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Secondary Pattern Computation of an Offset Reflector Antenna

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ERRATA

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Page 2, second paragraph, line 3 (line following eq. (1)): $\vec{f}(\theta, \phi)$ should be replaced by \vec{f} .

 $\sqrt{2}$ Page 2: Equations (1) and (4) should be enclosed in boxes.

 $\sqrt{Page 3}$: Equations (5), (6), and (7) should be enclosed in boxes.

Page 3, third paragraph, line 2: 0^r , should be 0^r ,.

Page 4, second paragraph from bottom, line 4: Kuffman and Crowell should be Kauffman and Croswell.

Page 4, second paragraph from bottom, line 13: Delete the following \checkmark sentence: The agreement is also very good for the directivity.

Page 11, reference 10: Clam, Peter T. should read Lam, Peter, T.C.

Figure 6: The legend should read as follows: On-focus case (feed is at focal point).

SECONDARY PATTERN COMPUTATION OF AN OFFSET REFLECTOR ANTENNA

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SUMMARY

Reflector antennas are widely used in communications satellite systems because they provide high gain at low cost. In analyzing reflector antennas the computation of the secondary pattern is the main concern. A computer program for calculating the secondary pattern of an offset reflector has been developed and implemented at the NASA Lewis Research Center. The theoretical foundation for this program is based on the use of geometrical optics to describe the fields from the feed to the reflector surface and to the aperture plane. The resulting aperture field distribution is then transformed to the far-field zone by the fast Fourier transform algorithm. Comparing this technique with other well-known techniques (the geometrical theory of diffraction, physical optics (Jacobi-Bessel), etc.) shows good agreement for large (diameter of 100 λ or greater) reflector antennas.

INTRODUCTION

The accurate prediction of radiation characteristics for a microwave antenna is essential in designing antenna systems. Antenna radiation characteristics such as beam width, gain, aperture efficiency, side-lobe level, and cross polarization are used in analyzing and designing advanced antenna systems. The aperture field method (ref. 1) described in this report is one of several methods for predicting antenna performance characteristics. The method assumes that the tangential electric field on a planar surface in front of the antenna reflector is known. This aperture field distribution is then transformed to the far-field zone of the reflector by using a two-dimensional Fourier transform.

To compute the tangential electric fields on the aperture surface, the geometrical optics method (ref. 2) is used. In this technique the energy coming from the feed and reradiating from the reflector surface is characterized by an astigmatic tube of rays (ref. 3) that allows calculation of the amplitude and polarization of the electric field. This report also presents a method for computing the secondary pattern by using the aperture field method and a fast Fourier transform (ref. 4). Computation of the tangential electric field in the aperture plane is briefly described. A reflector configuration (fig. 1) is analyzed, and the results are compared with other well-known computational techniques. A description and a copy of the program are included in appendixes A and B, respectively.

The author wishes to thank Dr. Shung-Wu Lee and Dr. Peter T.C. Lam, of the University of Illinois, for their cooperation and recommendations.

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APERTURE FIELD METHOD APPROACH

Description of Problem

The geometry of the problem under consideration is shown in figures 2 and 3. A reflector Σ_R is illuminated by the energy from a feed source at F₁. The problem is defined as (1) to determine the tangential electric field at an observation point on the aperture grid F₂, as shown in figure 2, and (2) to determine the secondary pattern from the near-field distribution by using the fast Fourier transform, as shown in figure 3.

Incident Electric Field on Reflector

The radiated electric field from the feed antenna has the asymptotic form given by equation (1):

$$\vec{E} \sim \frac{e^{-jkr}}{r} \vec{f}(\theta, \varphi)$$
(1)

where $\vec{f} = 2\pi/\lambda$ is the active element pattern, $k = 2\pi/\lambda$ is the wave number, and r is the distance from the source to the reflection point. The vector function in equation (1) can be approximated by equation (2).

