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COMPUTER PROGRAM FOR THIN WIRE ANTENNAS MOUNTED ON A SATELLITE --ETC(U)

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COMPUTER PROGRAM FOR THIN WIRE ANTENNAS MOUNTED ON A SATELLITE BODY MODELED BY FLAT PLATES

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A computer program is presented which employs the moment method representation of wire antennas in combination with the Uniform Theory of Diffraction to model antennas on a satellite body.

The development of the program is not completely done in that multiple diffractions are not yet included. In some analysis situations this will be of no concern while in others it may be a limitation on the use of the program.

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Contents

I. INTRODUCTION

This report describes a computer program which analyzes impedance and pattern characteristics of wire type antennas mounted on a satellite. The satellite body is modeled by an enclosing structure of flat plates, some of which act as ground planes for the wire antennas. The basic principles and techniques for the present analysis are similar to those developed previously for the case of wire antennas on a flat plate[1]. This work extends the analysis of reference 1 to account for a more complex multiplate structure and deals with the general case where several antennas can share the same ground plane or they can be located on different faces of the satellite structure. As a result, to obtain accurate values for the antenna impedances, it is essential that all coupling terms due to reflected and diffracted fields from nearby panels and wedges as well as those due to the presence of other wire antennas must be added to the appropriate terms of the open-circuit impedance matrix. Efforts have been directed to make the present program compatible in programming logic and terminology with existing thin wire antenna programs developed by Professor J. Richmond[2,3].

II. INPUT DATA AND SUBROUTINE CWIRE

Subroutine CWIRE is used to setup the input data for the main program. The following parameters must be specified in subroutine CWIRE

AL	wire radius in wavelengths
CMM	wire conductivity in megamhos/m
FMC	frequency in MHz
NPGP	number of wire end-points on the ground planes
NRP	number of real points including those on the ground planes
NSGP	number of wire segments touching the ground planes
NRS	number of real wire segments.

To illustrate the working of the subroutines and main program, a satellite structure consists of 10 plates as sketched in Figure 1 is used in the examples. In the first example, a quarter wave monopole is mounted at (0.,-λ,0.) on plate 1 of the structure. Subroutine CWIRE for this case is listed in Figure 2. In the second example, another quarter wave monopole is located at the center of plate 2 and perpendicular to this plate, the corresponding CWIRE is listed in Figure 3. In both cases, CWIRE first defines the wire geometry by specifying the coordinates XC, YC, ZC of the endpoints in meters. For more complex wire structures such as that of helical antennas, a subroutine which generates XC, YC, ZC similar to subroutine HELIX of Appendix 2 can be called for this purpose. Do loop 702 generates the segment numbers and the list of end-points IA, IB for each real wire segment (Figure 2). The array element IDPT (I) specifies the plate (number) that acts as the ground plane for endpoint I. It then reads in and stores input data describing the model of the satellite structure, which include the position vectors CR of the corners and the list of corner index NPLC. Figure 1 shows the carrier index written next to the corner, numbered from 1 to 12. The plate number is written on each plate and encircled. Plate 10 is the bottom plate defined by corners 9, 10, 11 and 12. This input data for satellite geometry is labeled file IN1 in user name 3468N. Type - COPY IN1,3468N TO .IN, user name will make this file available for input to subroutine CWIRE. The data file IN1 is listed below.

```
1   1.5    -2.    0.     1.5    1.5    0.
2  -1.      1.5   0.    -1.    -3.     0.
3   2.5    -3.   -1.     2.5    3.    -1.
4  -2.5     3.   -1.    -2.5   -3.    -1.
5   2.5    -3.   -2.5    2.5    3.    -2.5
6  -2.5     3.   -2.5   -2.5   -3.    -2.5
7   1   2   3   4   5   6   2   1   2   6   7   [illegible]   4   [illegible]   7   [illegible]
8   5   1   4   [illegible]   9   5   8   12   9   10   6   3   6   10   11   7
9   8   7   11   12   9   10   11   12
```

The meaning of the above figures is self-explained in the following tables.

Table 1

Corner index I	x CR(I,1)	y (in wavelengths) CR(I,2)	z CR(I,3)
1	1.5	-2.0	0.0
2	1.5	1.5	0.0
3	-1.0	1.5	0.0
4	-1.0	-2.0	0.0
5	2.5	-3.0	-1.0
6	2.5	3.0	-1.0
7	-2.5	3.0	-1.0
8	-2.5	-3.0	-1.0
9	2.5	-3.0	-2.5
10	2.5	3.0	-2.5
11	-2.5	3.0	-2.5
12	-2.5	-3.0	-2.5

Each plate is defined by 4 corners C1, C2, C3, C4.

Table 2

Plate Number J	Corner Index C1 NPLC(J,1)	C2 NPLC(J,2)	C3 NPLC(J,3)	C4 NPLC(J,4)
1	1	2	3	4
2	5	6	2	1
3	2	6	7	3
4	4	3	7	8
5	5	1	4	8
6	9	5	8	12
7	9	10	6	5
8	6	10	11	7
9	8	7	11	12
10	9	12	11	10

The position vectors CR of the corners are converted to metric units in Do 18. Subroutine CWIRE then generates the list of unit vectors VNP, where VNP (I,3) denotes the unit vector normal to plate I. The normal unit vector is defined as a cross-product of two edge vectors and points outward, away from the structure. This is done in loop Do 12. Note that the corner index NPLC (I,J), J= 1,2,3,4 has been arranged such that an observer proceeds from one corner to the next on the same plate in the direction of increasing J will see the normal vector to his left, pointing outward.

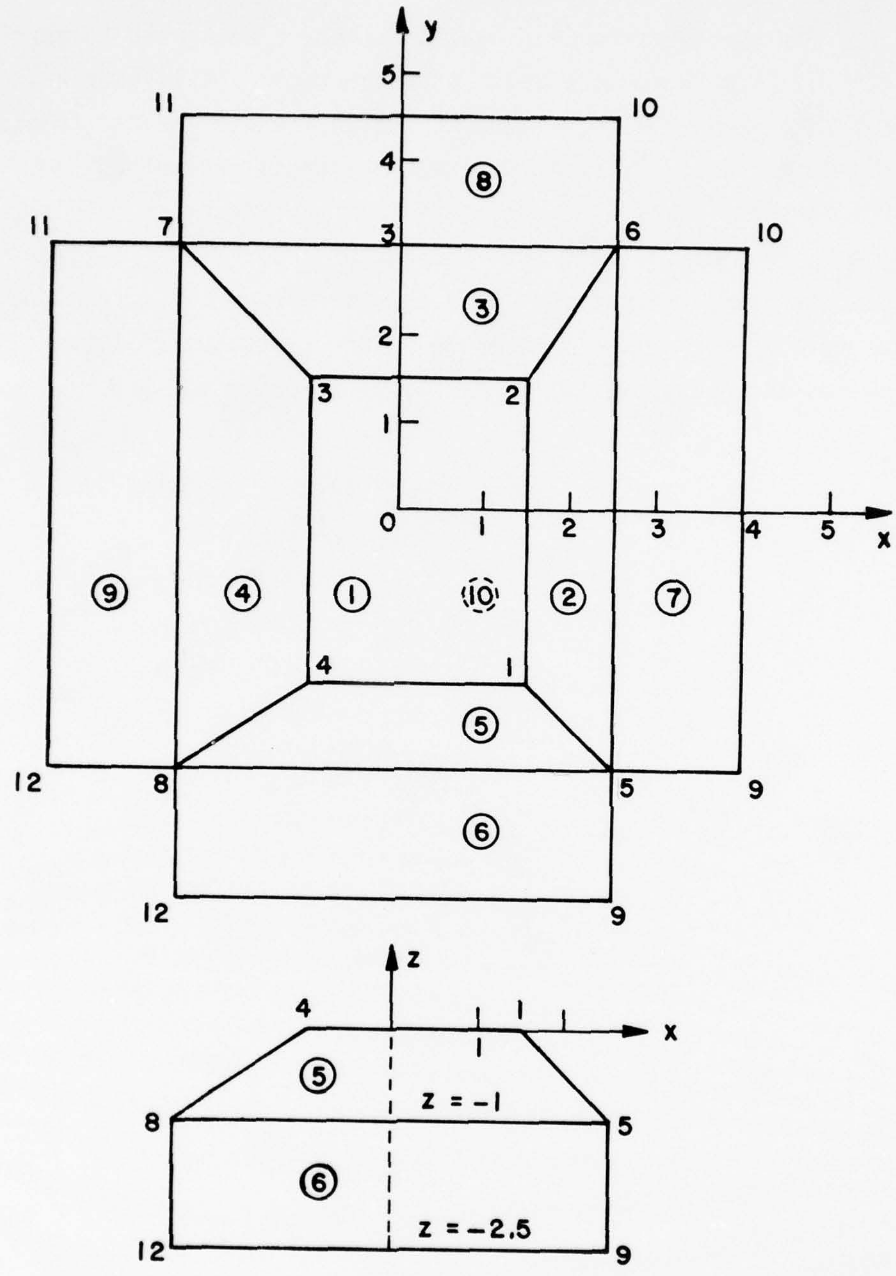


Figure 1. Model of 10-plate structure used in examples.
Dimensions in wavelengths.

```
      SUBROUTINE CWIRE(IA,IB,ICJ,INP,INS,INT,IWRCJ,IWRITE,NLD,NP,NS,
     &NRP,NRS,NPGP,NSGP,AL,CMM,DPH,FMC,SCALE,TH,VG,XC,YC,ZC,ZLD,
     &VNP,NPLC,CR,NOP,NOC,IDPT,WAVM)
      DIMENSION IA(1),IB(1),XC(1),YC(1),ZC(1),IOPT(1),VF3(3),V3(3)
      DIMENSION VNP(NOP,3),NPLC(NOP,4),CR(NOC,3),VF1(3),VF2(3)
      COMPLEX VG(1),ZLD(1)
C  IA(J) AND IB(J) ARE ENDPOINTS OF SEGMENT J
C  XC(I),YC(I),ZC(I) ARE COORDINATES OF POINT I WITH ARBITRARY UNITS
C  NRP = NUMBER OF REAL POINTS, INCLUDING THOSE ON THE GROUND PLANE
C  NRS = NUMBER OF REAL SEGMENTS
C  NPGP = NUMBER OF POINTS ON THE GROUND PLANE
C  NSGP = NUMBER OF REAL SEGMENTS WITH ENDPOINT ON GROUND PLANE
C  NLD = NUMBER OF LUMPED LOADS
      DO 9 J=1,ICJ
 9    IOPT(J)=1
      DO 10 J=1,INS
      VG(J)=(.0,.0)
 10   ZLD(J)=(.0,.0)
C  SET UP THE REAL GENERATORS AND REAL LUMPED LOADS
      JGN1=1
      JGN2=2
      VG(JGN1)=(1.,0.)
C     VG(JGN2)=(1.,0.)
      NLD=0
      INT=0
      AL=0.0001
      CMM=-1.
      FMC=1000.
      SCALE=1.
      WAVM=300./FMC
      IWRITE=1
      IWRCJ=1
      NSGP=1
      NPGP=1
      NRS=4
      NRP=5
      NS=2*NRS
      NP=2*NRP-NPGP
C**SET UP REAL SEGMENTS
      DO 702 J72=1,NRS
      IA(J72)=J72
 702  IB(J72)=J72+1
C**SET UP THE REAL END-POINTS
      DO 703 IOOP=1,NRP
      IOPT(IOOP)=1
      XC(IOOP)=0.
      YC(IOOP)=-1.*WAVM
 703  ZC(IOOP)=0.
      ZC(2)=WAVM/16.
```

