VSWR can probably be made less than 1.3 with some additional balun design work.

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Antenna Model 075-CS Serial Number 1

Test Data

1. Weight (Grams)		453
Frequency (MHz)	401	466
2. VSWR (at 50 ohms)	1.65 to 1	1.68 to 1
3. Elevation Angle of Beam Max (degrees)	36	33
4. Gain at Peak (DB)	3.8	4.2
5. Gain at 20° Elevation (DB)	2.2	2.9
6. Axial ratio at 20° Elevation (DB)	1.5	2.4

By Donald L Jarrell

Date July 18, 1967

Figure 39. Serial # 1 Test Data

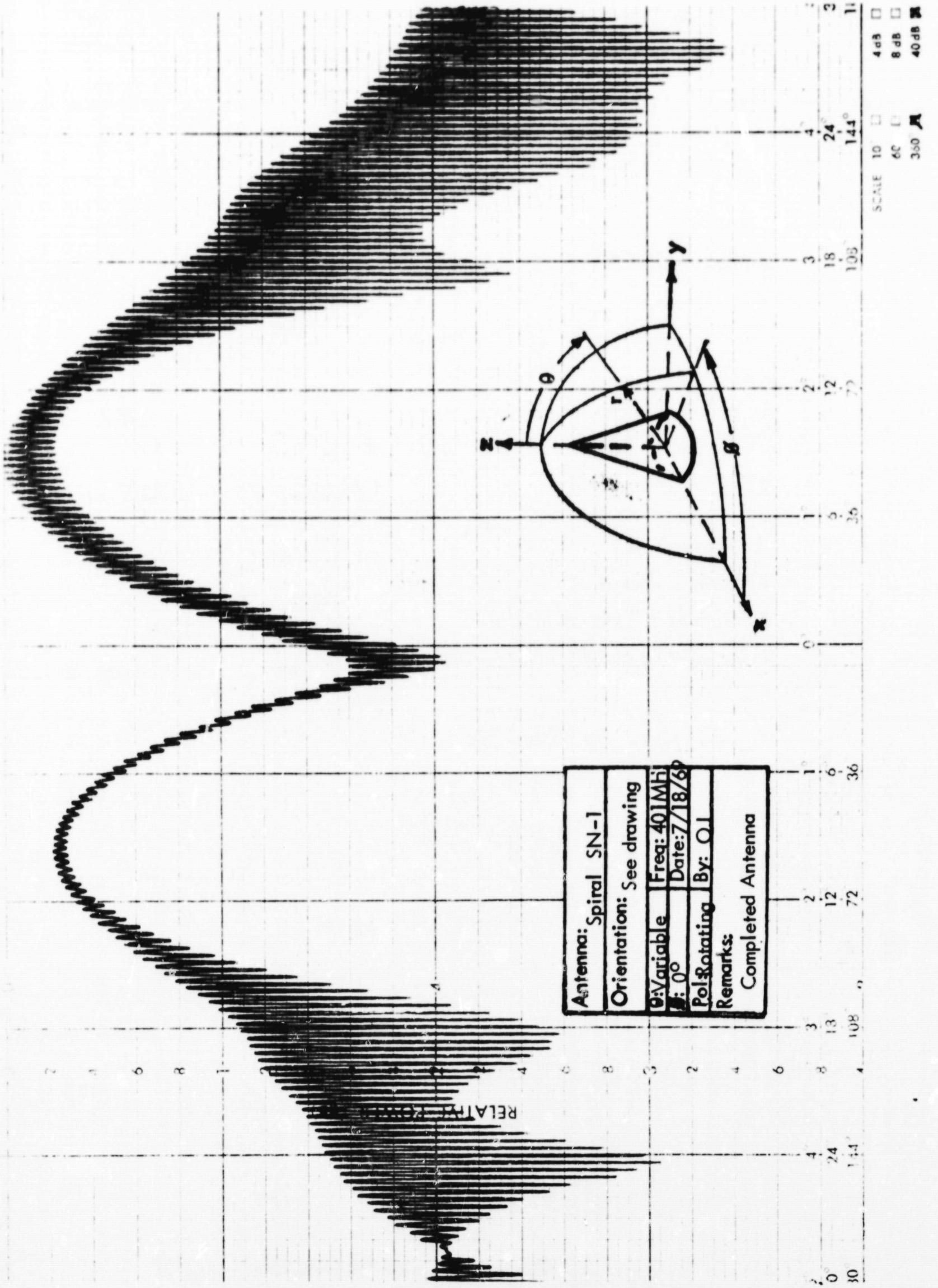


Figure 40. Serial # 1 Rotating Polarization Pattern, 401 MHz

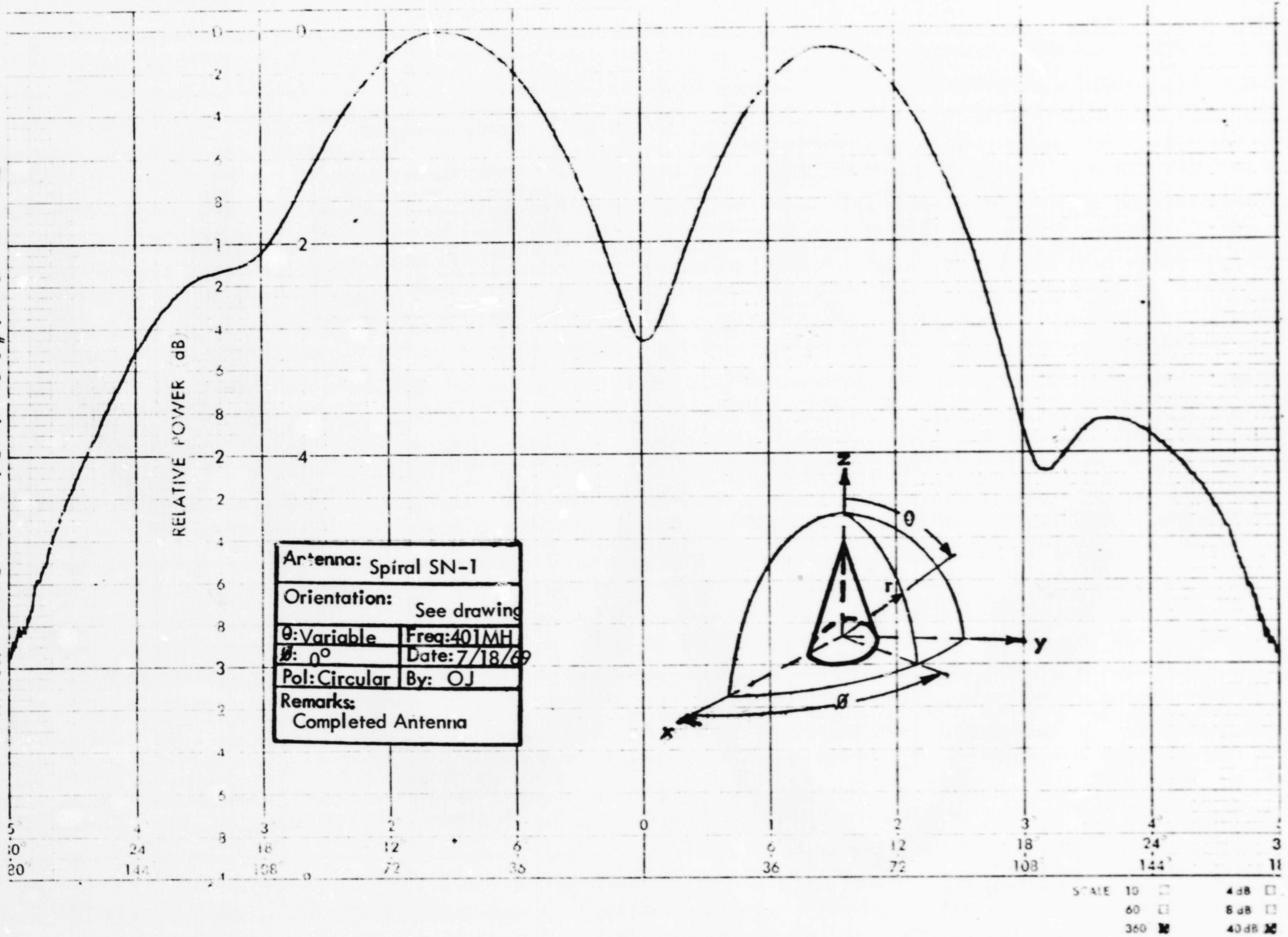


Figure 41. Serial # 1 Circular Polarization Pattern, 401 MHz

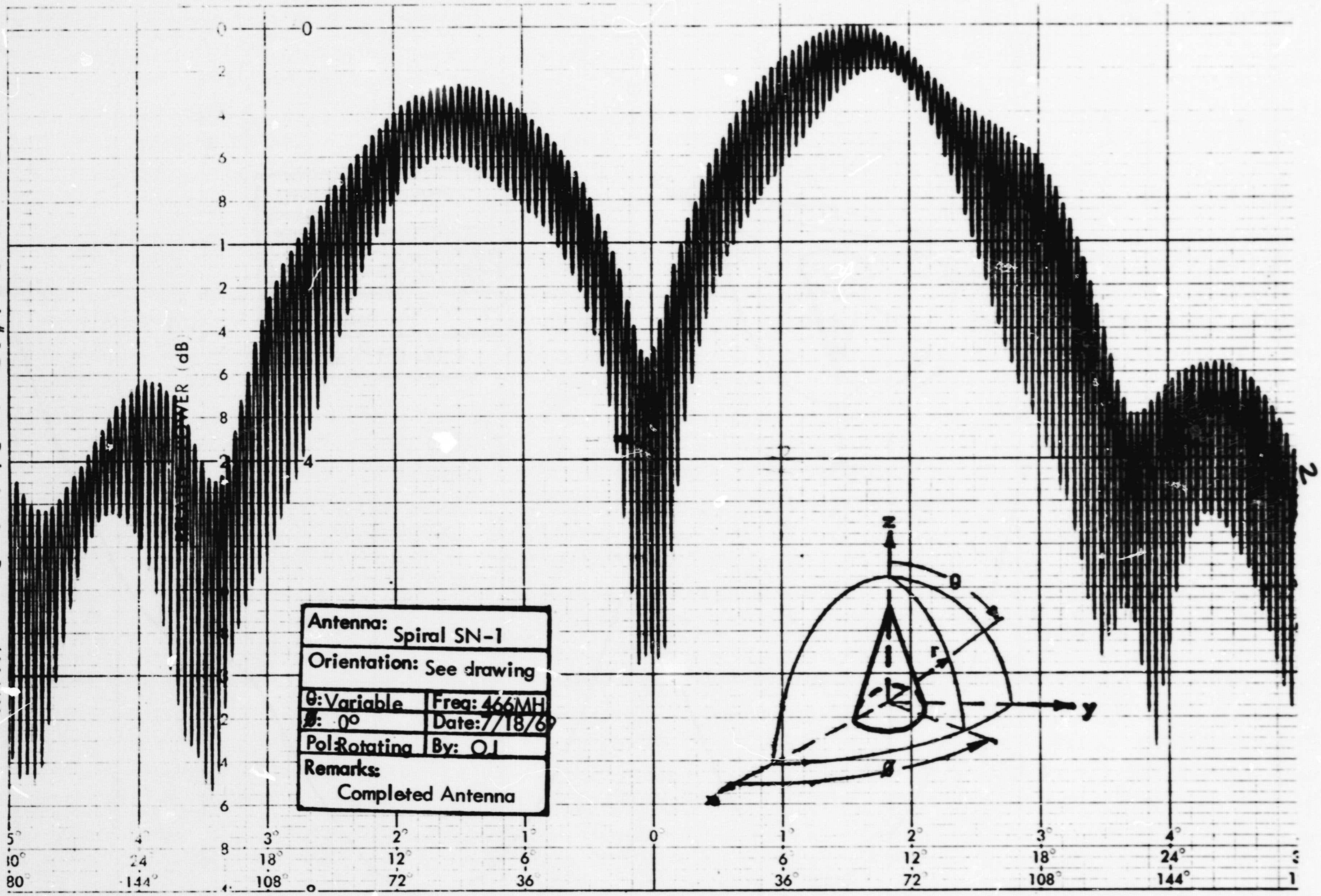


Figure 42. Serial # 1 Rotating Polarization Pattern, 466 MHz

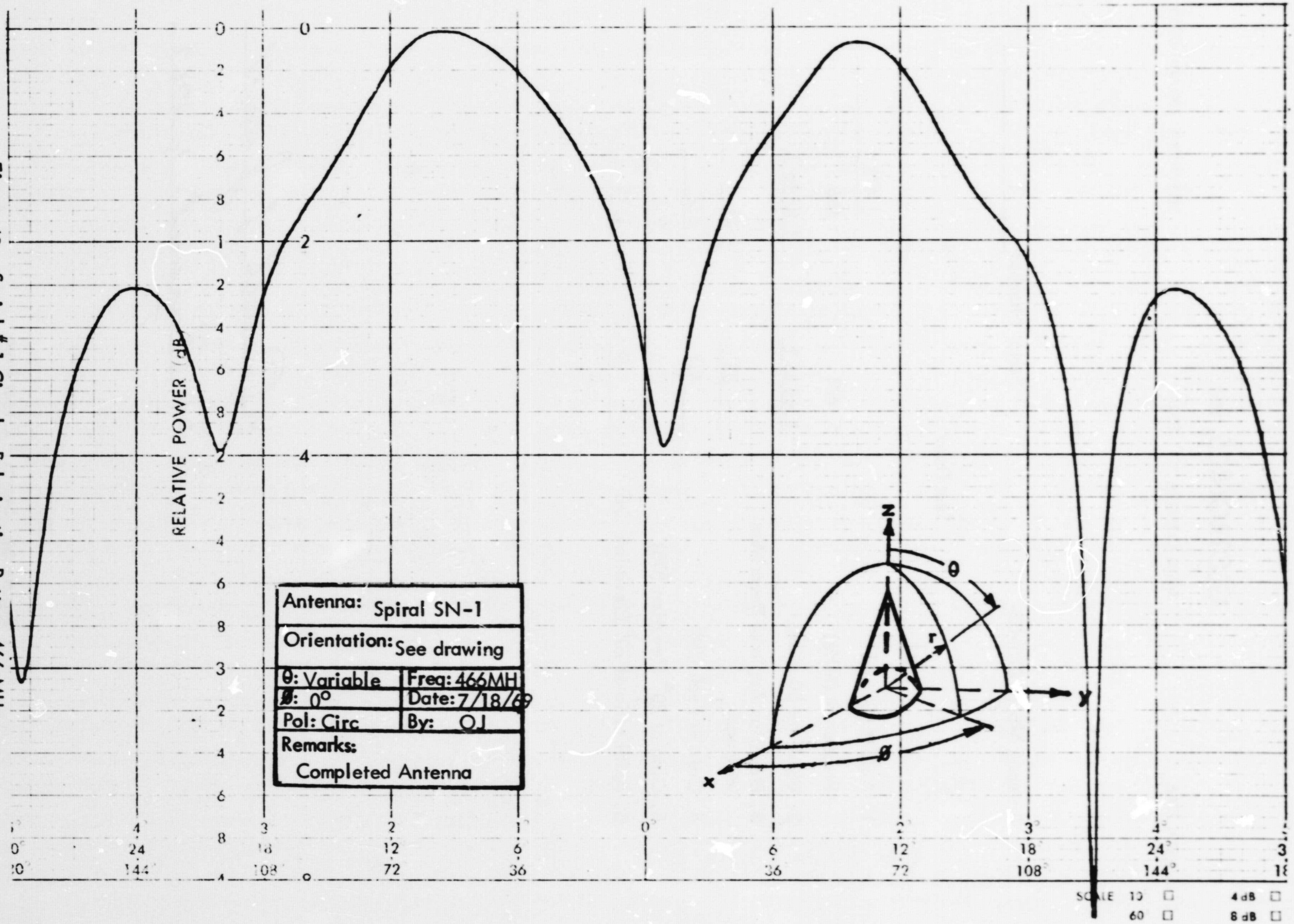


Figure 43. Serial # 1 Circular Polarization Pattern 466 MHz

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Antenna Model 075-CS Serial Number 2