$$\vec{f}$$
 (Θ, φ) $\cong \hat{\Theta} U_{E}(\Theta)(ae^{J\Psi} \cos \varphi + b \sin \varphi) + \hat{\varphi} U_{H}(\Theta)(b \cos \varphi - ae^{J\Psi} \sin \varphi)$ (2)

where $U_E(\Theta)$ is the E-plane active pattern, $U_H(\Theta)$ is the H-plane active pattern, and a, b, and ψ are polarization parameters:

The various feed polarizations are described in the following table:

	đ	D	Ψ
Linear x	ı	0	0
Linear y	°_		0
Right-hand circular polarized (RHCP)	1/√2	1/√2	π/2
Left-hand circular polarized (LHCP)	$1/\sqrt{2}$	1/√2	-π/2

Typically these element patterns can be approximated by $(\cos \theta)^{q}$; that is,

$$U_{E}(\Theta) = (\cos \Theta)^{q_{E}}$$
 (3a)

$$U_{H}(\Theta) = (\cos \Theta)^{q_{H}}$$
 (3b)

If equations (3a) and (3b) are used to represent the active element patterns, the power radiated (ref. 5) by this source is given by equation (4).

$$P_{RAD} = \frac{q_E + q_H + 1}{60(2q_E + 1)(2q_H + 1)}$$
(4)

<u>Two_coordinate</u> systems (fig. 4) are used, the feed coordinate system (x^{F}, y^{F}, z^{F}) and the reflector system (x, y, z). These two coordinate systems are related by Eulerian angles (α,β,γ) illustrated in figure 5. Reference 6 provides a good description of these angles, which transform the incident field on the feed coordinate system into the reflector coordinate system.

Reflected Electric Field

For a given feed point F_1 and an observation point F_2 (fig. 2), a reflection point O^r may exist on the reflector Σ_R . This point is called the specular point. This type of ray reflection satisfies Snell's law of reflection. Reference 7 describes a search procedure to obtain the specular point. The reflected field at the aperture point F_2 is given by equation (5).

$$\vec{E}_{(F_2)}^r = DF \cdot e^{-jkd_2} [2(\hat{n} \cdot \vec{E}^1)\hat{n} - \vec{E}^1]$$
(5)

where d_2 is the distance from O^r to F_2 .

Equation (5) is given in terms of the incident field \vec{E}^1 at the reflection point 0^r , the surface unit normal \hat{n} of the reflector at 0^r , and a divergence factor DF. The divergence factor in equation (5) is given by



where (R_1^r, R_2^r) are the principal radii of curvature of the reflected wavefront passing through O^r. Reference 7 gives an expression for these parameters as a function of the principal radii of curvature of a parabolic reflector.

Secondary Pattern

. From the Hygens theorem (ref. 1) a solution for the far-field zone may be obtained if the tangential fields at Σ_A (fig. 3) are known. The aperture plane Σ_{Λ} is taken to be perpendicular to the z-axis.

The field in the far-field zone is given in terms of the tangential electric field at Σ_A , which is denoted by \vec{E}_A (ref. 8). Equation (7) relates the aperture field \vec{E}_a to the far-field zone electric field.

$$\vec{E}(\vec{r}) \sim jk_0 \frac{e^{-jkr}}{2\pi r} \left[\hat{\Theta}E_{\theta} + \hat{\varphi}E_{\phi}\right]$$
(7)

 $E_{\theta} = F_{Y} \cos \varphi \cos \theta - F_{X} \sin \varphi \cos \theta \qquad (7a)$

 $E_{\varphi} = F_{\chi} \cos \varphi + F_{\gamma} \sin \varphi$ (7b)

$$\vec{F} = \iint_{\Sigma_A} \vec{E}_a e^{jk(ux+vy)} dx dy = F_x \hat{a}_x + F_y \hat{a}_y$$
(7c)

 $\mathbf{u} = \mathbf{k} \sin \Theta \cos \varphi \tag{7d}$

$$\mathbf{v} = \mathbf{k} \sin \Theta \sin \varphi \tag{7e}$$

and Θ and φ are the spherical coordinates of far-field point. The integral in equation (7c) is a double Fourier transform. The computer program developed uses a fast Fourier transform (FFT) algorithm to accomplish this task. References 9 and 10 describe in detail the use of the FFT algorithm to solve for the double Fourier transform.

