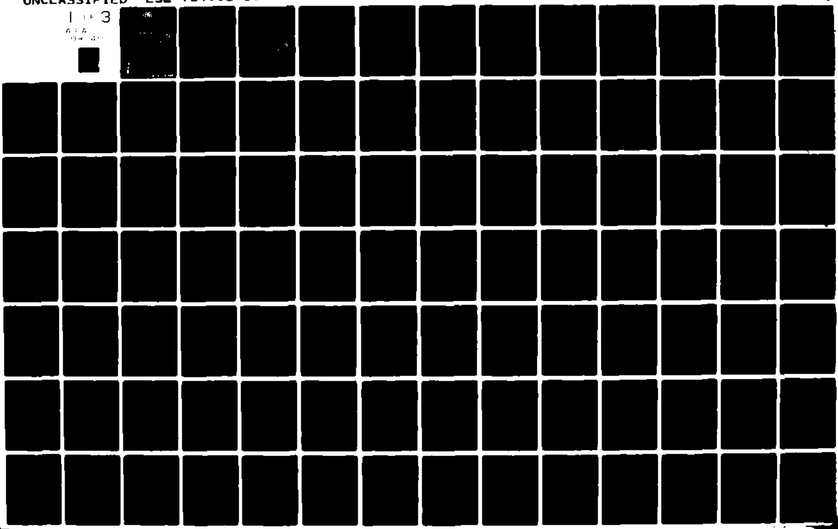
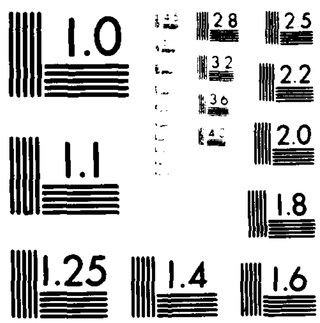
AD-A097 415 OHIO STATE UNIV COLUMBUS ELECTROSCIENCE LAB F/G 20/4
NUMERICAL ELECTROMAGNETIC CODE (NEC)-REFLECTOR ANTENNA CODE: PA--ETC(U)
SEP 79 S H LEE, R C RUDDUCK N00123-76-C-1371
UNCLASSIFIED ESL-784508-16 NL

1 OF 3





MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

[illegible] CODE (NEC) - REFLECTOR ANTENNA CODE [illegible]

[illegible]

The Ohio State University

[illegible] Laboratory

[illegible]

Columbus, Ohio [illegible]

Technical Report [illegible]

[illegible]

Approved for public release;
distribution unlimited.

NOTICES

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A097 45	3. RECIPIENT'S CATALOG NUMBER 14 ESL-784508-16
4. TITLE (and Subtitle) 6 NUMERICAL ELECTROMAGNETIC CODE (NEC) - REFLECTOR ANTENNA CODE: PART II. CODE MANUAL.		5. TYPE OF REPORT & PERIOD COVERED 9 Technical Report
		6. PERFORMING ORG. REPORT NUMBER ESL 4508-16 (784508)
7. AUTHOR(s) 10 S.H. Lee and R.C. Rudduck		8. CONTRACT OR GRANT NUMBER(s) 15 N00123-76-C-1371
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering Columbus, Ohio 43212		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project N00953/6/009121
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Regional Procurement Office Long Beach, California 90822		12. REPORT DATE 11 September 1979
		13. NUMBER OF PAGES 206 12 210
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DTIC ELECTE APR 7 1981 D C

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer Code | Reflector Antenna
Algorithm | Aperture Integration
Geometrical Theory of Diffraction | Near Field
Far Field Pattern

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The code manual documents a detailed explanation of the Numerical Electromagnetic Code - Reflector Antenna Code by which the near field and far field of a typical Navy reflector antenna can be calculated. One important feature of the code is the capability for a general reflector rim shape. Another important feature is the capability to input a practically arbitrary volumetric feed pattern. Only the class of parabolic surfaces was implemented in the computer code.

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

402 251

> The theoretical approach for computing the fields of the general reflector is based on a combination of the Geometrical Theory of Diffraction (GTD) and Aperture Integration (AI) techniques. Typically, AI is used to compute the main beam and near sidelobes; GTD is used to compute the wide-angle sidelobes and the backlobes.

The theoretical background on which the computer algorithms are based is described along with descriptions of the main program and the various subroutines. For each subsection of the main program and subroutine, the purpose and method are included, accompanied by a flow diagram, a key variable list and a listing of the code.

TABLE OF CONTENTS

I. INTRODUCTION

This code manual describes the Numerical Electromagnetic Code - Reflector Antenna Code by which the near field and far field of a typical Navy reflector antenna can be calculated. One important feature of the code is the capability for a general reflector rim shape. Another important feature is the capability to input a practically arbitrary volumetric feed pattern.

Since many Navy reflector antennas have parabolic surfaces, only the class of parabolic surfaces was implemented in the computer code. The geometry of the reflector rim is treated as piece-wise linear. The code for the reflector geometry is flexible enough to include offset fed reflectors and general reflector rim shapes such as elliptical and rectangular with chopped corners.

The theoretical approach for computing the fields of the general reflector is based on a combination of the Geometrical Theory of Diffraction (GTD) and Aperture Integration (AI) techniques. Typically, AI is used to compute the main beam and near sidelobes; GTD is used to compute the wide-angle sidelobes and the backlobes. To implement the computer algorithms based on these theories, efficient ways were developed to handle calculations involving the feed pattern, the aperture field and the far field pattern computation.

Sampled data from each measured feed pattern cut is input and stored in the code. Linear interpolation is then used to obtain a piece-wise linear representation of the input pattern cut. The feed patterns in planes other than those corresponding to the input pattern cuts also are calculated by linear interpolation. This method provides a computationally efficient way of calculating the aperture field without requiring large amounts of computer storage for the measured feed pattern. Only relatively few data points need to be stored for essentially complete feed pattern information. Furthermore, the piece-wise linear method has the advantages of flexibility and simplicity for general feed patterns. No cut-and-try procedures are needed; the sample feed values can be obtained directly from measured feed pattern data.

The aperture fields are calculated and stored on the principal grid for use in the aperture integration. The principal grid values are used for all output pattern cuts. The aperture fields are calculated at points off the principal grid by using linear interpolation from the principal grid. This is more efficient than calculating the aperture fields from the feed pattern for each rotated grid that is used for off-principal plane cuts.

The aperture integration uses an approach of overlapping subapertures which allows a piece-wise linear representation for the aperture distribution. Thus variations in the aperture fields can be represented with relatively few subapertures. Furthermore, the subapertures can be electrically large; thus minimizing the computer storage and also the amount of numerical integration required. For far field computations, a rotating grid method is employed in that the y-integrations are carried out for each column of the aperture and each one-dimensional integration result is stored. The stored values for the y-integration are then used for each pattern angle in the plane perpendicular to the y-axis; thus the efficiency approaches that of a one-dimensional integration. Even though the integration grid must be rotated to obtain the pattern in other planes, the required grid rotation is computationally much faster than the numerous two-dimensional integrations that would otherwise be required.

The GTD and AI approaches used for the reflector code have a basic limitation on the minimum size reflector that can be modeled. This limitation is probably on the order of 1λ to 3λ for the reflector diameter. However, virtually all practical reflector antennas exceed 3λ diameter. There is no limitation on the maximum size of the reflector for the basic analysis.

This code manual documents the detailed explanation of this code except the input data section which is described in the User's Manual [1]. The theoretical background on which the computer algorithms are based is discussed in Section II. Section III consists of the actual code descriptions of the main program and the various subroutines. For each subsection of the main program and subroutine, the purpose and method are included, accompanied by a flow diagram, a key variable list and a listing of the code.

II. BACKGROUND

A. Aperture Integration

For aperture fields with arbitrary polarization having both x and y components, the near field can be expressed as

$$\overline{E} = \frac{jk}{2\pi} \iint [\overline{F}_x E_x^a + \overline{F}_y E_y^a] \frac{e^{-jks}}{s} \, dx \, dy$$

where $\overline{F}_x$ and $\overline{F}_y$ are the modified vector element patterns associated with two Huygen's sources (crossed electric and magnetic dipoles)[2] each having its electric field vector parallel to the X- and Y-axis, respectively. These vector element patterns are expressed by

$$\overline{F}_x = [\hat{\theta} \cos\phi - \hat{\phi} \sin\phi] \cos\left(\frac{\theta}{2}\right)$$

$$\overline{F}_y = [\hat{\theta} \sin\phi + \hat{\phi} \cos\phi] \cos\left(\frac{\theta}{2}\right)$$

The aperture integration is performed over the portion of the aperture plane inside the reflector rim. For near field computations, a rectangular grid size (D_X and D_Y) is chosen so that the aperture can be divided into a principal rectangular grid as shown in Fig. 1. Using the approach of overlapping subapertures, the aperture is treated as a collection of overlapping subapertures. Each subaperture is rectangular in shape and consists of four adjacent grid rectangles. The aperture distribution for each subaperture is triangular. The use of overlapping, rectangular subapertures with triangular distributions permits a piecewise linear approximation to the overall aperture distribution of the reflector. Furthermore, the grid spacings D_X and D_Y can be electrically large, i.e., several wavelengths in size. This further minimizes the computation time. Thus the aperture integration results in a sum of the pattern functions of the rectangular subapertures weighted by the aperture field E^a and their respective areas. For far field computations, the rectangular grid is rotated to form a non-orthogonal rotating grid in which the y-axis is rotated an angle ϕ from the principal Y-axis.

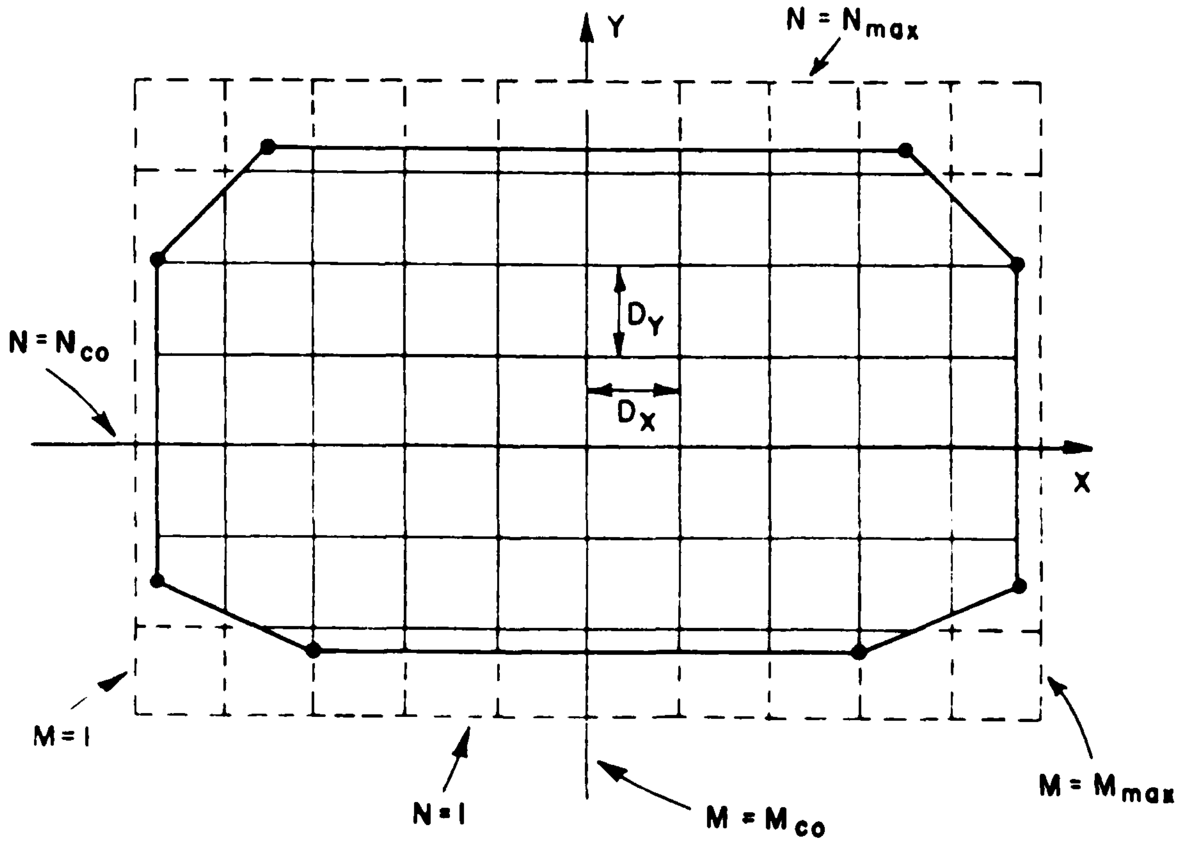


Figure 1. Geometry for principal rectangular grid.

Thus the y-integrations are independent of θ and can be stored. Consequently, the far field pattern in the plane perpendicular to the y-axis is reduced to a one-dimensional integration; this provides greatly improved efficiency over the many two-dimensional integrations that would otherwise be required. Detailed implementation of these integration techniques are given in the related sections.

B. GTD

This section summarizes the GTD analysis. For further detail, see the section describing the subroutine GTD.

The GTD analysis of the reflector is similar to that of diffraction by a flat plate[3,4], except that the curvature of the reflector surface must be taken into account. It was found that the reflector rim must be subdivided into nearly straight segments. A suitable criterion is that each segment of the reflector rim be small enough that the focus lies in the far field of the rim segment.

The GTD method used in the reflector code increments around the rim and determines whether a diffraction occurs for each linear rim segment. This is done by comparing the diffraction angle with the bounds on the permissible range of angles. If the diffraction for that segment is not significant, the code checks the next rim segment. If the diffraction is significant, the diffraction point and the vector for the incident ray from the feed are calculated. This procedure is the same as that used for the flat plate scattering code except that the geometry information associated with the parabolic reflector surface is changed.

Once the diffraction point X_D is located, the diffraction angles β_0 and ϕ are defined in the edge fixed coordinate system at the diffraction point. The three orthogonal unit vectors associated with this system on each segment of the reflector rim are the edge unit vector $\hat{V}$, the unit normal vector $\hat{VN}$ which is given by

$$\hat{VN} = -\hat{\rho} \sin \frac{\psi}{2} + \hat{z} \cos \frac{\psi}{2}$$

where

$$\hat{\rho} = \hat{X} \cos\phi + \hat{Y} \sin\phi$$

and the unit binormal vector $\hat{VP}=\hat{VN}x\hat{V}$ as shown in Fig. 2.

The incident angles β_0' and ϕ' and the diffraction angles β_0 and ϕ and the associated unit vectors $\hat{\beta}_0'$, $\hat{\phi}'$, $\hat{\beta}_0$ and $\hat{\phi}$ which define the ray fixed coordinate system are determined using the incident ray unit

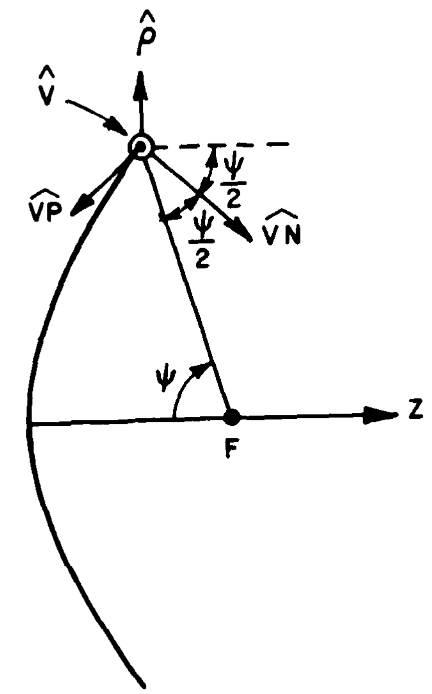


Figure 2. Unit vectors associated with the reflector rim.

vector $\hat{VI}$, the diffracted ray unit vector $\hat{d}$ and the unit vectors in the edge fixed system as given by

$$\beta_o' = \beta_o = \sin^{-1}|\hat{d}x\hat{V}| \quad ,$$

$$\phi' = \tan^{-1}\left(\frac{-\hat{VI}\cdot\hat{VN}}{-\hat{VI}\cdot\hat{VP}}\right) \quad ,$$

$$\phi = \tan^{-1}\left(\frac{\hat{d}\cdot\hat{VN}}{\hat{d}\cdot\hat{VP}}\right) \quad ,$$

$$\hat{\phi}' = -\hat{VP}\sin\phi' + \hat{VN}\cos\phi'$$

$$\hat{\phi} = -\hat{VP}\sin\phi + \hat{VN}\cos\phi$$

$$\hat{\beta}_o' = \hat{\phi}' \times \hat{VI}$$

and

$$\hat{\beta}_o = \hat{\phi} \times \hat{d}$$

as illustrated in Fig. 3.

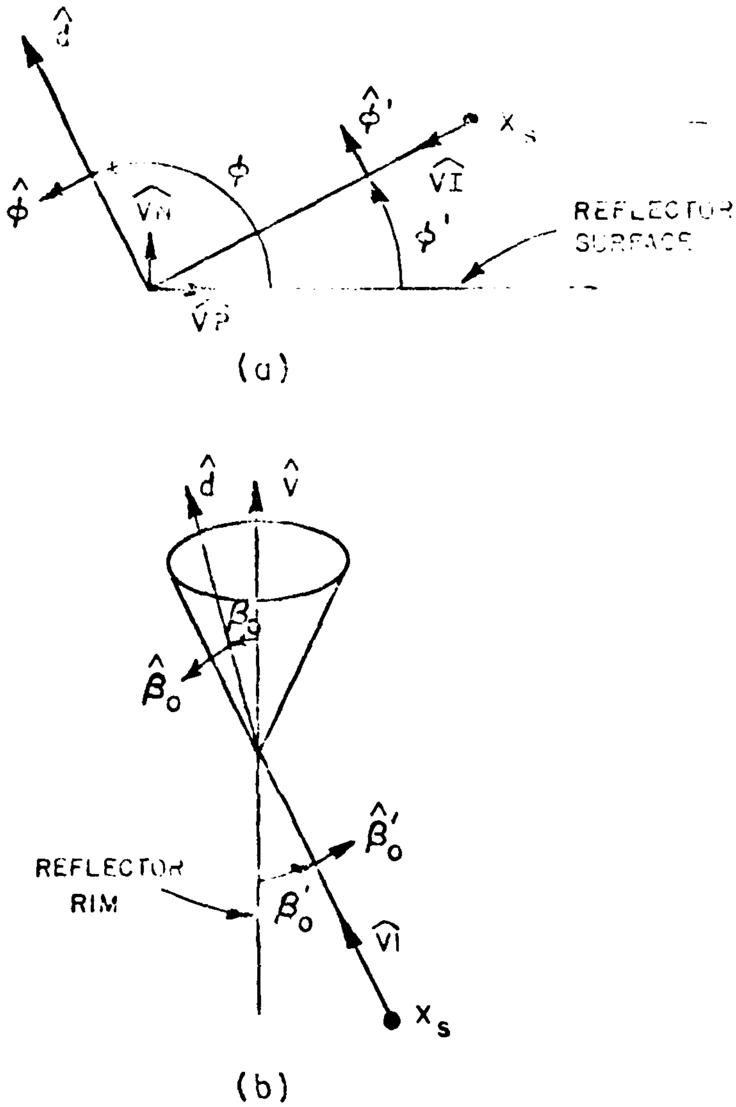


Figure 3a,b. Geometry for three dimensional diffraction of a half plane.

Thus the edge diffracted field from each segment, expressed in parallel and perpendicular components referred to the ray fixed system, is given by[5,6]

$$E_{\parallel}^{d}(S) = -E_{\parallel}^{i}(X_D)\; D_s(L)\; A(S)\; e^{-jks}$$

$$E_{\perp}^{d}(S) = -E_{\perp}^{i}(X_D)\; D_h(L)\; A(S)\; e^{-jks}$$

where

$$D_{s,h} = \frac{e^{-j\frac{\pi}{4}}}{2\sqrt{2\pi k}\,\sin\beta_o}\left[\frac{F[kLa(\beta^-)]}{\cos\frac{\beta^-}{2}} \mp \frac{F[kL(\beta^+)]}{\cos\frac{\beta^+}{2}}\right] \quad ,$$

$$\beta^{\mp} = \phi \mp \phi' \quad ,$$

$$a = 2\cos^2\left(\frac{\beta}{2}\right) \quad ,$$

$$F(X) = 2j|\sqrt{X}|e^{jX}\int_{|\sqrt{X}|}^{\infty} e^{-j\tau^2}\,d\tau \text{ is the transition function,}$$

$$\left\{\begin{array}{l} A(S) = \sqrt{\dfrac{S'}{S(S+S')}} \\ \\ L = \dfrac{SS'}{S+S'}\sin^2\beta_o \end{array}\right. \qquad \text{for near field,}$$

and

$$\left\{\begin{array}{l} A(S) = \dfrac{\sqrt{S'}}{S} \\ \\ L = S'\sin^2\beta_o \end{array}\right. \qquad \text{for far field} \quad .$$

The slope diffracted fields are calculated in a similar way except that the slope diffraction coefficients $\partial D_s/\partial\phi'$ and $\partial D_h/\partial\phi'$ and the slope $\partial E^i/\partial n$ of the incident field at the edge are used. Thus the respective parallel and perpendicular components of the slope diffracted field are given by

$$E_{\parallel}^{sd}(S) = \frac{1}{jk\sin\beta_o} \frac{\partial E_{\parallel}^{i}(X_D)}{\partial n} \frac{\partial D_s(L)}{\partial\phi'} A(S)e^{-jks}$$

$$E_{\perp}^{sd}(S) = \frac{1}{jk\sin\beta_o} \frac{\partial E_{\perp}^{i}(X_D)}{\partial n} \frac{\partial D_h(L)}{\partial\phi'} A(S)e^{-jks}$$

where

$$\frac{\partial D_{s,h}}{\partial\phi'} = j\sqrt{\frac{k}{2\pi}} \frac{e^{-j\frac{\pi}{4}} L}{\sin\beta_o} \left\{ \sin\left(\frac{\beta^-}{2}\right)[1-F[kLa(\beta^-)]] \pm \sin\left(\frac{\beta^+}{2}\right)[1-F[kLa(\beta^+)]] \right\} .$$

Since each rim segment is small, the diffractions from its two endpoints are significant. These diffractions are calculated by using the corner diffraction analysis developed by Burnside, et al[7]. The corner diffraction compensates for the discontinuity which occurs when the diffraction point moves off of the rim segment. The corner diffraction field is given by[7]

$$\begin{Bmatrix} E_{\parallel}^{c} \\ E_{\perp}^{c} \end{Bmatrix} = \begin{Bmatrix} IZ_o \\ MY_o \end{Bmatrix} \frac{\sin\beta_c \, e^{-j\frac{\pi}{4}}}{2\pi(\cos\beta_{oc}+\cos\beta_c)} F|kL_c a(\beta_{oc}+\beta_c)| \frac{e^{-jks_c}}{\sqrt{s_c}} \frac{e^{-jks_s}}{s_s}$$

where

$$\begin{Bmatrix} I \\ M \end{Bmatrix} = - \begin{Bmatrix} E_{\parallel}^{i}(X_D) \\ E_{\perp}^{i}(X_D) \end{Bmatrix} \begin{Bmatrix} C_s(X_D)Y_o \\ C_h(X_D)Z_o \end{Bmatrix} \sqrt{s'} \, e^{jks'}$$

and

$$C_{s,h}(X_D) = \frac{-e^{-j\frac{\pi}{4}}}{2\sqrt{2\pi k}\,\sin\beta_o} \left\{ \frac{F|kLa(\beta^-)|}{\cos\frac{\beta^-}{2}} \left| F\left[\frac{La(\beta^-)}{kL_c a(\beta_{oc}+\beta_c)}\right]\right| \right.$$

$$\left. \mp \frac{F|kLa(\beta^+)|}{\cos\frac{\beta^+}{2}} \left| F\left[\frac{La(\beta^+)}{kL_c a(\beta_{oc}+\beta_c)}\right]\right| \right\}$$

where

$$L_c = S_c \qquad \text{for far field}$$

and

$$L_c = \frac{S_c S_s}{S_c+S_s} \qquad \text{for near field}$$

The other variables associated with geometry are shown in Fig. 4.

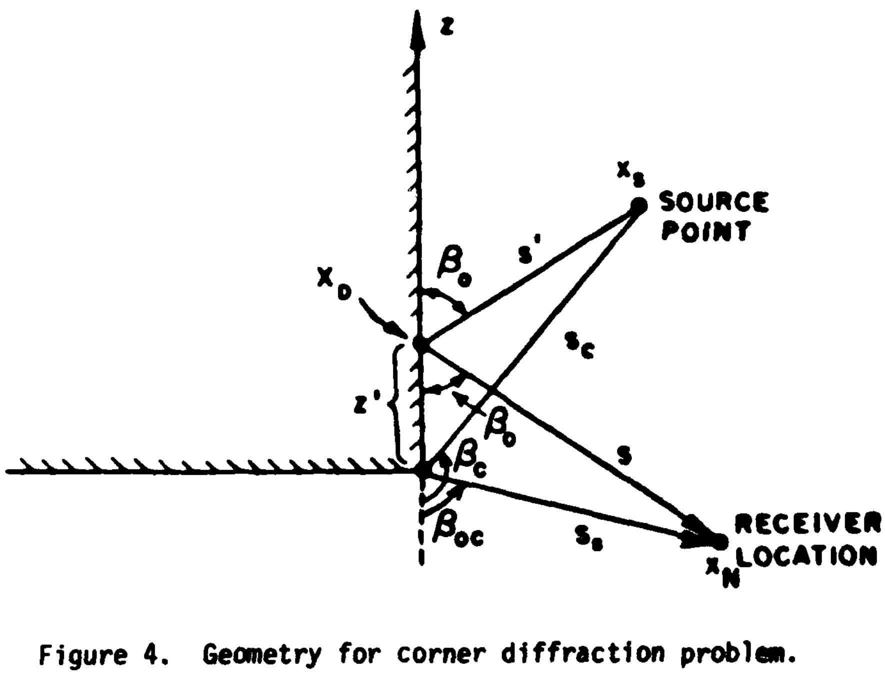


Figure 4. Geometry for corner diffraction problem.

For near field calculations, the geometrical optics reflected field must also be included in the total field if the observation point is inside the projected aperture. Since the reflected fields from a parabolic reflector are those of a plane wave with its wavefront parallel to the aperture plane, the magnitude of the reflected fields can be calculated from the aperture field and adding the appropriate phase term.

C. OUTPUT From the Code

If the field point is in the spillover region, the feed spillover field is calculated and added to the total field from the reflector as calculated by either AI or GTD.

For far field calculations or for near field calculations with constant range, the total field is converted to principal and cross polarized components as referred to the polarization of the field components from a Huygen's source. For near field calculations with constant z, the field is still expressed in rectangular components.

Far field calculations can be made with or without the e^{-jkR}/R range factor and this is controlled by the input logical variable LRANG. If the range factor is suppressed (LRANG=false) the dB output of the code is expressed as antenna gain relative to isotropic.

For far field calculations including the range factor (LRANG=true) or for near field calculations the output is expressed as the electric field relative to the field level of the feed along its axis and at a range equal to the focal distance of the reflector. In cases for which the feed axis is aligned with the reflector axis (zero feed tilt angle) this field reference is the aperture field at the center of the aperture. Thus, the power density (based on free space impedance) for these cases can be calculated from

$$S = \frac{P_T |E|^2}{F^2 P_{rad}}$$

where

$|E|$ = magnitude output of the code

P_T = transmitter power (radiated)

F = focal length of the reflector

P_{rad} = relative power radiated by the feed (see Section 1)

The information for F and P_{rad} are included in the variable

$$REFDB = 10 \log \frac{4\pi\lambda^2}{F^2 P_{rad}}$$

This variable is used to calculate far field gain and is given as output from the code. Thus the power density in dB relative to 1 Watt/meter^2 (assuming P_T is watts and λ is meters) is given by

$$S_{dB} = 20 \log|E| + REFDB + 10 \log \frac{P_T}{4\pi\lambda^2}$$

Power density calculations can be used for radiation hazard predictions or for calculating coupling in EMI predictions.

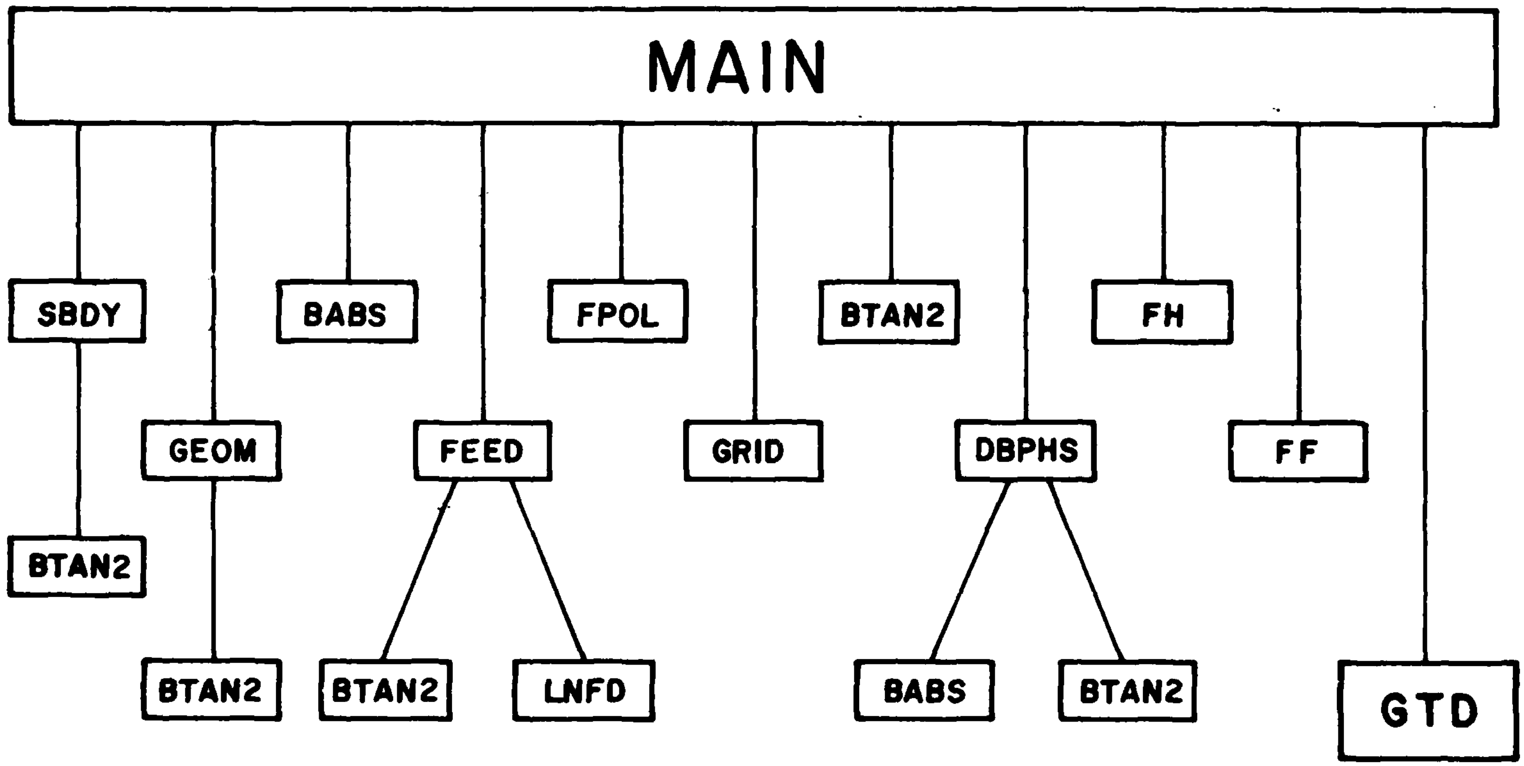
III. CODE DESCRIPTION

This computer code calculates both far field and near field patterns of reflector antennas with general rim shapes and arbitrary feed patterns. It uses a combination of Aperture Integration (AI) and the Geometrical Theory of Diffraction (GTD) techniques.

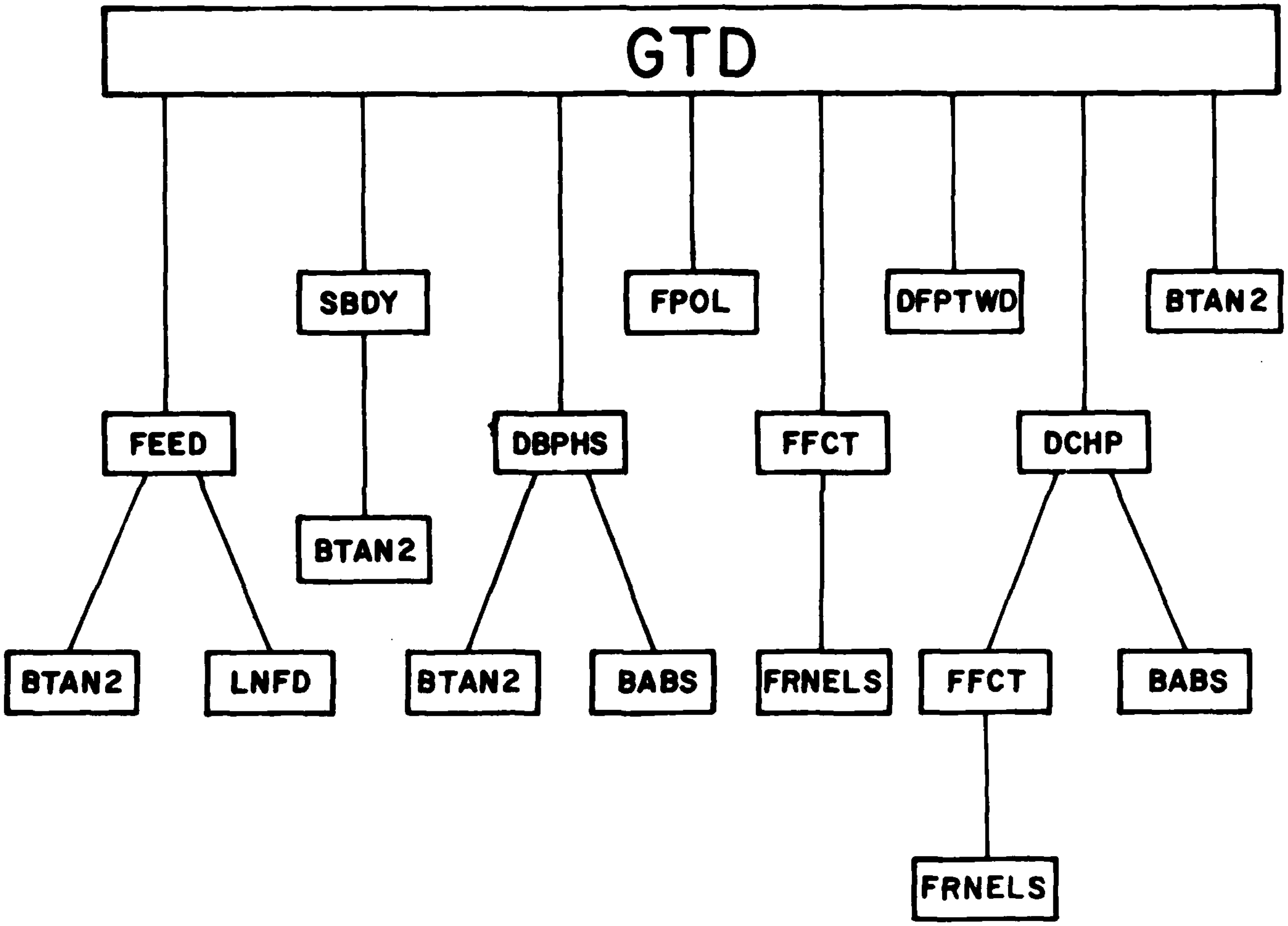
This code is divided into two parts. The first part consists of various command words which read all the input data. The details of this command word system is explained in the User's Manual[1] and thus is not repeated here.

The rest of this code belongs to the content of the XQ command which performs the unit conversion of input data and all the computations to get the far field or near field results. Various subroutines are called during the execution of this program and are described in Part B of this chapter. In the main program, some of the sections which need more detailed explanation are separated as subsections which are actually expansions of their corresponding blocks in the flow diagram of the main program.

The linkage of the subroutines to the main program is shown in the following flow charts. All GTD calculations are controlled by the subroutine GTD. The linkage of the subroutines to the subroutine GTD is shown in the second flow chart that follows:



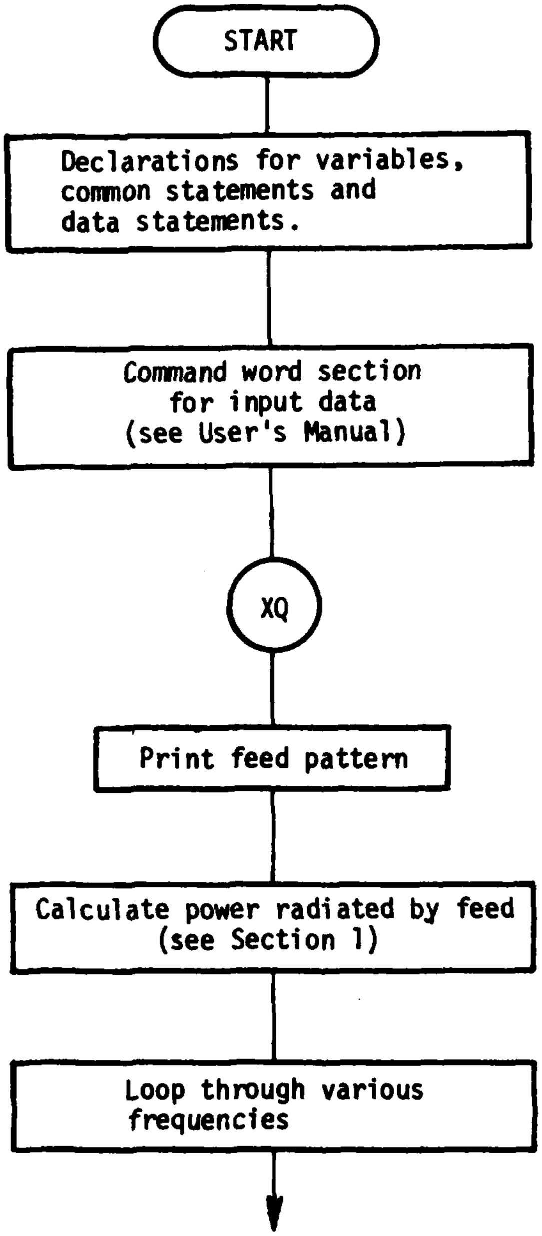
Subroutine Linkage Chart I

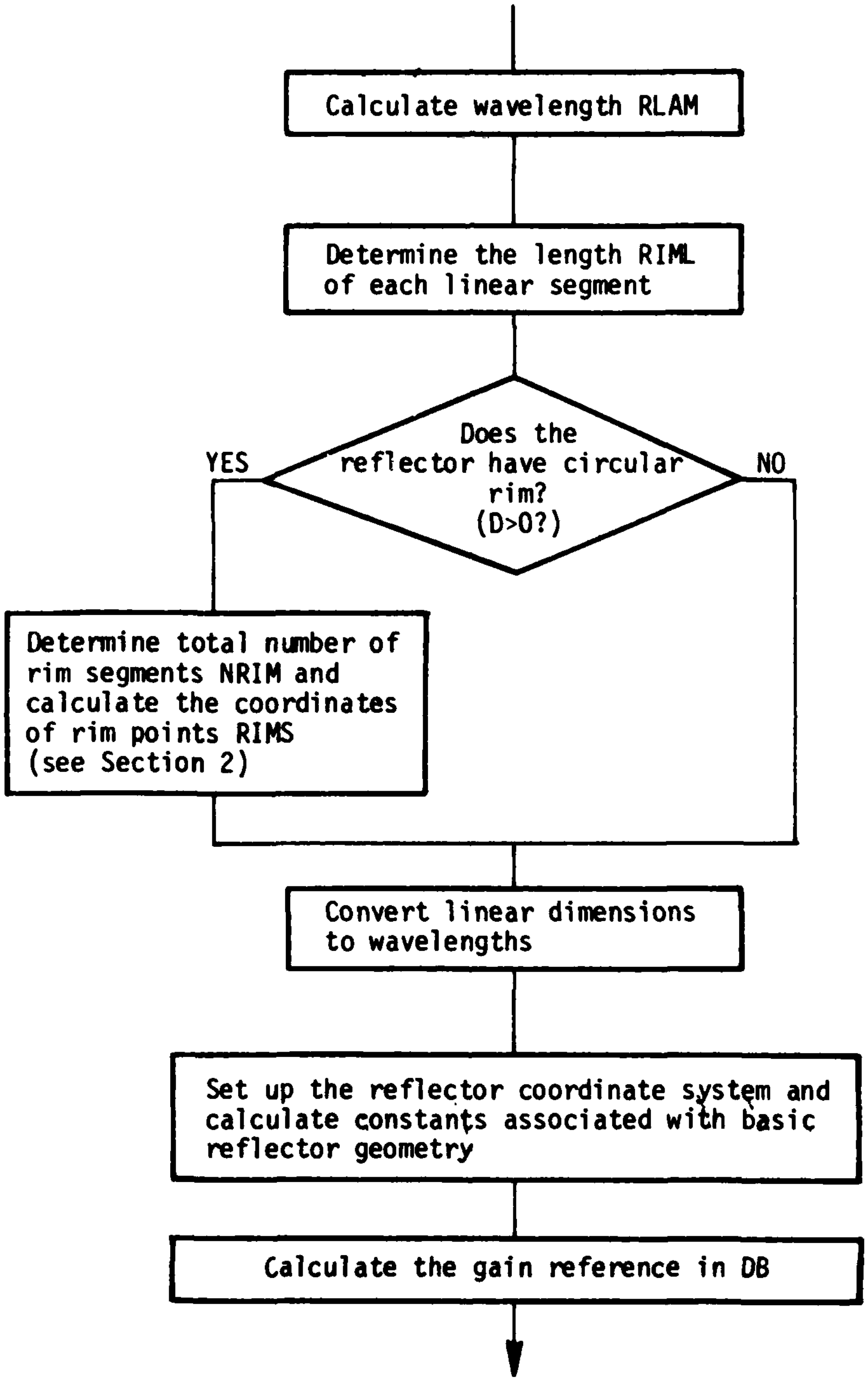


Subroutine Linkage Chart II

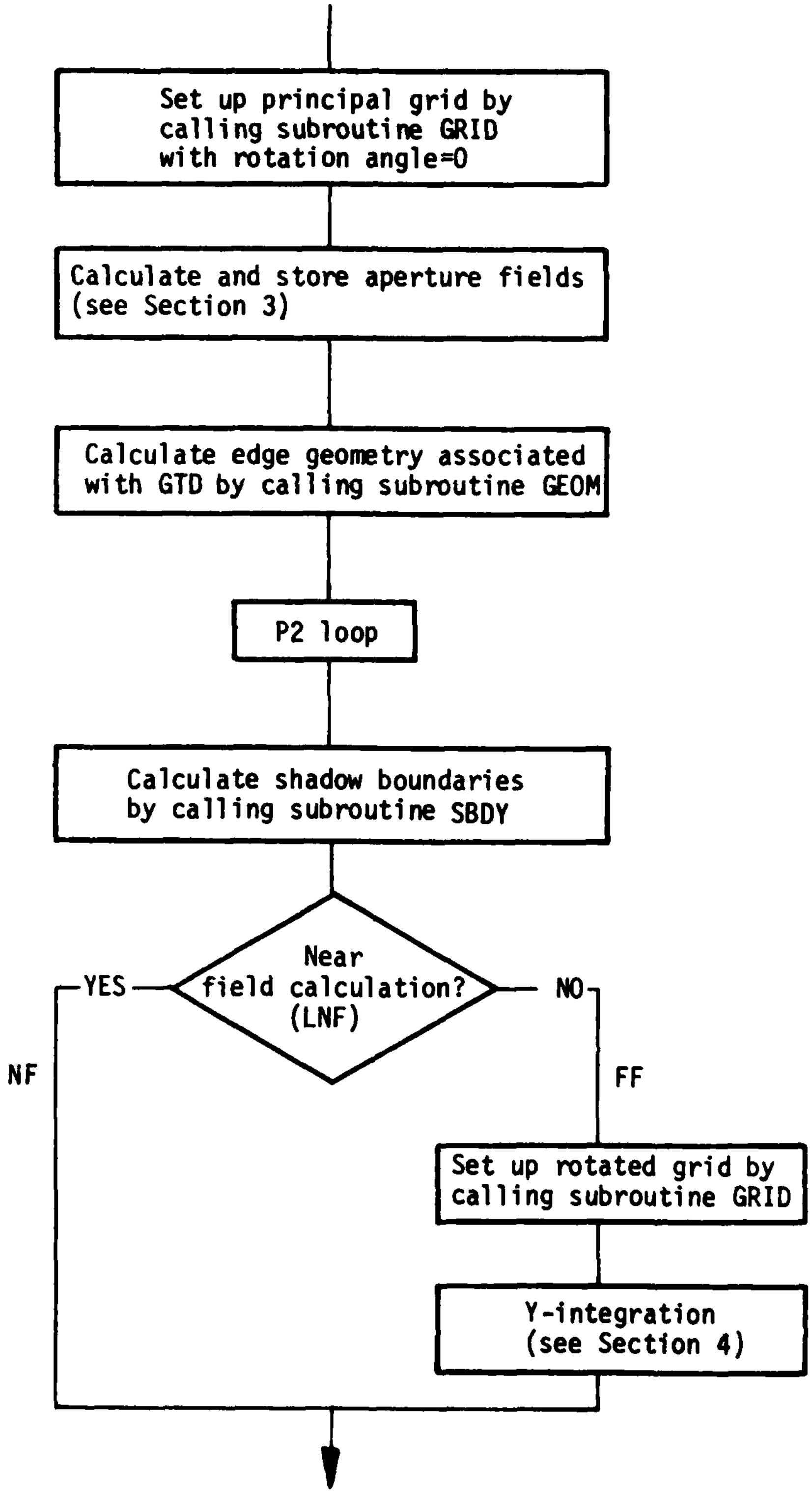
A. MAIN PROGRAM

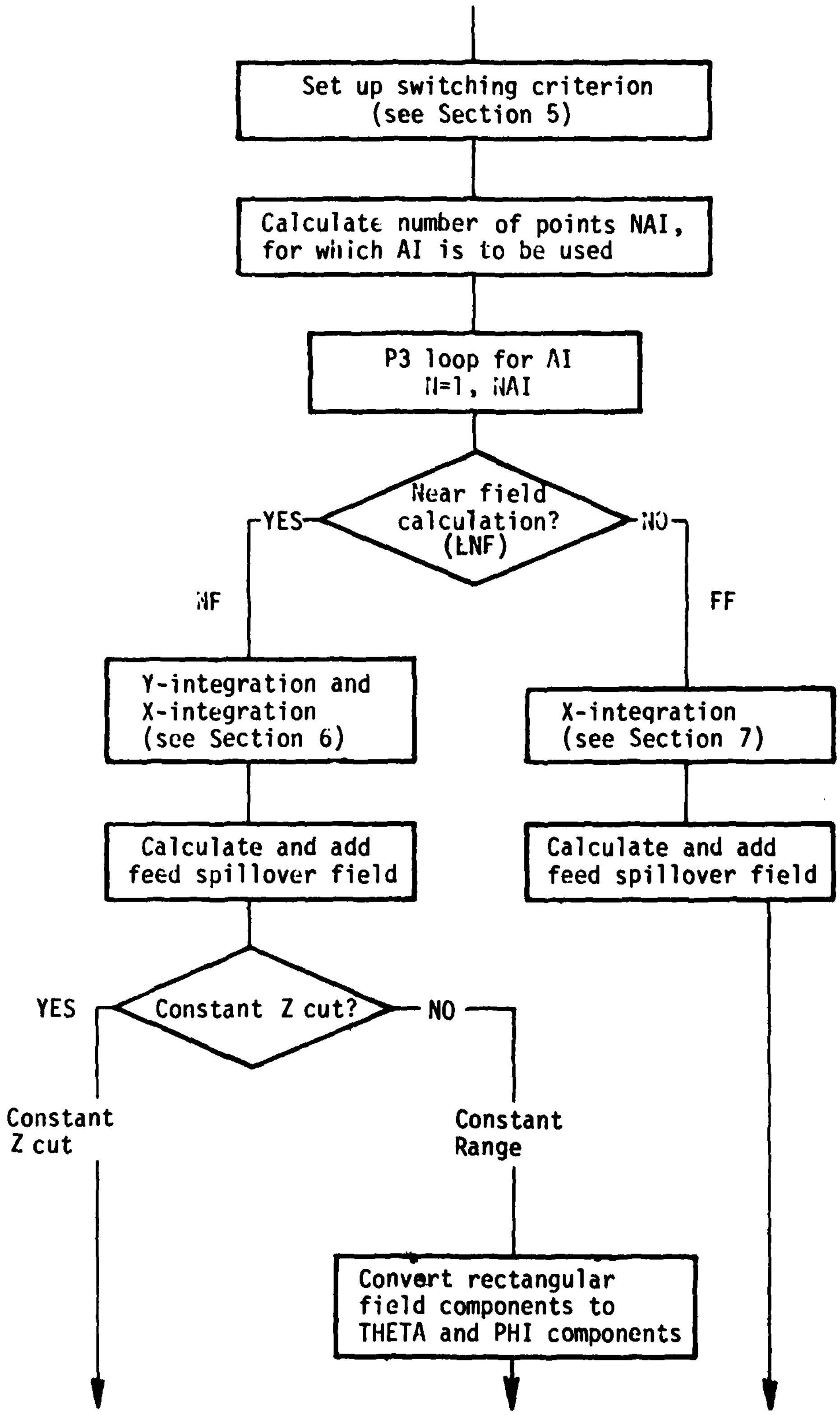
FLOW DIAGRAM

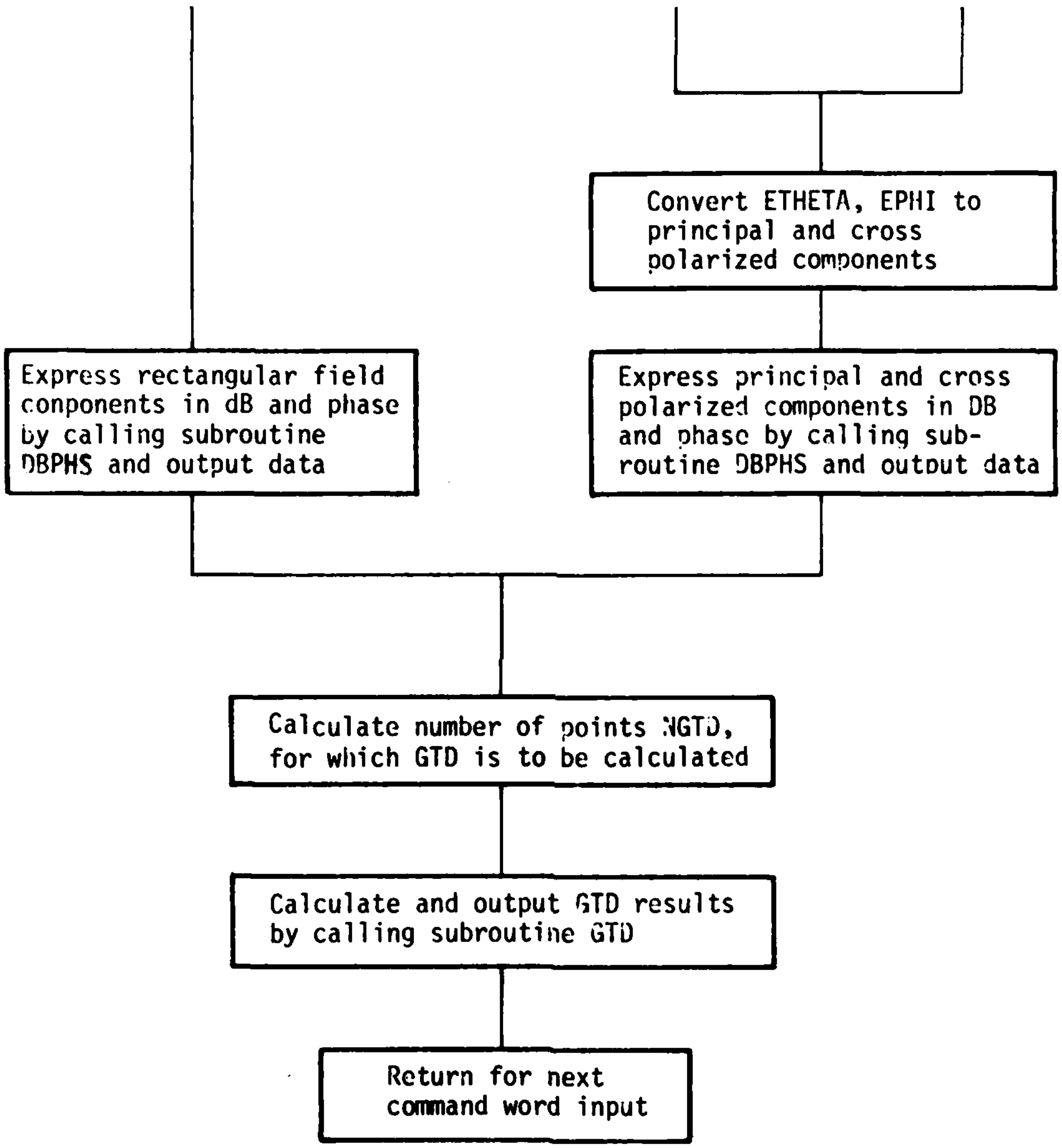




Calculate wavelength RLAM
Determine the length RIML of each linear segment
Does the reflector have circular rim? (D>0?)
YES
NO
Determine total number of rim segments NRIM and calculate the coordinates of rim points RIMS (see Section 2)
Convert linear dimensions to wavelengths
Set up the reflector coordinate system and calculate constants associated with basic reflector geometry
Calculate the gain reference in DB