Figure 2. Subroutine CWIRE.

```
      ZC(3)=WAVM/8.
      ZC(4)=3.*WAVM/16.
      ZC(5)=WAVM/4.
      WRITE(6,8)INP,NP,INS,NS
      IF(NSGP.LT.NPGP)GO TO 500
      IF(NS.GT.INS.OR.NP.GT.INP)GO TO 500
    8 FORMAT(4X,'INP=',I4,5X,'NP=',I4,5X,'INS=',I4,5X,'NS=',I4)
C** SATELLITE GEOMETRY*****************
      NOP=10
      NOC=12
      READ(5,15) ((CR(II,JJ),JJ=1,3),II=1,NOC)
      READ(5,16) ((NPLC(II,JJ),JJ=1,4),II=1,NOP)
   15 FORMAT(6E10.2)
   16 FORMAT(16I4)
      DO 17 I17=1,NOC
      DO 18 I18=1,3
      CR(I17,I18)=CR(I17,I18)*WAVM*SCALE
   18 CONTINUE
   17 CONTINUE
      AM=AL*WAVM
      DO 12 J12=1,NOP
      L1=NPLC(J12,1)
      L2=NPLC(J12,2)
      L3=NPLC(J12,3)
      DO 13 J13=1,3
      VE1(J13)=CR(L2,J13)-CR(L1,J13)
   13 VE2(J13)=CR(L3,J13)-CR(L2,J13)
      CALL CROSSP(VE1,VE2,VN3,V3)
      DO 14 J14=1,3
   14 VNP(J12,J14)=VN3(J14)
   12 CONTINUE
  500 RETURN
      END
```

Figure 2. (Cont'd).

```
      SUBROUTINE CWIRE(IA,IB,ICJ,INP,INS,INT,IWRCJ,IWRITE,NLD,NP,NS,
     $NRP,NRS,NRGP,NSGP,AL,CMM,DPP,FMC,SCALE,TH,VG,XC,YC,ZC,ZLD,
     $VMP,NPLC,CR,NOP,NOC,IDPT)
      DIMENSION IA(1),IB(1),XC(1),YC(1),ZC(1),IDPT(1),VMS(3),VS(3)
      DIMENSION VMP(NOP,3),NPLC(NOP,4),CR(NOC,3),VE1(3),VE2(3)
      COMPLEX VG(1),ZLD(1)
C   IA(J) AND IB(J) ARE ENDPOINTS OF SEGMENT J
C   XC(I),YC(I),ZC(I) ARE COORDINATES OF POINT I WITH ARBITRARY UNITS
C   NRP = NUMBER OF REAL POINTS, INCLUDING THOSE ON THE GROUND PLANE
C   NRS = NUMBER OF REAL SEGMENTS
C   NRGP = NUMBER OF POINTS ON THE GROUND PLANE
C   NSGP = NUMBER OF REAL SEGMENTS WITH ENDPOINT ON GROUND PLANE
C   NLD = NUMBER OF LUMPED LOADS
      DO 9 J=1,ICJ
    9 IDPT(J)=1
      DO 10 J=1,INS
      VG(J)=(.0,.0)
   10 ZLD(J)=(.0,.0)
C   SET UP THE REAL GENERATORS AND REAL LUMPED LOADS
      JGN1=1
      JGN2=2
      VG(JGN1)=(1.,0.)
      VG(JGN2)=(1.,0.)
      NLD=0
      INT=0
      AL=0.0001
      CMM=-1.
      FMC=1000.
      SCALE=1.
      WAVM=300./FMC
      IWRITE=1
      IWRCJ=1
      NSGP=2
      NRGP=2
      NRS=6
      NRP=10
      NS=2*NRS
      NP=2*NRP-NRGP
C**SET UP REAL SEGMENTS
      DO 702 J72=1,NRS
      IA(J72)=J72
  702 IB(J72)=J72+2
C**SET UP THE REAL END-POINTS
      DO 705 I=1,5
      IODD=2*I-1
      IDPT(IODD)=1
      XC(IODD)=0.
      YC(IODD)=-1.*WAVM
  705 ZC(IODD)=0.
```

Figure 3. Subroutine CWIRE.

```
      ZC(3)=WAVM/16.
      ZC(5)=WAVM/8.
      ZC(7)=3.*WAVM/16.
      ZC(9)=WAVM/4.
      WRITE(6,3)INP,NP,INS,NS
      IF(NSGP.LT.NPGP)GO TO 500
      IF(NS.GT.INS.OR.NP.GT.INP)GO TO 500
    3 FORMAT(4X,'INP=',I4,5X,'NP=',I4,5X,'INS=',I4,5X,'NS=',I4)
C** SATELLITE GEOMETRY*****************
      NOP=10
      NOC=12
      READ(5,15) ((CR(II,JJ),JJ=1,3),II=1,NOC)
      READ(5,16) ((NPLC(II,JJ),JJ=1,4),II=1,NOP)
   15 FORMAT(6E10.2)
   16 FORMAT(16I4)
      DO 17 I17=1,NOC
      DO 18 I18=1,3
      CR(I17,I18)=CR(I17,I18)*WAVM*SCALE
   18 CONTINUE
   17 CONTINUE
      AM=AL*WAVM
      DO 12 J12=1,NOP
      L1=NPLC(J12,1)
      L2=NPLC(J12,2)
      L3=NPLC(J12,3)
      DO 13 J13=1,3
      VE1(J13)=CR(L2,J13)-CR(L1,J13)
   13 VE2(J13)=CR(L3,J13)-CR(L2,J13)
      CALL CROSSF(VE1,VE2,VN3,V3)
      DO 14 J14=1,3
   14 VNP(J12,J14)=VN3(J14)
   12 CONTINUE
      DO 704 I=1,5
      IEVEN=2*I
      JOPT(IEVEN)=2
      XC(IEVEN)=(2.+VNP(2,1)*(I-1)/16.)*WAVM
      YC(IEVEN)=VNP(2,2)*(I-1)*WAVM/16.
  704 ZC(IEVEN)=(-0.5+VNP(2,3)*(I-1)/16.)*WAVM
  500 RETURN
      END
```

Figure 3. (Cont'd).

III. THE MAIN COMPUTER PROGRAM

The main computer program is listed in Figure 4. This program calls subroutine CWIRE for input data, namely the geometry of the wire antennas and the multiplate structure. The program next calls subroutine CSORT to generate appropriate image points and image segments. CSORT also sets up the dipole current modes for the wires and their images. Each dipole mode I has segments JA(I) and JB(I), terminals at point $I_2(I)$, and endpoints $I_1(I)$, $I_3(I)$. Subroutine CSORT generates the following information:

ND(J)	number of dipole modes sharing segment J
MD(J,K)	list of dipoles sharing segment J
NCM	size of the compressed open-circuit impedance matrix
N	number of dipole modes of the complete systems
IDSEG(J)	the plate (number) that acts as the ground plane for segment J.

The following quantities must be specified in the main program.

ICC	dimension the compressed matric C(I,J)
ICJ	dimension related to the number of dipole modes N
INP	dimension related to the number of points NP
INS	dimension related to the number of segments
NOP	number of plates of the structure
NOC	number of corners of the structure.

The numerical values assigned to the above quantities must agree with the dimensions actually reserved for the corresponding quantities in the COMPLEX and DIMENSION statements. For example when the structure has only one plate NOP=1, correspondingly we must redimension all related vectors, e.g.,

```
DIMENSION NPLC(1,4), VNP(1,4)
```

instead of

DIMENSION NPLC(10,4), VNP(10,4) for the 10-plate case.

X(I), Y(I), Z(I) denotes the dimensionless quantities kx, ky, kz for point I where $k = 2\pi/\lambda$. XC(I), YC(I), ZC(I) denotes the coordinates x, y, z in meters.

The main program calls subroutine CMATX (Appendix 10) to generate the compressed open circuit impedance matrix C(I,J). CMATX performs the same function as subroutine IDANT of Reference 3. The main difference lies with the addition of coupling terms due to reflected and diffracted fields in the matrix.

The program next calls subroutine ANTI (reference 3) to obtain the resultant current distribution on the wires and the radiation efficiency EFF. If the wire antennas have only one generator and VG = (1.,0.) then Y_{11}, Z_{11} denotes the antenna input admittance and impedance respectively (see example 1, section IV). If there are more than one generator; input impedance at input port J can be obtained by dividing VG(J) by CJ(J) (see example 2, section IV). (Note that if the generator excites a point on the ground plane - CJ(J) should be used, as the current for the ground plane dipole mode is defined in reverse direction from those of the real modes (see also reference 3)).

Finally the antenna pattern is obtained by calling subroutine CIFFLD (appendix 11). TH and PH denote the spherical coordinates θ,ϕ in degrees of the distant observer. CIFFLD is called once for each observed direction, TH, PH. CIFFLD is essentially the same as subroutine IFFLD of reference 3 except for the call CZFF. Patterns in xy, yx, xy planes are obtained by setting pattern indicators IXY, IYZ, IXY respectively to a positive integer value, if all indicators assume zero or negative integer values no pattern is computed. The resultant patterns are stored in library file PLDATB ready for plotting.

```
      OPTIONS 32K
      OPTIONS UP
      INCLUDE THNGPR,3468N;VRB3,3468N
      INCLUDE MESSR,SYS9;PACR,3468N
      INCLUDE CSOFTR,TEMP1;DOAMB,TEMP1
      INCLUDE FIELDR,TEMP1
C
C*****  THIN-WIRE HELICAL ANTENNA OVER FINITE PERFECT GROUND PLANE
C*****  SINUSOIDAL-GALERKIN FREQUENCY-DOMAIN
C*****  CALCULATE E-TH COMPONENT
C
      COMMON/COM/C
      COMMON/COM1/CJ,VJ,CG
      COMMON/COM2/CGD,SGD,DC
      COMMON/COM3/IA,IB,JA,JB,I1,I2,I3
      COMMON/COM4/TOTALT
      COMMON/COM6/VG,ZLD
      COMMON/COM8/X,Y,Z,XC,YC,ZC,CR,NPLC,VNP,MO,ND,D,IDSEG,IDPT
      COMMON/COM9/CDK,SDK,VNN,VN3,V3,VE1,VE2
      COMPLEX CJI,ET1,ET2,EP1,EP2,EPPS,ETTS,EPTS,ETPS,ZH,VP,VT
      COMPLEX EPH,ETH,Y11,Z11,ZH,EPP,ETT
      COMPLEX C(32,32),CGD(65),SGD(65),CG(130),VG(130),ZLD(130)
      COMPLEXTOTALT(361)
      COMPLEX CJ(70),VJ(70)
      DIMENSION IDSEG(65),IDPT(70)
      DIMENSION XC(70),YC(70),ZC(70),X(70),Y(70),Z(70)
      DIMENSION CR(12,3),D(65),DC(65),VNN(3)
      DIMENSION IA(65),IB(65),MO(65,4),ND(65),CDK(65),SDK(65)
      DIMENSION I1(70),I2(70),I3(70),JA(70),JB(70)
      DIMENSION NPLC(10,4),VNP(10,3),VN3(3),V3(3),VE1(3),VE2(3)
      DATA PI,TP,ETA/3.14159265,6.2831853,376.727/
C** IXZ,IYZ,IXY ARE FIELD PATTERN INDICATORS IN XZ,YZ,XY PLANES
      DATA IXZ/-1/,IYZ/-1/,IXY/-1/
      CALL SUPERR(3)
      CALL SUPERR(4)
      CALL SUPERR(5)
      CALL ASSIGN(6HDA01  ,0.,6)
      CALL ASSIGN(6HPLDATB,0.0,4)
C     CALL DEASSN
      CALL LUDEL(3)
      ICC=32
      ICJ=70
      INP=70
      INS=65
      RTD=180./PI
    1 FORMAT(8X,'JPP=',I5,5X,'MAX=',I5,5X,'MIN=',I5,5X,'N=',I5,5X,
     2'NCM=',I5)
    2 FORMAT(8X,'AL=',F8.6,5X,'CMM=',F8.4,5X,'FMC=',F8.2)
    3 FORMAT(8X,'EFF=',F7.2,3X,'Y11=',2F8.2,3X,'Z11=',2F8.2)
```

