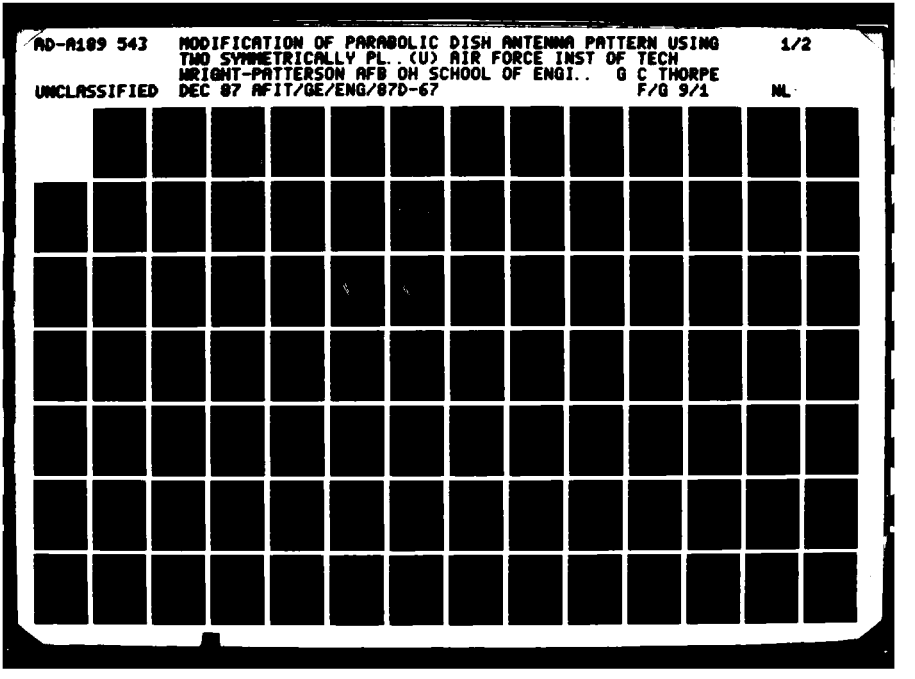
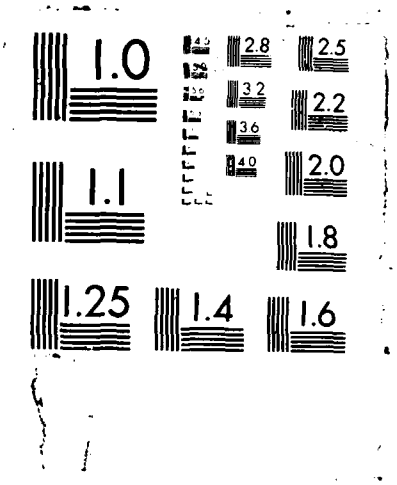
AD-A189 543 MODIFICATION OF PARABOLIC DISH ANTENNA PATTERN USING TWO SYMMETRICALLY PL..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. G C THORPE 1/2

UNCLASSIFIED DEC 87 AFIT/GE/ENG/87D-67 F/G 9/1 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

MODIFIC ION OF PARABOLIC DISH
ANTENNA PAT AN USING TWO SYMMETRICALLY
PLACED CIRCULAR FLAT PLATES

THESIS

Glen C. Thorpe
Flight Lieutenant, RAAF

AFIT/GE/ NG/67D-67

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

Wright-Patterson Air Force Base, Ohio

AFIT/GE/ENG/87D-67

MODIFICATION OF PARABOLIC DISH ANTENNA PATTERN USING TWO SYMMETRICALLY PLACED CIRCULAR FLAT PLATES

THESIS

Glen C. Thorpe
Flight Lieutenant, RAAF

AFIT/GE/ENG/87D-67

DTIC
ELECTE
MAR 0 3 1988
S D
H

Approved for public release; distribution unlimited

AFIT/GE/ENG/87D-67

MODIFICATION OF PARABOLIC DISH ANTENNA PATTERN USING TWO SYMMETRICALLY PLACED CIRCULAR FLAT PLATES

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Electrical Engineering

Glen C. Thorpe

Flight Lieutenant, RAAF

December 1987

Approved for public release; distribution unlimited

Acknowledgments

This work was sponsored by the Electromagnetic Technology Applications Section, Rome Air Development Center (RADC), Hanscom AFB MA, by Daniel Jacavanco. Through the efforts of Daniel Jacavanco, a near field range was constructed at RADC to aid in the experimental analysis associated with this study. Without this near field test facility, the data presented in this thesis could not have been obtained. I would also like to thank the other members of RADC whose enthusiasm and co-operativeness helped to bring this work to fruition.

My thanks also go to two members of the faculty at AFIT, who, while not on my thesis committee, provided important ideas and understanding when they were sorely needed. Specifically, I would like to thank Captain Steve Rogers and Major Glenn Prescott for their help in the signal processing areas. Also Captain Doug Havens and First Lieutenant Jeff Fath who had both previously worked on this type of problem, provided valuable help.

I would like to thank my thesis advisor (Dr. Andrew Terzuoli) and the members of my thesis committee (Dr. Vittal Pyati and Lieutent Colonel Baker) for their invaluable assistance. Lieutenant Colonel Baker deserves special thanks for all the hours he gave to this study.

DTIC COPY INSPECTED 1

ssion For
A&I
Dist Special
A-1

Table of Contents

	Page
Acknowledgements	ii
List of Figures	v
Abstract	vii
Introduction	1
Background	2
Problem Statement	3
Scope	4
Approach	4
Materials and Equipment	5
Other Support	5
Measurement Equipment and Results	6
Near Field Range	6
Unwanted Reflections	6
Antenna to Measurement Plane Separation	7
Near Field Errors	8
Data Analysis	11
Anomolous Effects	11
Large Dynamic Range of Results	14
Interpretation of Results	14
Data Sample Spacing	17
Near Field Phase and Amplitude Distribution	17
Effect of Moving Plates	19
Computed Near Field Phase Distribution	20
Comparison of Measured to Computed Results	43
Comparison of Side Lobe to Main Lobe	43
Null Movement	44
Recommendations and Suggestions for Further Work	57
Areas Worthy of Further Investigation	57
Implementation of Moment Method Technique	58
Appendix A: Development of the FFT Algorithm	60
Appendix B: Development of an Analytical Model	63
Appendix C: Near Field Measurement Control Program	76

Appendix D. Near Field Error Correction Program 81

Appendix E. Fast Fourier Transform Program 86

Appendix F. Near-Field Phase Distribution Program . . . 91

Bibliography 94

Vita 95

List of Figures

Figure		Page
1.	Basic Dish Antenna Geometry	3
2.	Near Field Amplitude Distribution - Plates Flush . .	9
3.	Near Field Phase Distribution - Plates Flush	10
4.	Anomolous Ripple in Near Field	12
5.	Data from Figure 4 after Correction.	13
6.	Computed Far Field Pattern Showing Exponential Decay	15
7.	Near Field Zones Due to Moveable Plate	18
8.	3-D Near Field Phase Distribution - Plates at 0° . .	23
9.	3-D Near Field Phase Distribution - Plates at 225° .	24
10.	Near Field Amplitude Distribution - Plates at 0° . .	25
11.	Near Field Amplitude Distribution - Plates at 45° .	26
12.	Near Field Amplitude Distribution - Plates at 90° .	27
13.	Near Field Amplitude Distribution - Plates at 135° .	28
14.	Near Field Amplitude Distribution - Plates at 180° .	29
15.	Near Field Amplitude Distribution - Plates at 225° .	30
16.	Near Field Amplitude Distribution - Plates at 270° .	31
17.	Near Field Amplitude Distribution - Plates at 315° .	32
18.	Near Field Amplitude Distribution - Plates at 360° .	33
19.	Near Field Phase Distribution - Plates at 0°	34
20.	Near Field Phase Distribution - Plates at 45° . . .	35
21.	Near Field Phase Distribution - Plates at 90° . . .	36
22.	Near Field Phase Distribution - Plates at 135° . . .	37

23. Near Field Phase Distribution - Plates at 180° . . . 38
24. Near Field Phase Distribution - Plates at 225° . . . 39
25. Near Field Phase Distribution - Plates at 270° . . . 40
26. Near Field Phase Distribution - Plates at 315° . . . 41
27. Near Field Phase Distribution - Plates at 360° . . . 42
28. Computed Far Field Pattern - Plates at 0° 47
29. Computed Far Field Pattern - Plates at 90° 48
30. Computed Far Field Pattern - Plates at 135° 49
31. Computed Far Field Pattern - Plates at 225° 50
32. Computed Far Field Pattern - Plates at 360° 51
33. Measured Far Field Pattern - Plates at 0° 52
34. Measured Far Field Pattern - Plates at 90° 53
35. Measured Far Field Pattern - Plates at 135° 54
36. Measured Far Field Pattern - Plates at 225° 55
37. Measured Far Field Pattern - Plates at 360° 56
38. Dish Antenna Geometry 64
39. Ray Reflected from Moveable Plate 66
40. Polar Representation of Point on Plate 68
41. Constant Phase Ray 69

Abstract

This study aims to formulate a method of predicting the far field pattern of a parabolic dish antenna with two moveable flat plates mounted symmetrically on either side of the feed horn. The approach taken has been to first analyze the radiation pattern of the antenna with the disks at certain heights out from the surface of the dish. To do this the near-field radiation in amplitude and phase was measured over a plane surface in the near-field and the values were then transformed into the far field using a Fast Fourier Transform.

Far field pattern values of the antenna were directly measured for each setting of the plates. The results obtained from the Fast Fourier Transform of the near field data were in good agreement with the values obtained by measurement.

Finally, an approximate model of the antenna was developed and implemented as a computer program. This model, while relatively unsophisticated, provided some insights into the changes in the near field phase distribution caused by the moveable circular flat plates.

MODIFICATION OF PARABOLIC DISH ANTENNA PATTERN USING SYMMETRICALLY PLACED CIRCULAR FLAT PLATES

I. Introduction

The purpose of this study is to predict the effect of two symmetrically placed flat plates on the far field of a parabolic dish antenna. The motivation for this work relates to the use of dish antennas in environments where unwanted signals are likely to be present. If a simple approach can be found to predict the effect of moving the plates out from the surface of the dish, then one can on command, move the plates to an appropriate location so as to cancel out the effect of an unwanted signal by placing nulls in the direction of the unwanted signal.

This study was sponsored by Daniel Jacavanco at the Electromagnetic Sciences Division, Rome Air Development Center (RADC), at Hanscom Air Force Base Massachusetts and was part of a continuing analysis (Havens, 1983, Rudisill, 1984).

Background

Adaptive antennas find their greatest application in situations where unwanted signals at the same frequency as the desired signals are being received. Such signals may be deliberate or accidental but usually their direction of arrival is not along the boresight of the receiving antenna. This means that an antenna that can change the locations of its nulls in response to the unwanted signals can greatly reduce the level of the interfering signals and yet receive the desired signal satisfactorily.

The technique usually employed at present involves the use of a phased array antenna where the phases of the individual antenna elements can be adjusted to synthesize practically any configuration of receive antenna pattern (Johnson and Jasik, 1984:9-13). Selective nulling in the receiver field pattern can be achieved through the use of a parabolic reflector antenna having symmetrically placed phase modifying elements. Standard reflector antennas with various feed configurations have been thoroughly analyzed both in the near and far field (Balanis, 1982:604-642; Milligan, 1985:220-265;) but symmetrically placed flat plates cannot be handled easily by the current models.

Problem Statement

The objective of this study is to fully analyze the major aspects associated with applying the method of moments to determining the far field pattern of a parabolic dish antenna having two circular flat plate reflectors placed symmetrically on either side of the y-axis. The layout of which is shown in figure 1.

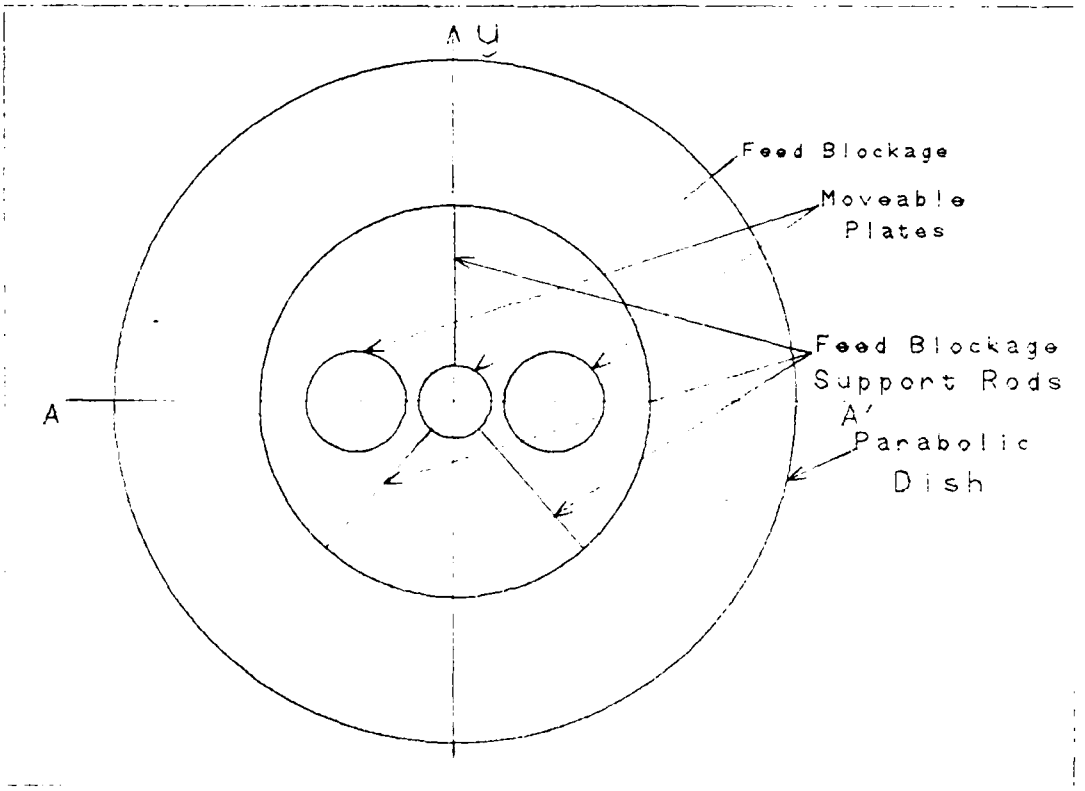


Figure 1. Basic Dish Antenna Geometry

Scope

This particular research topic has a number of avenues all of which would prove to be of unusual interest. However in view of the time constraints imposed by the thesis program the scope will be limited to:

1. Scaling the reflector elements so that all simplifying assumptions are valid.

2. Developing a mathematical model that satisfactorily describes the near field.

3. Correlation of computed to measured near field results and analysis of discrepancies.

4. Use of the Fast Fourier Transform to compute far field radiation pattern.

Approach

The approach in this problem has been to carefully analyze the desired physical setup to ensure that all simplifying assumptions are valid or else to take into account their effect on the accuracy of the final result.

Also the area of interest has been limited to a region extending thirty degrees either side of the antenna boresight. This is where interfering signals have their most effect since the antenna being jammed still has appreciable gain within this region.

Materials and Equipment

RADC as the sponsor of this work built a near field range so that a model of the total antenna system could be tested to obtain near field measurements. The results obtained in the near field range have acted as a bench mark to assess the validity of the model used for the analytical derivation of the near field pattern.

Other Support

Other equipment such as computer support was available on site at RADC and within the Air Force Institute of Technology (AFIT). These facilities proved to be entirely satisfactory except for the fact that there was no easy way of converting data obtained from the near field range using a Hewlett Packard computer to the MS-DOS format.

II. Measurement Equipment and Results

Near Field Range

To develop the far field pattern of the parabolic dish antenna through the use of a near field range turns out to be no small undertaking. The dish to be analysed was four feet in diameter and the maximum height of the measurement plane was only 52 inches while its width was 79 inches. As there was no way to modify the setup this limitation had to be accepted.

Unwanted Reflections

One consideration of major importance in any near field measurement is the problem of unwanted reflections (Newell, 1985:38). Use of RADAR absorbent material (RAM) can significantly reduce the effects of unwanted reflections and the chamber had been designed with this criteria in mind. However the vertical support that carried the measurement probe was not protected with RAM. Since this was a piece of heavy guage steel approximately six inches wide, its potential for reducing the accuracy of the measurements was substantial. A solution to overcome this problem was to offset the probe and suspend RAM material

from the top of the vertical column thereby allowing the measurement probe full unobstructed vertical mobility . This solution was quite successful but it reduced the useable width of the chamber by approximately eight inches.

Antenna to Measurement Plane Separation

A further question that was not immediately answered was at what distance should the measurement plane be from the antenna. Initial measurements were carried out with the closest part of the antenna approximately two feet from the antenna. As the system was being tested at 3.2 Ghz this was well inside the near field region with a radius of approximately 107 inches (Balanis, 1982:22). Analysis showed that the pattern obtained was not providing sufficient information about the antenna pattern off to the sides (Newell, 1985:39).

Subsequently the antenna was moved so that the nearest portion of the antenna was within two inches of the measurement plane. At this distance the effect of the feed support became quite dramatic causing a drop of over 15db in the near field amplitude and approximately 50 degrees increase in the phase (See Figure 2). From previous work (Newell, 1985:39), the angular range over which the far

field is valid can be computed using Equation 1.

$$A_c = \tan^{-1} (L_x - D)/(2d) \quad (1)$$

where L_x = Scan Length = 79.37 inches

D = Antenna diameter = 48 inches

d = Aperture plane to measurement plane = 21 inches

A_c = Azimuthal angle over which far field results are valid = 36.76°

Near Field Errors

Unfortunately all the measurements taken in the near field could not be observed at the same time and a phase difference of approximately 100 degrees from the top to the bottom of the projected dish was not observed (See Figure 3). From Equation B2 and the paragraph following, the phase of the reflected field as observed at the measurement plane of a parabolic dish should have a constant value. This observed anomoly could only have been caused by the top of the antenna and the measurement plane being closer than the bottom due to either misalignment of the dish or tilting of the vertical support structure due to the added weight of the RAM.

During dish alignment a phase difference (across AA' shown in Figure 1) of approximately 300 degrees was noted.

This equated to a distance of approximately three inches and to overcome this phase difference the dish edge having the larger phase was moved closer by approximately half the distance.

Figure 2. Near Field Amplitude Distribution - Plates Flush

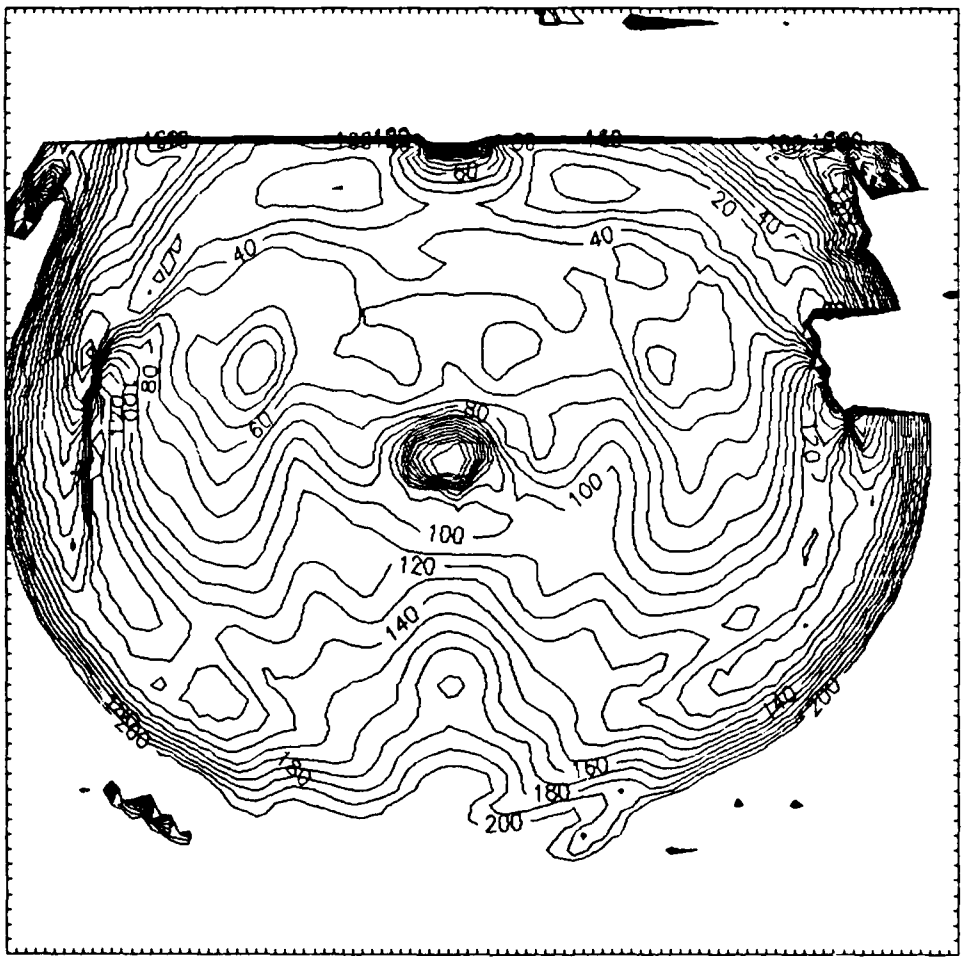


Figure 3. Near Field Phase Distribution - Plates Flush

III. Data Analysis

Anomolous Effects

Presenting the near field data as a contour map (See Figure 4) showed an unusual ripple. This ripple showed up when moving in a vertical direction through the plot. The effect of this high frequency ripple was to introduce an apparent aliasing effect (Newell, 1985:68) when the FFT was computed. The cause of this effect could only have been due to some anomoly in the sampling technique (Reddy, 1985:9). A raster sampling technique was used and the program that controlled the probe (Appendix C) should have moved the probe up to the next row in the measurement plane and then before moving on should have taken the first measurement. However apparently the probe moved one position horizontally before taking a measurement. An alternative explanation is that there was some backlash in the main worm drive that moved the vertical column (Newell, 1985:41). To overcome this effect, a short routine (Appendix D) was inserted in the processing software to move every second row of data one position horizontally (See Figure 5 for an example of corrected results). Once this was completed and the data was processed the aliasing effect no longer occurred.

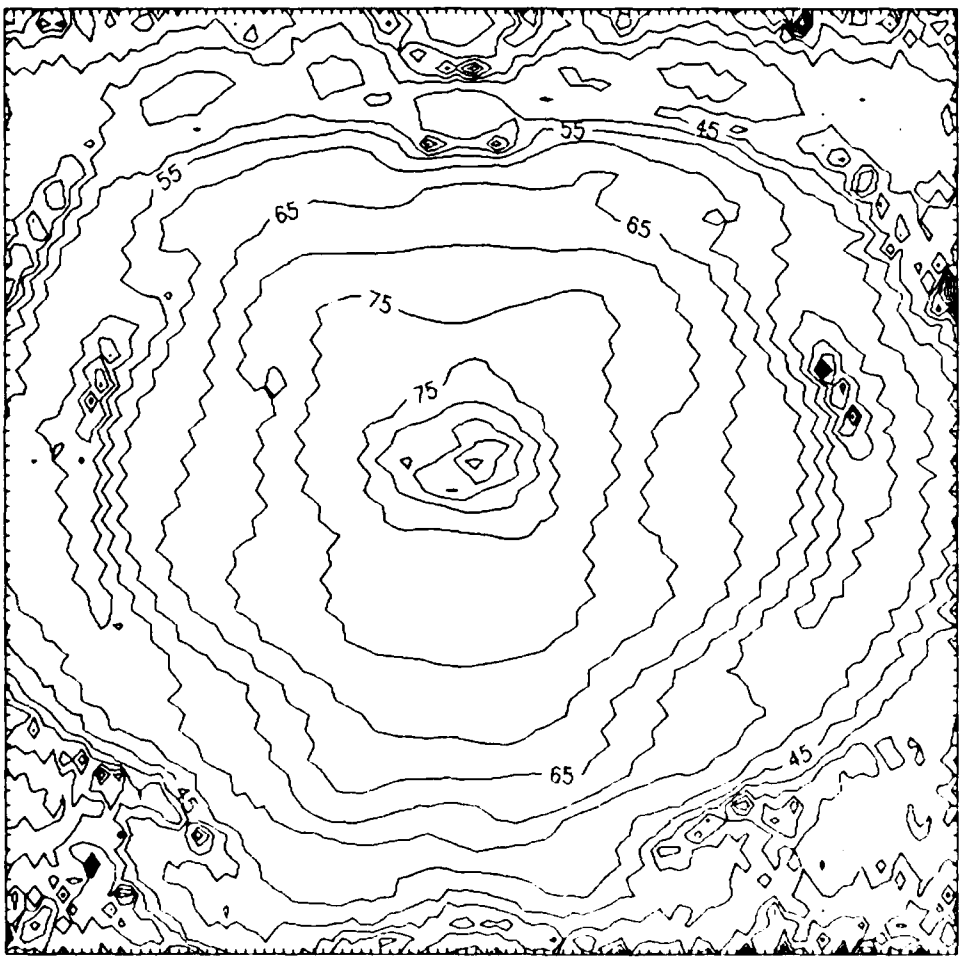


Figure 4. Anomolous Ripple in Near Field

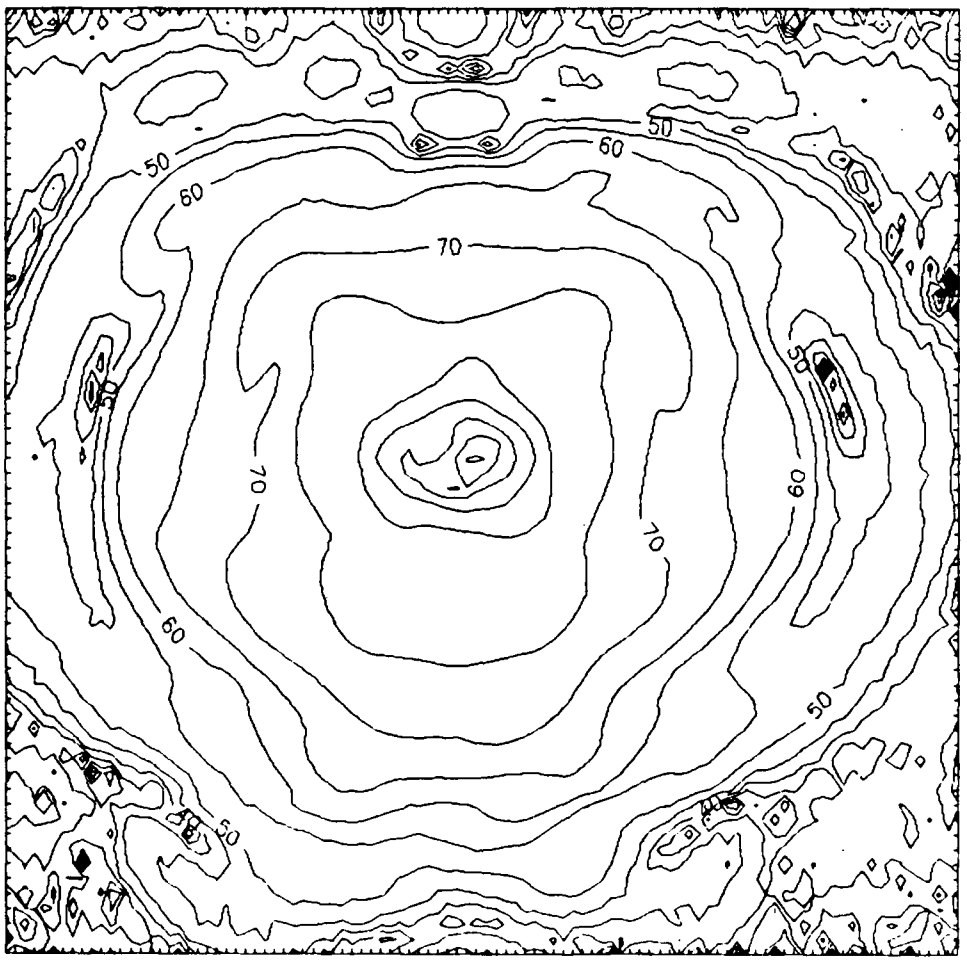


Figure 5. Data from Figure 4 after Correction.

Large Dynamic Range of Results

After completing the measurements the processing of the data remained and during this phase of the project some more interesting phenomena were observed. One perplexing aspect related to the dramatic range of the FFT results over 80db. After some research a possible explanation (Newell, 1985:51) for this was uncovered. Since the near field measurements were taken so close to the antenna evanescent waves were measured. The far field computed using a FFT consists of the sum of two parts consisting of an exponential term due to the evanescent waves and a second due to all sources of measurement error (Newell, 1985:68-69). In Figure 6 an exponential amplitude distribution has been superimposed onto the far field distribution to illustrate this point.

Interpretation of Results

Another feature of interest was noted when the data points obtained from the FFT were to be interpreted. The output of the FFT was in terms of Kx/K and Ky/K as shown in Figure 6 and not azmiuth and elevation.