Set up principal grid by calling subroutine GRID with rotation angle=0
Calculate and store aperture fields (see Section 3)
Calculate edge geometry associated with GTD by calling subroutine GEOM
P2 loop
Calculate shadow boundaries by calling subroutine SBDY
Near field calculation? (LNF)
YES
NO
NF
FF
Set up rotated grid by calling subroutine GRID
Y-integration (see Section 4)


Set up switching criterion (see Section 5)
Calculate number of points NAI, for which AI is to be used
P3 loop for AI N=1, NAI
Near field calculation? (LNF)
YES
NO
NF
FF
Y-integration and X-integration (see Section 6)
X-integration (see Section 7)
Calculate and add feed spillover field
Calculate and add feed spillover field
Constant Z cut?
YES
NO
Constant Z cut
Constant Range
Convert rectangular field components to THETA and PHI components


Convert ETHETA, EPHI to principal and cross polarized components
Express rectangular field conponents in dB and phase by calling subroutine DBPHS and output data
Express principal and cross polarized components in DB and phase by calling subroutine DBPHS and output data
Calculate number of points NGTD, for which GTD is to be calculated
Calculate and output GTD results by calling subroutine GTD
Return for next command word input

CODE LISTING

```
C
C  * FAR AND NEAR FIELD PATTERN FOR PARABOLIC REFLECTOR ANTENNA *
C      * WITH GENERAL RIM SHAPE AND ARBITRARY FEED PATTERN *
C
      DIMENSION JL(50),JU(50),YLR(50),YUR(50),QYL(50),QYU(50),XN(3)
      DIMENSION RHOS(2),CLRIM(67,2),CURIM(67,2),RIMS(67,2)
      DIMENSION RIM(67,2),VI(3),VIM(67,3),RMM(67),DELX(2)
      DIMENSION ANPF(10),AP2(10),FREQ(10),PHIN(15),PSIO(15),
     1FP(15,15),PX(15,15),AEX(15),CAN(15)
      DIMENSION NSNS(10)
      COMPLEX EDX,EDY,EDZ,EDT,EDP,EIP,EIT,EIX,EIY,EIZ,PHEI,YEXP
      COMPLEX YSUM(3,50),EA(2,50,50),E(2,50),CJ,FH,FHXP,FHXM,
     2FXP,FXM,YMR,YML,ERX,ERY,XEXP,EXPL,FXPI,EXPR,EXPM,EA1,EA2,
     3YSLX,YSLY,YSLZ,YSMX,YSMY,YSMZ,YSUX,YSUY,YSUZ,PHSEA,EAL,EAU,
     4SUMLX,SUMLY,SUMMX,SUMMY,SUMRX,SUMRY,SUMX,SUMY,SUMZ,TMX,TMT
      COMPLEX CX,CY,FFXN,FHYM,FHYP,FYM,FYP,RFCT
      LOGICAL LLFD,LAI,LFEED,LGTD
      LOGICAL LSLOPE,LCORNR,LOUT,LWFD,LRESET,LWRITE,LPLT
      LOGICAL LDEBUG,LTEST,LWYSUM,LDEAS,LDB,LCP,LNF,LRANG
      COMMON/LOGDIF/LSLOPE,LCORNR,LNF,LRANG
      COMMON /GRID1/GRIDX,GRIDY,EA
      COMMON /GRID2/CJ,CLRIM,CURIM,RIM,PG,XMIN,XMAX,YMIN,YMAX,
     2NLRIM,NURIM,GRDX,GRDY,ACOSP,TANP,PCHG,MAXO,NRIM
      COMMON /GEOM1/X(67,3),V(67,3),MRIM
      COMMON /GEOM2/VP(67,3),VN(67,3),BD(67,2),VMAG(67),RMC(67),
     2VIC(67,3),XM(67,3)
      COMMON /DIM/MDRIM
      COMMON /SORINF/XS(3)
      COMMON /DIR/DX(3),EIX,EIY,EIZ
      COMMON /NF/RFCT,XOO(3),PHIE,P2,RR
      COMMON /GTDD/LFEED,LOUT,LCP,LWRITE,COSPT,SINPT,REF,TEM2
      COMMON /FED/N2,PHIN,PX,FP,LDB,NCK,NPHI,NPW,AEX,CAN,PSIO,PSIT
      COMMON /COMP/CX,CY,GF,PHP,PHO,KX,KY,ISYM,SINTL,COSTL
      COMMON /PIS/PI,TPI,DPR
      COMMON /PREV/IPR,PREP,PREX,PRES
      COMMON /TEST/LDEBUG,LTEST,NTEST
      COMMON /FOCAL/F,ZOP
      COMMON /FEBDY/RHOS
      COMMON /BDY2/TH1,TH2,THEB
      COMMON /REFL/D,RO,ICQ,JCO
      COMMON /OUT/NW
      DIMENSION IR(24),IT(14)
      DIMENSION LABEL(2,3),UNIT(3)
      DATA UNIT/1.,.3048,0.0254/
      DATA LABEL/18HMETERSFEET  INCHES/
      DATA IT/42HDC:TO:FD:FO:NF:NX:LP:PP:CM:CE:TL:PZ:XO:EN:/
      DATA DEL/0.01/
      DATA C/3.D8/
      NTEST=0
      TEM2=0.70710678
```

```
      CJ=(0.,1.)
      MDPAT=361
      MDEA=50
      MDFP=15
      MDRIM=64
C!!!
C!!!  DEFAULT DATA   !!!
C!!!
C------
      WRITE(6,3002)
      WRITE(6,3006)
      WRITE(6,3010)
 3010 FORMAT(2H *,T20,'DEFAULT DATA',T79,1H*)
      WRITE(6,3006)
      WRITE(6,3006)
 3000 CONTINUE
C------   NX:   COMMAND   -------------
      LRESET=.TRUE.
      LDEBUG=.FALSE.
      LTEST=.FALSE.
      LWYSUM=.FALSE.
      LOUT=.FALSE.
      LWFD=.FALSE.
      LSLOPE=.TRUE.
      LCORNR=.TRUE.
      LAI=.TRUE.
      LFEED=.TRUE.
      LGTD=.FALSE.
      ZX=0.
      THETAX=0.
      LLFD=.FALSE.
      LCP=.FALSE.
      LDB=.TRUE.
      ISYM=1
      TAU=90.
      NPHI=2
      PHIN(1)=0.
      PHIN(2)=90.
      NPW=1
      AEX(1)=5.
      AEX(2)=6.
      CAN(1)=0.09
      CAN(2)=0.1
      PSIO(1)=120.
      PSIO(2)=140.
      IUNIT=3
      F=8.
      GRIDX=0.6
      GRIDY=0.6
      D=24.
```

```
      PSIT=0.
      YC=0.
      NFRQ=1
      FREQ(1)=11.
      IP2=1
      AP2(1)=0.
      AP3I=0.
      AP3F=90.
      ADP3=5.
      LWRITE=.TRUE.
      LPLT=.TRUE.
      INPF=0
      XOO(1)=0.
      XOO(2)=0.
      XOO(3)=0.
      PHIE=0.
      RANG=10000.
      LRANG=.FALSE.
      LNF=.FALSE.
      GO TO 3100
3000  CONTINUE
      LRESET=.FALSE.
      WRITE(6,3006)
3006  FORMAT(1X,1H*,76X,1H*)
      WRITE(6,3006)
      WRITE(6,3005)
3005  FORMAT(1X,26(3H***))
C!!!  READ IN VARIOUS COMMAND OPTIONS.
2999  READ(5,3001,END=3004)(IR(I),I=1,24)
3001  FORMAT(24A3)
3059  WRITE(6,3002)
3002  FORMAT(///1X,26(3H***))
      WRITE(6,3006)
      WRITE(6,3003)(IR(I),I=1,24)
3003  FORMAT(1X,1H*,2X,24A3,2X,1H*)
      IF(IR(1).EQ.IT(9).OR.IR(1).EQ.IT(10))GO TO 3900
      WRITE(6,3006)
      WRITE(6,3006)
C!!!
C!!!  CHECK AGAINST STORED OPTIONS
C!!!
C!!!  DG (IT(1)) : DISH GEOMETRY INPUT
C!!!  TO (IT(2)) : TEST DATA GENERATION OPTION.
C!!!  FD (IT(3)) : FEED PATTERN DEFINED
C!!!  FQ (IT(4)) : FREQUENCY RANGE DEFINED
C!!!  NF (IT(5)) : NEAR FIELD
C!!!  NX (IT(6)) : RESET DEFAULT DATA
C!!!  LP (IT(7)) : LINE PRINTER LISTING OF RESULTS
C!!!  PP (IT(8)) : PEN PLOT OF RESULTS
C!!!  CM (IT(9)) : COMMENT CARD
```

```
C!!!  CE (IT(10)) : END OF COMMENT INFORMATION
C!!!  TL (IT(11)) : FEED TILT ANGLE AND APERTURE CENTER
C!!!  PZ (IT(12)) : PHI PATTERN CUTS DEFINED
C!!!  XQ (IT(13)) : EXECUTE PROGRAM
C!!!  EN (IT(14)) : END PROGRAM
C!!!
      IF (IR(1).EQ.IT(1)) GO TO 3100
      IF (IR(1).EQ.IT(2)) GO TO 3200
      IF (IR(1).EQ.IT(3)) GO TO 3300
      IF (IR(1).EQ.IT(4)) GO TO 3400
      IF (IR(1).EQ.IT(5)) GO TO 3500
      IF (IR(1).EQ.IT(6)) GO TO 3600
      IF (IR(1).EQ.IT(7)) GO TO 3700
      IF (IR(1).EQ.IT(8)) GO TO 3800
      IF (IR(1).EQ.IT(11)) GO TO 4000
      IF (IR(1).EQ.IT(12)) GO TO 4100
      IF (IR(1).EQ.IT(13)) GO TO 4300
      IF (IR(1).EQ.IT(14)) GO TO 3004
      WRITE(6,3021)
 3021 FORMAT(' ***   PROGRAM ABORTS!!! COMMAND INPUT IS NOT PART OF
     ',
     1' STORED COMMAND LIST   ***')
 3004 CALL EXIT
C------
 3100 CONTINUE
C------    OG:    COMMAND    --------------
C$$$
C$$$  IUNIT=UNITS USED TO INPUT THE FOLLOWING LINEAR DIMENSIONS
C$$$        1=DIMENSIONS INPUT IN METERS
C$$$        2=DIMENSIONS INPUT IN FEET
C$$$        3=DIMENSIONS INPUT IN INCHES
C$$$
C$$$
C$$$  F=FOCAL DISTANCE OF THE PARABOLA
C$$$
C$$$  GRIDX=GRID SIZE IN X-DIRECTION USED IN APERTURE INTEGRATION
C$$$
C$$$  GRIDY=GRID SIZE IN Y-DIRECTION USED IN APERTURE INTEGRATION
C$$$
C$$$  D=DIAMETER OF REFLECTOR. IF INPUT GREATER THAN ZERO ASSUMED
C$$$    CIRCULAR AND CODE GENERATES THE RIM POINTS. IF LESS THAN ZE
     RO
C$$$    RIM DATA INPUT WITH FOLLOWING READ STATEMENT
C$$$
C$$$  NOTE: ALL ABOVE DATA INPUT IN UNITS SPECIFIED BY IUNIT
C$$$
      IF(.NOT.LRESET)READ (5,-) IUNIT,F,GRIDX,GRIDY,D
      WRITE (6,3101) (LABEL(N,IUNIT),N=1,2)
 3101 FORMAT (2H *,'  LINEAR DIMENSION INPUTS ARE IN ',2A3,T79,1H*)
      WRITE (6,3006)
      UNITC=UNIT(IUNIT)
      IF (D.LE.0.) GO TO 3104
```

```
          WRITE (6,3102) D
     3102 FORMAT(2H *,T8,'CIRCULAR REFLECTOR WITH APERTURE DIAMETER =',
         2F9.2,T79,1H*)
          WRITE(6,3006)
          GO TO 3112
C$$$
C$$$      IF DIAMETER OF DISH IS DEFINED NEGATIVE ABOVE,THEN INPUT RIM
C$$$      POINTS DIRECTLY
C$$$
C$$$      NRIM=NUMBER OF RIM POINTS INPUT
C$$$
C$$$      RIM(NE,1)=X-POSITION OF THE NE-TH RIM POINT
C$$$      RIM(NE,2)=Y-POSITION OF THE NE-TH RIM POINT
C$$$
     3104 IF (D.LE.0.AND.(.NOT.LRESET)) READ (5,-) NRIM,((RIM(NE,N),N=1
     ,2),
         1NE=1,NRIM)
          WRITE (6,3106)
     3106 FORMAT(2H *,T10,'COORDINATES OF RIM POINTS IN METERS',T79,1H*
     ,
         2/2H *,T20,'RIM POINT',9X,'X',14X,'Y',T79,1H*)
          WRITE(6,3006)
          DO 3110 NE=1,NRIM
          WRITE (6,3108) NE,(RIM(NE,N),N=1,2)
          RIMS(NE,1)=RIM(NE,1)*UNITO
          RIMS(NE,2)=RIM(NE,2)*UNITO
     3108 FORMAT(2H *,T20,I5,2F15.2,T79,1H*)
     3110 CONTINUE
     3112 WRITE (6,3006)
          WRITE (6,3115) F,GRIDX,GRIDY
     3115 FORMAT(2H *,T10,'FOCAL DISTANCE=',F9.2,T35,'GRIDX=',F7.3,5X,
         2'GRIDY =',F7.3,T79,1H*)
          FOCUS=F*UNITO
          GRX=GRIDX*UNITO
          GRY=GRIDY*UNITO
          A=0.5*D*UNITO
          IF(LRESET)GO TO 3300
          GO TO 3600
C------
     3200 CONTINUE
C-----    IO:   COMMAND   ------------
C$$$
C$$$      LDEBUG=DEBUG DATA OUTPUT ON LINE PRINTER(TRUE OR FALSE)
C$$$
C$$$      LTEST=TEST DATA TO INSURE PROGRAM OPERATION(TRUE OR FALSE)
C$$$
C$$$      LWYSUM=WRITE  YSUM DATA ON LINE PRINTER(TRUE OR FALSE)
C$$$
C$$$      LOUT=OUTPUT MAIN PROGRAM DATA ON LINE PRINTER(TRUE OR FALSE)
C$$$
C$$$      LWFD=OUTPUT FEED PATTERN DATA ON LINE PRINTER(TRUE OR FALSE)
C$$$
```

```
      READ (5,-) LDEBUG,LTEST,LWYSUM,LOUT,LWFD
      WRITE(6,3201)LDEBUG,LTEST,LWYSUM,LOUT,LWFD
 3201 FORMAT(2H *,5X,'LDEBUG= ',L2,5X,'LTEST= ',L2,5X,'LWYSUM=',L2,
     15X,'LOUT =',L2,5X,'LWFD =',L2,T79,1H*)
      WRITE(6,3006)
C$$$
C$$$  LSLOPE=SLOPE DIFFRACTED FIELD DESIRED (T OR F)
C$$$
C$$$  LCORNR=CORNER DIFFRACTED FIELD DESIRED (T OR F)
C$$$
      READ(5,-)LSLOPE,LCORNR
      WRITE(6,3202)LSLOPE,LCORNR
 3202 FORMAT(2H *,5X,'LSLOPE= ',L2,5X,'LCORNR= ',L2,5X,
     1T79,1H*)
C$$$
C$$$  LAI=APERTURE INTEGRATION SOLUTION INCLUDED (TRUE OR FALSE)
C$$$
C$$$  LFEED=FEED SPILLOVER INCLUDED IN SOLUTION (TRUE OR FALSE)
C$$$
C$$$  LGTD=GTD INCLUDED IN SOLUTION (TRUE OR FALSE)
C$$$
C$$$  THETAX=PATTERN SWITCHING ANGLE FROM AI TO GTD
C$$$
C$$$  ZX=STARTING CRITERION FOR USING AI IN NEAR FIELD CALCULATION
C$$$
      READ(5,-)LAI,LFEED,LGTD,THETAX,ZXP
      WRITE (6,3006)
      WRITE (6,3204) LAI,LFEED,LGTD
 3204 FORMAT(2H *,5X,'LAI =',L2,8X,'LFEED =',L2,6X,'LGTD =',
     2L2,T79,1H*)
      WRITE (6,3006)
      WRITE (6,3206) THETAX,ZXP
 3206 FORMAT (2H *,5X,'THETAX =',F5.2,5X,'ZX =',F10.3,T79,1H*)
      ZXP2=ZXP*UNITO
      GO TO 3000
C------
 3300 CONTINUE
C------   FD:   COMMAND   --------------
      KX=0
      KY=0
      CX=TEM2+CJ*0.
      CY=CJ*TEM2
C$$$
C$$$  LLFD=INPUT FEED PATTERN IN TERMS OF LINEAR DATA POINTS
C$$$       IF .TRUE. OR ANALYTIC FUNCTION IF .FALSE.
C$$$
C$$$  LCP=FEED IS CIRCULARLY POLARIZED (TRUE OR FALSE)
C$$$
C$$$  LDB=FEED DATA INPUT IN DB.,IF LDB=.TRUE.
C$$$      LINEAR FEED DATA INPUT, IF LDB=.FALSE.
```

```
C$$$
C$$$   COEFFICIENTS OF THE FEED PATTERN
C$$$
C$$$        ISYM=0     NO SYMMETRY
C$$$        ISYM=1     EVEN SYMMETRY W.R.T. X AND Y AXIS
C$$$        ISYM=-1    ODD SYMMETRY W.R.T. X AND Y AXIS
C$$$        ISYM=2     EVEN SYMMETRY W.R.T. X AXIS
C$$$        ISYM=-2    ODD SYMMETRY W.R.T. X AXIS
C$$$        ISYM=3     EVEN SYMMETRY W.R.T. Y AXIS
C$$$        ISYM=-3    ODD SYMMETRY W.R.T. Y AXIS
C$$$
C$$$
C$$$  PSIT=TILT ANGLE OF FEED RELATIVE TO -Z AXIS IN THE YZ PLANE.
C$$$         NORMALLY ZERO ;HOWEVER USEFUL FOR OFFSET REFLECTOR
C$$$
C$$$  TAU=LINEAR POLARIZATION ANGLE RELATIVE TO X-AXIS OF FEED
C$$$
      IF(.NOT.LRESET)READ(5,-)LLFD,LCP,LDB,ISYM,TAU
      NCK=2
      IF(LLFD)NCK=0
      IF (LCP) WRITE (6,3301)
 3301 FORMAT(2H *,T8,'CIRCULARLY POLARIZED FEED',T79,1H*)
      WRITE(6,3006)
      WRITE(6,3302)ISYM
 3302 FORMAT(2H *,T8,'FEED PATTERN SYMMETRY GIVEN BY:ISYM=',I2,
     1T79,1H*)
      WRITE(6,3006)
C$$$
C$$$  NPHI=NUMBER OF INPUT FEED PATTERN CUTS
C$$$
C$$$  PHIN(N)=PHI ANGLE OF N-TH INPUT PATTERN CUT
C$$$
      IF(.NOT.LRESET)READ (5,-) NPHI,(PHIN(N),N=1,NPHI)
      IF (LCP) GO TO 3305
      WRITE (6,3303) TAU
 3303 FORMAT(2H *,T8,'LINEARLY POLARIZED FEED',T79,1H*,/2H *,T79,
     21H*,/2H *,T10,'POLARIZED ANGLE =',F7.2,T79,1H*)
      WRITE(6,3006)
      TAUR=TAU/DPR
      SINTU=SIN(TAUR)
      COSTU=COS(TAUR)
      CX=COSTU+CJ*0.
      CY=SINTU+CJ*0.
 3305 CONTINUE
      IF(LDB)WRITE(6,4002)
 4002 FORMAT(2H *,T10,'FEED DATA INPUT IN DB.',T79,1H*)
      IF(.NOT.LDB)WRITE(6,4003)
 4003 FORMAT(2H *,T10,'LINEAR FEED DATA INPUT',T79,1H*)
      WRITE(6,3006)
      IF (BABS(CX).GT.1.D-5) KX=1
```

```
      IF (BABS(CY).GT.1.D-5) KY=1
      WRITE(6,3ØØ6)
      PN1=PHIN(1)
      PNN=PHIN(NPHI)
      IB=IABS(ISYM)
      PHQ=9Ø.
      PHP=Ø.
C!!!  CHECK INITIAL AND FINAL INPUT PHIN
      IF (IB.EQ.Ø.AND.PN1.NE.-18Ø.) GO TO 285
      IF (IB.EQ.1.AND.(PN1.NE.Ø..OR.PNN.NE.9Ø.)) GO TO 285
      IF (IB.EQ.2.AND.(PN1.NE.Ø..OR.PNN.NE.18Ø.)) GO TO 285
      IF (IB.EQ.3.AND.(PN1.NE.-9Ø..OR.PNN.NE.9Ø.)) GO TO 285
      IF (LLFD) GO TO 3315
C$$$
C$$$  ANALYTIC FEED PATTERN INPUT(LLDF=.FALSE.)
C$$$
C$$$  NPW=COSINE RAISED TO THIS POWER
C$$$
C$$$  AEX=EXPONENTIAL FACTOR TO CONTROL SIDE LOBE LEVEL
C$$$
C$$$  CAN=CONSTANT TERM TO APPROXIMATE FAR OUT SECTION OF FEED
C$$$  PATTERN
C$$$
C$$$  PSIO(N)=ANGLE TO CONTROL THE ZERO ASSOCIATED WITH COSINE
C$$$          FOR THE N-TH PHI INPUT FEED PATTERN CUT
C$$$
C$$$  NOTE: FEED=CEXP(-AEX*(PSI/PSIO)**2)*COS(.5*PI(PSI/PSIO))**NPW
 +CAN
C$$$
      IF(.NOT.LRESET)READ (5,-)NPW,(AEX(N),CAN(N),PSIO(N),N=1,NPHI)
      WRITE (6,33Ø8) NPW
 33Ø8 FORMAT (2H *,T12,5HNPW =,I2,T79,1H*,/2H *,T16,'N',T26,
     1'PHIN(N)',6X,'PSIO(N)',9X,'AEX(N)',7X,'CAN(N)',T79,1H*)
      DO 3312 N=1,NPHI
      WRITE (6,331Ø) N,PHIN(N),PSIO(N),AEX(N),CAN(N)
 331Ø FORMAT(2H *,T15,I2,3F14.1,F13.2,T79,1H*)
 3312 CONTINUE
      GO TO 3ØØØ
 3315 N1=Ø
C$$$
C$$$  LINEAR FEED PATTERN INPUT(LLFD=.TRUE.)
C$$$
C$$$  N2=MAXIMUM NUMBER OF FEED PATTERN POINTS TO BE READ FOR
C$$$     ALL INPUT PHI ANGLES
C$$$
      IF(.NOT.LRESET)READ (5,-) N2
      WRITE (6,3318) N2
 3318 FORMAT(2H *,T1Ø,'MAXIMUM NUMBER OF FEED POINTS=',I2,T79,1H*)
      WRITE(6,3ØØ6)
      IF (N2.GT.MDFP) GO TO 272
      NPP=NPHI+1
```

```
      IF (KY.EQ.0) WRITE (6,3320)
      IF (KX.EQ.0) WRITE (6,3322)
 3320 FORMAT(2H *,T8,'X-ORIENTED DIPOLE FEED',T79,1H*)
 3322 FORMAT(2H *,T8,'Y-ORIENTED DIPOLE FEED',T79,1H*)
      WRITE(6,3006)
      DO 3340 NP=1,NPHI
      WRITE (6,3325) NP,PHIN(NP)
3325  FORMAT(2H *,T8,5HPHIN(,I1,3H) =,F6.1,T79,1H*)
      WRITE(6,3006)
      WRITE (6,3326)
3326  FORMAT(2H *,T10,27HPIECEWISE LINEAR FEED INPUT,T79,1H*,/
     22H *,T18,3HPSI,T31,1HF,12X,5HF(DB),T79,1H*)
      WRITE(6,3006)
      DO 3340 K=1,N2
C$$$
C$$$  PSIX=K-TH PSI PATTERN ANGLE OF INPUT FEED POINT
C$$$
C$$$  FN=PATTERN VALUE IN DB.
C$$$
      IF(.NOT.LRESET)READ (5,-) PSIX,FN
      PX(NP,K)=PSIX
      FP(NP,K)=FN
      IF (NP.GT.1) GO TO 3328
      PX(NPP,K)=PSIX
      FP(NPP,K)=FN
3328  IF (LDB) GO TO 3330
      AFN=ABS(FN)
      IF (AFN.LT.1.E-5) FDB=-500.
      IF (AFN.GE.1.E-5) FDB=20.*ALOG10(AFN)
      GO TO 3332
3330  FDB=FN
      FN=10.**(FDB/20.)
3332  WRITE (6,3334) PSIX,FN,FDB
3334  FORMAT(2H *,T10,F10.2,F15.4,F13.2,T79,1H*)
 3340 CONTINUE
      GO TO 3000
C------
3400  CONTINUE
C------    FQ:   COMMAND   ------------
C$$$
C$$$  NFRQ=NUMBER OF FREQUENCIES CONSIDERED IN COMPUTATION
C$$$
C$$$  FREQ(I)=I-TH FREQUENCY IN GIGAHERTZ
C$$$
      READ(5,-)NFRQ,(FREQ(I),I=1,NFRQ)
      WRITE(6,3401)NFRQ,(FREQ(I),I=1,NFRQ)
3401  FORMAT(2H *,' FOR THIS GEOMETRY,THERE WILL BE ',I3,' FREQUENC
 IES'
     1,' CONSIDERED AS FOLLOWS:',T79,1H*,/2H *,10(F6.2,','),
     2T79,1H*)
      GO TO 3000
```

```
C------
3500  CONTINUE
C---     NF:    COMMAND    --------------
      READ (5,-) LNF,LRANG
      WRITE (6,3006)
      IF (LNF) GO TO 3505
      WRITE (6,3501)
3501  FORMAT (2H *,T5,'FAR FIELD PATTERN WILL BE CALCULATED',T79,1H
     *)
      IF (.NOT.LRANG) GO TO 3000
      READ (5,-) RANG
      WRITE (6,3502) RANG
3502  FORMAT (2H *,T10,'WITH RANGE =',F10.2,T79,1H*)
      RANG=RANG*UNITO
      GO TO 3000
3505  WRITE (6,3506)
3506  FORMAT (2H *,T5,'NEAR FIELD PATTERN WILL BE CALCULATED',T79,1
     H*)
      READ (5,-) PHIE,(XOO(I),I=1,3)
      WRITE (6,3507) PHIE,(XOO(I),I=1,3)
3507  FORMAT (2H *,T10,'IN PHIE =',F7.2,' DEGREE CUT, AND ORIGIN AT
      (',
     23(F6.2,',',),' )',T79,1H*)
      XO1=XOO(1)*UNITO
      XO2=XOO(2)*UNITO
      XO3=XOO(3)*UNITO
      IF (LRANG) WRITE (6,3508)
3508  FORMAT (2H *,T10,'WITH CONTANT RANGE',T79,1H*)
      IF (.NOT.LRANG) WRITE (6,3509)
3509  FORMAT (2H *,T10,'WITH CONTANT Z CUT',T79,1H*)
      WRITE (6,3006)
      GO TO 3000
C------
3700  CONTINUE
C---     LP:    COMMAND    --------------
C$$$
C$$$  SET WRITE OUTPUT FLAG SO DATA WRITTEN OUT ON LINE PRINTER.
C$$$
      WRITE(6,3701)
3701  FORMAT(2H *,5X,' DATA WILL BE OUTPUT ON LINE PRINTER !!!',
     1T79,1H*)
      LWRITE=.TRUE.
      GO TO 3000
C------
3800  CONTINUE
C---     PP:    COMMAND    --------------
C$$$
C$$$  SET FLAG SUCH THAT THE DATA WILL BE PEN PLOTTED
C$$$  IN RECTANGULAR FORM
C$$$
      READ (5,-) LPLT,INPF
      IF (LPLT) WRITE(6,3802)
3802  FORMAT(2H *,5X,'DATA WILL BE OUTPUT TO PEN PLOTTER !!!',T79,1
     H*)
```

```
      IF (.NOT.LPLT) WRITE (6,3804)
 3804 FORMAT (2H *,5X,'NO PLOT OUTPUT GENERATED',T79,1H*)
      IF (INPF.EQ.0) GO TO 3000
      IF (INPF.GT.0) READ (5,-) (ANPF(L),L=1,INPF)
      IF (INPF.LT.0)READ (5,-) ANPF(1),ANPF(2)
      GO TO 3000
C------
 3900 CONTINUE
C------   CM:   OR   CE:   COMMAND   -------------
C$$$
C$$$  READ "CM:" CARDS AS COMMENTS UNTIL A "CE:" CARD IS INPUT WHIC
     H
C$$$  ENDS COMMENTS
C$$$
 3999 IF(IR(1).EQ.IT(10))GO TO 3000
      READ(5,3001,END=3004)(IR(I),I=1,24)
      WRITE(6,3003)(IR(I),I=1,24)
      IF(IR(1).EQ.IT(9).OR.IR(1).EQ.IT(10))GO TO 3999
      GO TO 3059
C------
 4000 CONTINUE
C------   TL:   COMMAND   -------------
C$$$
C$$$  PSIT=TILT ANGLE OF FEED RELATIVE TO -Z AXIS IN THE YZ PLANE.
C$$$       NORMALLY ZERO :HOWEVER USEFUL FOR OFFSET REFLECTOR
C$$$
C$$$  YC=Y-COORDINATE OF APERTURE CENTER
C$$$
      READ (5,-) PSIT,YC
      WRITE (6,4001) PSIT,YC
 4001 FORMAT (2H *,T10,'FEED AXIS TILT ANGLE =',F8.2,T79,1H*,/2H *,
     2T79,1H*,/2H *,T10,'APERTURE CENTER AT (0.,',F8.3,')',T79,1H*
     )
      YCM=YC*UNITO
      WRITE (6,3006)
      GO TO 3000
C-------
 4100 CONTINUE
C------   PZ:   COMMAND   -------------
C$$$
C$$$  IP2=ABSOLUTE VALUE OF NUMBER OF PATTERN CUTS DESIRED.
C$$$      IF IP2 LESS THAN ZERO ,THEN INPUT ANP SUCH THAT
C$$$      P2=AP2(1)+(N-1)*AP2(2) FOR N=0 TO N=/IP2/-1.
C$$$      IF IP2 GREATER THAN ZERO ,THEN IP2UT THE DESIRED
C$$$      PATTERN CUT VALUES INPUT DIRECTLY
C$$$
      READ(5,-)IP2
      NP2=IABS(IP2)
      WRITE(6,4101)NP2
 4101 FORMAT(2H *,' USING THE PRESENT GEOMETRY,THERE WILL BE ',I3,
     1' PATTERN CUTS COMPUTED',T79,1H*)
      WRITE(6,3006)
      WRITE(6,3006)
```

```
C$$$
C$$$  ANP=INFORMATION ASSOCIATED WITH THE DESIRED CUTS. THE
C$$$  DEFINITION OF THIS ARANGAY IS GIVED IN THE PREVIOUS COMMENTS
C$$$
      IF (IP2.GT.0) READ (5,-) (AP2(L),L=1,NP2)
      IF(IP2.GT.0)WRITE(6,4102)(AP2(L),L=1,NP2)
 4102 FORMAT(2H *,' SINCE IP2 IS POSITIVE THE FOLLOWING CUTS WILL'
     1,' BE COMPUTED:',T79,1H*,/2H *,8(F6.1,','),T79,1H*)
      IF (IP2.LT.0) READ (5,-) (AP2(L),L=1,2)
      IF(IP2.LT.0)WRITE(6,4103)AP2(1),AP2(2)
 4103 FORMAT(2H *,' PATTERN CUTS WILL BE COMPUTED STARTING AT P2='
     1,F6.1,' AND INCREMENTED BY',F6.1,T79,1H*)
      WRITE(6,3006)
C$$$
C$$$  ADP3=INCREMENTS IN PATTERN VALUES FOR EACH CUT
C$$$
C$$$  AP3I=INITIAL THETA ANGLE OR RHO FOR EACH COMPUTED PATTERN CUT
C$$$
C$$$  AP3F=FINAL THETA ANGLE OR RHO FOR PATTERN CUT
C$$$
      READ(5,-)AP3I,AP3F,ADP3
      WRITE (6,4104) AP3I,AP3F
 4104 FORMAT(2H *,5X,'AP3I =',F7.2,5X,'AP3F =',F7.2,T79,1H*)
      WRITE (6,3006)
      WRITE(6,4105)ADP3
 4105 FORMAT(2H *,'  FOR EACH CUT THE PATTERN WILL BE COMPUTED EACH
 '
     1,F6.1,' DEGREES THETA OR',T79,1H*,/2H *,T79,1H*,/2H *,
     2'  INPUT UNIT IN RHO',T79,1H*)
      IF (.NOT.LNF) GO TO 4106
 4106 WRITE(6,3006)
      GO TO 3000
C------
 4300 CONTINUE
C------    XO:    COMMAND    ------------------------------
      RFCT=(1.,0.)
      SINTL=SIN(PSIT/DPR)
      COSTL=COS(PSIT/DPR)
      IF (.NOT.LWFD) GO TO 70
C
C     *** PRINT FEED PATTERN ***
C
      IF (NCK.EQ.0) DPSI=5.
      IF (NCK.EQ.2) DPSI=PSIO(1)/10.
      PHIP=0.
      DO 66 NP=1,2
      WRITE (6,60) PHIP
   60 FORMAT(/2H F,T5,6HPHIP =,F7.2,1X,20H DEGREE FEED PATTERN,T79,1
 HF
     2,/2H F,11X,3HPSI,T29,2HGX,11X,2HGY,T79,1HF)
      WRITE(6,3006)
```

```
      PSI=0.
      DO 65 I=1,19
      CALL FEED(PSI,PHIP,PSA,PHCAM)
      GX=BABS(GF*CX)
      GY=BABS(GF*CY)
      IF (.NOT.LDB) GO TO 62
      IF (GX.LT.1.E-5) GX=-100.
      IF (GY.LT.1.E-5) GY=-100.
      IF (GX.GE.1.E-5) GX=20.*ALOG10(GX)
      IF (GY.GE.1.E-5) GY=20.*ALOG10(GY)
   62 CONTINUE
      WRITE (NL,64) PSI,GX,GY
   64 FORMAT(2H F,T10,F7.2,5X,2F12.4,T79,1HF)
      PSI=PSI+DPSI
   65 CONTINUE
      PHIP=PHIP+90.
   66 CONTINUE
   70 TEMP=PSIT
      PSIT=0.
C
C     *** PLOT FEED PATTERN ***
C
      IF (INPF.EQ.0) GO TO 80
      NNF=IABS(INPF)
      LAB=0
      DO 76 MF=1,NNF
      IF (INPF.GT.0) PHIP=ANPF(MF)
      IF (INPF.LT.0) PHIP=ANPF(1)+(MF-1)*ANPF(2)
      PHIPF=PHIP
      PSI=0.
      DO 75 I=1,51
      PSIF=ABS(PSI)
      IF (PSI.LT.0.) PHIPF=PHIP-180.
       CALL FEED(PSIF,PHIPF,PSA,PHCAM)
      AGX=BABS(GF*CX)
      AGY=BABS(GF*CY)
      IF (AGX.LT.1.E-5) GXDB=-100.
      IF (AGY.LT.1.E-5) GYDB=-100.
      IF (AGX.GE.1.E-5) GXDB=20.*ALOG10(AGX)
      IF (AGY.GE.1.E-5) GYDB=20.*ALOG10(AGY)
      IF (KX.EQ.1) PLTF=GXDB
      IF (KY.EQ.1) PLTF=GYDB
      PSI=PSI+1.
   75 CONTINUE
   76 CONTINUE
      LAB=0.
      IF ((.NOT.LAI).AND.(.NOT.LCTP)) GO TO 3000
```

Power Radiated by feed (Section 1)

```
C
C      *** FREQUENCY LOOP ***
C
       DO 27Ø IQ=1,NFRQ
       WRITE(6,3ØØ6)
       WRITE (6,96) FREQ(IQ)
 96    FORMAT(2H *,T1Ø,'FREQUENCY =',F1Ø.3,' GHZ',T79,1H*)
       WRITE(6,3ØØ6)
       RLAM=1.D-9*C/FREQ(IQ)
       WRITE (6,97) RLAM
 97    FORMAT (2H *,T1Ø,'WAVELENGTH =',F12.6,' METERS',T79,1H*,/2H *,
      2T1Ø,'* THE FOLLOWING DIMENSION UNITS ARE IN WAVELENGTHS *',
      3T79,1H*)
       WRITE (6,3ØØ6)
       IF (.NOT.LNF) GO TO 98
       XOO(1)=XO1/RLAM
       XOO(2)=XO2/RLAM
       XOO(3)=XO3/RLAM
 98    RR=RANG/RLAM
       IF (LRANG) RFCT=CEXP(-CJ*TPI*RR)/RR
       D=2.*A/RLAM
       YC=YCM/RLAM
       F=FOCUS/RLAM
       ZX=ZXP2/RLAM
       RIML=SQRT(F/2.)
       IF (LNF) RIML=RIML/2.
       IF(D.LE.Ø.)GO TO 1Ø4
```

Rim point calculation for circular aperture (Section 2)

```
  104   WRITE(6,3ØØ6)
        WRITE (6,1Ø5)
   1Ø5 FORMAT(2H *,T1Ø,'COORDINATES OF RIM POINTS (WAVELENGTHS)',T7
     9,
      21H*,/2H *,T2Ø,'RIM POINT',9X,'X',14X,'Y',T79,1H*)
        RMAX=Ø.
        DO 1Ø8 NE=1,NRIM
        DO 1Ø6 N=1,2
   1Ø6  RIM(NE,N)=RIMS(NE,N)/RLAM
        RHOSO=RIM(NE,1)**2+RIM(NE,2)**2
        IF (RHOSO.GT.RMAX) RMAX=RHOSO
   1Ø8  WRITE (6,31Ø8) NE,(RIM(NE,N),N=1,2)
        WRITE(6,3ØØ6)
        GRIDX=GRX/RLAM
        GRIDY=GRY/RLAM
        WRITE (6,1Ø9) F,GRIDX,GRIDY
   1Ø9  FORMAT (2H *,T12,'FOCAL DISTANCE =',F9.2,T79,1H*,/2H *,T79,
      21H*,/2H *,T12,'GRIDX =',F7.2,5X,'GRIDY =',F7.2,T79,1H*,)
        WRITE (6,3ØØ6)
        ZOP=RMAX/(4.*F)
        ZO=F-ZOP
        RO=SQRT(RMAX+ZO**2)
        XS(1)=Ø.
        XS(2)=Ø.
        XS(3)=ZO
        IF (LTEST) WRITE (6,11Ø) ZOP,ZO,RO
  11Ø   FORMAT(2H D,T1Ø,4HZOP=,F9.2,5X,3HZO=,F9.2,5X,3HRO=,F9.3,T79,1H
     D)
        REFDB=1Ø.*ALOG1Ø(2.*TPI/(F*F*PRAD))
        REF=REFDB
        IF (LRANG) REF=Ø.
        WRITE(6,3ØØ6)
        WRITE (6,111) REF
   111  FORMAT(2H *,T12,'REF =',F1Ø.3,T79,1H*)
        WRITE(6,3ØØ6)
        PHSEA=CEXP(-CJ*TPI*RO)
        P3I=AP3I
        P3F=AP3F
        DP3=ADP3
        IF (.NOT.LNF.OR.LRANG) GO TO 112
        P3I=AP3I*UNITO/RLAM
        P3F=AP3F*UNITO/RLAM
        DP3=ADP3*UNITO/RLAM
   112  NT=(P3F-P3I)/DP3+1.1
C
C       *** ALL UNITS ARE IN WAVELENGTHS FROM HERE ON ***
C
        IF (LPLT) WRITE (2) LNF,LRANG,LAI,LGTD
        IF (LPLT) WRITE (2) P3I,P3F,DP3,NP2,PHIE,F,D,GRIDX,YC,RR,PSIT
C
C       *** SET UP PRINCIPAL GRID ***
```

```
C
      CALL GRID(0.,ICO,IMO)
      FJC=-YMIN/GRDY+DEL
      JCO=FJC+1
      IF (FJC.LT.-1.) JCO=JCO-1
      FJ=YMAX/GRDY+DEL
      JMO=FJ+JCO
      IF (LTEST) WRITE (6,113) ICO,IMO,JCO,JMO
  113 FORMAT(2H D,T10,4HICO=,I3,5X,4HIMO=,I3,T79,1HD,/2H D,T10,4HJ
  CO=,
     2,I3,5X,5HJMO =,I3,T79,1HT)
      IC=ICO
      JC=JCO
      IMAX=IMO
      MMAX=IMO+2
      NMAX=JMO+2
      MAXO=MMAX
      IF (NMAX.GT.MAXO) MAXO=NMAX
      MNO=(MAXO+1)/2
      AX=XMAX-XMIN
      BY=YMAX-YMIN
      IF (MAXO.LE.MDEA) GO TO 116
      MAX=MAXO
  114 WRITE(6,3006)
      WRITE (6,115) MAX
  115 FORMAT(2H E,T10,'MAX =',I3,T79,1HE)
      WRITE(6,3006)
      GO TO 272
  116 CONTINUE
C
      IF (LTEST.OR.LDEBUG) NTEST=1
      IF (LTEST.OR.LDEBUG) WRITE (6,117)
  117 FORMAT(2H T,T10,'TESTING APERTURE FIELDS',T79,1HT)
```

Aperture field calculations (Section 3)

```
C
      CALL GEOM(MRIM,RIML,RIM)
      IF (MRIM .LE.MDRIM) GO TO 123
      WRITE(6,3006)
      WRITE (6,122) MRIM
  122 FORMAT(2H E,T10,'MRIM =',I2,T79,1HE)
      WRITE(6,3006)
      GO TO 272
  123 CONTINUE
```

```
C
      IF ((.NOT.LNF).AND.(LRANG)) WRITE (6,126) RR
  126 FORMAT (/2H *,T1Ø,'** CONSTANT RANGE R =',F1Ø.2,' **',T79,1H*
     ,/)
C
C     *** P2 LOOP ***
C
      NP2=IABS(IP2)
      DO 27Ø MP=1,NP2
      IF (IP2.GT.Ø) P2=AP2(MP)
      IF (IP2.LT.Ø) P2=AP2(1)+(MP-1)*AP2(2)
      WRITE(6,3ØØ6)
      IF (LNF) PHI=PHIE
      IF (.NOT.LNF) PHI=P2
      WRITE (6,13Ø) PHI
  13Ø FORMAT(2H *,T5,5HPHI =,F8.2,T79,1H*)
      IF (PHI.GT.18Ø.) PHI=PHI-36Ø.
      IF (PHI.GT.18Ø..OR.PHI.LT.-18Ø.) WRITE (6,131)
  131 FORMAT (2H E,T1Ø,'***ERROR : INVALID PHI FOR SUBROUTINE SBDY'
     2,T79,1HE)
      IF (.NOT.LNF) GO TO 137
  132 P2=P2*UNITO/RLAM
      WRITE (6,3ØØ6)
      IF (LRANG) WRITE (6,135) P2
  135 FORMAT (2H *,T1Ø,'NEAR FIELD WITH CONSTANT RANGE R =',F1Ø.2,
     2T79,1H*)
      IF (.NOT.LRANG) WRITE (6,136) P2
  136 FORMAT (2H *,T1Ø,'NEAR FIELD OBSERVATION PLANE AT Z =',F1Ø.2,
     2T79,1H*)
  137 WRITE(6,3ØØ6)
      IF (LPLT) WRITE (2) P2
      PHIR=PHI/DPR
      COSP=COS(PHIR)
      IF (ABS(COSP).LT.1.D-5) COSP=Ø.
      SINP=SIN(PHIR)
      TH1=18Ø.
      TH2=18Ø.
      THEB=PI/2.
C
C     *** CALCULATE SHADOW BOUNDARIES ***
C
      CALL SBDY(MRIM,X,XS,PHI,TH1,TH2,THEB)
      WRITE (6,138) TH1,TH2
  138 FORMAT (2H F,T1Ø,'TH1 =',F8.2,5X,'TH2 =',F8.2,T79,1HF)
      WRITE(6,3ØØ6)
      IF (LNF.AND..NOT.LRANG) WRITE (6,139)
  139 FORMAT (2H W,T31,'EX',27X,'EY',27X,'EZ',//T7,3HRHO,6X
     2,3(5X,3HMAG,7X,2HDB,7X,5HPHASE))
      IF(.NOT.LNF.OR.LRANG)WRITE (6,1391)
 1391 FORMAT(2H W,T27,'PRINCIPAL POL',T55,'CROSS POL',T79
     2,1HW,/2H W,T79,1HW,/2H W,T6,5HTHETA,5X,
```

```
     32(5X,3HMAG,7X,2HDB,7X,5HPHASE),T79,1HW,/2H *,T79,1H*)
      PPT=(PHI-TAU)/DPR
      SINPT=SIN(PPT)
      COSPT=COS(PPT)
      IF(.NOT.LAI)GO TO 180
      IF (LNF) GO TO 148
C
C     *** SET UP ROTATED GRID ***
C
      PHIG=PHI
      CALL GRID(PHIG,IC,IMAX)
      IF (IMAX.GE.3) GO TO 142
      WRITE(6,3006)
      WRITE (6,140)
  140 FORMAT(2H E,T5,28H* ERROR : IMAX LESS THAN 3 *,T79,1HE)
      WRITE(6,3006)
      GO TO 3000
  142 IF (PCHG) 143,144,144
  143 JC=ICO
      JMAX=IMO
      ICOP=JCC
      GO TO 145
  144 JC=JCO
      JMAX=JMO
      ICOP=ICC
  145 IF (LTEST) WRITE (6,146) IC,IMAX,JC,JIMAX
  146 FORMAT(2H D,T5,3HIC=,I3,5X,5HIMAX=,I3,T79,1HD/2H D,T5,3HJC=,I
    3
     2,5X,6HJMAX =,I3,,T79,1HD)
  148 IF (LNF.AND.(MP.GT.1)) GO TO 173
      K=0
      L=0
      MC=IC+1
      MAX=IMAX+2
      MIX=MAX-1
      IF (MAX.GT.MDEA) GO TO 114
```

Y integration for far field (Section 4)

```
C
  173 DXL=(1-IC)*GRDX-XMIN
      QXL=DXL/GRDX
      DXR=XMAX-(IMAX-IC)*GRDX
      QXR=DXR/GRDX
      IF (LTEST) WRITE (6,175) DXL,DXR
  175 FORMAT(2H D,T5,5HDXL =,F6.2,5X,5HDXR =,F6.2,T79,1HD)
```

Switching criterion (Section 5)

```
C
C      *** P3 LOOP ***
C
  182  S=RR
       IF (.NOT.LNF) GO TO 185
       SINPE=SIN(PHIE/DPR)
       COSPE=COS(PHIE/DPR)
       IF (.NOT.LRANG) ZE=P2
       IF (LRANG) RE=P2
   185 P3=P31
       IF (LTEST) WRITE (6,186) THETAX,NAI
  186  FORMAT(2H D,T10,'THETAX =' F7.2,5X,'NAI =',I5,T79,1HD)
       DO 250 N=1,NAI
       THER=P3/DPR
       IF (.NOT.LNF) GO TO 196
C
C      *** NEAR FIELD COORDINATE CONVERSION ***
C
       IF (.NOT.LRANG) GO TO 190
       THE=P3/DPR
       SINTE=SIN(THE)
       COSTE=COS(THE)
  188  XN(1)=XCO(1)+RE*SINTE*COSPE
       XN(2)=XCO(2)+RE*SINTE*SINPE
       XN(3)=XCO(3)+RE*COSTE
       IF (XN(1).NE.0..OR.XN(2).NE.0.) GO TO 194
       SINTE=SINTE+0.001
       GO TO 188
  190  ZL=P3
   191 XN(1)=XCO(1)+ZL*COSPE
       XN(2)=XCO(2)+ZL*SINPE
       XN(3)=ZE
       IF (XN(1).NE.0..OR.XN(2).NE.0.) GO  TO 194
       ZL=ZL+0.001
       GO TO 191
   194 PHIR=ATAN2(XN(2),XN(1))
       SINP=SIN(PHIR)
       COSP=COS(PHIR)
       RR=SQRT(XN(1)*XN(1)+XN(2)*XN(2)+XN(3)*XN(3))
       IF (LTEST) WRITE (6,195) XN(1),XN(2),XN(3)
  195  FORMAT (T20,6F12.5)
       COST=XN(3)/RR
       THER=ACOS(COST)
       THETA=THER*DPR
       GO TO 200
```

```
  196 THETA=P3
      THER=THETA/DPR
C
  200 SINT=SIN(THER)
      COST=COS(THER)
      EDX=(Ø.,Ø.)
      EDY=(Ø.,Ø.)
      EDZ=(Ø.,Ø.)
      IF (.NOT.LNF) GO TO 227
```

Aperture integration for near field
(Section 6)

```
C
C      *** SPILLOVER FIELDS FOR NEAR FIELD ***
C
       X1=XN(1)-XS(1)
       X2=XN(2)-XS(2)
       X3=XN(3)-XS(3)
       RHO=SQRT(X1*X1+X2*X2)
       PHIPR=BTAN2(X2,X1)
       PHIP=PHIPR*DPR
       PSI=BTAN2(RHO,-X3)*DPR
       RS=SQRT(RHO*RHO+X3*X3)
       PHEI=CEXP(-CJ*TPI*RS)*F/RS
       CALL FEED(PSI,PHIP,PSA,PHGAM)
       CALL FPOL(EIX,EIY,EIZ,PSA,PHGAM)
       EIX=EIX*PHEI
       EIY=EIY*PHEI
       EIZ=EIZ*PHEI
       IF (LOUT) WRITE (6,222) EIX,EIY,EIZ
   222 FORMAT(2H 0,T15,5HEIX =,2E1Ø.4,5X,5HEIY =,2E1Ø.4,5X,5HEIZ =,
      22E1Ø.4,T79,1HO)
C
C      ***OUTPUT RECTANGULAR COMPONENTS FOR CONSTANT Z NEAR FIELD ***
C
       EDX=EDX+EIX
       EDY=EDY+EIY
       EDZ=EDZ+EIZ
   224 IF (LRANG) GO TO 225
       CALL DBPHS(AEDX,EDX,Ø.)
       CALL DBPHS(AEDY,EDY,Ø.)
       CALL DBPHS(AEDZ,EDZ,Ø.)
       IF(LWRITE)WRITE (6,226) P3,AEDX,EDX,AEDY,EDY,AEDZ,EDZ
   226 FORMAT(2H W,T5,F6.1,4X,,3(E1Ø.3,2F1Ø.2))
       PLT=AEDZ
```

```
      GO TO 249
  225 EDT=COST*(COSP*EDX+SINP*EDY)-SINT*EDZ
      EDP=-SINP*EDX+COSP*EDY
      GO TO 242
```

X-integration for far field (Section 7)

```
C
C     *** SPILLOVER FIELDS FOR FAR FIELD ***
C
      PHIP=PHI
      PSI=180.-THETA
      PSIR=PSI/DPR
      SINS=SIN(PSIR)
      COSS=COS(PSIR)
      CALL FEED(PSI,PHIP,PSA,PHGAM)
      CALL FPCL(EIX,EIY,EIZ,PSA,PHGAM)
      EIT=-COSS*COSP*EIX-COSS*SINP*EIY-SINS*EIZ
      EIP=-SINP*EIX+COSP*EIY
      PHEI=CEXP(CJ*TPI*ZO*COST)*F*RFCT
      EIT=EIT*PHEI
      EIP=EIP*PHEI
      EDT=EDT+EIT
      EDP=EDP+EIP
C
C     *** PRINCIPAL AND CROSS POLARIZED COMPONENTS FOR FAR FIELD ***
C                    AND CONSTANT RANGE NEAR FIELD
C
  242 IF (LTEST) WRITE (6,243) ACOSP,COSP,SINP,EDT,EDP
  243 FORMAT (T10,3F12.4,/T10,'EDT =',2F12.5,5X,'EDP =',2F12.5,/)
      TMT=EDT
      EDT=COSPT*EDT-SINPT*EDP
      EDP=SINPT*TMT+COSPT*EDP
      IF (.NOT.LCP) GO TO 245
      TMT=EDT
      EDT=TEM2*(EDT-CJ*EDP)
      EDP=TEM2*(TMT+CJ*EDP)
  245 CALL DBPHS(AEDT,EDT,REF)
      CALL DBPHS(AEDP,EDP,REF)
      IF (LTEST) WRITE (6,195) PHI,TAU,COSPT,SINPT
      IF(LWRITE)WRITE (6,248) P3,AEDT,EDT,AEDP,EDP
  248 FORMAT(2H W,T5,F6.1,4X,,2(E10.3,2F10.2),T79,1HW)
      PLT=REAL(EDT)
  249 CONTINUE
```

```
      IF (LPLT) WRITE (2) PLT
      P3=P3+DP3
  250 CONTINUE
      NGTD=NT-NAI
      IF (NGTD.LE.0) GO TO 270
      THI2=NAI*DP3+P3I
  255 CONTINUE
      IF (LTEST) WRITE (6,260) NT,NAI,NGTD,THI2
 260  FORMAT(2H D,T10,3I10,3F10.3,T79,1HD)
      IF(.NOT.LGTD)GO TO 270
      IF(LTEST.OR.LDEBUG)NTEST=2
C     CALL GTD(THI2,NGTD,NAI,DP3)
 270  CONTINUE
      GO TO 3000
  272 WRITE (6,275)
  275 FORMAT(2H E,T8,'** ERROR : DECLARED DIMENSION EXCEEDED',T79,
 1HE)
      GO TO 3000
 285  WRITE (6,290)
  290 FORMAT(2H E,T10,'***ERROR : INPUT PHIN(1) OR PHIN(NPHI) '
     2'INCORRECT ***',T79,1HE)
      GO TO 3000
      END
```

SECTION 1. RELATIVE POWER RADIATED BY FEED

PURPOSE

To calculate the relative power radiated by feed using the input feed pattern data

METHOD

The relative radiated power from the feed is given by

$$P_{rad} = \int_0^{2\pi}\int_0^{\pi} g^2(\psi,\phi)\sin\psi d\psi d\phi$$

where

$$g(\psi,\phi) = \frac{\phi-\phi_Q}{\phi_P-\phi_Q}\ g_P(\psi) + \frac{\phi_P-\phi}{\phi_P-\phi_Q}\ g_Q(\psi)$$

is obtained by linearly interpolating the input feed pattern g_P and g_Q in the two planes ϕ_P and ϕ_Q adjacent to ϕ.