Figure 4. Main program.

```
 5    FORMAT(1H0)
 6    FORMAT(1X,2F10.0,4F10.2)
 7    FORMAT(5X,'HERE')
      CALL CWIRE(IA,IB,ICJ,INP,INS,INT,IWRCJ,IWRITE,NLD,NP,NS,
     *NRP,NRS,NPGP,NSGP,AL,CMM,DPH,FMC,SCALE,TH,VG,XC,YC,ZC,ZLD,
     *VMP,NPLC,CR,NOP,NOC,IOPT,WAVM)
C**-----------------------******************
      CALL CSORT(IA,IB,ICC,ICJ,INS,IWRITE,I1,I2,I3,JA,JB,
     *MAX,MIN,MD,N,NCM,ND,NP,NS,NRP,NRS,NPGP,NSGP,DC,XC,YC,ZC,
     *VMP,NPLC,CR,NOP,NOC,IDSEG,IOPT)
C   NCM =  SIZE OF COMPRESSED MATRIX C(I,J)
      JPP=NCM-NPGP
      WRITE(6,1)JPP,MAX,MIN,N,NCM
      WRITE(6,5)
      IF(N.LE.0 .OR. N.GT.ICJ)GO TO 500
      IF(NCM.GT.ICC)GO TO 500
      IF(MAX.LE.0 .OR. MIN.LE.0)GO TO 500
      AK=TP*AL
      WRITE(6,2)AL,CMM,FMC
      WRITE(6,5)
      TPL=TP/WAVM
      DO 90 J=1,NS
 90   D(J)=TPL*DC(J)
      DO 100 I=1,NP
      X(I)=TPL*XC(I)
      Y(I)=TPL*YC(I)
 100  Z(I)=TPL*ZC(I)
      CALL CMATX(ICC,4,JPP,MD,N,NCM,ND,
     *NLD,NP,NPGP,NRS,NS,AK,CMM,D,FMC,CDK,SDK,-1,WAVM,
     *AM,XC,YC,ZC,CR,VMP,NOP,NOC,NSGP,NPLC,X,Y,Z,IDSEG)
      DO 11 J11=1,NS
      SGD(J11)=CMPLX(0.,SDK(J11))
 11   CGD(J11)=CMPLX(CDK(J11),0.)
      I12=1
      CALL ANTI(IA,IB,I1,I2,I3,IWRCJ,IWRITE,I12,ICC,INS,JA,JB,
     *JPP,MD,N,NCM,ND,NLD,NPGP,NRS,NS,C,CDK,SDK,CJ,CMM,D,EFF,G,VG,VJ,
     *Y11,Z11,ZH,ZLD)
      IF(I12.NE.12)GO TO 500
      WRITE(6,5)EFF,Y11,Z11
      IF(G.EQ.1. .AND. EFF.EQ.0.)GO TO 500
      CALL WRITE(IA,IB,INS,0,I1,I2,I3,MD,ND,NS,CJ,CG)
      IF(IX2.LT.1)GO TO 606
      WRITE(6,7)
      GMAX=0.
      DO 602 I=1,361
      IF(I.LE.181)TH=1.*(I-1)
      IF(I.LE.181)PH=0.
      IF(I.GT.181)TH=1.*(361-I)
      IF(I.GT.181)PH=180.
      CALL CIFFLD(INS,MD,N,ND,NRS,CDK,CJ,DC,
```

Figure 4 (Cont'd).

```
      &EPH,ETH,G,GPP,GTT,PH,SDK,TH,XC,YC,ZC,WAVM,AM,NPGP,
      &NCM,VNP,NPLC,CR,NOP,NOC,IOSFG)
      IF(GTT.GT.GMAX)GMAX=GTT
 602  TOTALT(I)=ETH
 603  FORMAT(4E15.5)
      WRITE(4)(TOTALT(I),I=1,361)
      IF(GMAX.GT.0.)DBM=10.*ALOG10(GMAX)
      WRITE(6,604)DBM
 604  FORMAT(5X'*** MAXIMUM POWER GAIN = ',F10.2,'  DB'/)
 606  IF(IYZ.LT.1)GO TO 614
      GMAX=0.
      DO 608 I=1,361
      IF(I.LE.181)TH=1.*(I-1)
      IF(I.LE.181)PH=90.
      IF(I.GT.181)TH=1.*(361-I)
      IF(I.GT.181)PH=270.
      CALL CIFFLD(INS,MD,N,ND,NRS,CDK,CJ,DC,
      &EPH,ETH,G,GPP,GTT,PH,SDK,TH,XC,YC,ZC,WAVM,AM,NPGP,
      &NCM,VNP,NPLC,CR,NOP,NOC,IOSFG)
      IF(GTT.GT.GMAX)GMAX=GTT
 608  TOTALT(I)=ETH
      WRITE(4)(TOTALT(I),I=1,361)
      IF(GMAX.GT.0.)DBM=10.*ALOG10(GMAX)
      WRITE(6,604)DBM
 614  CLOSE 4
 500  CALL EXIT
      END
```

Figure 4 (Cont'd).

IV. EXAMPLES

A. A Quarter Wave Monopole on Plate 1

The monopole is located at $(0.,-\lambda,0.)$ on plate 1 of the structure in Figure 1. It is fed with 1 volt delta gap generator at the point of contact with the ground plane. The output file DAΦ1 as generated by the program is listed in Figure 5. Input impedance Z_{11} is (40.12+j21.8) ohms. If the same monopole is located at the center of a square plate 200λ each side, computation with the present program yields Z_{11} = 39.66+j21.54 ohms, which is the same value as that of a quarter wave monopole mounted on an infinite ground plane obtained with programs of reference 3. Far field patterns in x-z, and y-z planes are shown in Figures 6 and 7, without inclusion of doubly diffracted fields. These patterns agree well with those independently generated by R. Marhefka's GTD computer program[4].

```
INP=  70      NP=   9     INS=  65     NS=   8

J IA(J) IB(J)    PLATE     K IA(K) IB(K) PLATE DC(J)
1    1    2          1     5    1    6     1    .01875
2    2    3          1     6    6    7     1    .01875
3    3    4          1     7    7    8     1    .01875
4    4    5          1     8    8    9     1    .01875

J      XC(I)       YC(I)       ZC(I)      J     XC(J)       YC(J)       ZC(J)
1    0.00000     -.30000     0.00000
2    0.00000     -.30000      .01875      6   0.00000     -.30000     -.01875
3    0.00000     -.30000      .03750      7   0.00000     -.30000     -.03750
4    0.00000     -.30000      .05625      8   0.00000     -.30000     -.05625
5    0.00000     -.30000      .07500      9   0.00000     -.30000     -.07500

I    JA    JB    I1    I2    I3                 K    JA    JB    I1    I2    I3
1     1     5     2     1     6
2     1     2     1     2     3                 5     5     6     1     6     7
3     2     3     2     3     4                 6     6     7  [illegible] 7  8
4     3     4     3     4     5                 7     7     8     7     8     9

     JPP=     3      MAX=     2      MIN=     1      N=     7      NCM=     4

     AL= .000100      CMM= -1.0000      FMC= 1000.00

     VG(  1)  =        1.00       0.00

        I    MAGNITUDE    PHASE          REAL           IMAGINARY
        1      1.000      151.5       -.0192407        .0104584
        2       .949      -30.7        .0178567       -.0106141
        3       .748      -32.0        .0138884       -.0066907
        4       .428      -33.1        .0078523       -.0051110

     FFF= 100.00   Y11=      .02     -.01   Z11=   46.12    21.21
```

Figure 5. Output file.

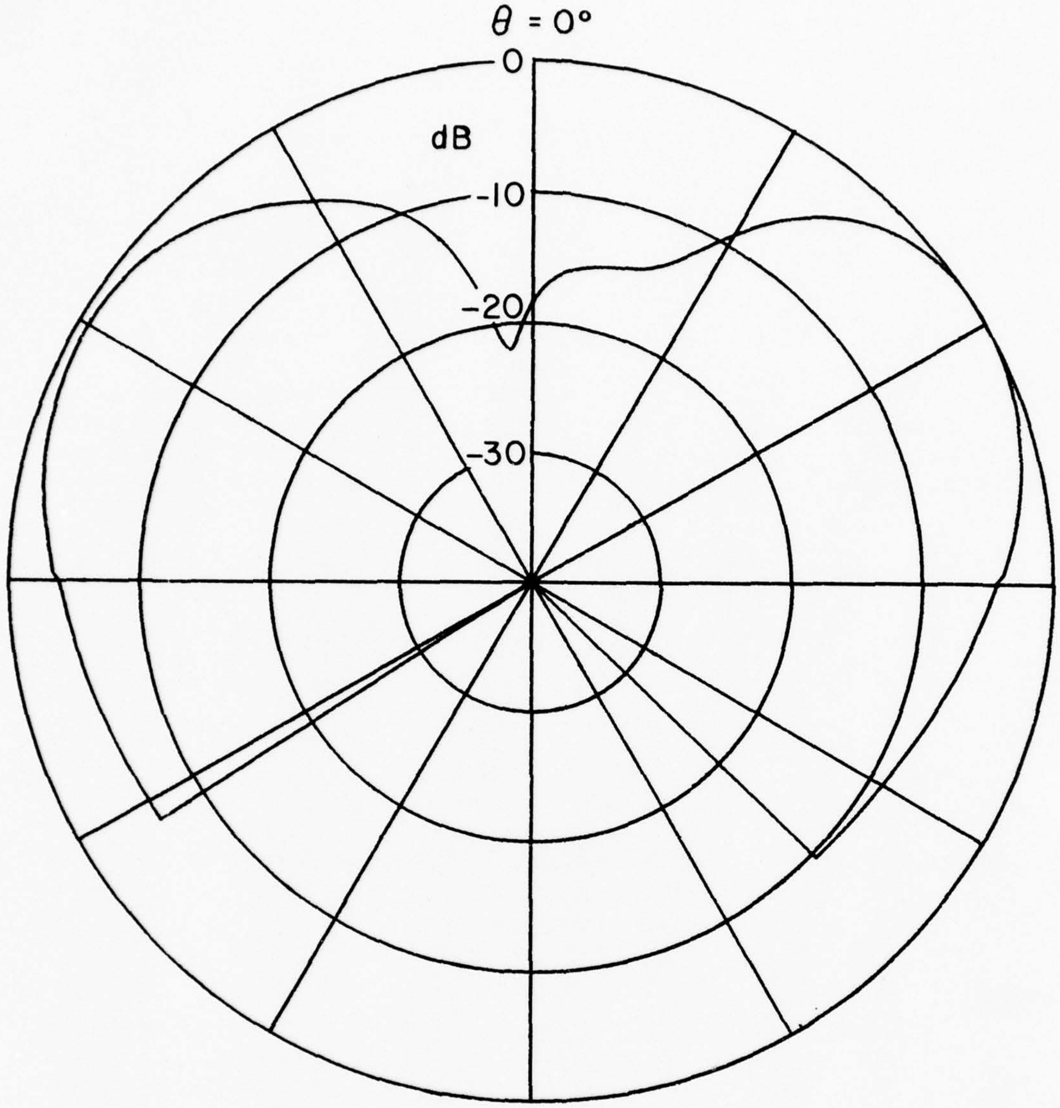


Figure 6. Pattern in the x-z plane.