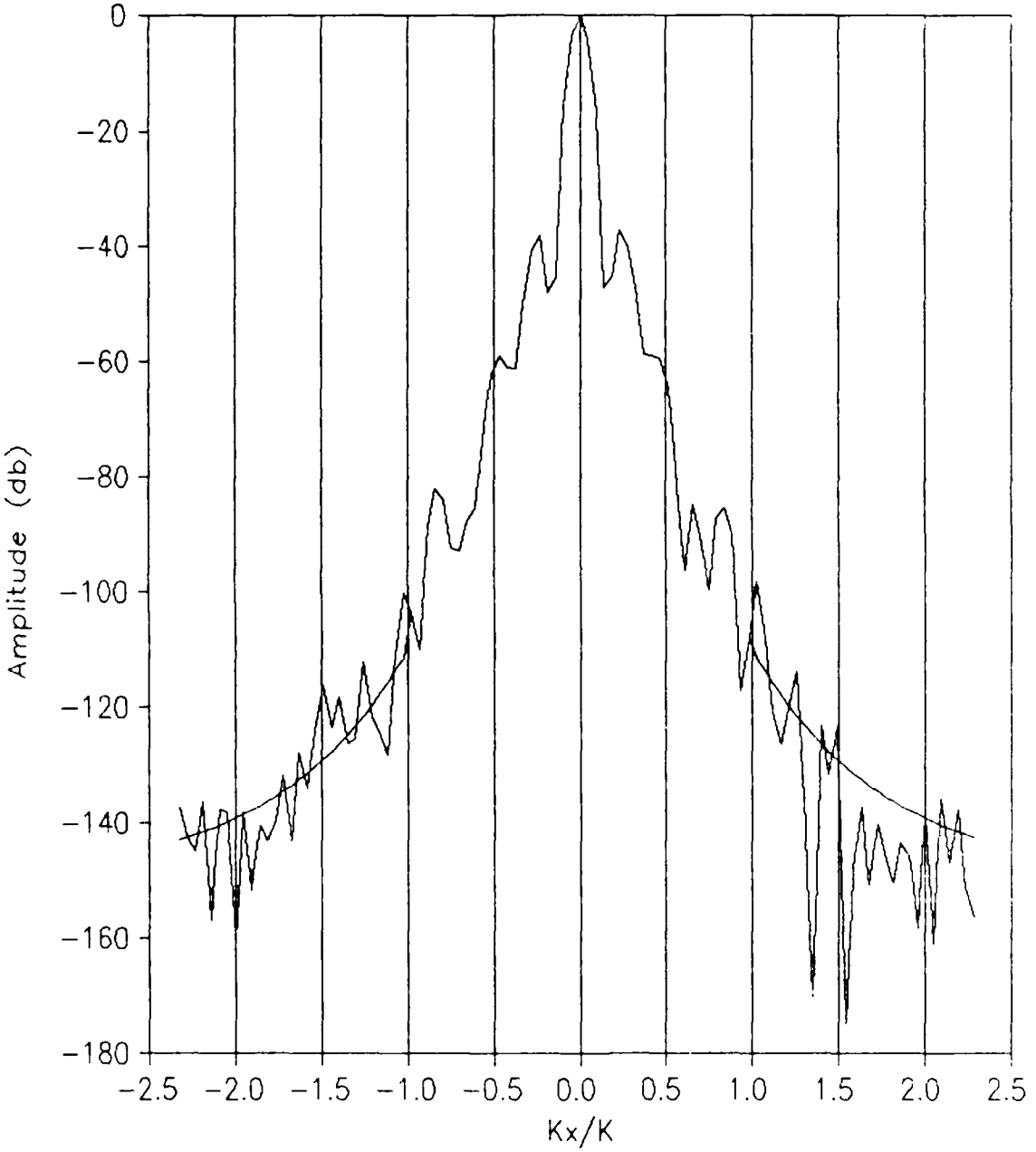


Figure 6. Far Field Exponential Decay

The values of Kx/K and Ky/K range from -2.976 to 2.976 and -2.271 to 2.271 respectively (See Appendix A page 3). The values of Kx/K and Ky/K having a magnitude greater than one correspond to the transformed evanescent waves. Only in the regions where the magnitudes of Kx/K and Ky/K are less than one can the output of the FFT be used to describe the far field since to relate the transformed data to azimuth and elevation, the sine of the Kx/K and the Ky/K values respectively, must be taken (Newell, 1985:6). Within this range only a somewhat smaller angle can really be considered to be effective data as found by solving Equation 1. To improve the accuracy of the results the size of the measurement plane should be increased as this would effectively reduce the size of Kx/K or Ky/K (refer to Equations A8 and A9) and thereby lead to more useful data. Zero filling can achieve similar results and involves explicitly inserting zeroes (these zeros are already implicit due to the truncated area of measurement) in the near field data outside of the areas where actual measurements were taken (Newell, 1985:28). Inserting zeroes does not imply any new data and the net effect is to increase the values of Lx or Ly which as indicated above improves resolution.

Data Sample Spacing

Further gains could be achieved by changing the distances between samples to approximately half wavelength increments (Newell, 1985:26). There is a one-to-one mapping of points from the near field to the far field and using a spacing closer than a half wavelength does not lead to greater azimuthal resolution in the far field plot (Newell, 1985:28). Also it should be noted that the number of sample points needed for use in the FFT algorithm (see Appendix A for development and Appendix E for the source code used) is an even integer power of two.

Near Field Phase and Amplitude Distribution

Figure 7 shows the moveable plate as the line segment RS with GH being perpendicular to the tangent (EGF) at G. As the plate RS moves out from the surface of the parabola on the axis GH it causes rays from the focus f to be reflected up to the reference plane ABCD. Figures 8 and 9 show a 3-dimensional representation of the near field phase for the parabolic reflector with the plates at 0 and 225 degrees respectively. The effect can be clearly seen in the form of twin bulges appearing symmetrically either side of the bulge caused by the feed support. The line segment BD in

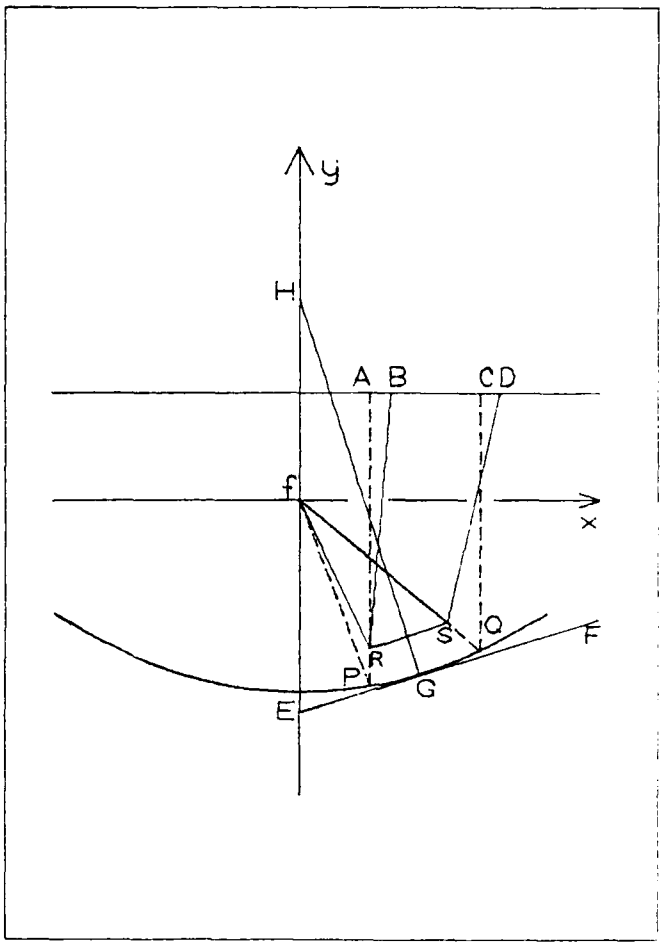


Figure 7. Near Field Zones Due to Moveable Plate

figure 7 denotes the region of illumination due to the moveable plate which moves to the right as the plate moves out from the surface of the parabola. Line segment AB represents the region on the measurement plane that is shadowed by the flat plate. As the flat plate moves out

from the parabolic surface AC increases in length and region AB is not illuminated by either rays reflected directly off the parabolic dish or rays reflected off the moveable plate (See Appendix E for a program that computes the co-ordinates of the various regions of this second model in the near field measurement plane). Rays reflecting off the plate illuminate the region BD, but region CD is also illuminated by rays reflecting off the dish.

Figures 8 to 16 show the distribution of energy in the the near field while Figures 17 to 25 show the phase distribution as the plates are moved out. These distributions are those recorded as the measurement probe travelled over the slice AA' shown in Figure 1. The phase distributions show the twin bulges as expected and as the plates move out the phase disturbance increases until 225° is reached. After this it decreases and at 360° the bulges dissapear entirely.

Effect of Moving Plates

If diffraction is ignored, then as the plate (refer to Figure 7) moves out (in 1/16 wavelength increments) from the dish surface, the transit time required for the rays

emaninating from the focus to travel to the measurement plane is reduced. When the plate is at 1/2 wavelength from the dish, a ray emaninating from the focus striking the plate and reaching the measurement plane, has travelled a shorter distance. This path is shortened by approximately one wavelength over a ray that struck the dish and reflected to the measurement plane directly. Thus these two rays are approximately back in phase. This effect can be seen quite clearly by comparing Figures 17 and 25 which show the near field phase distribution at 0 and 360 degrees respectively to be of fundamentally the same shape.

Computed Near Field Phase Distribution

The Near Field Phase Distribution Program (Appendix E) calculates the near field phase distribution for one plate since the results on the other side of the feed blockage should be a mirror image. This is an admittedly simple approach which relies entirely on ray tracing techniques and vectorial summation of rays reflected directly off the dish and those rays reflected off the moveable plate to model a very complicated problem. Modelling only a small portion of the near field is considered reasonable since one of the stated aims of this study was to develop a predictive ability regarding the far field behaviour as a

function of plate movement. Apart from being a two dimensional model no attempt is made to take account of diffraction effects which certainly would be important in view of the relatively small size of the moveable plates. Also the feed blockage causes a severe effect on the near field phase distribution and this has not been included.

Considering the results obtained there is an apparent correlation between the measured and computed near field phase distributions. This qualitative correlation seems strongest in the regions where the horn blockage and diffraction effects would be expected to be smallest (ie. nearest to the outside edge of the dish). In most cases the abrupt transition from the larger phase, attributed to the moveable plate, back to the smaller phase, due to reflection directly off the surface of the dish, in the computed results coincides reasonably in position and magnitude with the transition apparent in the measured plots. These results give some confidence to the concept of this simplified model. Adding to this model those rays which are diffracted by the edge of the plate may further enhance the accuracy of the predicted near field distribution.

A finite identifiable number of rays diffract directly

off the moveable plate and could strike a single point along AA' (Figure 1). There are two sources for these diffracted rays. The first source is rays that strike the plate edge with normal incidence and the second is rays that strike the plate edge with oblique incidence. These rays with appropriate diffraction coefficients would serve to enhance this simple model.