Test Data

1. Weight (Grams)		478
Frequency (MHz)	401	466
2. VSWR (at 50 ohms)	1.46 to 1	1.87 to 1
3. Elevation Angle of Beam Max (degrees)	33	31
4. Gain at Peak (DB)	4.1	3.7
5. Gain at 20° Elevation (DB)	2.6	2.3
6. Axial ratio at 20° Elevation (DB)	1.9	1.75

By Oswald L Jewell

Date August 1, 1969

Figure 44. Serial # 2 Test Data

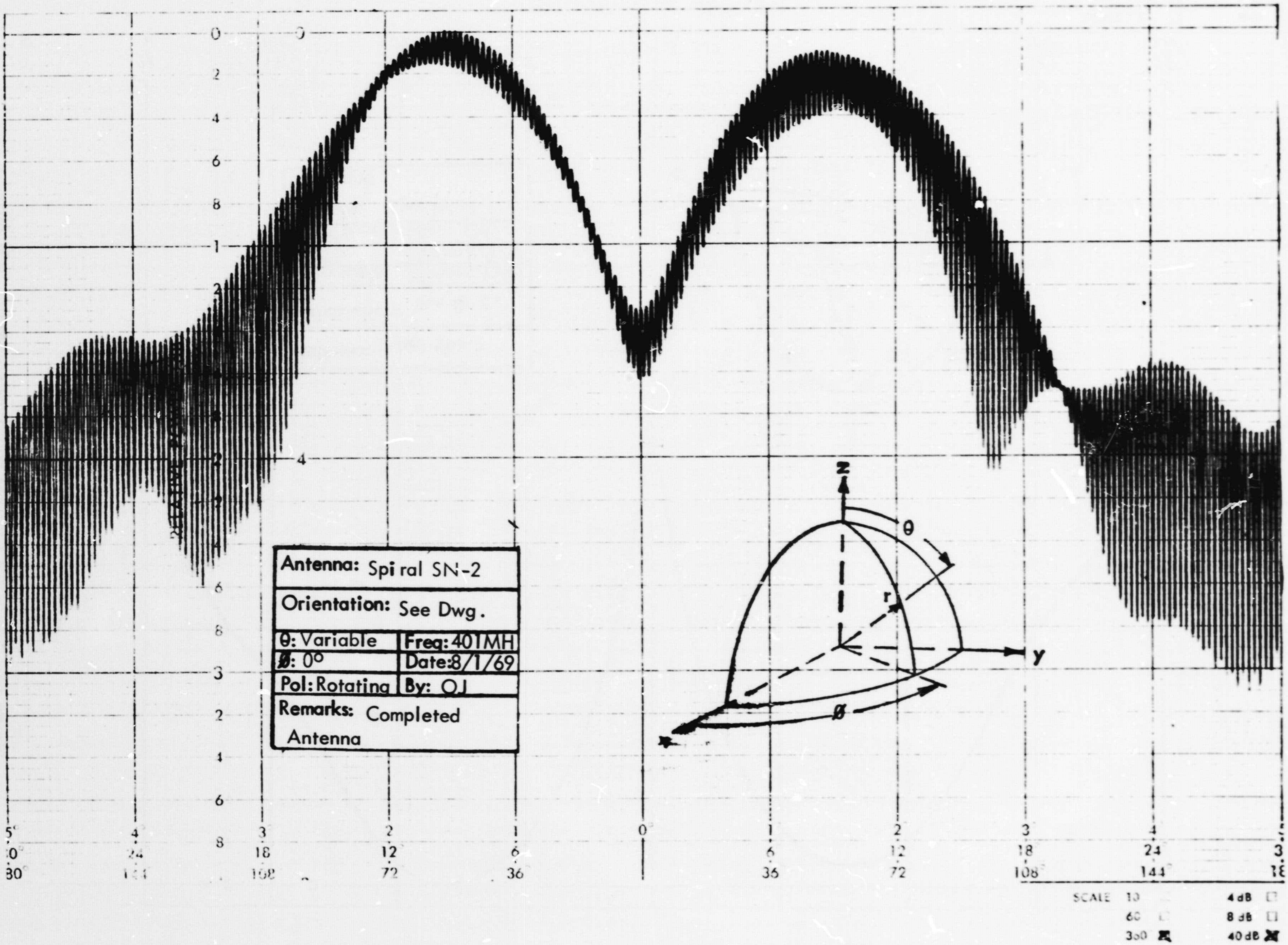


Figure 45. Serial # 2 Rotating Polarization Pattern, 401 MHz