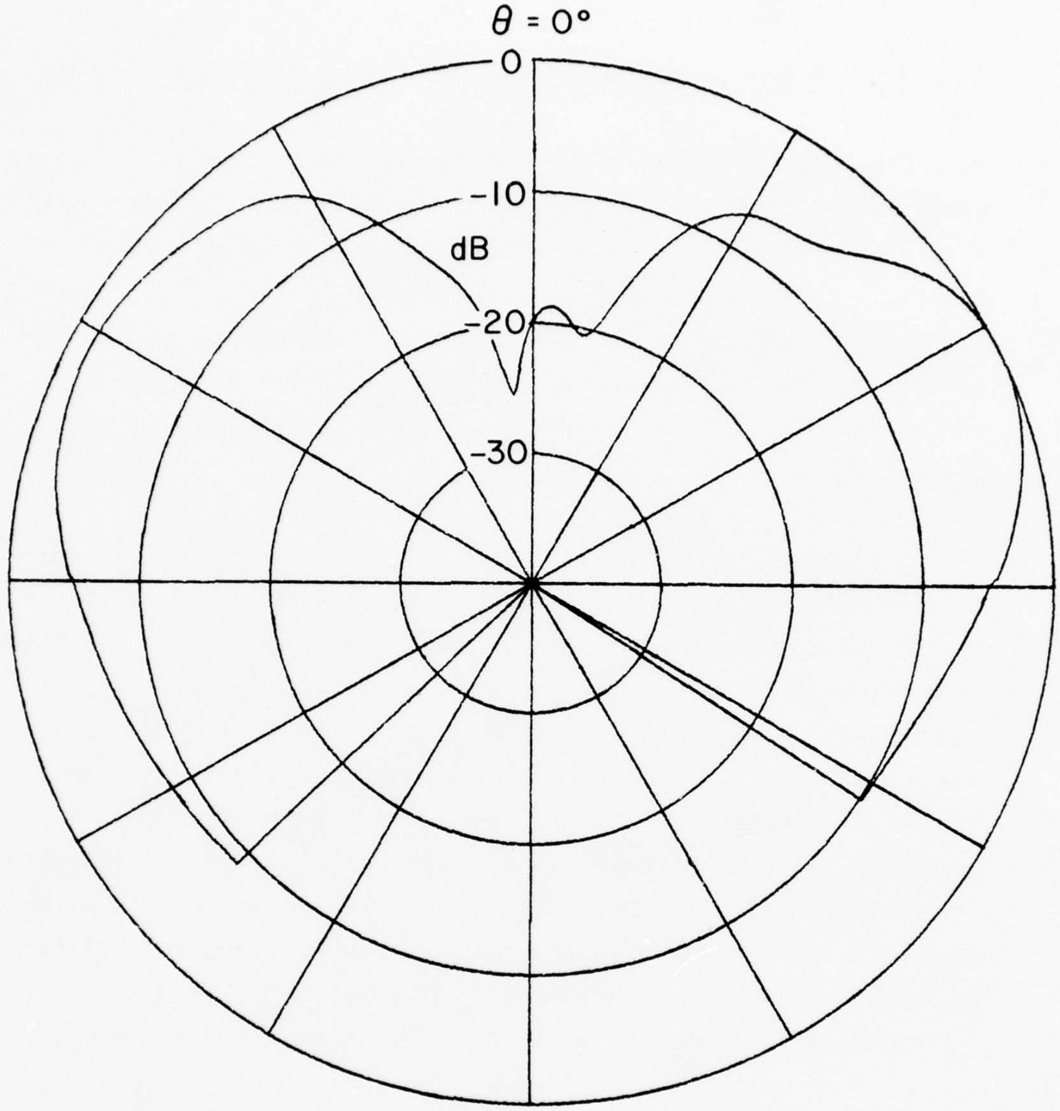


Figure 7. Pattern in the y-z plane.

B. Two Quarter Wave Monopoles on Plate 1 and Plate 2

Consider the second example where the first monopole is located as in example 1. The second monopole is at center of face 2 or at (-2λ,0.,-0.5λ) in x, y, z coordinate system as shown in Figure 1. The 2nd monopole is perpendicular to its ground plane and fed with 1.0 volt delta gap generator at ground plane end. Output file DAϕ1 resulted from this program is listed in Figure 8, where input impedances for monopole 1 and 2 are Z_{11} and Z_{22} respectively.

More importantly, the knowledge of the coupling or interference effects between wire antennas mounted on the satellite is essential in the design stage to evaluate alternative arrangements. The present program is well equipped for this purpose. For example, let us consider the case of two quarter wave monopoles mounted on plates 1 and 2 of the satellite (Figure 9). Here we wish to study the amount of interference or coupling between the two monopoles. Monopole on plate 1 is excited with a 1 volt delta-gap generator, and the program (DOAN1ϕ, 3468N) computes the complex voltage V_{12} which appears across the 50 termination of receiving monopole on plate 2. A plot of V_{12} versus distance d_2 is shown in Figure 10, where d_2 denotes the separation of the receiving monopole from the edge.

The dB plot shows a change in the slope of $|V_{12}|$ close to d_2 ~ 1.08λ, where the receiving monopole starts seeing the direct incident field from the monopole on plate 1.

INP= 70 NP= 18 INS= 65 NS= 16

J	IA(J)	IB(J)	PLATE	K	IA(K)	IB(K)	PLATE	FC(J)
1	1	3	1	9	1	11	1	.01875
2	2	4	2	10	2	12	2	.01875
3	3	5	1	11	11	13	1	.01875
4	4	6	2	12	12	14	2	.01875
5	5	7	1	13	13	15	1	.01875
6	6	8	2	14	14	16	2	.01875
7	7	9	1	15	15	17	1	.01875
8	8	10	2	16	16	18	2	.01875

I	XC(I)	YC(I)	ZC(I)	J	XC(J)	YC(J)	ZC(J)
1	0.00000	-.30000	0.00000				
2	.60000	0.00000	-.15000				
3	0.00000	-.30000	.01875	11	0.00000	-.30000	-.01875
4	.61326	0.00000	-.13674	12	.58674	0.00000	-.16326
5	0.00000	-.30000	.03750	13	0.00000	-.30000	-.03750
6	.62652	0.00000	-.12348	14	.57348	0.00000	-.17652
7	0.00000	-.30000	.05625	15	0.00000	-.30000	-.05625
8	.63977	0.00000	-.11023	16	.56023	0.00000	-.18977
9	0.00000	-.30000	.07500	17	0.00000	-.30000	-.07500
10	.65303	0.00000	-.09697	18	.54697	0.00000	-.20303

I	JA	JB	I1	I2	I3	K	JA	JB	I1	I2	I3
1	1	9	3	1	11						
2	2	10	4	2	12						
3	1	3	1	3	5	9	9	11	1	11	13
4	2	4	2	4	6	10	10	12	2	12	14
5	3	5	3	5	7	11	11	13	11	13	15
6	4	6	4	6	8	12	12	14	12	14	16
7	5	7	5	7	9	13	13	15	13	15	17
8	6	8	6	8	10	14	14	16	14	16	18

Figure 8. Output file.

```
JPP=      6      MAX=      2      MTT=      1      N=    14      NCM=      8

AL= .000100      CMP= -1.0000      FMC= 1000.00

VG(   1)   =        1.00       0.00
VG(   2)   =        1.00       0.00

   I    MAGNITUDE    PHASE          REAL          IMAGINARY
   1       .977      152.8       -.0196543        .0101365
   2      1.000      153.2       -.0202228        .0102030
   3       .926      -29.5        .0182652       -.0103135
   4       .947      -28.9        .0187630       -.0103724
   5       .730      -30.8        .0142065       -.0084571
   6       .745      -30.2        .0145883       -.0084963
   7       .417      -31.8        .0080358       -.0049792
   8       .426      -31.2        .0082450       -.0049996

FFF= 100.00   Z11=    40.15    20.66   Z22=    39.42    19.89
```

Figure 8 (Cont'd).

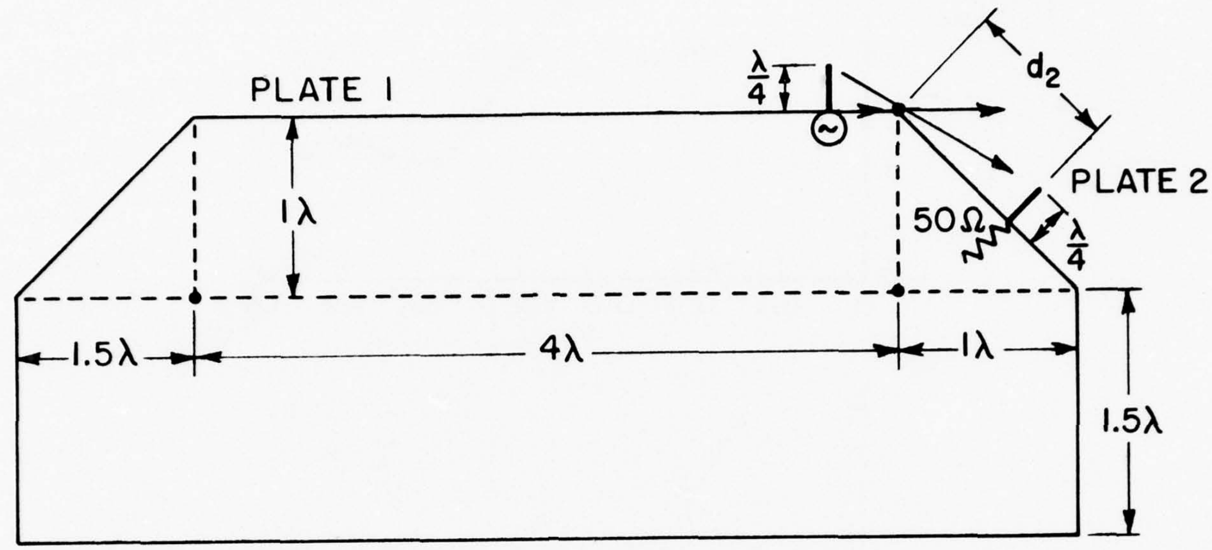


Figure 9. Satellite with a two antenna coupling problem.