Since the feed pattern $g(\psi,\phi)$ is piecewise linear between two input PHI planes, the integration over ϕ reduces to a sum of integrals as

$$SPHI = \sum_{1}^{NM} \int_{\phi_Q}^{\phi_P}\int_0^{\pi} g^2(\psi,\phi)\sin\psi d\psi d\phi$$

where

$$\begin{cases} NM = NPHI & \text{if } IB=0 \text{ (no symmetry)} \\ NM = NPHI - 1 & \text{if } IB\neq 0 \text{ (with symmetry)} \end{cases}$$

and ϕ_P and ϕ_Q represent the upper and lower bound for each subregion. NPHI is the number of input feed cuts and IB is the absolute value of the symmetry index.

The integration over ϕ can be carried out analytically which gives

$$SPHI = \sum_{1}^{NM} \frac{\phi_P - \phi_Q}{3} \; SPSI$$

where

$$SPSI = \int_0^{\pi} (g_P^2 + g_Q^2 + g_P g_Q) \sin\psi d\psi$$

which is carried out numerically by using the trapezoidal rule.

Then the relative radiated power is given by

$$P_{rad} = \begin{cases} SPHI & IB=0 \\ 2SPHI & IB=2 \text{ or } 3 \\ 4SPHI & IB=1 \end{cases}$$

The relative power radiated is used for the purpose of calculating the far field results in antenna gain when the range factor e^{-jkR}/R is suppressed. This is done through the variable REFDB as given by

$$REFDB = 10 \log \frac{4\pi\lambda^2}{F^2 P_{rad}}$$

which is calculated later in the main program and used as input to the subroutine DBPHS.

KEY VARIABLES

DELI		Angular increments for numerical integration over ψ
GFP	$(g_P(\psi))$	Calculated feed value in the plane ϕ_P at angle ψ
GFQ	$(g_Q(\psi))$	Calculated feed value in the plane ϕ_Q at angle ψ
IB		Absolute value of the symmetry index (see User's Manual)
NM		Number of integration regions over ϕ
NPHI		Number of input feed cuts
PHIP	(ϕ_P)	Upper input PHI cut adjacent to ϕ
PHIQ	(ϕ_Q)	Lower input PHI cut adjacent to ϕ
PRAD	(P_{rad})	Power radiated from feed
PSI	(ψ)	Theta coordinate angle of the observation direction referred to the feed axis
SPHI		Sum of numerical integration over ϕ
SPSI		Sum of numerical integration over ψ

```
C
C      *** CALCULATE POWER RADIATED BY FEED ***
C
   80  IN=181
       DELI=PI/(IN-1)
       SPHI=0.
       IF (IB.EQ.0) NM=NPHI
       IF (IB.NE.0) NM=NPHI-1
       IF(LTEST.OR.LDEBUG)NTEST=1
       DO 94 NQ=1,NM
       NP=NQ+1
       IF (NP.GT.NPHI) NP=1
       PHIQ=PHIN(NQ)+0.001
       PHIP=PHIN(NP)-0.001
       PSIR=0.
       SPSI=0.
       DO 92 I=1,IN
       IF(I.EQ.4)NTEST=0
       PSI=PSIR*DPR
       CALL FEED(PSI,PHIQ,PSA,PHGAM)
       GFQ=GF
       CALL FEED(PSI,PHIP,PSA,PHGAM)
       GFP=GF
       FI=GFQ*GFQ+GFP*GFP+GFQ*GFP
       IF (I.EQ.1.OR.I.EQ.IN) FI=FI/2.
       SPSI=SPSI+FI*DELI*SIN(PSIR)
       PSIR=PSIR+DELI
       IF(NTEST.EQ.1)WRITE(6,90)PSIR,SPSI
   90  FORMAT(2H *,T12,'PSIR=',F7.2,5X,'SPSI=',F10.3,T79,1H*)
   92  CONTINUE
       NTEST=0
       DPHI=(PHIP-PHIQ)/DPR
       IF (DPHI.LT.0.) DPHI=DPHI+TPI
       SPHI=SPHI+SPSI*DPHI/3.
   94  CONTINUE
       PRAD=SPHI
       IF (IB.EQ.2.OR.IB.EQ.3) PRAD=2.*PRAD
       IF (IB.EQ.1) PRAD=4.*PRAD
       WRITE (6,95) PRAD
   95  FORMAT(2H *,T10,6HPRAD =,E10.3,,T79,1H*)
       PSIT=TEMP
```

SECTION 2. RIM POINT CALCULATION FOR CIRCULAR APERTURE

PURPOSE

To calculate the rim point coordinates of a circular aperture.

METHOD

For circular reflectors, the rim points are not input as they are for noncircular rim shapes. Instead, the diameter of the aperture (D) and the y-coordinate of aperture center (Y_c) are input.

The coordinates of the rim points of a circular aperture are then calculated as follows:

First an approximate value of the number of rim points is estimated by

$$NRIM_{(APP)} = Int(\pi D/RIML)$$

where

Int(X) means the integer value of X,

D is the diameter of the aperture, and

RIML is the reference length of each rim segment.

Then the actual value of NRIM is obtained by adjusting the estimated value such that NRIM is a multiple of 4 and is given by

$$NRIM = 4\left(Int\left(\frac{NRIM_{(APP)}+2}{4}\right)\right) \quad .$$

This adjustment is done for the purpose of having symmetrical rim segments.

To maintain approximately the same aperture area as the original aperture, the polar distance of each rim point is determined by taking the average polar distance to the corners of an inscribed regular polygon and a circumscribed regular polygon to the original circle, thus the polar distance

$$AA = \frac{a}{2}\left(1 + \frac{1}{\cos\left(\frac{\Delta\phi}{2}\right)}\right)$$

where a is the radius of the circular aperture and

$$\Delta\phi = \frac{2\pi}{NRIM}$$

The rim points are then calculated by

$$X_{RIM} = AA \cos\phi_{en}$$

$$Y_{RIM} = AA \sin\phi_{en} + Y_C$$

where

$$\phi_{en} = \left(n - \frac{1}{2}\right)\Delta\phi \qquad n=1,2,3,\cdots,NRIM$$

and Y_C is the y-coordinate of the aperture center.

KEY VARIABLES

A	(a)	Radius of the circular aperture
AA		Polar distance of each rim point
D	(D)	Diameter of the circular aperture
DELP	($\Delta\phi$)	Sector angle associated with each rim segment
NRIM		Number of rim segments
PHE	(ϕ_{en})	Polar angle of a rim point
RIML		Reference rim segment length
RIMS		X and Y coordinates of rim point ME
YCM	(Y_C)	Y-coordinate of the center of aperture

```
C
C      *** CIRCULAR RIM SECTION ***
C
       NRIM=PI*D/RIML
       NRIM=4*((NRIM+2)/4)
       IF(NRIM.LT.16)NRIM=16
       IF (NRIM.GT.MDRIM) NRIM=MDRIM
       WRITE (6,1ØØ) NRIM
   1ØØ FORMAT(2H *,T1Ø,'NUMBER OF RIM SEGMENTS=',I3,T79,1H*)
       WRITE(6,3ØØ6)
       RIML=-1.
       DELP=2.*PI/NRIM
       PHE=Ø.5*DELP
C!!!   USE THE AVERAGE RADIUS TO COMPUTE RIM POINTS FOR CIRCULAR REF
L.
       AA=Ø.5*A*(1.+1./COS(PHE))
       DO 1Ø2 NE=1,NRIM
       RIMS(NE,1)=AA*COS(PHE)
       RIMS(NE,2)=AA*SIN(PHE)+YCM
       PHE=PHE+DELP
   1Ø2 CONTINUE
       WRITE(6,3ØØ6)
       IF (D.GT.Ø.) WRITE (6,1Ø3) D,YC
  1Ø3  FORMAT(2H *,T1Ø,'APERTURE DIAMETER =',F9.2,' WAVELENGTHS',T79
,
     2 1H*,/2H *,T79,1H*,/2H *,T1Ø,'APERTURE CENTER AT (Ø.,',F7.2,'
)',
     3T79,1H*)
```

SECTION 3. APERTURE FIELDS

PURPOSE

To calculate and store the aperture fields on the principal rectangular grid.

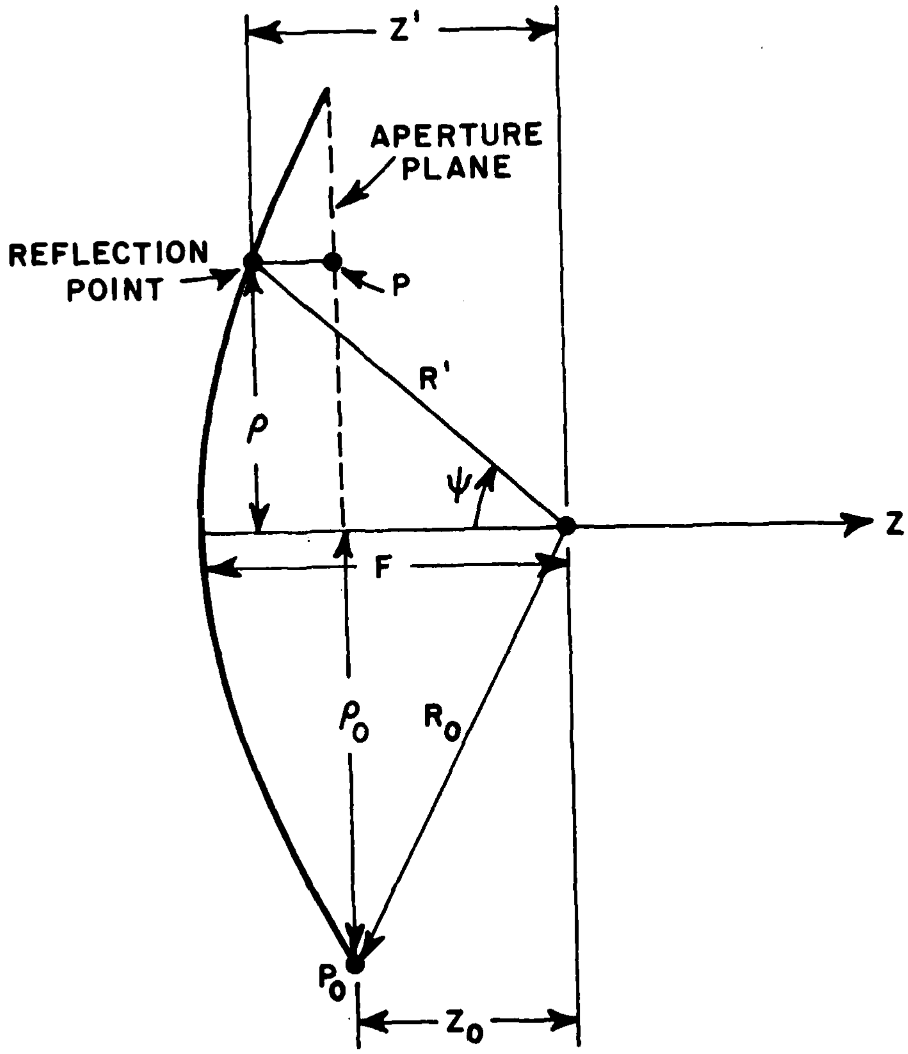


Figure 1. Coordinate system for the aperture field.

METHOD

The coordinate information for the aperture field is defined by the point of reflection on the reflector surface with coordinates X,Y as shown in Fig. 1. Thus

$$\phi' = \tan^{-1}\frac{Y}{X}$$

$$\rho = \sqrt{X^2+Y^2}$$

$$Z' = F - \frac{\rho^2}{4F}$$

$$R' = \sqrt{\rho^2 + Z'^2}$$

and

$$\psi = \tan^{-1}\frac{\rho}{Z'}$$

Let the vector incident feed pattern in the direction (ψ,ϕ) be of the form as

$$\overline{f^i} = \hat{\theta}\, f_\theta + \hat{\phi}'\, f_\phi$$

where f_θ and f_ϕ are the feed pattern values calculated in subroutines FEED and FPOL. The reflected field pattern from the parabolic surface is given by

$$\overline{f^r} = \hat{\rho}\, f_\theta - \hat{\phi}'\, f_\phi \quad .$$

Its corresponding rectangular components can be expressed as

$$f_x^r = \cos\phi' f_\theta + \sin\phi' f_\phi$$

$$f_y^r = \sin\phi' f_\theta - \cos\phi' f_\phi$$

The aperture plane is defined as the plane perpendicular to the Z-axis and passing through the rim point $P_0(X_0,Y_0,0)$ with the greatest distance

ρ_o from the Z-axis. The aperture field at the point P(X,Y,0) on the aperture plane is given by

$$E_x^a = F\, f_x^r\, \frac{e^{-jkR_o}}{R'}$$

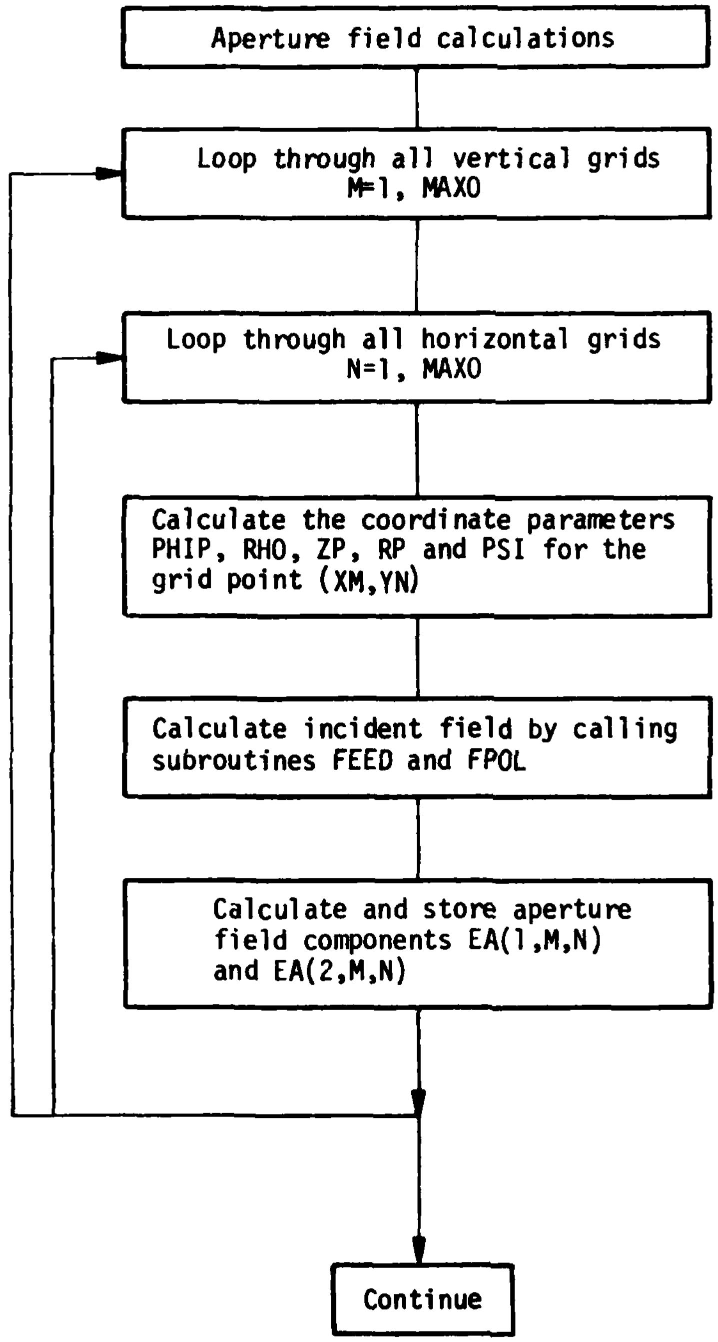
and

$$E_y^a = F\, f_y^r\, \frac{e^{-jkR_o}}{R'}$$

where F is the focal distance.

For any grid point (X_M, Y_N), the X and Y components, E_x^a and E_y^a of the aperture field are calculated by the above two equations. By looping through all the horizontal and vertical grid lines, a two dimensional array of the aperture fields is set and stored.

FLOW DIAGRAM



KEY VARIABLES

EA(1,M,N)	(E_x^a)	X component of the aperture field at grid point (XM,YN)
EA(2,M,N)	(E_y^a)	Y component of the aperture field at grid point (XM,YN)
EIP	(f_ϕ)	PHI component of feed pattern
EIT	(f_θ)	THETA component of feed pattern
EIX		X component of feed pattern
EIY		Y component of feed pattern
EIZ		Z component of feed pattern
ERX	(f_x^r)	X component of the reflected field pattern
ERY	(f_y^r)	Y component of the reflected field pattern
M		Index of vertical grid line
N		Index of horizontal grid line
MAXO		Maximum number of horizontal and Vertical grid line
PHSEA	(e^{-jkR_o})	Phase factor of the aperture field
PHIP	(ϕ')	PHI coordinate of grid point (XM,YN)
PSI	(ψ)	THETA coordinate of grid point (XM,YN) measured from the negative Z-axis
RP	(R')	The distance from the focal point to the reflection point
XX	(X)	X-coordinate of the reflection point
YY	(Y)	Y-coordinate of the reflection point
ZP	(Z')	The projected distance of RP on the Z-axis

```
C
C      *** CALCULATE APERTURE FIELDS ***
C
       DO 12Ø M=1,MAXO
       I=M-1
       XX=(I-ICO)*GRDX
       IF (LNF.AND.(M.EQ.1)) XX=XMIN
       IF (LNF.AND.(M.EQ.(MAX+1))) XX=XMAX
       DO 12Ø N=1,MAXO
       J=N-1
       YY=(J-JCO)*GRDY
       PHIPR=BTAN2(YY,XX)
       PHIP=PHIPR*DPR
       RHO=SQRT(XX*XX+YY*YY)
       ROSQ=RHO*RHO
       ZP=F-ROSQ/(4.*F)
       RP=SQRT(ROSQ+ZP**2)
       PSIR=BTAN2(RHO,ZP)
       PSI=PSIR*DPR
       CALL FEED(PSI,PHIP,PSA,PHGAM)
       CALL FPOL(EIX,EIY,EIZ,PSA,PHGAM)
       SINPP=SIN(PHIPR)
       COSPP=COS(PHIPR)
       SINS=SIN(PSIR)
       COSS=COS(PSIR)
       EIT=-COSS*COSPP*EIX-COSS*SINPP*EIY-SINS*EIZ
       EIP=-SINPP*EIX+COSPP*EIY
       NTEST=Ø
       ERX=COSPP*EIT+SINPP*EIP
       ERY=SINPP*EIT-COSPP*EIP
       EA(1,M,N)=F*ERX/RP*PHSEA
       EA1=EA(1,M,N)
       CALL DBPHS(AE1,EA1,Ø.)
       EA(2,M,N)=F*ERY/RP*PHSEA
       EA2=EA(2,M,N)
       CALL DBPHS(AE2,EA2,Ø.)
       IF (.NOT.LDEBUG) GO TO 12Ø
       IF (M.LE.MNO.AND.N.LE.MNO) WRITE (6,118) M,N,EA1,EA2
   118 FORMAT(2H D,T15,2I5,4F1Ø.2,T79,1HD)
   12Ø CONTINUE
  121  CONTINUE
```

SECTION 4. Y-INTEGRATION FOR FAR FIELD

PURPOSE

To numerically integrate the aperture fields along the rotated ϕ-grid lines.

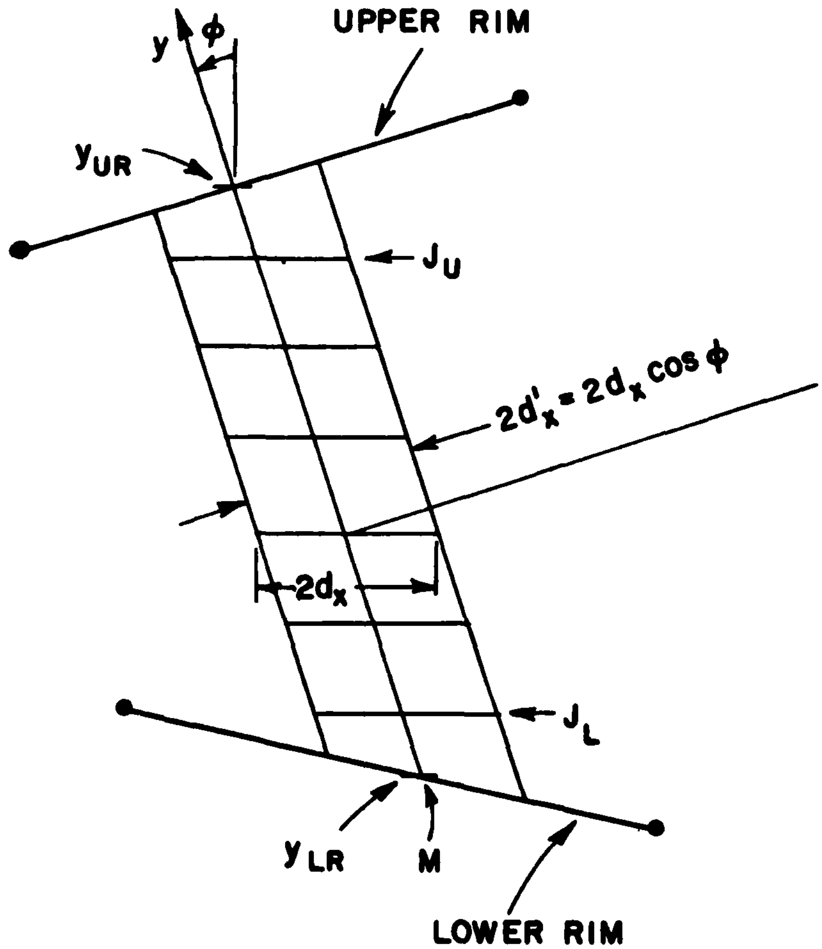


Figure 1. Geometry of y-integration for far field.

METHOD

The y-integration along the rotated grid line (M) as shown in Fig. 1 is represented by

$$Y_{SUM}(M) = \int_{y_{LR}}^{y_{UR}} E^a \, dy \tag{1}$$

where y_{LR} and y_{UR} correspond to the intersections of the grid line (M) with the lower and upper rims, respectively, as shown in Fig. 1 and E^a is the aperture field distribution along the grid line.

To determine these intersection points, the x-coordinate of the grid line (M) is compared with those of the rim points until a rim segment is found such that the x-coordinate of the grid line (M) is in between those of the two rim points of that segment. Then y_{LR} or y_{UR} is obtained by solving for the intersection point of the rim segment and the grid line (M).

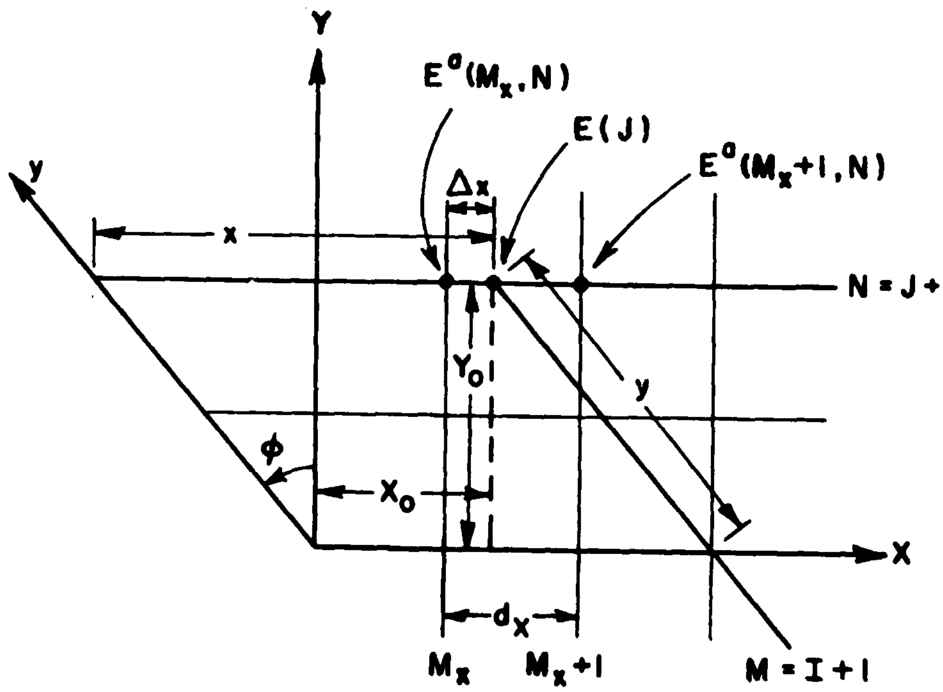


Figure 2. Geometry for interpolation of aperture field.

In order to carry out the y-integration in Equation (1) the aperture field E^a is calculated by interpolation from its stored values corresponding to points on the principal rectangular grid. The geometry for interpolation is shown in Fig. 2 where the rotated grid line I=M-1 intersects the horizontal grid line N=J+1 at the point with principal grid coordinates (X_0, Y_0). The principal grid coordinates are related to the rotated grid coordinates by

$$Y_0 = (J-J_c)d_y \cos\phi \tag{2}$$

and

$$X_0 = x - Y_0 \tan\phi \tag{3}$$

where

$$x = (I-I_c)d_x \quad .$$

The principal grid coordinates are then used to determine the integer value M_x for the nearest principal vertical grid line to the left of the point (X_0, Y_0) with aperture field E(J) as shown in Fig. 2. Thus, interpolation yields the aperture field at the point on the rotated grid as

$$E(J) = \left(1 - \frac{\Delta x}{d_x}\right) E^a(M_x, N) + \frac{\Delta x}{d_x} E^a(M_x+1, N) \tag{4}$$

where Δx is the displacement of the aperture field point from the vertical grid line (M_x).

Let J_L and J_U represents the indices of the lower and upper grid lines closest to the intersection y_{LR} and y_{UR} inside the aperture respectively. If $J_U - J_L \leq 1$, Equation (1) is approximated by

$$Y_{SUM}(M) = (y_{UR} - y_{LR})E(J_U) \quad . \tag{5}$$

If $J_U - J_L > 1$, the y-integration is divided into three parts as shown in Fig. 3. Using the subaperture method, the middle part Y_{SM} is given by

$$Y_{SM} = \sum_{J_L+1}^{J_U-1} E(J) \tag{6}$$

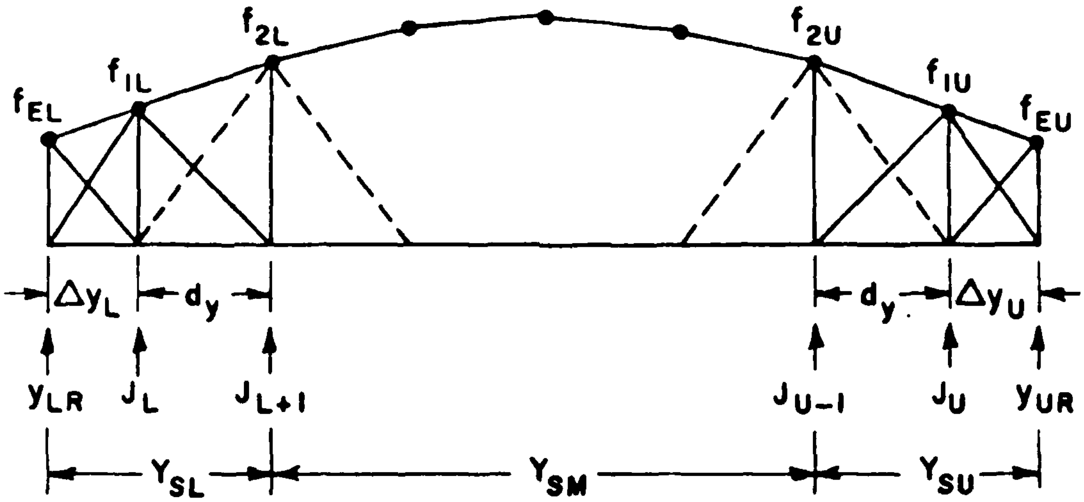


Figure 3. The *y*-integration parts for far field.

The lower part of the y-integration consists of the contribution Y_{SL} from y_{LR} to the (J_L+1) grid line and the upper part consists of the contribution Y_{SU} from the (J_U-1) grid line to y_{UR}

The contributions Y_{SU} from the upper part is given in terms of the aperture field values $f_{1U} = E(J_U)$ and $f_{EU} = E(y=y_{UR})$ as shown in Fig. 3. The edge value $f_E=f_{EU}$ is calculated by linear extrapolation from

$$f_E = f_1 + (f_1-f_2)\,\frac{\Delta y}{dy} \tag{7}$$

The contribution Y_{SL} from the lower part is obtained in a similar way. Thus both contributions can be represented by

$$Y_S dy = \frac{1}{2}\,dy\; f_1 + \frac{1}{2}\,\Delta y\; f_1 + \frac{1}{2}\,\Delta y\; f_E \quad . \tag{8}$$

Substituting Equation (7) into Equation (8) and simplifying terms yields

$$Y_{SL} = \frac{1}{2}\left[\left(1 + \frac{\Delta y_L}{dy}\right)^2 E(J_L) - \left(\frac{\Delta y_L}{dy}\right)^2 E(J_L+1)\right] \tag{9}$$

and

$$Y_{SU} = \frac{1}{2}\left[\left(1 + \frac{\Delta y_U}{dy}\right)^2 E(J_U) - \left(\frac{\Delta y_U}{dy}\right)^2 E(J_U-1)\right] \tag{10}$$

Thus the y-integration of Equation (1) can be calculated from

$$Y_{SUM}(M) = (Y_{SL}+Y_{SM}+Y_{SU})d_y \tag{11}$$

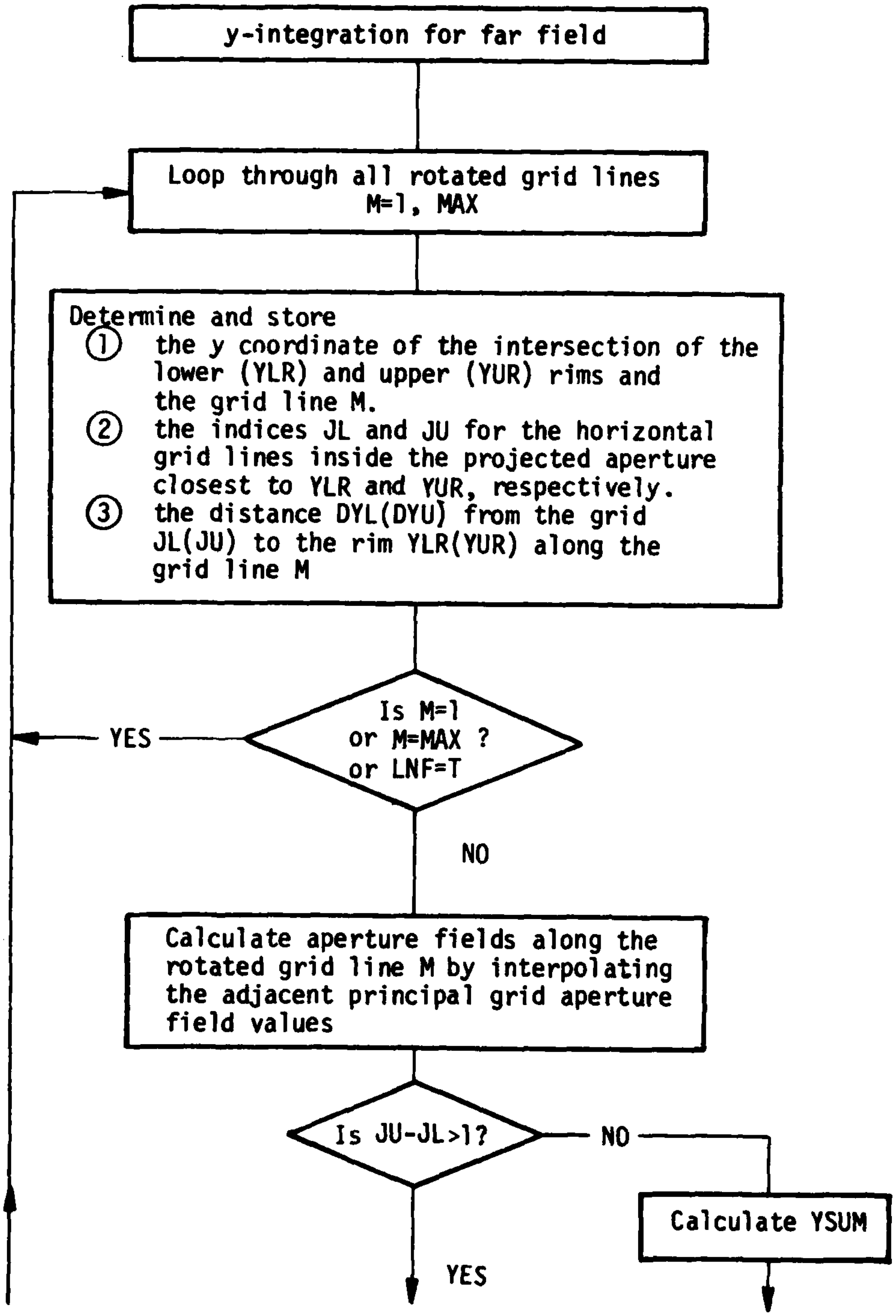
In general, the aprture field can be decomposed into x and y components. Thus two y-integration sums $Y_{SUM}(1,M)$ and $Y_{SUM}(2,M)$ are obtained by carrying the y-integration for each component respectively, i.e.,

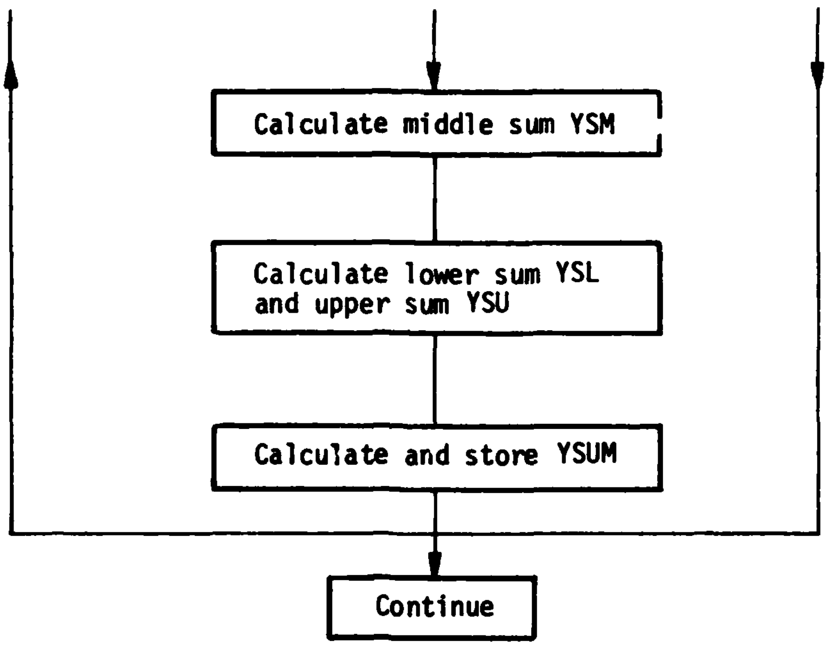
$$Y_{SUM}(1,M) = \int_{y_{LR}}^{y_{UR}} E_x^a\, dy \tag{12}$$

and

$$Y_{SUM}(2,M) = \int_{y_{LR}}^{y_{UR}} E_y^a\, dy \tag{13}$$

FLOW DIAGRAM




Calculate middle sum YSM
Calculate lower sum YSL and upper sum YSU
Calculate and store YSUM
Continue

KEY VARIABLES

DYL	(ΔY_L)	The distance from the horizontal grid line JL to the lower rim along the rotated grid line M
DYU	(ΔY_U)	The distance from the horizontal grid line JU to the upper rim along the rotated grid line M
E(1,J)		X component of the interpolated aperture field on the rotated grid
E(2,J)		Y component of the interpolated aperture field on the rotated grid
EA(1,M,N)	(E_x^a)	X component of the aperture field at grid point (XM,YN)
EA(2,M,N)	(E_y^a)	Y component of the aperture field at grid point (XM,YN)
GRDX	(d_x)	Grid size along the X-axis
GRDY	(d_y)	Grid size along the rotated Y-axis
GRIDY	(D_x)	Grid size along the principal Y-axis
IC		Vertical grid line index of the origin of the reflector coordinate system
JC		Horizontal grid line index of the origin of the reflector coordinate system
JLO	(J_L)	Index for the horizontal grid line inside the projected aperture closest to the lower intersection point on the grid line M
JUO	(J_U)	Index for the horizontal grid line inside the projected aperture closest to the upper intersection point on the grid line M
MAX		Maximum number of rotated grid lines
MX		Index of vertical principal grid line
QDX		Normalized distance from the integration point to the vertical grid line M
QYL		Normalized distance from the lower rim to the grid line JL

QYU		Normalized distance from the upper rim to the grid line JU
XO	(X_o)	X-coordinate of the integration point in the principal grid system
XX	(X)	X-coordinate of the integration point in the rotated gird system
YLR	(y_{LR})	Y-coordinate of the intersection of the grid line M and the lower rim
YO	(Y_o)	Y-coordinate of the integration point in the principal grid system
YSLX		X-component of the lower sum of the Y-integration
YSLY		Y-component of the lower sum of the Y-integration
YSMX		X-component of the middle sum of the Y-integration
YSMY		Y-component of the middle sum of the Y-integration
YSUX		X-component of the upper sum of the Y-integration
YSUY		Y-component of the upper sum of the Y-integration
YSUM(1,M)		X-component of the total sum of the Y-integration for grid line M
YSUM(2,M)		Y-component of the total sum of the Y-integration for grid line M
YUR	(y_{UR})	Y-coordinate of the intersection of the grid line M and the upper rim

```
C
C      *** Y INTEGRATION FOR FAR FIELD ***
C
       DO 172 M=1,MAX
       I=M-1
       XX=(I-IC)*GRDX
       IF (M.EQ.1) XX=XMIN
       IF (M.EQ.MAX) XX=XMAX
       IF (M.EQ.1) GO TO 150
       IF (XX.LE.XLKP) GO TO 152
 150   K=K+1
       IF (K.GE.NLRIM) GO TO 153
       XLK=CLRIM(K,1)
       XLKP=CLRIM(K+1,1)
       IF (XX.GT.XLKP) GO TO 150
       YLK=CLRIM(K,2)
       YLKP=CLRIM(K+1,2)
       IF (LDEBUG) WRITE (6,152) K,XLK,XLKP,YLK,YLKP
 152   FORMAT(2H D,T5,3HK =,I2,5X,5HXLK =,F6.2,5X,6HXLKP =,F6.2,
      25X,5HYLK =,F6.2,5X,6HYLKP =,F6.2,T79,1HD)
       TEMP=(YLKP-YLK)/(XLKP-XLK)
 153   YLR(M)=YLK+TEMP*(XX-XLK)
       JL(M)=(YLR(M)/GRDY)+JC+0.99
       IF (M.EQ.1) GO TO 154
       IF (XX.LE.XUKP) GO TO 158
 154   L=L+1
       IF (L.GE.NURIM) GO TO 158
       XUK=CURIM(L,1)
       XUKP=CURIM(L+1,1)
       IF (XX.GT.XUKP) GO TO 154
       YUK=CURIM(L,2)
       YUKP=CURIM(L+1,2)
       IF (LDEBUG) WRITE (6      L,XUK,XUKP,YUK,YUKP
 156   FORMAT(2H D,T5,3HL        ,5HXUK =,F6.2,5X,6HXUKP =,F6.2,
      25X,5HYUK =,F6.2,5X,6         F6.2,T79,1HD)
       TENP=(YUKP-YUK)/(XUKP-XU
 158   YUR(M)=YUK+TENP*(XX-XUK)
       JU(M)=(YUR(M)/GRDY)+JC+0.01
       IF (JU(M).LT.JL(M)) JU(M)=JL(M)
       IF (LDEBUG) WRITE (6,160) JL(M),JU(M),YLR(M),YUR(M)
 160   FORMAT(2H D,T12,'JL=',I2,' JU=',I2,' YLR=',F8.2,' YUR=',F8.2,
      1T79,1HD)
       DYL=(JL(M)-JC)*GRDY-YLR(M)
       OYL(M)=DYL/GRDY
       DYU=YUR(M)-(JU(M)-JC)*GRDY
       OYU(M)=DYU/GRDY
       IF (LDEBUG) WRITE (6,909) JL(M),JU(M),DYL,DYU,YLR(M)
      2,YUR(M),OYL(M),OYU(M)
 909   FORMAT (2I5,8F10.4)
```

```
      IF ((M.EQ.1.OR.M.EQ.MAX).OR.LNF) GO TO 172
      GDY=GRDY*ACOSP
      JLO=JL(M)
      JUO=JU(M)
      DO 165 J=JLO,JUO
      IF (NCK.NE.1) GO TO 162
      E(1,J)=(0.,0.)
      E(2,J)=(1.,0.)
      GO TO 165
  162 YO=(J-JC)*GDY
      XX=(I-IC)*GRDX
      XO=XX-YO*TANP
      FIX=XO/GRDX+ICOP
      IX=FIX
      MX=IX+1
      ODX=FIX-IX
      N=J+1
      E(1,J)=EA(1,MX,N)*(1.-ODX)+EA(1,MX+1,N)*ODX
      E(2,J)=EA(2,MX,N)*(1.-ODX)+EA(2,MX+1,N)*ODX
      IF (LDEBUG) WRITE (6,164) J,E(1,J),E(2,J),ODX
  164 FORMAT(2H D,I10,5F12.4,T79,1HD)
  165 CONTINUE
      IF (JUO-JLO.GT.1) GO TO 168
      YSUM(1,M)=(YUR(M)-YLR(M))*E(1,JUO)
      YSUM(2,M)=(YUR(M)-YLR(M))*E(2,JUO)
      IF (LWYSUM) WRITE (6,166) M,YSUM(1,M),YSUM(2,M)
  166 FORMAT (2H D,I5,8E10.3)
      GO TO 172
  168 CONTINUE
C
C        *** CALCULATE YSM ***
C
      JF=JUO-1
      JI=JLO+1
      KM=JF-JI+1
      YSMX=(0.,0.)
      YSMY=(0.,0.)
      DO 170 KJ=1,KM
      J=KJ+JI-1
      YSMX=YSMX+E(1,J)
      YSMY=YSMY+E(2,J)
  170 CONTINUE
C
C        *** CALCULATE YSL AND YSU ***
C
      YSLX=(E(1,JLO)*(OYL(M)+1.)**2-E(1,JLO+1)*OYL(M)**2)/2.
      YSLY=(E(2,JLO)*(OYL(M)+1.)**2-E(2,JLO+1)*OYL(M)**2)/2.
      YSUX=(E(1,JUO)*(OYU(M)+1.)**2-E(1,JUO-1)*OYU(M)**2)/2.
      YSUY=(E(2,JUO)*(OYU(M)+1.)**2-E(2,JUO-1)*OYU(M)**2)/2.
      YSUM(1,M)=(YSLX+YSMX+YSUX)*GRDY
      YSUM(2,M)=(YSLY+YSMY+YSUY)*GRDY
      IF (LWYSUM) WRITE (6,166) M,YSLX,YSMX,YSUX,YSUM(1,M)
      IF (LWYSUM) WRITE (6,166) M,YSLY,YSMY,YSUY,YSUM(2,M)
  172 CONTINUE
C
```

SECTION 5. SWITCHING CRITERION FOR AI AND GTD

PURPOSE

To calculate the switching criterion between AI and GTD in the near field or far field computation.

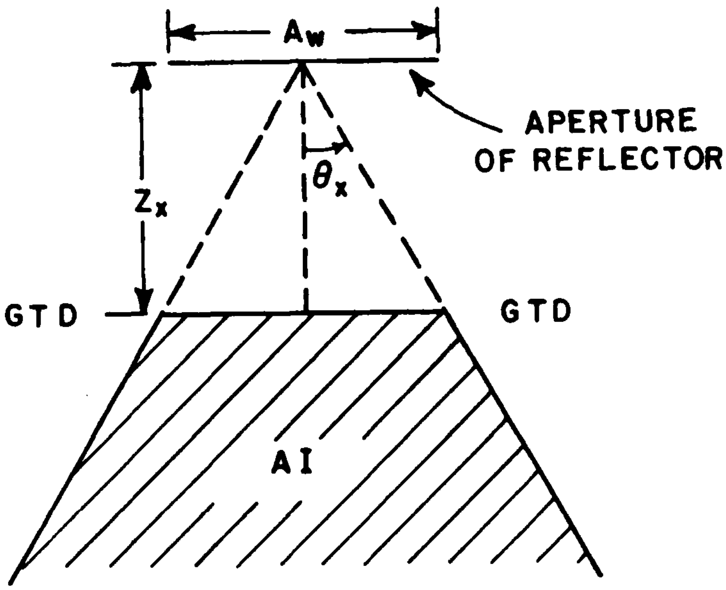


Figure 1. Geometry for switching criterion between AI and GTD.

METHOD

The angle criterion which is used for the near field as well as the far field, is defined as

$$\theta_X = \sin^{-1}\left(\frac{1}{\sqrt{Aw}}\right)$$

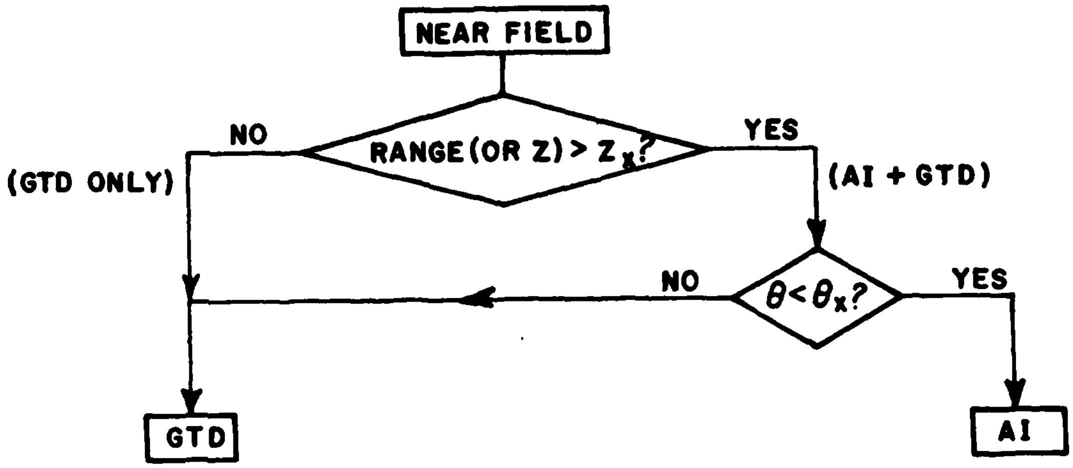
where Aw is the aperture width in the specific pattern cut. Thus AI is used when $0<\theta<\theta_X$ and GTD is used when $\theta\geq\theta_X$.

The range criterion is used solely for the near field and is defined by

$$Z_x = \frac{Aw}{2\tan\theta_x}$$

as shown in Fig. 1.

The usage of the above criteria for near field computation is summarized in the flow diagram as shown below.



KEY VARIABLES

AW	(A_w)	Aperture width in the specific pattern cut
P3X		Variable representing the switching criterion
THETAX	(θ_x)	Angle criterion in degrees
THEX	(θ_x)	Angle criterion in radians
ZX	(Z_x)	Range criterion

CODE LISTING

```
      C
      C      *** SET UP SWITCHING CRITERION ***
      C
             P3X=P3F
             IF (.NOT.LGTD) GO TO 179
             THEX=THETAX/DPR
             TANX=TAN(THEX)
             IF (ZX.GT.Ø..AND.THETAX.GT.Ø.) GO TO 177
             AW=RHOS(1)-RHOS(2)
             THEX=ASIN(1./SQRT(AW))
             TANX=TAN(THEX)
             IF (LNF.AND.(TANX.NE.Ø.)) ZX=Ø.5*AW/TANX
             THETAX=THEX*DPR
        177  P3X=THETAX
             IF (.NOT.LNF) GO TO 179
             IF (P2.LT.ZX) GO TO 18Ø
             IF (LRANG) GO TO 179
             P3X=P2*TANX
        179  NAI=(P3X-P3I)/DP3+1.1
             IF (NT.LT.NAI) NAI=NT
             IF (NAI.GT.Ø) GO TO 182
       18Ø   NAI=Ø
             NGTD=NT
             THI2=P3I
             GO TO 255
```

SECTION 6. APERTURE INTEGRATION FOR NEAR FIELD

PURPOSE

To numerically integrate the aperture fields for near field calculations and express the field in rectangular components.

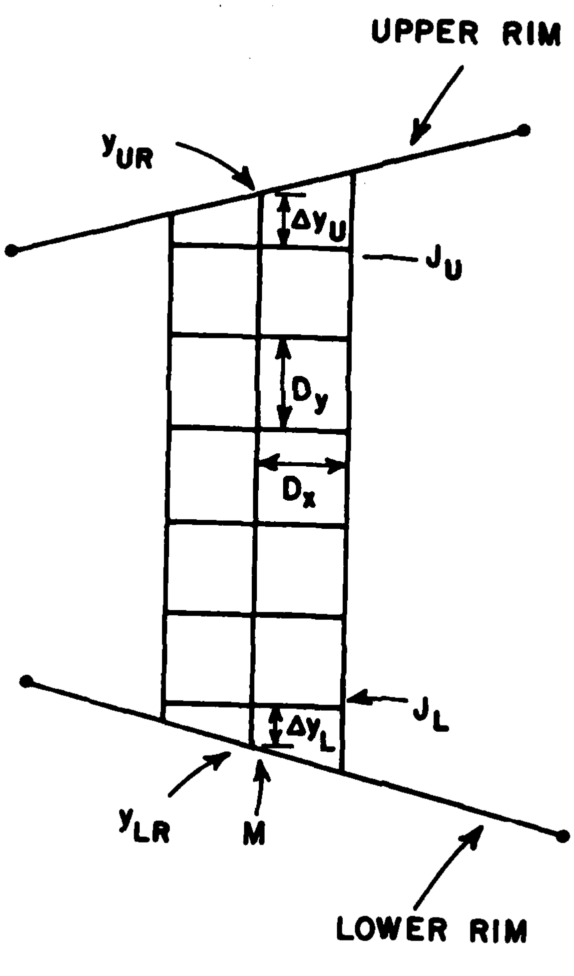


Figure 1. Geometry of y-integration for near field.

METHOD

For aperture fields with arbitrary polarization having both x and y components, the near field can be expressed as

$$\bar{E} = \frac{jk}{2\pi} \iint \left[\bar{F}_x\, E_x^a + \bar{F}_y\, E_y^a\right] \frac{e^{-jks}}{s}\, dx\, dy \qquad (1)$$

where $\bar{F}_x$ and $\bar{F}_y$ are the vector element patterns for the respective x and y components (E_x^a, E_y^a) of the aperture field.

By integrating numerically Equation (1) can be expressed in a sum of series form as

$$\bar{E} = \frac{j}{\lambda} \sum_M \sum_N \left[\bar{F}_{XMN} E^a_{XMN} + \bar{F}_{YMN} E^a_{YMN}\right] F_{RS} \frac{e^{-jks}}{s} \qquad (2)$$

where $\bar{F}_{XMN}$ and $\bar{F}_{YMN}$ are the vector element patterns of the equivalent aperture currents. These are assumed to radiate the same polarization as a Huygen's source and thus the vector element patterns are expressed in rectangular coordinates as

$$\begin{aligned}
\bar{F}_{XMN} &= \{\hat{x}[1+(\cos\theta_{MN}-1)\cos^2\phi_{MN}] \\
&\quad + \hat{y}(\cos\theta_{MN}-1)\sin\phi_{MN}\cos\phi_{MN} \\
&\quad - \hat{z}\sin\theta_{MN}\cos\phi_{MN}\} \cos\left(\frac{\theta_{MN}}{2}\right) \\
&= \{\hat{x}\, C_{xx} + \hat{y}\, C_{xy} - \hat{z}\sin\theta_{MN}\cos\phi_{MN}\}\mathrm{ELPAT}
\end{aligned} \qquad (3)$$

$$\begin{aligned}
\bar{F}_{YMN} &= \Big\{\hat{x}(\cos\theta_{MN}-1)\sin\phi_{MN}\cos\phi_{MN} \\
&\quad + \hat{y}[1+(\cos\theta_{MN}-1)\sin^2\phi_{MN}] \\
&\quad - \hat{z}\sin\theta_{MN}\sin\phi_{MN}\Big\} \cos\left(\frac{\theta_{MN}}{2}\right) \\
&= \{\hat{x}\, C_{xy} + \hat{y}\, C_{yy} - \hat{z}\sin\theta_{MN}\sin\phi_{MN}\}\mathrm{ELPAT}\ .
\end{aligned} \qquad (4)$$

The fields $E^a_{XMN}=E^a(1,M,N)$ and $E^a_{YMN}=E^a(2,M,N)$ are the X and Y components of the aperture field sampled at the points (X_M,Y_N) on the principal grid. The basic pattern F_{RS} of each rectangular subaperture is given by

$$F_{RS} = D_X D_Y F_{XN} F_{YN} \tag{5}$$

where F_{XN} and F_{YN} are the horizontal and vertical element patterns of each rectangular subaperture. The typical element patterns for a basic subaperture with full triangular distribution are given by

$$F_{XN} = \left(\frac{\sin \frac{\phi_x}{2}}{\frac{\phi_x}{2}} \right)^2 \tag{6}$$

$$F_{YN} = \left(\frac{\sin \frac{\phi_y}{2}}{\frac{\phi_y}{2}} \right)^2 \tag{7}$$

where

$$\phi_x = k\ D_X\ \sin\theta_{MN} \cos\phi_{MN} \tag{8}$$

and

$$\phi_y = k\ D_Y\ \sin\theta_{MN} \sin\phi_{MN} \tag{9}$$

The angles θ_{MN} and ϕ_{MN} are the polar coordinate angles to the near field point (X,Y,Z) as referred to the aperture point (X_M,Y_N). The distance S in Equation (2) is given by

$$S = \sqrt{(X-X_M)^2+(Y-Y_N)^2+Z^2} \quad . \tag{10}$$

The summations over N in Equation (2) are performed over the vertical grid lines; a typical vertical grid line is shown in Fig. 1. The y-integrations given by $Y_{SUM}(M)$ are calculated in a similar way as that for the far field (see Section 4) as expressed by

$$Y_{SUM}(M) = (y_{SL}+y_{SM}+y_{SU})D_Y \tag{11}$$

for each rectangular component of the near field. However, the vector element patterns in Equations (3) and (4) for the equivalent aperture currents and the element pattern functions F_{RS} in Equation (5) for the rectangular subaperture must be included for the near field. For subapertures near the rim, the element patterns F_{XN} and F_{YN} in Equation (5) are expressed by the pattern of a half triangular distribution (see Section 6).