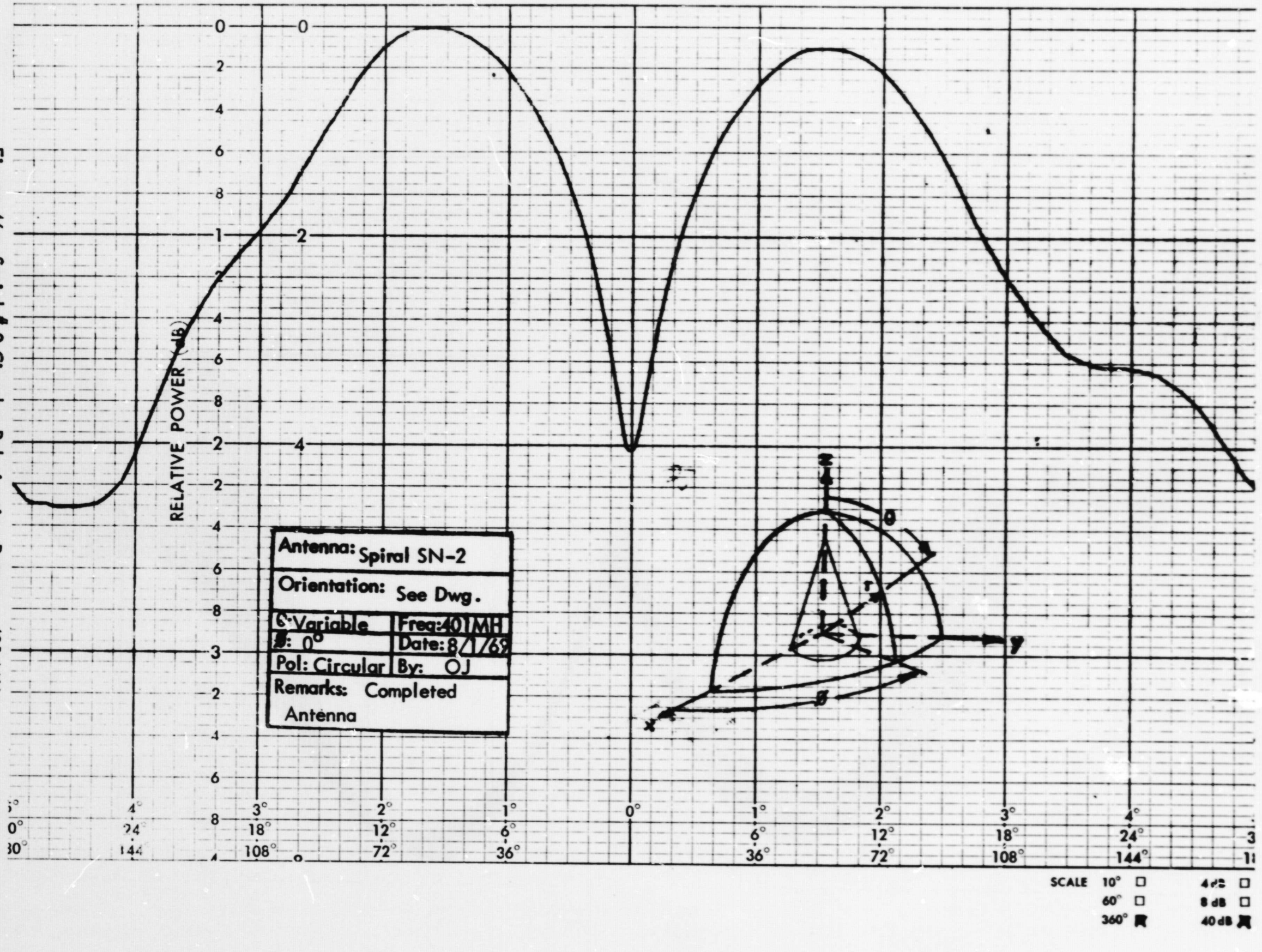


Figure 46. Serial # 2 Circular Polarization Pattern, 401 MHz

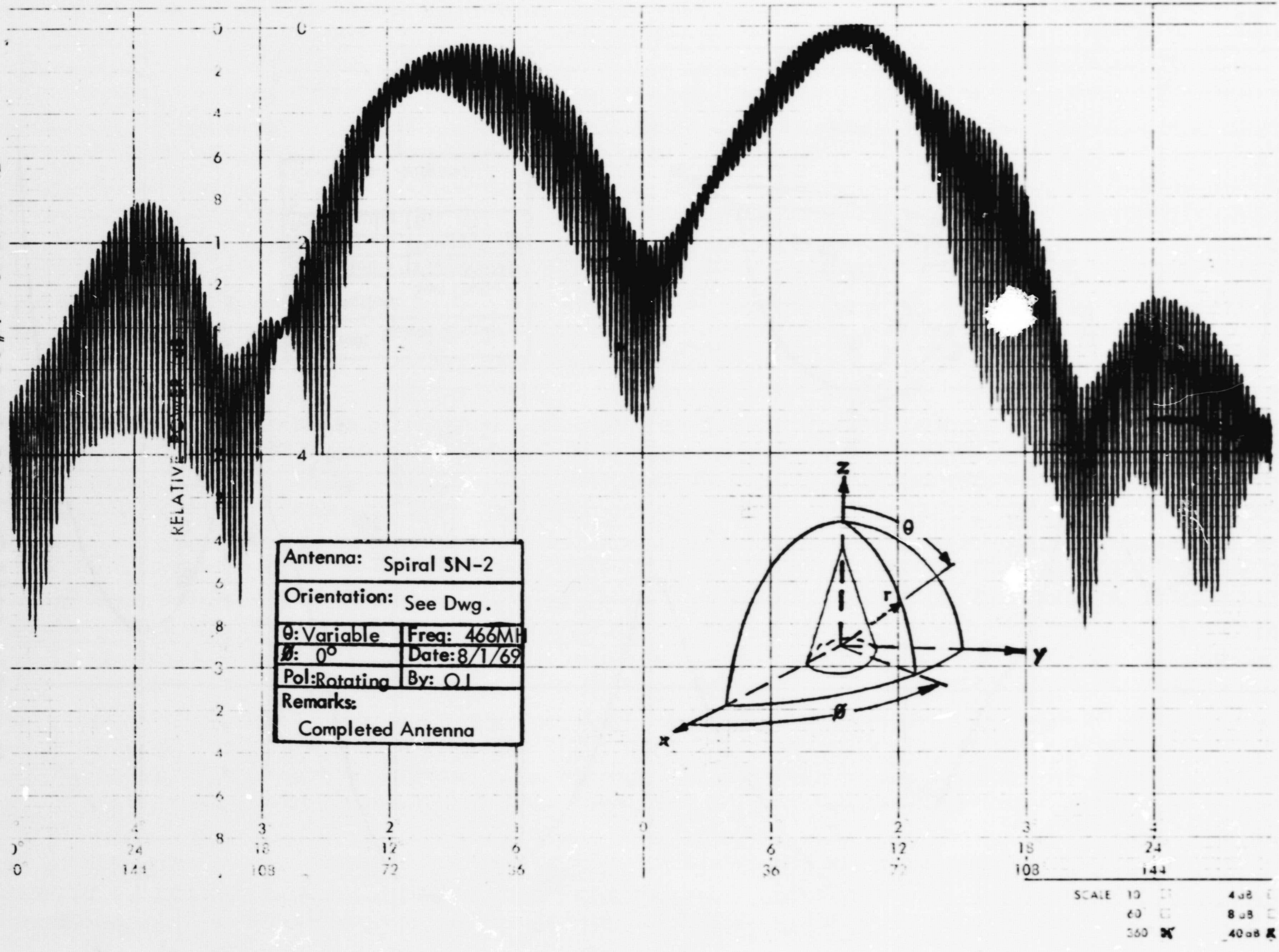


Figure 47. Serial # 2 Rotating Polarization Pattern, 466 MHz

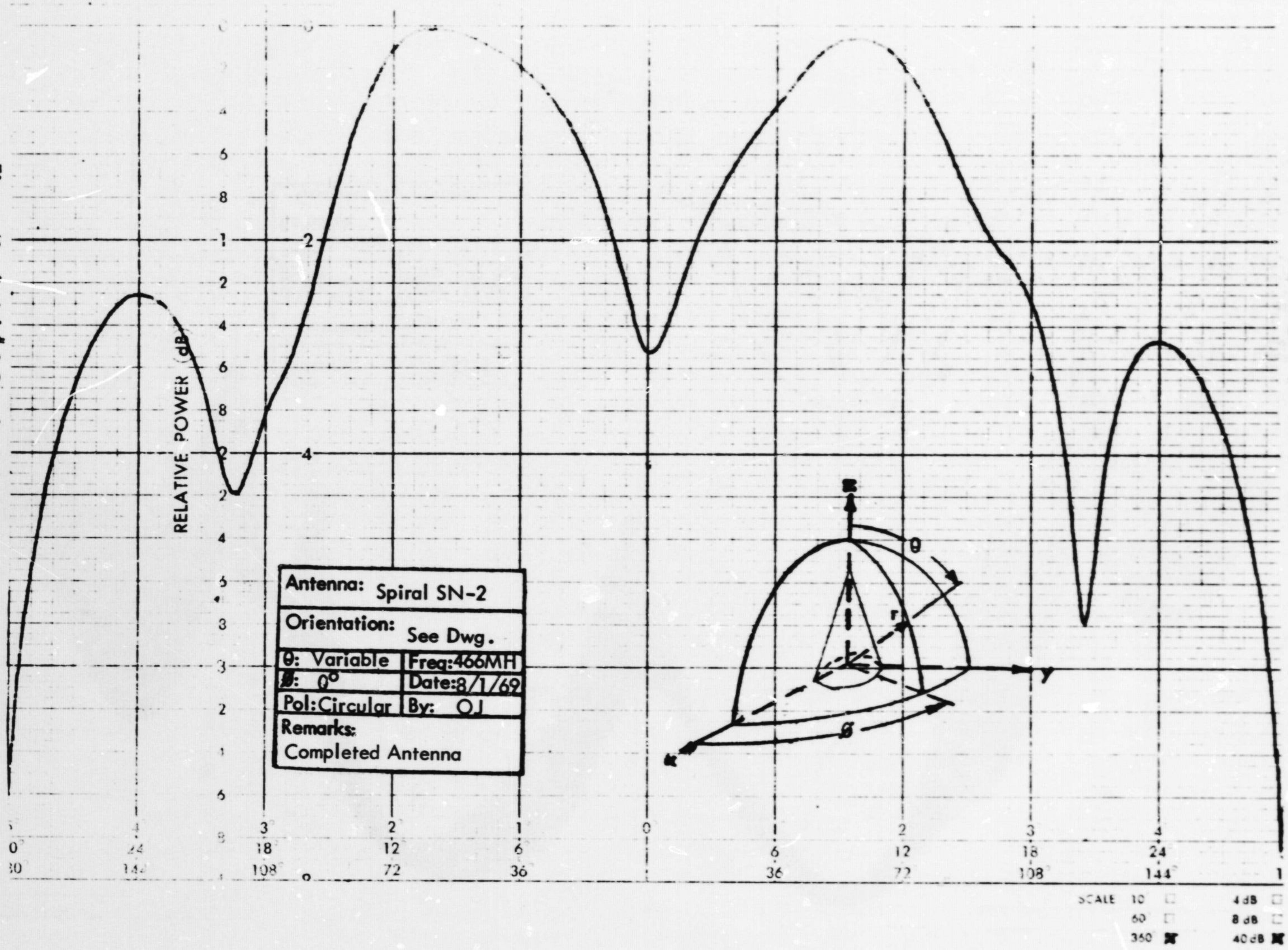


Figure 48. Serial # 2 Circular Polarization Pattern, 466 MHz

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Antenna Model 075-CS Serial Number 3