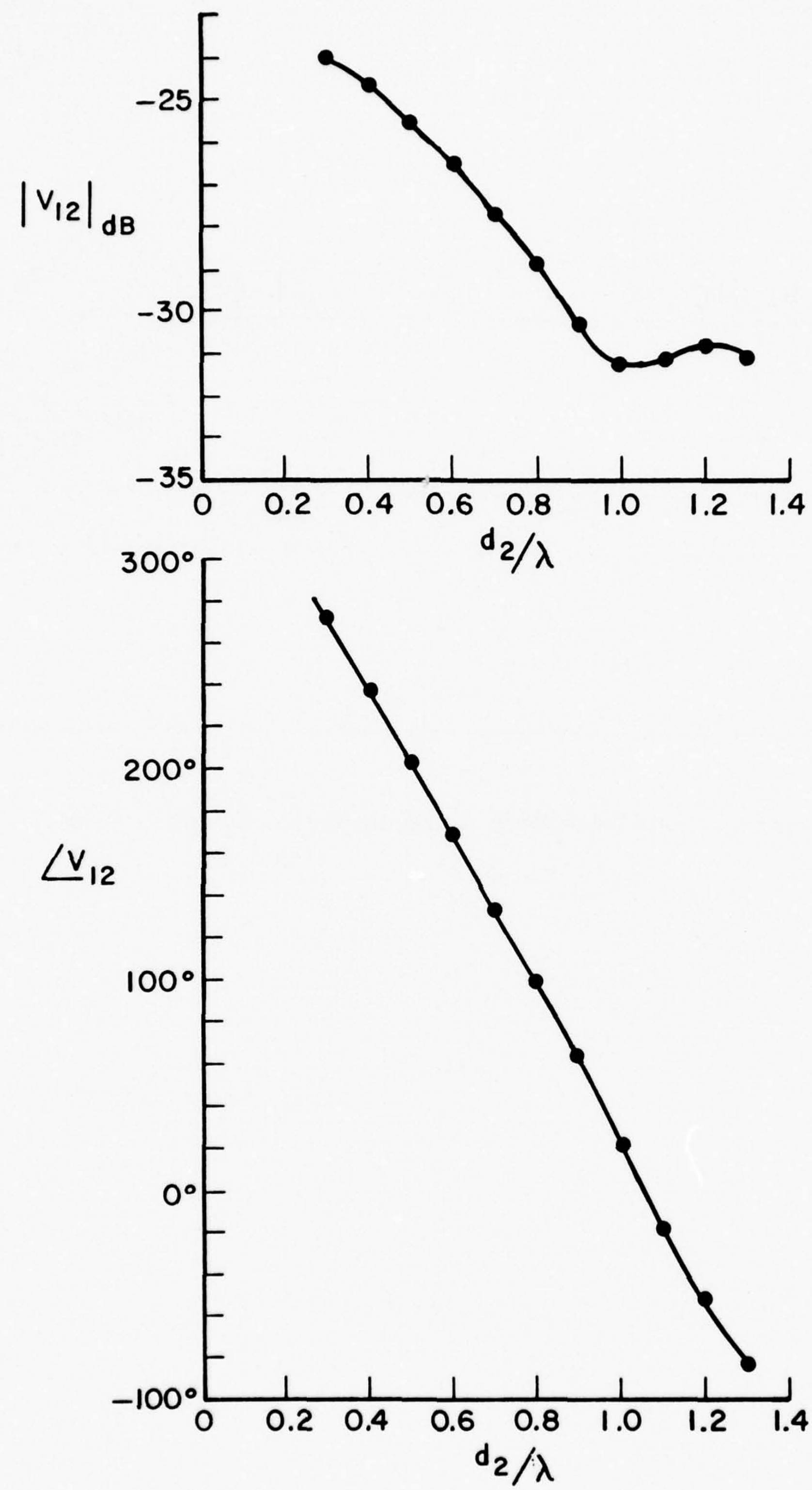


Figure 10. Coupled voltage of the configuration in Figure 9.

APPENDIX 1
SUBROUTINE CROSSP

CALL statement

CALL CROSSP (V1, V2, VN3, V3)

This subroutine computes the vector of products of V1 and V2

$$\vec{V3} = \vec{V1} \times \vec{V2}$$

$$\vec{VN3} = \frac{\vec{V3}}{|\vec{V3}|}$$ unit vector of cross product.

The listing of CROSSP is shown in Figure A.1.

```
      SUBROUTINE CROSSP(V1,V2,VN3,V3)
      DIMENSION V1(3),V2(3),VN3(3),V3(3)
      V3(1)=V1(2)*V2(3)-V1(3)*V2(2)
      V3(2)=V1(3)*V2(1)-V1(1)*V2(3)
      V3(3)=V1(1)*V2(2)-V1(2)*V2(1)
      A=SQRT((V3(1))**2+(V3(2))**2+(V3(3))**2)
      DO 1 I=1,3
      IF(ABS(A).LT.1.E-10) VN3(I)=0.
    1 IF(A.NE.0.) VN3(I)=V3(I)/A
      RETURN
      END
```

Figure A1. Subroutine CROSSP.

APPENDIX 2
SUBROUTINE HELIX

This subroutine is listed in Figure A.2. It describes the geometry of helical antennas.

CALL statement

CALL HELIX (XC,YC,ZC,IA,IB,CIRCM,ALFA,TURN,NANT,AXIS,ASTAR,NRS,NRP)

INPUT.

CIRCM:	Circumference of helix
ALFA:	Pitch angle
TURN:	Number of turns
NANT:	Number of helical antennas
AIXS(NANT,3):	Position vector of the feed point of the helical antenna NANT
ASTAR(NANT,3):	Position vector of the standing point of the helical antenna NANT (or end point of the connecting segment)

OUTPUT

XC,YC,ZC:	Coordinates of end points of all segments of the helical antennas
IA,IB:	List of index of end points
NRS:	Number of real segments
NRP:	Number of real points.

```
      SUBROUTINE HELIX(XC,YC,ZC,IA,IB,CIRM,ALFA,TURN,NART,AXIS,ASTAR
     1,NRS,NRP)
      DIMENSION XC(90),YC(90),ZC(90),IA(100),IB(100),AT(5)
      DIMENSION AXIS(5,3),ASTAR(5,3)
      DATA PI,TP/3.14159265,6.2831853/
      DT=PI/3.
      DO 1 I=1,NART
      B1=ASTAR(I,2)-AXIS(I,2)
      B2=ASTAR(I,1)-AXIS(I,1)
    1 AT(I)=ATAN2(B1,B2)
      NRP=NART
      B3=CIRM/TP
      IF(ALFA.NE.PI/2.0.OR.ALFA.NE.3.*PI/2.) B4=B3*TAN(ALFA)
      IF(ALFA.EQ.PI/2.0.OR.ALFA.EQ.3.*PI/2.) B4=B3
      M=IFIX(TURN*6.)+1
      DO 2 I=1,M
      DO 3 J=1,NART
      T=AT(J)+(I-1)*DT
      NRP=NRP+J
      XC(NRP)=AXIS(J,1)+B3*COS(T)
      YC(NRP)=AXIS(J,2)+B3*SIN(T)
      ZC(NRP)=ASTAR(J,3)+B4*(T-AT(J))
    3 CONTINUE
    2 CONTINUE
      DO 4 I=1,NART
      XC(I)=AXIS(I,1)
      YC(I)=AXIS(I,2)
    4 ZC(I)=AXIS(I,3)
      NRS=NRP-NART
      DO 5 I=1,NRS
      IA(I)=I
    5 IB(I)=I+NART
      RETURN
      END
```

Figure A2. Subroutine HELIX.

APPENDIX 3
SUBROUTINE COMED

This subroutine is listed in Figure A.3. It is used to find the plate (number) that shares corners C_1, C_2 with plate I.

CALL statement

CALL COMED (I,C1,C2,CR,NPLC,NCED,NALL,NOP,NOC)

Input:

I:	plate (number) under consideration
C1,C2:	position vectors of corners C1, C2. Dimension C1(3),C2(3)
CR:	List of position vectors of corners. Dimension CR(NOC,3), where the first parameter NOC is the corner index.
NPLC:	List of corner indices. Each corner index carries two parameter NPLC (NOP,J) where NOP is the plate index and J is the integer 1, 2, 3 or 4 assigned to each corner of the 4-corner plate.
NALL>0:	check out all plates (NALL plates)
NALL<0:	check only the plates with index number smaller than I
NOP:	total number of plates.

Output:

NCED>0	plate having index NCED shares corners C_1,C_2 with plate I
NCED<0:	no plate shares corners C_1,C_2 with plate I.

```
C
C*****   CHECK IF ANY PLATES SHARING CORNERS C1&C2 WITH PLATE J
C*****   INPUT: J,C1,C2,CR,NPLC,NALL
C*****   OUTPUT: CED
C*****   J: THE # OF THE PLATE WITH CORNERS C1&C2
C*****   MCED> 0. --- THERE IS A PLATE SHARING CORNERS C1&C2
C*****                & MCED REPPSENTS THE # OF THE PLATE
C*****                SHARING C1&C2 WITH PLATE J
C*****   MCED< 0. --- THERE IS NO PLATE SHARING CORNERS C1&C2
C*****   NALL> 0 --- CHECK OUT ALL THE POSSIBLE PLATES SHARING
C*****                THE  TWO CORNERS
C*****   NALL< 0 --- CHECK ONLY THE PLATES WITH PLATE # SMALLER
C*****               THAN THE  CURRENT PLATE #
C
      SUBROUTINE COMED(J,C1,C2,CR,NPLC,MCED,NALL,NOP,NOC)
      DIMENSION CR(NOC,3),NPLC(NOP,4),C1(3),C2(3),CK(3)
      MCED=-1
      IF(NALL.LT.0) L1=J-1
      IF(NALL.GT.0) L1=NALL
      DO 1 I1=1,L1
      IF(I1.EQ.J) GO TO 1
      I=0
      DO 2 I2=1,4
      L2=NPLC(I1,I2)
      DO 3 I3=1,3
    3 CK(I3)=CR(L2,I3)
      DO 4 I4=1,2
      IF(I4.EQ.2) GO TO 7
      DO 5 I5=1,3
    5 IF(C1(I5).NE.CK(I5)) GO TO 4
      GO TO 9
    7 DO 6 I6=1,3
    6 IF(C2(I6).NE.CK(I6)) GO TO 4
    9 I=I+1
      IF(I.EQ.2) MCED=I1
      IF(I.EQ.2) GO TO 10
    4 CONTINUE
    2 CONTINUE
    1 CONTINUE
   10 RETURN
      END
```

Figure A3. Subroutine COMED.

APPENDIX 4
SUBROUTINE IMAGE

This subroutine is listed in Figure A4. Subroutine IMAGE finds the position vector RI(3) of the image of a source vector RS(3) projected on the plate (number) I.

CALL statement

CALL IMAGE (RS,RI,I,NIMA,VNP,NPLC,CR,NOP,NOC)

Input:

I:	plate under consideration
RS:	position vector of source point
VNP:	list of unit vectors normal to plate I.
NPLC:	list of corner indices.
CR:	list of position vectors of corners
NOP:	total number of plates.
NOC:	total number of corners.

Output:

RI:	position vector of image point
NIMA:	image indicator
	NIMA>0 image exists and distinct from source
	NIMA<0 source is on the plate, RS=RI.

```
      SUBROUTINE IMAGE(RS,RI,J1,NIMA,VNP,NPLC,CR,NOP,NOC)
      DIMENSION RS(3),RI(3),VNP(NOP,3),NPLC(NOP,4),CR(NOC,3)
      NIMA=1
      J=NPLC(J1,1)
      A=0.
      DO 1 I1=1,3
    1 A=A+(RS(I1)-CR(J,I1))*VNP(J1,I1)
      IF(ABS(A).LT.1.E-10) NIMA=-1
      IF(ABS(A).LT.1.E-10) A=0.
      DO 3 I3=1,3
    3 RI(I3)=RS(I3)-2.*A*VNP(J1,I3)
    4 RETURN
      END
```

Figure A4. Subroutine IMAGE.

APPENDIX 5

SUBROUTINE REGION

This subroutine is listed in Figure A.5. Given a source point RRS and an observation point RRO, subroutine REGION will check if any plate is blocking the ray path. A plate does not block the ray path if either the source point or the observation point is on the plate.

CALL statement:

CALL REGION (RRS,RRO,RRT,CR,VNP,NN1,NN2,TELL,NPLC,NFAR,NALL,MM,
    NOP,NOC)

Input: Position vectors of source point and observation point respectively.

CR: List of position vectors of corners

VNP: List of unit vectors normal to the plates

NN1,NN2: Blocking check of plates NN1, NN2 not required. If want to check blocking by all plates, set NN1, NN2 to negative integers.