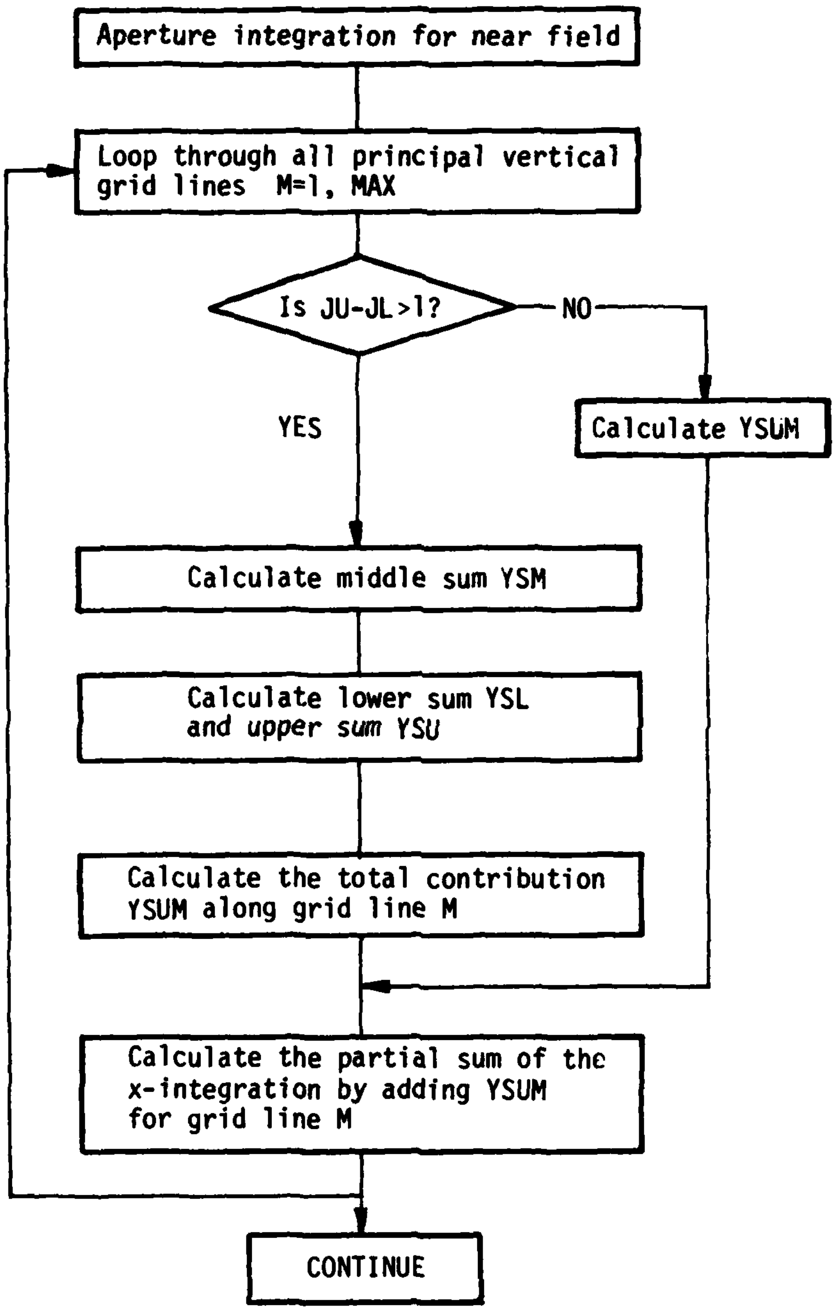
The summation over M in Equation (2), i.e., the x-integration part, is just a simple sum of Y_{SUM}'s as

$$SUM = D_X \sum_{M=1}^{MAX} Y_{SUM}(M) \tag{12}$$

for each rectangular component of the near field. Then the near field at point (x,y,z) is obtained by

$$\overline{E} = \frac{j}{\lambda} \left(SUM_x \hat{x} + SUM_y \hat{y} + SUM_z \hat{z} \right) \quad . \tag{13}$$

FLOW DIAGRAM



KEY VARIABLES

CXX		X component of a X-oriented Huygen's source
CXY		X component of a Y-oriented Huygen's source or Y component of an X-oriented Huygen's source
CYY		Y component of a Y-oriented Huygen's source
DPX	(ϕ_x)	Horizontal phase argument of a basic sub-aperture
DPXL		Horizontal phase argument of a subaperture at the left edge
DPXR		Horizontal phase argument of a subaperture at the right edge
DPY	(ϕ_y)	Vertical phase argument of a basic subaperture
DPYL		Vertical phase argument of a subaperture at the lower edge
DPYU		Vertical phase argument of a subaperture at the upper edge
EA(1,M,N)	(E_x^a)	X component of the aperture field at grid point (XM,YN)
EA(2,M,N)	(E_y^a)	Y component of the aperture field at grid point (XM,YN)
EAL		Interpolated aperture field at the lower rim point along grid line M
EAU		Interpolated aperture field at the upper rim point along grid line M
EDX		X component of the computed near field
EDY		Y component of the computed near field
EDZ		Z component of the computer near field
ELPAT		Element pattern function for equivalent aperture current
EXPI		Phase term for the leftmost grid point inside the aperture
EXPL		Phase term for the leftmost rim point

EXPM		Phase term for the rightmost grid point inside the aperture
EXPR		Phase term for the rightmost rim point
FFXN	(F_{XN})	Horizontal pattern function for a rectangular subaperture
FFY		Vertical pattern function for a basic rectangular subaperture
FHYM		Vertical pattern function for a basic rectangular subaperture with a half triangular distribution (negative argument)
FHYP		Vertical pattern function for a basic rectangular subaperture with a half triangular distribution (positive argument)
FYM		Vertical pattern function for a rectangular subaperture at the edge with a half triangular distribution (negative argument)
FYP		Vertical pattern function for a rectangular subaperture at the edge with a half triangular distribution (positive argument)
GRIDX	(D_X)	Horizontal grid size in the principal grid system
GRIDY	(D_Y)	Vertical grid size in the principal grid system
JC		Horizontal grid line index of the origin of the reflector coordinate system
JLO	(J_L)	Index for the horizontal grid line inside the projected aperture closest to the lower intersection point on the grid line M
JUO	(J_U)	Index for the horizontal grid line inside the projected aperture closest to the upper intersection point on the grid line M
MAX	(M_{MAX})	Maximum number of vertical grid lines
MC		Vertical grid line index M of the origin of the reflector coordinate system
PHIRN	(ϕ_{MN})	PHI coordinate angle of the near field point XN as referred to the aperture point (XM,YN)

QDX		Normalized distance f n the integration point to the vertical grid line M
QXL		Normalized distance from the leftmost rim point to the first vertical grid line inside the aperture
QXR		Normalized distance from the rightmost rim point to the last vertical grid line inside the aperture
QYL		Normalized distance from the lower rim to the grid line JL
QYU		Normalized distance from the upper rim to the grid line JU
S		Distance from a grid point not adjacent to the rim to the near field point XN
S1		Distance from the intersection point along the grid line M to the near field point XN
SUMX		X component of the x-integration sum
SUMY		Y component of the x-integration sum
SUMZ		Z component of the x-integration sum
THERN	(θ_{MN})	Theta coordinate angle of the near field point XN as referred to the aperture point (XM.YN)
XN		Coordinates of near field point
XP		X-coordinate of the near field point XN as referred to the aperture point (XM,YN)
YEXP		Phase term for near field integration for the grid point (XM,YN)
YLR	(y_{LR})	Y-coordinate of the intersection of the grid line M and the lower rim
YP		Y-coordinate of the near field point XN as referred to the aperture point (XM,YN)
YSLX		X component of the lower sum of the Y-integration

YSLY		Y component of the lower sum of the Y-integration
YSLZ		Z component of the lower sum of the Y-integration
YSMX		X component of the middle sum of the Y-integration
YSMY		Y component of the middle sum of the Y-integration
YSMZ		Z component of the middle sum of the Y-integration
YSUX		X component of the upper sum of the Y-integration
YSUY		Y component of the upper sum of the Y-integration
YSUZ		Z component of the upper sum of the Y-integration
YSUM(1,M)		X component of the total sum of the Y-integration for grid line M
YSUM(2,M)		Y component of the total sum of the Y-integration for grid line M
YSUM(3,M)		Z component of the total sum of the Y-integration for grid line M
YUR	(y_{UR})	The Y-coordinate of the intersection of the grid line M and the upper rim

CODE LISTING

```
C
C     ***Y INTEGRATION FOR NEAR FIELD ***
C
      SUMX=(0.,0.)
      SUMY=(0.,0.)
      SUMZ=(0.,0.)
      DO 220 M=1,MAX
      NPRI=0
      IF (LDEBUG.AND.(M.EQ.MNO)) NPRI=1
      XP=XN(1)-(M-MC)*GRDX
      IF (M.EQ.1) XP=XN(1)-XMIN
      IF (M.EQ.MAX) XP=XN(1)-XMAX
      RP=XP*XP+XN(3)*XN(3)
      JLO=JL(M)
      JUO=JU(M)
      IF (JUO-JLO.GT.1) GO TO 206
      YP=XN(2)-YLR(M)
      PHIRN=BTAN2(YP,XP)
      SINPN=SIN(PHIRN)
      COSPN=COS(PHIRN)
      THERN=BTAN2(SQRT(XP*XP+YP*YP),XN(3))
      SINTN=SIN(THERN)
      COSTN=COS(THERN)
      S=SQRT(YP*YP+RP)
      EXPL=CEXP(-CJ*TPI*S)
      YSUM(1,M)=(YUR(M)-YLR(M))*EA(1,M,JUO)*EXPL/S
      YSUM(2,M)=(YUR(M)-YLR(M))*EA(2,M,JUO)*EXPL/S
      ELPAT=COS(THERN/2.)
      DUMY=COSTN-1.
      CXX=1.+COSPN*COSPN*DUMY
      CXY=SINPN*COSPN*DUMY
      CYY=1.+SINPN*SINPN*DUMY
      YSUM(3,M)=-SINTN*(YSUM(1,M)*COSPN+YSUM(2,M)*SINPN)*ELPAT
      TMX=YSUM(1,M)
      YSUM(1,M)=(CXX*TMX+CXY*YSUM(2,M))*ELPAT
      YSUM(2,M)=(CXY*TMX+CYY*YSUM(2,M))*ELPAT
      IF (LWYSUM) WRITE (6,166) M,YSUM(1,M),YSUM(2,M),YSUM(3,M)
      GO TO 220
C
C        * CALCULATE YSM *
C
  206 JF=JUO-1
      JI=JLO+1
      KM=JF-JI+1
      YSMX=(0.,0.)
      YSMY=(0.,0.)
      YSMZ=(0.,0.)
      DO 208 KJ=1,KM
      J=KJ+JI-1
```

```
      NJ=J+1
      YP=XN(2)-(J-JC)*GRDY
      PHIRN=BTAN2(YP,XP)
      SINPN=SIN(PHIRN)
      COSPN=COS(PHIRN)
      THERN=BTAN2(SQRT(XP*XP+YP*YP),XN(3))
      SINTN=SIN(THERN)
      COSTN=COS(THERN)
      DPX=TPI*COSPN*SINTN*GRDX
      FFXN=FF(DPX)+CJ*0.
      DPXL=DPX*QXL
      DPXR=DPX*QXR
      IF (M.EQ.1) FFXN=QXL*FH(DPXL)
      IF (M.EQ.2) FFXN=FH(DPX)+QXL*FH(-DPXL)
      IF (M.EQ.MIX) FFXN=FH(-DPX)+QXR*FH(DPXR)
      IF (M.EQ.MAX) FFXN=QXR*FH(-DPXR)
      DPY=TPI*SINPN*SINTN*GRDY
      FFY=FF(DPY)
      S=SQRT(YP*YP+RP)
      YEXP=CEXP(-CJ*TPI*S)*FFXN*FFY
      ELPAT=COS(THERN/2.)
      DUMY=COSTN-1.
      CXX=1.+COSPN*COSPN*DUMY
      CXY=SINPN*COSPN*DUMY
      CYY=1.+SINPN*SINPN*DUMY
      YSMX=YSMX+(CXX*EA(1,M,NJ)+CXY*EA(2,M,NJ))*YEXP*ELPAT/S
      YSMY=YSMY+(CXY*EA(1,M,NJ)+CYY*EA(2,M,NJ))*YEXP*ELPAT/S
      YSMZ=YSMZ-SINTN*(EA(1,M,NJ)*COSPN+EA(2,M,NJ)*SINPN)*YEXP*ELPAT/S
  208 CONTINUE
C
C         * CALCULATE YSL *
C
      YP=XN(2)-YLR(M)
      S1=SQRT(YP*YP+RP)
      EXPL=CEXP(-CJ*TPI*S1)
      YP=XN(2)-(JLO-JC)*GRDY
      S2=SQRT(YP*YP+RP)
      EXPI=CEXP(-CJ*TPI*S2)
      PHIRN=BTAN2(YP,XP)
      SINPN=SIN(PHIRN)
      COSPN=COS(PHIRN)
      THERN=BTAN2(SQRT(XP*XP+YP*YP),XN(3))
      SINTN=SIN(THERN)
      COSTN=COS(THERN)
      DPX=TPI*COSPN*SINTN*GRDX
      FFXN=FF(DPX)+CJ*0.
      DPXL=DPX*QXL
      DPXR=DPX*QXR
      IF (M.EQ.1) FFXN=QXL*FH(DPXL)
      IF (M.EQ.2) FFXN=FH(DPX)+QXL*FH(-DPXL)
      IF (M.EQ.MIX) FFXN=FH(-DPX)+QXR*FH(DPXR)
```

```
      IF (M.EQ.MAX) FFXN=QXR*FH(-DPXR)
      DPY=TPI*SINPN*SINTN*GRDY
      FHYP=FH(DPY)
      DPYL=DPY*QYL(M)
      FYM=FH(-DPYL)
      FYP=FH(DPYL)
      EXPL=EXPL*FYP*QYL(M)
      EXPI=EXPI*(FYM*QYL(M)+FHYP)
      EAL=EA(1,M,JLO+1)*(QYL(M)+1.)-EA(1,M,JLO+2)*QYL(M)
      IF (NPRI.EQ.1) WRITE (6,-) EA(1,M,JLO+1),EA(1,M,JLO+2),EAL
      YSLX=FFXN*(EAL*EXPL/S1+EA(1,M,JLO+1)*EXPI/S2)
      EAL=EA(2,M,JLO+1)*(QYL(M)+1.)-EA(2,M,JLO+2)*QYL(M)
      IF (NPRI.EQ.1) WRITE (6,909) JLO,JI,EA(2,M,JI),EA(2,M,JLO+2)
     2,EAL
      YSLY=FFXN*(EAL*EXPL/S1+EA(2,M,JLO+1)*EXPI/S2)
      ELPAT=COS(THERN/2.)
      DUMY=COSTN-1.
      CXX=1.+COSPN*COSPN*DUMY
      CXY=SINPN*COSPN*DUMY
      CYY=1.+SINPN*SINPN*DUMY
      YSLZ=-SINTN*(YSLX*COSPN+YSLY*SINPN)*ELPAT
      TMX=YSLX
      YSLX=(CXX*YSLX+CXY*YSLY)*ELPAT
      YSLY=(CXY*TMX+CYY*YSLY)*ELPAT
C
C         * CALCULATE YSU *
C
      YP=XN(2)-YUR(M)
      S1=SQRT(YP*YP+RP)
      EXPR=CEXP(-CJ*TPI*S1)
      YP=XN(2)-(JUO-JC)*GRDY
      S2=SQRT(YP*YP+RP)
      EXPM=CEXP(-CJ*TPI*S2)
      PHIRN=BTAN2(YP,XP)
      SINPN=SIN(PHIRN)
      COSPN=COS(PHIRN)
      THERN=BTAN2(SQRT(XP*XP+YP*YP),XN(3))
      SINTN=SIN(THERN)
      COSTN=COS(THERN)
      DPX=TPI*COSPN*SINTN*GRDX
      FFXN=FF(DPX)+CJ*0.
      DPXL=DPX*QXL
      DPXR=DPX*QXR
      IF (M.EQ.1) FFXN=QXL*FH(DPXL)
      IF (M.EQ.2) FFXN=FH(DPX)+QXL*FH(-DPXL)
      IF (M.EQ.MIX) FFXN=FH(-DPX)+QXR*FH(DPXR)
      IF (M.EQ.MAX) FFXN=QXR*FH(-DPXR)
      DPY=TPI*SINPN*SINTN*GRDY
      FHYM=FH(-DPY)
      DPYU=DPY*QYU(M)
      FYM=FH(-DPYU)
```

```
      FYP=FH(DPYU)
      EXPM=EXPM*(FYP*QYU(M)+FHYM)
      EXPR=EXPR*FYM*QYU(M)
      EAU=EA(1,M,JUO+1)*(QYU(M)+1.)-EA(1,M,JUO)*QYU(M)
      IF (NPRI.EQ.1) WRITE (6,-) EA(1,M,JUO+1),EA(1,M,JUO),EAU
      YSUX=FFXN*(EAU*EXPR/S1+EA(1,M,JUO+1)*EXPM/S2)
      EAU=EA(2,M,JUO+1)*(QYU(M)+1.)-EA(2,M,JUO)*QYU(M)
      IF (NPRI.EQ.1) WRITE (6,909) JUO,JF,EA(2,M,JUO+1),EA(2,M,JUO)
     2,EAU
      IF (NPRI.EQ.1) WRITE (6,-) QYL(M),QYU(M),YLR(M),YUR(M)
      YSUY=FFXN*(EAU*EXPR/S1+EA(2,M,JUO+1)*EXPM/S2)
      ELPAT=COS(THERN/2.)
      DUMY=COSTN-1.
      CXX=1.+COSPN*COSPN*DUMY
      CXY=SINPN*COSPN*DUMY
      CYY=1.+SINPN*SINPN*DUMY
      YSUZ=-SINTN*(YSUX*COSPN+YSUY*SINPN)*ELPAT
      TMX=YSUX
      YSUX=(CXX*YSUX+CXY*YSUY)*ELPAT
      YSUY=(CXY*TMX+CYY*YSUY)*ELPAT
      YSUM(1,M)=(YSLX+YSMX+YSUX)*GRDY
      YSUM(2,M)=(YSLY+YSMY+YSUY)*GRDY
      YSUM(3,M)=(YSLZ+YSMZ+YSUZ)*GRDY
      IF (LWYSUM) WRITE (6,166) M,YSLX,YSMX,YSUX,YSUM(1,M)
      IF (LWYSUM) WRITE (6,166) M,YSLY,YSMY,YSUY,YSUM(2,M)
      IF (LWYSUM) WRITE (6,166) M,YSLZ,YSMZ,YSUZ,YSUM(3,M)
C
C     *** X INTEGRATION FOR NEAR FIELD ***
C
      SUMX=SUMX+YSUM(1,M)*GRDX
      SUMY=SUMY+YSUM(2,M)*GRDX
      SUMZ=SUMZ+YSUM(3,M)*GRDX
      IF (LWYSUM) WRITE (6,166) M,SUMX,SUMY,SUMZ
  220 CONTINUE
      EDX=CJ*SUMX
      EDY=CJ*SUMY
      EDZ=CJ*SUMZ
      IF (LTEST) WRITE (6,195) EDX,EDY,EDZ
      IF (.NOT.LFEED) GO TO 224
```

SECTION 7. X-INTEGRATION FOR FAR FIELD

PURPOSE

To numerically integrate the y-integration sums along the horizontal grid line and obtain the final far field pattern.

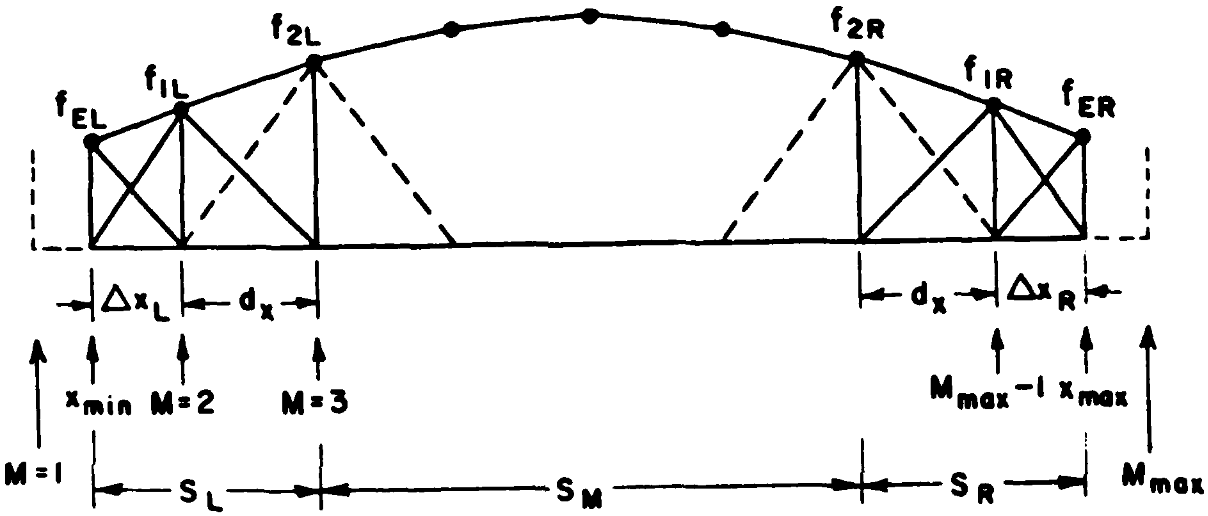


Figure 1. The x-integration parts

METHOD

Using the result of y-integration, the scalar radiation integral for the far field pattern reduces to

$$E = \frac{jk}{2\pi}\int_{x_{min}}^{x_{max}} Y_{SUM}\, e^{jkx\sin\theta\cos\phi}\, dx \quad .$$

The x-integration is divided into three parts in a similar way as was the y-integration. The middle part consists of the basic subapertures (subapertures with full grid size) with full triangular distribution as shown by the dashed lines in Fig. 1. The expression for the distribution of a basic subaperture is given by

$$f_F(x) = 1 - \frac{|x-x_0|}{d_x}$$

for $|x-x_o|<d_x$, as shown in Fig. 2a. The resulting far field pattern for the basic subaperture, i.e., element pattern, is given by

$$F_{SF}(\theta,\phi) = d_x \cos\phi \; F_F(\phi_x)$$

where

$$F_F(\phi_x) = \left[\frac{\sin\left(\frac{\phi_x}{2}\right)}{\left(\frac{\phi_x}{2}\right)}\right]^2$$

and the argument

$$\phi_x = k \; d_x \; \sin\theta\cos\phi \quad .$$

Thus the result for the middle part of the x-integration is simply the sum of the product of the y-integration sum and the phase exponential for each subaperture multiplied by its element pattern as given by

$$S_M = d_x \; F_F(\phi_x) \sum_{M=3}^{M_{max}-2} Y_{sum}(M) \; e^{j(I-I_c)\phi_x}$$

where I=M-1, I_c is the I index for the origin, and M_{max} is the maximum number of rotated grid lines.

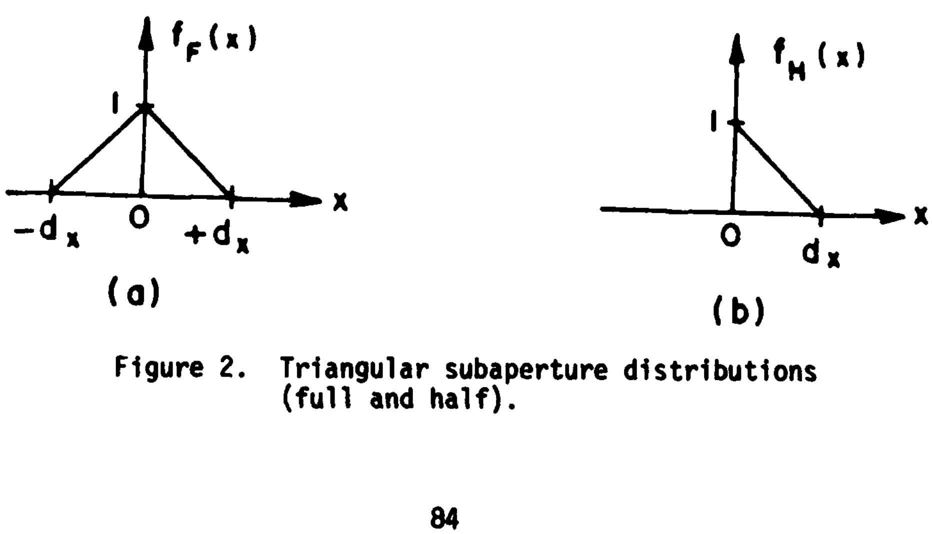


Figure 2. Triangular subaperture distributions (full and half).

The contributions from the left and right parts of the x-integration are treated in the same way as for the lower and upper parts of the y-integration, except that the element patterns are calculated separately for each of the three subapertures near each of the left and right edges of the reflector rim. Each of these subapertures has a half-triangular distribution as shown in Fig. 2b. The element patterns for these subapertures can be represented by

$$F_H(\phi_x) = \frac{1-e^{j\phi_x}}{(\phi_x)^2} + \frac{j}{\phi_x} \quad .$$

The contribution S_L from the left part is given in terms of the y-integration sums f_{1L} and f_{EL} as shown in Fig. 1. The edge value f_{EL} is obtained by extrapolation using Equation (15) with $f_{1L}=Y_{sum}(2)$ and $f_{2L}=Y_{sum}(3)$, thus

$$f_{EL} = Y_{sum}(x_{min}) = Y_{sum}(2)\left(1 + \frac{\Delta x_L}{d_x}\right) - Y_{sum}(3)\,\frac{\Delta x_L}{d_x}$$

where Δx_L is the distance between x_{min} and the M=2 grid line.

Consequently, the contributions from the three subapertures of the left part are given by

$$S_L = f_{EL}\, e^{jkx_{min}\sin\theta\cos\phi}\, F_H(+\phi_{xL})\Delta x_L$$

$$+ f_{1L}\, e^{j(1-I_c)\phi_x}\, [F_H(-\phi_{xL})\Delta x_L + F_H(+\phi_x)d_x]$$

where

$$f_{1L} = Y_{SUM}(2) \quad \text{and}$$

$$\phi_{xL} = k\,\Delta x_L \sin\theta\cos\phi$$

is the argument for the element patterns $F_H(\pm\phi_{xL})$ of the two subapertures with width Δx_L.

Similarly, the value f_{ER} for the y-integration at the right edge of the reflector rim is given by

$$f_{ER} = Y_{sum}(x_{max}) = Y_{sum}(M_{max}-1)\left(1 + \frac{\Delta x_R}{d_x}\right) - Y_{sum}(M_{max}-2)\,\frac{\Delta x_R}{d_x} \quad .$$

The contributions of the three subapertures of the right part can be obtained as

$$S_R = f_{ER}\, e^{jkx_{max}\sin\theta\cos\phi}\, F_H(-\phi_{xR})\Delta x_R$$

$$+ f_{1R}\, e^{j(I_{max}-I_c)\phi_x}\, [F_H(+\phi_{xR})\Delta x_R + F_H(-\phi_x)d_x]$$

where

$$f_{1R} = Y_{sum}(M_{max}-1) \text{ and}$$

$$\phi_{XR} = k\ \Delta x_R\ \sin\theta\cos\phi \quad .$$

Finally, the resulting far field pattern function as calculated by the rotating grid method is obtained by adding up the partial sums.

$$SUM = (S_L + S_M + S_R)\cos\left(\frac{\theta}{2}\right)$$

where $\cos(\theta/2)$ is the element pattern factor of the equivalent aperture currents.

Since the aperture field has both x and y components, the far field pattern associated with these two orthogonal aperture field components are calculated by the above equation and represented by SUMx and SUMy respectively. Each element of the aperture is assumed to radiate the same polarization as a Huygen's source, thus the spherical components of the far field pattern are given by

$$E_\theta^d = j(\cos\phi\cdot SUM_x+\sin\phi\cdot SUM_y)|\cos\phi|$$

and

$$E_\phi^d =-j(\sin\phi\cdot SUM_x-\cos\phi\cdot SUM_y)|\cos\phi|$$

where $|\cos\phi|$ is the correction factor for the enlarged grid size due to grid rotation.

FLOW DIAGRAM

x-integration for far field

Calculate argument DPX and the element pattern functions FFX, FHXP and FHXM associated with the basic subapertures

Calculate the
1. Middle sum SUMM
2. left sum SUML
3. right sum SUMR

Calculate the total sum and its spherical components EDT and EDP

Continue

KEY VARIABLES

ACOSP	$\lvert\cos\phi\rvert$	Absolute value of $\cos\phi$
DPX	(ϕ_x)	Phase argument of a basic subaperture
DPXL	(ϕ_{xL})	Phase argument of a subaperture at the left edge
DPXR	(ϕ_{xR})	Phase argument of a subaperture at the right edge
EDP	(E^d_ϕ)	PHI component of the radiation field
EDT	(E^d_θ)	THETA components of the radiation field
ELPAT		Element pattern function for equivalent aperture current
EXPI		Phase term for the leftmost grid point inside the aperture
EXPL		Phase term for the leftmost rim point
EXPM		Phase term for the rightmost grid point inside the aperture
EXPR		Phase term for the rightmost rim point
FFX	$(F_F(\phi_x))$	Horizontal pattern function for a basic subaperture with a full triangular distribution
FHXM		Horizontal pattern function for a basic subaperture with a half triangular distribution (negative argument)
FHXP		Horizontal pattern function for a basic subaperture with a half triangular distribution (positive argument)
FXM		Horizontal pattern function for a subaperture at the edge with a half triangular distribution (negative argument)
FYP		Vertical pattern function for a subaperture at the edge with a half triangular distribution (positive argument)
GRDX		Horizontal grid size

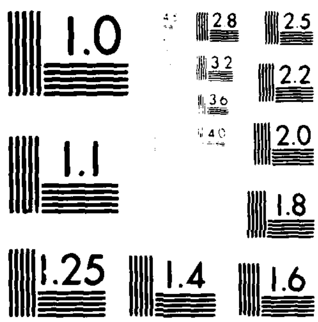
MAX	M_{max}	Maximum number of rotated grid lines
PG		Variable used for phase argument DPX (calculated in subroutine GRID)
PHSX		Phase path of an integration grid point on the aperture
PHXL		Phase path of the
PHXR		Phase path of the rightmost rim point
QXL		Normalized distance from the leftmost rim point to the first vertical grid line inside the aperture
QXR		Normalized distance from the rightmost rim point to the last vertical grid line inside the aperture
RFCT	$\left(\frac{e^{-jkR}}{R}\right)$	Range factor (used if LRANG is true)
SUMLX		X-component of the left x-integration sum
SUMLY		Y-component of the left x-integration sum
SUMMX		X-component of the middle x-integration sum
SUMMY		Y-component of the middle x-integration sum
SUMRX		X-component of the right x-integration sum
SUMRY		Y-component of the right x-integration sum
SUMX		X-component of the total x-integration sum
SUMY		Y-component of the total x-integration sum
XEXP		Phase term for an integration grid point
YML		Interpolated YSUM value at the left edge
YMR		Interpolated YSUM value at the right edge
YSUM(1,M)		X-component of the total sum of the Y-integration for grid line M
YSUM(2,M)		Y-component of the total sum of the Y-integration for grid line M

```
C
C      ***** X INTEGRATION FOR FAR FIELD *****
C
  227  DPX=PG*SINT
       FFX=FF(DPX)
       FHXP=FH(DPX)
       FHXM=FH(-DPX)
       IF (LTEST) WRITE (6,228) DPX,FFX,FHXP,FHXM
  228  FORMAT(2H D,T10,'DPX =',F7.4,5X,5F10.5,T79,1HD)
C
C            * MIDDLE SUM *
C
       SUMMX=(0.,0.)
       SUMMY=(0.,0.)
       DO 230 M=1,MAX
       IF (M.LE.2.OR.M.GE.MIX) GO TO 230
       I=M-1
       IX=I-IC
       PHSX=IX*DPX
       XEXP=CEXP(CJ*PHSX)
       SUMMX=SUMMX+YSUM(1,M)*XEXP*FFX*GRDX
       SUMMY=SUMMY+YSUM(2,M)*XEXP*FFX*GRDX
       IF (LWYSUM) WRITE (6,166) M,SUMMX,SUMMY
  230  CONTINUE
C
C            * LEFT SUM *
C
       PHXL=(XMIN/GRDX)*DPX
       DPXL=QXL*DPX
       FXP=FH(DPXL)
       FXM=FH(-DPXL)
       EXPL=CEXP(CJ*PHXL)
       EXPI=CEXP(CJ*(I-IC)*DPX)
       YML=YSUM(1,2)*(QXL+1.)-YSUM(1,3)*QXL
       SUMLX=YML*EXPL*FXP*DXL+YSUM(1,2)*EXPI*(FXM*DXL+FHXP*GRDX)
       YML=YSUM(2,2)*(QXL+1.)-YSUM(2,3)*QXL
       SUMLY=YML*EXPL*FXP*DXL+YSUM(2,2)*EXPI*(FXM*DXL+FHXP*GRDX)
C
C            * RIGHT SUM *
C
       PHXR=(XMAX/GRDX)*DPX
       DPXR=QXR*DPX
       FXP=FH(DPXR)
       FXM=FH(-DPXR)
       EXPR=CEXP(CJ*PHXR)
       EXPM=CEXP(CJ*(IMAX-IC)*DPX)
       YMR=YSUM(1,MIX)*(QXR+1.)-YSUM(1,IMAX)*QXR
       SUMRX=YMR*EXPR*FXM*DXR+YSUM(1,MIX)*EXPM*(FXP*DXR+FHXM*GRDX)
       YMR=YSUM(2,MIX)*(QXR+1.)-YSUM(2,IMAX)*QXR
```

```
      SUMRY=YMR*EXPR*FXM*DXR+YSUM(2,MIX)*EXPM*(FXP*DXR+FHXM*GRDX)
      IF (LWYSUM) WRITE (6,166) M,SUMLY,SUMRY
      ELPAT=COS(THER/2.)
      SUMX=ELPAT*(SUMLX+SUMMX+SUMRX)
      SUMY=ELPAT*(SUMLY+SUMMY+SUMRY)
      IF (LTEST) WRITE (6,195) SUMX,SUMY
      EDT=CJ*(COSP*SUMX+SINP*SUMY)*RFCT*ACOSP
      EDP=CJ*(-SINP*SUMX+COSP*SUMY)*RFCT*ACOSP
      IF (LTEST) WRITE (6,195) COSP,SINP,ACOSP
      IF (LTEST) WRITE (6,235) N,EDT,EDP
  235 FORMAT(2H T,I5,4E11.3,T79,1HT)
      IF (.NOT.LFEED) GO TO 242
```

AD-A097 415 OHIO STATE UNIV COLUMBUS ELECTROSCIENCE LAB F/G 20/4
NUMERICAL ELECTROMAGNETIC CODE (NEC)-REFLECTOR ANTENNA CODE: PA--ETC(U)
SEP 79 S H LEE, R C RUDDUCK N00123-76-C-1371
UNCLASSIFIED ESL-784508-16 NL

2 of 3



MICROCOPY RESOLUTION TEST CHART

B. SUBROUTINES

SUBROUTINE BABS

PURPOSE

This function computes the absolute value of a complex argument. It is similar to CABS, except it avoids run time errors when the real part and imaginary part of the argument are zero.

METHOD

The system function CABS is used unless the absolute value of the real part and the imaginary part of the argument are close to zero, in which case a very small value is returned.

KEY VARIABLES

X	Absolute value of the real part of Z
Y	Absolute value of the imaginary part of z
Z	The complex argument

CODE LISTING

```
      FUNCTION BABS(Z)
C!!!
C!!!  THIS ROUTINE IS USED TO GIVE COMPLEX ABSOLUTE VALUES. IT IS
C!!!  USED RATHER STANDARD ROUTINES TO AVOID EXECUTION ERRORS.
C!!!
      COMPLEX Z
      X=ABS(REAL(Z))
      Y=ABS(AIMAG(Z))
      IF(X.LT.1.E-20.AND.Y.LT.1.E-20) GO TO 10
      BABS=CABS(Z)
      RETURN
   10 BABS=1.E-20
      RETURN
      END
```

SUBROUTINE BTAN2

PURPOSE

This function computes the two argument arctangent function. It is similar to ATAN2, except it avoids run time errors when the second argument is zero.

METHOD

The system function ATAN2(Y,X) is used to return the angle in radians, whose sine is Y and cosine is X unless the second argument or both of the arguments are zero. If the second argument is zero, either $\pi/2$ or $-\pi/2$ is returned depending on the sign of the first argument. If both arguments are zero, a zero value is returned.

KEY VARIABLES

X	Second argument, which is the cosine of the angle to be computed
Y	First argument, which is the sine of the angle to be computed

CODE LISTING

```
      FUNCTION BTAN2(Y,X)
C!!!
C!!!  THIS ROUTINE IS USED TO COMPUTE THE ARCTANGENT. IT IS SIMILAR
C!!!  TO ATAN2 EXCEPT IT AVOIDS THE RUN TIME ERRORS.
C!!!
      COMMON/PIS/PI,TPI,DPR
      IF(ABS(X).GT.1.E-20) GO TO 50
      IF(ABS(Y).GT.1.E-20) GO TO 10
      BTAN2=0.
      RETURN
   10 BTAN2=PI/2.
      IF(Y.LT.0.) BTAN2=-BTAN2
      RETURN
   50 BTAN2=ATAN2(Y,X)
      RETURN
      END
```

SUBROUTINE DBPHS

PURPOSE

To calculate the normalized power level in dB and the phase of a complex field value.

METHOD

The power of a complex field value E expressed in dB is given by

$$DB = 20 \log_{10}|E| + REF$$

and the phase of E by

$$\phi = \tan^{-1}\left(\frac{Im(E)}{Re(E)}\right)$$

where Re(E) and Im(E) are the real and imaginary part of E.

For far field calculations without the range factor e^{-jkR}/R (LRANG =false). The output of the code is expressed as antenna gain relative to isotropic. In this case, the value of REF is set equal to REFDB which is calculated in the main program using the information of relative power radiated by feed (see Section 1 of the main program).

For far field calculations including the range factor or for near field calculations the value of REF is set to zero. The value of REF is summarized in the table below.

TABLE FOR REF VALUE

INPUT VARIABLE LRANG	FAR FIELD (LNF=false)	NEAR FIELD (LNF=true)
True	REF = 0	REF = 0
False	REF = REFDB	REF = 0

FLOW DIAGRAM

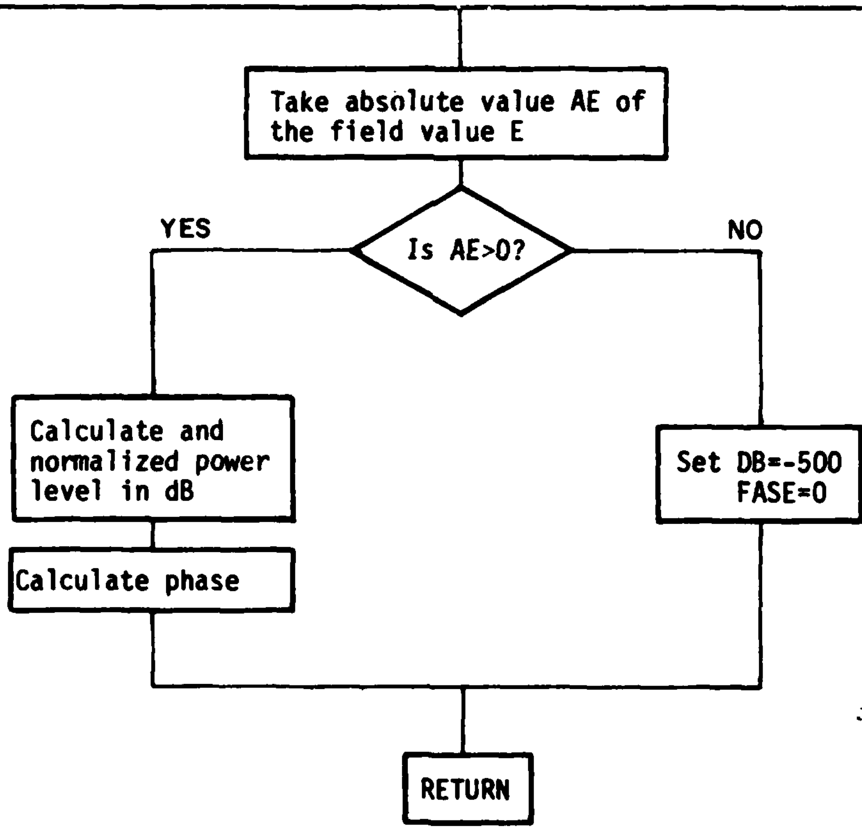
DBPHS(AE,E,REF)

INPUT VARIABLES

E	Complex field value
REF	Reference power level

OUTPUT VARIABLES

AE	Absolute value of the field value
E	Normalized power level and phase of the field value



KEY VARIABLES

DB	Normalized power level of complex field value E
FASE (ϕ)	Phase of the complex field value E

CODE LISTING

```
      SUBROUTINE DBPHS(AE,E,REF)
      COMPLEX E
      COMMON /PIS/PI,TPI,DPR
      AE=BABS(E)
      IF (AE.GT.0.) GO TO 10
      DB=-500.
      FASE=0.
      GO TO 20
   10 DB=20.*ALOG10(AE)+REF
      FASE=BTAN2(AIMAG(E),REAL(E))*DPR
   20 E=CMPLX(DB,FASE)
      RETURN
      END
```

SUBROUTINE DCHP

PURPOSE

To calculate the edge diffraction coefficients, the slope diffraction coefficients of a half plane, the corner diffraction coefficients and the slope corner diffraction coefficients for a plate.

METHOD

Using the wedge diffraction coefficient formulation [5,6], the edge diffraction coefficients for a half plane can be expressed by

$$D_{s,h}(\beta,\beta_o) = DI^- \mp DI^+$$

where

$$DI^- = \frac{-e^{-j\frac{\pi}{4}}}{2\sqrt{2\pi k}\,\sin\beta_o} \; \frac{F[kLa(\beta^-)]}{\cos\frac{\beta^-}{2}}$$

$$DI^+ = \frac{-e^{-j\frac{\pi}{2}}}{2\sqrt{2\pi k}\,\sin\beta_o} \; \frac{F[kL(\beta^+)]}{\cos\frac{\beta^+}{2}}$$

$$\beta^{\mp} = \phi \mp \phi' \quad ,$$

$$a = 2\cos^2\left(\frac{\beta}{2}\right) \quad ,$$

L is the distance parameter,

$F(X) = 2j|\sqrt{X}|e^{jX}\int_{|\sqrt{X}|}^{\infty} e^{-j\tau^2}\,d\tau$ is the transition function,

β_o is the diffracted cone angle and

ϕ and ϕ' are the diffraction angles for the diffracted field and incident field, respectively.

The slope diffraction coefficient for a half plane is given by

$$\frac{\partial D_{s,h}}{\partial \phi'} = DPI^{-} \pm DPI^{+}$$

where

$$DPI^{-} = j\sqrt{\frac{k}{2\pi}}\ \frac{e^{-j\frac{\pi}{4}}L}{\sin\beta_o}\ \sin\left(\frac{\beta^{-}}{2}\right)\ [1-F[kLa(\beta^{-})]]$$

and

$$DPI^{+} = j\sqrt{\frac{k}{2\pi}}\ \frac{e^{-j\frac{\pi}{4}}L}{\sin\beta_o}\ \sin\left(\frac{\beta^{+}}{2}\right)\ [1-F[kLa(\beta^{+})]] \quad .$$

The corner diffraction fields from a corner of a plate (see Fig. 1) can be represented by[7]

$$\begin{Bmatrix} E^c_{\parallel} \\ E^c_{\perp} \end{Bmatrix} = \text{CORN} \begin{Bmatrix} C_s E^i_{\parallel} \\ C_h E^i_{\perp} \end{Bmatrix}$$

where

$$\text{CORN} = -\frac{\sin\beta_c\ e^{-j\frac{\pi}{4}}}{2\pi(\cos\beta_{oc}+\cos\beta_c)}\ F|kL_c a(\beta_{oc}+\beta_c)|\ \sqrt{\frac{s'}{s_c}}\ e^{-jk(s_c-s')}$$

$$\frac{e^{-jks}}{s}$$

$$C_{s,h} = DI^{-} \times AFC^{-} \mp DI^{+} \times AFC^{+}$$

and

$$AFC^{\mp} = \left| F\left[\frac{La(\beta^{\mp})}{kL_c a(\beta_{oc}+\beta_c)}\right]\right| \quad \text{is the heuristic function .}$$

Note that the angles β_{oc}, β_c (see Fig. 1) and the corner distance parameter

$$L_c = \frac{s_c s}{s_c + s}$$

are calculated in the subroutine GTD.

In the code the diffracted fields from both corners ME and ME+1 of a rim segment ME are combined in the following way

$$\begin{Bmatrix} E_{\parallel}^{c} \\ E_{\perp}^{c} \end{Bmatrix} = - \begin{Bmatrix} B_s E_{\parallel}^{i} \\ B_h E_{\perp}^{i} \end{Bmatrix}$$

where the coefficients B_s and B_h are given by

$$B_{s,h} = DI^{-} \times CC^{-} \mp DI^{+} \times CC^{+}$$

and

$$CC^{\mp} = CORN_{ME} \times AFC_{ME}^{\mp} + CORN_{ME+1} \times AFC_{ME+1}^{\mp} \quad ,$$

Similarly, the coefficients for slope corner diffraction are given by

$$\frac{\partial B_{s,h}}{\partial \phi'} = \frac{\partial D_{s,h}}{\partial \phi'} \times (CORN_{ME} + CORN_{ME+1}) \quad .$$

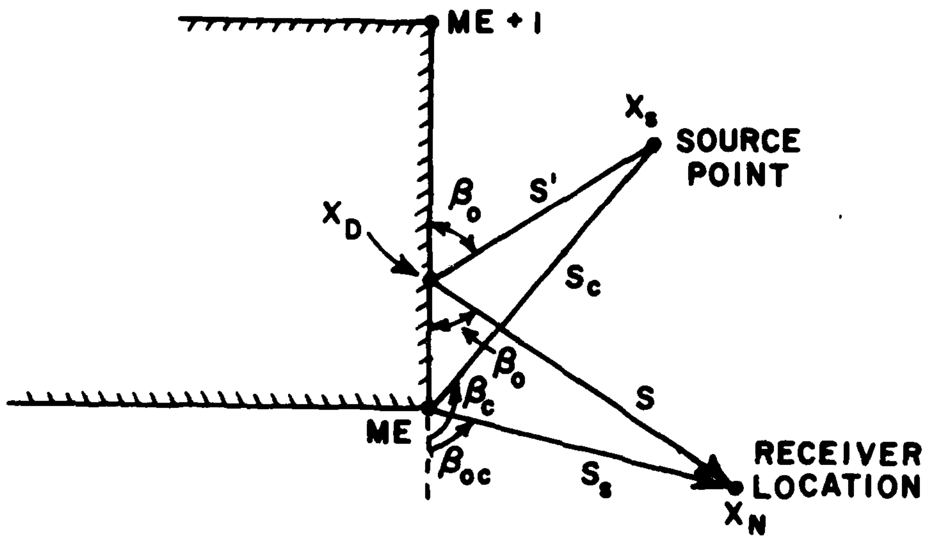


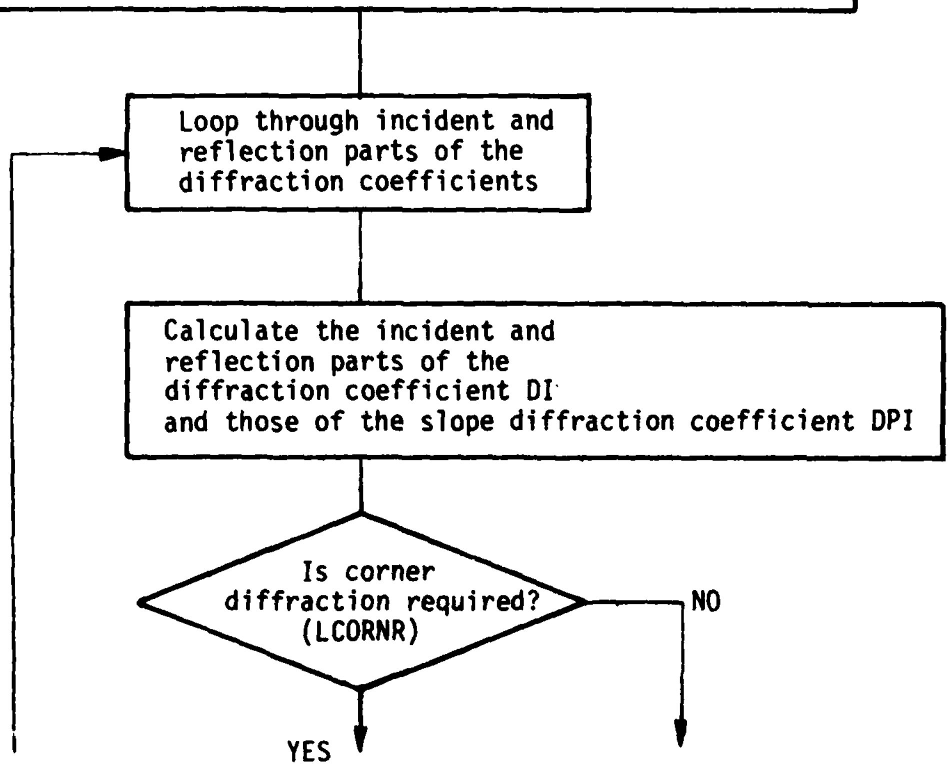
Figure 1. Geometry for corner diffraction problem.