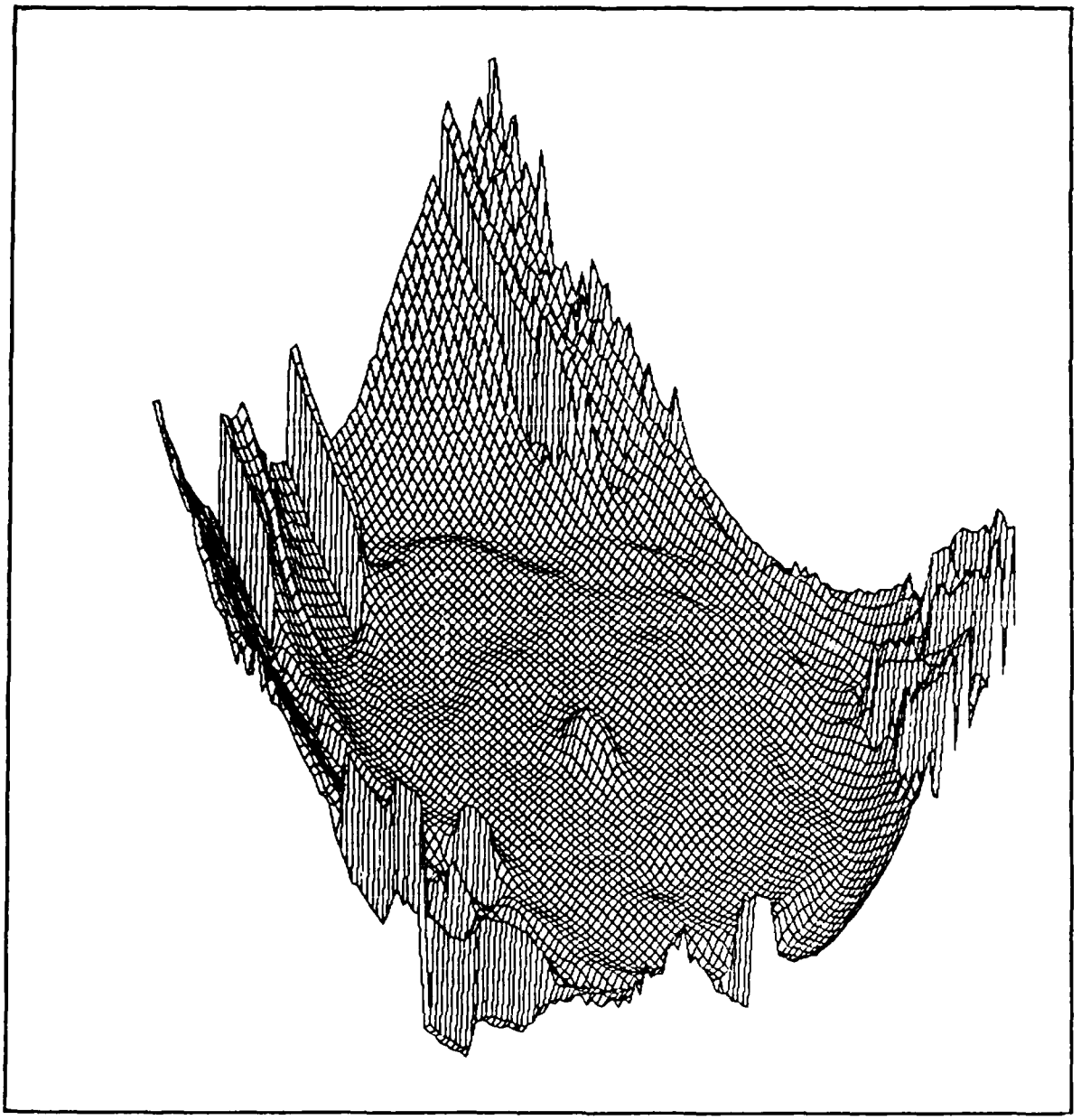


Figure 8. 3-D Near Field Phase Distribution - Plates at 0°

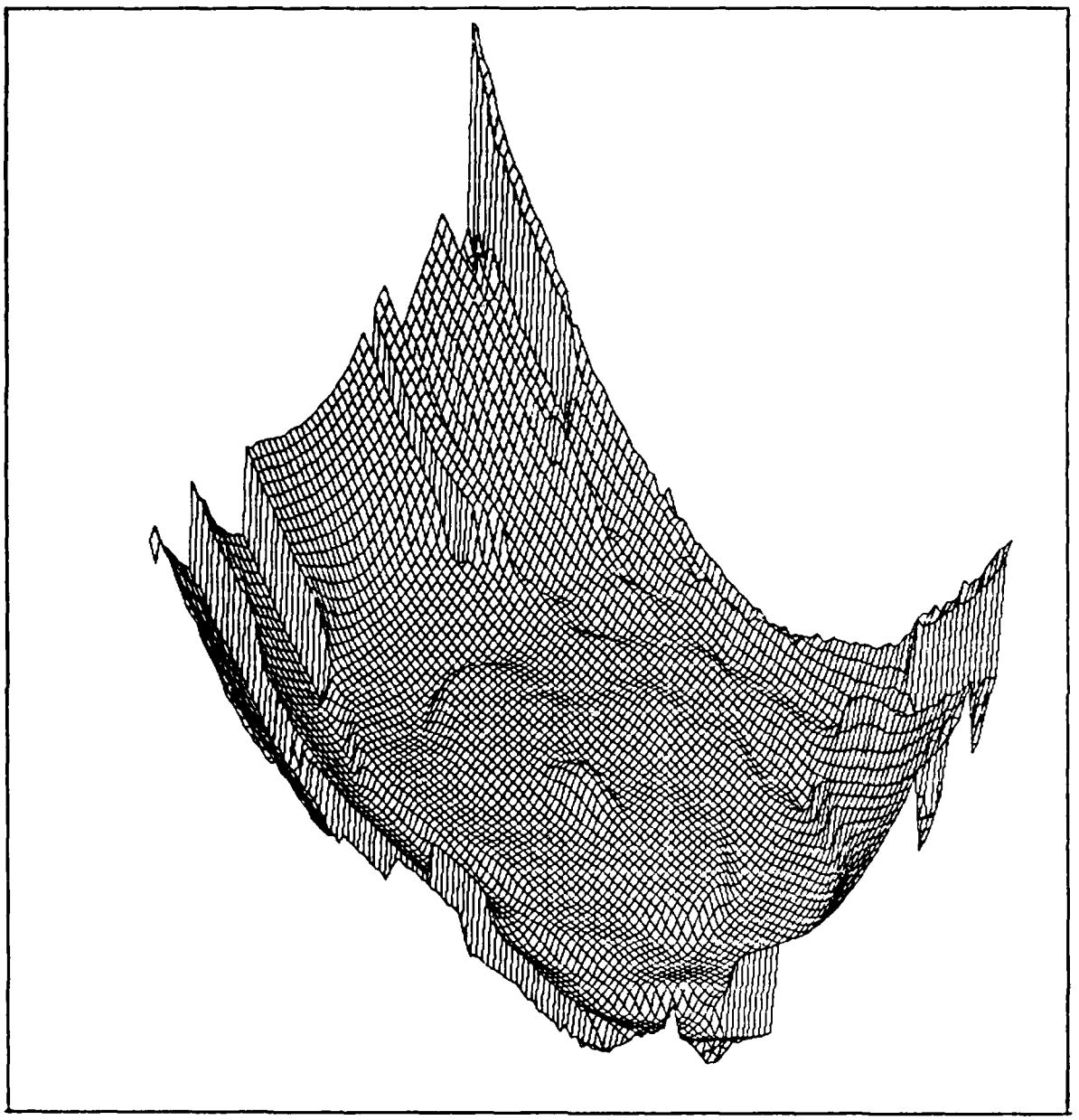


Figure 9. 3-D N/Field Phase Distribution - Plates at 225°

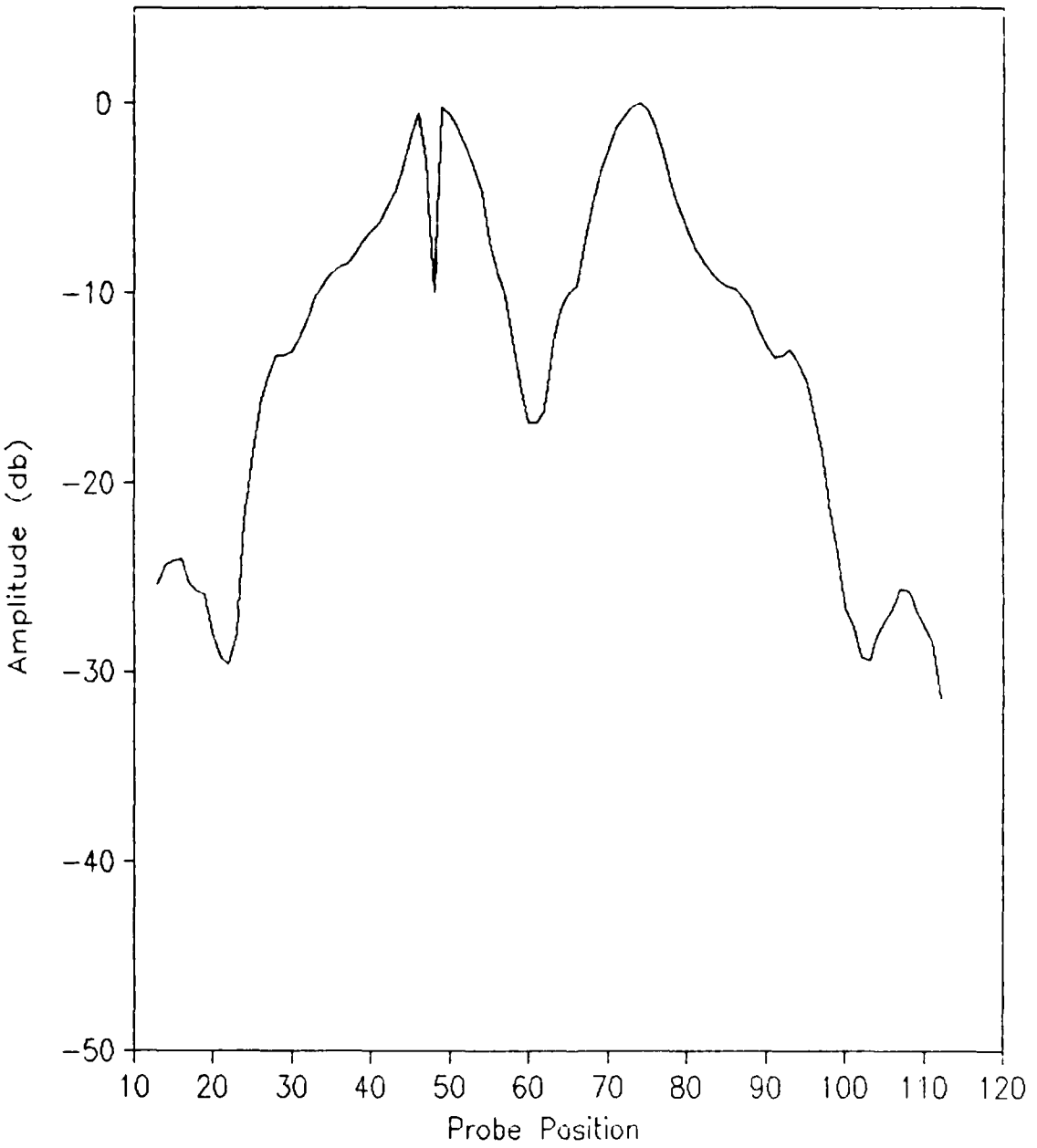


Figure 10. Near Field Amplitude Distribution - Plates at 0°

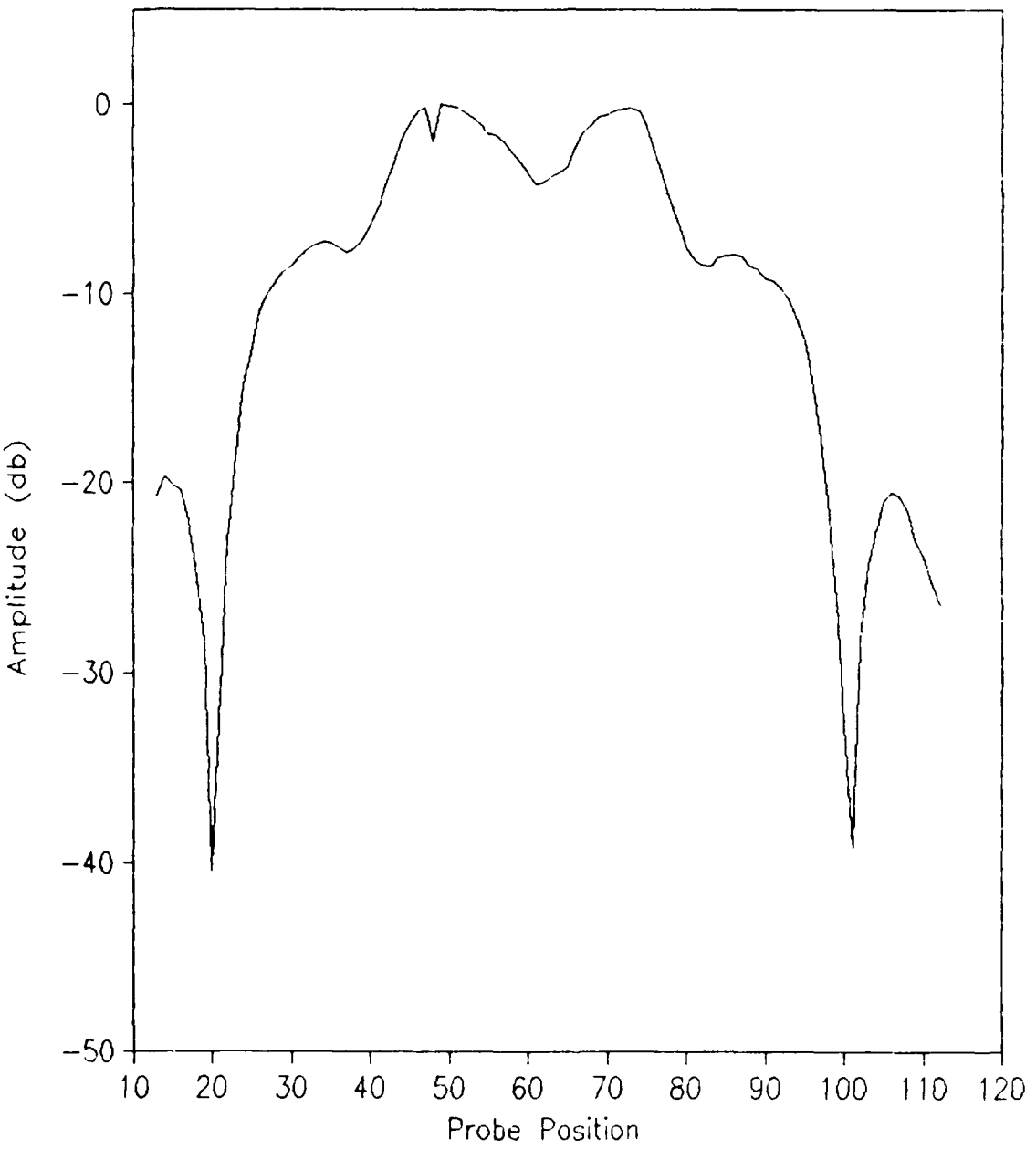


Figure 11. Near Field Amplitude Distribution - Plates at 45°

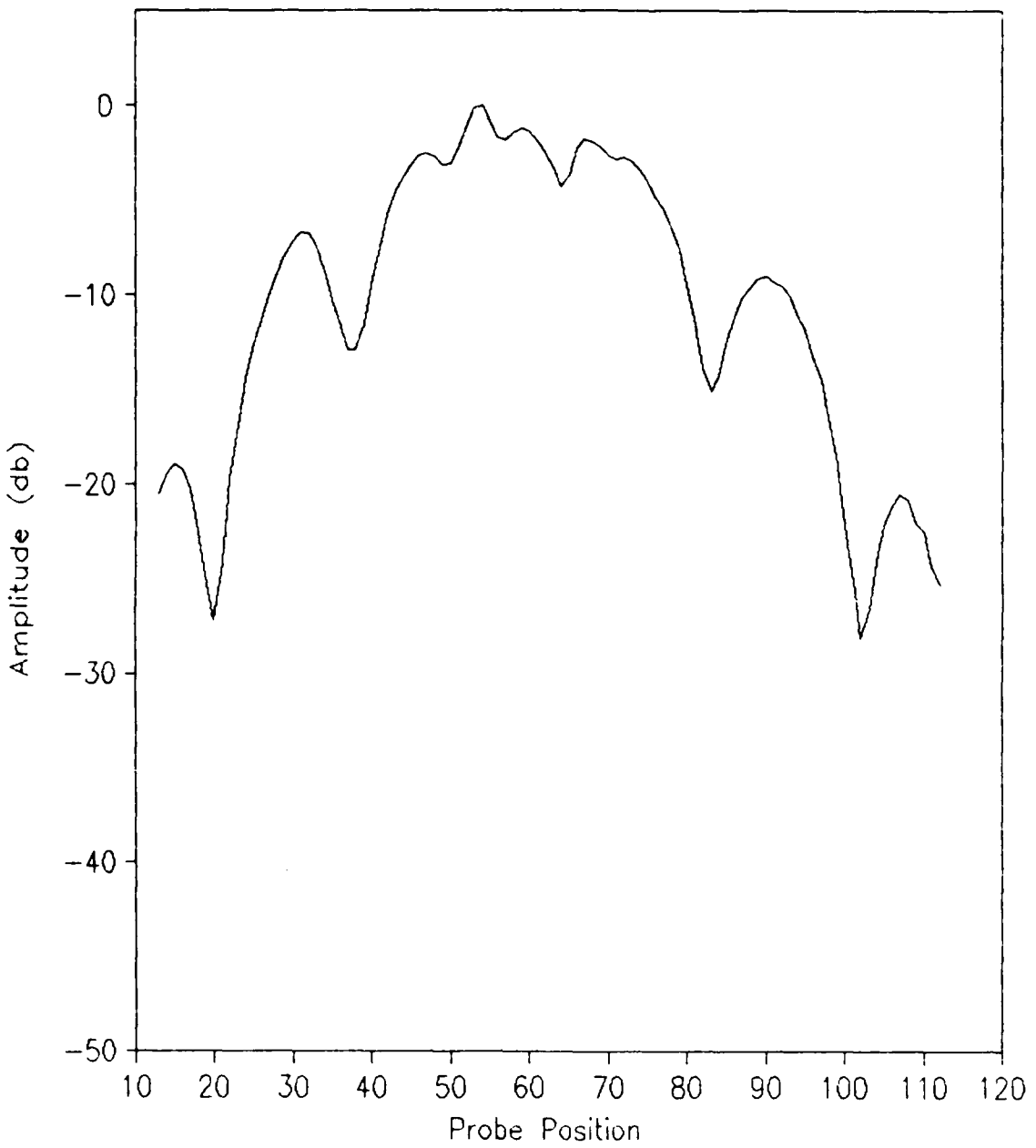


Figure 12. Near Field Amplitude Distribution - Plates at 90°

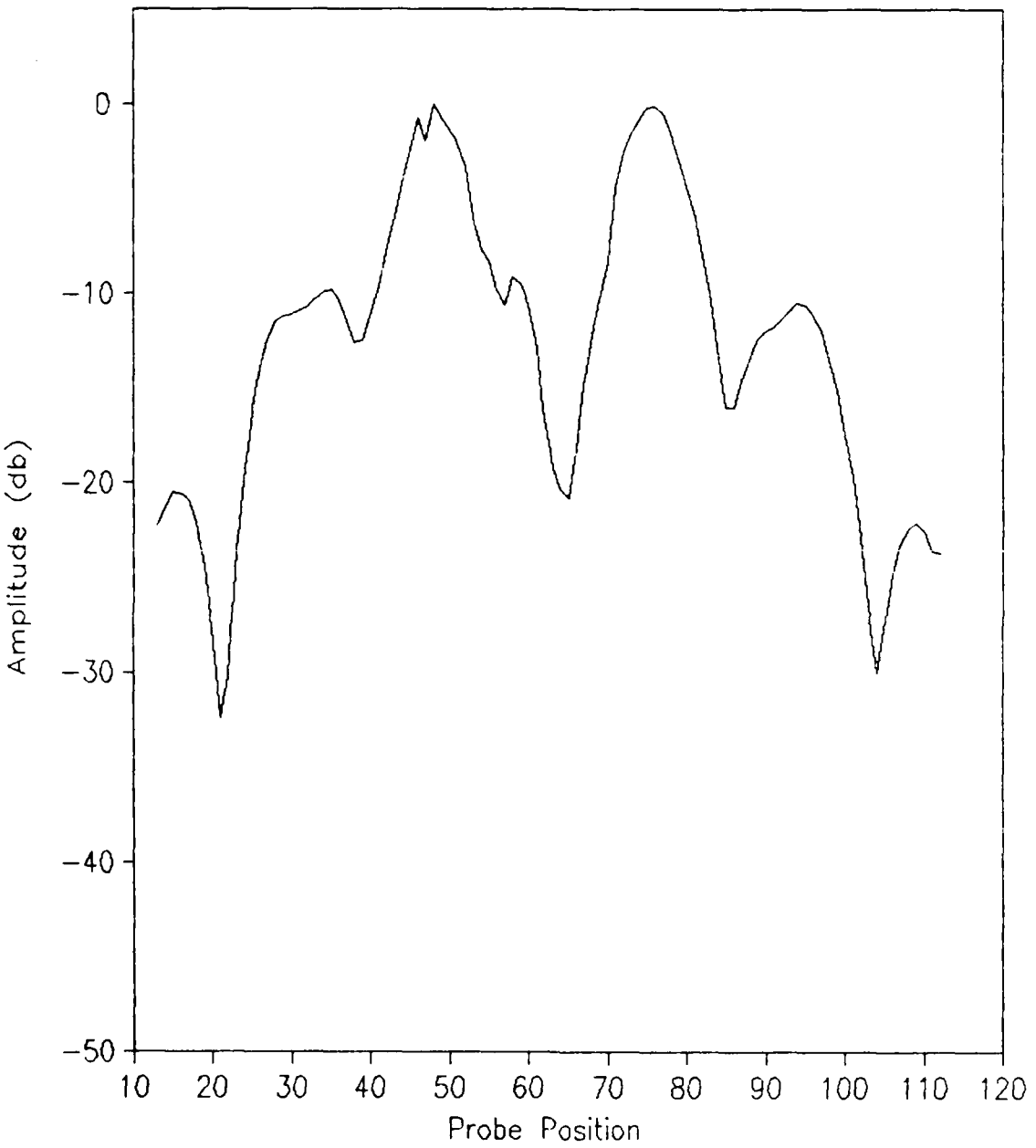


Figure 13. N/Field Amplitude Distribution - Plates at 135°

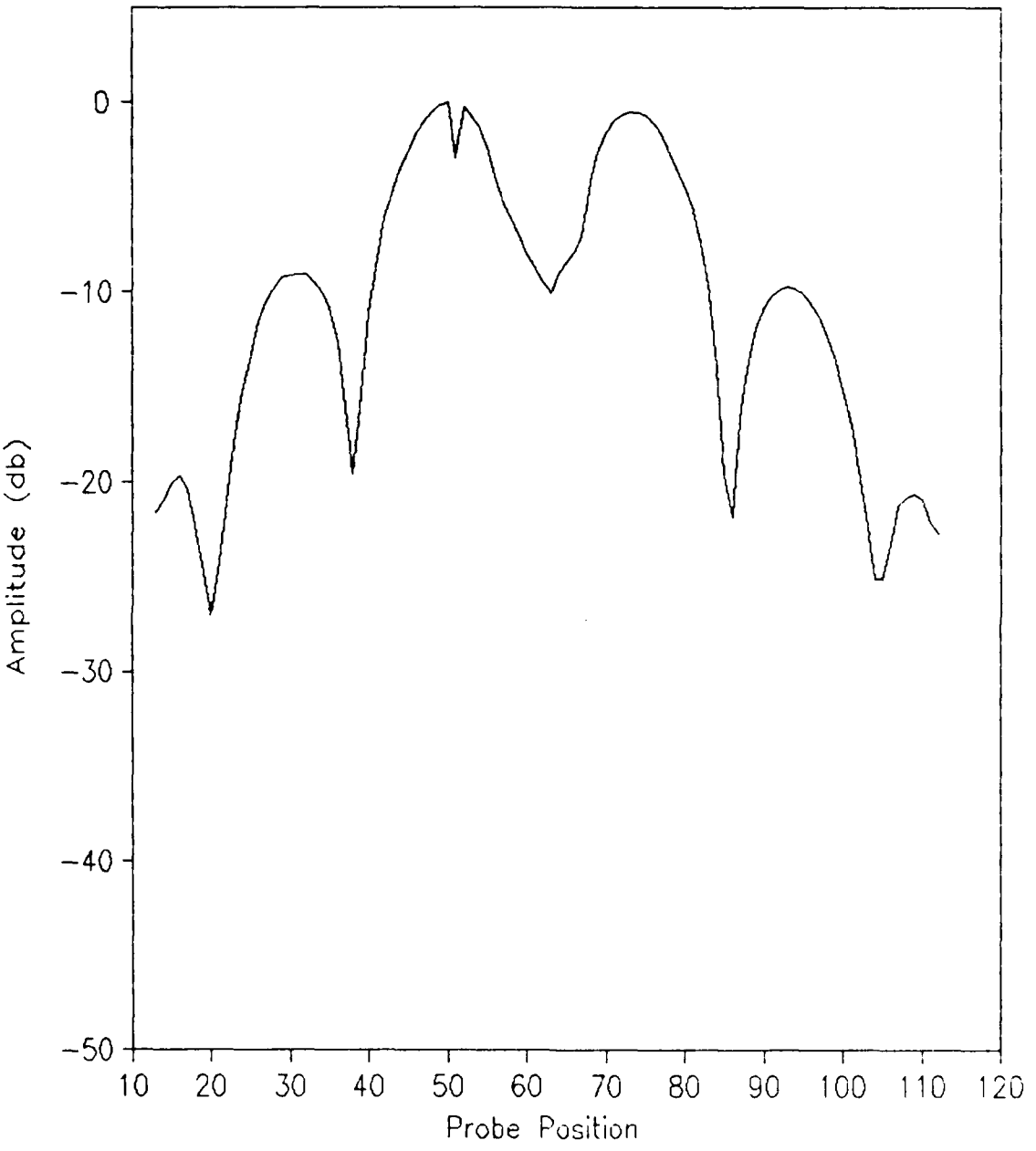


Figure 14. N/Field Amplitude Distribution - Plates at 180°

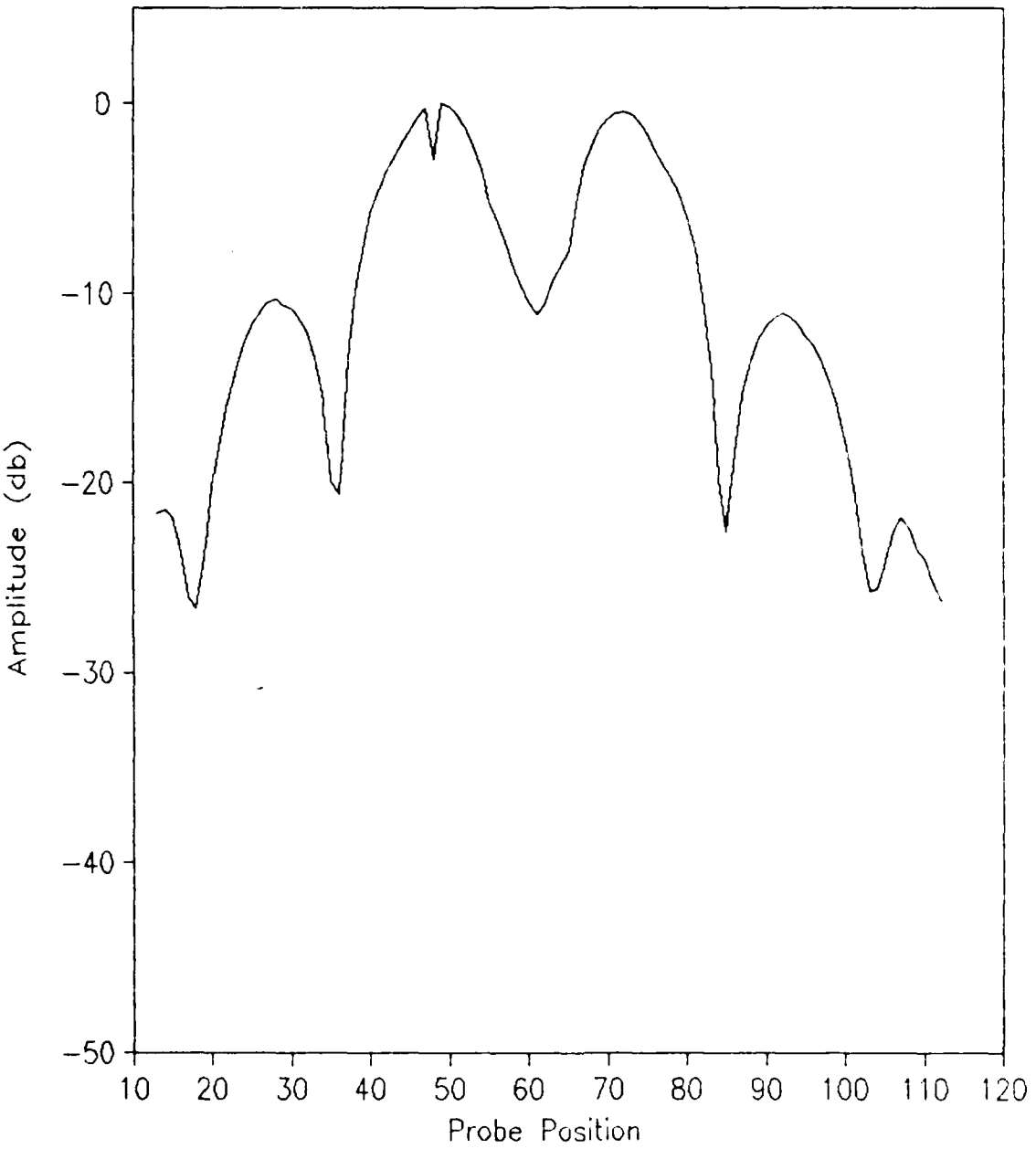


Figure 15. N/Field Amplitude Distribution - Plates at 225°

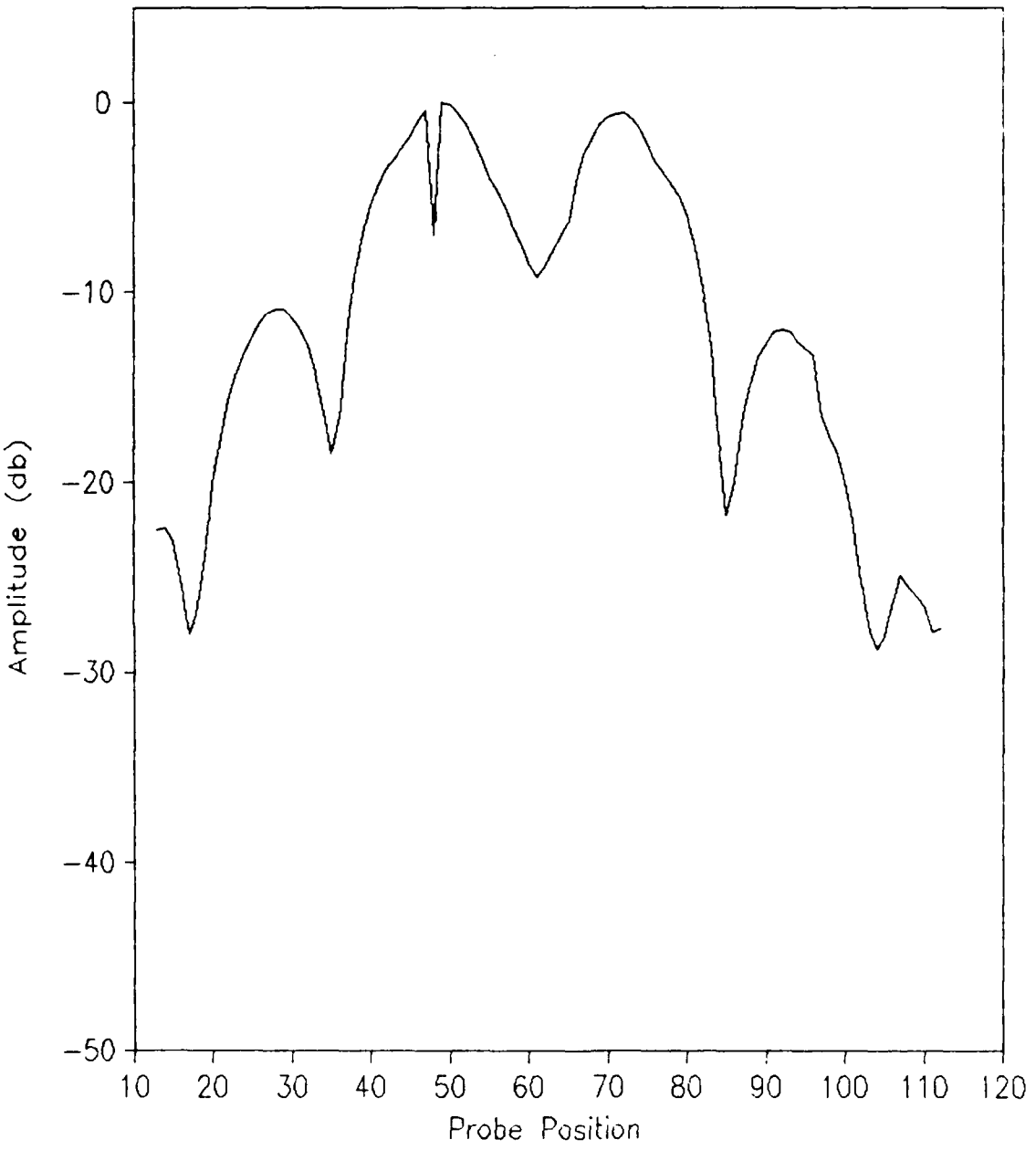


Figure 16. N/Field Amplitude Distribution - Plates at 270°

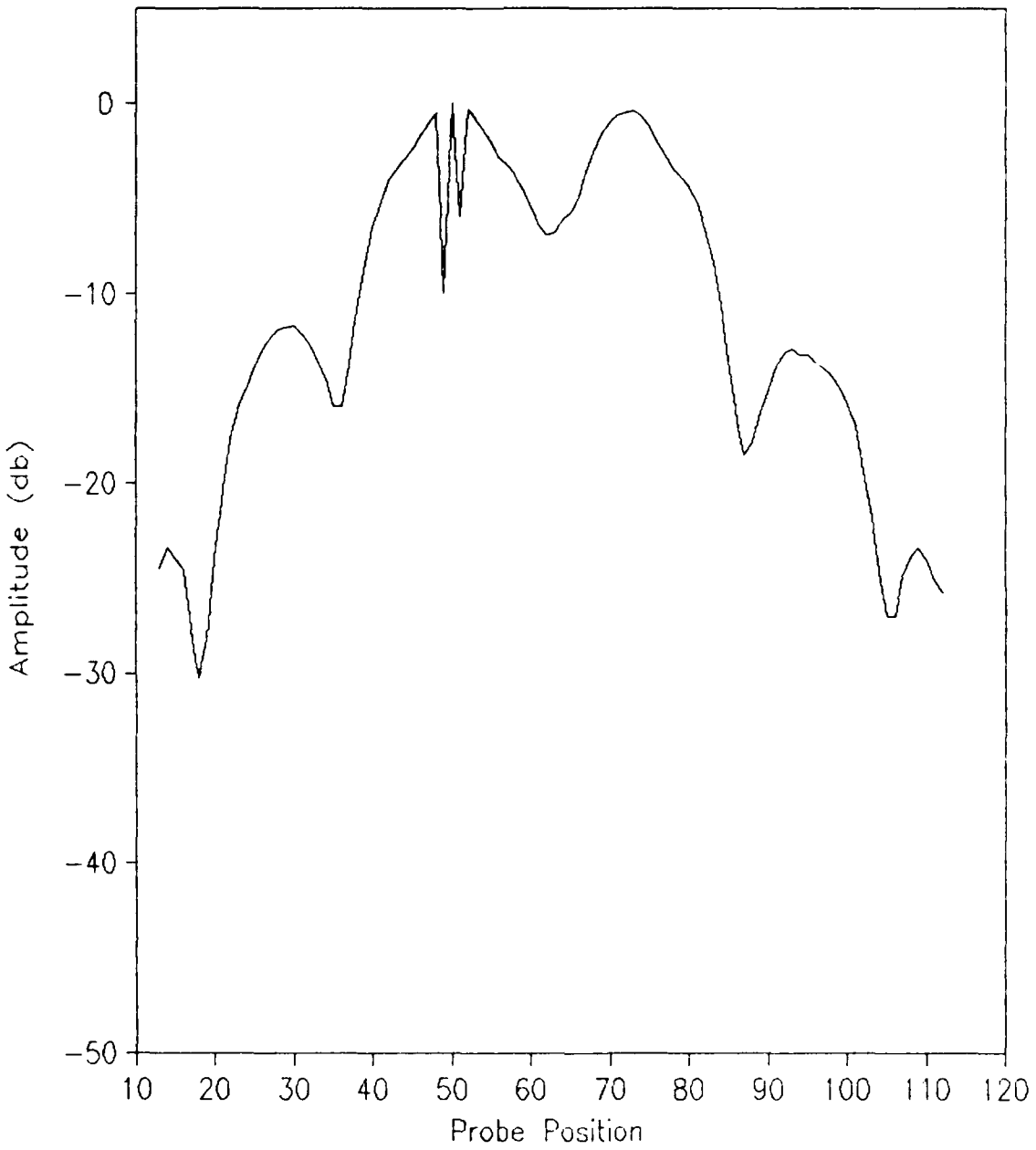


Figure 17. N/Field Amplitude Distribution - Plates at 315°

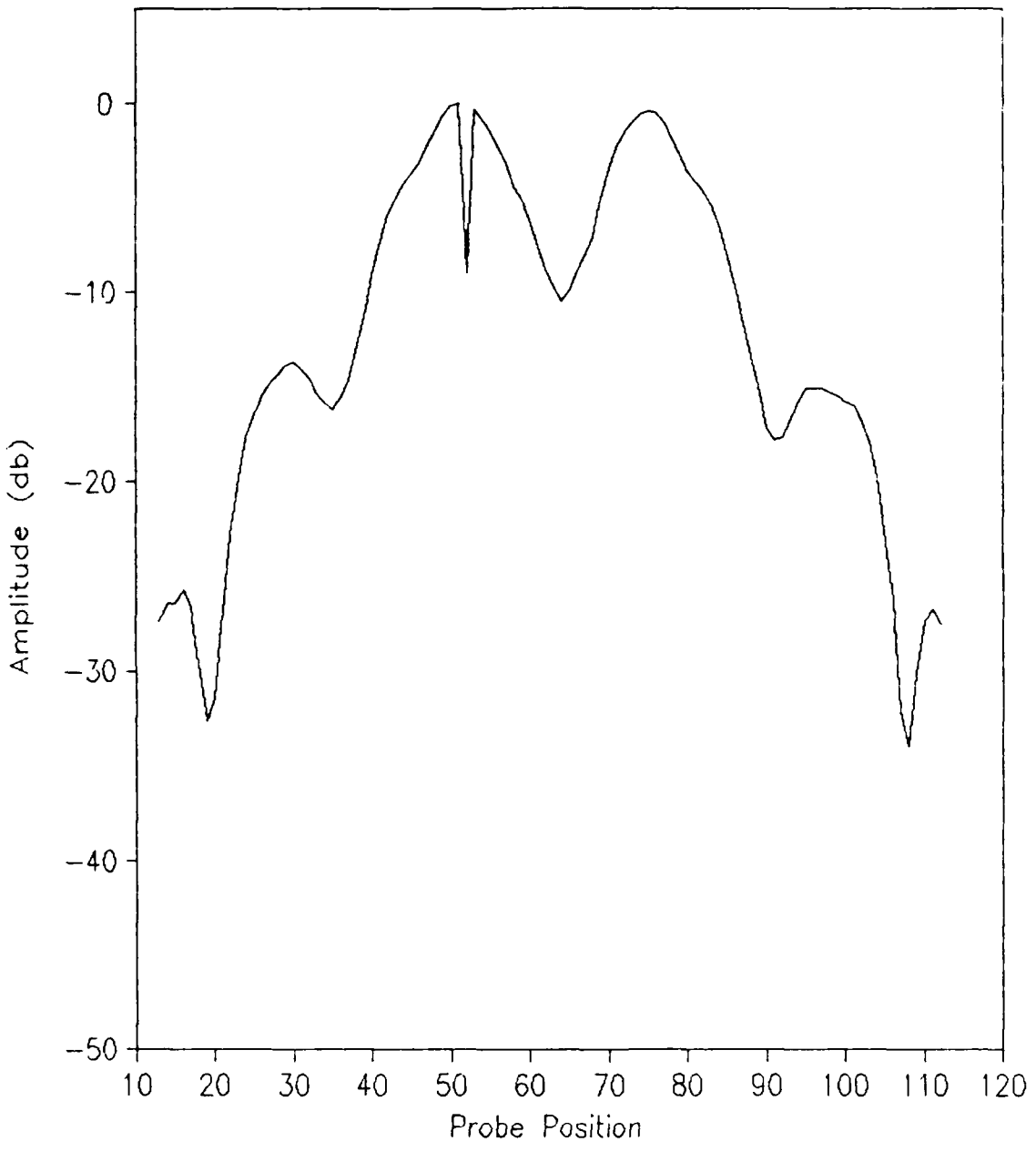


Figure 18. N/Field Amplitude Distribution - Plates at 360°

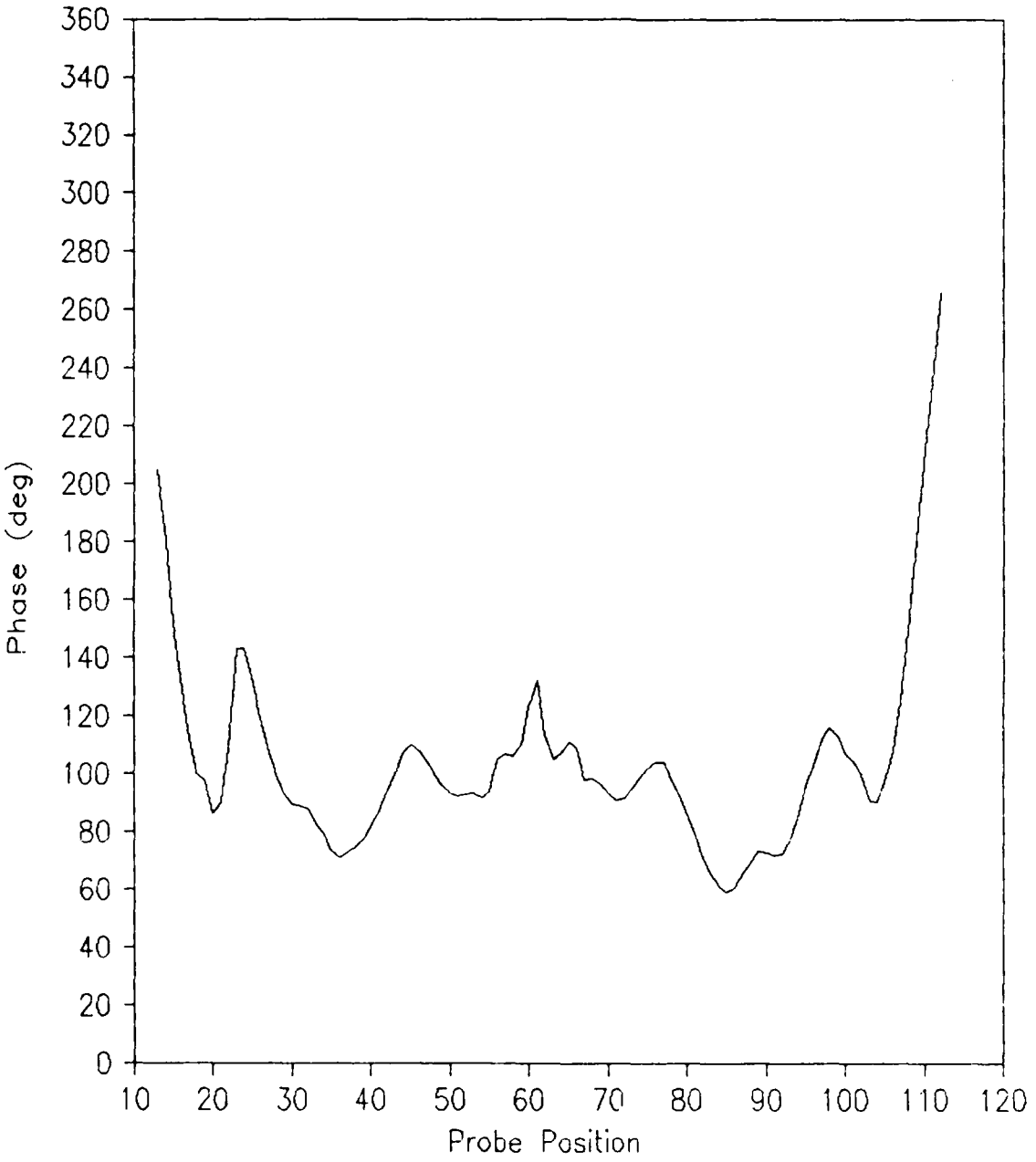