The aperture field theory used to determine the secondary pattern is exact if the tangential fields are known everywhere on the aperture plane Σ_A . When employing the FFT, Σ_A is truncated. To minimize the amount of computer time, Σ_A should be as small as possible while capturing almost all of the field. The number of grid points should satisfy the Nyquist (sampling) theorem. The secondary pattern can be reconstructed from a discrete set of near-field values Xif the spacing is $\lambda/2$ or less. Reference 11 describes sample spacing for high-gain reflector antennas.

This method of calculating the secondary pattern, is accurate in cases the where the antenna diameter is of the order of 100 or more. If the antenna diameter is less than 100 where the accuracy is reduced, specifically in the side-lobe region. This approach was originally used by Kuffman and Crowell (ref. 4) and developed extensively by many others (e.g., Hwang, et al., ref. 12). The reflector configuration described in figure 1 was analyzed by using various methods (physical optics (Jacobi-Bessel) (refs. 13 and 14), the geometrical theory of diffraction (ref. 15), and geometrical optics). The calculated patterns and directivities are shown in figures 6 and 7. Figure 6 shows an on-focus case; the directivity and the far-field pattern are in very good agreement. Figure 7 shows an off-focus (or scan) case; the agreement is still very good. The computer program given in appendix B was used to analyze this configuration. The agreement is also very good for the directivity. Appendix A contains a detailed description (users guide) of all the input parameters, including those for the configuration shown in figure 1.

Directivity

The far-field zone is usually divided into two orthogonal polarizations. Following Ludwig's definition 3 (ref. 16), the following unitary polarization vectors are introduced:

$$\widehat{R} = \widehat{\Theta}(ae^{j\psi}\cos\varphi + b\sin\varphi) + \widehat{\varphi}(-ae^{j\psi}\sin\varphi + b\cos\varphi)$$
(8a)

$$\hat{C} = \hat{\Theta}(ae^{-j\psi} \sin \varphi - b \cos \varphi) + \hat{\varphi}(-ae^{-j\psi} \cos \varphi + b \sin \varphi)$$
(8b)

If the secondary pattern can be expressed as

$$\vec{E} = \frac{e^{-jkr}}{r} [\hat{\Theta}E_{\Theta} + \hat{\varphi}E_{\varphi}]$$
(9)

the reference-polarization expression for \vec{E} is

and the cross-polarization expression is

The directivity for the reference polarization is defined by

$$D_{R}(\Theta,\varphi) = \frac{4\pi |\vec{E} \cdot \hat{R}|^{2}/Z_{0}}{P_{rad}}$$
 (11a)

Similarly directivity for the cross polarization is defined by

$$D_{C}(\theta,\varphi) = \frac{4\pi |\vec{E} \cdot \hat{C}|^{2}/Z_{0}}{P_{rad}}$$
(11b)

CONCLUDING REMARKS

A method, called the aperture field technique, has been developed for calculating the secondary pattern of an offset reflector illuminated by a feed with arbitrary polarization. By using the fast Fourier transform the far-zone electric field is computed very efficiently. The results for the secondary pattern are in good agreement with those obtained by other well-known techniques. This method can be conveniently extended to secondary pattern computation for multiple and numerically specified reflectors.

The computer program based on the aperture field technique is one of the main research tools used at the NASA Lewis Research Center for analyzing advanced antenna systems.

APPENDIX A

DESCRIPTION OF PROGRAM

A computer program was designed to calculate the antenna far-field performance characteristics. The method of analysis is geometrical optics. The output (unit FT07) is interfaced with a plotting program to display the far-field values. Any of the available plotting routines in the computer library may be used. The main features in this program (SOURCE \cdot RAP\$11) are the calculation of directivity, feed efficiency, and plots of E or H far-field plane cuts.