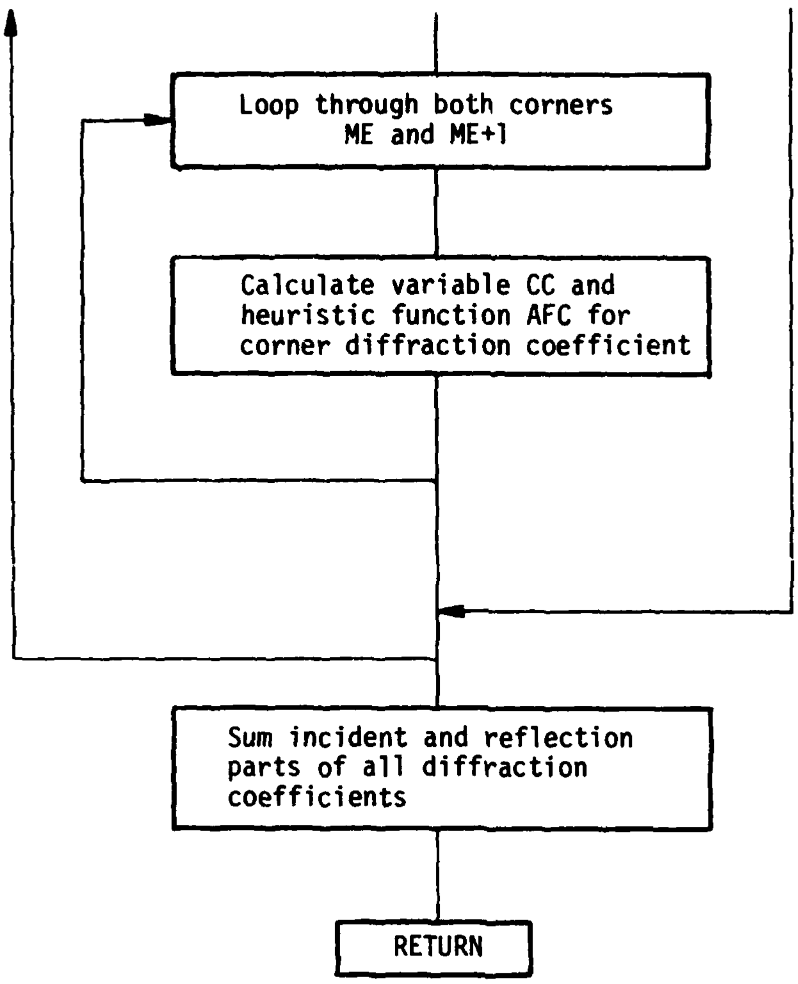
FLOW DIAGRAM

DCHP(DEL,CORN,R,PS,PSO,SBO)

INPUT VARIABLES

DEL		Variable representing the value of $kL_c a(\beta_{oc}+\beta_c)$
CORN		Variable representing the part of the corner diffraction coefficient exclusive of $C_{s,h}$
R	(L)	Distance parameter
PS	(ϕ)	Diffraction angle for diffracted field
PSO	(ϕ')	Diffraction angle for incident field
SBO		Sine of the diffracted cone angle β_o




Loop through both corners ME and ME+1
Calculate variable CC and heuristic function AFC for corner diffraction coefficient
Sum incident and reflection parts of all diffraction coefficients
RETURN

KEY VARIABLES			INPUT/ OUTPUT
A	(a)	Angular separation parameter	
AFC		Heuristic function for corner diffraction	
ANG		Variable for PS±PSO in radians	
ARG		Argument for AFC	
BET	(β)	Variable for PS±PSO in degrees	
BH	(B_h)	Hard corner diffraction coefficient	(0)
BPH	$\left(\frac{\partial B_h}{\partial \phi'}\right)$	Hard slope corner diffraction coefficient	(0)
BPS	$\left(\frac{\partial B_s}{\partial \phi'}\right)$	Soft slope corner diffraction coefficient	(0)
BS	(B_s)	Soft corner diffraction coefficient	(0)
CC		Variable representing the combined effect for both corners ME and ME+1 in the corner diffraction	
DI		The incident or reflection part of the edge diffraction coefficient	
DH	(D_h)	Hard diffraction coefficient for edge	(0)
DPH	$\left(\frac{\partial D_h}{\partial \phi'}\right)$	Hard slope diffraction coefficient for edge	(0)
DPS	$\left(\frac{\partial D_s}{\partial \phi'}\right)$	Soft slope diffraction coefficient for edge	(0)
DS	(D_s)	Soft diffraction coefficient for edge	(0)
FA		Transition function for edge diffraction	
FFCT		Transition function (see section on FFCT)	
LCORNR		Logical variable for corner diffraction (see User's Manual)	(I)
LSLOPE		Logical variable for slope diffraction (see User's Manual)	(I)

SL	Value for DI near the shadow boundaries
TERM	Temporary coefficient for DS,DH
TERMP	Temporary coefficient for DPS,DPH

CODE LISTING

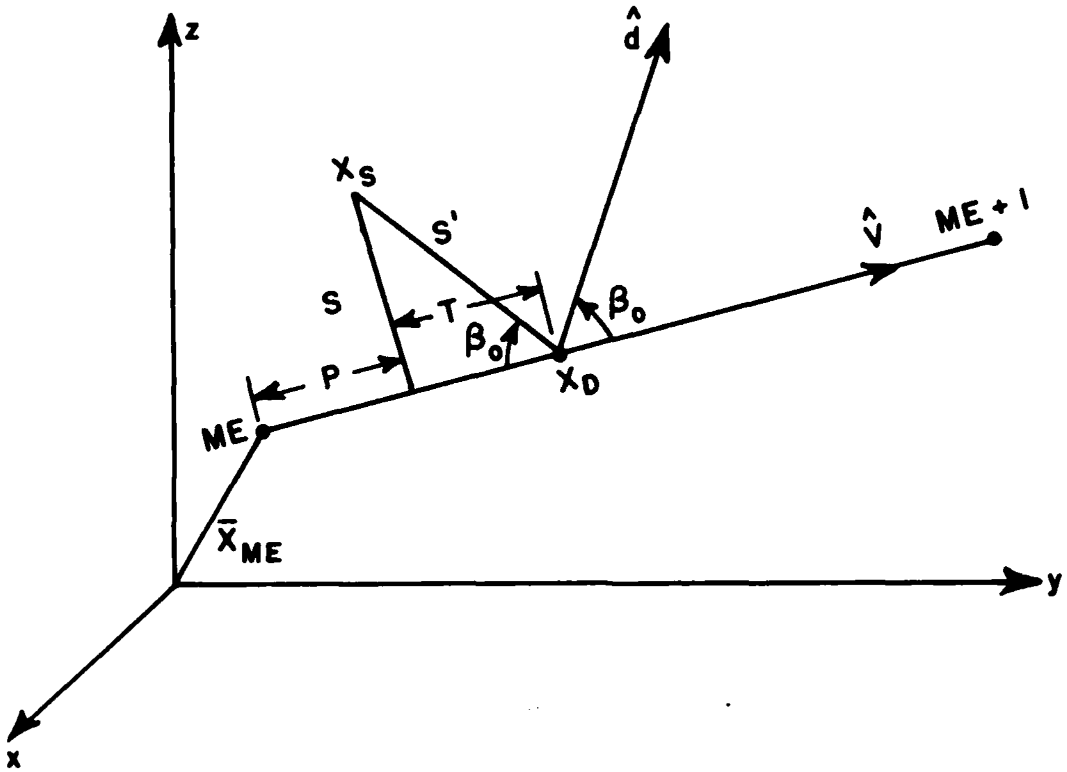
```
      SUBROUTINE DCHP(DEL,CORN,R,PS,PSO,SBO)
      DIMENSION DEL(2)
      COMPLEX CORN(2),DI(2),DPI(2),CC(2),TERM,TERMP,FFCT,FA,TOP
      COMPLEX CJ,DS,DH,DPS,DPH,BS,BH,BPS,BPH,CIN,CIP,CCP
      COMMON /DSC/DS,DH,DPS,DPH,BS,BH,BPS,BPH
      COMMON /PIS/PI,TPI,DPR
      COMMON /LOGDIF/LSLOPE,LCORNR,LNF,LRANG
      COMMON /TEST/LDEBUG,LTEST,NTEST
      COMMON /TOPD/TOP
      COMMON /OUT/NW
      LOGICAL LCORNR,LSLOPE,LDEBUG,LTEST
      IF (LDEBUG) WRITE (NW,2) R,PS,PSO,SBO,LOG,DEL(1),DEL(2)
    2 FORMAT (T5,'DEBUGGING SUBROUTINE DCHP',//4F10.2,L5,2F10.4)
      CJ=(0.,1.)
      TERM=TOP/(2.*TPI*SBO)
      TERMP=CJ*2.*TPI*TERM*R
      IF (LDEBUG) WRITE (NW,3) TERM,TERMP
    3 FORMAT (T10,6HTERM =,2F10.4,5X,7HTERMP =,2F10.4)
      SL=0.5*SQRT(R)/SBO
      IF (DEL(1).LT.1.D-20) DEL(1)=1.D-20
      IF (DEL(2).LT.1.D-20) DEL(2)=1.D-20
      BET=PS-PSO
      DO 20 N=1,2
      ANG=BET/DPR
      SB=SIN(ANG/2.)
      CB=COS(ANG/2.)
      A=2.*CB*CB
      IF (LDEBUG) WRITE (NW,4) BET,CB,A
    4 FORMAT (T10,5HBET =,F8.2,5X,4HCB =,F10.6,5X,3HA =,F10.6)
      X=TPI*ABS(R*A)
      IF ((LSLOPE).OR.(X.LE.10.)) FA=FFCT(X)
      IF (X.GT.10.) FA=1.+CJ/(2.*X)-3./(4.*X*X)
      IF (LDEBUG) WRITE (NW,7) X,FA
    7 FORMAT (T10,3HX =,F10.4,5X,4HFA =,2F10.6)
      IF (A.GT.1.D-20) GO TO 5
      DI(N)=-SL+CJ*0.
      GO TO 8
    5 CONTINUE
```

```
      DI(N)=TERM*FA/CB
 8    CONTINUE
      DPI(N)=TERMP*SB*(1.-FA)
      IF (LDEBUG) WRITE (NW,9) DI(N),DPI(N)
 9    FORMAT (T1Ø,4HDI =,2F1Ø.5,5X,5HDPI =,2F1Ø.5)
      IF (.NOT.LCORNR) GO TO 15
      CC(N)=(Ø.,Ø.)
      DO 12 I=1,2
      ARG=R*A/DEL(I)
      AFC=1.
      IF (ARG.LE.1Ø.) AFC=BABS(FFCT(ARG))
      CC(N)=CC(N)+CORN(I)*AFC
      IF (LDEBUG) WRITE (NW,11) ARG,AFC,CC(N),CORN(1),CORN(2)
 11   FORMAT (T5,5HARG =,F1Ø.4,5X,5HAFC =,7F1Ø.6)
 12   CONTINUE
 15   BET=PS+PSO
 2Ø   CONTINUE
      DS=DI(1)-DI(2)
      DH=DI(1)+DI(2)
      DPS=DPI(1)+DPI(2)
      DPH=DPI(1)-DPI(2)
      IF (.NOT.LCORNR) RETURN
      CIN=DI(1)*CC(1)
      CIP=DI(2)*CC(2)
      BS=CIN-CIP
      BH=CIN+CIP
      CCP=CORN(1)+CORN(2)
      BPS=DPS*CCP
      BPH=DPH*CCP
      RETURN
      END
```

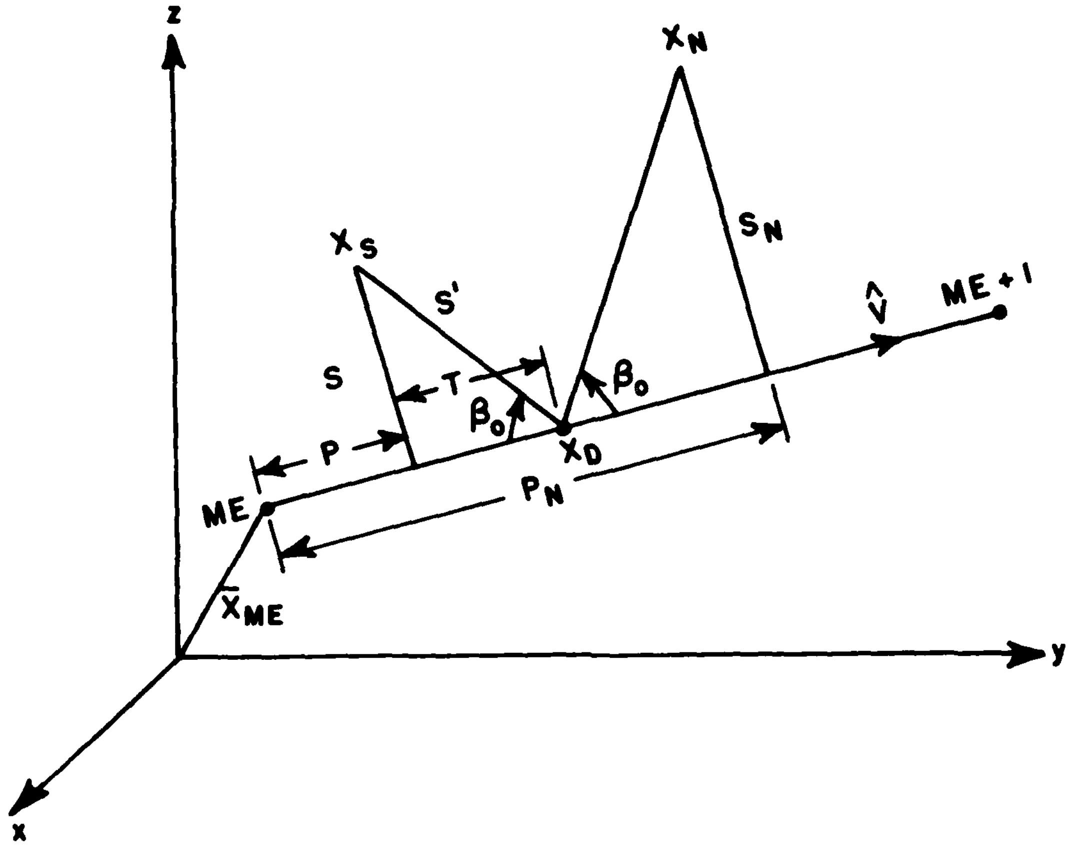
SUBROUTINE DFPTWD

PURPOSE

To determine the diffraction point on a rim segment for either a far field or near field point and determine the incident ray unit vector.



(a) far field



(b) Near field

Figure 1. Geometry for locating diffraction point X_D on edge ME.

METHOD

The coordinates of the diffraction point X_D are determined by solving a similar triangle system. For edge ME,

$$P = (\bar{X}_S - \bar{X}) \cdot \hat{V}$$

and

$$S = |\bar{X}_S - \bar{X}_{ME} - P\hat{V}|$$

For far field (see Fig. 1a), since $\cos\beta_0 = \hat{d}\cdot\hat{V}$ then

$$\cot\beta_0 = \frac{\hat{d}\cdot\hat{V}}{\sqrt{1-(\hat{d}\cdot\hat{V})^2}}$$

and $T = S \cdot \cot\beta_0$.

For near field (see Fig. 1b)

$$P_N = (\overline{X}_N - \overline{X}_{ME})\cdot\hat{V}$$

$$S_N = |\overline{X}_N - \overline{X}_{ME} - P_N\hat{V}|$$

and

$$T = (P_N - P)S/(S+S_N) \quad .$$

Thus the coordinates of the diffraction point are determined by the vector

$$\overline{X}_D = \overline{X}_{ME} + (P+T)\hat{V} \quad .$$

The distance S' from the source X_S to the diffraction point X_D is determined from

$$\overline{VI} = \overline{X}_D - \overline{X}_S$$

and

$$S' = |\overline{VI}| \quad .$$

The unit vector for the incident ray is then obtained by normalizing the above vector

$$\hat{VI} = \frac{\overline{VI}}{S'}$$

FLOW DIAGRAM

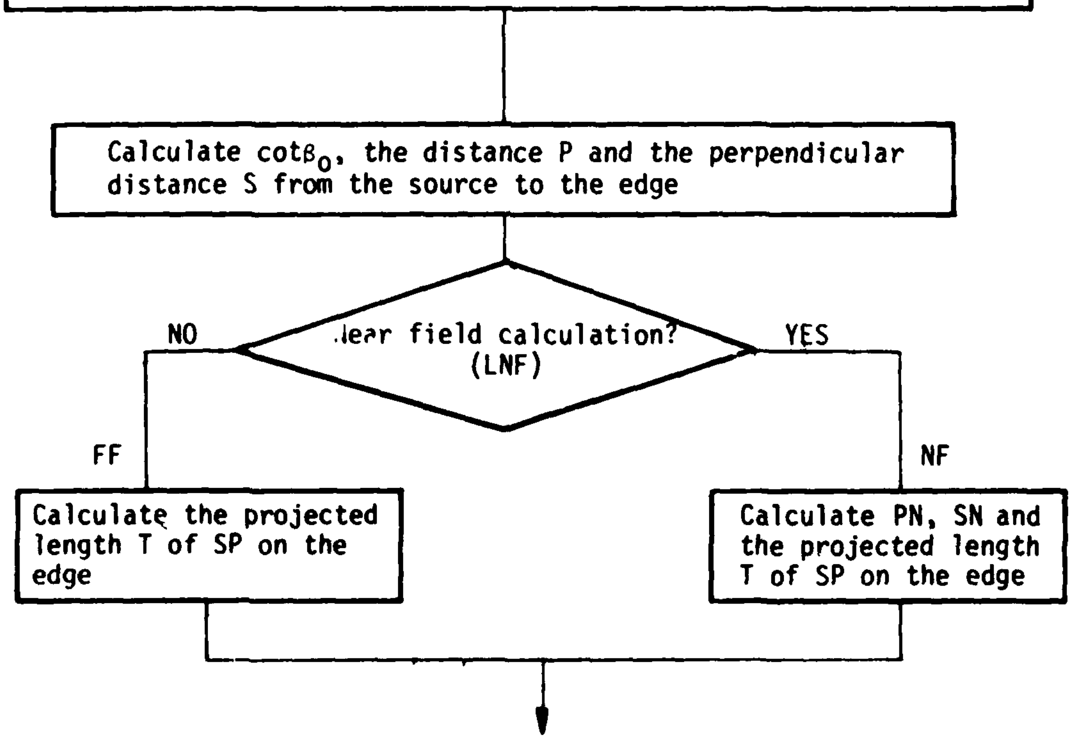
DFPTWD(XS,XN,DV,VI,SP,XD,ME)

INPUT VARIABLES

XS	Source location in rectangular coordinate system
XN	Near field point coordinates
DV	Inner product of the diffraction vector and the edge vector
ME	Rim segment index

OUTPUT VARIABLES

VI	Incident ray unit vector
SP	Incident ray path length
XD	Coordinates of the diffraction point



Calculate the coordinates of the diffraction point XD, the incident ray path length SP and the incident ray unit vector VI

RETURN

KEY VARIABLES INPUT/OUTPUT

			INPUT/ OUTPUT
CTB		Cotangent of diffraction angle β_o	
LNF		Logical variable to determine whether near field or far field is calculated	(I)
P		Distance from the source to the corner ME projected on the edge	
PN	(P_N)	Distance from the near field point XN to the corner ME projected on the edge	
S		Perpendicular distance from the source to the edge	
SN	(S_N)	Perpendicular distance from the near field point to the edge	
SP	(S')	Incident ray path length	
T		Projected length of SP on the edge	
X	(X_{ME})	Rectangular coordinate components of the rim point ME	(I)

CODE LISTING

```
      SUBROUTINE DFPTWD(XS,XN,DV,VI,SP,XD,ME)
C!!!
C!!!  DETERMINATION OF THE DIFFRACTION POINT
C!!!
      DIMENSION XS(3),XN(3),XD(3),VI(3)
      LOGICAL LSLOPE,LCORNR,LNF,LRANG
      COMMON /GEOM1/X(67,3),V(67,3),MRIM
      COMMON /LOGDIF/LSLOPE,LCORNR,LNF,LRANG
      CTB=DV/SQRT(1.-DV*DV)
      P=0.
      PN=0.
      DO 10 N=1,3
      IF (LNF) PN=PN+(XN(N)-X(ME,N))*V(ME,N)
   10 P=P+(XS(N)-X(ME,N))*V(ME,N)
      S=0.
      SN=0.
      DO 20 N=1,3
      SY=XN(N)-X(ME,N)-PN*V(ME,N)
      SX=XS(N)-X(ME,N)-P*V(ME,N)
      SN=SN+SY*SY
   20 S=S+SX*SX
      S=SQRT(S)
      SN=SQRT(SN)
      T=S*CTB
      IF (LNF) T=(PN-P)*S/(S+SN)
      DO 30 N=1,3
   30 XD(N)=X(ME,N)+(P+T)*V(ME,N)
      SP=0.
      DO 40 N=1,3
      VI(N)=XD(N)-XS(N)
   40 SP=SP+VI(N)*VI(N)
      SP=SQRT(SP)
      DO 50 N=1,3
   50 VI(N)=VI(N)/SP
      RETURN
      END
```

SUBROUTINE FEED

PURPOSE

To determine the magnitude of the feed pattern in any given direction as referred to the reflector coordinate system.

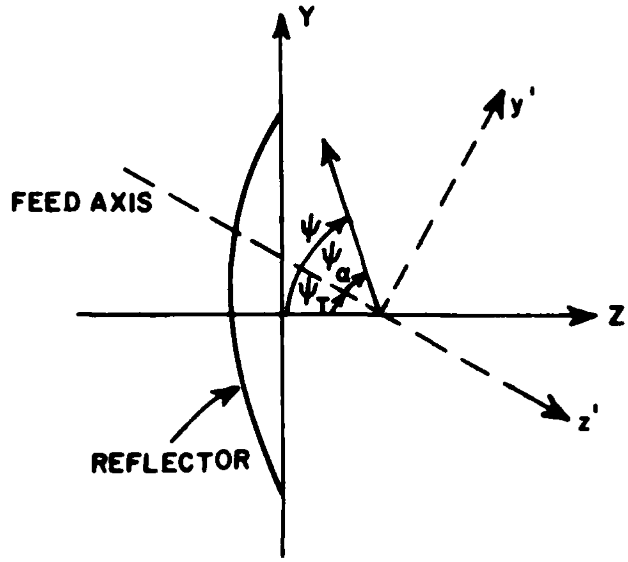


Figure 1. Geometry of the feed coordinate system.

METHOD

For a given direction (ψ,ϕ) in the reflector coordinate system the transformation from (ψ,ϕ) to $(\psi_\alpha,\phi_\gamma)$ in the feed coordinate is given by

$$\psi_\alpha = \cos^{-1}(\sin\psi_T \sin\psi\sin\phi + \cos\psi_T \cos\psi)$$

$$\phi_\gamma = \tan^{-1} \frac{\cos\psi_T\sin\psi\sin\phi - \sin\psi_T\cos\psi}{\sin\psi\cos\phi}$$

where $\psi = \pi - \theta$ and ψ_T is the feed tilt angle (in the YZ plane).

Various symmetry options are available to reduce the amount of input data required for symmetrical feed patterns, as shown in Table 1.

TABLE 1

|ISYM|	SYMMETRY	ϕ_X	LIMITS FOR ϕ_X
0	NO	ϕ	$-\pi < \phi_X \leq \pi$
1	x- and y-axis	$\|\phi\|$ or $\pm\pi-\phi$	$0 \leq \phi_X \leq \frac{\pi}{2}$
2	x-axis	$\|\phi\|$	$0 \leq \phi_X \leq \pi$
3	y axis	$\pm\pi-\phi$	$-\frac{\pi}{2} \leq \phi_X \leq \frac{\pi}{2}$

To find the feed pattern value at $(\psi_\alpha, \phi_\gamma)$, ϕ_γ is adjusted and is represented by ϕ_X according to the symmetry index ISYM. Then the two PHI cuts ϕ_P, ϕ_Q of the input feed pattern adjacent to ϕ_X are determined by comparison. The feed pattern values g_P and g_Q are calculated at the angle $\psi=\psi_\alpha$ in the planes ϕ_P and ϕ_Q, respectively, by using either linear interpolation between stored values or an analytic pattern function.

The linear interpolation is performed by calling subroutine LNFD.

The analytic pattern is constructed by

$$
\begin{cases}
g_n = C\, e^{-A\left(\frac{\psi}{\psi_o}\right)^2} \sin^N\left(\frac{\pi\psi}{2\psi_o}\right) & \text{if ISYM} < 0 \text{ (odd symmetry)} \\[2ex]
g_n = \dfrac{e^{-A\left(\frac{\psi}{\psi_o}\right)^2} \cos^N\left(\frac{\pi\psi}{2\psi_o}\right) + C}{1 + C} & \text{if ISYM} \geq 0 \text{ (even symmetry)}
\end{cases}
$$

$$\text{for } \psi \leq \psi_L$$

$$g_n = g_n(\psi_L)\left(1 - \frac{\psi-\psi_L}{\psi_L}\right) \qquad \text{for } \psi_L < \psi < 2\psi_L$$

and

$$g_n = 0 \qquad \text{for } 2\psi_L \leq \psi$$

where

$$\psi_L = \sqrt{\frac{3}{A}\,\psi_o}$$

is an empirical cutoff criterion and N, C, A and ψ_o are input parameters to control the feed pattern.

Finally, the magnitude of the feed pattern value g_f at $(\psi_\alpha,\phi_\gamma)$ is obtained by interpolating g_P and g_Q as follows:

$$g_f = d_{PQ}\, g_P + (1-d_{PQ})g_Q$$

where

$$d_{PQ} = \frac{\phi\ -\phi_Q}{\phi_P-\phi_Q}$$

FLOW DIAGRAM

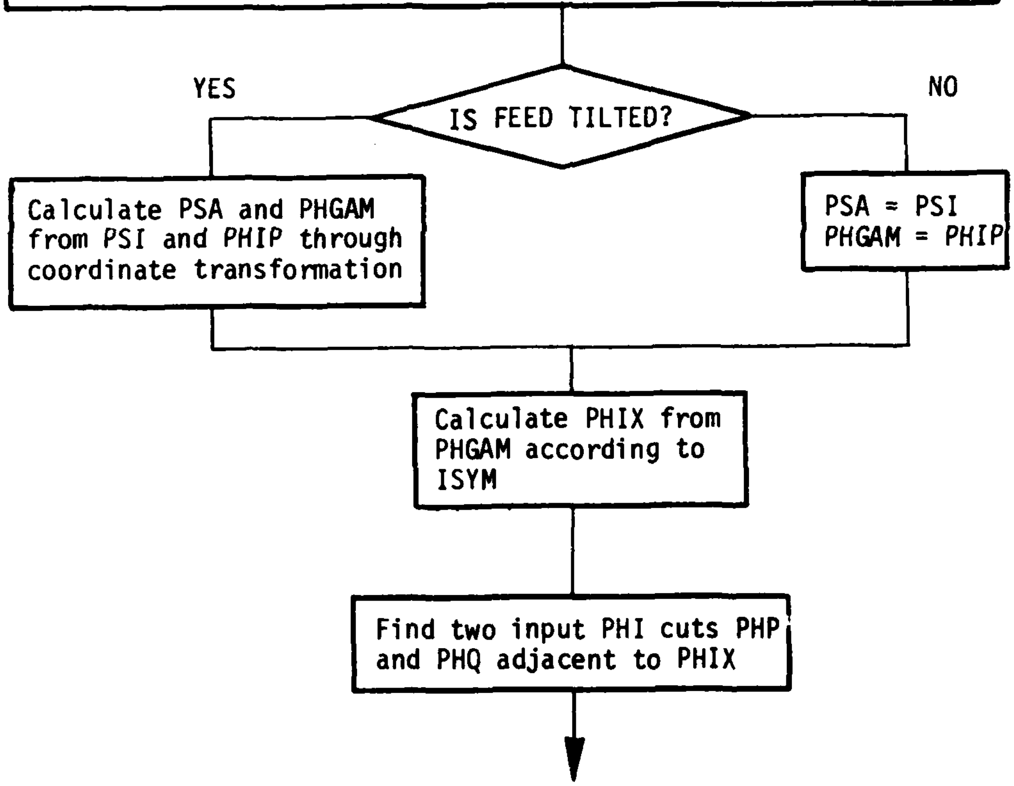
FEED (PSI,,PHIP,PSA,PHGAM)

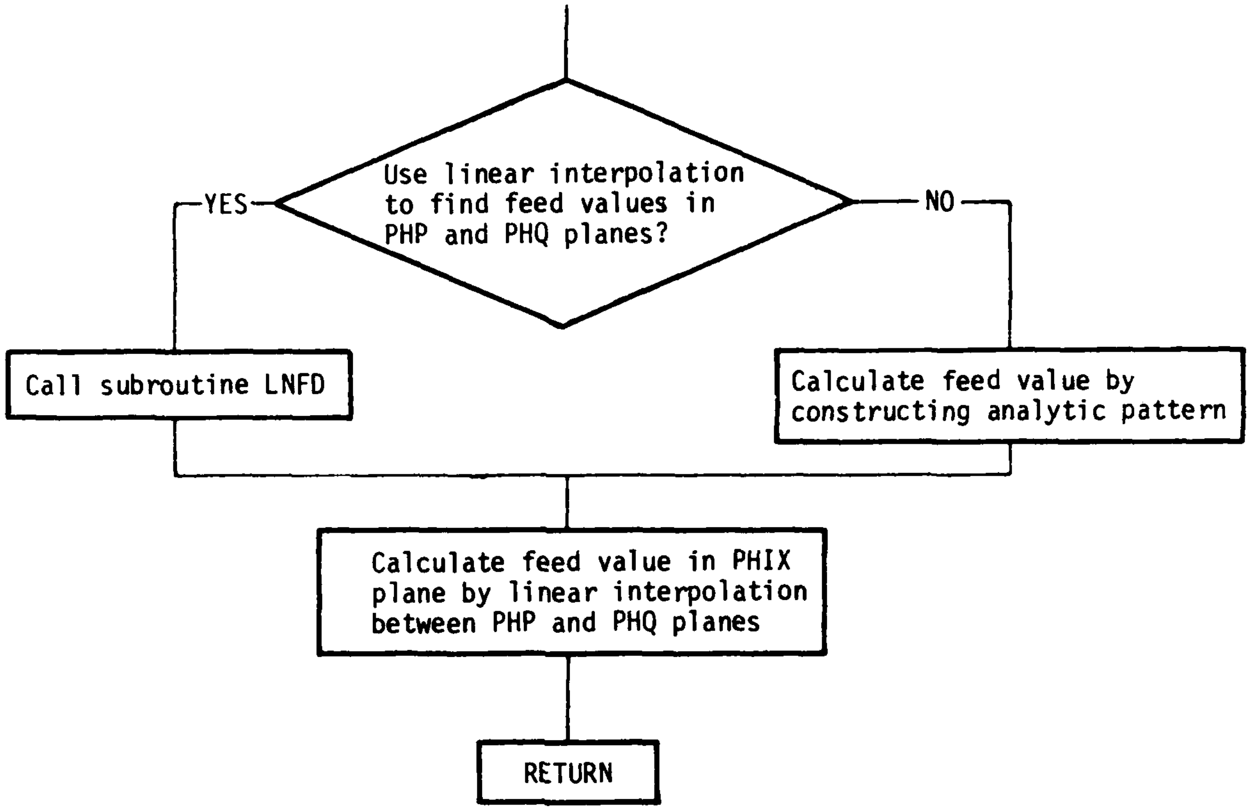
INPUT VARIABLES

PSI	(ψ)	Theta coordinate of the observation direction measured from the negative Z-axis.
PHIP	(ϕ')	Phi corrdinate of the observation direction.

OUTPUT VARIABLES

PSA	(ψ_α)	Theta coordinate of the observation direction measured from the feed axis.
PHGAM	(ϕ_γ)	Phi coordinate of the observation direction referred to the tilted feed system.




Use linear interpolation to find feed values in PHP and PHQ planes?
YES
NO
Call subroutine LNFD
Calculate feed value by constructing analytic pattern
Calculate feed value in PHIX plane by linear interpolation between PHP and PHQ planes
RETURN

KEY VARIABLES			INPUT/ OUTPUT
FP		Input feed pattern data for linear interpolation	(I)
GF	(g_f)	Feed pattern value at (PSA, PHGAM)	(O)
GP	(g_p)	Feed pattern value calculated at PSA in PHP cut	
GQ	(g_q)	Feed pattern value calculated at PSA in PHQ cut	
ISYM		Symmetry index for input feed pattern	
PHIN		Input feed pattern cut angle	(I)
PHIX	(ϕ_X)	Adjusted PHGAM angle according to ISYM	
PHP	(ϕ_P)	Upper input PHI cut adjacent to PHIX	
PHQ	(ϕ_Q)	Lower input PHI cut adjacent to PHIX	
PSIL	(ψ_L)	Cutoff criterion for analytic pattern	
PSIO	(ψ_o)	Input parameter to control the feed pattern	(I)
PSIT	(ψ_T)	Feed tilt angle	(I)
PX		Input feed pattern angle	(I)

CODE LISTING

```
      SUBROUTINE FEED(PSI,PHIP,PSA,PHGAM)
      DIMENSION PHIN(15),FP1(15),FP(15,15),AEX(15),CAN(15),
     1PX1(15),PX(15,15),GN(2),FP2(15),PX2(15),PSIO(15)
      COMPLEX CX,CY
      LOGICAL LDEBUG,LTEST,LPSL,LDB
      COMMON /FED/N2,PHIN,PX,FP,LDB,NCK,NPHI,NPW,AEX,CAN,PSIO,PSIT
      COMMON /COMP/CX,CY,GF,PHP,PHO,KX,KY,ISYM,SINT,COST
      COMMON /PIS/PI,TPI,DPR
      COMMON /PREV/IPR,PREP,PREX,PRES
      COMMON /TEST/LDEBUG,LTEST,NTEST
      COMMON /OUT/NW
      IF (NTEST.EQ.1) WRITE (NW,8) PSI,PHIP
    8 FORMAT (//T8,'DEBUGGING SUBROUTINE FEED',/T12,'PSI =',
     2F7.2,5X,'PHIP =',F7.2,/)
      PHGAM=PHIP
      PSA=PSI
      IF (PSIT.EQ.0.) GO TO 10
      PSIR=PSA/DPR
      PHIPR=PHIP/DPR
      SINS=SIN(PSIR)
      COSS=COS(PSIR)
      SINP=SIN(PHIPR)
      COSP=COS(PHIPR)
      PSA=ACOS(SINT*SINS*SINP+COST*COSS)*DPR
      TEMP=COST*SINS*SINP-SINT*COSS
      IF ((ABS(TEMP)+ABS(COSP)).LT.0.0001) TEMP=0.0001
      PHGAM=ATAN2(TEMP,SINS*COSP)*DPR
   10 CONTINUE
    5 FORMAT (3F12.4)
      IF (ISYM.EQ.IPR.AND.PHGAM.EQ.PREP) GO TO 15
      PHIX=PHGAM
      IB=IABS(ISYM)
      IF (IB.EQ.0) GO TO 15
      IF (IB.EQ.3) GO TO 12
      PHIX=ABS(PHIX)
      IF (IB.EQ.2) GO TO 15
   12 IF (PHIX.GT.90.) PHIX=180.-PHIX
      IF (PHIX.LT.-90.) PHIX=-180.-PHIX
   15 CONTINUE
      IF (NTEST.EQ.2.OR.NTEST.EQ.1) WRITE (NW,18) PHGAM,PSA,PHIX
   18 FORMAT (/T12,'PHGAM =',F7.2,' PSA =',F7.2,' PHIX =',F7.2)
      SINPX=SIN(PHIX/DPR)
      IF (PHIX.GE.PHO.AND.PHIX.LE.PHP) GO TO 30
      DO 20 NP=2,NPHI
      IF (PHIX.LE.PHIN(NP)) GO TO 22
   20 CONTINUE
      NP=NPHI+1
      PHIN(NP)=PHIN(1)+360.
      PSIO(NP)=PSIO(1)
```

```
22    NQ=NP-1
      PHQ=PHIN(NQ)
      PHP=PHIN(NP)
      IF (NTEST.EQ.1) WRITE (NW,25) PHQ,PHP
 25   FORMAT (T12,'PHQ =',F7.2,5X,'PHP =',F7.2)
      IF (NCK.EQ.2) GO TO 32
 27   DO 28 K=1,N2
      PX1(K)=PX(NQ,K)
      FP1(K)=FP(NQ,K)
      PX2(K)=PX(NP,K)
      FP2(K)=FP(NP,K)
 28   CONTINUE
30    IF (NCK.EQ.2) GO TO 32
      DPSI=ABS(PSA-PRES)
      IF (DPSI.LT.0.1.AND.PHIX.EQ.PREX) GO TO 39
      CALL LNFD(PX1,FP1,PSA,N2,GQ,LDB)
      CALL LNFD(PX2,FP2,PSA,N2,GP,LDB)
      IF (NTEST.EQ.1) WRITE (6,5) PSA,GQ,GP
      IF (.NOT.LDB) GO TO 39
      GQ=10.**(GQ/20.)
      GP=10.**(GP/20.)
      GO TO 39
 32   LPSL=.FALSE.
      SLOPE=0.
      PSY=PSA
      DO 38 N=1,2
      NN=NQ+N-1
      IF (ISYM.LT.0) GO TO 33
      IF (NPW.NE.1.OR.CAN(NN).LT.0..OR.AEX(NN).LT.3.) GO TO 33
      PSL=SQRT(3./AEX(NN))*PSIO(NN)
      DPSL=PSA-PSL
      IF (DPSL.LE.0.) GO TO 33
      PSY=PSL
      LPSL=.TRUE.
      IF (DPSL.LT.PSL) GO TO 33
      GN(N)=0.
      GO TO 38
 33   QX=PSY/PSIO(NN)
      ARG=0.5*PI*QX
      ARGEX=AEX(NN)*QX*QX
      IF (ARGEX.LT.20.) EXPN=EXP(-ARGEX)
      IF (ARGEX.GE.20.) EXPN=0.
      IF (NTEST.EQ.1) WRITE (NW,35) ARG,AEX(NN),CAN(NN),EXPN
 35   FORMAT (/T12,'ARG =',F9.3,5X,'AEX(N) =',F9.3,5X,'CAN(N) =',
     2F9.3,5X,'EXPN =',F9.3,/)
      IF (ISYM.GE.0) GO TO 37
      GN(N)=CAN(NN)*EXPN*SIN(ARG)**NPW
      GO TO 38
```

```
 37  GN(N)=EXPN*COS(ARG)**NPW
     GN(N)=(GN(N)+CAN(NN))/(1.+CAN(NN))
     IF (LPSL) SLOPE=-GN(N)/PSL
     GN(N)=GN(N)+SLOPE*DPSL
 38  CONTINUE
     GO=GN(1)
     GP=GN(2)
 39  DPO=(PHIX-PHO)/(PHP-PHO)
     GF=GP*DPO+GO*(1-DPO)
     IF ((NTEST.EQ.1).OR.(NTEST.EQ.2)) WRITE (NW,50) GF
 50  FORMAT (/T10,'GF =',F10.4)
     PREX=PHIX
     PREP=PHGAM
     PRES=PSA
     IPR=ISYM
     RETURN
     END
```

FUNCTION FF

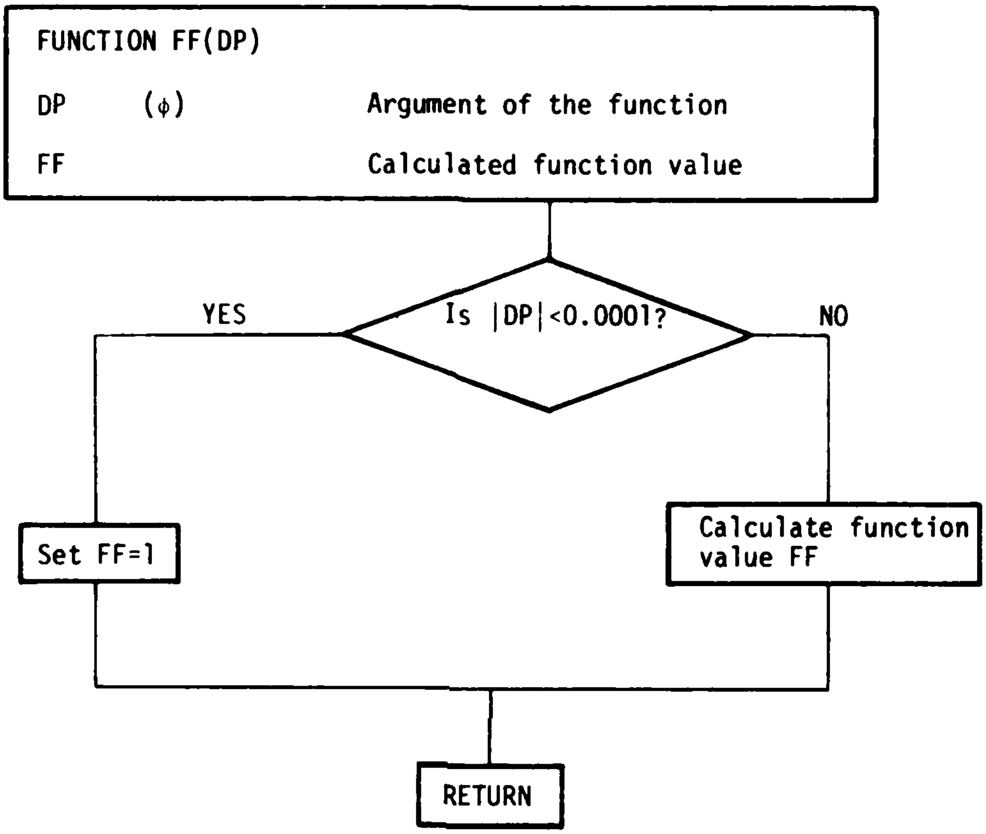
PURPOSE

To calculate the element pattern function of a rectangular sub-aperture with full triangular distribution.

METHOD

$$F_F(\phi) = \left(\frac{\sin \frac{\phi}{2}}{\frac{\phi}{2}}\right)^2$$

FLOW DIAGRAM



CODE LISTING

```
      FUNCTION FF(DP)
      IF (ABS(DP).LT.Ø.ØØØ1) GO TO 11
      X=DP/2.
      TEMP=SIN(X)/X
      FF=TEMP*TEMP
      GO TO 12
11    FF=1.
12    RETURN
      END
```

FUNCTION FFCT

PURPOSE

The purpose of this function is to determine the transition function for the edge and corner diffraction coefficients.

METHOD

The transition function for the edge and corner diffraction coefficients is given by[5]:

$$FFCT(x) = 2j|\sqrt{x}|\ e^{jx} \int_{|\sqrt{x}|} e^{-j\tau^2}\, d\tau.$$

This can also be written as

$$FFCT(x) = j\sqrt{2\pi|x|}\ e^{jx}\left[(0.5-j0.5)-\left(C\left(\sqrt{\frac{2|x|}{\pi}}\right)-jS\left(\sqrt{\frac{2|x|}{\pi}}\right)\right]$$

where

$$\int_0^{\alpha} e^{-j\frac{\pi}{2}t^2}\, dt = C(\alpha) - jS(\alpha).$$

KEY VARIABLES

CFR	Real part of Fresnel integral
DEL	Argument of transition function
FFCT	Transition function
S	Argument of Fresnel integral
SDEL	SQRT(ABS(DEL))
SFR	Imaginary part of Fresnel integral

CODE LISTING

```
      COMPLEX FUNCTION FFCT(DEL)
C!!!
C!!!  DETERMINES THE TRANSITION FUNCTION RESULT FOR
C!!!  CORNER DIFFRACTED FIELD
C!!!
      COMMON/PIS/PI,TPI,DPR
      COMMON /OUT/NW
      SDEL=SQRT(ABS(DEL))
      S=SQRT(2./PI)*SDEL
      CALL FRNELS(CFR,SFR,S)
      FFCT=CMPLX(Ø.5-CFR,SFR-Ø.5)
      FFCT=SQRT(TPI)*SDEL*FFCT*CEXP(CMPLX(Ø.,DEL+PI/2.))
      RETURN
      END
```

FUNCTION FH

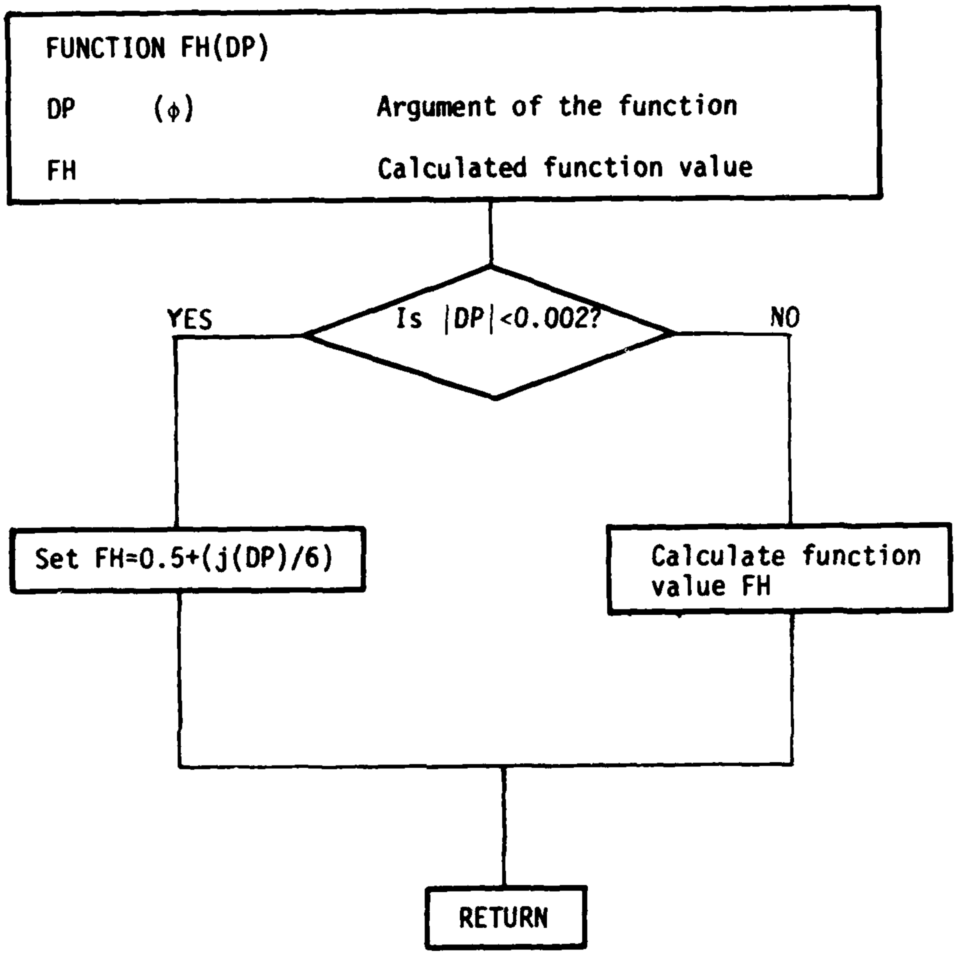
PURPOSE

To calculate the element pattern function of a rectangular sub-aperture with half triangular distribution.

METHOD

$$F_H(\phi) = \frac{1-e^{j\phi}}{(\phi)^2} + \frac{j}{\phi}$$

FLOW DIAGRAM



CODE LISTING

```
      COMPLEX FUNCTION FH(DP)
      COMPLEX CJ,CDP,TEMP
      CJ=(0.,1.)
      CDP=CJ*DP
      IF (ABS(DP).LT.0.002) GO TO 21
      TEMP=(1.-CEXP(CDP))/(DP*DP)
      FH=TEMP-(1./CDP)
      GO TO 22
   21 FH=0.5+CDP/6.
   22 RETURN
      END
```

SUBROUTINE FPOL

PURPOSE

To calculate the rectangular vector components of the E-field of the feed as referred to the reflector coordinate system.

METHOD

The two linear polarization components of the feed pattern of an arbitrarily oriented (in the x-y plane) Huygen's source (crossed electric and magnetic dipoles [2]) are given by

$$f_x = C_x \cdot \phi_s \cdot g_f$$

$$f_x = C_y \cdot \phi_s \cdot g_f$$

where C_x and C_y are polarization parameters expressed as

$$\begin{cases} C_x = \cos(\tau) \\ C_y = \sin(\tau) \end{cases} \qquad \text{for linearly polarized feed with polarization angle} = \tau$$

or

$$\begin{cases} C_x = \dfrac{1}{\sqrt{2}} \\ C_y = \dfrac{j}{\sqrt{2}} \end{cases} \qquad \text{for circularly polarized feed} .$$

ϕ_s is the phase of excitation as given by

$$\phi_s = 1 \qquad \text{ISYM} \geq 0 \text{ (even symmetry)}$$

$$\left.\begin{aligned} \phi_s &= e^{j\phi} && \text{ISYM} = -1 \\ \phi_s &= \frac{\sin\phi}{|\sin\phi|} && \text{ISYM} = -2 \\ \phi_s &= \frac{\cos\phi}{|\cos\phi|} && \text{ISYM} = -3 \end{aligned}\right\} \text{ (odd symmetry)} .$$

and g_f is the magnitude of the feed pattern which is calculated by the subroutine FEED.

The spherical vector components of the feed pattern are obtained by

$$E^i_{\theta_\alpha} = -\cos\phi_\gamma f_x - \sin\phi_\gamma f_y$$

$$E^i_{\phi_\gamma} = -\sin\phi_\gamma f_x + \cos\phi_\gamma f_y$$

where θ_α and ϕ_γ are the spherical coordinate angles in the feed coordinate system.

The rectangular components are calculated by

$$E^i_x = -\cos\psi_\alpha \cos\phi_\gamma E^i_{\theta_\alpha} - \sin\phi_\gamma E^i_{\phi_\gamma}$$

$$E^i_y = -\cos\psi_\alpha \sin\phi_\gamma E^i_{\theta_\alpha} + \cos\phi_\gamma E^i_{\phi_\gamma}$$

and

$$E^i_z = -\sin\psi_\alpha E^i_{\theta_\alpha} \quad .$$

The electric field vector is then transformed from the tilted feed coordinate system to the reflector coordinate system as follows:

$$E^i_x = E^i_x$$

$$E^i_y = \cos\psi_T E^i_y - \sin\psi_T E^i_z$$

$$E^i_z = \sin\psi_T E^i_y + \cos\psi_T E^i_z$$

FLOW DIAGRAM

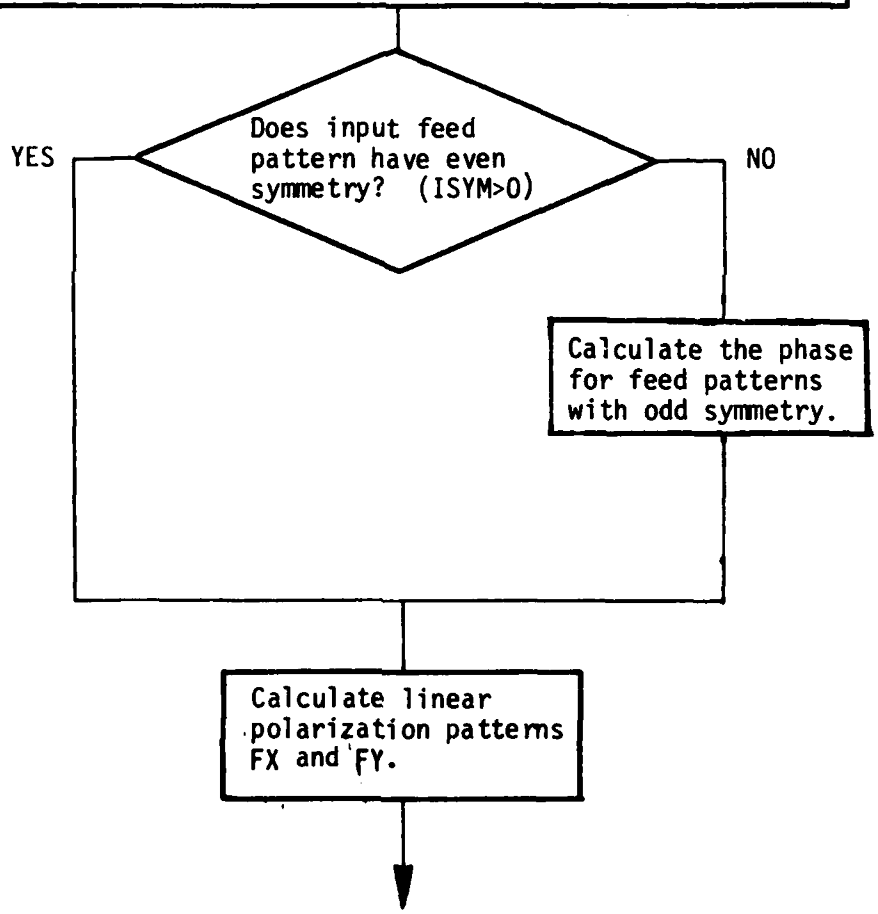
FPOL (EIX,EIY,EIZ,PSA,PHI)

INPUT VARIABLES

PSA	(ψ_α)	Theta coordinate of the observing direction measured from the feed axis.
PHI	(ϕ_γ)	Phi coordinate of the observing direction referred to the tilted feed system.

OUTPUT VARIABLES

EIX, EIY, EIZ	X,Y,Z components of the electric field of the feed referred to the reflector coordinate system.



Calculate spherical and rectangular vector components of the E-field of the feed.

Transform the rectangular components of the E-field from the tilted feed coordinate system to reflector coordinate system.

RETURN

KEY VARIABLES			INPUT/ OUTPUT
CX	(C_x)	Polarization parameter for x-polarized feed.	(I)
CY	(C_y)	Polarization parameter for y-polarized feed.	(I)
EIP	($E^i_{\phi_\gamma}$)	PHI component of the electric field in the feed coordinate system.	
EIT	($E^i_{\theta_\alpha}$)	THETA component of the electric field in the reflector coordinate system.	
FX	(f_x)	x-polarized feed pattern.	
FY	(f_y)	y-polarized feed pattern.	
GF	(g_f)	Feed pattern value calculated by subroutine FEED	(I)
PHASE	(ϕ_s)	Phase of feed pattern	

CODE LISTING

```
      SUBROUTINE FPOL(EIX,EIY,EIZ,PSA,PHI)
      COMPLEX CJ,EIX,EIY,EIZ,EIP,EIT,PHASE,FX,FY,CX,CY
      COMPLEX TEMP
      COMMON /PIS/PI,TPI,DPR
      COMMON /COMP/CX,CY,GF,PHP,PHQ,KX,KY,ISYM,SINT,COST
      COMMON/TEST/LDEBUG,LTEST,NTEST
      LOGICAL LDEBUG,LTEST
      CJ=(Ø.,1.)
      PSI=PSA
      IF (NTEST.GT.Ø) WRITE (6,1) PSI,PHI,SINT,COST
    1 FORMAT (/T1Ø,'DEBUGGING FPOL SUBROUTINE',/T15,4F1Ø.3)
      IF (ABS(PSI-9Ø.).LT.Ø.ØØØ1) PSI=89.9
      PSIR=PSI/DPR
      PHIR=PHI/DPR
      SINS=SIN(PSIR)
      COSS=COS(PSIR)
      SINP=SIN(PHIR)
      COSP=COS(PHIR)
      PHASE=(1.,Ø.)
      IF (ISYM.GE.Ø) GO TO 8
      IF (ISYM+2) 4,2,6
```

```
    2   REL=SINP/ABS(SINP)
        PHASE=REL+CJ*0.
        GO TO 8
    4   REL=COSP/ABS(COSP)
        PHASE=REL+CJ*0.
        GO TO 8
    6   PHASE=CEXP(CJ*PHIR)
    8   FX=CX*PHASE*GF
        FY=CY*PHASE*GF
        EIX=(0.,0.)
        EIY=(0.,0.)
        EIZ=(0.,0.)
        EIT=(0.,0.)
        EIP=(0.,0.)
        IF (KX.EQ.0) GO TO 10
        EIT=-COSP*FX
        EIP=-SINP*FX
   10   IF (KY.EQ.0) GO TO 20
        EIT=EIT-SINP*FY
        EIP=EIP+COSP*FY
   20   CONTINUE
        EIX=-COSP*COSS*EIT-SINP*EIP
        EIY=-SINP*COSS*EIT+COSP*EIP
        EIZ=-SINS*EIT
        IF (SINT.LT.0.01) GO TO 25
        TEMP=COST*EIY-SINT*EIZ
        EIZ=SINT*EIY+COST*EIZ
        EIY=TEMP
   25   CONTINUE
        IF (NTEST.EQ.0) GO TO 40
        WRITE (6,30) PSI,PHI,EIX,EIY,EIZ
   30   FORMAT (/T10,'PSA =',F8.2,5X,'PHGAM =',F8.2,/3(T10,2F10.4,/))
   40   RETURN
        END
```

FUNCTION FRNELS

PURPOSE

To compute the Fresnel integral,

$$f(x_s) = \int_0^{x_s} e^{-j\pi/2\, u^2}\, du = C(x_s) - j\, S(x_s).$$

METHOD

The integral is evaluated using an approximation by J. Boersma[8]. The integral

$$f(x) = \int_0^{x} \frac{e^{-jt}}{\sqrt{2\pi t}}\, dt$$

is approximated as follows:

$$\text{for } 0 \leq x \leq 4 \quad f(x) = \epsilon^{-jx} \sqrt{\frac{x}{4}} \sum_{n=0}^{11} (a_n + jb_n) \left(\frac{x}{4}\right)^n$$

$$\text{for } x \geq 4 \quad f(x) \simeq \frac{1-j}{2} + e^{-jx} \sqrt{\frac{4}{x}} \sum_{n=0}^{11} (c_n + jd_n) \left(\frac{4}{x}\right)^n$$

(the constants a_n, b_n, c_n and d_n are provided by Boresma and are defined in data statements in the subroutine).