Test Data

1. Weight (Grams)		442
Frequency (MHz)	.401	466
2. VSWR (at 50 ohms)	1.56 to 1	1.76 to 1
3. Elevation Angle of Beam Max (degrees)	34	36
4. Gain at Peak (DB)	4.2	3.9
5. Gain at 20° Elevation (DB)	2.8	2.4
6. Axial ratio at 20° Elevation (DB)	2.4	2.5

By Donald L Jessell

Date August 1, 1969

Figure 49. Serial # 3 Test Data

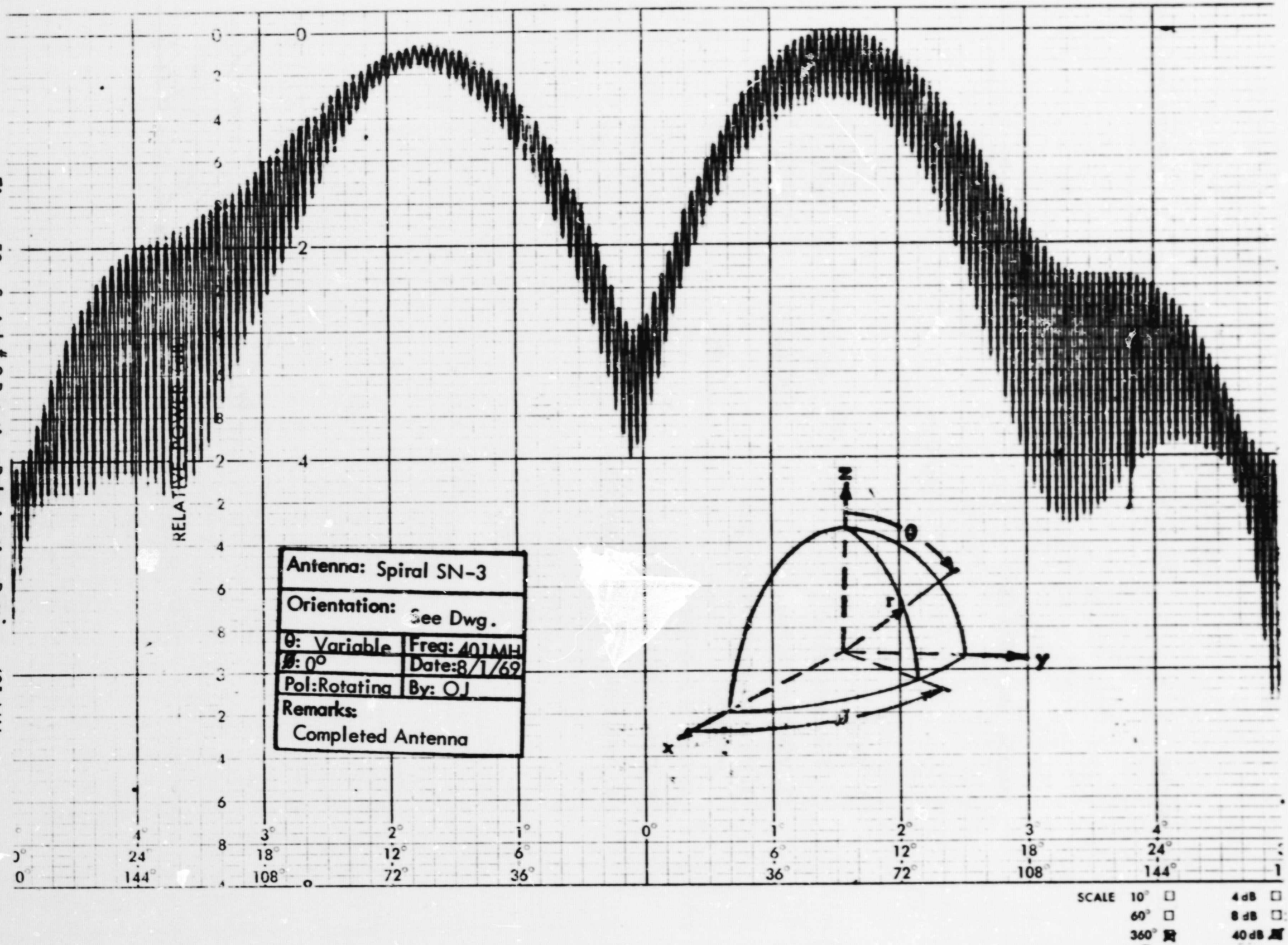


Figure 50. Serial # 3 Rotating Polarization Pattern, 401 MHz

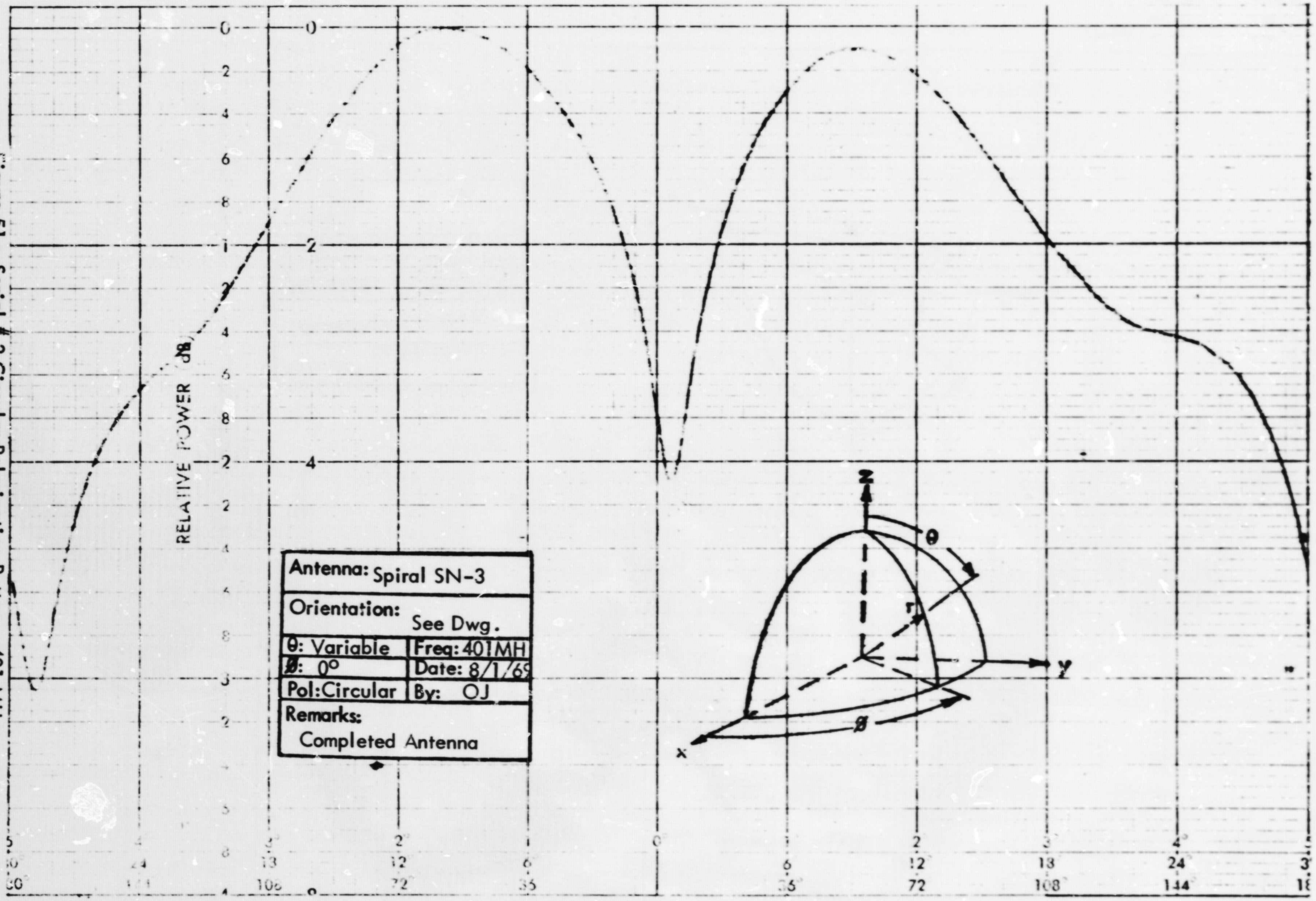


Figure 51. Serial # 3 Circular Polarization Pattern, 401 MHz