Input (Unit FTO5) Parameters to RAP\$11

F F1 F2 DIA XF,YF,ZF	focal length, m fraction of wavelength that defines surface sample spacing fraction of wavelength that defines aperture sample spacing diameter of reflector (if circular projection), m coordinates of center (origin) of feed coordinate system on reflector coordinate system
DELTX	offset of center of reflector relative to x-axis, m
DELTY	offset of center of reflector relative to y-axis, m
FREQ	frequency
QE	E-plane cosine pattern exponent
QH	H-plane cosine pattern exponent
POL	1, Y-POL; 2, X-POL; 3, RHCP; 4, LHCP
ZETA	maximum far-field angle for which pattern will be calculated

The input is described in figure 8.

The input for the case described in figures 1, 6, and 7 (to be read in FTO5) is as follows:

F = 2.43	DELTY = 0.434
F1 = 0.5	FREQ = 11.74E9
F2 = 0.5	QE = 3.2
DIA = 2.754	QH = 2.6
XF = YF = ZF = 0.0	POL = 3
DELTX = -1.377	ZETA = 4.0

APPENDIX B

COMPUTER PROGRAM

0000100 C*****THIS PROGRAM IS REFLECTOR ANALYSIS THIS THE MOST GENERAL VERSION 0000200 C******THE METHOD OF ANALYSIS IS APERTURE INTEGRATION. 0000300 0000350 DIMENSION PNUM(500,500) 0000400 DIMENSION X(500), Y(500), ERX(500, 500), ERY(500, 500) 0000410 DIMENSION PH(500,500), EXR(5000), EXI(5000), EYR(5000), EYI(5000) DIMENSION FIELDX(1000), FIELDY(1000), FIELD(1000), ANG(1000) 0000420 0000425 **DIMENSION RTNARR(2)** 0000501 C*****F : FOCAL LENTGTH M 0000502 C*****F1 : FRACTION OF WAVELENTGH (SURFACE SAMPLE SPACING) 0000503 C*****F2 : FRACTION OF WAVELENTGH (APERTURE SAMPLE SPACING) 0000504 C*****DIA : DIAMETER M 0000505 C*****XF,YF,ZF : ORIGIN OF FEED COORDINATE SYSTEM. 0000506 C*****DELTX, DELTY : OFFSET X-AXIS, Y-AXIS RESP. 0000507 C****FREQ : FREQUENCY HZ 0000508 C*****QE,QH,Q :COSINE PATTERN EXPONENT 0000509 C*****POL : 1 Y-POL, 2 X-POL, 3 RHCP, 4 LHCP 0000510 C****ZETA : MAX FAR-FIELD ANGLE. INTEGER*2 N1 0000550 0000600 NAMELIST/INPUT/F,F1,F2,DIA,XF,YF,ZF,DELTX,DELTY,FREQ,Q,ZETA,QH, QE,POL 0000700 0000710 PINT=0. WRITE(9,997) 0000801 0000802 997 FORMAT(5X, 'THIS IS RFLECTOR ANALYSIS PROGRAM. BY R.J. ACOSTA') 0000900 PI=4. *ATAN(1.) AWAVE=3E8/FREQ 0001000 0001100 SSP=F1×AWAVE NSP=(DIA/SSP)+1 0001200 0001300 SAP=F2*AWAVE NAP=(DIA*1.5/SAP)+1 0001400 0001500 RMAX=0.5*DIA 0001600 XC=DELTX+RMAX 0001700 YC=DELTY+RMAX 0001710 ZC=-(XC**2+YC**2)/(4.*F)+F 0001800 XSMAX=XC+RMAX YSMAX=YC+RMAX 0001900 0002000 XAMAX=XC+RMAX*1.5 YAMAX=YC+RMAX*1.5 0002100 ALIM=.5×SAP 0002110 0002120 FACT=((AWAVE**2)*(120.*PI)) FACT=1/FACT 0002130 PRAD=60.*(2.*Q+1) 0002140 0002150 PRAD=1/PRAD 0002151 C*****THIS CALCULATES THE SUBSTENTED ANGLE BY REFLECTOR REL TO FEED***** 0002160 XU=XC 0002161 YU=YC+RMAX ZU=-(XU**2+YU**2)/(4.*F)+F 0002162 0002165 XL=XC 0002166 YL=YC-RMAX ZL=-(XL**2+YL**2)/(4.*F)+F 0002168 0002169 A117=(XU-XF)*(XL-XF)+(YU-YF)*(YL-YF)+(ZU-ZF)*(ZL-ZF)0002170 A115=(XU-XF)**2+(YU-YF)**2+(ZU-ZF)**2 A115=SQRT(A115) 0002171 0002175 A116=(XL-XF)**2+(YL-YF)**2+(ZL-ZF)**2 0002176 A116=SQRT(A116) 0002180 SI=ARCOS(A117/(A115*A116))