Figure 19. N/Field Phase Distribution - Plates at 0°

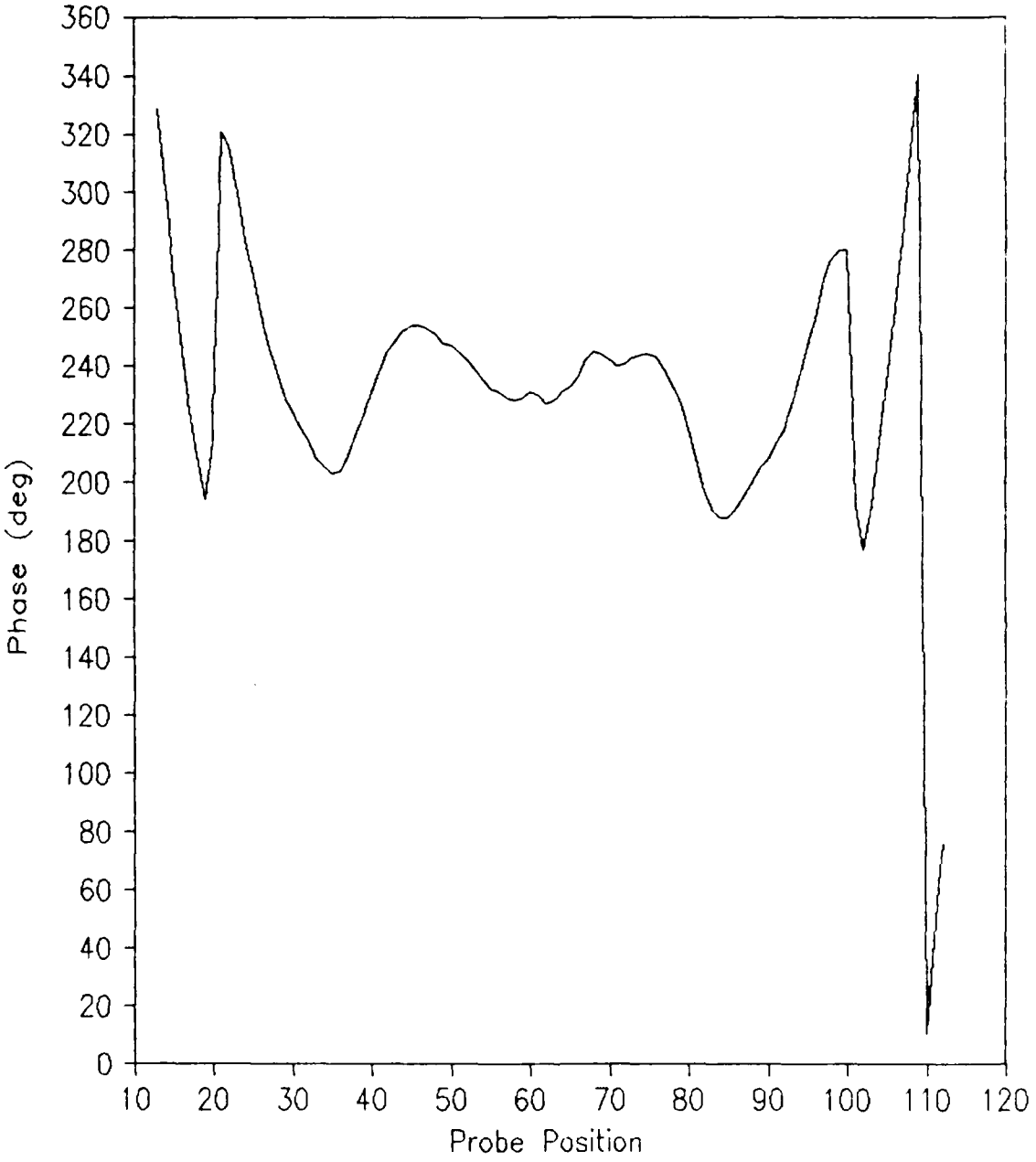


Figure 20. N/Field Phase Distribution - Plates at 45°

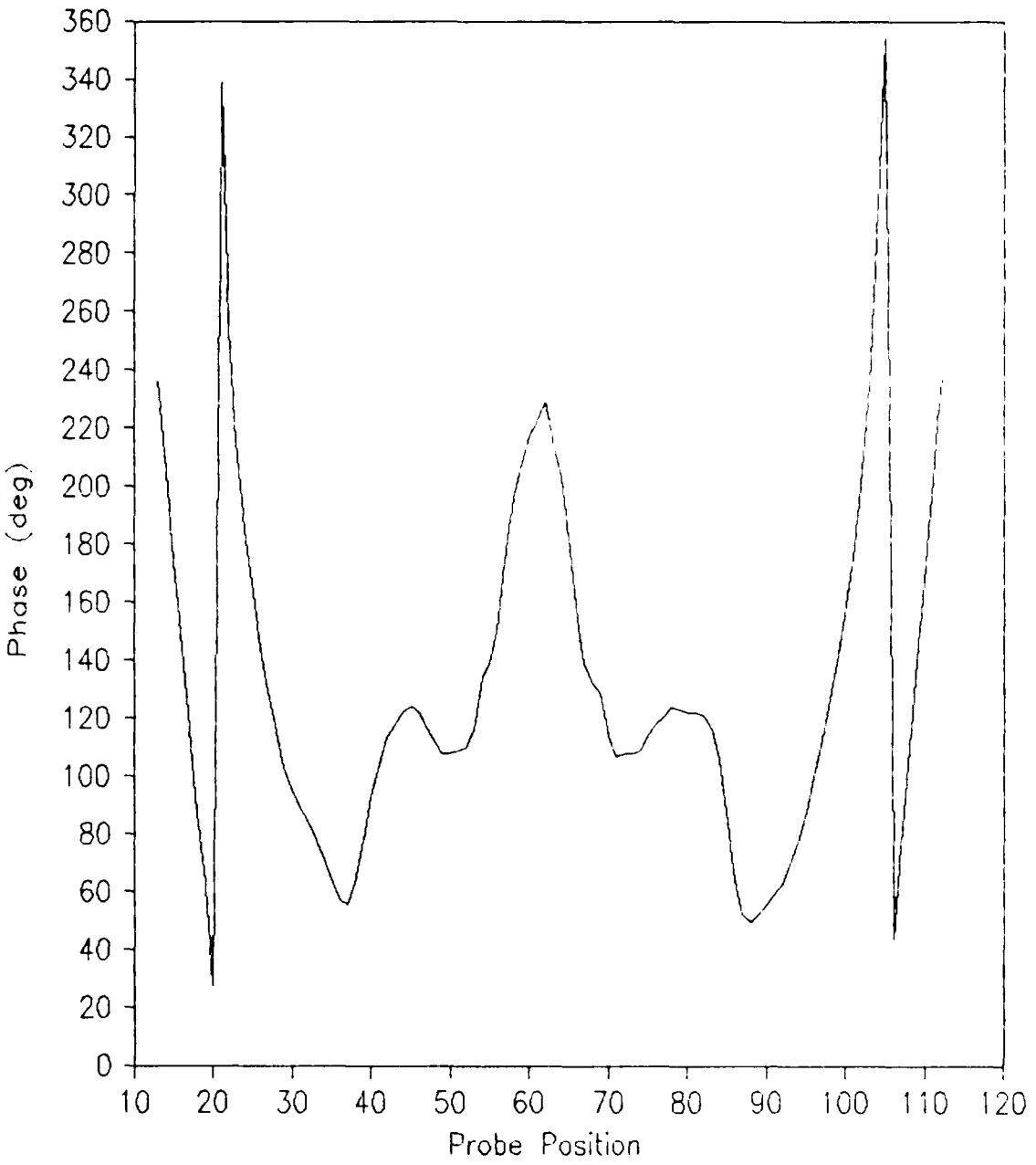


Figure 21. N/Field Phase Distribution - Plates at 90°

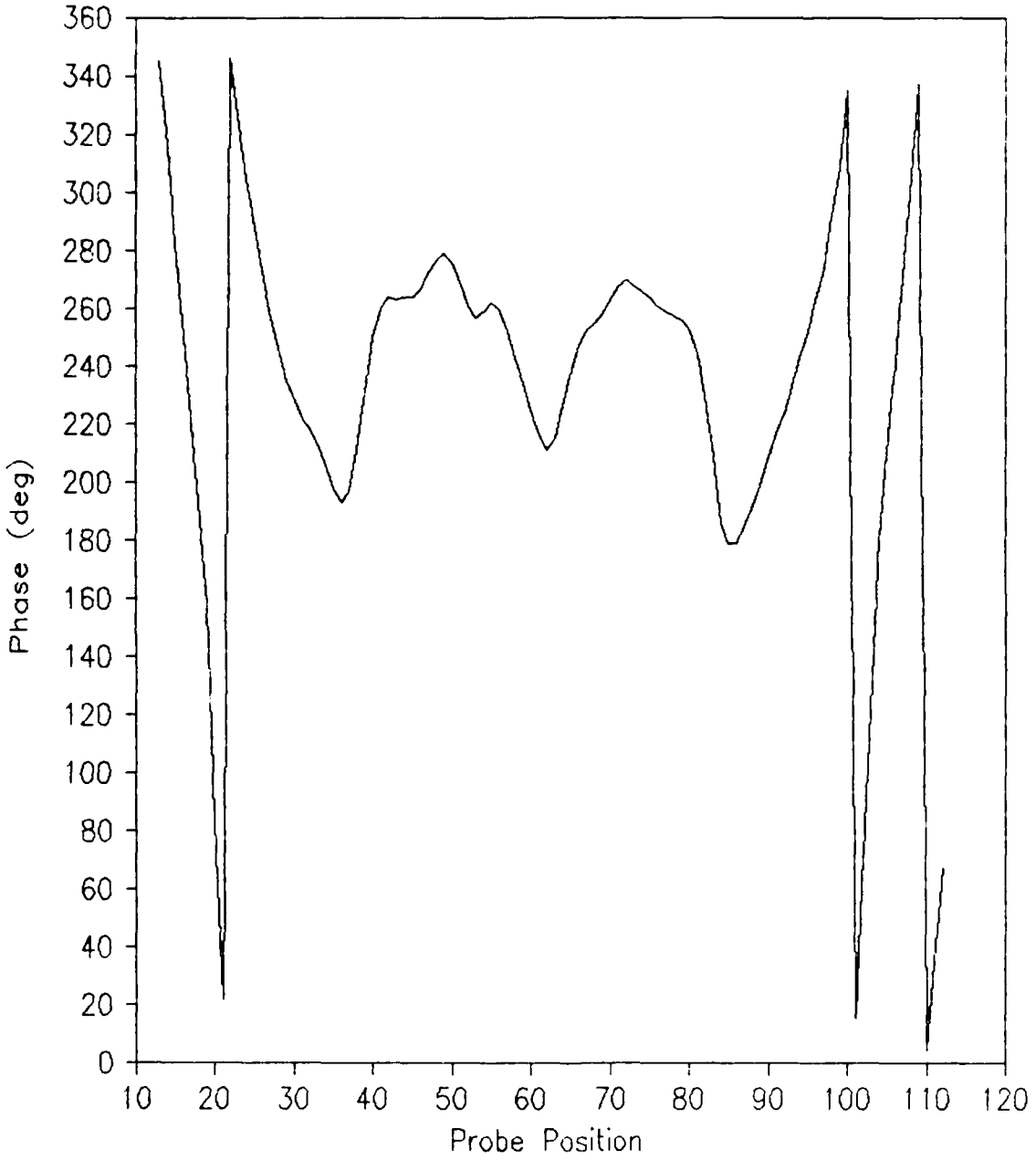


Figure 22. N/Field Phase Distribution - Plates at 135°

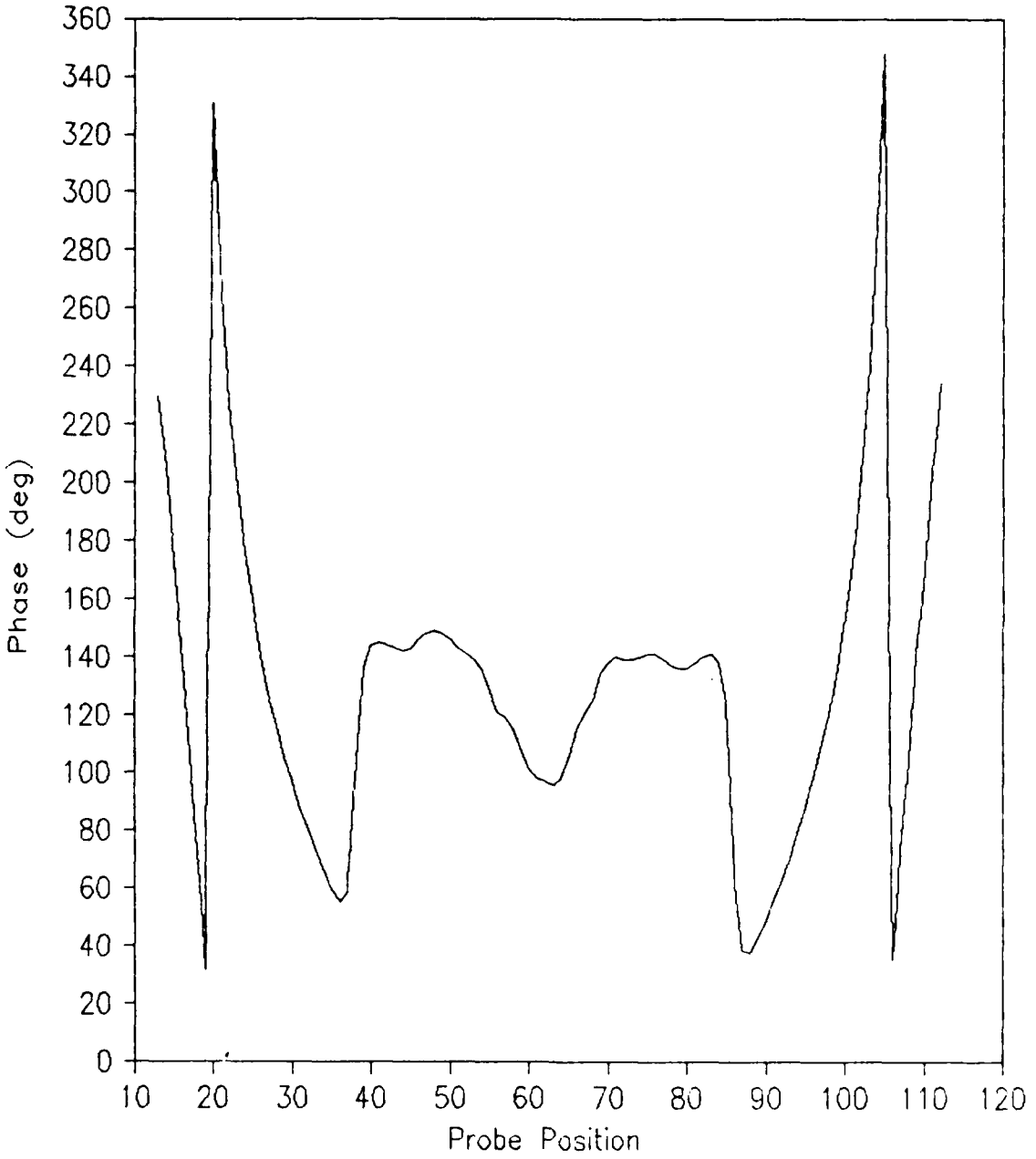


Figure 23. N/Field Phase Distribution - Plates at 180°

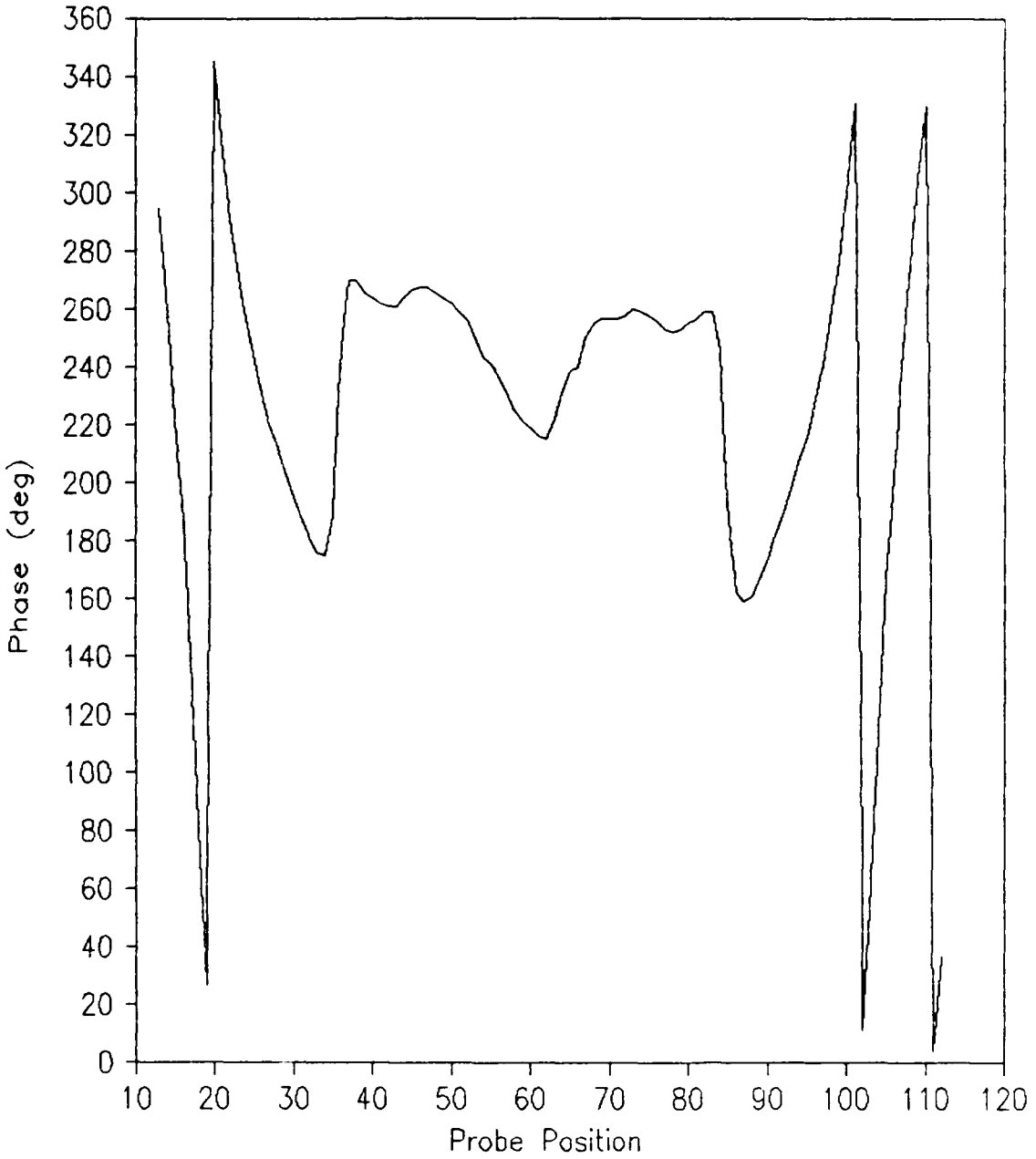


Figure 24. N/Field Phase Distribution - Plates at 225°

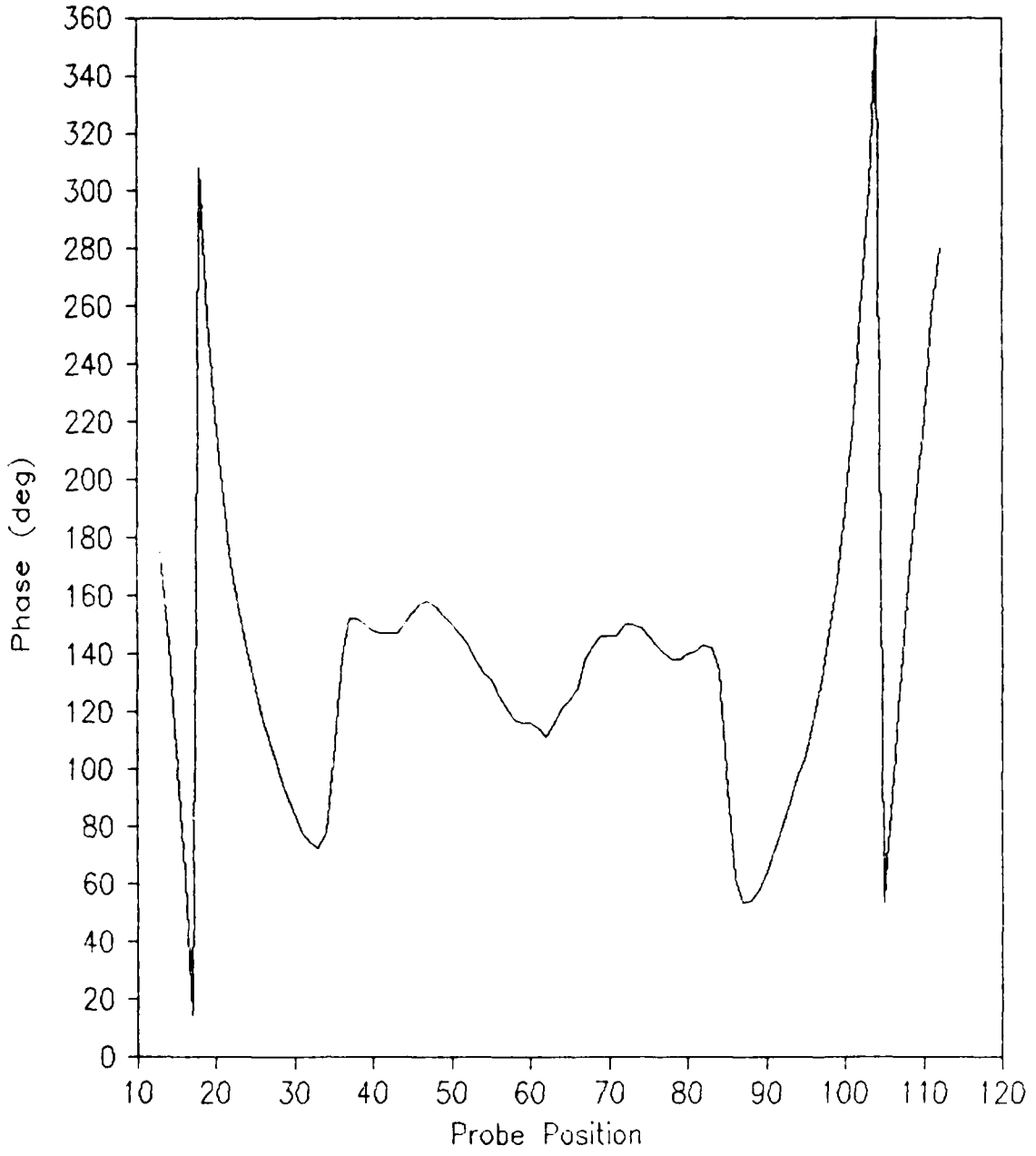


Figure 25. N/Field Phase Distribution - Plates at 270°

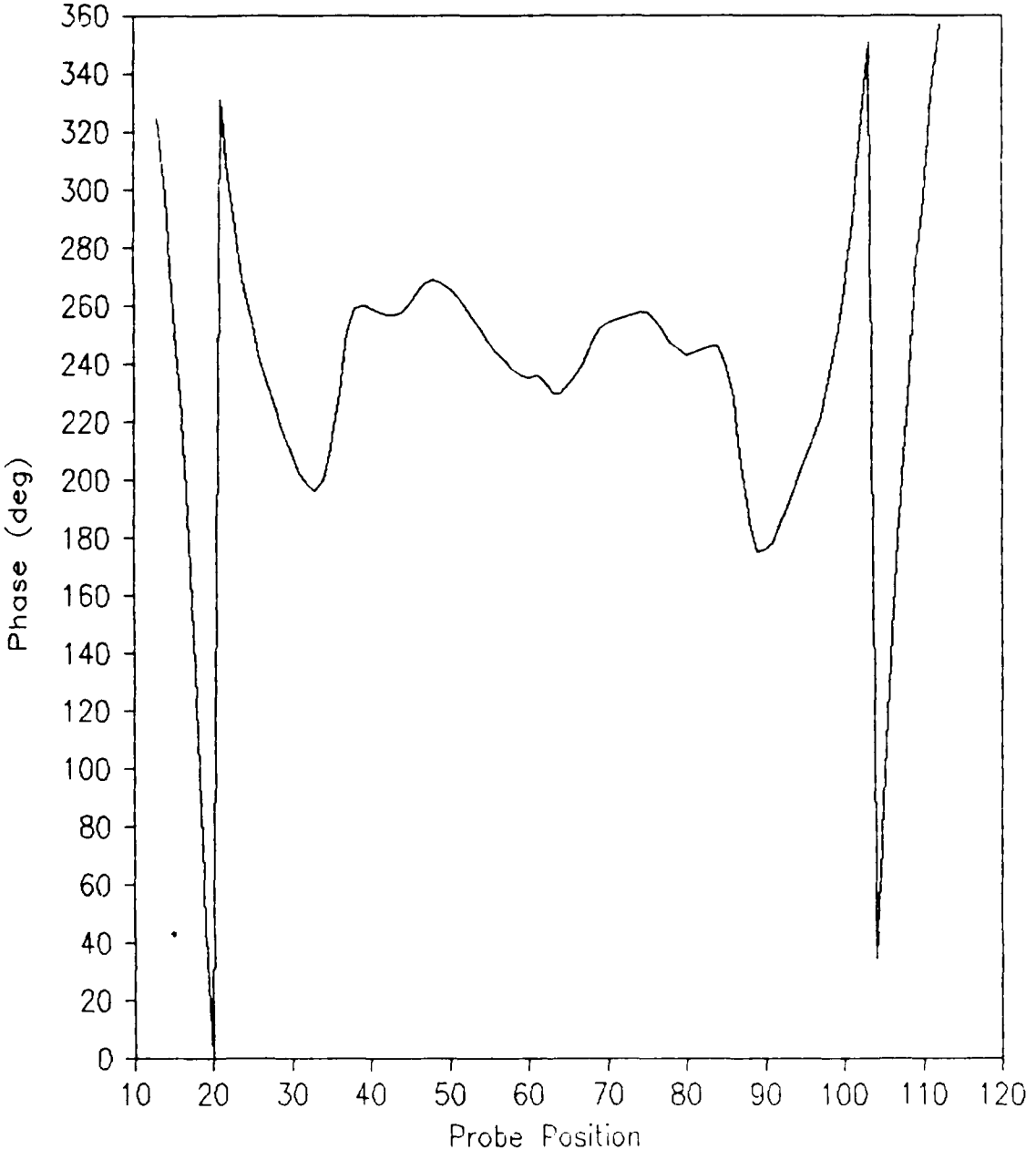


Figure 26. N/Field Phase Distribution - Plates at 315°

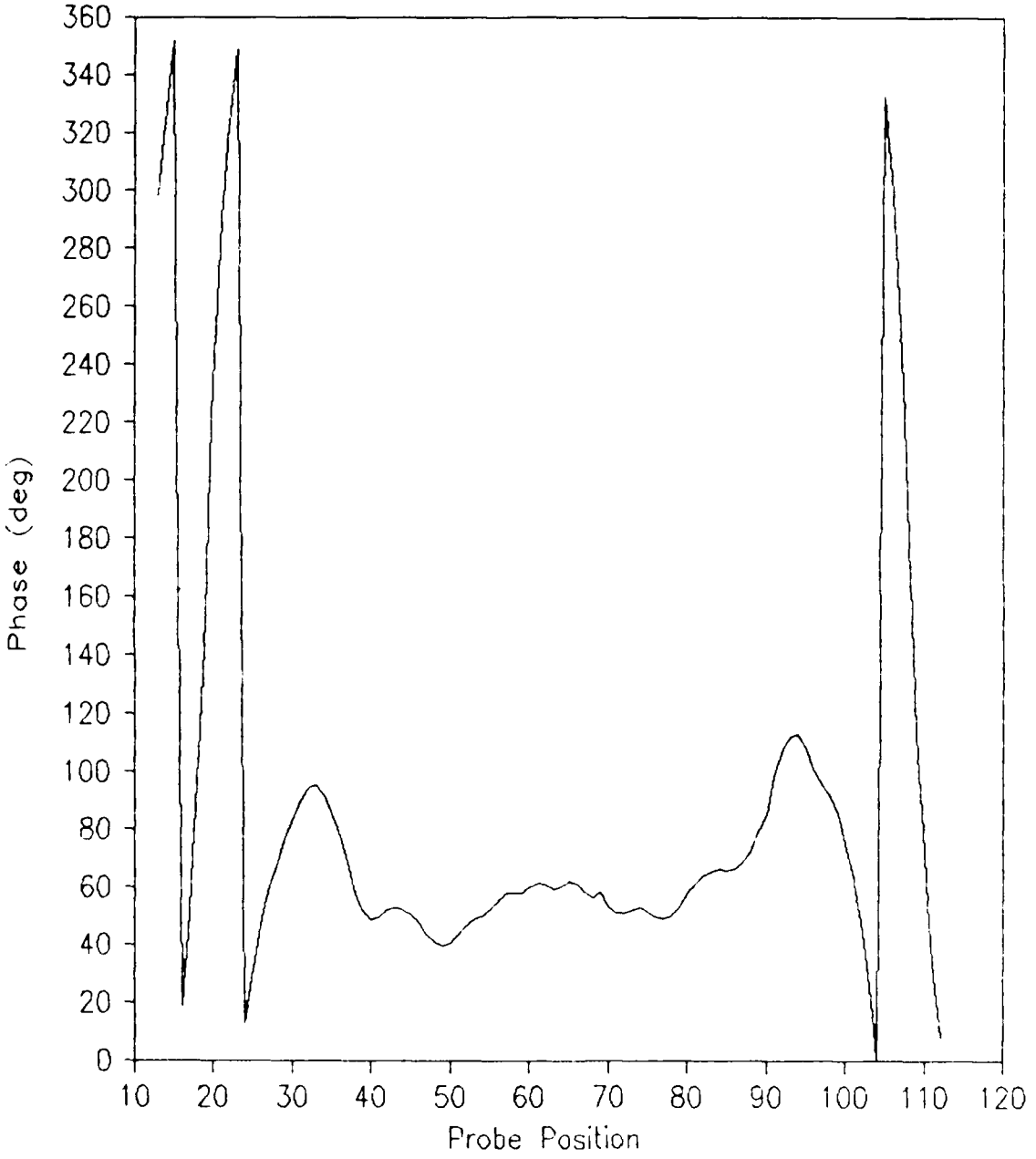


Figure 27. N/Field Phase Distribution - Plates at 360°

IV. Comparison of Measured to Computed Results

The near field results shown in the previous chapter were processed using the fast fourier transform program shown in Appendix D and sample amplitude distributions are provided by figures 28 to 32 inclusive. Plots of the corresponding measured data is shown in figures 33 to 37.