Note that by performing a change of variable, the integral to be solved becomes of the form of the integral which Boersma solved;

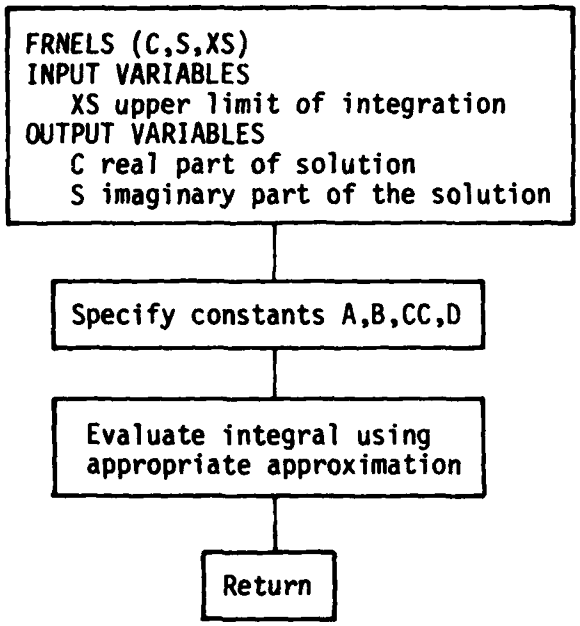
$$t = \frac{\pi}{2}\, u^2.$$

By applying this change of variable, we get

$$f(x_s) = \int_0^{x_s} e^{-j\frac{\pi}{2}u^2}\, du = \int_0^{x} \frac{e^{-jt}}{\sqrt{2\pi t}}\, dt$$

where $x = \frac{\pi}{2} x_s^2$.

FLOW DIAGRAM



KEY VARIABLE

A, B, CC, D	Constants used in evaluating integral
FI	Imaginary component of summation function
FR	Real component of summation function

CODE LISTING

```
      SUBROUTINE FRNELS(C,S,XS)
C!!!
C!!! THIS IS THE FRESNEL INTEGRAL SUBROUTINE WHERE THE INTEGRAL IS FROM
C!!! U=Ø TO XS, THE INTEGRAND IS EXP(-J*PI/2.*U*U),AND THE OUTPUT IS
C!!!  C(XS)-J*S(XS).
C!!!
      LOGICAL LDEBUG,LTEST
      COMMON/TEST/LDEBUG,LTEST,NTEST
      COMMON/PIS/PI,TPI,DPR
      COMMON /OUT/NW
      DIMENSION A(12),B(12),CC(12),D(12)
      DATA A/1.595769140,-Ø.ØØØØØ17Ø2,-6.8Ø8568854,-Ø.ØØØ576361,6.92Ø691
     &9Ø2,-Ø.Ø16898657,-3.Ø5Ø48566Ø,-Ø.Ø75752419,Ø.85Ø663781,-Ø.Ø2563904
     &1,-Ø.15Ø23Ø96Ø,Ø.Ø344Ø4779/
      DATA B/-Ø.ØØØØØØØ33,4.255387524,-Ø.ØØØØ9281Ø,-7.78ØØ2Ø4ØØ,-Ø.ØØ952
     &Ø895,5.Ø75161298,-Ø.138341947,-1.363729124,-Ø.4Ø3349276,Ø.7Ø222201
     &6,-Ø.216195929,Ø.Ø19547Ø31/
      DATA CC/Ø.,-Ø.Ø24933975,Ø.ØØØØØ3936,Ø.ØØ577Ø956,Ø.ØØØ689892,-Ø.ØØ9
     &497136,Ø.Ø11948809,-Ø.ØØ6748873,Ø.ØØØ24642Ø,Ø.ØØ21Ø2967,-Ø.ØØ12179
     &3Ø,Ø.ØØØ233939/
      DATA D/Ø.19947114Ø,Ø.ØØØØØØØ23,-Ø.ØØ9351341,Ø.ØØØØ23ØØ6,Ø.ØØ485146
     &6,Ø.ØØ19Ø3218,-Ø.Ø17122914,Ø.Ø29Ø64Ø67,-Ø.Ø27928955,Ø.Ø164973Ø8,-Ø
     &.ØØ5598515,Ø.ØØØ838386/
      IF(XS.LE.Ø.Ø) GO TO 414
      X=XS
      X = PI*X*X/2.Ø
      FR=Ø.Ø
      FI=Ø.Ø
      K=13
      IF(X-4.Ø) 1Ø,4Ø,4Ø
 1Ø   Y=X/4.Ø
 2Ø   K=K-1
      FR=(FR+A(K))*Y
      FI=(FI+B(K))*Y
      IF(K-2) 3Ø,3Ø,2Ø
 3Ø   FR=FR+A(1)
      FI=FI+B(1)
      C=(FR*COS(X)+FI*SIN(X))*SQRT(Y)
      S=(FR*SIN(X)-FI*COS(X))*SQRT(Y)
      GO TO 1
 4Ø   Y=4.Ø/X
 5Ø   K=K-1
      FR=(FR+CC(K))*Y
      FI=(FI+D(K))*Y
      IF(K-2) 6Ø,6Ø,5Ø
 6Ø   FR=FR+CC(1)
      FI=FI+D(1)
```

```
      C=Ø.5+(FR*COS(X)+FI*SIN(X))*SQRT(Y)
      S=Ø.5+(FR*SIN(X)-FI*COS(X))*SQRT(Y)
      GO TO 1
  414 C=-Ø.Ø
      S=-Ø.Ø
    1 IF (.NOT.LTEST) GO TO 2
      WRITE (NW,3)
    3 FORMAT (/,' TESTING FRNELS SUBROUTINE')
      WRITE (NW,-) C,S,XS
    2 RETURN
      END
```

SUBROUTINE GEOM

PURPOSE

To approximate the reflector rim by straight segments and to calculate the unit vectors for each segment. Also the permissible range for the diffraction angle β_0 for each rim segment is determined.

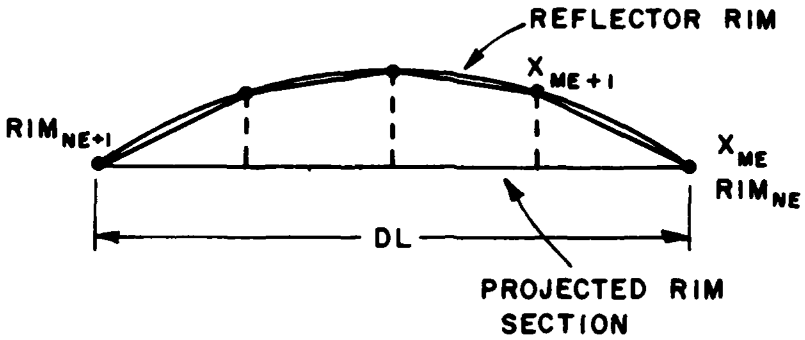


Figure 1. Illustration of subdivision of a reflector rim into straight segments

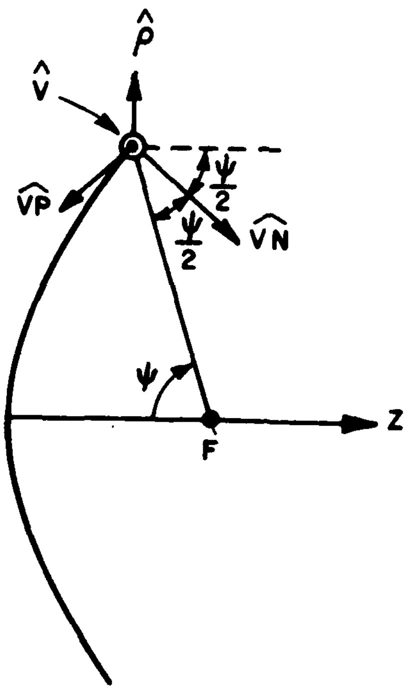


Figure 2. Unit vectors associated with the reflector rim.

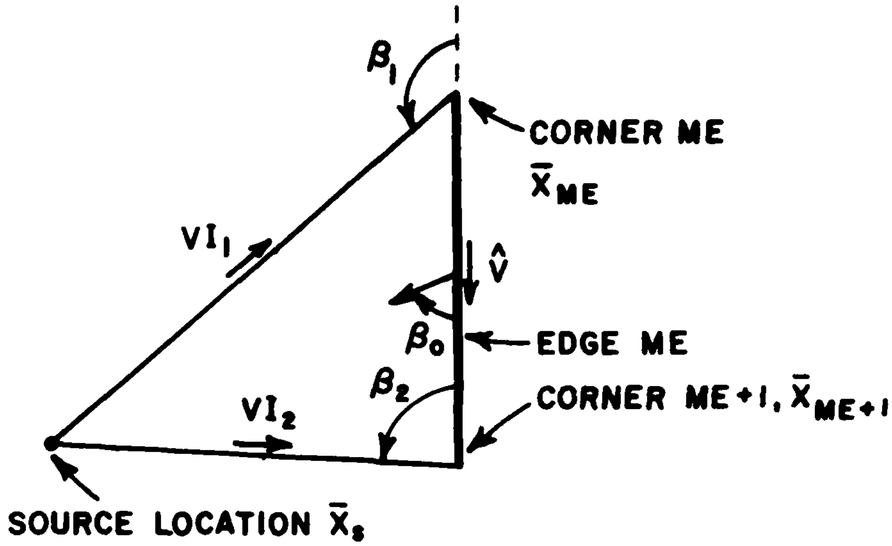


Figure 3. Geometry for determining diffraction angle range.

METHOD

a). Subdividing the reflector rim into straight segments

To ensure the focus of the parabola lies in the far field of the reflector rim, the section of the reflector rim between each pair of input rim points RIM_{NE} and RIM_{NE+1} is subdivided into K straight segments. The integer K is obtained by the formula

$$K = \text{Int}\left(\frac{DL}{RIML} + 1\right)$$

where DL is the length of the projected rim section on the aperture plane and RIML is the approximate length of a straight segment which is defined in the main program.

The coordinates of the new rim points, as shown in Fig. 1, are calculated by

$$X(ME+L,N) = RIM(NE,N) + L \times DEL(N)$$

where

$L=I-1$, $I=1,2,----K$ is the number of segments in rim section NE

DEL(N) is the length of each rim segment and

N=1,2 representing the X and Y components respectively.

The Z coordinate of the rim point ME is given by

$$X(ME,3) = \frac{X(ME,1)^2+X(ME,2)^2}{4F} - Z'$$

where F is the focal distance and Z' is the coordinate of the vertex of the parabolic reflector.

b). *The unit vectors*

The edge unit vectors are found by

$$-\hat{V}_{ME} = \frac{\overline{X}_{ME+1}-\overline{X}_{ME}}{|\overline{X}_{ME+1}-\overline{X}_{ME}|}$$

The unit normals are determined by considering that the normal vector of each rim edge is also normal to the parabolic surface for the limiting case. Since the diffraction point is not determined until all the unit vectors of that edge are found, the normal at the midpoint of an edge is used to approximate that at the diffraction point. Thus, as shown in Fig. 2

$$\hat{VN}_{ME} = -\hat{\rho}\sin\frac{\psi}{2} + \hat{z}\cos\frac{\psi}{2}$$

where

$$\hat{\rho} = \hat{x}\cos\phi + \hat{y}\sin\phi$$

Note that ψ and ϕ are the spherical coordinates of the midpoint with respect to the source point X_S and are given by

$$\psi = \tan^{-1}\frac{\sqrt{VIM_x^2+VIM_y^2}}{(-VIM_z)}$$

and

$$\phi = \tan^{-1}\left(\frac{VIM_y}{VIM_x}\right)$$

where

$$\overline{VIM} = \frac{\overline{X}_{ME+1}+\overline{X}_{ME}}{2} - \overline{X}_S$$

The unit binormals are obtained by

$$\hat{VP}_{ME} = \hat{VN}_{ME} \times \hat{V}_{ME} \quad .$$

c). The permissible range for the diffraction angle.

The law of diffraction dictates that diffraction from a plate edge is possible when

$$\cos\beta_2 \leq \cos\beta_0 \leq \cos\beta_1 \quad ,$$

where β_0 is the angle that the incident and diffracted rays make with the edge (see Fig. 3). β_1 and β_2 are diffraction angle limits and are defined in terms of their cosines as:

$$BD(ME,1) = \cos\beta_1 = \hat{VI}_1 \cdot \hat{V}$$

$$BD(ME,2) = \cos\beta_2 = \hat{VI}_2 \cdot \hat{V} \quad ,$$

where

$$\hat{VI}_1 = \frac{\overline{X}_{ME}-\overline{X}_S}{|\overline{X}_{ME}-\overline{X}_S|}$$

$$\hat{VI}_2 = \frac{\overline{X}_{ME+1}-\overline{X}_S}{|\overline{X}_{ME+1}\ \overline{X}_S|}$$

FLOW DIAGRAM

GEOM(NRIM,RIML,RIM)

INPUT VARIABLES

NRIM	Number of input rim points
RIML	Maximum length of straight rim segments
RIM	Coordinates of input rim points

(a)

Loop through all input rim points RIM
NE=1, NRIM

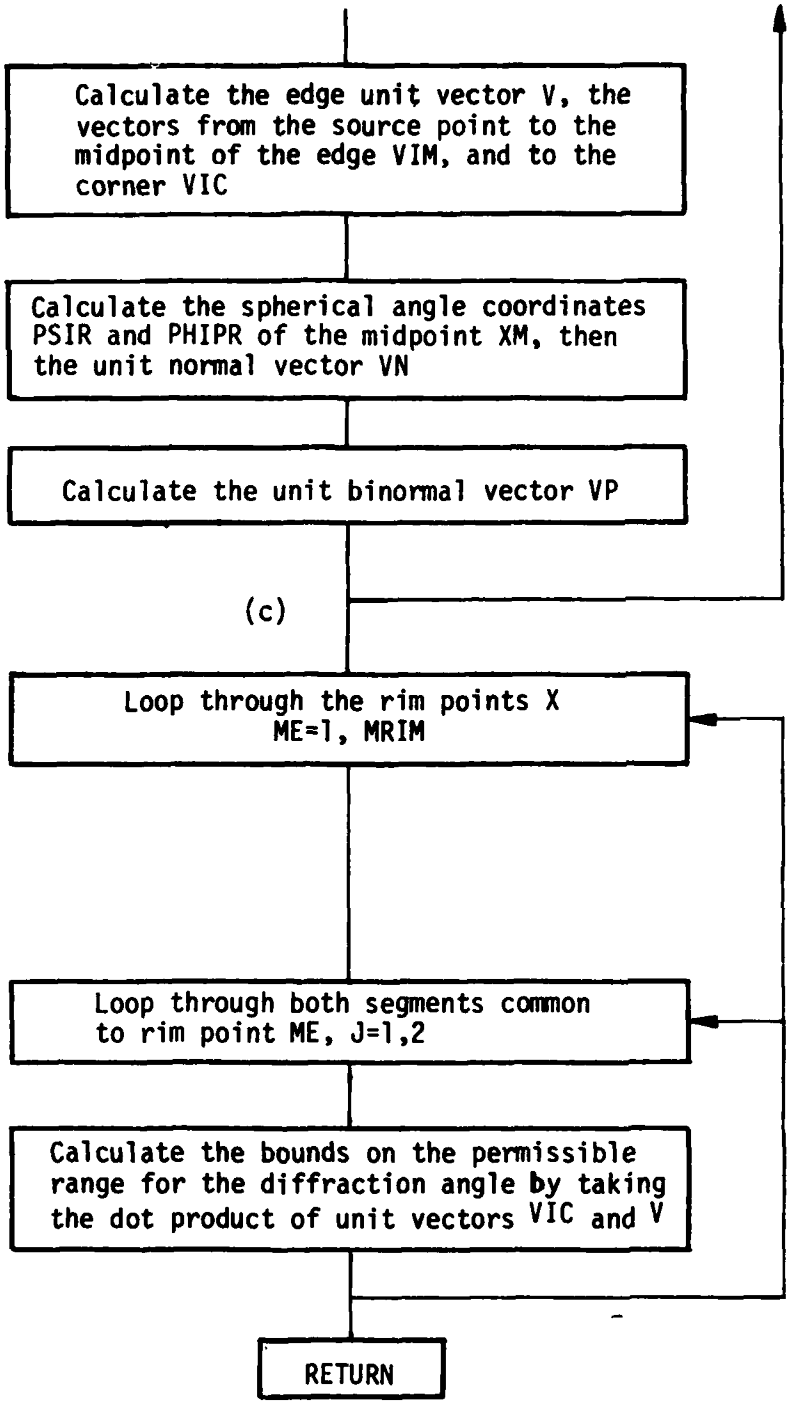
Calculate the projected rim length DL

Determine the number K of segments that the input rim section is to be subdivided

Divide DL into K equal sections and calculate the coordinates X of the new rim points on the reflector surface

(b)

Loop through all rim points X
ME=1, MRIM


Calculate the edge unit vector V, the vectors from the source point to the midpoint of the edge VIM, and to the corner VIC
Calculate the spherical angle coordinates PSIR and PHIPR of the midpoint XM, then the unit normal vector VN
Calculate the unit binormal vector VP
(c)
Loop through the rim points X ME=1, MRIM
Loop through both segments common to rim point ME, J=1,2
Calculate the bounds on the permissible range for the diffraction angle by taking the dot product of unit vectors VIC and V
RETURN

KEY VARIABLES			INPUT/ OUTPUT
BD		Bounds for diffraction angle	(0)
DEL		x and y components of the subdivided segment length	
DL		Projected rim segment	
DSQ		Square of DL	
K		Number of straight segments into which an input rim section is subdivided	
ME		Loop index of subdivided rim points X	
MRIM		Total number of subdivided rim points	
NE		Loop index of input rim points RIM	
NRIM		Number of input rim points	(I)
PHIPR	(ϕ)	PHI coordinate angle of the midpoint XM with respect to the source point in radians	
PSIR	(ψ)	THETA coordinate angle of the midpoint XM with respect to the source point in radians	
RMC		Incident ray path length at the corner	(0)
RMM		Incident ray path length at the midpoint XM of a straight edge	
THNR	$\left(\frac{\psi}{2}\right)$	Half angle of PSIR	
V		X, Y and Z components of the edge unit vector	(0)
VIC		Stored X, Y and Z components of the incident ray vector at the corner for all edges	(0)
VIM		X, Y and Z components of the incident ray vector at the midpoint	
VN		X, Y and Z components of the unit normal vector	(0)
VP		X, Y and Z components of the unit binormal vector	(0)

X	(X_{ME})	Coordinates of the new rim point ME	(O)
XM		Coordinates of the midpoint of edge ME	
ZOP		Z-coordinate of the vertex of the parabolic reflector	(I)

CODE LISTING

```
      SUBROUTINE GEOM(NRIM,RIML,RIM)
C
      DIMENSION RIM(67,2),VI(3),VIM(67,3),RMM(67),DEL(2)
      LOGICAL LDEBUG,LTEST
      COMMON /GEOM1/X(67,3),V(67,3),MRIM
      COMMON /GEOM2/VP(67,3),VN(67,3),BD(67,2),VMAG(67),RMC(67),
     2VIC(67,3),XM(67,3)
      COMMON /FOCAL/F,ZOP
      COMMON /DIM/MDRIM
      COMMON /SORINF/XS(3)
      COMMON /PIS/PI,TPI,DPR
      COMMON /OUT/NW
      COMMON /TEST/LDEBUG,LTEST,NTEST
      IF (LDEBUG) WRITE (NW,2)
    2 FORMAT (/T5,'DEBUGGING SUBROUTINE GEOM',//)
C
C     *** APPROXIMATE THE CURVE EDGES BY LINE SEGMENTS ***
C
      ME=0
      DO 22 NE=1,NRIM
      NEP=NE+1
      IF (NE.EQ.NRIM) NEP=1
      DSQ=0.
      DO 5 N=1,2
      XX=RIM(NEP,N)-RIM(NE,N)
    5 DSQ=DSQ+XX**2
      DL=SQRT(DSQ)
      K=DL/RIML+1
      IF (RIML.LE.0) K=1
      IF (LDEBUG) WRITE (6,8) NE,DL,RIML,K
    8 FORMAT (/T10,4HNE =,I2,5X,4HDL =,2F8.2,5X,3HK =,I2,/)
      DO 10 N=1,2
   10 DEL(N)=(RIM(NEP,N)-RIM(NE,N))/K
      DO 20 I=1,K
      L=I-1
      ME=ME+1
      IF (ME.GT.MDRIM) GO TO 50
      DO 15 N=1,2
   15 X(ME,N)=RIM(NE,N)+L*DEL(N)
      X(ME,3)=(X(ME,1)**2+X(ME,2)**2)/(4.*F)-ZOP
```

```
      IF (LDEBUG) WRITE (6,18) ME,(X(ME,N),N=1,3)
   18 FORMAT (I15,5F10.3)
   20 CONTINUE
   22 CONTINUE
      MRIM=ME
C
C!!!  DETERMINATION OF EDGE UNIT VECTORS
C
      MEX=MRIM
      DO 38 ME=1,MEX
      MME=ME+1
      IF(MME.GT.MEX) MME=1
      VM=0.
      VMM=0.
      VMC=0.
      DO 25 N=1,3
      V(ME,N)=X(MME,N)-X(ME,N)
      XM(ME,N)=(X(MME,N)+X(ME,N))/2.
      VIM(ME,N)=XM(ME,N)-XS(N)
      VIC(ME,N)=X(ME,N)-XS(N)
      VMM=VMM+VIM(ME,N)*VIM(ME,N)
      VMC=VMC+VIC(ME,N)*VIC(ME,N)
   25 VM=VM+V(ME,N)*V(ME,N)
      VMAG(ME)=SQRT(VM)
      RMM(ME)=SQRT(VMM)
      RMC(ME)=SQRT(VMC)
   28 FORMAT (T10,2F12.4)
      IF (LDEBUG) WRITE (NW,30) ME
   30 FORMAT (/T8,4HME =,I2,4X,3HVIM,7X,3HVIC,/)
      DO 32 N=1,3
      VIM(ME,N)=VIM(ME,N)/RMM(ME)
      IF (LDEBUG) WRITE (NW,28) VIM(ME,N),VIC(ME,N)
   32 V(ME,N)=V(ME,N)/VMAG(ME)
C
C     ***** CALCULATE THE NORMAL VECTORS OF THE EDGES ***
C
      PSIR=BTAN2(SQRT(VIM(ME,1)**2+VIM(ME,2)**2),-VIM(ME,3))
      PHIPR=BTAN2(VIM(ME,2),VIM(ME,1))
      PSI=PSIR*DPR
      PHIP=PHIPR*DPR
      SINPP=SIN(PHIPR)
      COSPP=COS(PHIPR)
      THNR=PSIR/2.
      SINR=SIN(THNR)
      COSR=COS(THNR)
      VN(ME,1)=-SINR*COSPP
      VN(ME,2)=-SINR*SINPP
      VN(ME,3)=COSR
      VNM=0.
      DO 34 N=1,3
   34 VNM=VNM+VN(ME,N)*VN(ME,N)
      VNM=SQRT(VNM)
```

```
      DO 35 N=1,3
35    VN(ME,N)=VN(ME,N)/VME
C
C!!!  DETERMINATION OF UNIT VECTOR FOR RAY FIXED COORDINATE SYSTEM
C
      VP(ME,1)=VN(ME,2)*V(ME,3)-VN(ME,3)*V(ME,2)
      VP(ME,2)=VN(ME,3)*V(ME,1)-VN(ME,1)*V(ME,3)
      VP(ME,3)=VN(ME,1)*V(ME,2)-VN(ME,2)*V(ME,1)
      IF (LDEBUG) WRITE(NW,36) (V(ME,N),VN(ME,N),VP(ME,N),
     2N=1,3)
 36   FORMAT (T10,3F12.4)
      IF (LDEBUG) WRITE (NW,37) RMM(ME),RMC(ME)
 37   FORMAT (/T10,5HRMM =,F7.3,5X,5HRMC =,F7.3,/)
38    CONTINUE
C
C!!!  DETERMINATION OF PERMISSABLE RANGE FOR DIFFRACTION ANGLE
C
      DO 45 ME=1,MEX
      VME=0.
      DO 40 N=1,3
      VI(N)=X(ME,N)-XS(N)
40    VME=VME+VI(N)*VI(N)
      RME=SQRT(VME)
      DO 41 J=1,2
      MJ=ME+1-J
      IF(MJ.EQ.0) MJ=MEX
      BD(MJ,J)=0.
      DO 41 N=1,3
  41  BD(MJ,J)=BD(MJ,J)+V(MJ,N)*VI(N)/RME
   45 CONTINUE
      RETURN
   50 MRIM=ME
      RETURN
      END
```

SUBROUTINE GRID

PURPOSE

To set up a rotated coordinate system such that the aperture integration for far field results can be carried out efficiently. This subroutine is also used to set up the principal grid which is used for aperture field calculations and aperture integration for near field results.

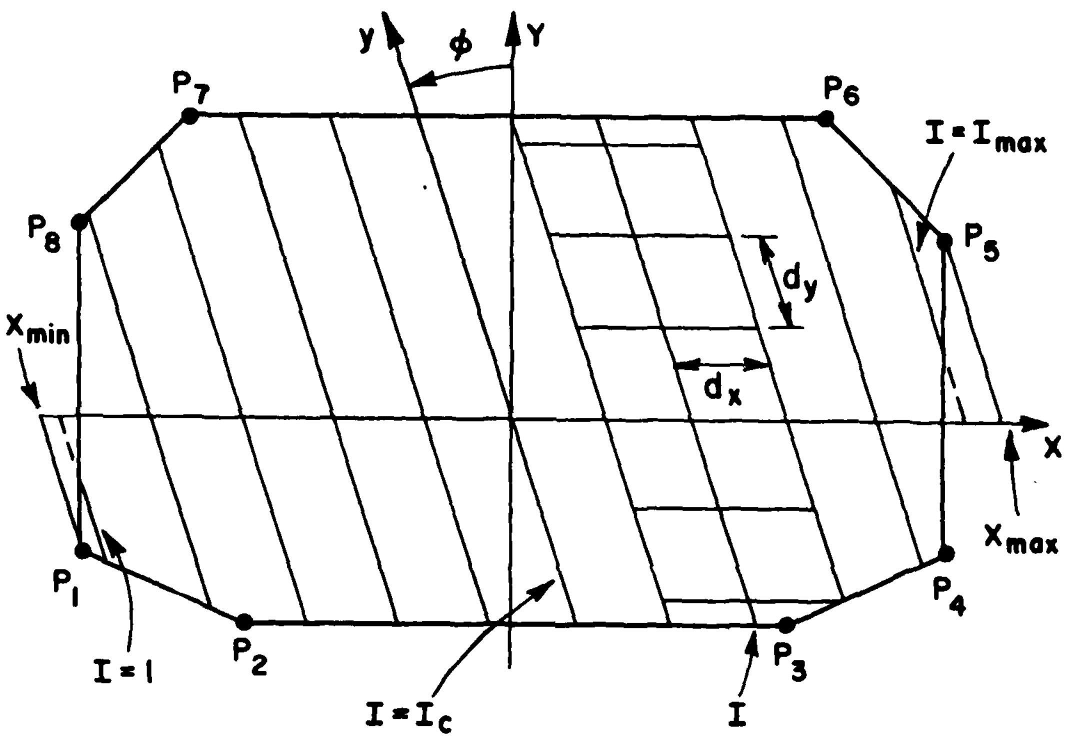


Figure 1. Rotated grid.

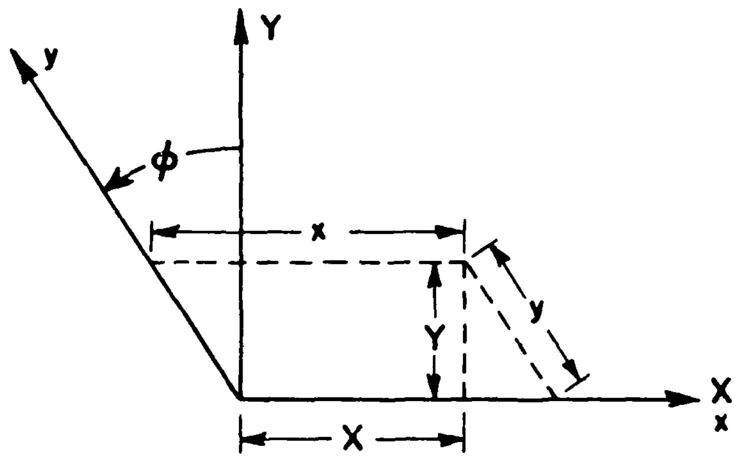


Figure 2. Coordinate transformation from principal rectangular grid to rotated grid.

METHOD

The rotating grid method sets up a nonorthogonal rotating grid as shown in Fig. 1 by rotating the principal Y-axis with ϕ such that the y-integrations are independent of θ. Consequently, the far field pattern in the plane perpendicular to the y-axis is reduced to a one-dimensional integration.

The coordinate transformation from the principal rectangular grid (X,Y) to the rotated grid is shown in Fig. 2 and is given by

$$x = X + Y \tan\phi$$

and

$$y = Y/\cos\phi.$$

The rotated grid sizes are expressed by

$$d_x = D_X$$

$$d_y = D_Y/\cos\phi.$$

Note that the rotated grid size d_y becomes quite large if the rotated angle is close to 90°. This may affect the accuracy of the result. Consequently, the rotated angle is restricted to be not greater than 45°. Thus, for PHI cuts in the interval (45°,135°), the x-axis is effectively rotated instead of the y-axis. This is done indirectly in the code by transforming rim points such that the x- and y-coordinates of the rim points are interchanged and the indices are adjusted to stay in a counterclockwise order. Then the new y-axis is rotated by an angle $90°-\phi$ which is less than 45°. For PHI cuts in the other quadrants, a similar procedure is followed. To implement the interchange, two integer parameters related to the quadrants are used. These parameters are defined as

$$K_{QUAD} = \text{Integ. } (\phi_+ + 45°)/90°$$

and

$$L_{QUAD} = \text{Integ. } K_{QUAD}/2$$

where ϕ_+ is the positive angle expression for ϕ, i.e., $0 \leq \phi_+ < 360°$. Then the interchange parameter, given by

$$CHG = (-1)^{K_{QUAD}}$$

is defined in such a way that a rim point transformation takes place when CHG<0. Note that the rotated grid sizes are also interchanged when CHG<0, i.e.,

$$d_x = D_Y$$

$$d_y = D_X/\cos\phi$$

Values assigned to K_{QUAD} and CHG are shown in Fig. 3.

In order to maintain the correct aperture distribution over the transformed antenna aperture, the array of the aperture fields is transposed at the same time as an interchange of the x- and y-coordinates of the rim points.

Note that the parameter L_{QUAD} is used to correct the sign of the phase path of the x-integration. The phase variable associated with L_{QUAD} is given by

$$PG = kd_x|\cos\phi|(-1)^{L_{QUAD}} \quad .$$

In setting up the rotated grid the coordinates of each rim point P_k are first transformed to rotated grid coordinates (x_k, y_k). Then the reflector rim is separated into upper and lower rim sections by finding the rim points where x is minimum and maximum, respectively. Furthermore, the "vertical" grid lines of the rotated grid system are numbered from I=1 to I_{max} as shown in Fig. 1. The index of the origin (IC) is also calculated for future use in the main program.

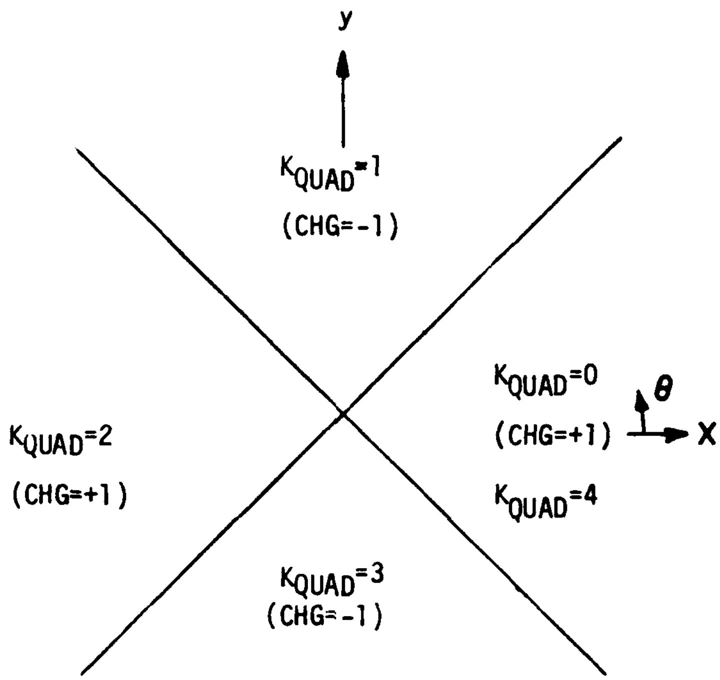


Figure 3. Quadrants for interchange parameters.

FLOW DIAGRAM

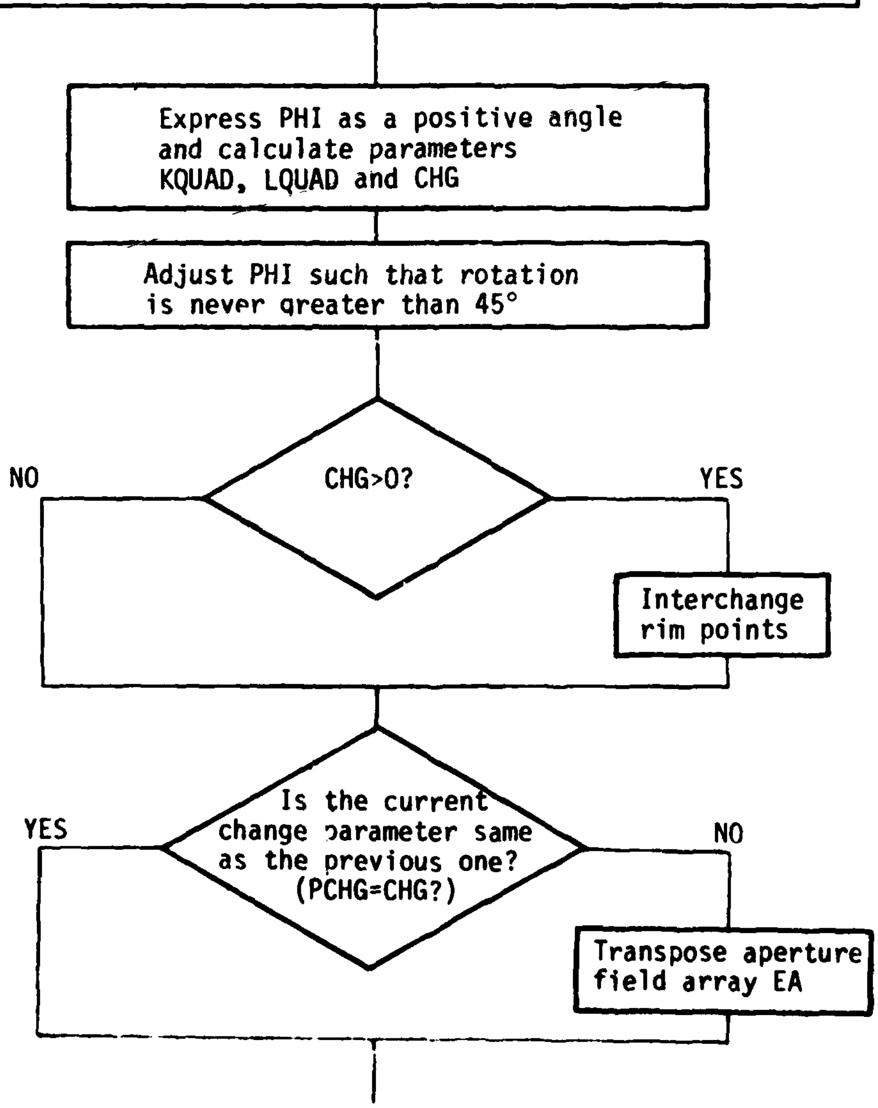
GRID(PHI,IC,IMAX)

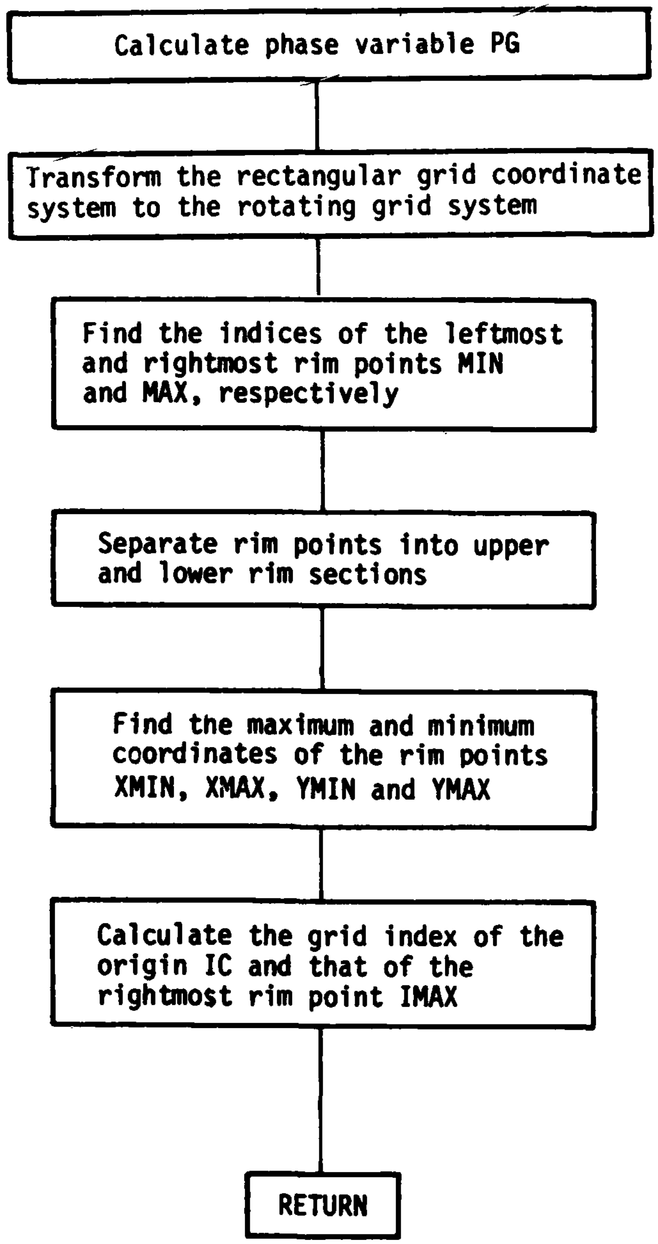
INPUT VARIABLES

PHI	(ϕ)	Rotation angle

OUTPUT VARIABLES

IC	Index of the "vertical" gridline passing through the origin
IMAX	Index of the rightmost "vertical" gridline inside the aperture




Calculate phase variable PG
Transform the rectangular grid coordinate system to the rotating grid system
Find the indices of the leftmost and rightmost rim points MIN and MAX, respectively
Separate rim points into upper and lower rim sections
Find the maximum and minimum coordinates of the rim points XMIN, XMAX, YMIN and YMAX
Calculate the grid index of the origin IC and that of the rightmost rim point IMAX
RETURN

KEY VARIABLES

			INPUT/ OUTPUT
CHG		Interchange parameter	
CLRIM		Coordinates of lower rim points	
CURIM		Coordinates of upper rim points	
EA		Aperture Field Array	(I)
GRDX	(d_x)	Rotated horizontal grid size	(O)
GRDY	(d_y)	Rotated "vertical" grid size	(O)
GRIDX	(D_X)	Principal horizontal grid size	(I)
GRIDY	(D_Y)	Principal vertical grid size	(I)
IC		Grid index of the origin	
IMAX		Maximum grid indes of "vertical" grid lines after rotation	
KQUAD		Integer parameter to determine if an interchange of x- and y-coordinate of rim points is required	
LQUAD		Integer parameter to specify the sign of the phase argument for x-integration	
MAX		Index of the rim point with maximum x-coordinate	
MIN		Index of the rim point with minimum x-coordinate	
NLRIM		Number of lower rim points	
NRIM		Number of input rim points	
NURIM		Number of upper rim points	
PCHG		Previous value of CHG	
PG		Variable used for phase argument	(O)
POS	(ϕ_+)	Positive angle representation for PHI	
RIM		Coordinates of input rim points	(I)
XMAX		Maximum x-coordinate of all rotated rim points	(O)

XMIN	**Minimum x-coordinate of all rotated rim points**	**(0)**
YMAX	**Maximum y-coordinates of all rotated rim points**	**(0)**
YMIN	**Minimum y-coordinates of all rotated rim points**	**(0)**

CODE LISTING

```
      SUBROUTINE GRID(PHI,IC,IMAX)
      DIMENSION RIM(67,2),CP(67,2),CLRIM(67,2),CURIM(67,2),MIN(2),MAX(2
     )
      COMPLEX CJ,DUMMY,EA(2,50,50)
      LOGICAL LDEBUG,LTEST
      COMMON /GRID1/GRIDX,GRIDY,EA
      COMMON /GRID2/CJ,CLRIM,CURIM,RIM,PG,XMIN,XMAX,YMIN,YMAX,
     2NLRIM,NURIM,GRDX,GRDY,ACOSP,TANP,PCHG,MAXO,NRIM
      COMMON /TEST/LDEBUG,LTEST,NTEST
      COMMON /PIS/PI,TPI,DPR
      COMMON /OUT/NW
      DATA DEL/0.01/
      IF (LTEST) WRITE (NW,3)
    3 FORMAT (/T5,'TESTING SUBROUTINE GRID',//)
      DO 1 K=1,NRIM
      CP(K,1)=RIM(K,1)
      CP(K,2)=RIM(K,2)
    1 CONTINUE
      GRDX=GRIDX
      GRDY=GRIDY
      SIGN=1.
      POS=PHI
      IF (PHI.GE.0.) GO TO 2
      SIGN=-1.
      POS=PHI+360.
    2 KQUAD=(POS+45.)/90.
      LQUAD=KQUAD/2
      CHG=(-1.)**KQUAD
      IF (CHG.GT.0.) GO TO 6
      DO 4 K=1,NRIM
      KP=NRIM+1-K
      CP(K,1)=RIM(KP,2)
      CP(K,2)=RIM(KP,1)
    4 CONTINUE
      TEMG=GRDY
      GRDY=GRDX
      GRDX=TEMG
```

```
      IF (PHI.GT.18Ø.) PHI=PHI-36Ø.
      PHI=SIGN*(9Ø.-ABS(PHI))
    6 IF (PCHG*CHG.GT.Ø.) GO TO 12
      MT=MAXO-1
      DO 11 NI=1,2
      DO 1Ø K=1,MT
      IT=K+1
      DO 1Ø JT=1,K
      DUMMY=EA(NI,JT,IT)
      EA(NI,JT,IT)=EA(NI,IT,JT)
      EA(NI,IT,JT)=DUMMY
   1Ø CONTINUE
   11 CONTINUE
   12 PHIR=PHI/DPR
      ACOSP=ABS(COS(PHIR))
      TANP=TAN(PHIR)
      GRDY=GRDY/ACOSP
      PG=2.*PI*ABS(ACOSP)*GRDX*(-1)**LOUAD
      PCHG=CHG
      IF (LTEST) WRITE (NW,18) GRDX,GRDY
   18 FORMAT (T1Ø,7HGRDX = ,F5.2,5X,7HGRDY = ,F5.2,' WAVELENGTHS',
     /)
C
C                       * COORDINATE TRANSFORMATION *
C
      DO 2Ø K=1,NRIM
      CP(K,1)=CP(K,1)+CP(K,2)*TANP
      CP(K,2)=CP(K,2)/ACOSP
   2Ø CONTINUE
      CP(NRIM+1,1)=CP(1,1)
      CP(NRIM+1,2)=CP(1,2)
      CP(NRIM+2,1)=CP(2,1)
      CP(NRIM+2,2)=CP(2,2)
      MX=Ø
      MN=Ø
      IN=1
      ND=NRIM
      IF (CP(2,1).NE.CP(1,1)) GO TO 21
      IN=2
      ND=NRIM+1
   21 DO 25 I=IN,ND
      DX1=CP(I+1,1)-CP(I,1)
      DX2=CP(I+2,1)-CP(I+1,1)
      IF (ABS(DX1).LT.Ø.Ø1.OR.ABS(DX2).LT.Ø.Ø1) GO TO 22
      IF (DX1*DX2.GT.Ø.) GO TO 25
   22 IF (DX1.GT.DX2) GO TO 24
      MN=MN+1
      MIN(MN)=I+1
      GO TO 25
   24 MX=MX+1
      MAX(MX)=I+1
   25 CONTINUE
```

```
C
C                        *FIND UPPER AND LOWER RIM POINT SETS*
C
      IF (MN .EQ. 1) MIN(2)=MIN(1)
      IF (MX .EQ. 1) MAX(2)=MAX(1)
      NLRIM=MAX(1)-MIN(2)+1
      IF (NLRIM .LE. 0) NLRIM=NLRIM+NRIM
      NURIM =MIN(1)-MAX(2)+1
      IF (NURIM .LE. 0) NURIM=NURIM+NRIM
      DO 30 K=1,NLRIM
      I=MIN(2)+K-1
      IF (I .GT. NRIM) I=I-NRIM
      CLRIM(K,1)=CP(I,1)
      CLRIM(K,2)=CP(I,2)
   30 CONTINUE
      DO 32 K=1,NURIM
      I=MIN(1)-K+1
      IF (I .LE. 0) I=I+NRIM
      CURIM(K,1)=CP(I,1)
      CURIM(K,2)=CP(I,2)
   32 CONTINUE
      IF (.NOT.LTEST) GO TO 38
      WRITE (NW,35)
   35 FORMAT (//T10,'LOWER RIM POINT COORDINATES',//)
      WRITE (NW,33) (K,(CLRIM(K,I),I=1,2),K=1,NLRIM)
      WRITE (NW,37)
   37 FORMAT (//T10,'UPPER RIM POINT COORDINATES',//)
      WRITE (NW,33) (K,(CURIM(K,I),I=1,2),K=1,NURIM)
   33 FORMAT (20(T10,I5,2F10.2,/))
   38 CONTINUE
      GRSQ=GRDX*GRDY
      YMIN=CLRIM(1,2)
      YMAX=CURIM(1,2)
      N1=NLRIM-1
      DO 40 K=1,N1
      YLKP=CLRIM(K+1,2)
      YUKP=CURIM(K+1,2)
      IF (YUKP.GT.YMAX) YMAX=YUKP
      IF (YLKP.LT.YMIN) YMIN=YLKP
   40 CONTINUE
      XMIN=CLRIM(1,1)
      XMAX=CLRIM(NLRIM,1)
      FIC=-XMIN/GRDX+DEL
      IC=FIC+1
      IF (FIC.LT.-1.) IC=IC-1
      FI=XMAX/GRDX+DEL
      IMAX=FI+IC
      IF (LTEST) WRITE (NW,50) XMIN,XMAX,YMIN,YMAX
   50 FORMAT (T5,6HXMIN =,F10.3,5X,6HXMAX =,F10.3,/T5,6HYMIN =,
     2F10.3,5X,6HYMAX =,F10.3,/)
      RETURN
      END
```

SUBROUTINE GTD

PURPOSE

To use the Geometrical Theory of Diffraction (GTD) to calculate the edge, corner and slope diffraction fields in the wide angle side-lobe and backlobe regions for the reflector antenna patterns. For near field calculations, GTD is sometimes used for the whole region including the near axis region if the near field points are close to the aperture.

METHOD

This subroutine calculates and sums the diffracted field contribution for each rim segment. If the contribution for a rim segment is expected to be negligible, the subroutine skips to the next rim segment without further calculation. The subroutine uses BDLOW and BDHI for this test as discussed below. To determine if the diffraction from rim segment ME is significant, the cosine of the diffracted cone angle β_0 is calculated by taking the dot product of the edge unit $\hat{V}$ and the diffracted ray unit vector $\hat{d}$, and then is compared with the upper and lower bounds BDHI and BDLOW, respectively, of the diffracted angle. The diffraction contribution from rim segment ME is added only if

$$\text{BDLOW} < \text{DV} < \text{BDHI}$$

where

$$\text{DV} = \hat{d}\cdot\hat{V} = \cos\beta_0$$

$$\text{BDLOW} = \begin{cases} \text{BD(ME,1)} & \text{if edge diffraction only} \\ \text{BD(ME,1)-0.5} & \text{if corner diffraction included} \end{cases}$$

$$\text{BDHI} = \begin{cases} \text{BD(ME,2)} & \text{if edge diffraction only} \\ \text{BD(ME,2)+0.5} & \text{if corner diffraction included} \end{cases}$$

and BD is defined and calculated in subroutine GEOM.

Note that for the near field, the unit vector $\hat{d}$ is approximated for this purpose by taking the midpoint X_M of the edge instead of the diffraction point X_D which is calculated next.

If the contribution from the rim segment is significant, the coordinates of the diffraction point X_D are computed by calling subroutine DFPTWD. The diffracted ray unit vector $\hat{d}$ for near field is recalculated by using the actual diffraction point X_D as

$$\hat{d} = \frac{\bar{X}_N - \bar{X}_D}{|\bar{X}_N - \bar{X}_D|}$$

where X_N is the near field point.

If the diffraction point lies on the rim segment as shown in Fig. 1a (LDIF=true), both edge diffraction and corner diffraction are included and the incident vector $\hat{VI}$ is calculated to the diffraction point X_D. If the diffraction point does not lie on the rim segment as shown in Fig. 1b (LDIF=false), there are only contributions from corner diffraction and the incident vector $\hat{VI}$ is calculated to the nearest corner.

The incident and diffraction angles are calculated by using the orthogonal unit vectors $\hat{V}$, $\hat{VN}$ and $\hat{VP}$ of the rim segment ME. These unit vectors are computed and stored by subroutine GEOM. The incident and diffracted PHI angles* are given by

$$\phi' = \tan^{-1}\left(\frac{-\hat{VI}\cdot\hat{VN}}{-\hat{VI}\cdot\hat{VP}}\right)$$

and

$$\phi = \tan^{-1}\left(\frac{\hat{d}\cdot\hat{VN}}{\hat{d}\cdot\hat{VP}}\right)$$

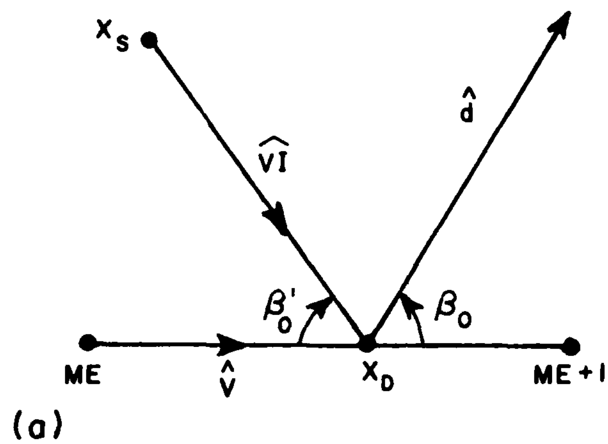
Note that the diffracted field from one rim segment is shadowed by the reflector over a certain range of θ as shown in Fig. 2. The subroutine will skip to the next rim segment if θ falls in this range, i.e., if

$$\phi \geq 0 \text{ and } \theta > \theta_B$$

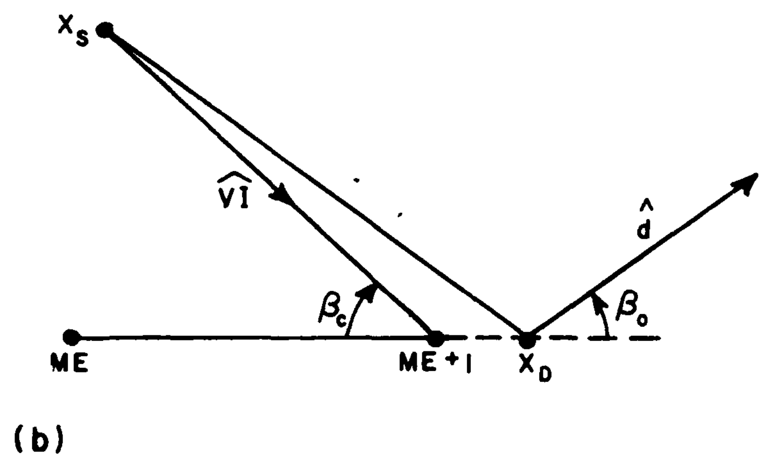
where θ_B is the diffracted shadow boundary angle calculated in subroutine SBDY.

---

*Note that ϕ and ϕ' are used in this section for the wedge diffraction angles as shown in Fig. 3a. They should not be confused with the phi coordinate angles PHI and PHIP which represent the field point and the feed observation directions, respectively.



a) Diffraction point inside the edge (edge diffraction + corner diffraction).



b) Diffraction point outside the edge: (corner diffraction only).

Figure 1. Geometry for edge and corner diffracted fields.