NPLC: List of corner indices

NFAR: Far field indicator. For observation point in the far field NFAR>0

NALL: Number of plates that may block the ray path (usually NALL=NOP)

NOP: Total number of plates on structure

NOC: Total number of corners on structure

Output:

RRT(3): Position vector of point of intersection

MM: The plate (number) that first blocks the ray.

TELL: Blocking indicator

TELL=.TRUE.: A plate is blocking

TELL=.FALSE. No plate is blocking the ray.

Subroutine called is CROSSP.

```
      SUBROUTINE REGION(RRS,RRO,RPT,CR,VNP,NN1,NN2,TELL,NPLC
     A,NFAR,NALL,NA,NOP,NOC)
      LOGICAL TELL
      DIMENSION RRO(3),RRS(3),CR(NOC,3),VNP(NOP,3),RPT(3),VE1(3),VE2(3)
      DIMENSION VE3(3),VS(3),NPLC(NOP,4),D(3)
      PI=3.14159265
      TELL=.FALSE.
      DO 12 N=1,NALL
C**** IF PLATE IS NN1 OR NN2 DO NOT CHECK
      IF(N.EQ.NN1.OR.N.EQ.NN2) GO TO 12
      L=NPLC(N,1)
      A=0.
      B=0.
      DO 2 I2=1,3
      A=A+(RRS(I2)-CR(L,I2))*VNP(N,I2)
      IF(NFAR.GE.0) B=B+RRO(I2)*VNP(N,I2)
    2 IF(NFAR.LT.0) B=B+(RRO(I2)-CR(L,I2))*VNP(N,I2)
CA    WRITE(6,-) N,A,B
C****
      IF(ABS(A).LT.1.E-10) A=0.
      IF(ABS(B).LT.1.E-10) B=0.
CA    WRITE(6,-)N,A,B
C**** A*B GE 0..S AND O ON SAME SIDE OF PLATE
      IF(A*B.GE.0) GO TO 12
      IF(NFAR.GE.0) GO TO 4
      E=0.
      DO 5 I5=1,3
      D(I5)=RRO(I5)-RRS(I5)
    5 E=E+(D(I5))**2
      E=SQRT(E)
    4 DO 6 I6=1,3
      IF(NFAR.GE.0) D(I6)=RRO(I6)
    6 IF(NFAR.LT.0) D(I6)=D(I6)/E
      C=0.
      DO 7 I7=1,3
    7 C=C+D(I7)*VNP(N,I7)
      DO 8 I8=1,3
    8 RPT(I8)=RRS(I8)-A*D(I8)/C
CA    WRITE(6,14) (RPT(I),I=1,3)
      E=0.
      DO 9 I9=1,4
      C=0.
      A1=0.
      A2=0.
      J=I9+1
      IF(I9.EQ.4) J=1
      J1=NPLC(N,I9)
      J2=NPLC(N,J)
CA    WRITE(6,-) I9,J,J1,J2
```

Figure A5. Subroutine REGION.

```
      DO 10 I10=1,3
      VE1(I10)=CP(J1,I10)-PRT(I10)
      VE2(I10)=CP(J2,I10)-PRT(I10)
      A1=A1+(VE1(I10))**2
      A2=A2+(VE2(I10))**2
   10 C=C+VE1(I10)*VE2(I10)
      A1=SQRT(A1)
      A2=SQRT(A2)
      IF(A1.LT.1.E-06.OR.A2.LT.1.E-06) GO TO 15
      CALL CROSSP(VE1,VE2,VN3,V3)
CA    WRITE(6,14) (VE1(I),I=1,3)
CA    WRITE(6,14) (VE2(I),I=1,3)
CA    WRITE(6,14) (CP(J1,I),I=1,3)
CA    WRITE(6,14) (CP(J2,I),I=1,3)
CA    WRITE(6,14) (VN3(I),I=1,3)
CA    WRITE(6,14) (V3(I),I=1,3)
      H=0.
      DO 11 I11=1,3
   11 H=H+V3(I11)*VNP(N,I11)
      F1=ATAN2(H,C)
      IF(PI-ABS(F1).LT.1.E-06) GO TO 17
      F=F+F1
CA    WRITE(6,*) F1,C,H
    9 CONTINUE
   14 FORMAT(3E15.5)
CA    WRITE(6,*)F
      IF(ABS(F).LT.PI) GO TO 12
      GO TO 13
   15 CONTINUE
CA    WRITE(6,16) J1,J2
CA    WRITE(6,19) A1,A2
   16 FORMAT(/'INTERSECTION PT COINCIDES WITH CORNER',I4,' OR',I4)
   19 FORMAT(/'A1=',F15.5,' A2=',E15.5)
     &' A2=',F15.5)
      GO TO 13
   17 CONTINUE
CA    WRITE(6,18) J1,J2
   18 FORMAT(/'INTERSECTION POINT IS ON THE EDGE DEFINED BY CORNERS'
     &,I4,' &',I4)
   13 MM=N
      TELL=.TRUE.
      GO TO 3
   12 CONTINUE
    3 RETURN
      END
```

Figure A5 (Cont'd).

APPENDIX 6
SUBROUTINE DIFPT

This subroutine is listed in Figure A.6. Given a source point RS and a near-zone observation point RO, subroutine DIFPT finds the position of the diffraction point on the edge (wedge) following the procedure described in reference 1.

CALL statement:

```
CALL DIFPT (RS,RO,C1,C2,VNN,SP,S,ANI,RD,VI,IDX,VPHNS,VPHND,VBNS,
        VBND,PHS,PHD,BN,E)
```

Input:

RS(3),RO(3):	Position vectors of source point and near-field observation point respectively.
C1(3),C2(3):	Position vectors of corners C1, C2 defining the edge
VNN(3):	Unit vector normal to the plate, $\hat{n}$.

Output:

RD(3):	Position vector of diffraction point Q
SP:	Distance between source and diffraction point in meters.
S:	Distance between observation point and diffraction point in meters.
ANI:	Angle of incidence w.r.t. the edge in radians
VI(3);	Unit vector along incident ray from source to diffraction point
IDX:	Edge diffraction indicator IDX<0 no diffraction by the edge, vice versa
VPHNS(3),VPHND(3)	$\hat{\beta}'$, $\hat{\beta}$ unit vectors (see accompanying Figure, Figure 11)
VBNS(3),VBND(3):	$\hat{\phi}'$, $\hat{\phi}$ unit vectors
PHS,PHD:	ϕ', ϕ angles in degrees.
E(3):	Unit vector along edge: from corner C1 to C2, $\hat{E}$.
BN(3):	BN=VNNxE, unit vector perpendicular to the edge, $\hat{B}$.

Subroutine called is CROSSP.

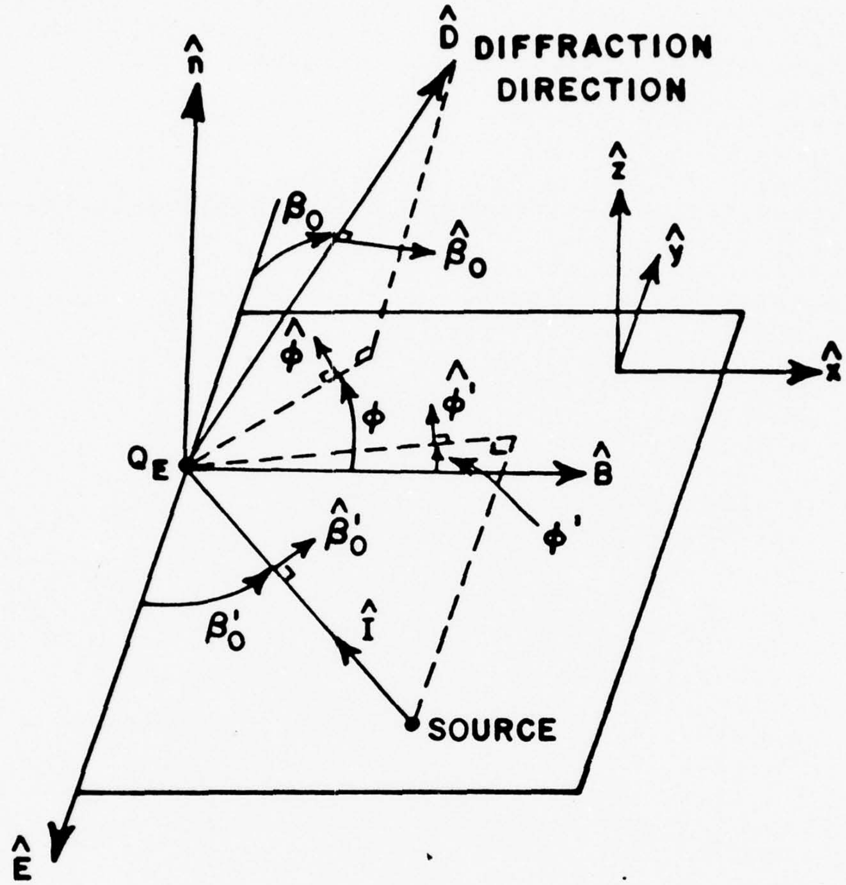


Figure 11. Unit vectors for ray-fixed coordinate system.

```
      SUBROUTINE DIFPT(RS,RO,C1,C2,VNN,SP,S,ANI,RD,VI ,IDX,
     1VPENS,VPEND,VBNS,VBND,PHS,PHD,BN,E)
      DIMENSION RS(3),RO(3),C1(3),C2(3),RD(3),RP(3),RQ(3),E(3)
      DIMENSION VPENS(3),VPEND(3),VBNS(3),VBND(3),VI(3),VD(3)
      DIMENSION VPN(3),VN(3),BN(3),B(3),VBS(3),VBD(3)
      DATA PI,TP/3.141592654,6.283185308/
      W=0.
      G=0.
      Q1=0.
      Q2=0.
      F=SQRT((C2(1)-C1(1))**2+(C2(2)-C1(2))**2+(C2(3)-C1(3))**2)
      DO 1 I=1,3
      E(I)=(C2(I)-C1(I))/F
      Q1=Q1+(C1(I)-RS(I))**2
      Q2=Q2+(C2(I)-RS(I))**2
      Q3=(C1(I)-RS(I))*E(I)
    1 G=G+(RS(I)-C2(I))*E(I)
      Q1=SQRT(Q1)
      Q2=SQRT(Q2)
      DO 2 I=1,3
      RQ(I)=C2(I)+G*E(I)
    2 W=W+(RO(I)-RS(I))*E(I)
      H=0.
      G=0.
      DO 3 I=1,3
      RP(I)=RQ(I)+W*E(I)
      H=H+(RS(I)-RQ(I))**2
    3 G=G+(RO(I)-RP(I))**2
      IF(ABS(G).LT.1.E-10.OR.ABS(H).LT.1.E-10)GO TO 5
      H=SQRT(H)
      G=SQRT(G)
      V=(W*G)/(G+H)
      ANI=ATAN2(G,ABS(V))
      SP=0.
      S=0.
      DO 4 I=1,3
      RD(I)=RP(I)-V*E(I)
      VI(I)=RD(I)-RS(I)
      VD(I)=RO(I)-RD(I)
      SP=SP+(VI(I))**2
    4 S=S+(VD(I))**2
      SP=SQRT(SP)
      S=SQRT(S)
      P=0.
      DO 6 I=1,3
      VI(I)=VI(I)/SP
      VD(I)=VD(I)/S
    6 P=P+VD(I)*E(I)
      Q3=Q3/Q1
```

Figure A6. Subroutine DIFPT.

```
      Q4=-Q/Q2
      IF(P.GT.Q3.AND.P.GT.Q4) GO TO 5
      IF(P.LT.Q3.AND.P.LT.Q4) GO TO 5
      CALL CROSSF(VNN,E,BN,B)
      P1=0.
      P2=0.
      P3=0.
      P4=0.
      DO 10 I=1,3
      P1=P1-VI(I)*VNN(I)
      P2=P2-VI(I)*BN(I)
      P3=P3+VO(I)*VNN(I)
   10 P4=P4+VO(I)*BN(I)
      PHS=ATAN2(P1,P2)
      PHD=ATAN2(P3,P4)
      IF(PHS.LT.0.) PHS=TP+PHS
      IF(PHD.LT.0.) PHD=PHD+TP
      DO 11 I=1,3
      VPHNS(I)=COS(PHS)*VNN(I)-SIN(PHS)*BN(I)
   11 VPHND(I)=COS(PHD)*VNN(I)-SIN(PHD)*BN(I)
      CALL CROSSF(VPHNS,VI,VBNS,VBS)
      CALL CROSSF(VPHND,VO,VBND,VBD)
      IDX=1
      GOTO 12
    5 IDX=-1
   12 RETURN
      END
```

Figure A6 (Cont'd).