Comparison of Side Lobe to Main Lobe

Comparison of the results is facilitated by considering the amplitude of the first side lobe relative to the main lobe. In each case reasonable correlation of the measured to computed results is obtained. (See Table 1). Where discrepencies occur it is an indication of two problem areas. The first is the size of the measurement plane which could be extended by zero filling to provide enhanced resolution in the far field (Newell, 1985:28). Also the taking of accurate measurements in the near or far field is made very difficult by the large number of systematic sources of error. These error sources are (Newell, 1985:67-85) as follows:

1. Multiple reflections.

2. Probe positioning uncertainties.
3. System amplitude and phase nonlinearities (receiver and attenuator).
4. Impedence changes due to probe and receiver cable movement.
5. Aliasing if no band limit exists on the FFT results (band limit is inversely proportional to the size of the near field sample step).
6. Aliasing if near field samples are spaced too widely.
7. Area truncation (ie sampling over a limited area in the near field).

Null Movement

Also of interest is how much does the first null move as the plates move out from the surface of the dish. The computed results do not provide sufficient resolution to allow any meaningful conclusions to be drawn. However the measured results do indicate that there was some slight movement of the null. (See Table 2).

TABLE I

Main Lobe to First Side Lobe Amplitude Difference

Plate Position (deg)	Amplitude Difference (db)	
	Measured	Computed
0	20.4	17
90	18	22
135	16	18
225	14.6	18
360	16.6	15

TABLE II

Antenna Beamwidth Comparison at Various Plate Settings

	Null to Null Beamwidth (deg)	
Plate Position (deg)	Measured	Computed
0	15.4	16
90	16.5	21.2
135	16.5	16
225	15.5	18.8
360	15	16