0002185 EXP=2.*Q+1 P11=-COS(.5*SI)**EXP 0002186 0002187 P12=P11/EXP+1/EXP 0002188 PINT=P12/60 0002189 PEFFR=PINT/PRAD TAPPER=20.*ALOG10(COS(SI*.5)**Q) 0002190 WRITE(9,998)PEFFR, TAPPER 0002195 0002196 998 FORMAT(/////,5X,'EFFICIENCY OF FEED',F10.3,5X,'TAPPER OF FEED =',E15.5) DO 400 I=1,NAP DO 410 J=1,NAP 0002200 0002210 PNUM(I,J)=0. 0002220 0002230 ERX(I, J)=0. ERY(I, J)=0. 0002240 0002250 CONTINUE 410 0002260 400 CONTINUE 0002300 DELTAP=PI/NSP 0002309 DELTA=SI/NSP 0002310 0002311 NSP1=NSP×.5 DO 201 I=1,NSP1 ZETA1=DELTA*(I-1) 0002315 0002320 A145=2.×Q 0002325 0002326 FACT1=COS(ZETA1)**A145 FACT1=FACT1*SIN(ZETA1)*DELTA 0002327 PINTN=PINTN+FACT1 0002328 0002330 201 CONTINUE 0002350 PINTN=PINTN/60 PNUR=PINTN/PINT 0002360 0002370 WRITE(9,993)PNUR 993 FORMAT(////,5X, THIS NUMERICAL TO EXACT RATIO =', F10.3) 0002371 0002400 0002500 0002600 0002700 0002900 0003000 DO 10 J=1,NSP DO 11 I=1,NSP 0003100 XS=XSMAX-SSP*(I-1) 0003200 YS=YSMAX-SSP*(J-1) 0003300 RS=SQRT((XS-XC)**2+(YS-YC)**2) 0003400 IF(RS.LE.RMAX)GO TO 12 0003500 0003600 GO TO 11 CONTINUE 0003700 12 25=-(X5**2+Y5**2)/(4.*F)+F 0003800 0004000 AMAGN=SQRT(X5**2+Y5**2+(4.*F**2)) 0004100 ANX=-XS/AMAGN 0004200 0004300 ANY=-YS/AMAGN ANZ=-2.*F/AMAGN 0004400 0004600 0004700 AIMAGN=SQRT((XS-XF)**2+(YS-YF)**2+(ZS-ZF)**2) 0004800 SIX=(XS-XF)/AIMAGN SIY=(YS-YF)/AIMAGN 0004900 SIZ=(ZS-ZF)/AIMAGN 0005000 0005200 0005300 SRX=SIX-2.*(SIX*ANX+SIY*ANY+SIZ*ANZ)*ANX 0005400 SRY=SIY-2.*(SIX*ANX+SIY*ANY+SIZ*ANZ)*ANY 0005500 SRZ=SIZ-2.*(SIX*ANX+SIY*ANY+SIZ*ANZ)*ANZ 0005600