APPENDIX 7
SUBROUTINE DIFPTF

This subroutine is listed in Figure A.7. Given a source point RS and a far-zone unit vector RO, subroutine DIFPTF finds the position vector of the diffraction point RD, if any, on the edge defined by corner C1 and C2. Relevant expressions are described in Reference 1.

CALL Statement:

```
CALL DIFPTF (RS,C1,C2,VNN,RO,SP,ANI,RD,IDX,VPHNS,VPHNS,VBNS, VBND,
        PHS,PHD,BN,E)
```

Input:

RS(3),RO(3):	Position vectors of source point and far-zone unit vector
C1(3),C2(3):	Position vectors of 2 corners defining the edge
VNN(3):	Unit vector normal to the plate

Output:

RD(3):	Position vector of the diffraction point on the edge.
SP:	Distance between source and diffraction point in meters.
ANI:	Angle of incidence w.r.t. the edge in radians
IDX:	Edge diffraction indicator; IDX<0, no diffraction by the edge, vice versa.
VPHNS(3),VPHND(3);	$\hat{\phi}',\hat{\phi}$
VBNS(3),VBND(3);	$\hat{\beta}',\hat{\beta}$
PHS,PHD:	ϕ',ϕ
BN(3):	BN=VNNxE; also a unit vector perpendicular to the edge.
E(3):	Unit vector directing along the edge from corner C_1 to C_2.

```
      SUBROUTINE DIFPTF(RS,C1,C2,VNN,VD,VI,SP,ANI,RD,IDX,VPHNS
     &,VPHND,VBNS,VBND,PHS,PHD,BN,F)
      DIMENSION RS(3),C1(3),C2(3),RD(3),RQ(3),E(3)
      DIMENSION VPHNS(3),VPHND(3),VBNS(3),VBND(3),VI(3),VD(3)
      DIMENSION VNN(3),VD3(3),V3(3),BN(3),P(3),VBS(3),VBD(3)
      DATA PI,TPI/3.141592654,6.283185308/
      Q=0.
      B2=0.
      F=SQRT((C2(1)-C1(1))**2+(C2(2)-C1(2))**2+(C2(3)-C1(3))**2)
      DO 1 I=1,3
      E(I)=(C2(I)-C1(I))/F
      B2=B2+(RS(I)-C1(I))**2
    1 Q=Q+(RS(I)-C1(I))*E(I)
      B2=SQRT(B2)
      CALL CROSSP(VD,E,VD3,V3)
      H=0.
      P=0.
      PP=0.
      DO 2 I=1,3
      H=H+(RS(I)-C1(I)-Q*E(I))**2
      RQ(I)=C1(I)+Q*E(I)
      P=P+VD(I)*E(I)
    2 PP=PP+V3(I)*VD3(I)
      IF(ABS(H).LT.1.E-10) GO TO 5
      H=SQRT(H)
      IF(ABS(PP).LT.1.E-10)GO TO 5
      ANI=ATAN2(PP,P)
      W=H*COS(ANI)/SIN(ANI)
      B1=0.
      B3=0.
      SP=0.
      DO 3 I=1,3
      RD(I)=RQ(I)+W*E(I)
      VI(I)=RD(I)-RS(I)
      B1=B1+(C2(I)-RS(I))*E(I)
      B3=B3+(C2(I)-RS(I))**2
    3 SP=SP+(VI(I))**2
      IF(SP.EQ.0.) GO TO 5
      SP=SQRT(SP)
      B3=SQRT(B3)
      IF(ANI.LT.0.) ANI=ABS(ANI)
      B1=B1/B3
      B4=-Q/B2
      IF(P.GT.B1.AND.P.GT.B4) GO TO 5
      IF(P.LT.B1.AND.P.LT.B4) GO TO 5
      DO 6 I=1,3
    6 VI(I)=VI(I)/SP
      CALL CROSSP(VNN,E,BN,B)
      B1=0.
```

Figure A7. Subroutine DIFPTF.

```
          P2=0.
          P3=0.
          P4=0.
          DO 10 I=1,3
          P1=P1-VI(I)*VNN(I)
          P2=P2-VI(I)*BN(I)
          P3=P3+VO(I)*VNN(I)
    10    P4=P4+VO(I)*BN(I)
          PHS=ATAN2(P1,P2)
          PHO=ATAN2(P3,P4)
          IF(PHS.LT.0.) PHS=TP+PHS
          IF(PHO.LT.0.) PHO=TP+PHO
CA        PHO1=PHO*180./PI
CA        PHS1=PHS*180./PI
CA        WRITE(6,13)PHS1,PHO1
    13    FORMAT(3X,4E15.5)
          DO 11 I=1,3
          VPHNS(I)=COS(PHS)*VNN(I)-SIN(PHS)*BN(I)
    11    VPHNO(I)=COS(PHO)*VNN(I)-SIN(PHO)*BN(I)
          CALL CROSSP(VPHNS,VI,VBNS,VBS)
          CALL CROSSP(VPHNO,VO,VBNO,VBO)
          IDX=1
          GOTO 12
    5     IDX=-1
    12    RETURN
          END
```

Figure A7 (Cont'd).

APPENDIX 8
SUBROUTINE WEDIFF

Subroutine WEDIFF is listed in Figure A-8. Given a source point RS and an observation point RO in the far-field (NFAR>0) or near-field zone (NFAR<0), subroutine WEDIFF generates relevant parameters for the computation of the diffracted field in the presence of the edge defined by corners C1 and C2.

CALL statement:

```
CALL WEDIFF (RS,C1,C2,RO,RD,IPL,NFAR,AM,WAVM,NCM,VNP,CR,NPLC,NOP,
        NOC,VBNS,VPHNS,CONS1,VB2,VB2,IDIF,VBND,VPHND)
```

Input:

RS(3),RO(3):	Position vectors of source point and observation point
IPL:	Plate under consideration
NFAR:	Far field indicator
AM:	Wire radius in meter
WAVM:	Wavelength in meter
NCM:	Size of the compressed matrix
VNP:	List of unit vectors normal to the plates
CR:	List of position vectors of corners
NPLC:	List of corner index
NOP:	Number of plates
NOC:	Number of corners
C1,C2:	Corners C1 and C2 defining the edge

Output:

VBNS(3),VPHNS(3):	Unit vectors $\hat{\beta}'$,$\hat{\phi}'$ (Figure 11)
VBND(3),VPHND(3):	Unit vectors $\hat{\beta}'$,$\hat{\phi}$ (Figure 11)
IDIF:	Diffraction indicator

CONS1: Diffraction coefficient

VB1,VB2: $V_B(L,\beta^-,n)$, $V_B(L,\beta^+,n)$; $\beta^{\pm}=\phi\pm\phi'$

such that

$$E_{\parallel}^{d} = -(VB1-VB2)*E_{\parallel}^{i}*CONS1$$
$$E_{\perp}^{d} = -(VB1+VB2)*E_{\perp}^{i}*CONS1$$

Phase of $E_{\parallel}^{d}$ and $E_{\perp}^{d}$ is referred to origin of coordinate system when NFAR>0, to source point when NFAR<0. Subroutines called DIFPT, REGION,DIFPTF,COMED,CROSSP.

```
C**WEDGE DIFFRACTION
      SUBROUTINE WEDIFF(RS,C1,C2,RO,RD,IPL,NFAR,AM,WAVM,NCM,VNP,
     &CR,NPLC,NOP,NOC,VENS,VPENS,CONS1,VB1,VB2,IDIF,
     &VPHND,VPHNE)
      LOGICAL TELL
      DIMENSION VNP(NOP,3),NPLC(NOP,4),CR(NOC,3),VNN(3),VN(3)
      DIMENSION RRT(3),RS(3),RO(3),C1(3),C2(3),RD(3),VI(3)
      DIMENSION VEHNS(3),VEHND(3),VBNS(3),VBND(3),BN(3),E(3),
     &EDN2(3),BN2(3),V3(3),VN3(3)
      COMPLEX VB1,VB2,CONS1
      DATA TP/6.2831853/,PI/3.1415926 5/
      DO 31 I31=1,3
   31 VNN(I31)=VNP(IPL,I31)
      TPL=TP/WAVM
      IDIF=1
      RTD=180./PI
      IF(NFAR.GT.0) GO TO 40
      CALL DIFPT(RS,RO,C1,C2,VNN,SP,S,ANI,RD,VI,IDX,VPHNS,
     &VPHND,VBNS,VBND,PHS,PHD,BN,E)
      IF(IDX.EQ.-1) GO TO 22
      CALL REGION(RS,RD,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,
     &MM,NOP,NOC)
      IF(TELL) GO TO 22
      CALL REGION(RD,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,
     &MM,NOP,NOC)
      IF(TELL) GO TO 22
      GO TO 42
   40 CALL DIFPTF(RS,C1,C2,VNN,RO,VI,SF,ANI,RD,IDX,VPHNS,
     &VPHND,VBNS,VBND,PHS,PHD,BN,E)
      IF(IDX.EQ.-1) GO TO 22
      CALL REGION(RS,RD,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP
     &,MM,NOP,NOC)
      IF(TELL) GO TO 22
      CALL REGION(RD,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,1,NOP,
     &MM,NOP,NOC)
      IF(TELL) GO TO 22
C** CALCULATE WEDGW ANGLE
   42 CALL COMED(IPL,C1,C2,CR,NPLC,NCED,NOP,NOP,NOC)
      IF(NCED-0)34,34,35
   34 AN=2.
      GO TO 36
   35 DO 37 I37=1,3
      EDN2(I37)=-E(I37)
   37 VN(I37)=VNP(NCED,I37)
      CALL CROSSP(VN,EDN2,BN2,V3)
      CALL CROSSP(BN,BN2,VN3,V3)
      AA1=0.
      AA2=0.
      DO 38 I38=1,3
```

Figure A8. Subroutine WEDIFF.

```
      AA1=AA1+BN(I38)*BN2(I38)
38    AA2=AA2+V3(I38)*V4(I38)
      WN=2.-ABS(ATAN2(AA2,AA1))/PI
36    A1=(PHP-PHS)*RTD
      A2=(PHP+PHS)*RTD
      IF(NFAR.GT.0) GO TO 39
      ALWL=SP*S*(SIN(ANI))**2/((SP+S)*WAVM)
      GO TO 40
39    ALWL=SP*(SIN(ANI))**2/WAVM
40    CALL VB(RVB,TVB,ALWL,A1,WN)
      VB1=CMPLX(RVB,TVB)
      CALL VB(RVB,TVB,ALWL,A2,WN)
      VB2=CMPLX(RVB,TVB)
      A3=0.
      DO 17 I17=1,3
17    A3=A3+(RO(I17))*RO(I17)
      IF(NFAR.GT.0) GO TO 23
      CONS1=(SP/(SP+S))*CEXP(CMPLX(0.,TP*(ALWL-S/WAVM)))
      GO TO 21
23    CONS1=(SP)*CEXP(CMPLX(0.,TPI*(SP*(SIN(ANI))**2+A3)))
      GO TO 21
22    IETF=1
21    RETURN
      END
```

Figure A8 (Cont'd).