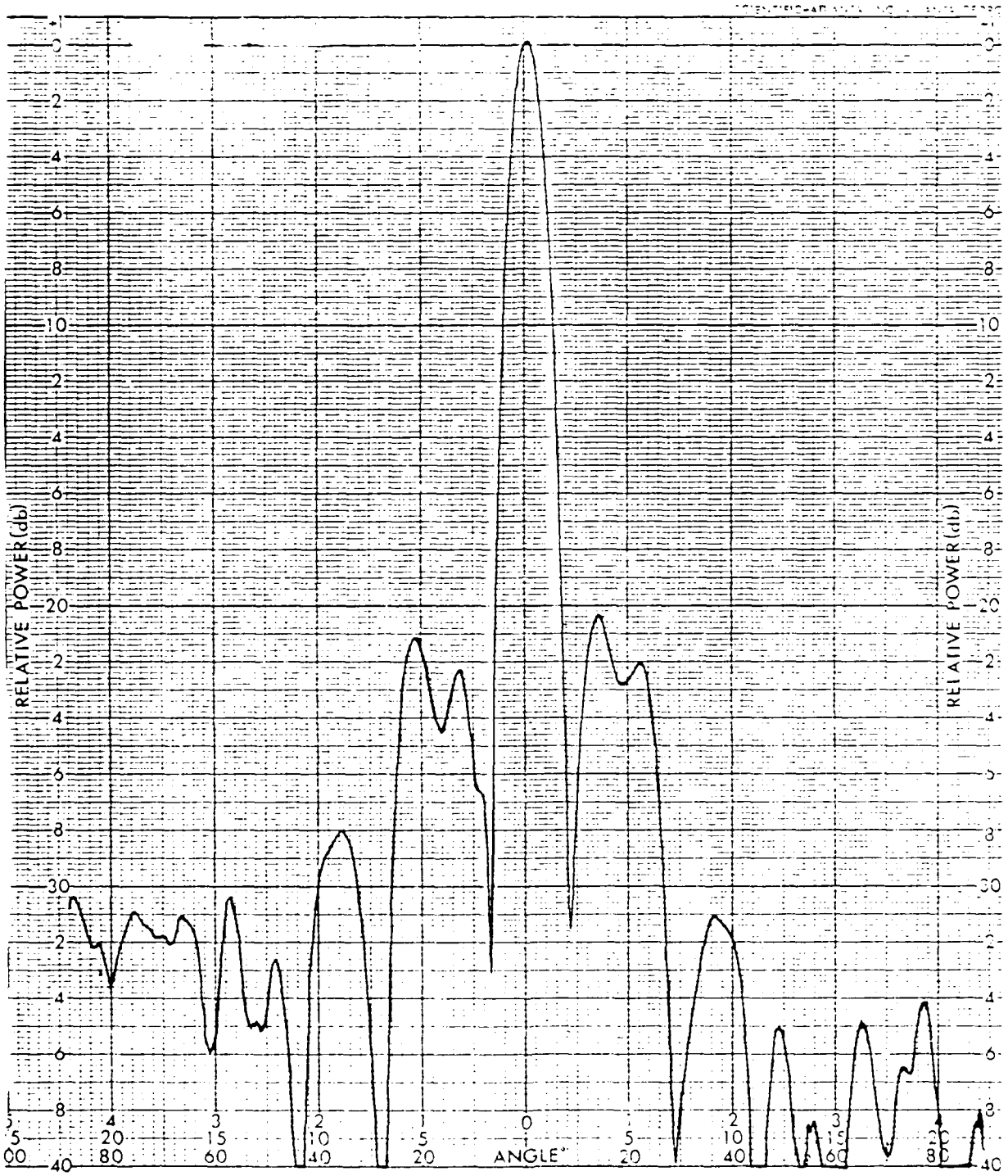


Figure 28. Computed Far Field Pattern - Plates at 0°

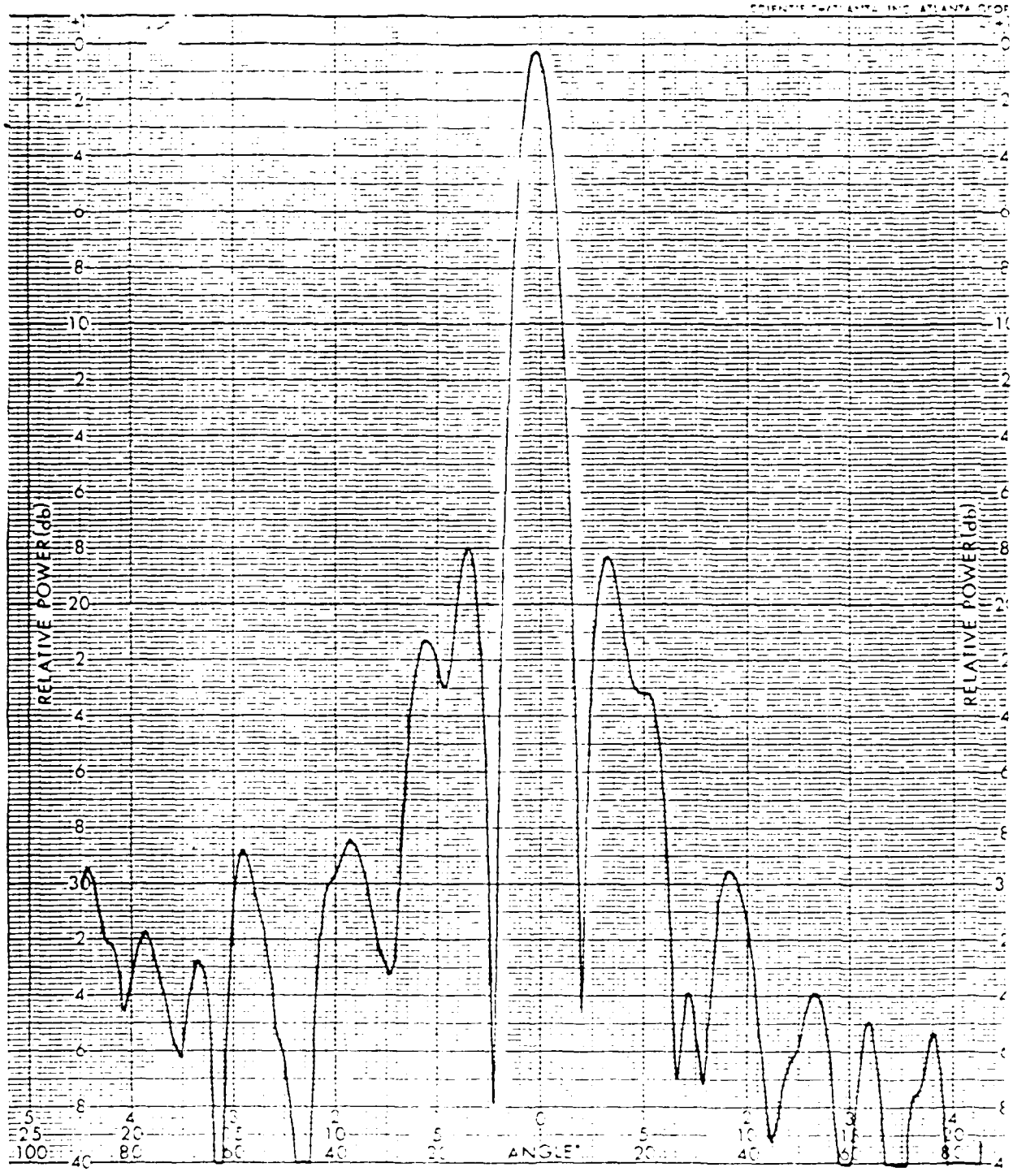


Figure 29. Computed Far Field Pattern - Plates at 90°

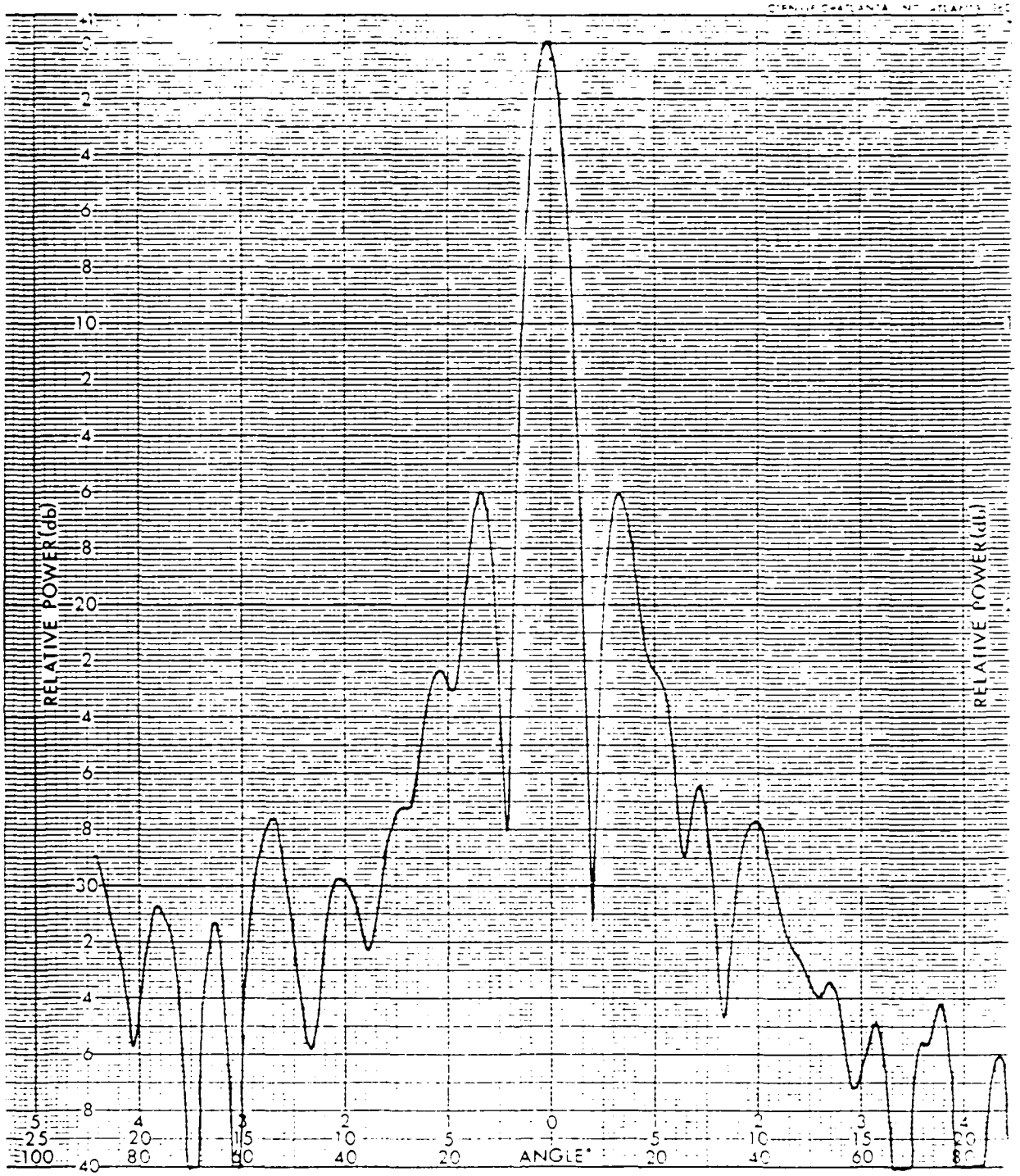


Figure 30. Computed Far Field Pattern - Plates at 135°

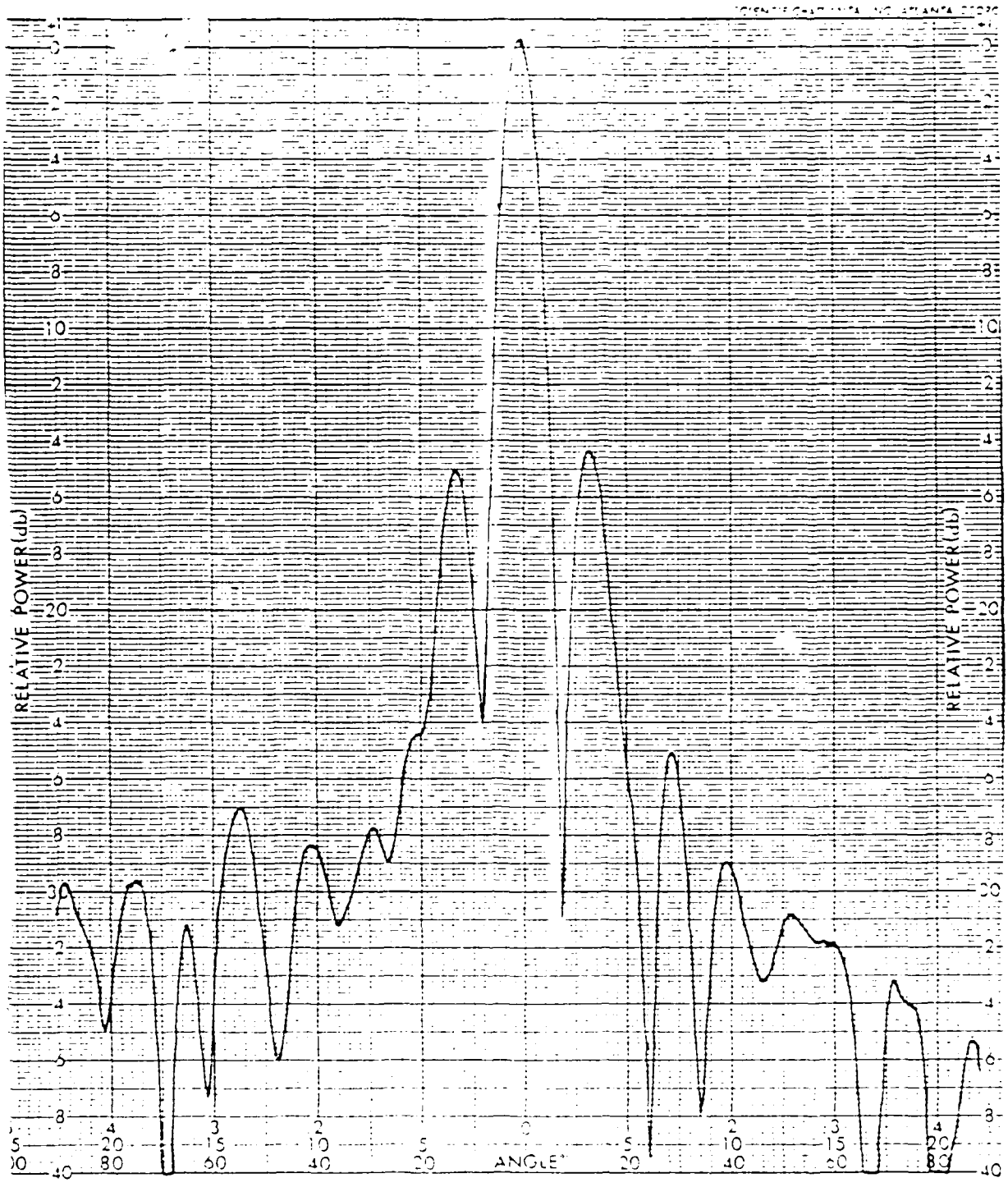


Figure 31. Computed Far Field Pattern - Plates at 225°

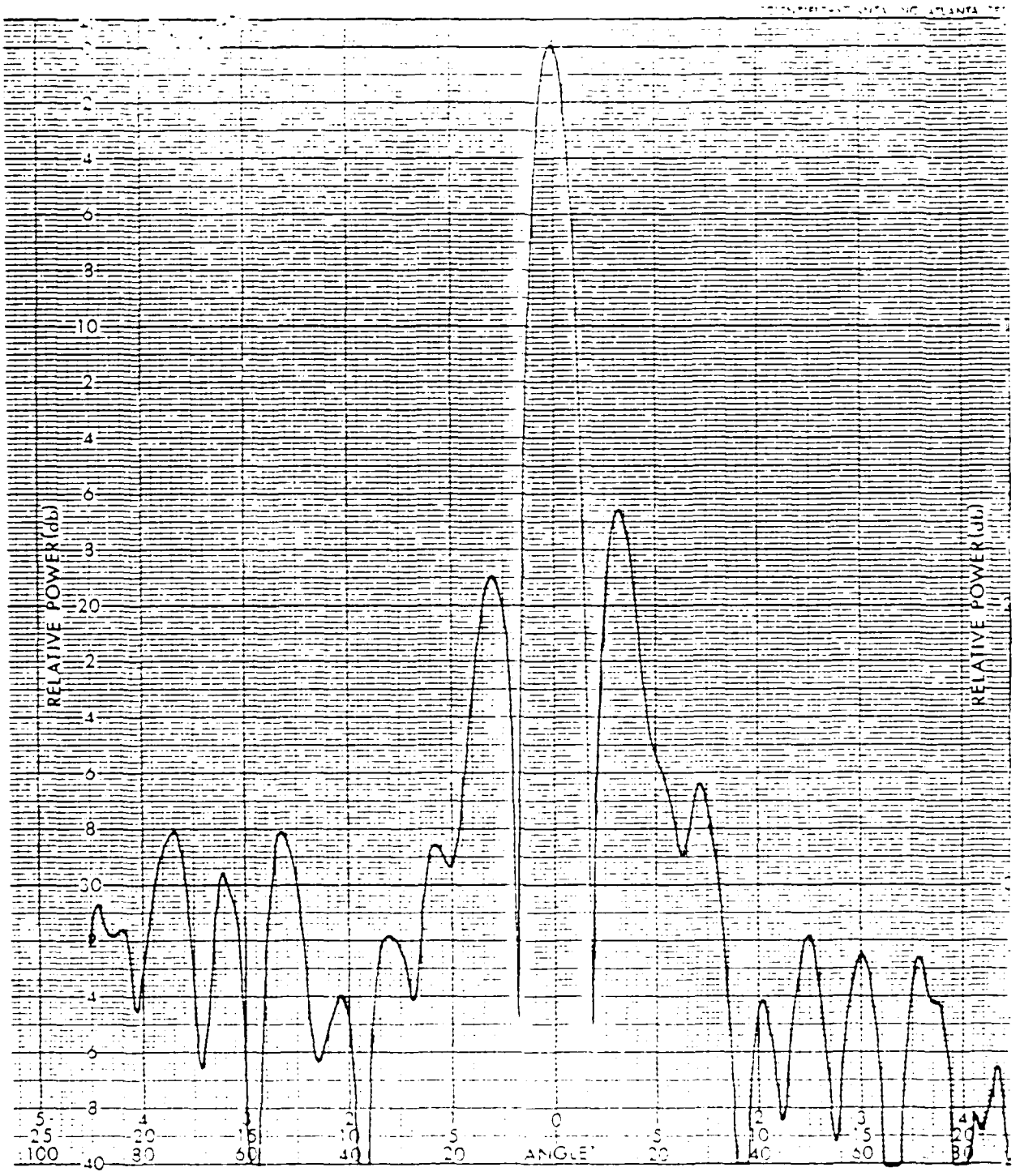


Figure 32. Computed Far Field Pattern - Plates at 360°

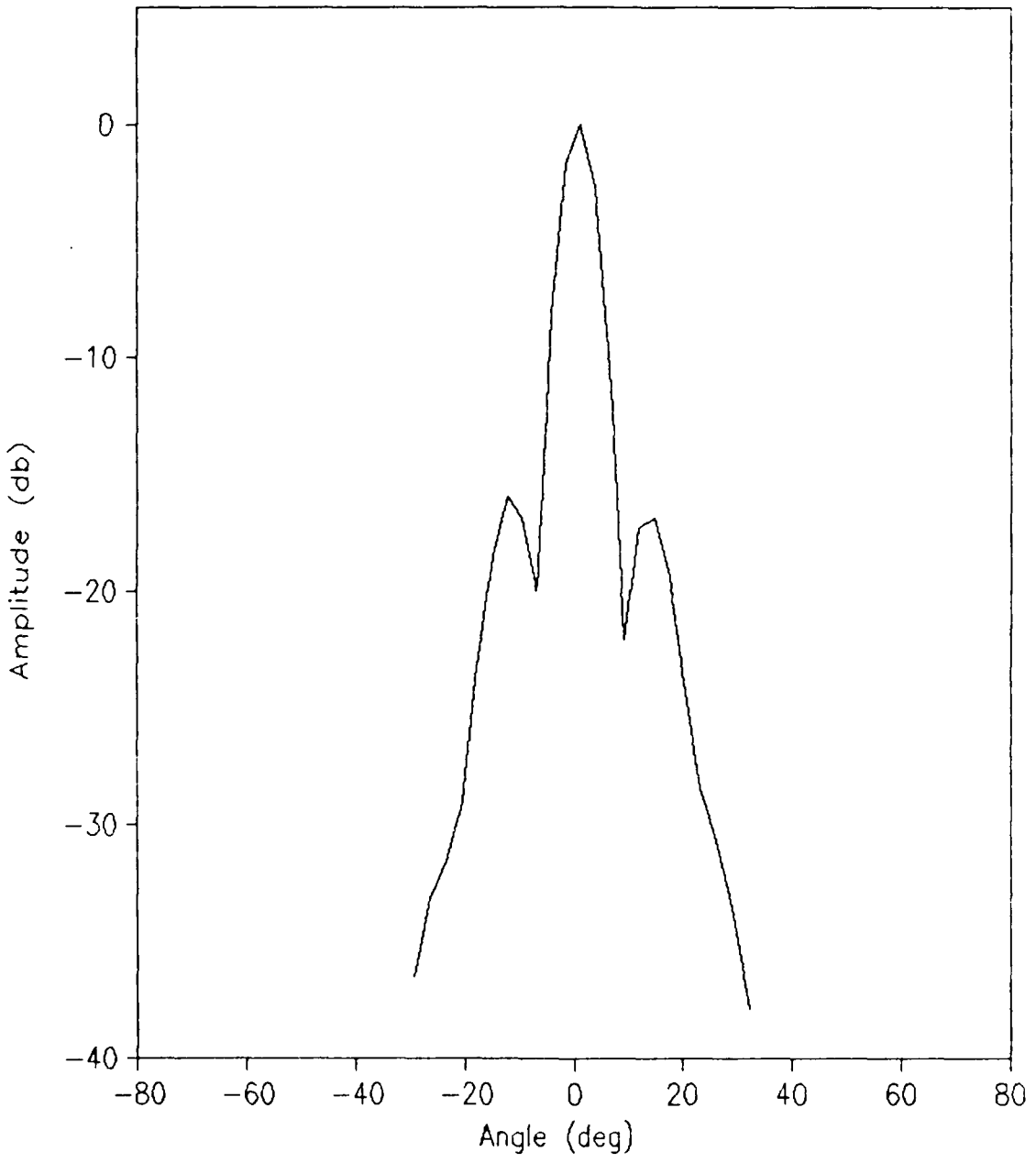


Figure 28. Computed Far Field Pattern - Plates at 0°

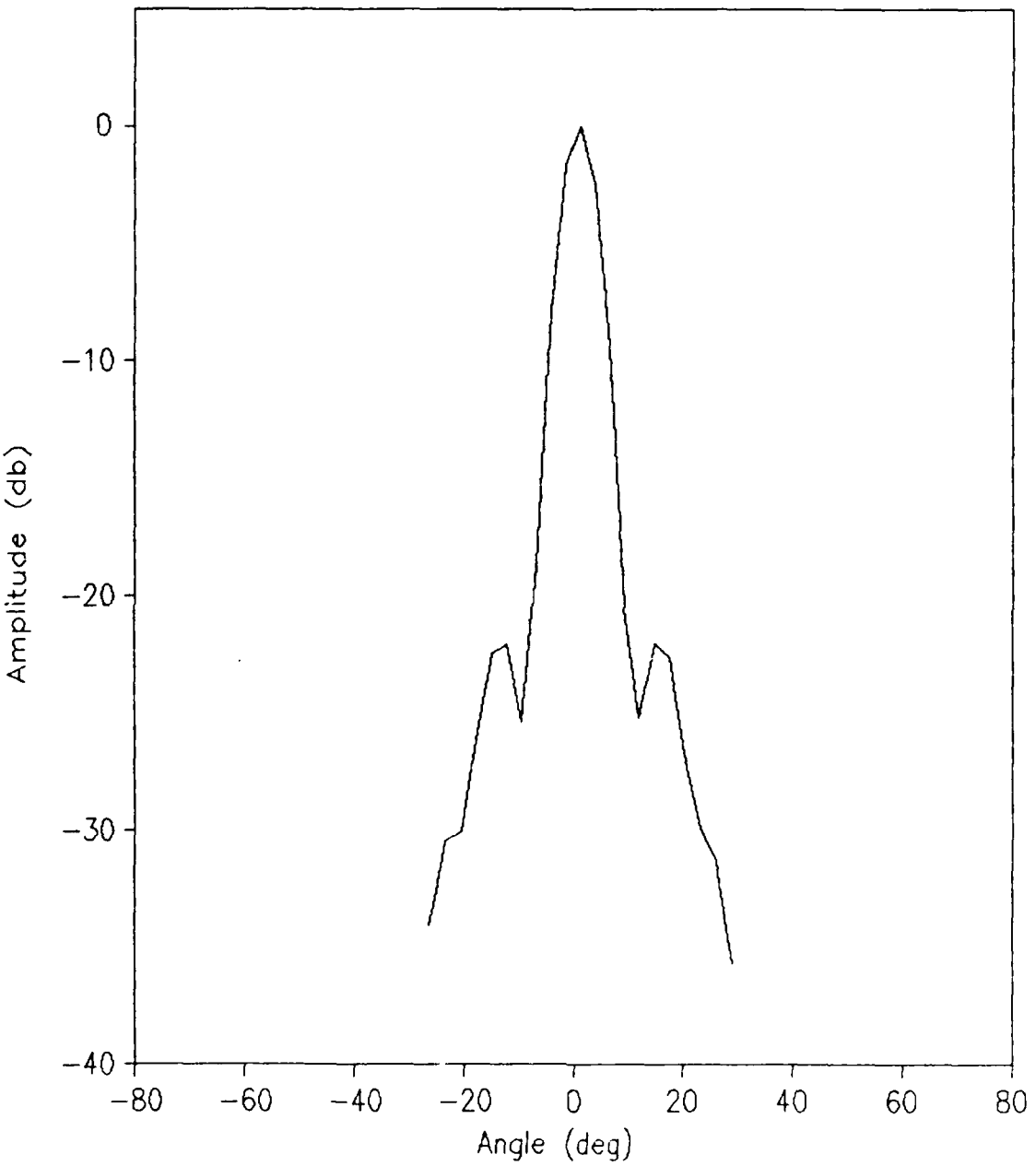


Figure 29. Computed Far Field Pattern - Plates at 90°

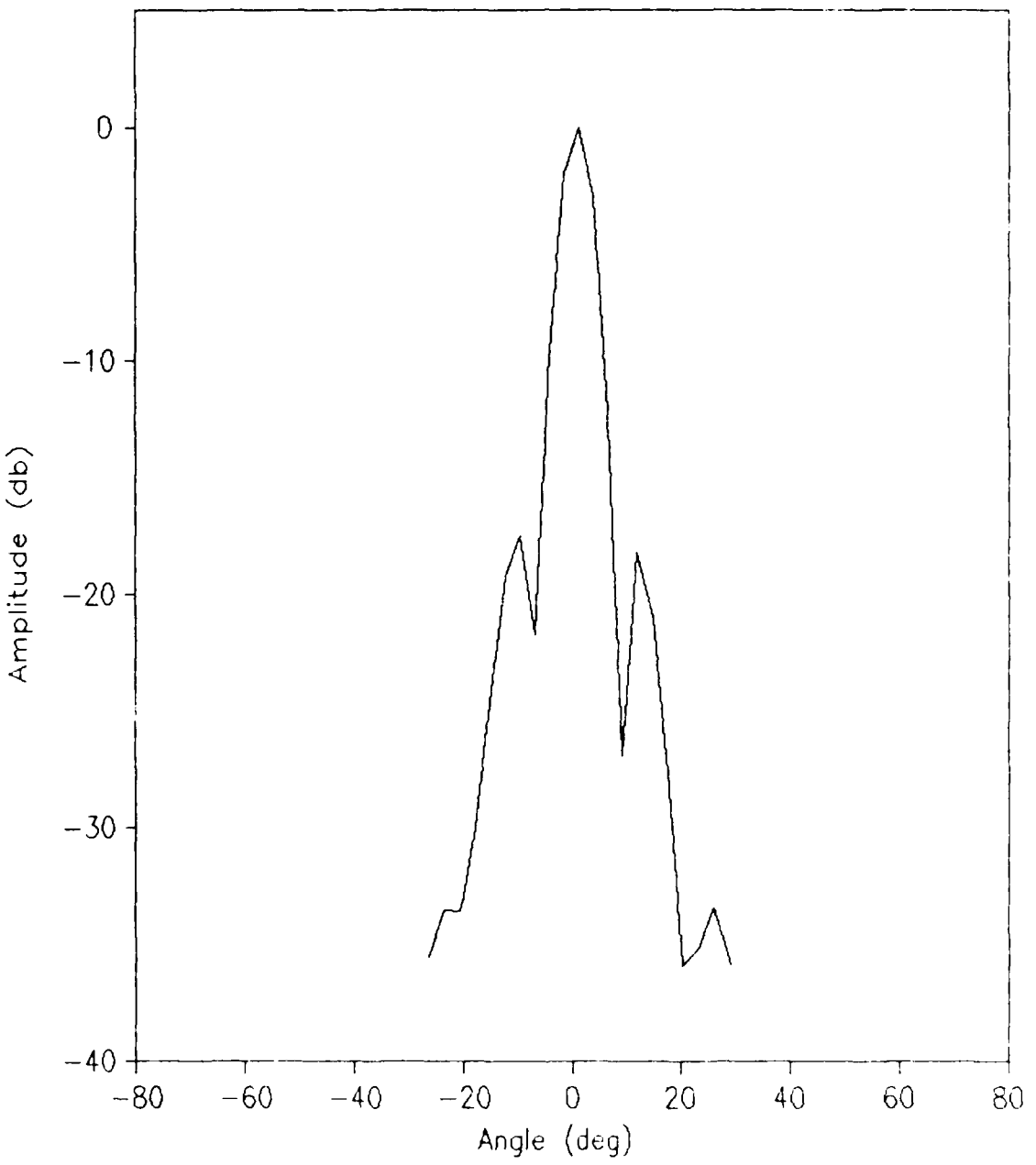


Figure 30. Computed Far Field Pattern - Plates at 135°

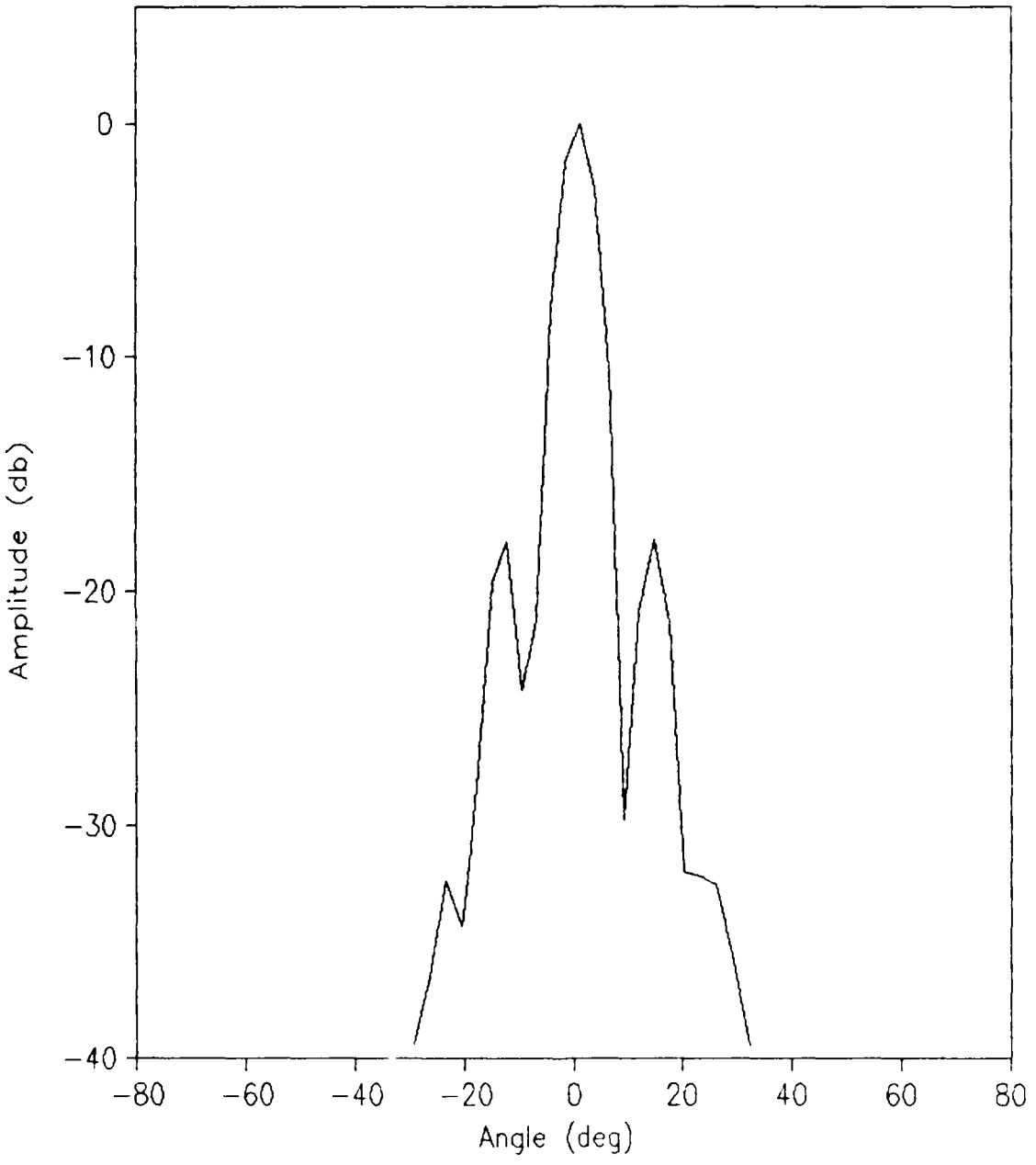


Figure 31. Computed Far Field Pattern - Plates at 225°

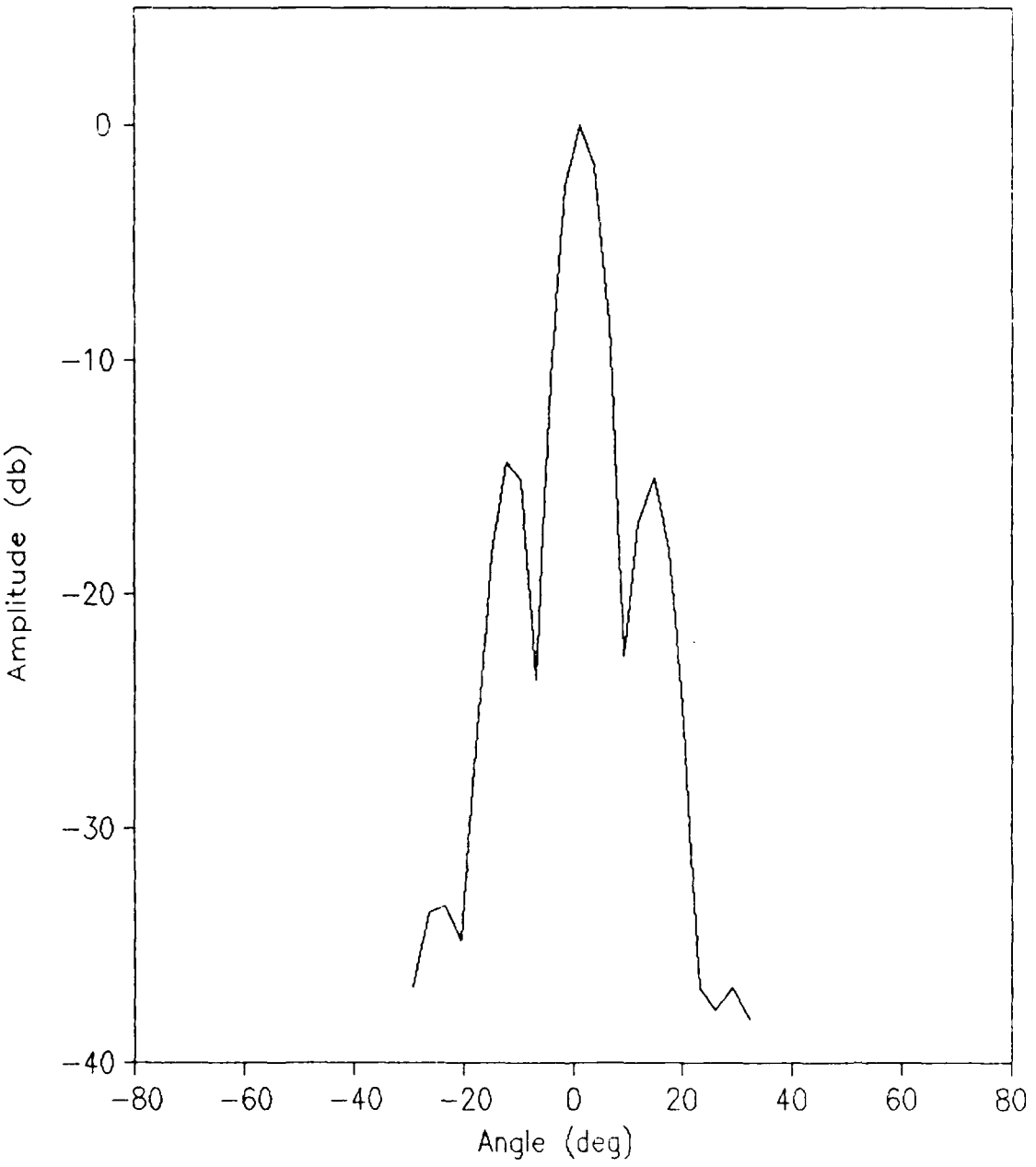


Figure 32. Computed Far Field Pattern - Plates at 360°

V. Recommendations and Suggestions for Further Work

Areas Worthy of Further Investigation

During the course of the investigations into the effects of moveable flat plates on the surface of a parabolic dish antenna some areas where further investigation would be warranted were discovered. Due to time considerations these potentially interesting areas could not be investigated. Aspects that may well prove worthy of further work include:

1. Analyzing whether parasitic fields are set up between the reflector disks and the main reflector and if so how they influence the final results.

2. Considering the effects that different field distributions in the feed horn have on the near field pattern.

3. Introducing the effects that random variations in the surface of the main reflector will cause to the near field.

4. Reducing the size of the parabolic dish so that the region of interest is not on the extreme of the useable data from the FFT.

5. Using disks that can be tilted with respect to their support shaft so that the angular location of the null might be moved.

6. Increasing the size of the disks to determine if further enhancement of the null may be possible or if degradation of the main lobe would be the major effect.

Implementation of Moment Method Technique

In all moment method codes there are essentially three main problems that must be addressed before valid results can be obtained. Firstly the structure must be gridded up so that no segment has a side longer than 1/4 wavelength and the end point co-ordinates for all of these separate segments must be fed to the moment method program. For anything more than very simple structures this procedure must be handled using a computer program. Secondly since only straight lines allowed by the code the most appropriate method of approximating curved structures must

be considered. Finally a model of the antenna feed structure that is able to approximate the salient features of the feed distibution is required. This last requirement can cause some difficulty since the model should account for the feed polarization as well as the overall pattern.

Whether a simplified model can be derived that approximately accounts for all observed effects or whether the method of moments is the only technique that can provide the required accuracy is unclear at the moment.

Appendix A: Development of the FFT Algorithm

$$\mathbb{A}(k_x, k_y) = 2j\sqrt{k^2 - k_x^2 - k_y^2} \int_{-L_y}^{L_y} \int_{-L_x}^{L_x} f(\zeta, \eta)\, e^{-j(k_x\zeta + k_y\eta)}\, d\zeta\, d\eta \quad \text{(A1)}$$

define $g(\zeta, \eta) = f(\zeta - L_x, \eta - L_y)$ then

$$\mathbb{A}(k_x, k_y) = 2j\sqrt{k^2 - k_x^2 - k_y^2} \int_{0}^{2L_y} \int_{0}^{2L_x} g(\zeta, \eta) e^{-j(k_x\zeta + k_y\eta)}\, d\zeta\, d\eta$$

$$\cdot\, e^{j(k_x L_x + k_y L_y)} \quad \text{(A2)}$$

$$= 2j\sqrt{k^2 - k_x^2 - k_y^2}\; e^{j(k_x L_x + k_y L_y)}\, \mathbb{G}(k_x, k_y) \quad \text{(A3)}$$

where $$\mathbb{G}(k_x, k_y) = \int_{0}^{2L_y} \int_{0}^{2L_x} g(\zeta, \eta) e^{-j(k_x\zeta + k_y\eta)}\, d\zeta\, d\eta \quad \text{(A4)}$$

$$\text{let} \quad h_x = \frac{2L_x}{M} \quad \text{(A5)}$$

$$\text{and} \quad h_y = \frac{2L_y}{N} \quad \text{(A6)}$$

where $M = 2^s$ and $N = 2^t$ where M and N are the number of rows and columns in the reference plane respectively.

then

$$\mathbb{G}(k_{x,p}, k_{y,q}) = \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} g(mh_x, nh_y)\, e^{-jk_{x,p}mh_x}$$

$$\cdot\, e^{-jk_{y,q}nh_y}\, h_x\, h_y \quad \text{(A7)}$$

where $p = 0,1,2,\ldots\ldots,M-1$ and $q = 0,1,2,\ldots\ldots,N-1$

To put this into the standard form of an FFT define W_M and W_N as follows:

$$\text{Let } W_M = e^{-j2\pi/M} \quad \text{and} \quad W_N = e^{-j2\pi/N}$$

$$\therefore \quad W_M^{mp} = e^{\frac{-j2\pi}{M} mp} \quad \text{and} \quad W_N^{nq} = e^{\frac{-j2\pi}{N} nq}$$

however in the discrete Fourier integral above (Eq A7) we find that:

$$e^{-jk_{x,p}m\hbar_x} = e^{\frac{-j2\pi}{M} mp} \quad \text{and} \quad e^{-jk_{y,q}n\hbar_y} = e^{\frac{-j2\pi}{N} nq}$$

equating powers provides $k_{x,p}$ and $k_{y,q}$

$$k_{x,p}m\hbar_x = \frac{2\pi}{M} mp \quad \text{and} \quad k_{y,q}n\hbar_y = \frac{2\pi}{N} nq$$

$$\therefore \quad k_{x,p} = \frac{2\pi p}{M\,\hbar_x} \quad \text{and} \quad k_{y,q} = \frac{2\pi q}{N\,\hbar_y}$$

substituting in the values for $\hbar_x$ and $\hbar_y$ produces

$$k_{x,p} = \frac{\pi p}{L_x} \tag{A8}$$

$$\text{and} \quad k_{y,q} = \frac{\pi q}{L_y} \tag{A9}$$

$$\therefore \; k_{x,p} L_x + k_{y,q} L_y = \pi (p + q)$$

$$ie. \; e^{-j(k_{x,p} L_x + k_{y,q} L_y)} = e^{-j\pi(p+q)}$$

$$= (-1)^{(p+q)}$$

substituting these values for W_M^{mp} and W_N^{nq} into the discrete Fourier integral given above (Eq A7) results in the following:

$$G(k_{x,p}, k_{y,q}) = \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} g(m\Delta_x, n\Delta_y)\ W_M^{mp}\ W_N^{nq}\ \Delta_x\ \Delta_y \qquad \text{(A10)}$$

The implementation of Equation A10 is shown in Appendix E. Equations A8 and A9 permit the determination of the maximum values of k_x and k_y.

$p_{max} = M-1 = 127$

$L_x = 1.008$ metres

$q_{max} = N-1 = 63$

$L_y = .66$ metres

$k = 2\pi/\lambda$

$\lambda = c/f$

$c = 3\times10^8$ metres/sec

$f = 3.2\times10^9$ Hz

Substituting the above values into Equations A8 and A9 the following values for k_x/k and k_y/k are obtained :

$k_x/k \in [-2.976, 2.976]$ and $k_y/k \in [-2.271, 2.271]$

Appendix B: Development of an Analytical Model

Consider the situation firstly from the point of view of tracing rays from the focus of the parabolic dish antenna to the surface of the dish.

Suppose that the focus is at the origin and the distance to the directrix of the parabola is d. Since this model is to be compared to the experimentally derived results let us consider that there is a measurement plane a distance h away from the origin and parallel to the x-axis as shown in Figure 38. We can now write the equation of the parabola in polar form as follows:

$$r = g(\theta) = \frac{d}{1 - \sin \theta} \qquad \text{(B1)}$$

where r is the distance from the focus to the surface of the parabolic surface and θ is the angle measured clockwise from the x-axis.

Now to define the distance of the reference plane from the surface of the parabola we need to first note that the distance from the x-axis to the parabolic surface is $-r \sin \theta$ therefore the distance to the reference plane is $h + (-r \sin \theta)$

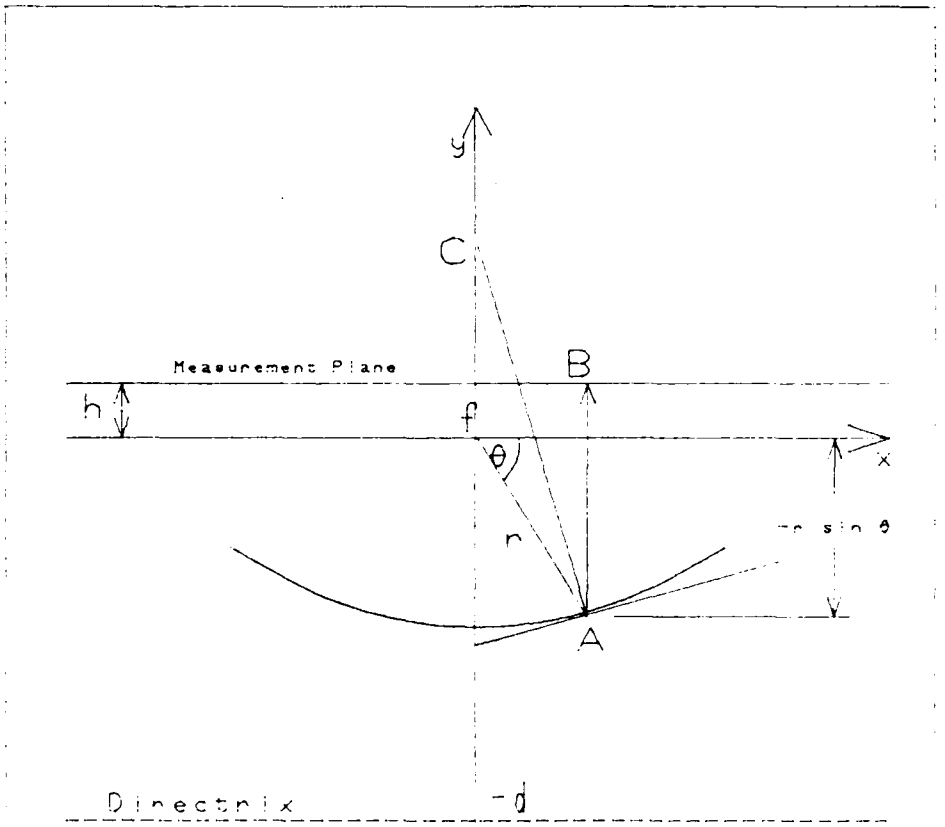


Figure 38. Dish Antenna Geometry

therefore the distance travelled by any ray from the focus to the measurement plane is

$$D = r + h - r \sin \theta$$

$$D = h + r\,(1 - \sin \theta)$$

Using Equation (1) here, we obtain,

$$D = h + \frac{d}{1 - \sin \theta}\,(1 - \sin \theta)$$

$$D = h + d \qquad \text{(B2)}$$

ie. D is a constant value independent of θ which was expected since a wave of constant phase should be reflected from the surface of a parabolic surface.

The next step is to find the gradient of a tangent to the surface of the parabola at any point. Note that this will be the gradient of the moveable flat plate which moves up from the surface of the parabola since it is mounted on a shaft which is perpendicular to the surface at this point. (See Figure 38)

Suppose that the angle from positive direction of the x-axis to the general point (x,y) is θ_0 then

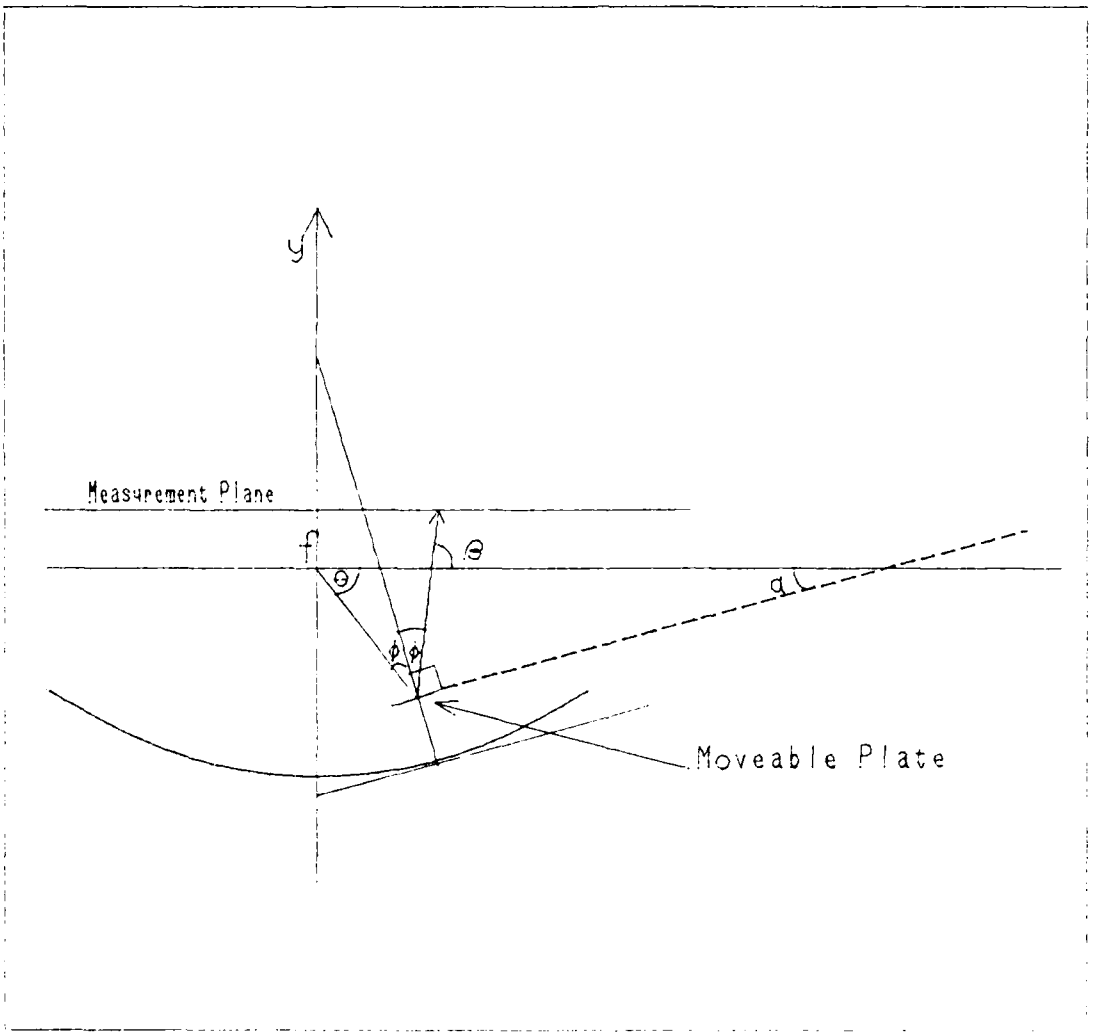


Figure 39. Ray Reflected from Moveable Plate

$$\frac{dy}{dx} = \frac{dy/d\theta}{dx/d\theta}\Bigg|_{\theta = \theta_0}$$

now $x = r\cos\theta$, $y = r\sin\theta$ and $r = \frac{d}{1 - \sin\theta}$

$$\therefore x(\theta) = \frac{d\cos\theta}{1 - \sin\theta} \quad \text{and} \quad y(\theta) = \frac{d\sin\theta}{1 - \sin\theta}$$

firstly to find the value of $dx/d\theta$

$$\frac{dx}{d\theta} = \frac{d\cos\theta(-\cos\theta) + d(1 - \sin\theta)\sin\theta}{(1 - \sin\theta)^2}$$

$$= \frac{-d\cos^2\theta + d\sin\theta - d\sin^2\theta}{(1 - \sin\theta)^2}$$

$$= \frac{-d(\sin^2\theta + \cos^2\theta) + d\sin\theta}{(1 - \sin\theta)^2}$$

$$\frac{dx}{d\theta} = \frac{d(\sin\theta - 1)}{(1 - \sin\theta)^2}$$

now to find $dy/d\theta$

$$\frac{dy}{d\theta} = \frac{d\sin\theta(-\cos\theta) - d(1 - \sin\theta)\cos\theta}{(1 - \sin\theta)^2}$$

$$= \frac{-d\sin\theta\cos\theta - d\cos\theta + d\cos\theta\sin\theta}{(1 - \sin\theta)^2}$$