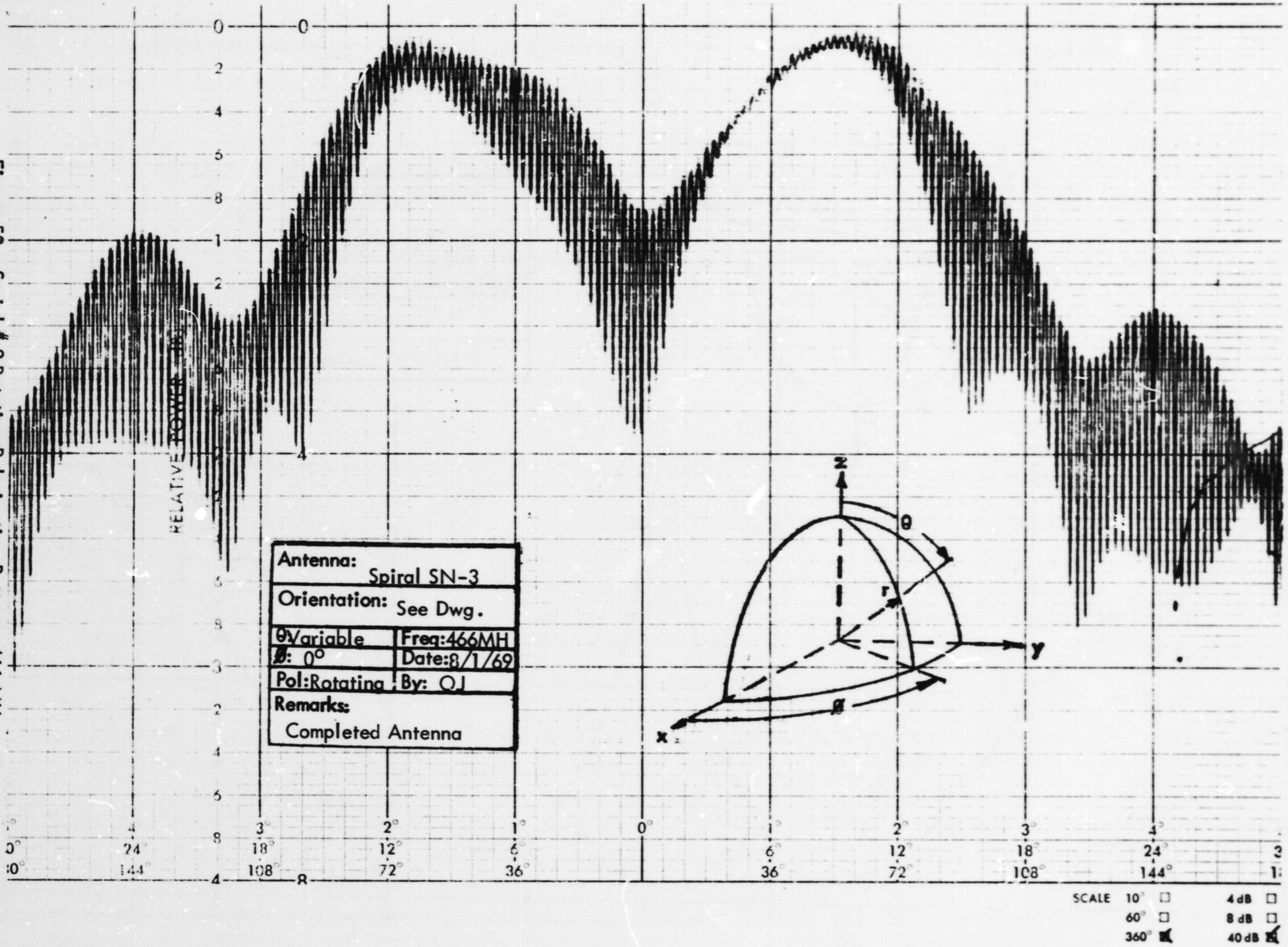


Figure 52. Serial # 3 Rotating Polarization Pattern, 466 MHz

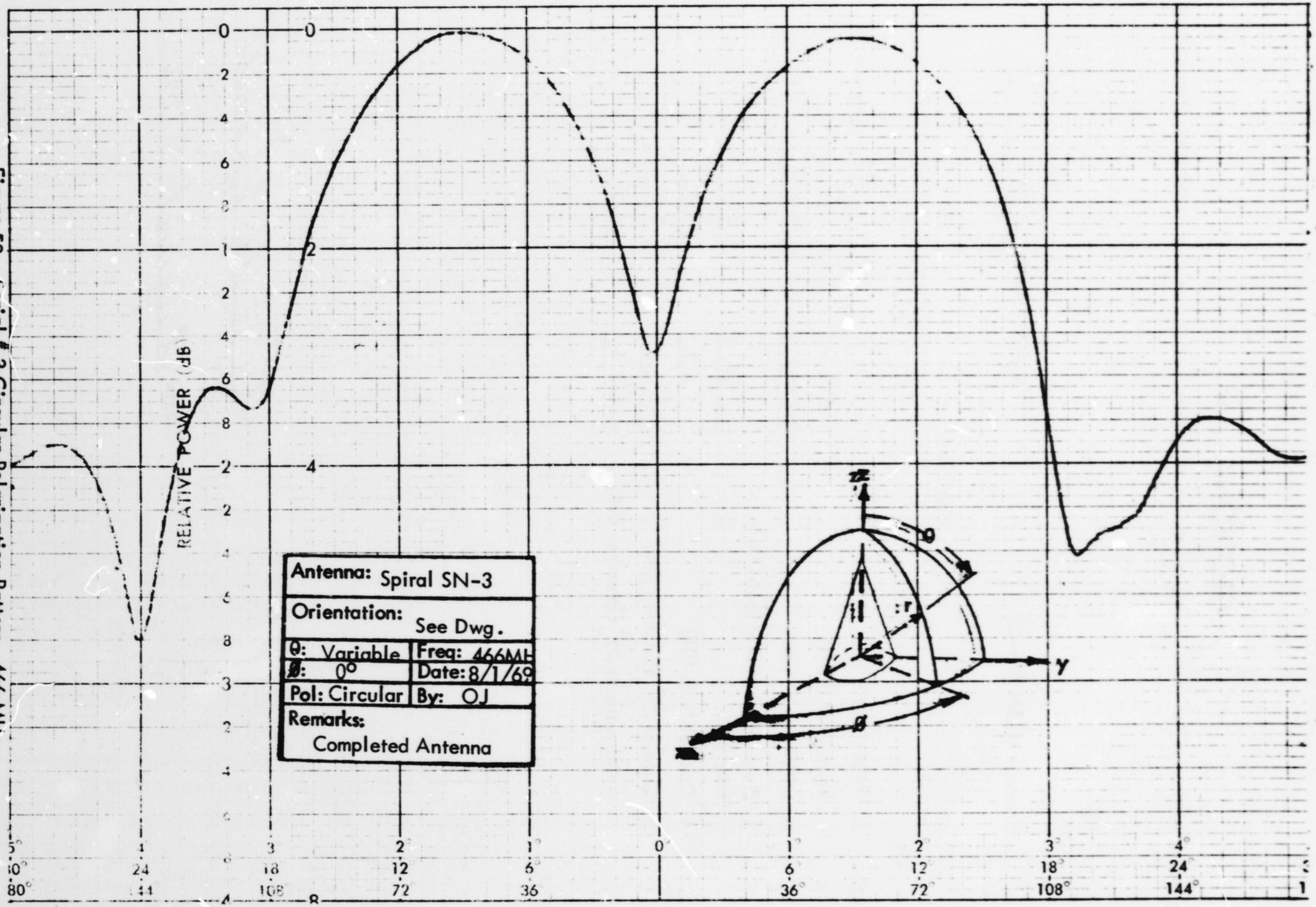


Figure 53. Serial # 3 Circular Polarization Pattern, 466 MHz

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Antenna Model 075-CS Serial Number 4

Test Data

1. Weight (Grams)		410
Frequency (MHz)	401	466
2. VSWR (at 50 ohms)	1.91 to 1	1.96 to 1
3. Elevation Angle of Beam Max (degrees)	36	34
4. Gain at Peak (DB)	4.1	3.8
5. Gain at 20° Elevation (DB)	2.3	1.0
6. Axial ratio at 20° Elevation (DB)	2.6	4.5