0005800 0005900 XA=XS-ZS*(SRX/SRZ) 0006000 YA=YS-ZS*(SRY/SRZ) 0006100 C******LOCATE THIS RAY IN THE APERTURE GRID MATRIX********************** 0006200 0006300 0006400 0006500 DO 21 N=1, NAP 0006700 0086000 X(N)=XAMAX-SAP*(N-1) XDELTA=ABS(X(N)-XA) 0007000 0007100 IF(XDELTA.LE.ALIM) GO TO 30 0007200 CONTINUE 21 0007210 GO TO 500 CONTINUE 0007300 30 0007400 DO 20 M=1, NAP Y(M)=YAMAX-SAP*(M-1) 0007500 0007600 YDELTA=ABS(Y(M)-YA) 0007700 IF(YDELTA.LE.ALIM) GO TO 40 0007800 20 CONTINUE 0007810 GO TO 500 Continue 0007900 40 0008000 C*****STAR THE CALCULATION OF FIELDS AT APERTURE************ 0008100 0008200 A11=SQRT((XC-XF)**2+(YC-YF)**2+(ZC-ZF)**2) 0008300 A12=SQRT((XS-XF)**2+(YS-YF)**2+(ZS-ZF)**2 ADOT=(XC-XF)*(XS-XF)+(YC-YF)*(YS-YF)+(ZC-ZF)*(ZS-ZF) 0008500 0008600 ADOT=ADOT/(A11×A12) 0008612 0008700 FPAT=ADOT**Q 0008710 C****THIS IS TO CALCULATE THE TOTAL POWER INTERCEPTED BY REFLECTOR**** 0008712 0008800 IF(FPAT.LT.1E-5)FPAT=1E-5 0008810 C*****FINISH FEED PATTERN CALCULATIONS**************************** 0008820 C*****INCIDENT UNIT VECTOR CALCULATION*********************************** 0008900 EIX=-(SIX*SIY) EIY=(SIX**2+SIZ**2) 0009000 0009100 EIZ=-(SIZ*SIY) 0009200 A13=SQRT(EIX*EIX+EIY*EIY+EIZ*EIZ) ÊÎX=ÊÎX/AI3 0009300 0009400 EIY=EIY/A13 0009500 EIZ=EIZ/A13 0009700 EINX=EIX*FPAT/A12 EINY=EIY*FPAT/A12 0009800 0009900 EINZ=EIZ×FPAT/A12 0010000 C*****REFLECTED FIELD AMPLITUDE CALCULATION****************************** ERFX=2.*(ANX*EINX+ANY*EINY+ANZ*EINZ)*ANX-EINX 0010100 0010200 ERFY=2.*(ANX*EINX+ANY*EINY+ANZ*EINZ)*ANY-EINY ERFZ=2.*(ANX*EINX+ANY*EINY+ANZ*EINZ)*ANZ-EINZ 0010300 A31=SQRT((XA-XS)*(XA-XS)+(YA-YS)*(YA-YS)+Z5*Z5) 0010409 0010410 PHASE=(2*PI/AWAVE)*(A12+A31) ERX(N,M)=ERX(N,M)+ERFX 0010500 ERY(N,M)=ERY(N,M)+ERFY 0010600 0010700 PH(N,M)=PH(N,M)+PHASE 0010800 PNUM(N,M)=PNUM(N,M)+1 0010900 GO TO 11 WRITE(9,300) 0011000 500 0011100 300 FORMAT(5X, 'CAN NOT LOCATE THIS RAY????????????????? 0011200 11 CONTINUE 0011300 10 CONTINUE 0011301 C*****THIS WILL TAKE THE AVERAGE AMPLITUDE/PHASE************************* 0011310 DO 60 I=1, NAP DO 61 J=1,NAP 0011315