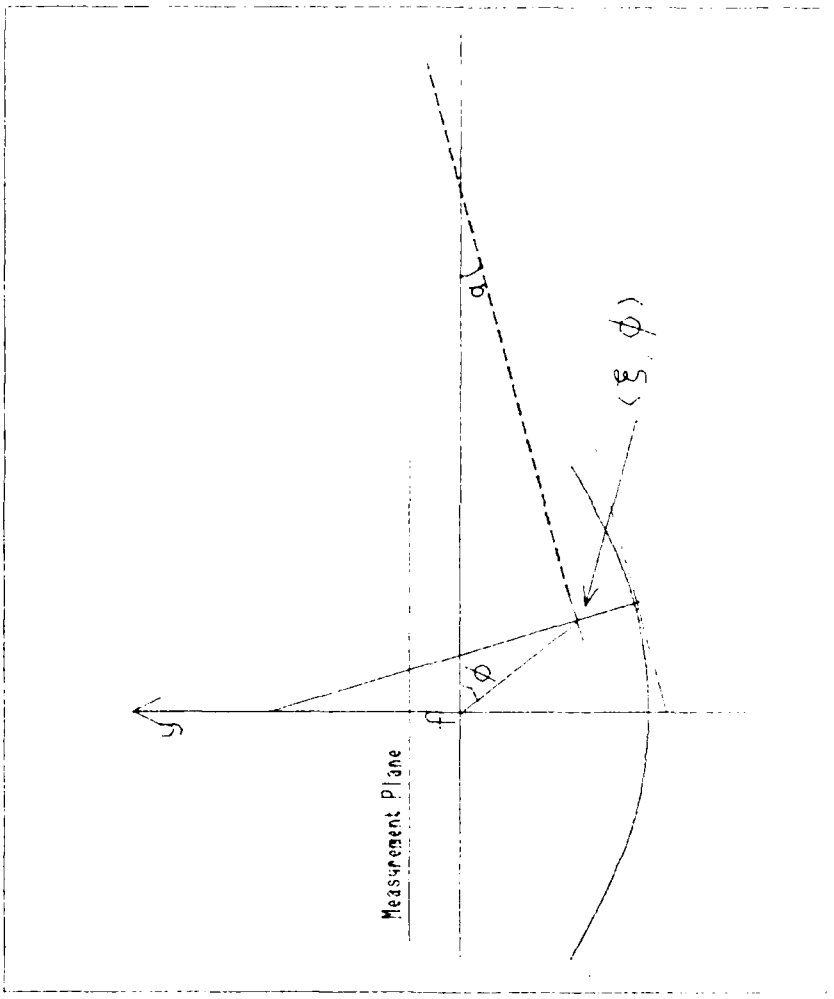


Figure 40. Polar Representation of Point on Plate

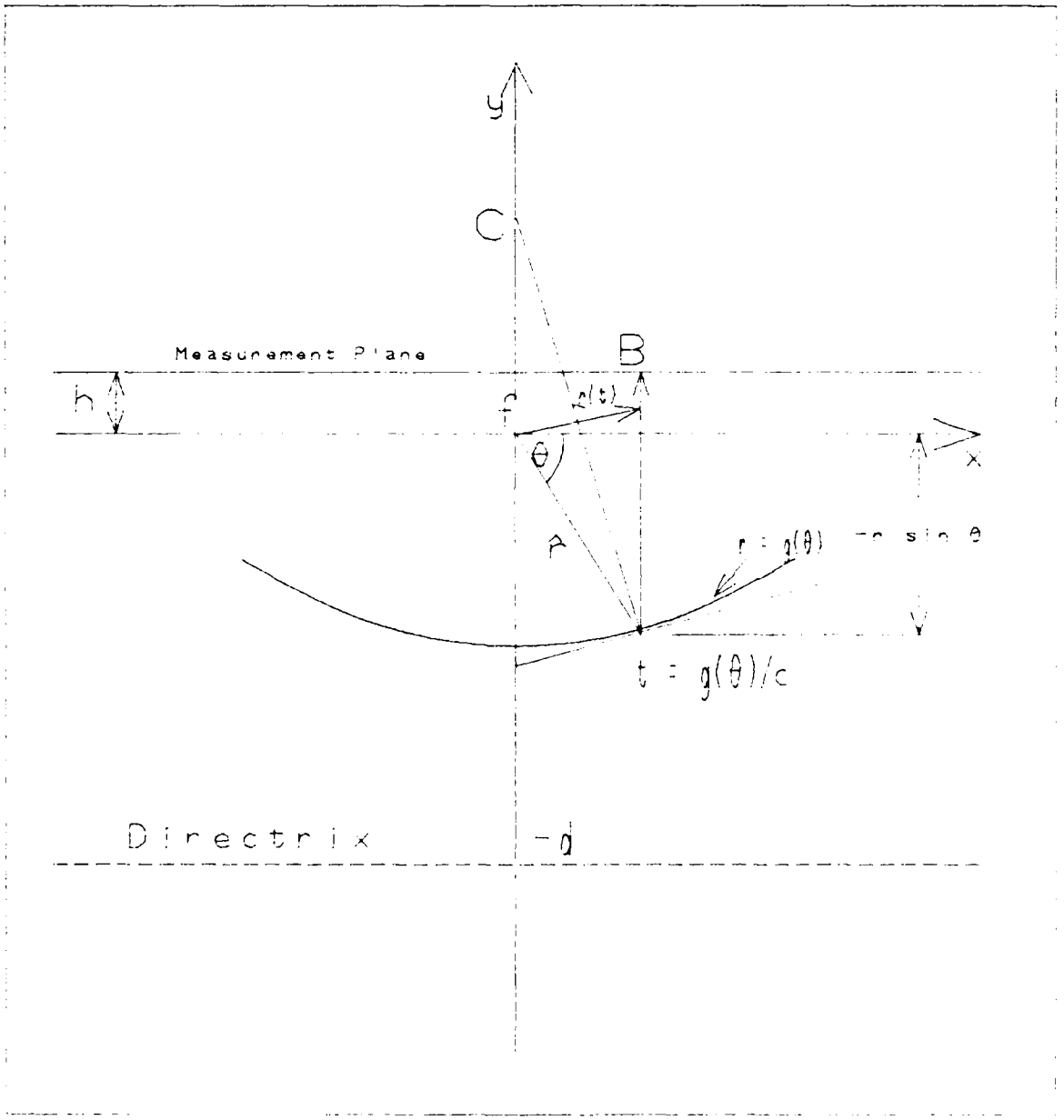


Figure 41. Constant Phase Ray

$$\frac{dy}{d\theta} = \frac{-d\cos\theta}{(1-\sin\theta)^2}$$

$$\therefore \quad \frac{dy}{dx} = \frac{-d\cos\theta}{(1-\sin\theta)^2} \cdot \frac{(1-\sin\theta)^2}{d(\sin\theta - 1)}$$

$$\therefore \quad \frac{dy}{dx} = \frac{dy/d\theta}{dx/d\theta}\Bigg|_{\theta=\theta_0} = \frac{\cos\theta_0}{1-\sin\theta_0} \qquad \text{(B3)}$$

Which gives the gradient of the tangent at $(g(\theta_0),\theta_0)$.

The next thing to consider is the effect of the moveable flat plates on rays coming from the focus. Firstly considering a ray that strikes the center of the plate and reflects towards the measurement plane. (See Figure 39)

$$\beta + 2\phi - \theta = \pi \qquad \text{(B4)}$$

$$(\pi - \beta) + (\pi/2 - \phi) + \alpha = \pi \qquad \text{(B5)}$$

$$\alpha - \beta + \pi/2 = \phi$$

Substituting into equation (B4) for ϕ we obtain

$$\beta + 2\alpha - 2\beta + \pi - \theta = \pi$$

$$2\alpha - \theta = \beta \qquad \text{(B6)}$$

However equation (B3) above gives the value of the tangent of α

$$\tan \alpha = \frac{\cos \theta}{1 - \sin \theta} \qquad \text{(B7)}$$

Using equation (B6) to find the value tan β

$$\tan \beta = \tan (2\alpha - \theta)$$

$$= \frac{\tan 2\alpha - \tan \theta}{1 + \tan 2\alpha \tan \theta}$$

$$= \frac{\left\{\dfrac{2 \tan \alpha}{1 - \tan^2 \alpha}\right\} - \tan \theta}{1 + \left\{\dfrac{2 \tan \alpha \tan \theta}{1 - \tan^2 \alpha}\right\}}$$

$$= \frac{2 \tan \alpha - ((1 - \tan^2 \alpha) \tan \theta)}{1 - \tan^2 \alpha + 2 \tan \alpha \tan \theta}$$

Substituting in the value for tan α from equation (B7) above, we obtain

$$\tan \beta = \frac{2(1 - \sin \theta)(\cos \theta) - (1 - \sin \theta)^2 \tan \theta + \sin \theta \cos \theta}{(1 - \sin \theta)^2 - \cos^2 \theta - 2 \sin \theta (1 - \sin \theta)}$$

Considering the situation depicted in Figure (40).

The next step is to find the equation defining the line of which the flat plate is a line segment. Let (ζ, ϕ) be the polar co-ordinates of a general point on the line. The line segment can be defined to exist between θ_1 and θ_2 *ie.*

$$\phi \in [\theta_1 , \theta_2]$$

From equation (B3) we have the gradient of the line segment

$$\therefore \quad \frac{y - \zeta \sin \phi}{x - \zeta \cos \phi} = \tan \alpha \qquad \text{(B8)}$$

into which the equations in polar co-ordinates for x and y can be substituted as follows:

$$\frac{r \sin \theta - \zeta \sin \phi}{r \cos \theta - \zeta \cos \phi} = \frac{\sin \alpha}{\cos \alpha}$$

$$\cos \alpha (r \sin \theta - \zeta \sin \phi) = \sin \alpha (r \cos \theta - \zeta \cos \phi)$$

$$r (\cos\alpha \sin\theta - \sin\alpha \cos\theta) = \zeta (\cos\alpha \sin\phi - \sin\alpha \cos\phi)$$

$$r \sin (\alpha - \theta) = \zeta \sin (\alpha - \phi)$$

$$r = \frac{\zeta \sin (\alpha - \phi)}{\sin (\alpha - \theta)} \qquad \text{(B9)}$$

Also, from (B8) $$r = \frac{\zeta (\sin \phi - \tan \alpha \cos \phi)}{(\sin \theta - \tan \alpha \cos \theta)} \qquad \text{(B10)}$$

Considering next a constant phase ray as it scatters from the parabola described by equation (B1).

$$\underset{\sim}{r}(t) = \begin{cases} ct \langle \cos\theta, \sin\theta \rangle & 0 \le t \le g(\theta)/c \\ \hat{r} + (ct - g(\theta)) \langle 0,1 \rangle & t > g(\theta)/c \end{cases}$$

where $\hat{r} = g(\theta) \langle \cos\theta, \sin\theta \rangle$

Next, consider a constant phase front ray as it scatters from the line segment described by equation (B9).

$$\text{let} \quad h(\theta) = r = \frac{\zeta \sin(\alpha - \phi)}{\sin(\alpha - \theta)}$$

$$\underset{\sim}{r}(t) = \begin{cases} ct \langle \cos\theta, \sin\theta \rangle & 0 \le t \le h(\theta)/c \\ \hat{s} + (ct - h(\theta)) \langle \cos\beta, \sin\beta \rangle & t > h(\theta)/c \end{cases}$$

where $\hat{s} = h(\theta) \langle \cos\theta, \sin\theta \rangle$

and β is defined in equation (B6) as $\beta = 2\alpha - \phi$

However if the line segment is defined to lie between $\theta \in [\theta_1, \theta_2]$ then we have

$$\underset{\sim}{r}(t,\theta) = \left\{ \begin{array}{ll} ct \langle \cos\theta, \sin\theta \rangle & \forall\, t > 0, \quad \theta \notin [\theta_1, \theta_2] \\ ct \langle \cos\theta, \sin\theta \rangle & 0 \le t \le h(\theta)/c \\ \hat{s} + (ct - h(\theta)) \langle \cos(2\alpha - \phi), \sin(2\alpha - \phi) \rangle, t > h(\theta)/c & \end{array} \right\} \theta \in [\theta_1, \theta_2]$$

$$\underset{\sim}{r}(t) = \begin{cases} ct\, e^{j\theta} & 0 \le t \le h(\theta)/c \\ h(\theta)\, e^{j\theta} + (ct - h(\theta)) e^{j\beta} & t > h(\theta)/c \end{cases}$$

where the distance from the x-axis to the reference plane is

$$d = \text{Im}\{h(\theta)e^{j\theta} + (ct - h(\theta))e^{j\beta}\}$$

$$= h(\theta)\sin\theta + (ct - h(\theta))\sin(2\alpha - \phi)$$

and the path length from the focus to the reference plane is

$$ct = \frac{d - h(\theta)\sin\theta}{\sin(2\alpha - \phi)} + h(\theta)$$

The next step is to find the boundaries of the regions indicated in Figure 43. Noting that the center of the plate is defined by $T(\zeta,\phi)$, its cartesian co-ordinates are

$$x \text{ co-ordinate} = \zeta\cos\phi$$

$$y \text{ co-ordinate} = \zeta\sin\phi$$

now the co-ordinates of R and S can be written in cartesian co-ordinates as follows:

$$R(\zeta\cos\phi - k/2\cos\alpha,\ \zeta\sin\phi - k/2\sin\alpha)$$

$$S(\zeta\cos\phi + k/2\cos\alpha,\ \zeta\sin\phi + k/2\sin\alpha)$$

where k is the diameter of the moveable plate and α is the gradient of the plate. Now finding the co-ordinates of B and D:

let $y_1 = \zeta \sin \phi + k/2 \sin \alpha$ and $y_2 = \zeta \sin \phi - k/2 \sin \alpha$

where y_1 and y_2 are the y co-ordinates of S and R respectively

$D(\zeta \cos \phi + k/2 \cos \alpha + (y_1 + D)/\tan \beta_1, D)$

$B(\zeta \cos \phi - k/2 \cos \alpha + (y_2 + D)/\tan \beta_2, D)$

$A(\zeta \cos \phi - k/2 \cos \alpha, D)$

$C(r \cos \theta_1, D)$ where $r = d/(1 - \sin \theta)$ and β_1 and β_2 are the angles that rays bouncing from the extreme edges at S R respectively make with the positive x direction.

The point T is defined by its distance above the surface of the parabola (B1) therefore T needs to be available in terms of this variable.

The gradient of the tangent is $\cos \theta_0/(1 - \sin \theta_0)$ therefore the gradient of the shaft to which the plate is attached will be

$$\gamma = \tan^{-1}(-(1 - \sin \theta_0)/\cos \theta_0)$$

where γ is the angle that the perpendicular makes with the x-axis.

therefore the co-ordinates of T are as follows:

$T(r \cos \theta_0 - l \sin (\gamma - 90), -r \sin \theta_0 - l)$

Appendix C: Near Field Measurement Control Program

```
50
52      !  THIS PROGRAM WAS USED TO CONTROL THE NEAR FIELD EXPERIMENT CONDUCTED
53      ! FOR GLEN THORPE IN THE SUMMER OF 1987.
54      !
55      ! THE PROGRAM:
56      !
58      !       A)  CONTROLS THE TWO DIM SCAN (X,Y) OF AN APERATURE PROBE.
60      !
61      !       B)  READS AND STORES DATA FROM THE SCIENTIFIC ATLANTA 1783
62      !       PHASE AMPLITUDE RECEIVER, CONTROL UNIT.
63      !
64      !       C)  CONTROLS THE MOVEMENT OF TED DISC LOCATED ON A FOUR FOOT
65      !       DISH.
66      !
70      !*************************************************************************
80      OPTION BASE 1
100     DIM Amp(128),Phase(128)
110     PRINTER IS 1
120     INTEGER Fts,Np,Vpos,Hpos,Hstpp,Vstpp,Dirh,Dirv,Hstp,Vstp,Motor,K
121     !
122     !THE NEXT FEW LINES ARE USED TO SET UP THE RUN
123     !
130     PRINT "THE PROBE MOVES HORIZONTALLY FROM POS1(LEFT) TO POS128(RIGHT)"
140     INPUT "INPUT THE PRESENT HOR LOCATION ",Mota
150     PRINT "THE PROBE MOVES VERTICALLY FROM POS 1(LOWEST) TO POS 64(HIGHEST)"
160     INPUT "INPUT THE PRESENT VERT LOCATION ",Motb
170     INPUT "INPUT THE PRESENT DISC POSITION",Dsc
180     INPUT "DO YOU WANT TO MOVE DISC BEFORE THE RUN (Y/N)",Yn$
190     IF Yn$="N" THEN 210
200     CALL Dscmov(Dsc)
210     INPUT "DO YOU WISH TO SET POWER AT A SPECIFIC LOCATION (Y/N)",A$
220     IF A$="N" THEN 550
230     IF A$<>"Y" THEN 210
240     ON KEY 5 LABEL "PROBE LEFT" GOTO 300
250     ON KEY 6 LABEL "PROBE DOWN" GOTO 420
260     ON KEY 0 LABEL "RET. TO MAIN" GOTO 550
270     ON KEY 7 LABEL "PROBE RIGHT" GOTO 340
280     ON KEY 1 LABEL "PROBE UP" GOTO 380
290     GOTO 240
300     A=4
310     Stp=491
320     Mota=Mota-1
330     GOTO 450
340     A=3
350     Stp=491
360     Mota=Mota+1
370     GOTO 450
380     A=2
390     Stp=740
400     Motb=Motb+1
410     GOTO 450
420     A=1
430     Stp=740
440     Motb=Motb-1
450     Motor=2^A-1
460     ASSIGN @Gpib TO 12;FORMAT OFF
```

```
470     FOR K=1 TO Stp
480       OUTPUT @Gpio USING "#,W";Motor
490       OUTPUT @Gpio;0
500       WAIT .0025
510     NEXT K
520     PRINT "HORIZONTAL LOCATION =";Mota,"VERTICAL LOCATION =";Motb
530     LOCAL 703
540     GOTO 240
550     INPUT "DO YOU WISH TO REPOSITION THE PROBE(Y/N)",A$
560     IF A$="N" THEN 590
570     IF A$<>"Y" THEN 550
580     CALL Motmov(Mota,Motb)
590     Vpos=64
600     Dirv=1
610     Vstpp=1
620     Dirh=1
630     Hpos=128
640     Hstpp=1
650     E=Mota
660     IF Motb=64 THEN
670       Dirv=1
680       Vpos=1
690       Vstpp=-1
700     END IF
710     IF Motb=1 THEN
720       Dirv=1
730       Vpos=64
740       Vstpp=1
750     END IF
760     F=Motb
770     ON KEY 2 LABEL "END PROG" GOTO 1630
780     FOR Posb=F TO Vpos STEP Vstpp
790       IF Mota=128 THEN Dirh=4
800       IF Mota=128 THEN Hpos=1
810       IF Mota=128 THEN Hstpp=-1
820       IF Mota=1 THEN Dirh=1
830       IF Mota=1 THEN Hpos=128
840       IF Mota=1 THEN Hstpp=1
850       FOR Posa=E TO Hpos STEP Hstpp
860         Mota=Posa
870         Motb=Posb
880         PRINT "HORIZONTAL =";Mota,"VERTICAL =";Motb,"DISC POSITION=";Dsc
881         !
882         !THE NEXT SET OF CODE READS THE S/A 1780
883         !
890         ASSIGN @Gpio TO 12;FORMAT OFF !\
900         ASSIGN @R TO 703
910         REMOTE @R
920         OUTPUT @R;"W1"
930         OUTPUT @R;"68765"
940         CLEAR @R
950         WAIT .1
960 Tg:     TRIGGER @R
970 Stat:   Istat=SPOLL(7)
980         IF BIT(Istat,7)=1 AND B.T(Istat,4)=1 THEN Bad
990         IF BIT(Istat,7)=1 THEN Stat
1000        IF BIT(Istat,5)=1 THEN Stat
1010        ENTER @R;A,B,C,Ac,Bc
1030        Amp(Posa)=A
1040        Phase(Posa)=Ac
```

```
1050        GOTO Okay
1060 Bad:   WAIT .5
1070        Ser=SPOLL(709)
1080        PRINT "RECEIVER IS WORKING INCORRECTLY.  ERROR NUMBER IS ";Ser
1090        LOCAL 709
1100        PRINT "PRESS CONTINUE ONCE ERROR IS FOUND"
1110        BEEP
1120        PAUSE
1130        CLEAR @R
1140        GOTO Tg
1150 Okay:  !
1151        !
1152        !NEXT MOVE THE PROBE HOEIZONTALLY
1153        !
1160        Motor=2^(Dirh-1)
1170        FOR K=1 TO 491
1180          OUTPUT @Gpio USING "#,W":Motor
1190          OUTPUT @Gpio;0
1200          WAIT .0025
1210        NEXT K
1220        WAIT .5
1230      NEXT Posa
1231      !
1232      !NEXT STOR THE DATA IN THE PROPER MASS STORAGE DEVICE
1233      !
1240      IF Dsc=360 THEN
1250        CALL Dataf1(Amp(*),Phase(*),128,Motb,Dsc)
1260      END IF
1270      IF Dsc=225 THEN
1280        CALL Dataf2(Amp(*),Phase(*),128,Motb,Dsc)
1290      END IF
1300      IF Dsc=315 THEN
1310        CALL Dataf3(Amp(*),Phase(*),128,Motb,Dsc)
1320      END IF
1330      Motor=2^(Dirv-1)
1331      !
1332      !NOW MOVE THE PROBE VERTICALLY
1333      !
1340      FOR K=1 TO 742
1350        OUTPUT @Gpio USING "#,W":Motor
1360        OUTPUT @Gpio;0
1370        WAIT .0025
1380      NEXT K
1390      E=Mota
1400    NEXT Posb
1410    IF Dsc=360 THEN 1610
1420    Dsc=Dsc+45
1430    Dsca=1
1440    Dscb=4
1450    ASSIGN @Gpio TO 15;FORMAT OFF
1460    Motor=2^(Dsca-1)
1470    FOR K=1 TO 568
1480      OUTPUT @Gpio USING "#,W":Motor
1490      OUTPUT @Gpio;0
1500      WAIT .0025
1510    NEXT K
1520    Motor=2^(Dscb-1)
1530    FOR K=1 TO 568
1540      OUTPUT @Gpio USING "#,W":Motor
1550      OUTPUT @Gpio;0
```

```
1560    WAIT .0025
1570  NEXT K
1580  ASSIGN @Gpio TO 12;FORMAT OFF
1590  PRINT "THE CURRENT DISC POSITION IS";Dsc
1600  GOTO 560 ! ONE MORE TIME
1610  PRINT "DATA IS COMPLETE"
1620  BEEP 2000,.5
1630  END
1640  SUB Dataf1(Amp(*),Phase(*),Npts,Motb,Dsc)
1650    !*************************************************************************
1660    !THIS SUBPROGRAM SETS UP A DATA FILE CONSISTING OF THE AMPLITUDE AND    *
1670    !              PHASE DATA RECORDED IN THE MAIN PROGRAM                  *
1680    !*************************************************************************
1690    CREATE BDAT "D_"&VAL$(Motb)&"_"&VAL$(Dsc)&":INTERNAL,4,0",Npts,16
1700    ASSIGN @P TO "D_"&VAL$(Motb)&"_"&VAL$(Dsc)&":INTERNAL,4,0"
1710    OUTPUT @P;Amp(*),Phase(*)
1720    ASSIGN @P TO *
1730    PRINT "DATA_";Motb;"HAS BEEN CREATED"
1740  SUBEND
1750  SUB Motmov(Mota,Motb)
1760    ASSIGN @Gpio TO 12;FORMAT OFF
1770    INPUT "INPUT THE NEW HORIZONTAL LOCATION FOR THE PROBE",Hnew
1780    Hstp=1
1790    Dirh=3
1800    INPUT "INPUT THE REQUIRED VERTICAL LOCATION FOR THE PROBE",Vnew
1810    Vstp=1
1820    Dirv=2
1830    IF Mota-Hnew>0 THEN Hstp=-1
1840    IF Mota-Hnew>0 THEN Dirh=4
1850    IF Motb-Vnew>0 THEN Vstp=-1
1860    IF Motb-Vnew>0 THEN Dirv=1
1870    IF Mota-Hnew=0 THEN 1970
1880    FOR Mota=Mota TO Hnew STEP Hstp
1890      PRINT "HORIZONTA=";Mota,"VERTICAL=";Motb
1900      Motor=2^(Dirh-1)
1910      FOR K=1 TO 491
1920        OUTPUT @Gpio USING "#,W";Motor
1930        OUTPUT @Gpio;0
1940        WAIT .0025
1950      NEXT K
1960    NEXT Mota
1970    IF Motb-Vnew=0 THEN 2070
1980    FOR Motb=Motb TO Vnew STEP Vstp
1990      PRINT "HORIZONTAL=";Mota,"VERTICAL";Motb
2000      Motor=2^(Dirv-1)
2010      FOR K=1 TO 742
2020        OUTPUT @Gpio USING "#,W";Motor
2030        OUTPUT @Gpio;0
2040        WAIT .0025
2050      NEXT K
2060    NEXT Motb
2070  SUBEND
2071  !*******************************
2072  !THIS SUBPROGRAM IS USED TO MOVE THE TWO DISC LOCATED ON THE FOUR
2073  !FOOT DISH
2074  !
2080  SUB Dscmov(Dsc)
2090    ASSIGN @Gpio TO 12;FORMAT OFF
2100    ON KEY 1 LABEL "DISC OUT" GOTO 2140
2110    ON KEY 2 LABEL "DISC IN" GOTO 2190
```

```
2120    ON KEY 4 LABEL "ABORT" GOTO 2360
2130    GOTO 2100
2140    Dsca=1
2150    Dscb=4
2160    Bbo=+45
2170    GOTO 2210
2180    Bbo=-45
2190    Dsca=2
2200    Dscb=3
2210    Motor=2^(Dsca-1)
2220    FOR K=1 TO 568
2230      OUTPUT @Gpio USING "#,W";Motor
2240      OUTPUT @Gpio;0
2250      WAIT .0025
2260    NEXT K
2270    Motor=2^(Dscb-1)
2280    FOR K=1 TO 568
2290      OUTPUT @Gpio USING "#,W";Motor
2300      OUTPUT @Gpio;0
2310      WAIT .0025
2320    NEXT K
2330    Dsc=Dsc+Bbo
2340    PRINT "THE CURRENT DISC POSITION IS";Dsc
2350    GOTO 2100
2360    ASSIGN @Gpio TO 12;FORMAT OFF
2370  SUBEND
2371  !********************
2372  !THE NEXT TWO SUBPROGRAMS ARE USED TO STORE DATA IN DIFFERENT MSI
2373  !
2380  SUB Dataf2(Amp(*),Phase(*),Npts,Motb,Dsc)
2390    CREATE BDAT "D_"&VAL$(Motb)&"_"&VAL$(Dsc)&":INTERNAL,4,1",Npts,16
2400    ASSIGN @P TO "D_"&VAL$(Motb)&"_"&VAL$(Dsc)&":INTERNAL,4,1"
2410    OUTPUT @P;Amp(*),Phase(*)
2420    ASSIGN @P TO *
2430    PRINT "DATA_";Motb;"HAS BEEN CREATED"
2440  SUBEND
2450  SUB Dataf3(Amp(*),Phase(*),Npts,Motb,Dsc)
2460    CREATE BDAT "D_"&VAL$(Motb)&"_"&VAL$(Dsc)&":CS80,700",Npts,16
2470    ASSIGN @P TO "D_"&VAL$(Motb)&"_"&VAL$(Dsc)&":CS80,700"
2480    OUTPUT @P;Amp(*),Phase(*)
2490    ASSIGN @P TO *
2500    PRINT "DATA_";Motb;"HAS BEEN CREATED"
2510  SUBEND
```