By Emil L Farrell

Date August 2, 1969

Figure 54. Serial # 4 Test Data

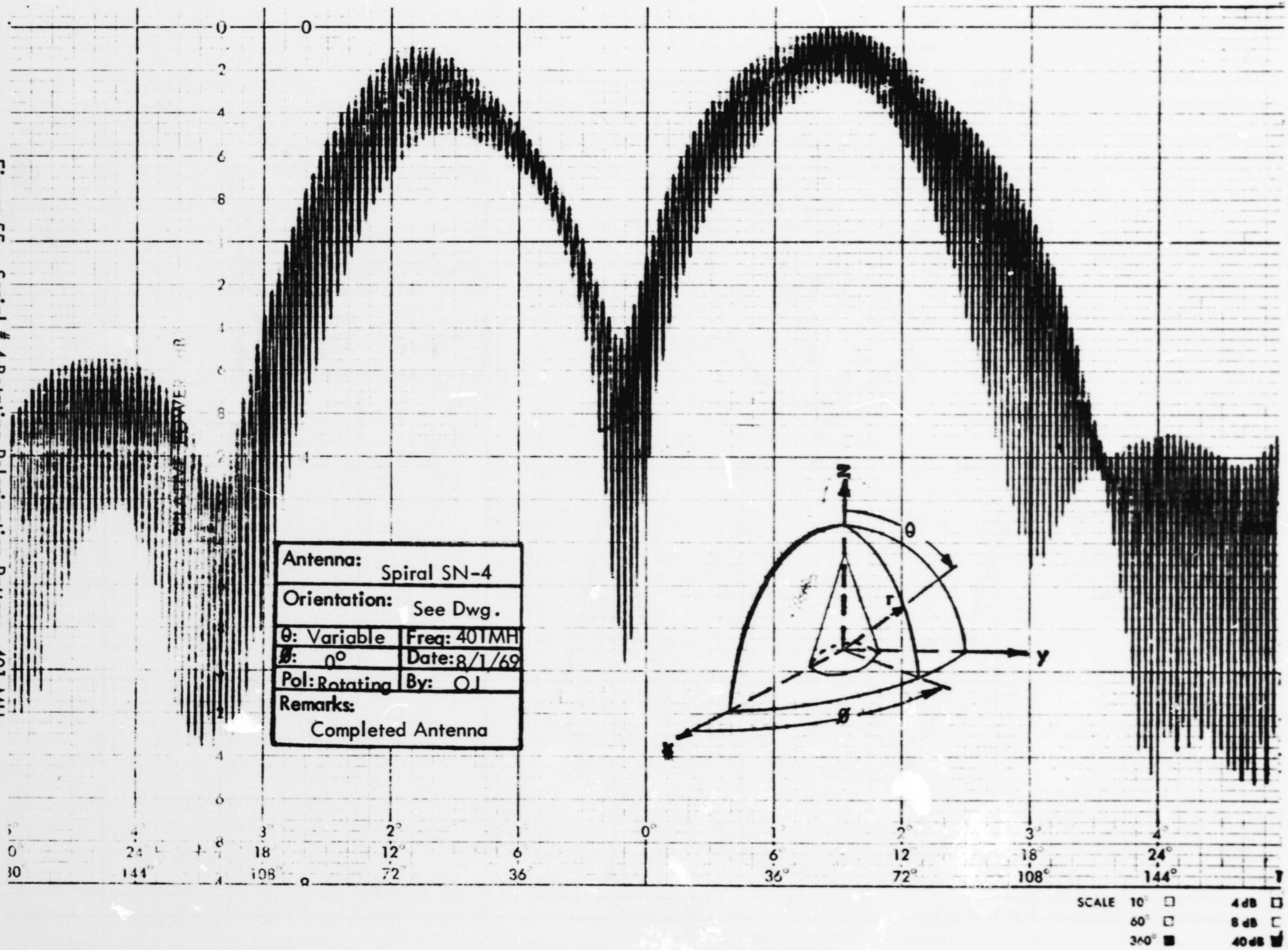


Figure 55. Serial # 4 Rotating Polarization Pattern, 401 MHz

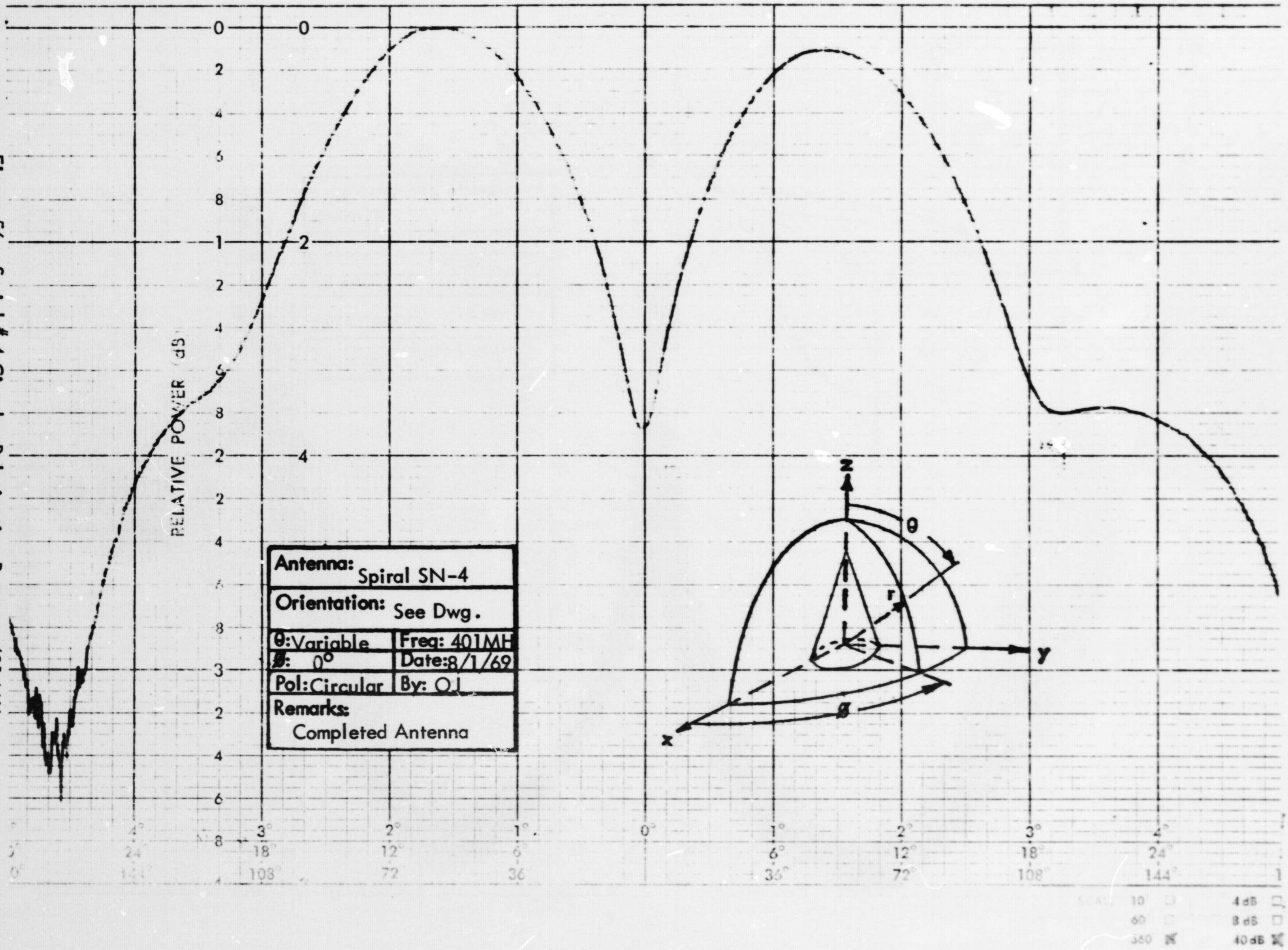


Figure 56. Serial # 4 Circular Polarization Pattern, 401 MHz

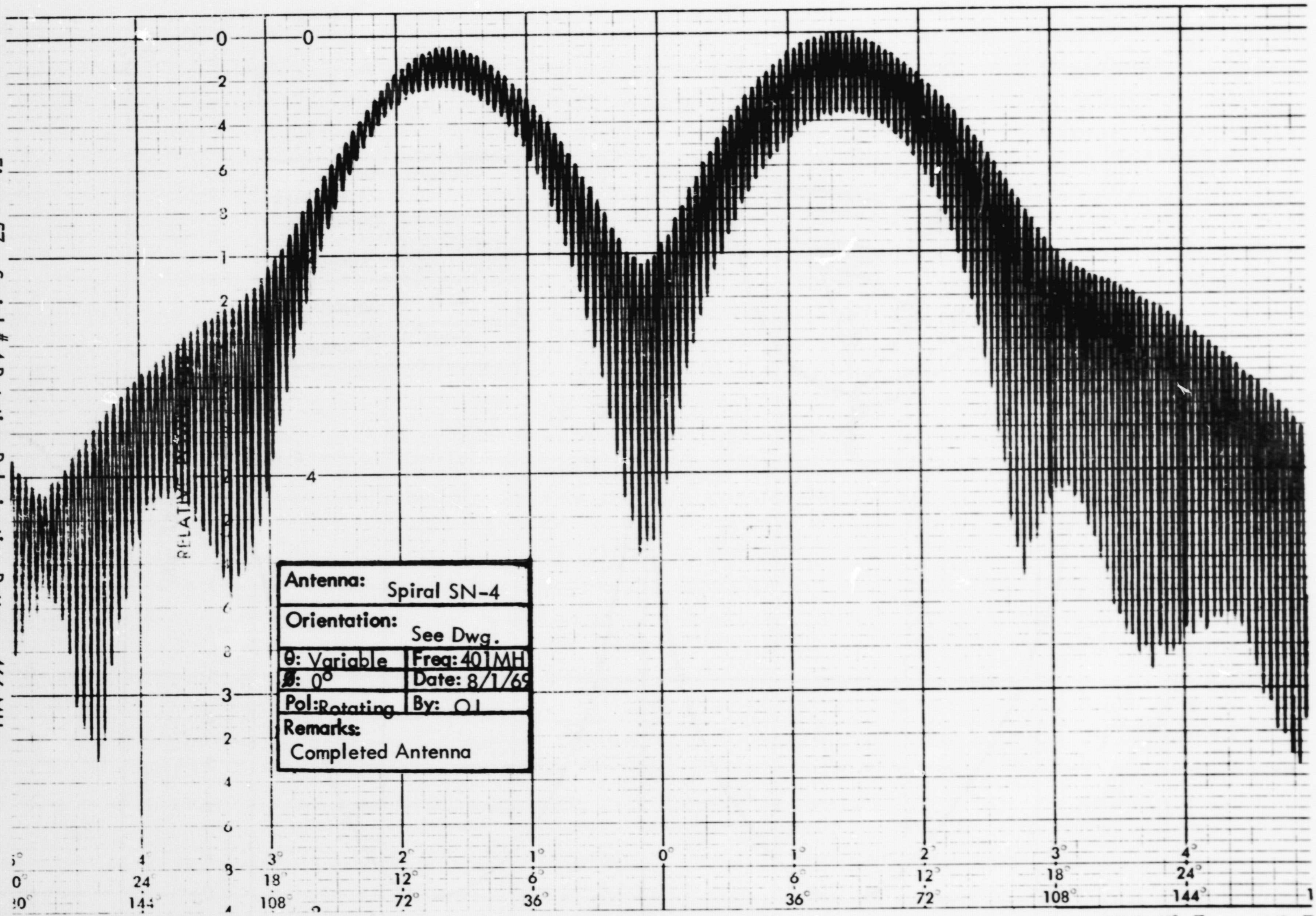


Figure 57. Serial # 4 Rotating Polarization Pattern, 466 MHz

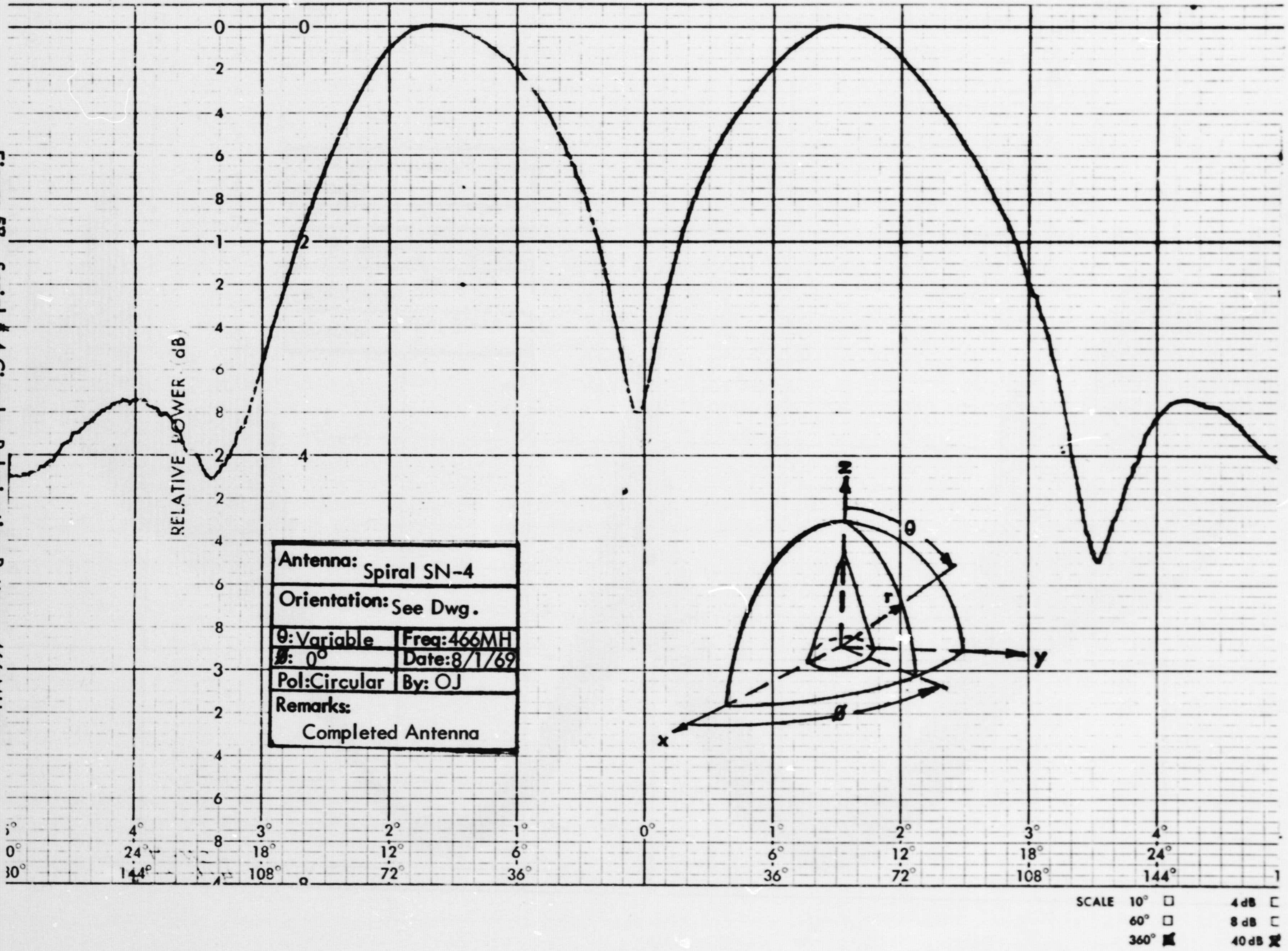


Figure 5B. Serial # 4 Circular Polarization Pattern, 466 MHz

5.0 NEW TECHNOLOGY

The development work was monitored by the Project Engineer on a continuing basis in an effort to identify items of new technology realized under this contract.

The only development regarded as new is the actual four arm conical spiral developed and delivered. The only thing new about this antenna is the adjustment made in the antenna parameters to optimize the performance and multipath descrimination when used in conjunction with a satellite interrogated package.

This final report documents this development in detail.

6.0 BIBLIOGRAPHY

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2. FR-2 Antenna Study. Final Report, Contract No. NAS5-9453, Keltec Industries, August 31, 1967. 181 pages