0011318 IF(PNUM(I,J).EQ.0.) GO TO 61 0011320 ERX(I,J)=ERX(I,J)/PNUM(I,J) ERY(I, J)=ERY(I, J)/PNUM(I, J) 0011321 PH(I, J)=PH(I, J)/PNUM(I, J) 0011322 0011325 CONTINUE 61 0011326 60 CONTINUE 0011400 C******COLLAPSE THE FIELD BY ROWS OR IN X,****************************** WRITE(55)NAP, NAP 0011410 WRITE(55)((ERY(I,J),J=1,NAP),I=1,NAP) 0011417 0011425 WRITE(55)((PH(I,J),J=1,NAP),I=1,NAP) WRITE(55)((ERX(I,J),J=1,NAP),I=1,NAP) 0011431 0011437 WRITE(55)((PH(I,J),J=1,NAP),I=1,NAP) 0011500 C******TO GET A COLUMN VECTOR OR Y DISTRIBUTION******************* 0011600 0011700 DO 15 I=1,NAP DO 16 J=1,NAP 0011800 0011820 0011825 0011900 EXR(I)=EXR(I)+ERX(J,I)*COS(PH(J,I)) 0012000 EXI(I)=EXI(I)+ERX(J,I)*SIN(PH(J,I)) 0012100 EYR(I)=EYR(I)+ERY(J,I)*COS(PH(J,I)) 0012200 EYI(I)=EYI(I)+ERY(J,I)*SIN(PH(J,I)) 0012300 16 CONTINUE 0012400 15 CONTINUE 0012600 NAP=NAP×5 0012700 0012800 CALL FFT(EXR, EXI, NAP, NAP, NAP, 1) CALL FFT(EYR, EYI, NAP, NAP, NAP, 1) 0012900 A133=NAP*SAP/AWAVE 0013000 0013100 NMAX=A133*SIN(ZETA*PI/180.) 0013200 NMAX=NMAX+1 0013300 DO 70 I=1,NMAX J1=NMAX-(I-1) 0013400 0013500 A134=J1/A133 ANG(I)=-ARSIN(A134)×180./PI 0013600 J2=I+NMAX 0013700 Ā135=(I-1)/A133 0013800 0013900 ANG(J2)=ARSIN(A135)*180/PI CONTINUE 0014000 70 DO 71 J=1,NMAX 0014100 I1=NAP-NMAX-1+1+J 0014200 FIELDX(J)=FACT*(EXR(I1)*EXR(I1)+EXI(I1)*EXI(I1))*COS(ANG(J) 0014300 *PI/180)**2 0014400 FIELDY(J)=FACT*(EYR(I1)*EYR(I1)+EYI(I1)*EYI(I1)) 0014500 FIELD(J)=FIELDX(J)+FIELDY(J) 0014600 I2=J+NMAX 0014700 FIELDX(I2)=FACT*(EXR(J)*EXR(J)+EXI(J)*EXI(J))*COS(ANG(J) *PI/180)**2 0014800 FIELDY(I2)=FACT*(EYR(J)*EYR(J)+EYI(J)*EYI(J)) FIELD(12)=FIELDX(12)+FIELDY(12) 0014900 CONTINUE 0015000 71 0015100 N1=2×NMAX 0015200 CALL SCLBAK(.FALSE.,N1,FIELD,RTNARR) 0015300 GAIN=10.*ALOGIO(4.*PI*RTNARR(2)*SAP**4/PRAD) 0015400 WRITE(9,950)GAIN 0015500 950 FORMAT(////,5X, 'THIS IS THE GAIN VALUE =', E15.5) 0015510 WRITE(9,965)N1 0015511 965 FORMAT(////,5X, 'TOTAL NUMBER OF CALCULATED FAR-FIELD VALUES =', I5) 0015600 DO 73 I=1,N1 FIELD(I)=FIELD(I)/RTNARR(2) 0015700 0015800 IF(FIELD(I).LT.1E-6)FIELD(I)=1E-6 0015900 FIELD(I)=10.*ALOG10(FIELD(I)) WRITE(7,565)ANG(I),FIELD(I) FORMAT(5X,E15.5,5X,E15.5) 0016000 0016100 565 0016200 73 CONTINUE 0016300 STOP 0016400 END

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Figure 2. - Reflector Σ_R being illuminated by incident field from point source at F1.



Figure 3 - Secondary pattern using fast Fourier transform (FFT).



Figure 4. - Feed and reflector coordinate systems.



Figure 5. - Eulerian angles.





Figure 7. - Scan case (feed moved off focus).



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