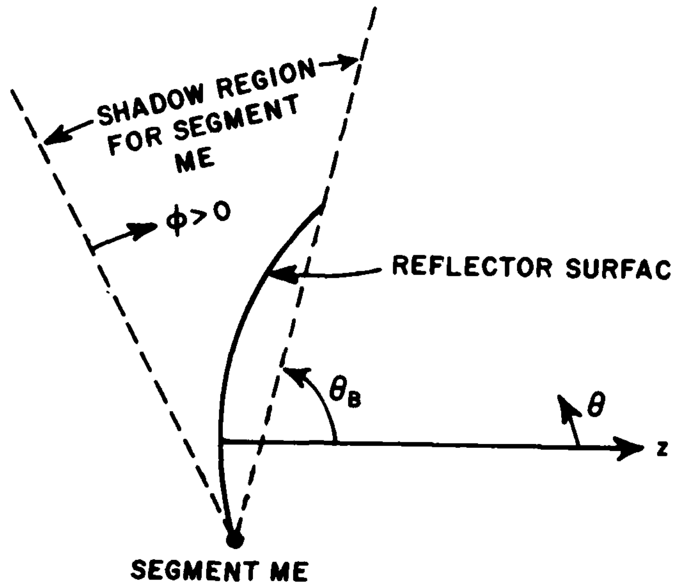


Figure 2. Geometry for diffracted shadow boundary for rim segment ME.

If θ is outside this shadow region, the unit vectors $\hat{\phi}'$, $\hat{\phi}$, $\hat{\beta}_o'$ and $\hat{\beta}_o$ of the ray fixed coordinate system are calculated. These unit vectors are defined by

$$\hat{\phi}' = -\widehat{VP}\sin\phi' + \widehat{VN}\cos\phi'$$

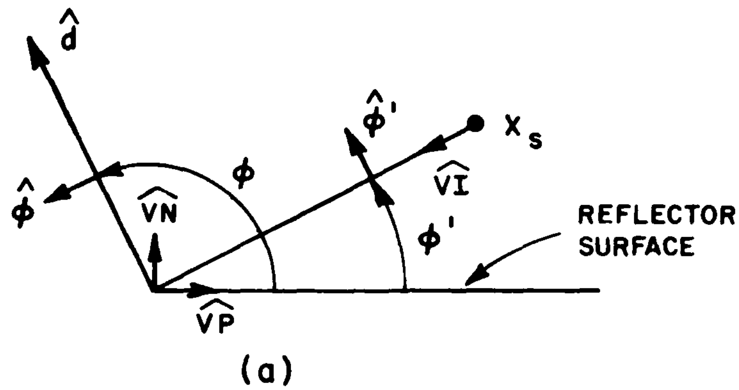
$$\hat{\phi} = -\widehat{VP}\sin\phi + \widehat{VN}\cos\phi$$

$$\hat{\beta}_o' = \hat{\phi}' \times \widehat{VI}$$

and

$$\hat{\beta}_o = \hat{\phi} \times \hat{d}$$

as illustrated in Fig. 3.



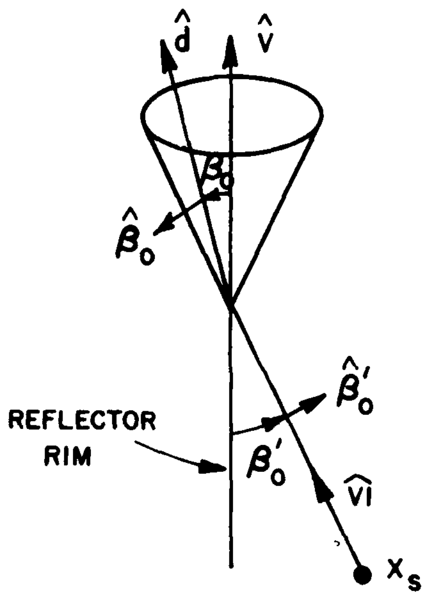


Figure 3a,b. Geometry for three dimensional diffraction of a half plane.

To determine the incident field at the diffraction point X_D, the spherical coordinate angles PSI and PHIP corresponding to the feed pattern direction are calculated. Then the feed pattern value incident on the diffraction point is calculated by calling the subroutine FEED. The rectangular components E_x^i, E_y^i and E_z^i of the feed pattern are then calculated in the subroutine FPOL. These are then transformed to perpendicular and parallel components $E_\perp^i$ and $E_\parallel^i$ in the ray fixed coordinate system.

For slope diffraction the slope of the incident field at the diffraction point X_D is used. The slope of the incident field is calculated from two adjacent values of the feed pattern. The perpendicular and parallel components of the slope of the incident field $\partial E_\perp^i/\partial n$ and $\partial E_\parallel^i/\partial n$ are calculated in the same way as for the incident field by using the subroutine FPOL.

The distance parameters L and the spread factors A(S) of the diffracted fields are given below.

For far field

$$L = S' \sin^2\beta_o$$

and

$$A(S) = \sqrt{S'} \quad .$$

For near field

$$L = \frac{S'S}{S+S'} \sin^2\beta_o$$

and

$$A(S) = \sqrt{\frac{S'}{S(S+S')}}$$

where

$\beta_o = \sin^{-1}|\hat{d}x\hat{V}|$ is the half diffracted cone angle (see Fig. 3b) and

S' and S are the distances from the diffraction point to the source point and the field point respectively.

For corner diffraction as shown in Fig. 4, the spread factor $A_C(S) = \frac{1}{S_S}$ has the form of a spherical wave, since the corner is treated as a point source to radiate the corner diffracted field. The distance parameter is given by

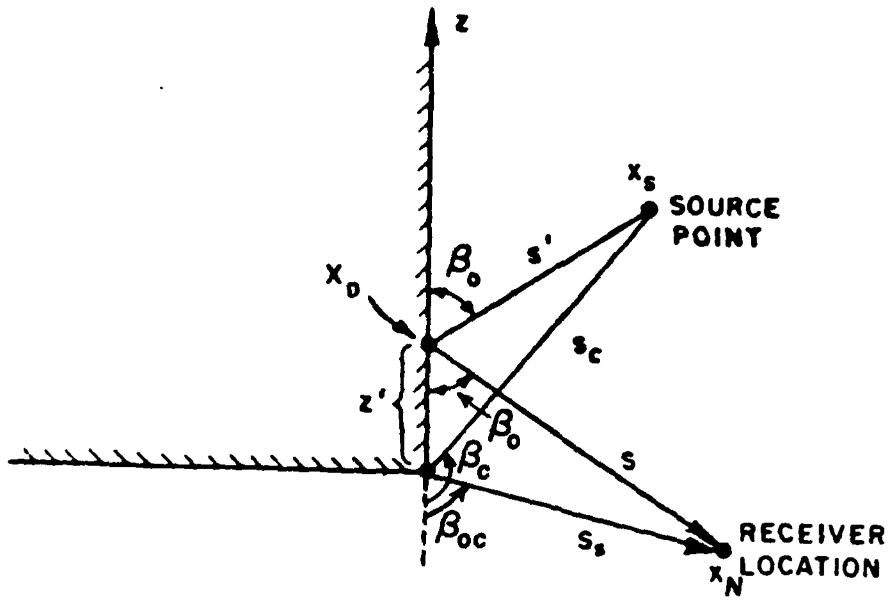


Figure 4. Geometry for corner diffraction problem for near field.

$$L_C = S_C \qquad \text{for far field}$$

$$L_C = \frac{S_C \cdot S_S}{S_C + S_S} \qquad \text{for near field}$$

where S_C and S_S are the distances from the corner to the source point and the field point, respectively.

The corner diffracted field also depends on the corner angles β_C and β_{OC} (see Fig. 4) as defined by

$$\beta_C = \cos^{-1}|\hat{V} \cdot \hat{V}I_C|$$

and

$$\beta_{OC} = \begin{cases} \cos^{-1}|\hat{d} \cdot \hat{V}| & \text{for far field} \\ \cos^{-1}\left|\frac{(\bar{X}_N - \bar{X}_{ME}) \cdot \hat{V}}{S_S}\right| & \text{for near field} \end{cases}$$

where VI_c is the incident ray unit vector at the corner X_{ME}, and is calculated in subroutine GEOM.

Two variables which are used in calculating the corner diffraction coefficients are defined by

$$DEL(I) = k\, L_c\, a(\beta_{oc}+\beta_c)$$

and

$$CORN(I) = -\frac{\sin\beta_c e^{-j\frac{\pi}{4}}}{2\pi(\cos\beta_{oc}+\cos\beta_c)} F|kL_c a(\beta_{oc}+\beta_c)| \sqrt{\frac{S'}{S_c}}\, e^{-jk(S_c-S')} \frac{e^{-jks_s}}{S_s}$$

where I=1,2 representing the first and second corners of the edge ME, respectively.

Next the subroutine DCHP is called to calculate the edge diffraction coefficients D_s, D_h; the slope diffraction coefficients $\partial D_s/\partial\phi$, $\partial D_h/\partial\phi$; the corner diffraction coefficients B_s, B_h and the slope corner diffraction coefficients $\partial B_s/\partial\phi'$, $\partial B_h/\partial\phi'$.

Thus the diffracted field is given by

$$\begin{Bmatrix} E_{\parallel}^{d} \\ E_{\perp}^{d} \end{Bmatrix} = -\begin{Bmatrix} D_s E_{\parallel}^{i} \\ D_h E_{\perp}^{i} \end{Bmatrix} A(S)\, e^{jk\gamma} \quad ,$$

the slope diffracted field by

$$\begin{Bmatrix} E_{\parallel}^{s} \\ E_{\perp}^{s} \end{Bmatrix} = \begin{Bmatrix} \frac{\partial D_s}{\partial\phi'} \frac{\partial E_{\parallel}^{i}}{\partial n} \\ \frac{\partial D_h}{\partial\phi'} \frac{\partial E_{\perp}^{i}}{\partial n} \end{Bmatrix} \frac{A(S)}{C_p}\, e^{jk\gamma} \quad ,$$

the corner diffracted field by

$$\begin{Bmatrix} E_{\parallel}^{c} \\ E_{\perp}^{c} \end{Bmatrix} = - \begin{Bmatrix} B_s E_{\parallel}^{i} \\ B_h E_{\perp}^{i} \end{Bmatrix}$$

and the slope corner diffracted field by

$$\begin{Bmatrix} E_{\parallel}^{sc} \\ \\ E_{\perp}^{sc} \end{Bmatrix} = \begin{Bmatrix} \dfrac{\partial B_s}{\partial \phi'} & \dfrac{\partial E_{\parallel}^{i}}{\partial n} \\ \\ \dfrac{\partial B_h}{\partial \phi'} & \dfrac{\partial E_{\perp}^{i}}{\partial n} \end{Bmatrix} \quad \frac{1}{C_p}$$

where $C_p = jkS'\sin\beta_o$ and γ is the phase factor which refers the contribution from each rim segment to the origin. The total diffracted field for segment ME is summed in terms of perpendicular and parallel components for that segment as expressed by

$$E^D = E^d + E^s + (E^c + E^{sc})_{ME} + (E^c + E^{sc})_{ME+1}$$

The diffracted field from segment ME is then transformed to rectangular components in the reflector coordinate system so that the total diffracted field from the reflector rim can be summed.

For near field calculations, the geometrical optics reflected field must also be included in the total field if the observation point is inside the projected aperture. The reflected field is calculated by using interpolation between the aperture field values at the adjacent grid points (see Fig. 5) as given by

$$E^R = \left[E^a(M,N) \left(1 - \frac{\Delta x}{D_x} - \frac{\Delta y}{D_y} \right) + E^a(M+1,N) \frac{\Delta x}{D_x} + E^a(M,N+1) \frac{\Delta y}{D_y} \right] e^{-jkz}$$

where z is the distance from the observation point to the aperture plane.

If the field point is in the spillover region, the feed spillover field is calculated and added to the total field.

Finally, for far field calculations or for near field calculation with constant range, the total field is converted to principal and cross polarized components as referred to the polarization of the field components from a Huygen's source. For near field calculations with constant z, the field is still expressed in rectangular components.

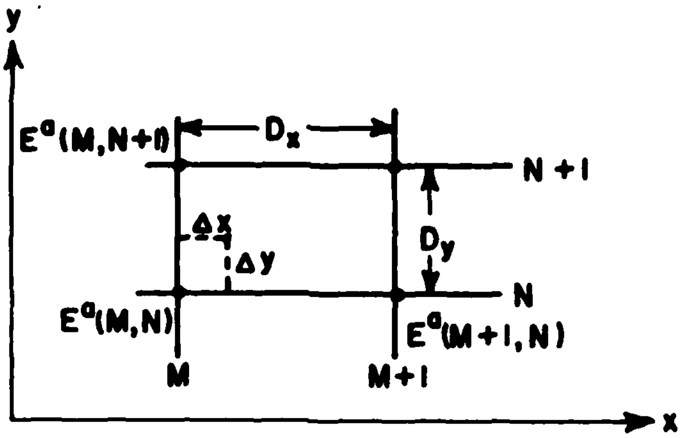
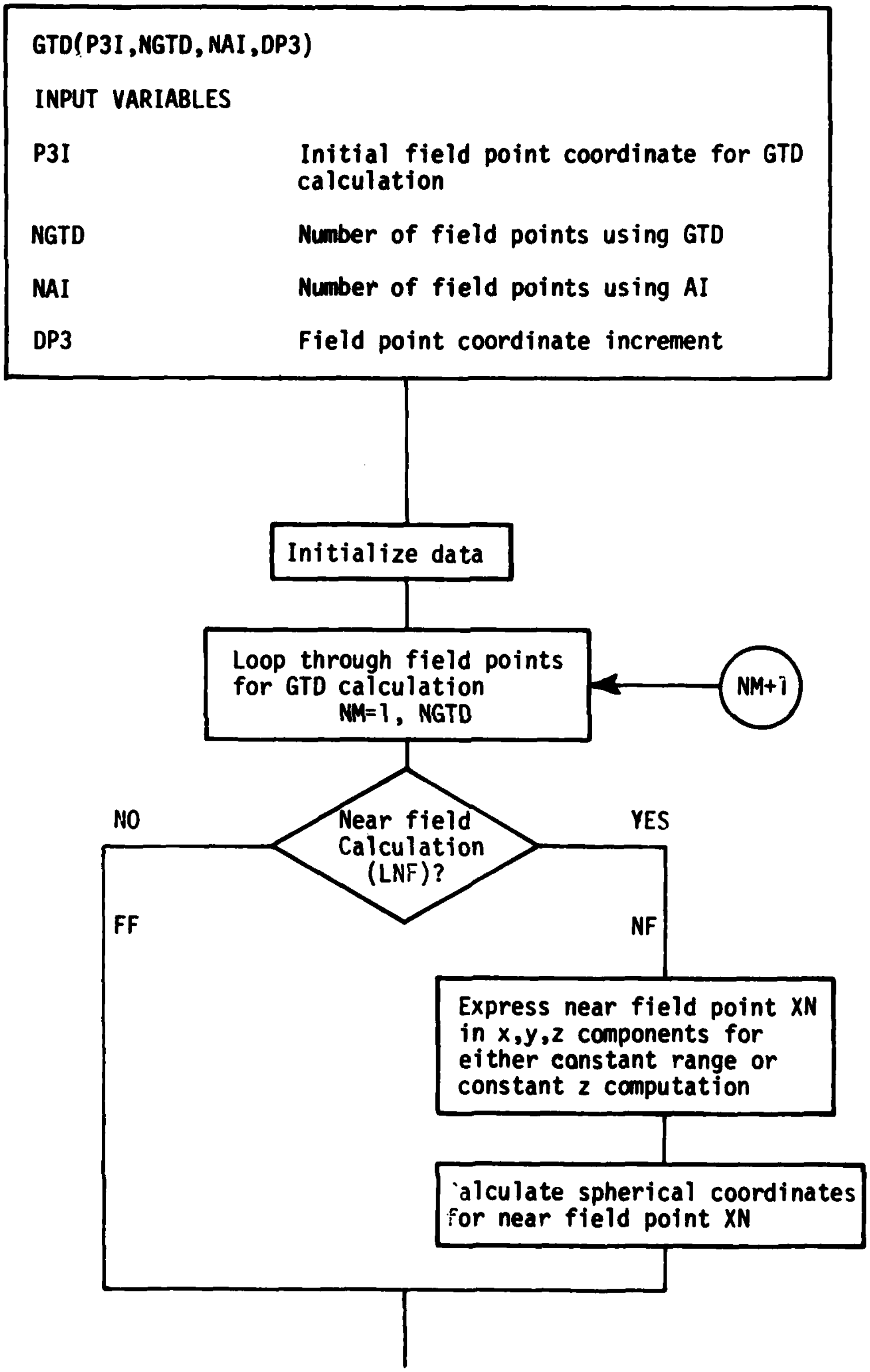
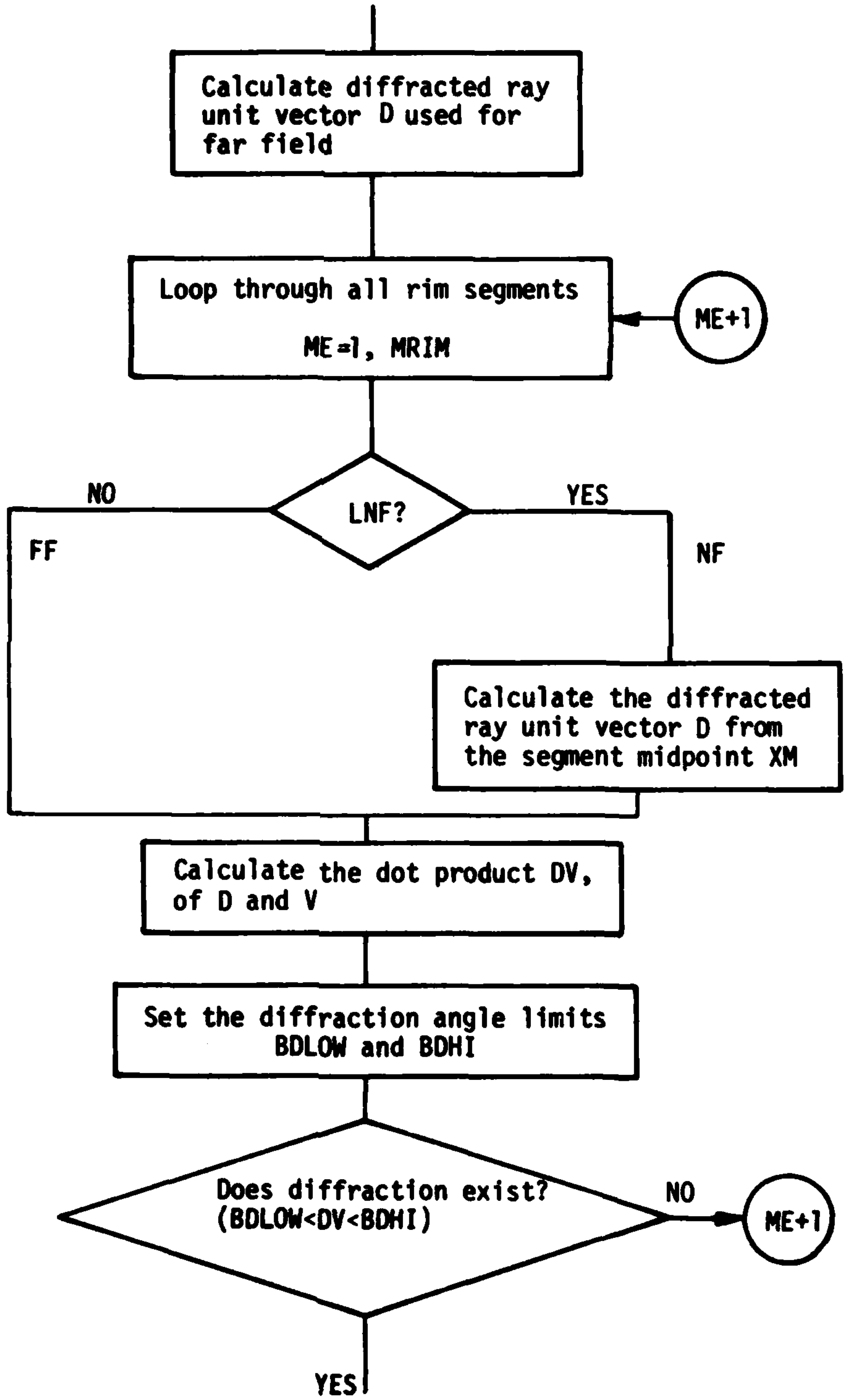
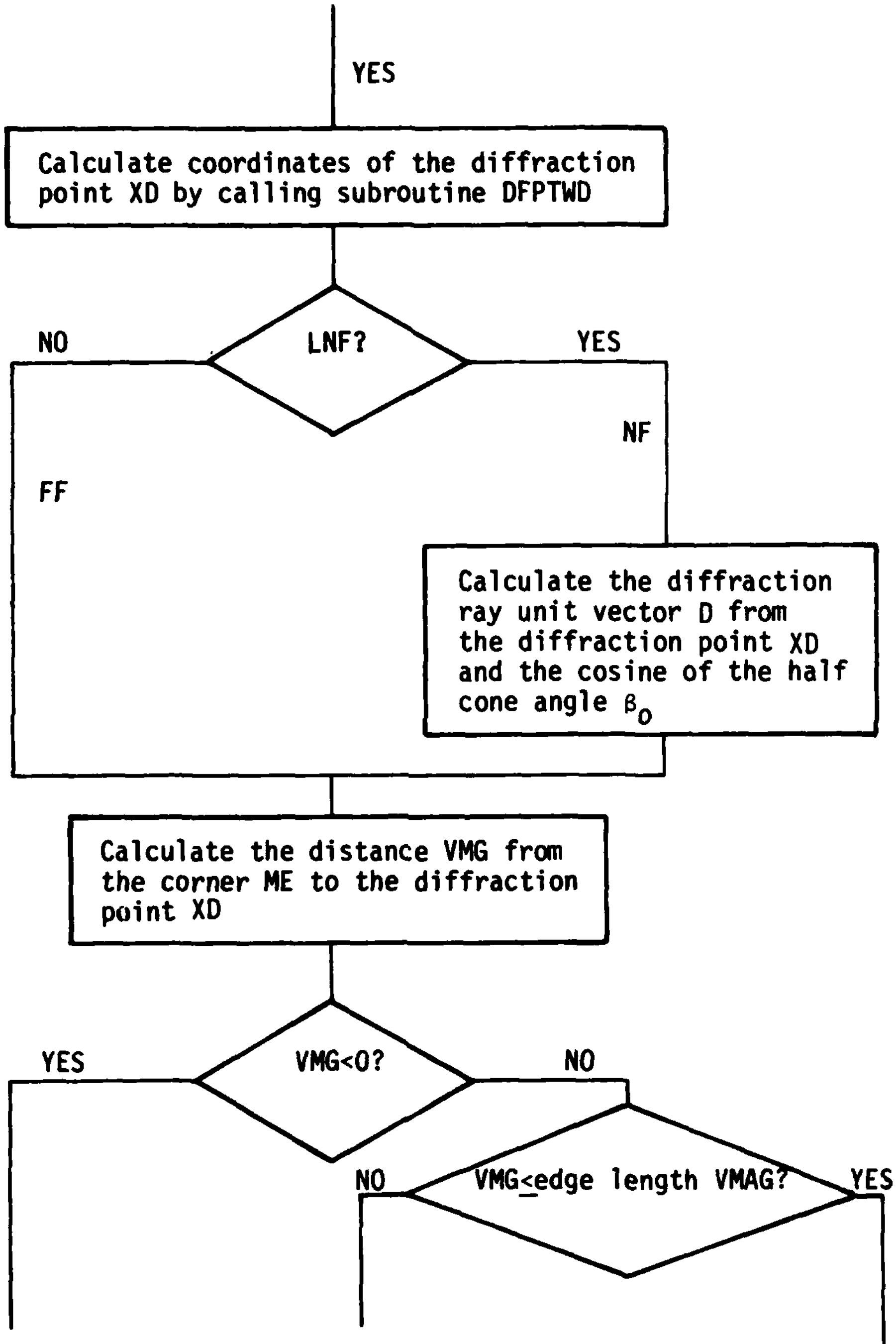


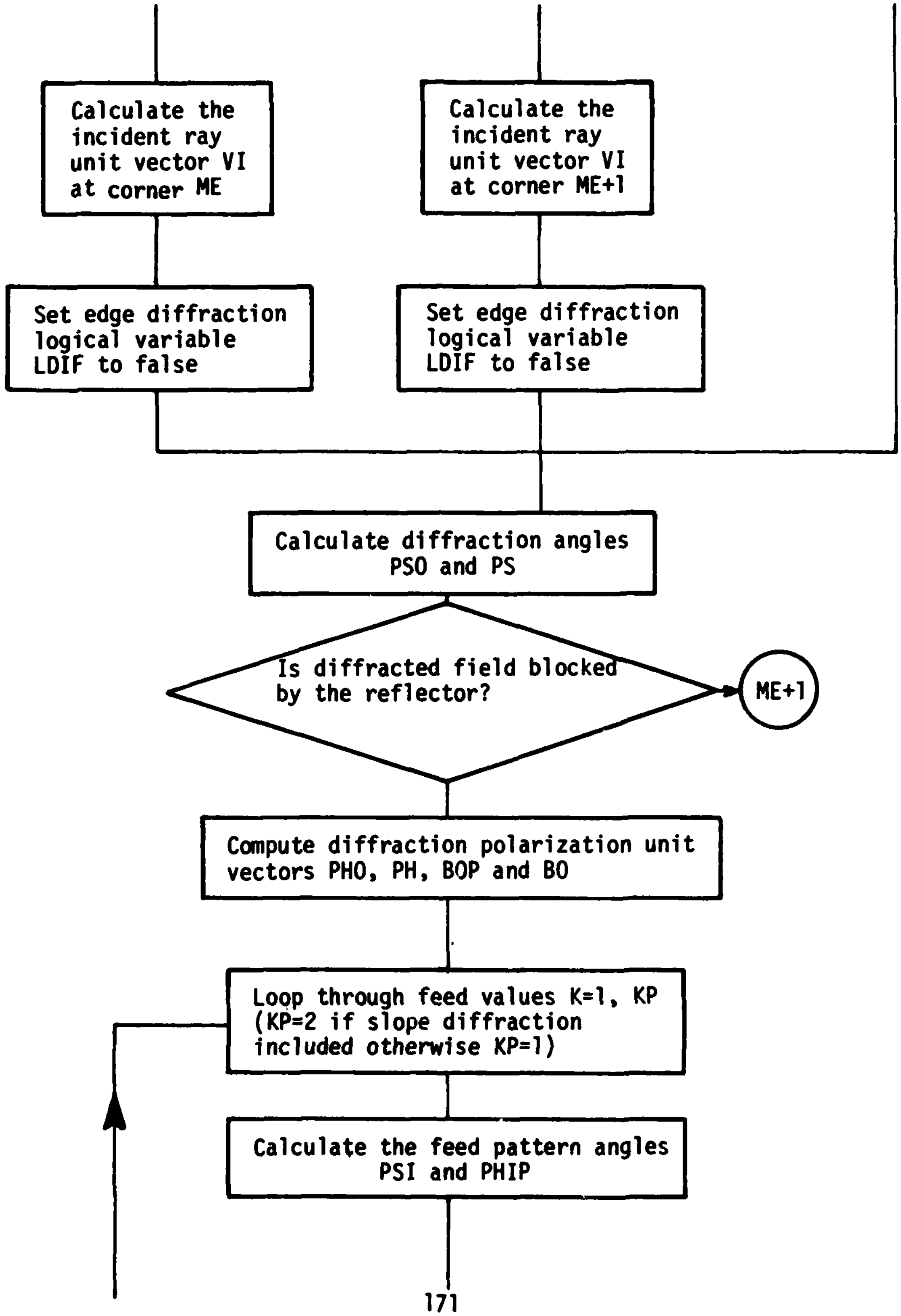
Figure 5. Interpolation of aperture field.

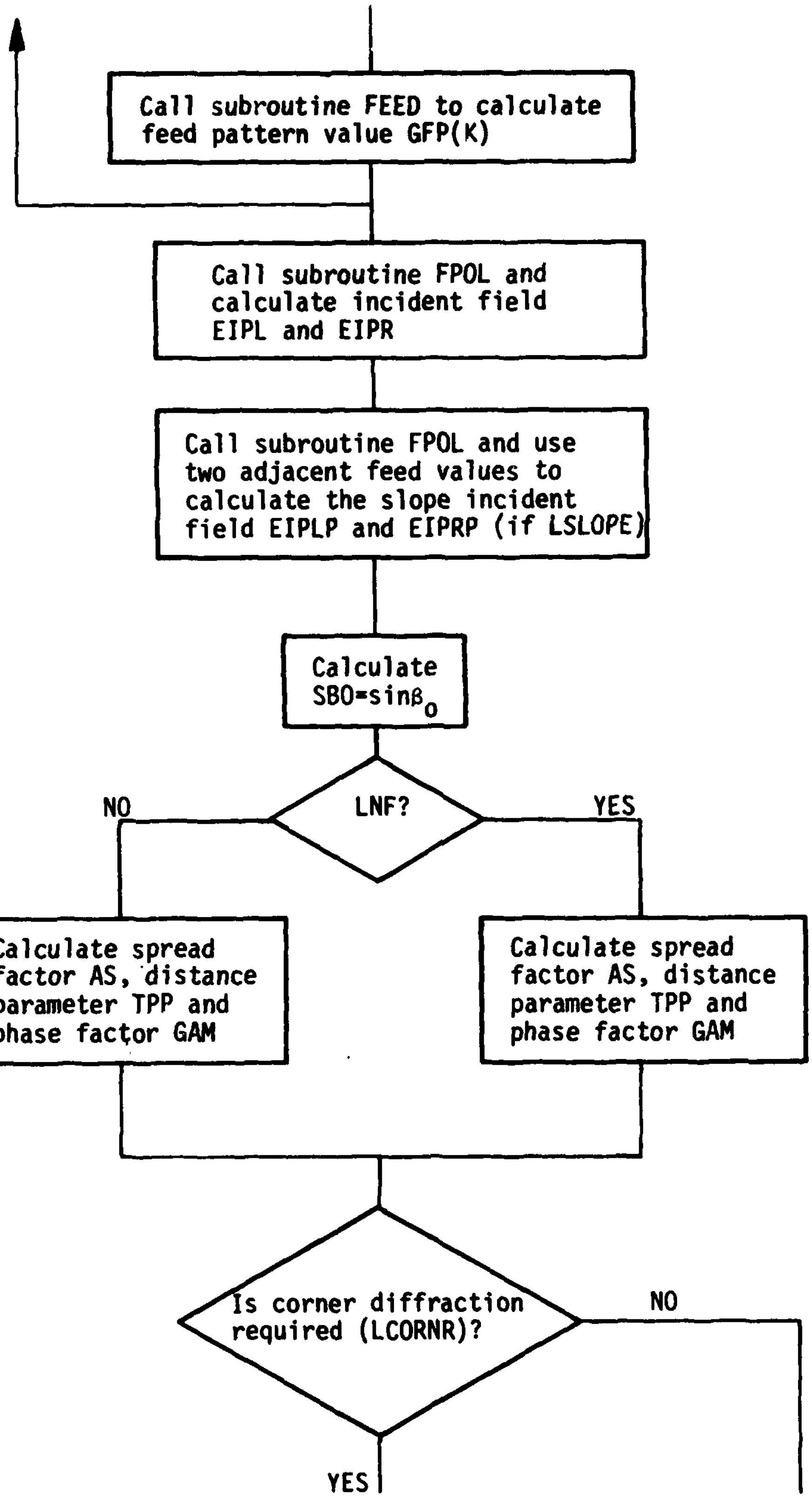
FLOW DIAGRAM

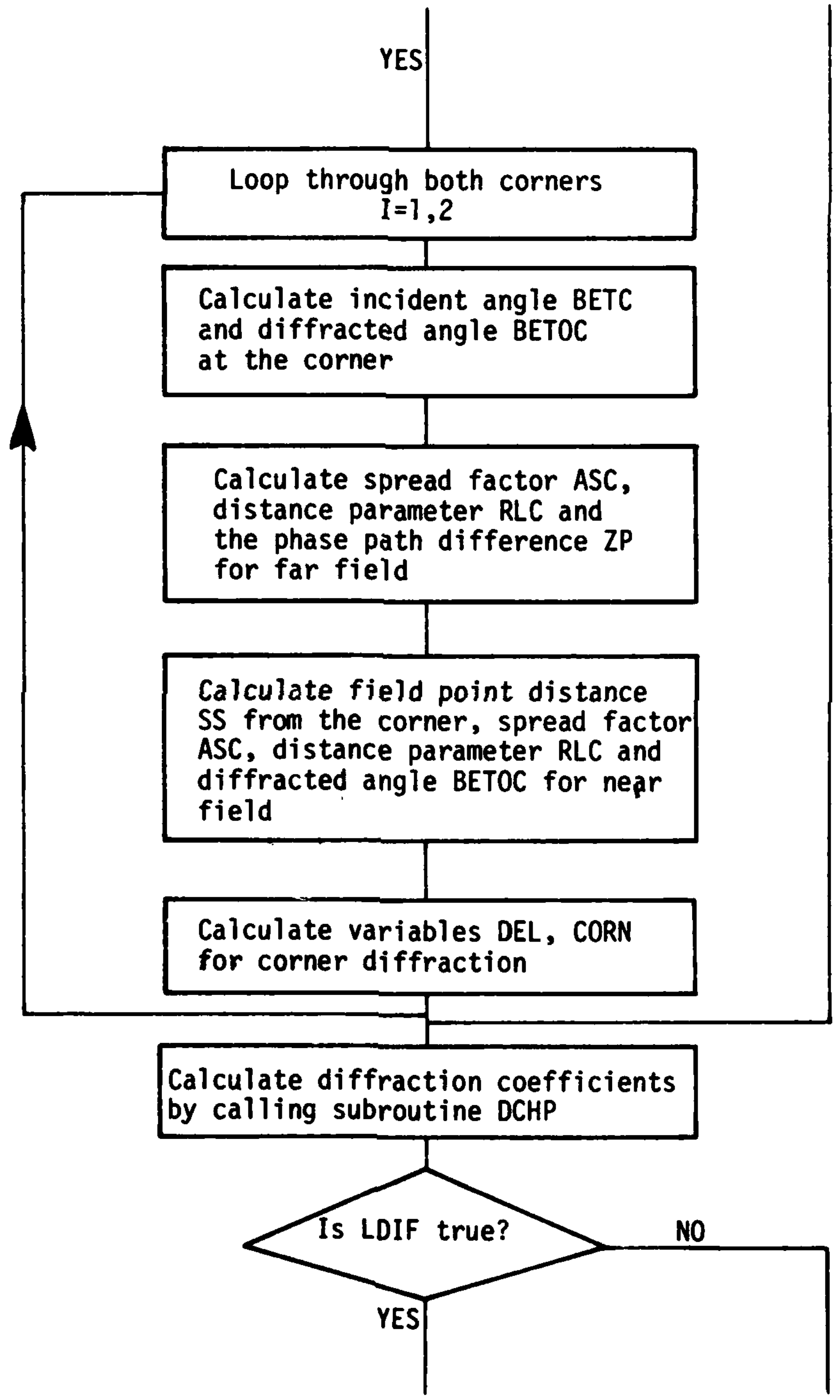


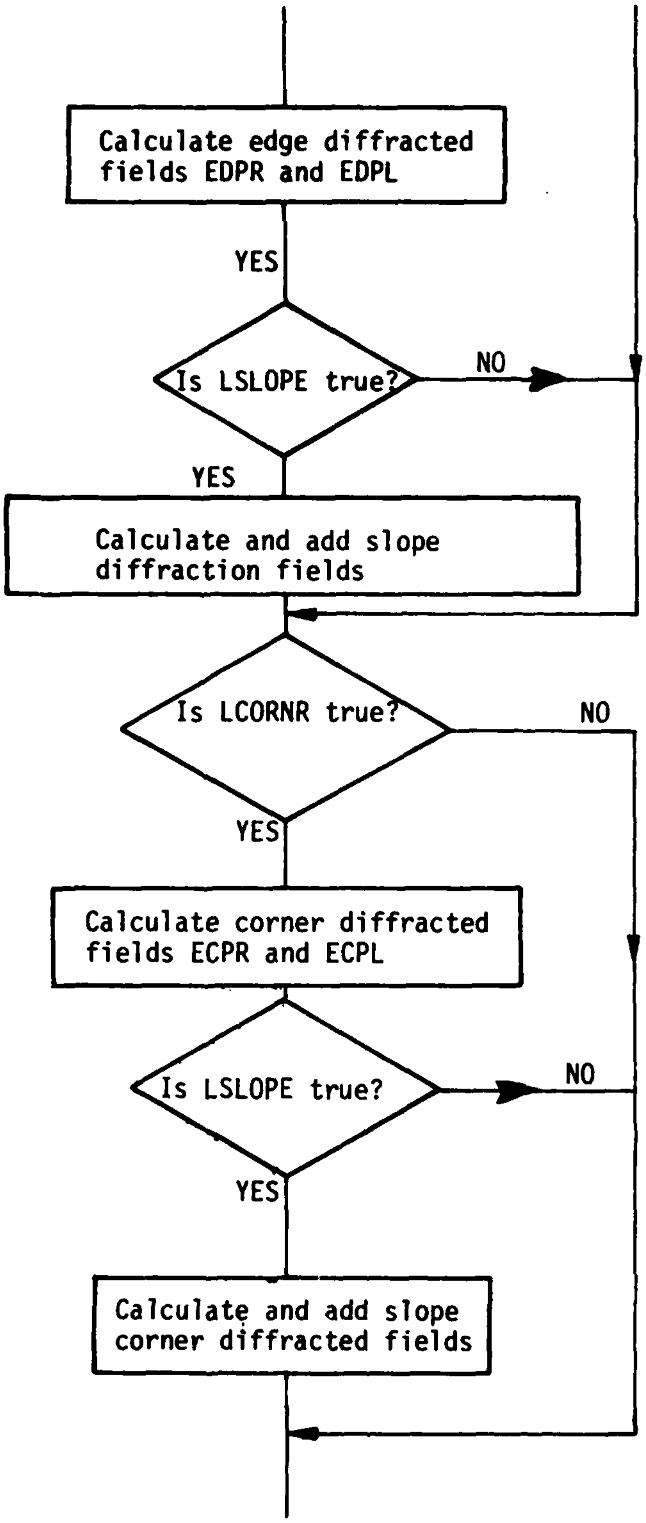

Calculate diffracted ray unit vector D used for far field
Loop through all rim segments
ME=1, MRIM
ME+1
LNF?
NO
YES
FF
NF
Calculate the diffracted ray unit vector D from the segment midpoint XM
Calculate the dot product DV, of D and V
Set the diffraction angle limits BDLOW and BDHI
Does diffraction exist? (BDLOW<DV<BDHI)
NO
ME+1
YES

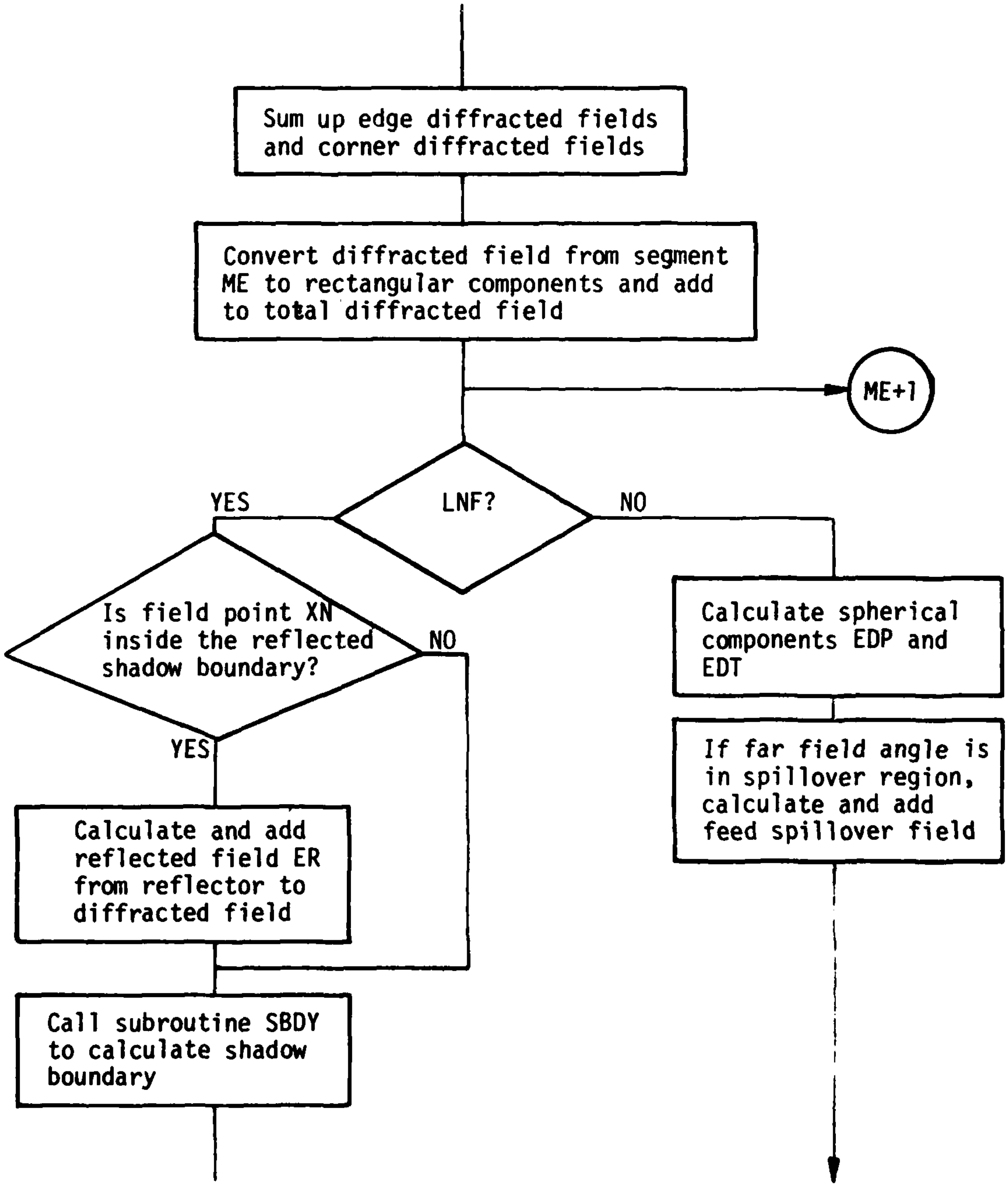

YES
Calculate coordinates of the diffraction point XD by calling subroutine DFPTWD
NO
LNF?
YES
NF
FF
Calculate the diffraction ray unit vector D from the diffraction point XD and the cosine of the half cone angle β_o
Calculate the distance VMG from the corner ME to the diffraction point XD
YES
VMG<0?
NO
NO
VMG≤edge length VMAG?
YES

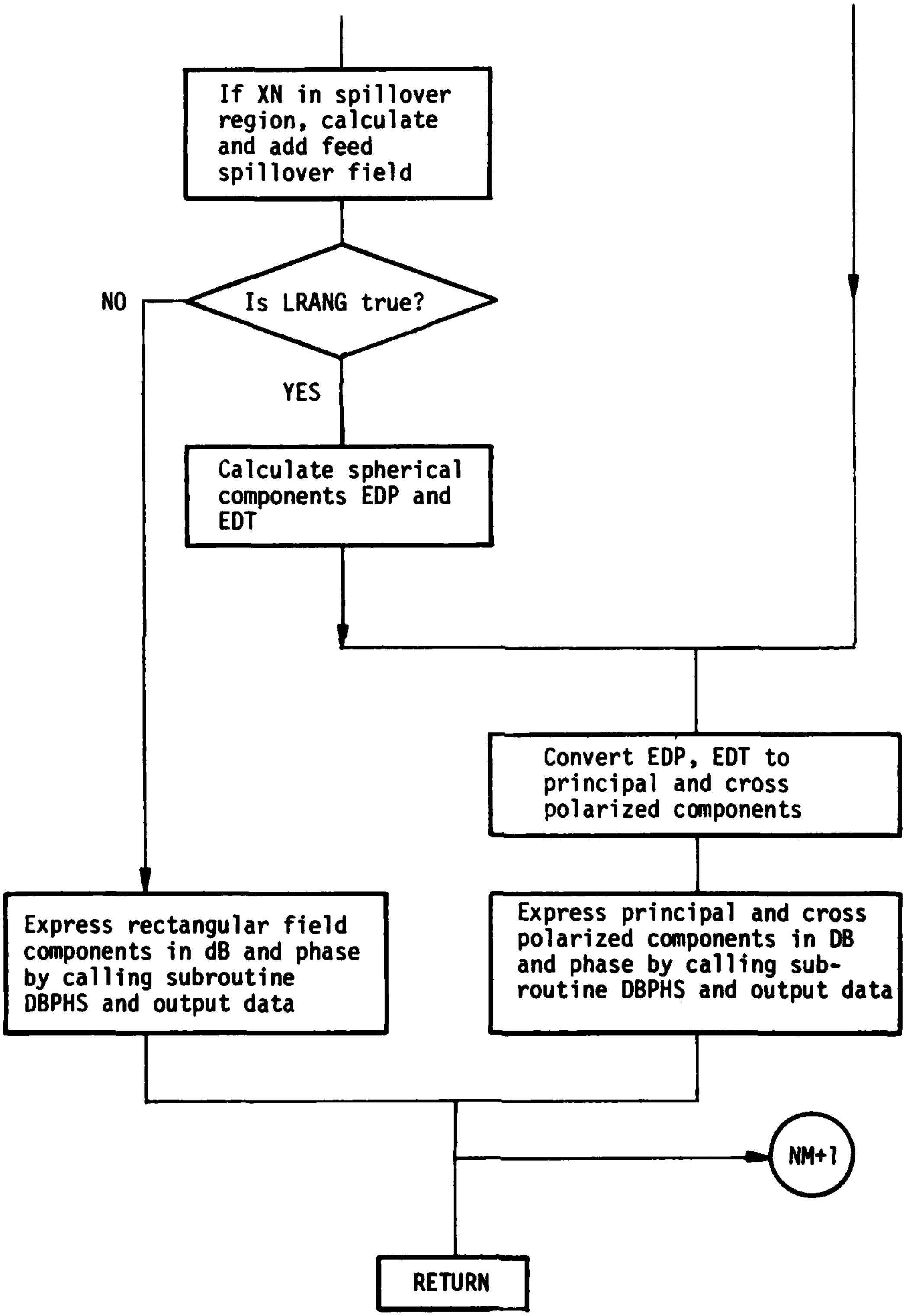

Calculate the incident ray unit vector VI at corner ME
Calculate the incident ray unit vector VI at corner ME+1
Set edge diffraction logical variable LDIF to false
Set edge diffraction logical variable LDIF to false
Calculate diffraction angles PSO and PS
Is diffracted field blocked by the reflector?
ME+1
Compute diffraction polarization unit vectors PHO, PH, BOP and BO
Loop through feed values K=1, KP (KP=2 if slope diffraction included otherwise KP=1)
Calculate the feed pattern angles PSI and PHIP


Call subroutine FEED to calculate feed pattern value GFP(K)
Call subroutine FPOL and calculate incident field EIPL and EIPR
Call subroutine FPOL and use two adjacent feed values to calculate the slope incident field EIPLP and EIPRP (if LSLOPE)
Calculate SBO=sinβo
LNF?
NO
YES
Calculate spread factor AS, distance parameter TPP and phase factor GAM
Calculate spread factor AS, distance parameter TPP and phase factor GAM
Is corner diffraction required (LCORNR)?
NO
YES


YES
Loop through both corners
I=1,2
Calculate incident angle BETC and diffracted angle BETOC at the corner
Calculate spread factor ASC, distance parameter RLC and the phase path difference ZP for far field
Calculate field point distance SS from the corner, spread factor ASC, distance parameter RLC and diffracted angle BETOC for near field
Calculate variables DEL, CORN for corner diffraction
Calculate diffraction coefficients by calling subroutine DCHP
Is LDIF true?
NO
YES


Calculate edge diffracted fields EDPR and EDPL
YES
Is LSLOPE true?
NO
YES
Calculate and add slope diffraction fields
Is LCORNR true?
NO
YES
Calculate corner diffracted fields ECPR and ECPL
Is LSLOPE true?
NO
YES
Calculate and add slope corner diffracted fields


Sum up edge diffracted fields and corner diffracted fields
Convert diffracted field from segment ME to rectangular components and add to total diffracted field
ME+1
LNF?
YES
NO
Is field point XN inside the reflected shadow boundary?
NO
YES
Calculate and add reflected field ER from reflector to diffracted field
Call subroutine SBDY to calculate shadow boundary
Calculate spherical components EDP and EDT
If far field angle is in spillover region, calculate and add feed spillover field


If XN in spillover region, calculate and add feed spillover field
Is LRANG true?
NO
YES
Calculate spherical components EDP and EDT
Convert EDP, EDT to principal and cross polarized components
Express rectangular field components in dB and phase by calling subroutine DBPHS and output data
Express principal and cross polarized components in DB and phase by calling sub-routine DBPHS and output data
NM+1
RETURN

KEY VARIABLES			INPUT/ OUTPUT
AS	$(A(S))$	Spread factor for diffracted field	
ASC	$(A_c(S))$	Spread factor for corner diffracted field	
BD		Bounds of the permissible range for diffraction angle	(I)
BDEL		Adjustment to the bounds for corner diffraction	
BDHI		Upper bound for diffraction angle after adjusted	
BDLOW		Lower bound for diffraction angle after adjusted	
BETC	(β_c)	Incident angle at the corner	
BETOC	(β_{oc})	Diffraction angle at the corner	
BO	$(\hat{\beta}_o)$	Rectangular components of the unit vector in the direction of increasing diffraction cone angle β_o	
BOP	$(\hat{\beta}_o')$	Rectangular components of the unit vector in the direction of increasing incident angle β_o'	
CBOC	$(\cos\beta_c)$	Cosine of angle BETC	
CORN		Variable used for calculating the corner diffraction coefficients	
CP	(C_p)	Variable used for slope diffraction	
CPH	$(\cos\phi)$	Cosine of diffraction angle PS	
CPHO	$(\cos\phi')$	Cosine of incident angle PSO	
D	$(\hat{d})$	Rectangular components of the unit diffracted ray vector	
DEL		Variables used for corner diffraction	
DLVI		Increment of the incident ray vector VI along the normal vector VN	
DMAG		Diffracted ray path length for near field	

DV		Dot product of the unit vectors D and V	
EA	(E^a)	x and y components of the aperture fields	(I)
ECPL	($E^c_\parallel$)	Parallel component of the corner diffracted field	
ECPR	($E^c_\perp$)	Perpendicular component of the corner diffracted field	
ED		Rectangular components of the total diffracted field from the segment ME.	
EDP		PHI component of the total diffracted field from all the segments. Also used for cross polarization component	(0)
EDPL	($E^d_\parallel$)	Parallel component of the diffracted field	
EDPR	($E^d_\perp$)	Perpendicular component of the diffracted field	
EDT		Theta component of the total diffracted field from all the segments. Also used for principal polarization component	(0)
EDX		x component of the total diffracted field	(0)
EDY		y component of the total diffracted field	(0)
EDZ		z component of the total diffracted field	(0)
ERX		x component of the reflected field	
ERY		y component of the reflected field	
EXPH		Phase term associated with the diffracted field	
GAM	(γ)	Phase factor for diffracted field	
GF	(g_f)	Feed pattern value calculated in subroutine FEED	(I)
GFP		Feed pattern values used for incident field and its slope	
KP		Loop index for calculating the incident feed value and its slope	

LCORNR		Logical variable for corner diffraction	(I)
LDIF		Logical variable for edge diffraction	(I)
LNF		Logical variable for near field calculation	(I)
LRANG		Logical variable for constant range field calculation	(I)
LSLOPE		Logical variable for slope diffraction	(I)
P2,P3		Field point coordinates (see User's Manual)	(I)
PH	$(\hat{\phi})$	Rectangular components of the unit vector of the direction of increasing diffraction angle PS	
PHEI		Phase term associated with the feed spillover field	
PHGAM	(ϕ_γ)	PHI coordinate of the field point referred to the tilted feed system	
PHI		PHI coordinate of the field point	
PHIP		PHI coordinate of the feed observation direction as referred to the source XS	
PHO	$(\hat{\phi}')$	Rectangular components of the unit vector in the direction of increasing incident PHI angle PSO	
PS	(ϕ)	Wedge diffraction angle (see Fig. 3a)	
PSA	(ψ_α)	Theta coordinate of the observation direction measured from the feed axis	
PSI	(ψ)	Theta coordinate of the feed observation direction measured from the negative z-axis of the reflector	
PSO	(ϕ')	Incidence angle for wedge diffraction (see Fig. 3a)	
RHON	(ρ)	Radial coordinate of the near field point XN	
RHOS		Radii to the reflected shadow boundaries calculated in subroutine SBDY	(I)
RLC	(L_c)	Distance parameter for corner diffraction	

RR	(R)	Range to the field point from the origin	
S	(s)	Distance from the diffraction point XD to the near field point XN	
SBO	$(\sin\beta_o)$	Sine of the diffracted cone half angle	
SC	(s_c)	Incident ray path length to the corner	
SP	(s')	Incident ray path length to the diffraction point XD	
SPH	$(\sin\phi)$	Sine of diffraction angle PS	
SPHO	$(\sin\phi')$	Sine of incident angle PSO	
SS	(s_s)	Diffracted ray path length from the corner to the near field point	
TERM		Temporary variable for corner diffraction	
THEB	(θ_B)	Theta coordinate of diffraction shadow boundary to opposite side of reflector rim	(I)
THETA	(θ)	Theta coordinate of the field point	
TPP	(L)	Distance parameter for edge diffraction	
V	$(\hat{V})$	Rectangular components of the edge unit vector of segment ME	(I)
VI	$(\hat{VI})$	Rectangular components of the incident ray unit vector to the diffraction point	
VIC	$(\hat{VI}_c)$	Rectangular components of the incident ray unit vector to the corner	(I)
VMAG		Segment length	
VMG		Distance from the first corner to the diffraction point XD	
VN	$(\hat{VN})$	Rectangular components of the unit normal vector of the segment ME	(I)
VP	$(\hat{VP})$	Rectangular components of the unit binormal vector of the segment ME	(I)
XI		X component of the direct incident ray path for near field	

X2 — Y component of the direct incident ray path for near field

X3 — Z component of the direct incident ray path for near field

XD — Rectangular coordinates of the diffraction point

XN — Rectangular components of the near field point coordinates

XOO — Origin of the near field plane cut (I)