Appendix D. Near Field Error Correction Program

```
PRINT "***********    NFPHAD1.BAS   ******************** "
PRINT "THIS PROGRAM TAKES THE SEPARATE NEAR FIELD DATA "
PRINT "FILES READS IN THE DATA AND OUTPUTS THE DATA TO A "
PRINT "RANDOM ACCESS FILE.  THIS RANDOM ACCESS FILE CAN
THEN" PRINT "BE USED THE PLOTTING ROUTINES TO CREATE
TOPOGRAPHICAL" PRINT "MODELS AND SURFACE REPRESENTATIONS OF
THE NEAR FIELD" PRINT "DATA. HOW MANY DEGREES ARE THE
PLATES ABOVE THE DISH"; INPUT P%
PRINT "YOU MUST ASSIGN A VALUE OF EITHER O OR 1 TO K ";
PRINT "DEPENDING ON WHETHER YOU WANT EVERY SECOND ROW OF ";
PRINT "NEAR FIELD DATA TO BE SHIFTED TO THE LEFT OR RIGHT";
PRINT "WHAT VALUE WOULD YOU LIKE TO ASSIGN TO K (0/1) ";
INPUT K%
INPUT "HOW MANY FILES OF INPUT DATA ",M%
MM%=M%-1
mu% = cint(log(m%)/log(2))
INPUT "HOW MANY DATA ELEMENTS IN EACH INPUT FILE ",N%
NN%=N%-1
nu% = cint(log(n%)/log(2))
DIM AMOP!(0:MM%, 0:NN%),PHOP!(0:MM%, 0:NN%)
DIM AMP!(0:NN%), PH!(0:NN%), PHASE!(0:NN%)
PRINT "***************    WORKING     *****************"
ALO! = 9.9E+30
AHI! = -ZLO
BLO! = 9.9E+30
BHI! = -ZLO
IF P% < 10 THEN
            P$ = RIGHT$(STR$(P%),1)
        ELSEIF  P% > 9 AND P% < 100 THEN
            P$ = RIGHT$(STR$(P%),2)
        ELSE
            P$ = RIGHT$(STR$(P%),3)
        END IF
FOR R% = 0 TO MM%
        IF R% < 9 THEN
            B$ = RIGHT$(STR$(R%+1),1)
        ELSE
            B$ = RIGHT$(STR$(R%+1),2)
        END IF
   c$ = "A:"+P$+"DAT"+B$+".BAS"
        open c$ for input as #1
        K% = K% + 1
        C% = 0
            DO UNTIL EOF(1)
            input #1, AMP!(C%),PH!(C%)
            IF AMP!(C%) < ALO! THEN ALO! = AMP!(C%)
```

```
                    IF AMP!(C%) > AHI! THEN AHI! = AMP!(C%)
                    C% = C% + 1
                    LOOP
                    IF K% = 2 THEN
                      FOR I% = 0 TO C% - 1
                           J% = I% + 1
                           IF J% = 128 THEN J% = 127
                           AMOP!(R%,I%) = AMP!(J%)
                           PHOP!(R%,I%) = PH!(J%)
                      NEXT I%
                      K% = 0
                    ELSE
                      FOR I% = 0 TO C% - 1
                           AMOP!(R%,I%) = AMP!(I%)
                           PHOP!(R%,I%) = PH!(I%)
                      NEXT I%
                    END IF
   CLOSE #1
NEXT R%
A$ = "AMP"
B$ = "PHS"
AHI! = AHI! - ALO!
CALL  RANDOMIO(AMOP!(),NN%,MM%,ALO!,AHI!,A$)
CALL  ANGLEFIX(PHOP!(),NN%,MM%)
FOR R% = 0 TO MM%
   FOR C% = 0 TO NN%
        IF PHOP!(R%,C%) < BLO! THEN BLO! = PHOP!(R%,C%)
                    IF PHOP!(R%,C%) > BHI! THEN BHI! =
PHOP!(R%,C%)
        NEXT C%
NEXT R%
BHI! = BHI! - BLO!
CALL  RANDOMIO(PHOP!(),NN%,MM%,BLO!,BHI!,B$)
PRINT "************     ALL DONE    **************"
END
SUB RANDOMIO (AMOP!(2),NN%,MM%,ZLO!,ZHI!,A$)
REM THIS SUBROUTINE PRODUCES RANDOM ACCESS FILES OF BOTH
REM THE AMPLITUDE DATA AND PHASE DATA
LOCAL C%,R%,J%
SHARED P$
OPEN "E:"+P$+A$+".GRD" AS #2 LEN = 4
FIELD #2, 4 AS VERIFY$
LSET VERIFY$ = "DSPM": PUT #2
FIELD #2, 2 AS BYTE1$, 2 AS BYTE2$
LSET BYTE1$ = MKI$(100)
LSET BYTE2$ = MKI$(64) : PUT #2
FIELD #2, 4 AS SP$
LSET SP$ = MKMS$(0): PUT #2
LSET SP$ = MKMS$(74): PUT #2
LSET SP$ = MKMS$(0): PUT #2
```

```
LSET SP$ = MKMS$(51.1875): PUT #2
LSET SP$ = MKMS$(0): PUT #2
LSET SP$ = MKMS$(ZHI!): PUT #2
FOR R% = 0 TO MM%
   FOR C% = 0 TO 99
        J% = C% + 14
        LSET SP$ = MKMS$(AMOP!(R%,J%)- ZLO!) : PUT #2
   NEXT C%
NEXT R%
CLOSE #2
END SUB
SUB ANGLEFIX(PHOP!(2),NN%,MM%)
REM THIS SUBROUTINE REMOVES THE EFFECTS OF THE RECEIVER
MODULO
REM 360 DEGREE EFFECT ON THE DATA
LOCAL C%,  K% , B!
REM ************** WORKING ALONG THE ROWS **************
REM THIS PART STARTS AT 0,0 AND MOVES ALONG THE ROWS TO
MM,NN FOR R% = 0 TO MM%
   C% = 0
   WHILE C% < 64
        IF PHOP!(R%,C%+1) - PHOP!(R%,C%) >225 THEN
             FOR K% = 0 TO C%
                  PHOP!(R%,K%) = PHOP!(R%,K%) + 360
             NEXT K%
        END IF
   INCR C%
   WEND
   WHILE C% < NN%
                IF PHOP!(R%,C%) - PHOP!(R%,C%+1) >225 THEN
             FOR K% = C%+1 TO NN%
                  PHOP!(R%,K%) = PHOP!(R%,K%) + 360
             NEXT K%
        END IF
        INCR C%
   WEND
NEXT R%
REM*************************************************
REM************ WORKING UP THE COLUMNS **************
REM THIS PART STARTS AT 0,0 AND MOVES UP THE COLUMNS TO
MM,NN FOR C% = 0 TO NN%
   R% = 32
   WHILE R% > 0
        WHILE PHOP!(R%,C%) - PHOP!(R%-1,C%)>200
             PHOP!(R%-1,C%) = PHOP!(R%-1,C%) + 360
        WEND
        WHILE PHOP!(R%-1,C%) - PHOP!(R%,C%)>200
             PHOP!(R%-1,C%) = PHOP!(R%-1,C%) - 360
        WEND
        INCR R%,-1
```

```
   WEND
NEXT C%
FOR C% = 0 TO NN%
   R% = 32
   WHILE R% < MM%
        WHILE PHOP!(R%,C%) - PHOP!(R%+1,C%)>200
             PHOP!(R%+1,C%) = PHOP!(R%+1,C%) + 360
        WEND
        WHILE PHOP!(R%+1,C%) - PHOP!(R%,C%)>200
             PHOP!(R%+1,C%) = PHOP!(R%+1,C%) - 360
        WEND
        INCR R%
   WEND
NEXT C%
REM ************** WORKING UP THE COLUMNS ****************
REM THIS PART STARTS AT 0,0 AND MOVES UP THE COLUMNS TO
MM,NN FOR R% = 32 TO MM%
   C% = 27
   WHILE C% > 0
        WHILE PHOP!(R%,C%) - PHOP!(R%,C%-1)>200
             PHOP!(R%,C%-1) = PHOP!(R%,C%-1) + 360
        WEND
        WHILE PHOP!(R%,C%-1) - PHOP!(R%,C%)>200
             PHOP!(R%,C%-1) = PHOP!(R%,C%-1) - 360
        WEND
        INCR C%,-1
   WEND
NEXT R%
FOR R% = 32 TO MM%
   C% = 27
   WHILE C% < 64
        WHILE PHOP!(R%,C%) - PHOP!(R%,C%+1)>200
             PHOP!(R%,C%+1) = PHOP!(R%,C%+1) + 360
        WEND
        WHILE PHOP!(R%,C%+1) - PHOP!(R%,C%)>200
             PHOP!(R%,C%+1) = PHOP!(R%,C%+1) - 360
        WEND
        INCR C%
   WEND
NEXT R%
REM ************************************************
FOR R% = 32 TO MM%
   C% = 90
   WHILE C% > 63
        WHILE PHOP!(R%,C%) - PHOP!(R%,C%-1)>200
             PHOP!(R%,C%-1) = PHOP!(R%,C%-1) + 360
        WEND
        WHILE PHOP!(R%,C%-1) - PHOP!(R%,C%)>200
             PHOP!(R%,C%-1) = PHOP!(R%,C%-1) - 360
        WEND
```

```
          INCR C%,-1
     WEND
NEXT R%
FOR R% = 32 TO MM%
     C% = 90
     WHILE C% < NN%
          WHILE PHOP!(R%,C%) - PHOP!(R%,C%+1)>200
               PHOP!(R%,C%+1) = PHOP!(R%,C%+1) + 360
          WEND
          WHILE PHOP!(R%,C%+1) - PHOP!(R%,C%)>200
               PHOP!(R%,C%+1) = PHOP!(R%,C%+1) - 360
          WEND
          INCR C%
     WEND
NEXT R%
REM THIS PART STARTS AT 0,0 AND MOVES UP THE COLUMNS TO
MM,NN FOR R% = 0 TO 32
     C% = 64
     WHILE C% > 0
          WHILE PHOP!(R%,C%) - PHOP!(R%,C%-1)>200
               PHOP!(R%,C%-1) = PHOP!(R%,C%-1) + 360
          WEND
          WHILE PHOP!(R%,C%-1) - PHOP!(R%,C%)>200
               PHOP!(R%,C%-1) = PHOP!(R%,C%-1) - 360
          WEND
          INCR C%,-1
     WEND
NEXT R%
FOR R% = 0 TO 32
     C% = 64
     WHILE C% < NN%
          WHILE PHOP!(R%,C%) - PHOP!(R%,C%+1)>200
               PHOP!(R%,C%+1) = PHOP!(R%,C%+1) + 360
          WEND
          WHILE PHOP!(R%,C%+1) - PHOP!(R%,C%)>200
               PHOP!(R%,C%+1) = PHOP!(R%,C%+1) - 360
          WEND
          INCR C%
     WEND
NEXT R%
END SUB
```

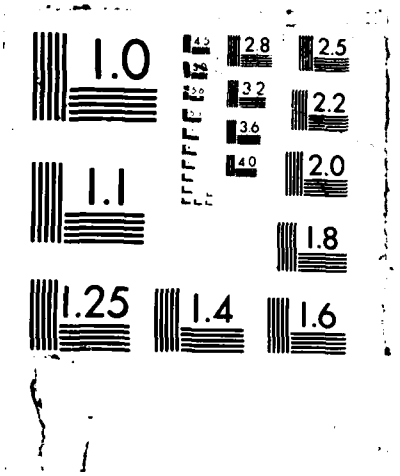
Appendix E. Fast Fourier Transform Program

```
PRINT "***************     FFTAZEL.BAS     *************** "
PRINT "THIS PROGRAM IS DESIGNED TO TAKE DATA FROM A 2-D "
PRINT "MATRIX ARRAY REPRESENTING THE NEAR FIELD IN "
PRINT "AMPLITUDE (DB) AND PHASE (DEG) OF AN ANTENNA AND "
PRINT "TURN IT INTO THE FAR FIELD IN AMPLITUDE AND PHASE "
PRINT "OF THE ANTENNA IN THE FAR FIELD.  "
PRINT "THE OUTPUT IS CONVERTED TO AZIMUTH AND ELEVATION"
PRINT "VALUES FOR EASY COMPARISON WITH MEASURED VALUES."
PRINT "PLEASE ENSURE THAT THE DATA DISKETTE IS IN DRIVE A:"
PRINT "ENSURE DATA FILES ARE LABELLED 0-360FDT1-64.BAS."
PRINT "RESULTS FOR PLOTTING WILL BE IN E:0-360FFA.GRD"
PRINT "HOW MANY DEGREES ARE THE PLATES ABOVE THE DISH ";
INPUT P%
INPUT "HOW MANY ROWS IN THE MATRIX TO BE PROCESSED ",M%
MM%=M%-1
mu% = cint(log(m%)/log(2))
INPUT "HOW MANY COLUMNS IN THE MATRIX TO BE PROCESSED ",N%
NN%=N%-1
nu% = cint(log(n%)/log(2))
pi# = 3.1415926535897793
DIM XR!(0:MM%, 0:NN%),XI!(0:MM%, 0:NN%)
DIM TXR!(0:MM%, 0:NN%),TXI!(0:MM%, 0:NN%)
DIM AMOP!(0:MM%, 0:NN%),PHOP!(0:MM%, 0:NN%)
DIM XXR!(0:NN%), XXI!(0:NN%)
DIM XXRR!(0:MM%), XXIR!(0:MM%)
DIM AMP!(0:NN%), PH!(0:NN%), PHASE!(0:NN%)
PRINT "***************     WORKING     *****************"
    FOR I%=0 TO MM%
        IF I% < 9 THEN
             B$ = RIGHT$(STR$(I%+1),1)
        ELSE
             B$ = RIGHT$(STR$(I%+1),2)
        END IF
   IF P% < 10 THEN
             P$ = RIGHT$(STR$(P%),1)
        ELSEIF  P% > 9 AND P% < 100 THEN
             P$ = RIGHT$(STR$(P%),2)
        ELSE
             P$ = RIGHT$(STR$(P%),3)
        END IF
   c$ = "A:"+P$+"FDT"+B$+".BAS"
        open c$ for input as #1
        FOR JL%=0 TO NN%
            input #1, AMP!(jl%),PH!(jl%)
            PHASE!(jl%) = 2*pi#*PH!(jl%)/360
            XR!(I%,JL%) =10^(AMP!(JL%)/10)*COS(PHASE!(JL%))
```

```
        XI!(I%,JL%) =10^(AMP!(JL%)/10)*SIN(PHASE!(JL%))
    NEXT JL%
         CLOSE #1
NEXT I%
FOR R% = 0 TO MM%
    FOR C% = 0 TO NN%
         XXR!(C%) = XR!(R%,C%)
         XXI!(C%) = XI!(R%,C%)
    NEXT C%
CALL FFT(XXR!(),XXI!(),N%,nu%)
         FOR C% = 0 TO NN%
              XR!(R%,C%) = XXR!(C%)
              XI!(R%,C%) = XXI!(C%)
         NEXT C%
NEXT R%
REM
************************************************************
REM ****THIS PORTION OF THE PROGRAM DOES A CUT AND*****
REM ********** DIAGONAL SWAP OF THE DATA VALUES.*******
REM************************************************************
FOR C% = 0 TO NN%
     FOR R% = 0 TO MM%
         XXRR!(R%) = XR!(R%,C%)
         XXIR!(R%) = XI!(R%,C%)
     NEXT R%
CALL FFT(XXRR!(),XXIR!(),M%,mu%)
     FOR R%=0 TO MM%
         XR!(R%,C%) = XXRR!(R%)
    XI!(R%,C%) = XXIR!(R%)
     NEXT R%
NEXT C%
PRINT "***************    STILL WORKING    ***************"
FOR R% = 0 TO MM%
         FOR C% = 0 TO NN%
              J% = C% + N%/2
              IF J% > NN% THEN J% = J% - N%
              TXR!(R%,C%) = XR!(R%,J%)
              TXI!(R%,C%) = XI!(R%,J%)
         NEXT C%
NEXT R%
FOR C% = 0 TO NN%
    FOR R% = 0 TO MM%
         K% = R% + M%/2
         IF K% > MM% THEN K% = K% - M%
         XR!(R%,C%) = TXR!(K%,C%)
         XI!(R%,C%) = TXI!(K%,C%)
    NEXT R%
NEXT C%
PRINT "***************    STILL AT IT    ***************"
```

AD-A189 543 MODIFICATION OF PARABOLIC DISH ANTENNA PATTERN USING TWO SYMMETRICALLY PL..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. G C THORPE 2/2

UNCLASSIFIED DEC 87 AFIT/GE/ENG/87D-67 F/G 9/1 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

```
ZLO! = 9.9E+30
ZHI! = -ZLO!
FOR R% = 0 TO MM%
    FOR C% = 0 TO NN%
     AMOP!(R%,C%) = 10*LOG(SQR(XR!(R%,C%)^2+XI!(R%,C%)^2))
     IF AMOP!(R%,C%) < ZLO! THEN ZLO! = AMOP!(R%,C%)
     IF AMOP!(R%,C%) > ZHI! THEN ZHI! = AMOP!(R%,C%)
     IF XR!(R%,C%) = 0 THEN
      PHOP!(R%,C%) = 90
     ELSE
      PHOP!(R%,C%) =
(ATN(XI!(R%,C%)/XR!(R%,C%))*360)/(2*PI#)
     END IF
    NEXT C%
NEXT R%
CALL  DATAFILE(AMOP!(),NN%,MM%,ZLO!,ZHI!)
PRINT "************      ALL DONE     **************"
END
SUB FFT(XXR!(1),XXI!(1),N%,NU%)
    SHARED PI#
    LOCAL J%,C%,KK%,K%,B,I%,L%,K2%,TRE!,TIM!,XRT!,XIT!
    FOR I%=0 TO N%-1
        J%=0
        KK%=I%
        K%=1
TEST:
     B=KK%/2^(NU%-K%)
     IF B >= 1 THEN
        J% = J% + 2^(K% - 1)
        KK%=KK% - 2^(NU% - K%)
     END IF
     K%=K%+1
     IF K% > NU% THEN
        GOTO CHK
     ELSE
        GOTO TEST
     END IF
CHK:
   IF J% < I% THEN
        GOTO JMP
   ELSE
             TRE!=XXR!(J%)
             TIM!=XXI!(J%)
        XXR!(J%)=XXR!(I%)
        XXI!(J%)=XXI!(I%)
        XXR!(I%)=TRE!
             XXI!(I%)=TIM!
        END IF
JMP:
    NEXT I%
```

```
     FOR L%=0 TO NU%-1
          C%=1
          K2%=2^L%
          P#=PI#/K2%
          FOR K%=0 TO N%-1

XRT!=XXR!(K%+K2%)*COS(K%*P#)+XXI!(K%+K2%)*SIN(K%*P#)

XIT!=XXI!(K%+K2%)*COS(K%*P#)-XXR!(K%+K2%)*SIN(K%*P#)
            XXR!(K%+K2%)=XXR!(K%)-XRT!
            XXI!(K%+K2%)=XXI!(K%)-XIT!
            XXR!(K%)=XXR!(K%)+XRT!
            XXI!(K%)=XXI!(K%)+XIT!
            IF C%=K2% THEN
                 K%=K%+K2%
                 C%=0
              END IF
              C%=C%+1
          NEXT K%
     NEXT L%
END SUB
'************************     DATA FILE    ********************
SUB DATAFILE (AMOP!(2),NN%,MM%,ZLO!,ZHI!)
LOCAL C%,R%
SHARED P$,PI#
A$ = "A:"+P$+"FFAA.DAT"
B$ = "A:"+P$+"FFKS.DAT"
OPEN A$ FOR OUTPUT AS #1
OPEN B$ FOR OUTPUT AS #2
I% = -9732
FOR R% = 18 TO 45
   J% = -9995
   I! = I%/10000                    :REM Ky VALUE
   FOR C% = 42 TO 85
        J! = J%/10000               :REM Kx VALUE
        ELL! = ATN(I!/SQR(1-I!^2))
        AZARG! = J!/COS(ELL!)
        IF 1-AZARG!^2 < 0 THEN GOTO XMP
        AZZ! = ATN(AZARG!/SQR(1-AZARG!^2))
        AZM! = (AZZ!/PI#)*180
        ELV! = (ELL!/PI#)*180
        IF AMOP!(R%,C%) < 30 THEN AMOP!(R%,C%) = 30
        Q$ = LEFT$(STR$(J!),9)
        R$ = "    "+LEFT$(STR$(I!),9)+"    "
        S$ = LEFT$(STR$(AMOP!(R%,C%)),8)
        PRINT #2, Q$,R$,S$
        AMOP!(R%,C%) = AMOP!(R%,C%)*COS(AZZ!)*COS(ELL!)
        Q$ = LEFT$(STR$(AZM!),9)
        R$ = "    "+LEFT$(STR$(ELV!),9)+"    "
        S$ = LEFT$(STR$(AMOP!(R%,C%)),8)
```

```
        PRINT #1, Q$,R$,S$
      XMP:
        INCR J%,464
   NEXT C%
   INCR I%, 721
NEXT R%
CLOSE #1
CLOSE #2
END SUB
```

Appendix F. Near-Field Phase Distribution Program

```
PRINT "THIS PROGRAM IS DESIGNED TO FIND THE DISTANCES"
PRINT "TO THE REFERENCE PLANE AND THE X  CO-ORDINATES"
PRINT "OF THE POINTS THAT REFLECT OFF THE MOVEABLE PLATE"
PRINT "THE PLATE IS MOVED OUT 1/16 WAVELENGTH EACH TIME"
PRINT "FROM POSITION 0 TO POSITION 8."
PRINT "WHERE 0 MEANS AT THE LOWEST POSITION AND 8 IMPLIES"
PRINT "THAT THE PLATE IS 1/2 WAVELENGTH ABOVE THE SURFACE"
INPUT "WHAT POSITION IS THE PLATE IN? ";L%
REM FROM THIS VALUE OF L% THE HEIGHT IN INCHES IS FOUND
L!=L%*.230625+.2
L$ = RIGHT$(STR$(L%),1)
REM TPI! = 2 PI
TPI!=2*3.141592654
REM B! IS THE ANGLE THE TANGENT MAKES WITH THE X-AXIS
REM THIS ANGLE HAS A VALUE OF 14.6 DEGREES
B!= 0.25481876
REM TH! IS THE ANGLE MEASURED CLOCKWISE FROM THE X-AXIS
REM TO THE RAY THAT INTERSECTS WITH THE TANGENT AND THE
REM PARABOLA ;ITS VALUE IS 60.8 DEGREES
TH!=1.0611588
REM FIRST STEP IS TO FIND THE CENTER CO-ORDINATES OF THE
PLATE
REM 8.986 IS THE X CO-ORDINATE ON THE PARABOLA SURFACE
REM 16.08 IS THE Y CO-ORDINATE ON THE PARABOLA SURFACE
XC!=8.986-L!*SIN(B!)
YC!=16.08-L!*COS(B!)
REM PLATE CENTER X CO-ORD = XC!
REM PLATE CENTER Y CO-ORD = YC!
REM OPEN FILES TO ACCEPT AMPLITUDE AND PHASE VALUES
CALCULATED
A$ = "A:PLAMP"+L$+".DAT"
B$ = "A:PLPHS"+L$+".DAT"
OPEN A$ FOR OUTPUT AS #1
OPEN B$ FOR OUTPUT AS #2
REM NOW FIND THE LEFT EDGE CO-ORDINATES OF THE PLATE
REM PRC! IS THE CO-ORDINATE ON THE SURFACE OF THE PLATE
FOR PRC!=-2.5 TO 2.5 STEP .1
   REM XL! IS THE X CO-ORDINATE ON THE SURFACE OF THE PLATE
   XL!=XC!+PRC!*COS(B!)
   REM YL! IS THE Y CO-ORDINATE ON THE SURFACE OF THE PLATE
   YL!=YC!-PRC!*SIN(B!)
   IF PRC!=-2.5 THEN XPL!=XL!
        REM X CO-ORD. OF LEFT MOST POINT ON PLATE
   REM FIND ANGLE FROM FOCUS TO THE EDGE OF PLATE
   PHI#=ATN(YL!/XL!)
   IF PRC! = -2.5 THEN PHIL#=PHI#
```

```
   REM PHIL# IS THE ANGLE TO THE LEFT EDGE OF THE PLATE
   IF PRC! > 2.4 THEN PHIR#=PHI#
   REM PHIR# IS THE ANGLE TO THE RIGHT EDGE OF THE PLATE
   REM FIND CW COMP. FROM THE VERT. OF REFLECTION ANGLE
   VC#=1.570796327-PHI#-2*B!
   REM FIND THE DISTANCE FROM THE FOCUS TO THIS POINT
   DTLE!=SQR(XL!^2+YL!^2)
   REM FIND DISTANCE TO THE REFERENCE PLANE
   DTRP!=(12.25+YL!)/COS(VC#)
   REM FIND TOTAL DISTANCE FROM FOCUS TO REFERENCE PLANE
   TOTD!=DTRP!+DTLE!
   REM FIND X CO-ORDINATE OF RAY IMPACT IN REF. PLANE
   XCRP!=((TAN(VC#))*(YL!+12.25))+XL!
   IF PRC! = -2.5 THEN LXCRP!=XCRP!
   REM LXCRP! IS THE LEFT MOST CO-ORD OF REFLECTION ZONE
   IF PRC! > 2.4 THEN RXCRP!=XCRP!
REM RXCRP! IS THE RIGHT MOST CO-ORD OF REFLECTION ZONE
NEXT PRC!
REM LTPRL! IS THE DISTANCE FROM THE FOCUS TO THE PARABOLA
REM OF THE RAY THAT JUST MISSES THE LEFT EDGE OF THE PLATE
   LTPRL!=34.5/(1-SIN((2*3.141592654)-PHIL#))
   XCPRL!=LTPRL!*COS(PHIL#)
   REM XCPRL! IS CO-ORD OF POINT ON PARABOLA
   LTPRR!=34.5/(1-SIN((2*3.141592654)-PHIR#))
REM LTPRR! IS THE DISTANCE FROM THE FOCUS TO THE PARABOLA
REM OF THE RAY THAT JUST MISSES THE RIGHT EDGE OF THE PLATE
   XCPRR!=LTPRR!*COS(PHIR#)
   REM TO THE RIGHT OF XCPRR! DIRECT RAYS CAN REACH THE
REF. PLANE
REM FIND THE AMPLITUDE OF THE REFLECTED ENERGY
REAMP!= (XCPRR!-XCPRL!)/(RXCRP!-LXCRP!)
REM REPEAT ABOVE LOOP WITH KNOWN VALUES
FOR PRC!=-2.5 TO 2.5 STEP .1
   XL!=XC!+PRC!*COS(B!)
   YL!=YC!-PRC!*SIN(B!)
        REM FIND ANGLE FROM FOCUS TO THE EDGE OF PLATE
   PHI#=ATN(YL!/XL!)
REM FIND CW COMP. FROM THE VERT. OF REFLECTION ANGLE
   VC#=1.570796327-PHI#-2*B!
   REM FIND THE DISTANCE FROM THE FOCUS TO THIS POINT
   DTLE!=SQR(XL!^2+YL!^2)
   REM FIND DISTANCE TO THE REFERENCE PLANE
   DTRP!=(12.25+YL!)/COS(VC#)
   REM FIND TOTAL DISTANCE FROM FOCUS TO REFERENCE PLANE
   TOTD!=DTRP!+DTLE!
        TOTD!=46.75-TOTD!
   PHSR!=((TOTD!/3.69)*TPI!)
   REM FIND X CO-ORDINATE OF RAY IMPACT IN REF. PLANE
   XCRP!=((TAN(VC#))*(YL!+12.25))+XL!
   XPOS!=64+(XCRP!/39.685)*64
```

```
    IF PHSR! > 1.5707963 THEN PHSR! = PHSR! - 1.5707963
    IF XCRP!< XPL! THEN
         RFPXA!=0.5*(COS(PHSR!)) + 1
         RFPYA!=0.5*SIN(PHSR!)
         RFPA! =SQR(RFPXA!^2+RFPYA!^2)
         PHSE! =ATN(RFPYA!/RFPXA!)
    ELSEIF XCRP!>XCPRR! THEN
         RFPXA!=0.5*(COS(PHSR!)) + 1
         RFPYA!=0.5*SIN(PHSR!)
         RFPA! =SQR(RFPXA!^2+RFPYA!^2)
         PHSE! =ATN(RFPYA!/RFPXA!)
    ELSE
         RFPXA!=0.5*COS(PHSR!)
         RFPYA!=0.5*SIN(PHSR!)
         RFPA! =SQR(RFPXA!^2+RFPYA!^2)
         PHSE! =ABS(ATN(RFPYA!/RFPXA!))
    END IF
    PHSE! =((PHSE!/(TPI!))*360)
         WRITE #1, XPOS!,RFPA!
         WRITE #2, XPOS!,PHSE!
NEXT PRC!
CLOSE #1
CLOSE #2
END
```

Bibliography

Balanis, Constantine A. Antenna Theory Analysis and Design. New York: Harper and Row, 1982.

Braza, Rudy and Fath Jeff Geometrical Theory of Diffraction (GTD) - Aperture Integration (AI) Model of Two Circular Plates on a Parabolic Reflector Antenna. Research Paper. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, November 1986.

Havens, Second Lieutenant Douglas A. Pattern Nulling by Reflector Shaping. MS Thesis GE/EE/83D-26. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1983.

Johnson, Richard C and Henry Jasik. Antenna Applications Reference Guide (Second Edition). New York: McGraw Hill Book Company, 1984.

Milligan, Thomas A. Modern Antenna Design. New York: McGraw Hill Book Company, 1985.

Newell, Allen C. Planar Near-Field Measurements. National Bureau of Standards Lecture Notes, National Bureau of Standards, Boulder Colorado 80303, June 1985.

Reddy, David R. Correction for Probe-Position Errors in Planar, Near-Field Scanning. MS Thesis GE/ENG/85D-34. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1985.

Rudisill, Michael D. Null Generation Using Discs on Reflector. MS Thesis GE/ENG/84D-55. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1984.

Trapp, Dick A. Physical Optics Model of Side Lobe Nulling by Discs on a Parabolic Reflector. MS Thesis GE/ENG/85D-51. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1985.

Vita

Flight Lieutenant Glen C. Thorpe was born on 23 April 1951 in Nanango, Queensland (Australia). After completing secondary education in Brisbane, Queensland in 1968, he joined the Royal Australian Air Force (RAAF). He trained as a Radio Technician and worked for a number of years in various posts before continuing his engineering training at Swinburne Institute of Technology in Melbourne, Victoria. In 1978 he graduated with a Diploma in Electronic Engineering and for the next three years he instructed Radio Technicians at the RAAF School of Radio in Melbourne. During this same time he studied at the Hawthorn Teachers' Training College and graduated in 1981 with a Diploma of Technical Teaching. He held a number of RAAF posts before entering the Air Force Institute of Technology in June 1986.

Permanent Address: 2344 Wynnum Rd.,
Wynnum, 4178, Q'ld
Australia

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A181543

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GE/ENG/87D-67	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION School of Engineering 6b. OFFICE SYMBOL (If applicable) AFIT/ENG	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB OH 45433	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Modification of Parabolic Dish Antenna Pattern Using Two Symmetrically Placed Circular Flat Plates

12. PERSONAL AUTHOR(S)
Thorpe, Glen Campbell

13a. TYPE OF REPORT	13b. TIME COVERED FROM ____ TO ____	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Antenna Configurations, Antennas Fastfourier Transforms, Antenna Radiation Patterns
25	01		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
Dr. A.J. Terzuoli

(over)

Approved for public release: IAW AFR 190-1.
22 Feb 88
Dean for Research and Professional Development

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
Dr. A.J. Terzuoli	513 255-6913	AFIT/ENG

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

ABSTRACT

This study aims to formulate a method of predicting the far field pattern of a parabolic dish antenna with two moveable flat plates mounted symmetrically on either side of the feed horn. The approach taken has been to first analyze the radiation pattern of the antenna with the disks at certain heights out from the surface of the dish. To do this the near-field radiation in amplitude and phase was measured over a plane surface in the near-field and the values were then transformed into the far field using a Fast Fourier Transform.

Far field pattern values of the antenna were directly measured for each setting of the plates. The results obtained from the Fast Fourier Transform of the near field data were in good agreement with the values obtained by measurement.

Finally, an approximate model of the antenna was developed and implemented as a computer program. This model, while relatively unsophisticated, provided some insights into the changes in the near field phase distribution caused by the moveable circular flat plates.

END

DATE

FILMED

MARCH

1988

DTIC