CODE LISTING

```
      SUBROUTINE GTD(P3I,NGTD,NTHE,DP3)
C!!!
C!!!  DETERMINES THE DIFFRACTED FIELD,WITH PHASE REFERRED TO ORIGI
     N.
C!!!  FIELD DIFF. FROM EDGE #ME
C!!!  CORNER DIFF. IS OPTIONAL FROM INPUT DATA.
C!!!
      COMPLEX EA(2,50,50),ERX,ERY,PHER,RFCT
      COMPLEX CJ,DS,DH,DPS,DPH,BS,BH,BPS,BPH
      COMPLEX EF,EG,EDPR,EDPL,ED(3),IMT,EDX,EDY,EDZ,EDT,EDP
      COMPLEX EIPRP,EIPLP,EIX,EIY,EIZ,EIT,EIP,CORN(2),FFCT
      COMPLEX EIPL,EIPR,ECPL,ECPR,EXPH,CP,CX,CY,PHEI
      DIMENSION RHOS(2),GFP(2),DEL(2)
      DIMENSION VI(3),XN(3),XD(3),PHO(3),PH(3),ROP(3),RO(3),VIP(3)
      LOGICAL LSLOPE,LCORNR,LDIF,LDEBUG,LTEST,LNF,LRANG
      LOGICAL LFEED,LOUT,LCP,LWRITE
      COMMON /GEOM1/X(67,3),V(67,3),MRIM
      COMMON /GEOM2/VP(67,3),VN(67,3),BD(67,2),VMAG(67),RMC(67),
     2VIC(67,3),XM(67,3)
      COMMON / FBDY/RHOS
      COMMON /FOCAL/F,ZOP
      COMMON /SORINF/XS(3)
      COMMON /BDY2/TH1,TH2,THEB
      COMMON /DIR/D(3),EIX,EIY,EIZ
      COMMON /NF/RFCT,XOO(3),PHIF,P2,RR
      COMMON /GTDD/LFEED,LOUT,LCP,LWRITE,COSPT,SINPT,REFDF,TEMP
      COMMON /DSC/DS,DH,DPS,DPH,BS,BH,BPS,BPH
      COMMON /COMP/CX,CY,GF,PHP,PHO,KX,KY,ISYM,SINTL,COSTL
      COMMON /PIS/PI,TPI,DPR
      COMMON /LOGDIF/LSLOPE,LCORNR,LNF,LRANG
      COMMON /TEST/LDEBUG,LTEST,NTEST
      COMMON /REFL/DD,RO,ICO,JCO
      COMMON /GRIDI/GRIDX,GRIDY,EA
```

```
      COMMON /OUT/NW
      DATA DLVI/0.02/
      DATA DELT/0.01/
C
      ZO=F-ZOP
      CJ=(0.,1.)
      BDEL=0.
      IF (LCORNR) BDEL=0.5
      FN=2.
      KP=1
      PHP=0.
      PHQ=90.
      IF (LSLOPE) KP=2
      IF (LDEBUG) WRITE (NW,106)
  106 FORMAT (/,' DEBUGGING GTD SUBROUTINE')
      IF (LNF) GO TO 1
      PHI=P2
      PHIR=P2/DPR+1.E-4
      SINP=SIN(PHIR)
      COSP=COS(PHIR)
      S=RR
      GO TO 255
    1 SINPE=SIN(PHIE/DPR)
      COSPE=COS(PHIE/DPR)
      IF (.NOT.LRANG) ZE=P2
      IF (LRANG) RE=P2
C
      WRITE (NW,240) RHOS(1),RHOS(2)
  240 FORMAT (/T12,'THE REFLECTED SHADOW BOUNDARIES IN THE PHIE',
     2' PLANE ARE AT',//T20,'RHOS1 =',F9.3,5X,'AND RHOS2 =',F9.3,/
 /)
      PREVP=361.
  255 P3=P3I
      DO 100 NM=1,NGTD
      NN=NM+NTHE
      IF (.NOT.LNF) GO TO 5
C
C     ***** NEAR FIELD COORDINATE CONVERSION *****
C
      IF (.NOT.LRANG) GO TO 3
      THE=P3/DPR
      SINTE=SIN(THE)
      COSTE=COS(THE)
  242 XN(1)=XCO(1)+RE*SINTE*COSPE
      XN(2)=XCO(2)+RE*SINTE*SINPE
      XN(3)=XCO(3)+RE*COSTE
      IF (LDEBUG) WRITE (NW,205) RE,P3
  205 FORMAT (/T10,'RE =',F10.3,5X,'THE =',F7.2,/)
      IF (XN(1).NE.0..OR.XN(2).NE.0.) GO TO 4
      SINTE=SINTE+0.001
      GO TO 242
```

```
    3    ZL=P3
         DRHO=ZL-RHOS(1)
         IF (DRHO.LE.Ø.21.AND.DRHO.GE.Ø.) ZL=RHOS(1)-Ø.Ø5
         DRHO=ZL-RHOS(2)
         IF (DRHO.LE.Ø.21.AND.DRHO.GE.Ø.) ZL=RHOS(2)+Ø.Ø5
         XN(1)=XOO(1)+ZL*COSPE
         XN(2)=XOO(2)+ZL*SINPE
         XN(3)=ZE
         IF (LDEBUG) WRITE (NW,3Ø2) ZE,P3
  3Ø2    FORMAT (/T1Ø,'ZE =',F1Ø.3,5X,'ZL =',F1Ø.4,/)
    4    PHIR=ATAN2(XN(2),XN(1))
         SINP=SIN(PHIR)
         COSP=COS(PHIR)
         RR=SQRT(XN(1)*XN(1)+XN(2)*XN(2)+XN(3)*XN(3))
         IF (LDEBUG) WRITE (NW,1Ø8) XN(1),XN(2),XN(3)
         COST=XN(3)/RR
         THER=ACOS(COST)
         THETA=THER*DPR
         GO TO 6
    5    THETA=P3
         THER=THETA/DPR
C
    6    IF ((LTEST).OR.(LDEBUG)) WRITE (NW,2) THETA
    2    FORMAT (/T2,7HTHETA =,F7.2/)
         SINT=SIN(THER)
         COST=COS(THER)
         EDX=(Ø.,Ø.)
         EDY=(Ø.,Ø.)
         EDZ=(Ø.,Ø.)
         D(1)=SINT*COSP
         D(2)=SINT*SINP
         D(3)=COST
         DO 6Ø ME=1,MRIM
         EDPR=(Ø.,Ø.)
         EDPL=(Ø.,Ø.)
         ECPR=(Ø.,Ø.)
         ECPL=(Ø.,Ø.)
         MC=ME+1
         IF(MC.GT.MRIM) MC=1
         IF (.NOT.LNF) GO TO 9
         DMAG=Ø.
         DO 7 N=1,3
         D(N)=XN(N)-XM(ME,N)
    7    DMAG=DMAG+D(N)*D(N)
         DMAG=SQRT(DMAG)
         S=DMAG
         IF (LDEBUG) WRITE (NW,199) DMAG
         DO 8 N=1,3
    8    D(N)=D(N)/DMAG
    9    DV=Ø.
```

```
      DO 10 N=1,3
      IF (LDEBUG) WRITE(NW,108) D(N)
 10   DV=DV+D(N)*V(ME,N)
      BDLOW=BD(ME,1)-BDEL
      BDHI=BD(ME,2)+BDEL
      IF (LDEBUG) WRITE (NW,12) ME,DV,BDLOW,BDHI
 12   FORMAT (/T10,I2,' DV=',F8.4,5X,'BDLOW =',F8.4,5X,'BDHI =',F8.4
     ,/)
C!!!  DETERMINE IF DIFFRACTION EXISTS
      IF(DV.LT.BDLOW.OR.DV.GT.BDHI)GO TO 60
C
C!!!  COMPUTE EDGE DIFFRACTION POINT
C
      CALL DFPTWD(XS,XN,DV,VI,SP,XD,ME)
      IF (LDEBUG) WRITE (NW,112) ME,SP,(XS(N),XM(ME,N),XD(N),VI(N),
     2N=1,3)
 112  FORMAT (I5,5X,4HSP =,F10.4,11X,2HXS,8X,2HXM,8X,2HXD,9X,2HVI,
     23(/T30,4F10.4),/)
      IF (.NOT.LNF) GO TO 14
      DMAG=0.
      DO 11 N=1,3
      D(N)=XN(N)-XD(N)
 11   DMAG=DMAG+D(N)*D(N)
      DMAG=SQRT(DMAG)
      S=DMAG
      IF (LDEBUG) WRITE (NW,199) DMAG
 199  FORMAT (/T10,'DMAG =',F10.3,/)
      DV=0.
      DO 13 N=1,3
      D(N)=D(N)/DMAG
      DV=DV+D(N)*V(ME,N)
 13   IF (LDEBUG) WRITE (NW,-) D(N)
 14   ADN=0.
      VMG=0.
C!!!  COMPUTE VMG,WHICH IS DISTANCE FROM FIRST CORNER OF
C!!!  EDGE TO DIFFRACTION POINT.
      DO 15 N=1,3
      VMG=VMG+(XD(N)-X(ME,N))*V(ME,N)
 15   ADN=ADN+(XS(N)-X(1,N))*VN(ME,N)
      LDIF=.TRUE.
      IF (LDEBUG) WRITE (NW,200) VMG,VMAG(ME),DV
 200  FORMAT (/T10,'VMG =',E10.3,5X,'EDGE LENGTH =',E10.3,/T10,
     2'DV =',F10.4,/)
      IF(VMG.LT.0.)GO TO 101
      IF(VMG.LE.VMAG(ME))GO TO 102
      SP=RMC(MC)
      DO 103 N=1,3
 103  VI(N)=VIC(MC,N)/SP
      LDIF=.FALSE.
      GO TO 102
 101  SP=RMC(ME)
```

```
      DO 104 N=1,3
  104 VI(N)=VIC(ME,N)/SP
      LDIF=.FALSE.
  102 QI=0.
      PP=0.
      QD=0.
      PD=0.
      DO 20 N=1,3
      QI=QI-VN(ME,N)*VI(N)
      PP=PP-VP(ME,N)*VI(N)
      QD=QD+VN(ME,N)*D(N)
   20 PD=PD+VP(ME,N)*D(N)
C!!!  PS,PSO ARE THE DIFFRACTION PHI ANGLES,WHERE PSO IS
C!!!  INCIDENT PHI AND PS IS DIFFRACTED PHI.
      PSOR=BTAN2(QI,PP)
      PSO=DPR*PSOR
      IF(PSO.LT.0.) PSO=360.+PSO
      PSR=BTAN2(QD,PD)
      PS=DPR*PSR
      IF (LDEBUG) WRITE (NW,107) ME,PSO,PS
  107 FORMAT (/T10,I5,5X,'PSO =',F7.2,5X,'PS =',F7.2,/)
C
C     * CHECK IF DIFFRACTED FIELD IS BLOCKED BY THE REFLECTOR *
C
      IF (PS.GE.0..AND.THER.GT.THEB) GO TO 60
      IF(PS.LT.0.) PS=360.+PS
      FNP=FN*180.
      SPHO=SIN(PSOR)
      CPHO=COS(PSOR)
      SPH=SIN(PSR)
      CPH=COS(PSR)
C!!!  COMPUTE DIFFRACTION POLARIZATION UNIT VECTORS(PHO,PH,BOP,BO)
      DO 30 N=1,3
      PHO(N)=-VP(ME,N)*SPHO+VN(ME,N)*CPHO
   30 PH(N)=-VP(ME,N)*SPH+VN(ME,N)*CPH
      BOP(1)=PHO(2)*VI(3)-PHO(3)*VI(2)
      BOP(2)=PHO(3)*VI(1)-PHO(1)*VI(3)
      BOP(3)=PHO(1)*VI(2)-PHO(2)*VI(1)
      BO(1)=PH(2)*D(3)-PH(3)*D(2)
      BO(2)=PH(3)*D(1)-PH(1)*D(3)
      BO(3)=PH(1)*D(2)-PH(2)*D(1)
      IF (LDEBUG) WRITE (NW,108) (PHO(N),PH(N),BOP(N),BO(N),N=1,3)
  108 FORMAT (T20,4F12.5)
C
C!!!  COMPUTE SOURCE PATTERN FACTORS
C
      DO 29 K=1,KP
      PSIR=BTAN2(SQRT(VI(1)*VI(1)+VI(2)*VI(2)),-VI(3))
      PHIPR=BTAN2(VI(2),VI(1))
      PSI=PSIR*DPR
```

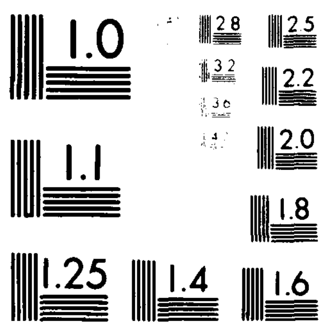
```
      PHIP=PHIPR*DPR
      CALL FEED(PSI,PHIP,PSA,PHGAM)
      IF (K.EQ.2) GO TO 24
      PSA1=PSA
      PHGAM1=PHGAM
   24 GFP(K)=GF
      DO 27 N=1,3
      VI(N)=VI(N)+PHO(N)*DLVI
   27 CONTINUE
   29 CONTINUE
      GF=GFP(1)
      CALL FPOL(EIX,EIY,EIZ,PSA1,PHGAM1)
      IF ((LDIF).AND.(LDEBUG)) WRITE (NW,25) EIX,EIY,EIZ
   25 FORMAT (/T10,5HEIX =,2F10.4,5X,5HEIY =,2F10.4,5X,5HEIZ =,
     12F10.4,/)
      EIPR=(EIX*PHO(1)+EIY*PHO(2)+EIZ*PHO(3))*F/SP
      EIPL=(EIX*BOP(1)+EIY*BOP(2)+EIZ*BOP(3))*F/SP
      IF (LDEBUG) WRITE (NW,31) SP,EIPR,EIPL
   31 FORMAT (T5,4HSP =,F10.4,5X,6HEIPR =,2E10.3,5X,6HEIPL =,2E10.3)
      IF (.NOT.LSLOPE) GO TO 36
      GF=(GFP(2)-GFP(1))/DLVI
      CALL FPOL(EIX,EIY,EIZ,PSA1,PHGAM1)
      EIPRP=(EIX*PHO(1)+EIY*PHO(2)+EIZ*PHO(3))*F/SP
      EIPLP=(EIX*BOP(1)+EIY*BOP(2)+EIZ*BOP(3))*F/SP
      IF (LDEBUG) WRITE (NW,37) EIPRP,EIPLP
   37 FORMAT (T24,7HEIPRP =,2E10.3,4X,7HEIPLP =,2E10.3)
C
C!!!  COMPUTE SBO=SINE(BO)
C
   36 CONTINUE
      SBO=SQRT((V(ME,3)*D(2)-V(ME,2)*D(3))**2+(V(ME,1)
     &*D(3)-V(ME,3)*D(1))**2+(V(ME,2)*D(1)-V(ME,1)*D(2))
     &**2)
      TPP=SP*SBO*SBO
      IF(LNF) GO TO 592
      GAM=0.
      AS=SQRT(SP)
      DO 590 N=1,3
  590 GAM=GAM+XD(N)*D(N)
      GO TO 595
  592 GAM=-S
      AS=SQRT(SP/(S*(S+SP)))
      TPP=TPP*S/(S+SP)
  595 IF (LDEBUG) WRITE (NW,599) ME,TPP,PS,PSO,SBO
  599 FORMAT (I10,5X,3HR =,F9.4,5X,4HPS =,F9.4,5X,5HPSO =,F9.4,
     25X,5HSBO =,F6.3)
      EXPH=CEXP(CMPLX(0.,TPI*(GAM-SP0)))
      EIPR=EIPR*EXPH
      EIPL=EIPL*EXPH
      EIPRP=EIPRP*EXPH
```

```
      EIPLP=EIPLP*EXPH
      CP=CJ*TPI*SP*SBO
      IF (LDEBUG) WRITE (NW,601) GAM,AS,EXPH,EIPR,EIPL,EIPRP,EIPLP
  601 FORMAT (T10,5HGAM =,F15.6,5X,'AS =',F15.6,/10E12.6)
      DO 361 J=1,2
      DEL(J)=0.
  361 CORN(J)=(0.,0.)
C
C     ***** SKIP LOOP 22 IF LCORNR FALSE *****
C
      IF (.NOT.LCORNR) GO TO 26
      MC=ME
      ISN=1
C!!!  LOOP THRU BOTH CORNERS ON EDGE #ME.
      DO 22 I=1,2
      IF(MC.GT.MRIM) MC=1
      ISN=-ISN
      SC=RMC(MC)
      IF (LDEBUG) WRITE (NW,301) (V(ME,N),VIC(MC,N),N=1,3)
  301 FORMAT (/3(T10,2F10.5,/))
      COSBC=V(ME,1)*VIC(MC,1)+V(ME,2)*VIC(MC,2)+V(ME,3)*VIC(MC,3)
      COSBC=-ISN*COSBC/SC
      CBOC=ISN*DV
      IF (LDEBUG) WRITE (NW,-) ISN,SC,COSBC,DV,CBOC
      BETC=ACOS(COSBC)
      SINBC=SIN(BETC)
      RLC=SC
      ASC=1.
      ZP=(X(MC,1)-XD(1))*D(1)+(X(MC,2)-XD(2))*D(2)
     &+(X(MC,3)-XD(3))*D(3)
      IF (.NOT.LNF.AND..NOT.LRANG) GO TO 305
      SV=0.
      SSM=0.
      DO 304 N=1,3
      SX=XN(N)-X(MC,N)
      SV=SV+SX*V(ME,N)
  304 SSM=SSM+SX*SX
      SS=SQRT(SSM)
      CBOC=ISN*SV/SS
      RLC=SC*SS/(SC+SS)
      ASC=1/SS
      ZP=S-SS
  305 BETOC=ACOS(CBOC)
      DEL(I)=2.*TPI*RLC*(COS(.5*(BETC+BETOC))**2)
      TERM=-SINBC*SQRT(SP/SC)*ASC/(TPI*(COSBC+CBOC))
C!!!  COMPUTE CORNER DIFFRACTION COEFFICIENT(CORN).
      CORN(I)=-TERM*FFCT(DEL(I))*CEXP(CMPLX(0.,-TPI*(SC-SP-ZP)-.25*P
      IF (LDEBUG) WRITE (NW,331) BETC,BETOC,SC,SP,SS,RLC,ZP,DEL(I),
     2TERM,CORN(I)
   22 MC=MC+1
   26 CONTINUE
```

AD-A097 415   OHIO STATE UNIV COLUMBUS ELECTROSCIENCE LAB   F/G 20/4
NUMERICAL ELECTROMAGNETIC CODE (NEC)-REFLECTOR ANTENNA CODE: PA--ETC(U)
SEP 79 S H LEE, R C RUDDUCK   N00123-76-C-1371
UNCLASSIFIED ESL-784508-16   NL

3 of 3

END
DATE
FILMED
5-81
DTIC



MICROCOPY RESOLUTION TEST CHART

```
      CALL DCHP(DEL,CORN,TPP,PS,PSO,SBO)
      IF (LDEBUG) WRITE (NW,32) DS,DH,DPS,DPH
   32 FORMAT (/T10,4HDS =,2F10.5,5X,4HDH =,2F10.5,/T10,5HDPS =,
     22F10.5,5X,5HDPH =,2F10.5,/)
      IF (.NOT.LDIF) GO TO 202
      EDPR=-EIPR*AS*DH
      EDPL=-EIPL*AS*DS
      IF (LDEBUG) WRITE (NW,34) ME,EDPR,EDPL
  201 IF (.NOT.LSLOPE) GO TO 202
      EDPR=EDPR+EIPRP*AS*DPH/CP
      EDPL=EDPL+EIPLP*AS*DPS/CP
  202 CONTINUE
      IF ((LDIF).AND.(LDEBUG)) WRITE (NW,34) ME,EDPR,EDPL
   34 FORMAT (I15,5X,6HEDPR =,2F10.4,5X,6HEDPL =,2F10.4)
C
C!!!  IS CORNER DIFFRACTED FIELD DESIRED?
C
      IF (.NOT.LCORNR) GO TO 45
      IF (LDEBUG) WRITE (NW,35) BS,BH,BPS,BPH
   35 FORMAT (T10,4HBS =,2F10.5,4X,4HBH =,2F10.5,/T10,5HBPS =,
     22F10.5,4X,5HBPH =,2F10.5,/)
      ECPR=-EIPR*BH
      ECPL=-EIPL*BS
      IF (LDEBUG) WRITE (NW,42) ME,ECPR,ECPL
      IF(.NOT.LSLOPE)GO TO 203
      ECPR=ECPR+EIPRP*BPH/CP
      ECPL=ECPL+EIPLP*BPS/CP
  203 CONTINUE
      IF (LDEBUG) WRITE (NW,42) ME,ECPR,ECPL
   42 FORMAT (I15,5X,6HECPR =,2E10.3,5X,6HECPL =,2E10.3)
      EDPR=EDPR+ECPR
      EDPL=EDPL+ECPL
      IF (LDEBUG) WRITE (NW,38) ME,EDPR,EDPL
   38 FORMAT (I15,5X,6HEDPR =,2E10.3,5X,6HEDPL =,2E10.3)
C!!!  COMPUTE THETA AND PHI COMPONENTS OF TOTAL DIFF. FIELD
C
   45 CONTINUE
      DO 48 N=1,3
   48 ED(N)=EDPL*BO(N)+EDPR*PH(N)
      IF (LDEBUG) WRITE (NW,55) ME,ED(1),ED(2),ED(3)
   55 FORMAT (I15,5X,5HED1 =,2E10.3,5X,5HED2 =,2E10.3,5X,5HED3 =,
     22E10.3)
      EDX=EDX+ED(1)
      EDY=EDY+ED(2)
      EDZ=EDZ+ED(3)
   60 CONTINUE
      IF (.NOT.LNF) GO TO 80
      IF (LOUT) WRITE (NW,62) EDX,EDY,EDZ
   62 FORMAT (/T10,T10,5HEDX =,2E10.3,5X,5HEDY =,2E10.3,5X,
     25HEDZ =,2E10.3,/)
C
C     ***** NEAR FIELD SECTION *****
C
```

```
      X1=XN(1)-XS(1)
      X2=XN(2)-XS(2)
      X3=XN(3)-XS(3)
      RHO=SQRT(X1*X1+X2*X2)
      IF (XN(3).LT.0.) GO TO 65
      RHON=SQRT((XN(1)-X00(1))**2+(XN(2)-X00(2))**2)
      IF (RHON.LT.RHOS(2).OR.RHON.GT.RHOS(1)) GO TO 65
C
C          *** REFLECTED FIELDS ***
C
      I=ICO+XN(1)/GRIDX+DELT
      J=JCO+XN(2)/GRIDY+DELT
      M=I+1
      N=J+1
      DX=XN(1)/GRIDX+ICO-I
      DY=XN(2)/GRIDY+JCO-J
      PHER=CEXP(-CJ*TPI*XN(3))
      ERX=(EA(1,M,N)*(1.-DX-DY)+EA(1,M+1,N)*DX+EA(1,M,N+1)*DY)*PHER
      ERY=(EA(2,M,N)*(1.-DX-DY)+EA(2,M+1,N)*DX+EA(2,M,N+1)*DY)*PHER
      IF (LOUT) WRITE (NW,64) ERX,ERY
  64  FORMAT (/T10,'ERX =',2E12.4,5X,'ERY =',2E12.4,/)
      EDX=EDX+ERX
      EDY=EDY+ERY
C
C          *** SPILLOVER FIELDS ***
C
  65  IF (.NOT.LFEED) GO TO 74
      PHIPR=BTAN2(X2,X1)
      PHIP=PHIPR*DPR
      PSI=BTAN2(RHO,-X3)*DPR
      THETA=180.-PSI
      RS=SQRT(RHO*RHO+X3*X3)
      PHEI=CEXP(-CJ*TPI*RS)*F/RS
      IF (XN(3).GE.0.) GO TO 70
      IF (ABS(PHIP-PREVP).GT.0.001) CALL SBDY(MRIM,X,XS,PHIE,
     2TH1,TH2,THEB)
      PREVP=PHIP
      IF (ABS(THETA-TH1).LT.0.05) THETA=THETA+0.05
      IF (ABS(THETA-TH2).LT.0.05) THETA=THETA-0.05
      IF (THETA.LE.TH2.AND.THETA.GE.TH1) GO TO 74
  70  CALL FEED(PSI,PHIP,PSA,PHGAM)
      CALL FPOL(EIX,EIY,EIZ,PSA,PHGAM)
      EIX=EIX*PHEI
      EIY=EIY*PHEI
      EIZ=EIZ*PHEI
      IF (LOUT) WRITE (NW,72) EIX,EIY,EIZ,EDX,EDY,EDZ
  72  FORMAT(2H 0,T15,5HEIX =,2E10.4,5X,5HEIY =,2E10.4,5X,5HEIZ =,
     22E10.4,T79,1H0,/2H 0,T15,5HEDX =,2E10.4,5X,5HEDY =,2E10.4,
     35X,5HEDZ =,2E10.4,T79,1H0)
      EDX=EDX+EIX
```

```
      EDY=EDY+EIY
      EDZ=EDZ+EIZ
   74 IF (.NOT.LRANG) GO TO 75
      EDT=COST*(COSP*EDX+SINP*EDY)-SINT*EDZ
      EDP=-SINP*EDX+COSP*EDY
      GO TO 84
   75 CALL DBPHS(AEDX,EDX,0.)
      CALL DBPHS(AEDY,EDY,0.)
      CALL DBPHS(AEDZ,EDZ,0.)
      IF(LWRITE)WRITE (NW,76) P3,AEDX,EDX,AEDY,EDY,AEDZ,EDZ
   76 FORMAT(2H W,T5,F6.2,4X,,3(E10.3,2F10.2))
      PLT=REAL(EDY)
      GO TO 90
C
C     ***** FAR FIELD SECTION *****
C
   80 EDT=(COST*COSP*EDX+COST*SINP*EDY-SINT*EDZ)*RFCT
      EDP=(-SINP*EDX+COSP*EDY)*RFCT
      IF (LOUT) WRITE (NW,82) EDT,EDP
   82 FORMAT(2H T,T10,'EDT =',2E11.3,5X,'EDP =',2E11.3,T79,1HT)
      IF (.NOT.LFEED) GO TO 84
      IF (THETA.LT.TH2.AND.THETA.GT.TH1) GO TO 84
C
C          *** SPILLOVER FIELDS ***
C
      PSI=180.-THETA
      PSIR=PSI/DPR
      SINS=SIN(PSIR)
      COSS=COS(PSIR)
      CALL FEED(PSI,PHI,PSA,PHGAM)
      CALL FPOL(EIX,EIY,EIZ,PSA,PHGAM)
      EIT=-COSS*COSP*EIX-COSS*SINP*EIY-SINS*EIZ
      EIP=-SINP*EIX+COSP*EIY
      PHEI=CEXP(CJ*TPI*ZO*COST)*F*RFCT
      EIT=EIT*PHEI
      EIP=EIP*PHEI
      IF (LOUT) WRITE (NW,-) EIT,EIP
      EDT=EDT+EIT
      EDP=EDP+EIP
      IF (LOUT) WRITE (NW,82) EDT,EDP
C
C          *** PRINC AND CROSS POLARIZED COMPONENTS ***
C
   84 TMT=EDT
      EDT=COSPT*EDT-SINPT*EDP
      EDP=SINPT*TMT+COSPT*EDP
      IF (.NOT.LCP) GO TO 85
      TMT=EDT
      EDT=TEM2*(EDT-CJ*EDP)
      EDP=TEM2*(TMT+CJ*EDP)
```

```
   85 CALL DBPHS(AEDT,EDT,REFDB)
      CALL DBPHS(AEDP,EDP,REFDB)
      IF(LWRITE)WRITE (NW,86) P3,AEDT,EDT,AEDP,EDP
   86 FORMAT(2H W,T5,F6.2,4X,,2(E10.3,2F10.2),T79,1HW)
      PLT=REAL(EDT)
   90 CONTINUE
      WRITE (2) PLT
      P3=P3+DP3
  100 CONTINUE
      RETURN
      END
```

SUBROUTINE LNFD

PURPOSE

To calculate the feed pattern value by linearly interpolating the input feed data in a given PHI cut.

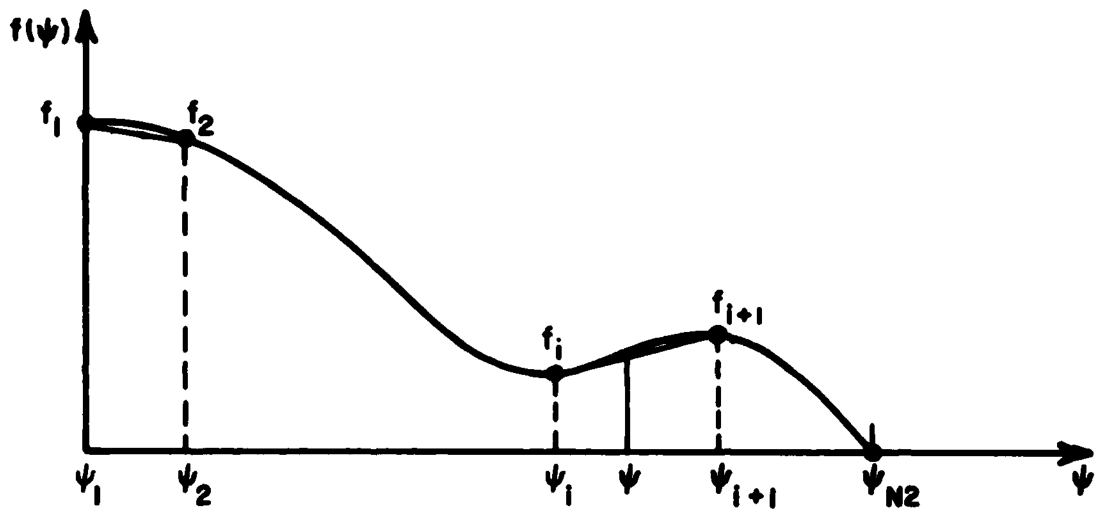


Figure 1. Piece-wise linear approximation for feed patterns.

METHOD

The feed pattern value f_e at an angle ψ is calculated by

$$f_e = f_i \cdot (1-dp) + f_{i+1} \cdot dp$$

where

$$dp = \frac{\psi-\psi_i}{\psi_{i+1}-\psi_i}$$

and f_i's are the input feed pattern data.

FLOW DIAGRAM

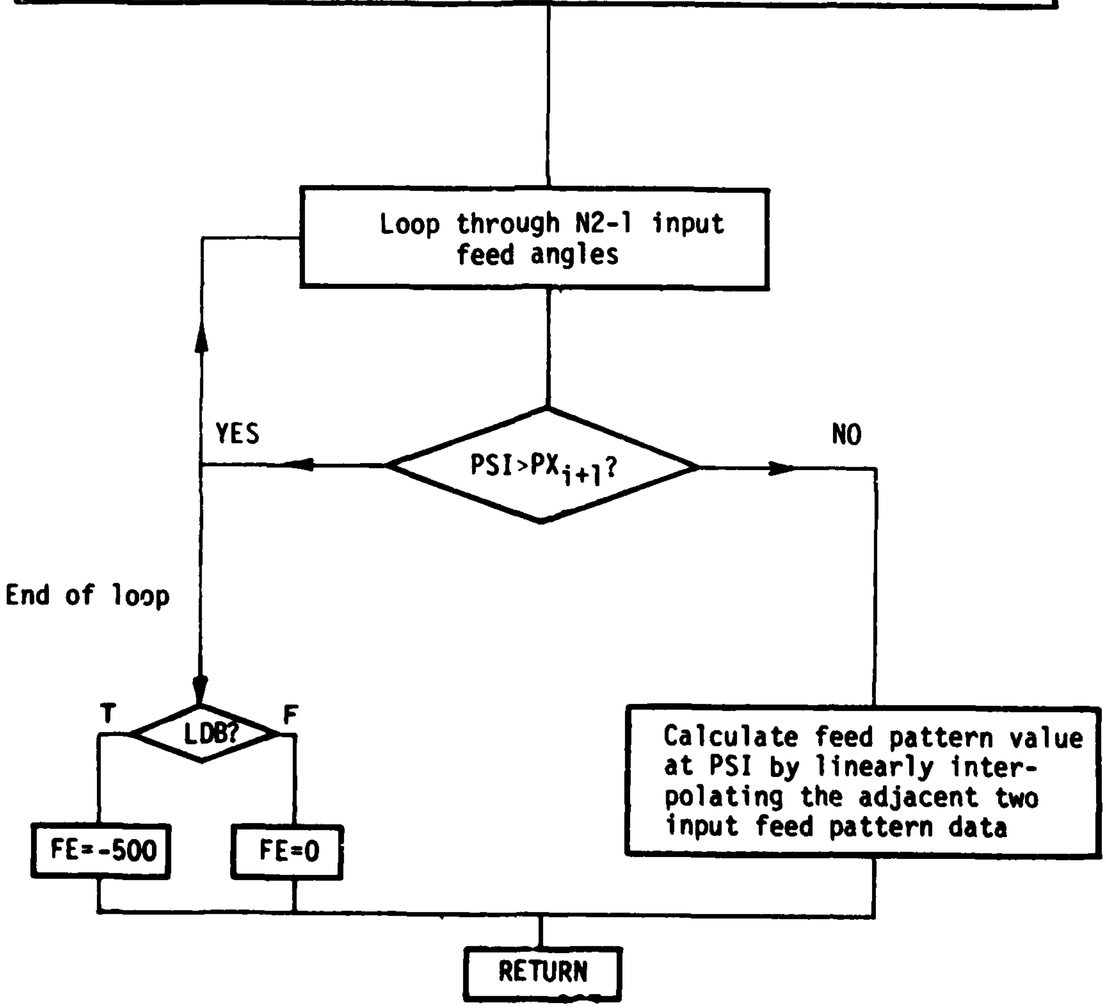
LNFD(PX,F,PSI,N2,FE,LDB)

INPUT VARIABLES

PX	(ψ_i)	Input feed pattern angles
F	(f_i)	Input feed pattern data at PX
PSI	(ψ)	Feed pattern angle at which the feed pattern value is to be calculated
N2		Total number of input data points
LDB		Logical variable which specifies the feed pattern in dB values, if true, or as linear field values, if false

OUTPUT VARIABLES

FE	(f_e)	Calculated feed pattern value



CODE LISTING

```
      SUBROUTINE LNFD(PX,F,PSI,N2,FE,LDB)
      DIMENSION PX(15),F(15)
      LOGICAL LDB
      N3=N2-1
      DO 10 I=1,N3
      IF (PSI.GT.PX(I+1)) GO TO 10
      DP=(PSI-PX(I))/(PX(I+1)-PX(I))
      FE=F(I)*(1.-DP)+F(I+1)*DP
      RETURN
   10 CONTINUE
      FE=0.
      IF (LDB) FE=-500.
      RETURN
      END
```

SUBROUTINE SBDY

PURPOSE

To calculate the shadow boundary angles for the spillover field, the edge diffracted field and the reflected field.

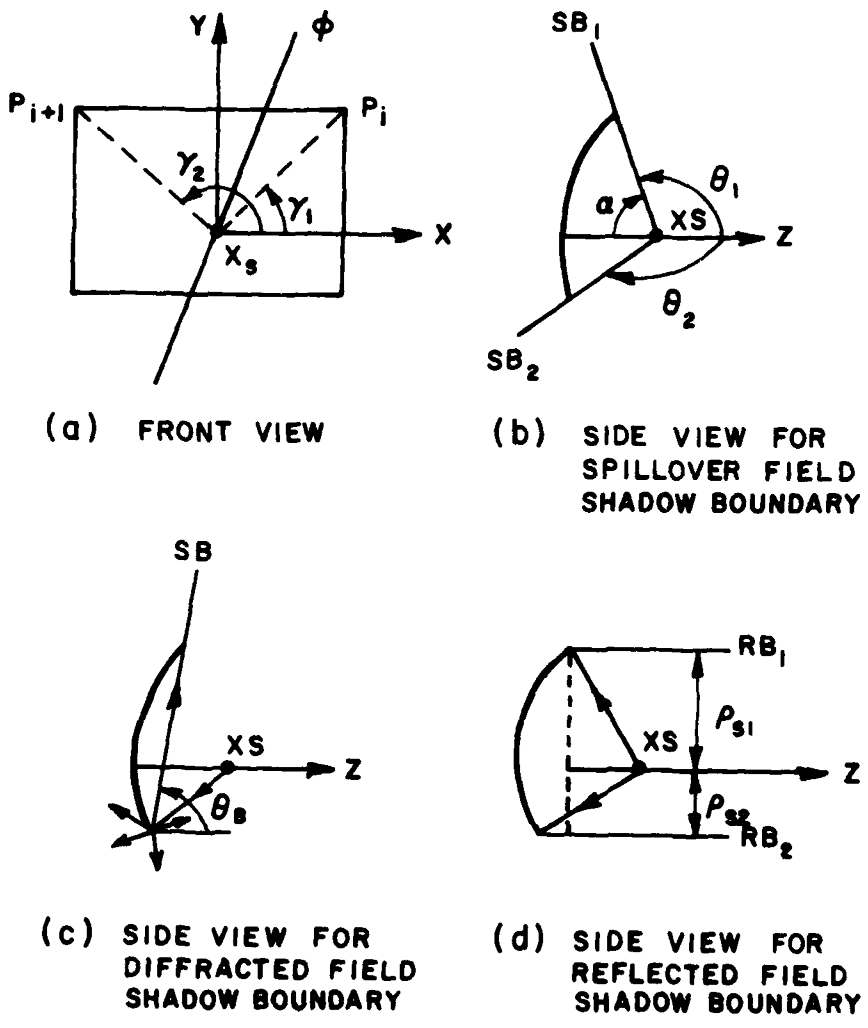


Figure 1. Geometry for shadow boundary angles.

METHOD

In order to find the appropriate shadow boundary angles and distances, the intersecting points on the reflector rim cut by the PHI plane must be located. By comparing ϕ with γ_1 and γ_2, which are the projected angles defined by the source XS and the rim points P_i and P_{i+1}, respectively, measured from the x-axis, on the aperture plane, (Fig. 1a) the index of the rim section cut by the ϕ plane is found and the intersecting point coordinates x and y can be obtained by solving the linear equation of the corresponding edge and $y=x\ \tan\phi$; then z by solving

$$z = \frac{x^2+y^2}{4F} \quad .$$

Once x,y and z are determined, the parameters for the different shadow boundaries are readily found as follows:

a) Incident shadow boundary angle θ

$$\theta_{1,2} = \pi-\alpha_{1,2}$$

where α is defined by XS and the intersecting points on the rim (see Fig. 1b) and is given by

$$\alpha = \tan^{-1}\left(\frac{\sqrt{(x-XS(1))^2+(y-XS(2))^2}}{z-XS(3)}\right) \quad .$$

b) Diffracted shadow boundary angle θ_B

This angle is defined by the two intersecting points on the upper and lower rim respectively, measured from the z-axis (Fig. 1c) and is given by

$$\theta_B = \tan^{-1}\left(\frac{\Delta\rho}{\Delta z}\right)$$

where

$$\Delta\rho = \sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$$

and

$$\Delta z = z_1-z_2$$

c) Reflected shadow boundary distance ρ_s

$$\rho_{s1,2} = \sqrt{(x-XS(1))^2+(y-XS(2))^2}$$

which is illustrated in Fig. 1d.

FLOW DIAGRAM

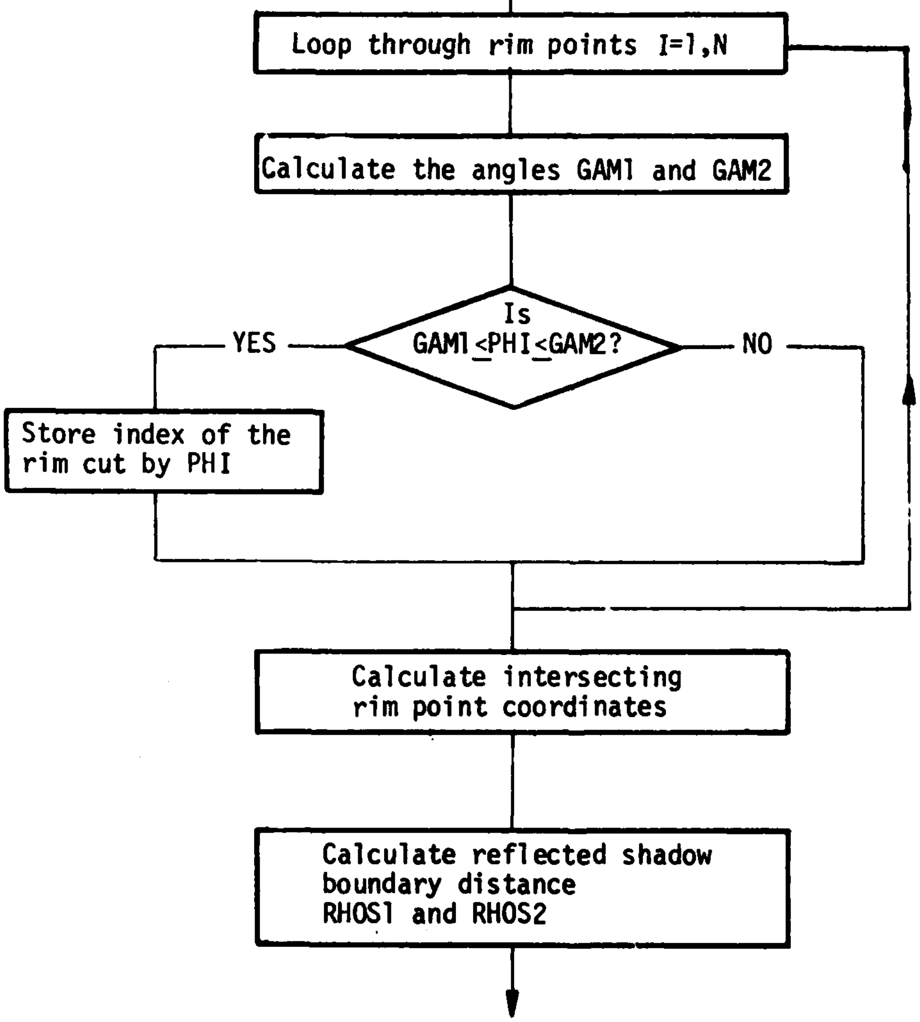
SBDY(N,RIM,XS,PHI,TH1,TH2,THEB)

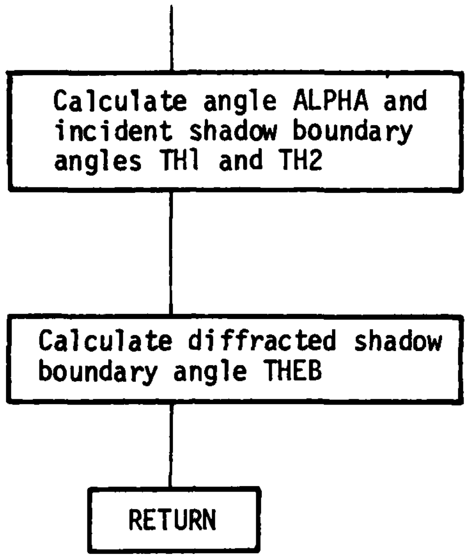
INPUT VARIABLES

N		Number of rim points
RIM		Rim point coordinates
PHI		Pattern plane cut
XS		Source location

OUTPUT VARIABLES

TH1,TH2	(θ_1, θ_2)	Shadow boundary angles for spillover field
THEB	(θ_B)	Shadow boundary angle for diffracted field




Calculate angle ALPHA and incident shadow boundary angles TH1 and TH2
Calculate diffracted shadow boundary angle THEB
RETURN

KEY VARIABLES

			INPUT/ OUTPUT
ALPHA	(α)	Incident shadow boundary angles measured from negative z-axis	
GAM1	(γ_1)	Projected angle defined by XS and RIM POINT P: measured from the x-axis	
GAM2	(γ_2)	Projected angle defined by XS and RIM POINT P_{i+1} measured from the x-axis	
ML		Index of the lower rim cut by PHI	
MU		Index of the upper rim cut by PHI	
RHOS	(ρ_s)	Reflected shadow boundary distances	(O)
X(1)		X-coordinate of the upper intersecting rim point	
X(2)		X-coordinate of the lower intersecting rim point	
X1		X-component of the distance from the source to rim point P_i	
X2		X-component of the distance from the source to rim point P_{i+1}	
Y(1)		Y-coordinate of the upper intersecting rim point	
Y(2)		Y-coordinate of the lower intersecting rim point	
Y1		Y component of the distance from the source to rim point P_i	
Y2		Y component of the distance from the source to rim point P_{i+1}	

CODE LISTING

```
      SUBROUTINE SBDY(N,RIM,XS,PHI,TH1,TH2,THEB)
C
C     *** THIS SUBROUTINE CALCULATES THE SHADOW BOUNDARY ANGLES
C         FOR SPILLOVER FIELDS AS WELL AS EDGE DIFFRACTED FIELDS
C         OF A PARABOLIC REFLECTOR ANTENNA.
C
C     *** THE RANGE OF INPUT PHI ANGLE IS IN (-180.,180.)
C
      DIMENSION RIM(67,2),ALPHA(2),X(2),Y(2),Z(2),XS(3),RHOS(2)
      DIMENSION MU(2),ML(2),SIGN(2)
      LOGICAL LTEST,LDEBUG
      COMMON /RFBDY/RHOS
      COMMON /FOCAL/F,ZOP
      COMMON /PIS/PI,TPI,DPR
      COMMON /OUT/NW
      COMMON /TEST/LDEBUG,LTEST,NTEST
      IF (LTEST) WRITE (6,-) N,PHIR
      HPI=PI/2.
      THPI=3.*HPI
      PHIR=PHI/DPR
      TANP=TAN(PHIR)
      IF (PHIR.GT.0.) PHIPR=PHIR-PI
      IF (PHIR.LE.0.) PHIPR=PHIR+PI
      L1=0
      L2=0
C
C     *** L : # OF INTERSECTING POINTS ON THE APERTURE RIM CUT BY PHI
C               AND PHIP.
C         MU,ML: INDEX OF THE RIM POINT CORRESPONDING TO THE RIM SECTI
     ON
C               CUT BY PHI AND/OR PHIP RESPECTIVELY.
C
      DO 10 I=1,N
      X1=RIM(I,1)-XS(1)
      Y1=RIM(I,2)-XS(2)
      GAM1=BTAN2(Y1,X1)
      J=I+1
      IF (J.GT.N) J=1
      X2=RIM(J,1)-XS(1)
      Y2=RIM(J,2)-XS(2)
      GAM2=BTAN2(Y2,X2)
      IF (GAM1.GE.0..AND.GAM2.LT.0.) GAM2=GAM2+TPI
      IF (ABS(GAM1-GAM2).LT.PI) GO TO 6
      IF (TAN(GAM1)*TAN(GAM2).GT.0) GO TO 100
      GO TO 8
    6 IF (GAM2.GT.GAM1) GO TO 8
      TEMP=GAM1
```

```
      GAM1=GAM2
      GAM2=TEMP
    8 CONTINUE
      IF (PHIR.LT.GAM1.OR.PHIR.GE.GAM2) GO TO 9
      L1=L1+1
      MU(L1)=I
    9 IF (PHIPR.LT.GAM1.OR.PHIPR.GE.GAM2) GO TO 10
      L2=L2+1
      ML(L2)=I
   10 CONTINUE
      L=L1+L2
      IF (L.GT.2) WRITE (6,12) L
   12 FORMAT (/T10,'L=',I2,5X,'ABNORMAL RIM SHAPE',/)
      IF (LDEBUG) WRITE (6,14) L,L1,L2,MU(1),MU(2),ML(1),ML(2)
   14 FORMAT (/T10,'L=',I2,5X,6I5,/)
      IF (L.EQ.2) GO TO 15
C
C     *** L<2, EITHER PHI CUT TANGENT TO THE APERTURE RIM (L=1),
C              OR MISSING THE APERTURE PLANE (L=0).
C
      TH1=180.
      TH2=180.
      RETURN
   15 IF (L1-1) 16,17,18
   16 M1=ML(1)
      M2=ML(2)
      SIGN(1)=-1.
      SIGN(2)=-1.
      GO TO 20
   17 M1=MU(1)
      M2=ML(1)
      SIGN(1)=1.
      SIGN(2)=-1.
      GO TO 20
   18 M1=MU(1)
      M2=MU(2)
      SIGN(1)=1.
      SIGN(2)=1.
   20 IF (LDEBUG) WRITE (6,-) M1,M2
C
C     *** CALCULATE THE COORDINATES OF THE INTERSECTING POINTS
C         (X(I),Y(I),Z(I)) AND THEIR CORRESPONDING ANGLES ALPHA(1) AND
C         ALPHA(2) MEASURED FROM THE NEGATIVE Z-AXIS.
C         ALL REFERRING TO THE SOURCE POINT XS.
C
      I1=M1
      DO 30 I=1,2
      X1=RIM(I1,1)-XS(1)
      Y1=RIM(I1,2)-XS(2)
      IF (LDEBUG) WRITE (6,32) X1,Y1
```

```
      I2=I1+1
      IF (I2.GT.N) I2=1
      X2=RIM(I2,1)-XS(1)
      Y2=RIM(I2,2)-XS(2)
      IF (LDEBUG) WRITE (6,32) X2,Y2
      IF (ABS(X1-X2).LT.1.E-3) GO TO 25
      SLP=(Y2-Y1)/(X2-X1)
      IF (ABS(PHI-9Ø.).LT.1.E-3) GO TO 22
      X(I)=(X2*SLP-Y2)/(SLP-TANP)
      Y(I)=X(I)*TANP
      GO TO 28
 22   Y(I)=Y2-X2*SLP
      X(I)=Ø.
      GO TO 28
 25   X(I)=X1
      Y(I)=X(I)*TANP
  28  RHOS(I)=SIGN(I)*SQRT(X(I)*X(I)+Y(I)*Y(I))
      IF (LDEBUG) WRITE (6,*) I,I1,X(I),Y(I),RHOS(I)
      I1=M2
  3Ø  CONTINUE
C
      IF (L1.EQ.1) GO TO 31
      IF (RHOS(1).GE.RHOS(2)) GO TO 31
      TEMP=X(1)
      X(1)=X(2)
      X(2)=TEMP
      TEMP=Y(1)
      Y(1)=Y(2)
      Y(2)=TEMP
      TEMP=RHOS(1)
      RHOS(1)=RHOS(2)
      RHOS(2)=TEMP
C
C     *** X(K),Y(K),Z(K) REFER TO THE REFLECTOR COORDINATE
C
  31  DO 4Ø K=1,2
      XP=X(K)
      YP=Y(K)
      X(K)=XP+XS(1)
      Y(K)=YP+XS(2)
      RHO2=X(K)**2+Y(K)**2
      Z(K)=RHO2/(4.*F)-ZOP
      IF (LTEST) WRITE (6,32) X(K),Y(K),Z(K)
  32  FORMAT (T2Ø,3E12.4)
      D=SQRT(XP*XP+YP*YP)
      ZZ=XS(3)-Z(K)
      ALPHA(K)=BTAN2(D,ZZ)*DPR
      IF (LTEST) WRITE (6,35) K,ALPHA(K)
  35  FORMAT (T1Ø,'ALPHA(',I1,')',F7.2)
 4Ø   CONTINUE
```

```
C
C      *** SHADOW BOUNDARY ANGLES FOR SPILLOVER FIELD ***
C
       TH1=180.-SIGN(1)*ALPHA(1)
       TH2=180.-SIGN(2)*ALPHA(2)
C
C      *** SHADOW BOUNDARY ANGLE FOR EDGE DIFFRACTED FIELD ***
C
       THEB=HPI
       IF (ABS(Z(1)-Z(2)).LT.1.D-4) GO TO 70
       DRHO=SQRT((Y(2)-Y(1))**2+(X(2)-X(1))**2)
       DZ=Z(1)-Z(2)
       THEB=BTAN2(DRHO,DZ)
   70  IF (LTEST) WRITE (6,80) THEB
   80  FORMAT (/T15,'THEB =',F10.4,' RADIANS',/)
       RETURN
  100  WRITE (6,120)
  120  FORMAT (/T10,'*** ERROR : TWO CONSECUTIVE RIM POINTS MUST '
      2'LOCATE IN THE SAME QUADRANT OR ADJACENT QUADRANTS',/)
       CALL EXIT
       END
```

REFERENCES

1. R.C. Rudduck, and S.H. Lee, "User's Manual for Numerical Electromagnetic Code (NEC)," Report 784508-19, September 1979, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract N00123-76-C-1371 for Naval Regional Procurement Office, Long Beach, California 90822

2. A.C. Ludwig, "The Definition of Cross Polarization," IEEE Trans. on Antennas and Propagation, AP-21, January 1973, pp. 116-119.

3. R.J. Marhefka, "Analysis of Aircraft Wing-Mounted Antenna Patterns," Report 2902-25, June 1976, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Grant No. NGL-36-008-138 for National Aeronauctics and Space Administration.

4. Numerical Electromagnetic Code (NEC) - Basic Scattering Code, Part II: Code Manual," F.W. Schmidt and R.J. Marhefka, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract N00123-76-C-1371 for Naval Regional Procurement Office, Long Beach, California 90822.

5. R.G. Kouyoumjian and P.H. Pathak, "A Uniform Geometrical Theory of Diffraction for an Edge in a Perfectly-Conduction Surface, Proc. IEEE, Vol. 62, November 1974, pp. 1448-1461.

6. R.G. Kouyoumjian, "The Geometrical Theory of Diffraction and Its Applications," Numerical and Asymptotic Techniques in Electromagnetics, edited by R. Mittra, Spring-Verlag, New York, 1975.

7. W.D. Burnside, N. Wang and E.L. Pelton, "Near Field Pattern Computations for Airborne Antennas," Report 4685-4, June 1978, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract N00019-77-C-0299 for Department of the Navy, Naval Air Systems Command. (AD/A 057 244)

8. J. Boersma, "Computation of Fresnel Integrals," Math. Comp., Vol. 14, 1960, p. 380.

DATE
ILMED
- 8