APPENDIX 9
SUBROUTINE CSORT

This subroutine is listed in Figure A.9. It is used to set up the image points and image segments, generate ID indices for these points and segments, derive the size of the compressed impedance matrix, set up the modes and provide a list of modes MD(J,K) and a list of dipoles ND(J) sharing segment J. Basically CSORT is a modified version of subroutine ISORT in reference 2 to deal with wire antennas on different plates of the satellite structure. Input data for the satellite structure are entered through the last seven parameters in the CALL statement, namely VNP,NPLC,CR,NOP,NOC, IDSEG,IDPT. Output parameters are NCM,IDSEG,MD,N,DC,I1,I2,I3,IA(K), IB(K),XC(I),YC(I),ZC(I).

CALL statement:

CALL CSORT (IA,IB,ICC,ICJ,INS,IWRITE,I2,I2,I3,JA,JB,MAX,MIN,MD,N, NCM,ND,NP,NS,NRP,NRS,NPGP,NSGP,DC,XC,YC,ZC,VNP,NPLC,RC,NOP,NOC,IDSEG, IDPT)

The above parameters are defined as follows:

<u>Variables</u>

Input:

IA(J),IB(J):	End points index of segment J extending from A to B
ICC:	Dimension relating to matrix C(I,J)
ICJ:	Dimensions relating to the number of dipole modes N
INP:	Dimension relating to the number of points NP
INS:	Dimension relating to the number of segments NS

XC,YC,ZC:	Coordinates of real points in meters
NRP:	Number of real points
NRS:	Number of real segments
NPGP:	number of points touching the ground plane (plates)
NSGP:	Number of segments with end points on the plates
NP:	Number of points for the complete antenna system
NS:	Number of segments for the complete antenna system
VNP,NPLC,CR,NOP,NOP:	Parameters relating to satellite structure as defined previously

Output:

NCM:	Size of the compressed matrix
ND(J):	List of dipoles sharing segment J
MD(J,K):	List of dipole modes sharing segment J
N:	Number of dipole modes of the complete system
I_1,I_2,I_3:	Terminal point I_2, end points I_1, I_3 of dipole modes
XC,YC,ZC:	Coordinates of imaginary and real points
IA,IA:	End points of real and imaginary segments
JA,JB:	Segment number for each dipole mode
DC:	Segment length in meters
IDSEG(K);	Plate that accomodates segment K
IDPT(I):	Plate that relates to endpoint I

Subroutine called IMAGE.

Output:

NCM:	Size of the compressed matrix
ND(J):	List of dipoles sharing segment J
MD(J,K):	List of dipole mode sharing segment J
<N>	Number of dipole modes of the complete system
I_1, I_2, I_3:	Terminal point I_2, end points I_1, I_3 of dipole modes
XC,YC,ZC:	Coordinates of imaginary and real points
IA,IA:	End points of real and imaginary segments
JA,JB:	Segment number for each dipole mode
DC:	Segment length in meters
IDSEG(K);	Plate that accomodates segment K
IDPT(I):	Plate that relates to endpoint I

Subroutine called IMAGE.

```
      OPTIONS 32K
      SUBROUTINE CSORT(IA,IB,ICC,ICJ,IDS,IWRITE,I1,I2,I3,JA,JB,
     &MAX,MIN,MP,M,NCM,ND,NP,NS,NRP,NRS,NPGP,NSGP,DC,XC,YC,ZC,
     &VHP,HPLC,CR,NOP,NOC,IDSEG,IDPT)
      DIMENSION JSP(20),DC(1),XC(1),YC(1),ZC(1)
      DIMENSION I1(1),I2(1),I3(1),JA(1),JB(1)
      DIMENSION VHP(NOP,3),HPLC(NOP,4),CR(NOC,3),PS(3),PI(3),IDSEG(65)
      DIMENSION IDPT(70)
      DIMENSION IA(1),IB(1),ND(1),MO(INS,4)
    1 FORMAT(5X,'J',1X,'IA(J)',1X,'IB(J)',3X,'PLATE',4X,'K',
     &1X,'IA(K)',1X,'IB(K)',1X,'PLATE',1X,'DC(J)')
    2 FORMAT(1X,3I5,T9,I6,2I5,T6,2F10.5)
    3 FORMAT(1X,I15,3F10.5,I15,3F10.5)
    4 FORMAT(1X,FI5,1I15,6I5)
    5 FORMAT(1H0)
    6 FORMAT(5X,'I',4X,'XC(I)',5X,'YC(I)',5X,'ZC(I)',
     &5X,'J',4X,'XC(J)',5X,'YC(J)',5X,'ZC(J)')
    7 FORMAT(5X,'I',3X,'JA',3X,'JB',5X,'I1',3X,'I2',3X,'I3',
     &14X,'K',3X,'JA',3X,'JB',3X,'I1',3X,'I2',3X,'I3')
      IGPP=NPGP+1
      NPT=NRP-NPGP
C     NEXT SET UP THE IMAGE SEGMENTS
      DO 18 J=1,NRS
      K=J+NRS
      IA(K)=IA(J)
      IF(IA(J).GT.NPGP)IA(K)=IA(J)+NPT
      IB(K)=IB(J)
   18 IF(IB(J).GT.NPGP)IB(K)=IB(J)+NPT
C     NEXT SET UP THE IMAGE POINTS
      DO 20 I=IGPP,NRP
      J=I+NPT
      PS(1)=XC(I)
      PS(2)=YC(I)
      PS(3)=ZC(I)
      IDPTI=IDPT(I)
      CALL IMAGE(PS,PI,IDPTI,NTNA,VHP,HPLC,CR,NOP,NOC)
      XC(J)=PI(1)
      YC(J)=PI(2)
      ZC(J)=PI(3)
   20 IDPT(J)=IDPT(I)
      DO 21 I=1,NRS
      IAI=IA(I)
   21 IDSEG(I)=IDPT(IAI)
C     NEXT CALCULATE THE SEGMENT LENGTHS DC(J)
      IF(IWRITE.LE.0)GO TO 22
      WRITE(6,5)
      WRITE(6,1)
   22 DO 25 J=1,NRS
      K=IA(J)
      L=IB(J)
      DX=XC(K)-XC(L)
      DY=YC(K)-YC(L)
      DZ=ZC(K)-ZC(L)
      DC(J)=SQRT(DX*DX+DY*DY+DZ*DZ)
      K=J+NRS
```

Figure A9. Subroutine CSORT.

```
      DC(K)=DC(J)
 28   IF(IWRITE.GE.1)WRITE(6,2)J,IA(J),IB(J),IDSEG(J),K,IA(K),IB(K),
     &IDSEG(K),DC(J)
      IF(IWRITE.LE.0)GO TO 32
      WRITE(6,5)
      WRITE(6,6)
      DO 30 I=1,NRP
      IF(I.GT.NPGP)GO TO 29
      WRITE(6,3)I,XC(I),YC(I),ZC(I)
      GO TO 30
 29   J=I+NPI
      WRITE(6,3)I,XC(I),YC(I),ZC(I),J,XC(J),YC(J),ZC(J)
 30   CONTINUE
      WRITE(6,5)
C   CHECK INPUT DATA FOR CONSISTENCE
 32   N=0
      MIN=100
      MAX=100
      IF(NPGP.LE.0)GO TO 40
      DO 38 I=1,NPGP
      L=0
      DO 35 J=1,NSGP
      K=(IA(J)-I)*(IB(J)-I)
 35   IF(K.EQ.0)L=L+1
      IF(L.GT.MAX)MAX=L
 38   N=N+2*L-1
 40   IF(NRP.LE.NPGP)GO TO 50
      DO 46 I=IGPP,NRP
      L=0
      DO 44 J=1,NFS
      K=(IA(J)-I)*(IB(J)-I)
 44   IF(K.EQ.0)L=L+1
      IF(L.LT.MIN)MIN=L
 46   N=N+2*(L-1)
 50   IF(N.LE.0 .OR. N.GT.ICJ)GO TO 500
      IF(MAX.LE.0 .OR. MIN.LE.0)GO TO 600
      IF(NPGP.LE.0)GO TO 58
C   SET UP THE NODES AT THE GROUND PLANES THAT WILL NOT HAVE IMAGES
      DO 56 I=1,NPGP
      J=0
 52   J=J+1
      IAJ=IA(J)
      IBJ=IB(J)
      KK=(IAJ-I)*(IBJ-I)
      IF(J.EQ.NSGP)GO TO 54
      IF(KK.NE.0)GO TO 52
 54   JA(I)=J
      JB(I)=J+NRS
      I2(I)=I
      I1(I)=IBJ
      IF(IBJ.EQ.I)I1(I)=IAJ
 56   I3(I)=I1(I)+NPI
 58   I=NPGP
      N=NPGP
      NCN=NPGP
```

Figure A9 (Cont'd)

```
      JPP=0
      IF(NRS.EQ.NPGP) GO TO 75
C SET UP THE REST OF THE REAL MODES
      DO 65 K=1,NPP
      NJK=0
      DO 60 J=1,NRS
      IND=(IA(J)-K)*(IB(J)-K)
      IF(IND.NE.0)GO TO 60
      NJK=NJK+1
      JSP(NJK)=J
   60 CONTINUE
      MOD=NJK-1
      IF(MOD.LE.0)GO TO 65
      DO 62 IMD=1,MOD
      I=I+1
      IPD=IMD+1
      JAI=JSP(IMD)
      JA(I)=JAI
      JBI=JSP(IPD)
      JB(I)=JBI
      I1(I)=IA(JAI)
      IF(IA(JAI).EQ.K)I1(I)=IB(JAI)
      I2(I)=K
      I3(I)=IA(JBI)
   62 IF(IA(JBI).EQ.K)I3(I)=IB(JBI)
   65 CONTINUE
      NCM=I
      JPP=NCM-NPGP
C  NEXT SET UP TE IMAGE MODES
      DO 70 I=IGPP,NCM
      K=I+JPP
      JA(K)=JA(I)+NRS
      JB(K)=JB(I)+NRS
      IIA=I1(I)
      IIB=I2(I)
      IIC=I3(I)
      I1(K)=IIA
      IF(IIA.GT.NPGP)I1(K)=IIA+NPT
      I2(K)=IIB
      IF(IIB.GT.NPGP)I2(K)=IIB+NPT
      I3(K)=IIC
   70 IF(IIC.GT.NPGP)I3(K)=IIC+NPT
      N=2*NCM-NPGP
   75 MAX=0
      MIN=100
C  ND(J) = NUMBER OF DIPOLE MODES SHARING SEGMENT J
C  MD(J,K)=LIST OF DIPOLE SHARING SEGMENT J
      DO 100 J=1,NS
      DO 80 K=1,4
   80 MD(J,K)=0
      K=0
      DO 90 I=1,N
      JAI=JA(I)
      JBI=JB(I)
      L=(JAI-J)*(JBI-J)
```

Figure A9 (Cont'd)

```
      IF(L.NE.0)GO TO 90
      K=K+1
      MD(J,K)=I
   90 CONTINUE
      ND(J)=K
      IF(K.GT.MAX)MAX=K
  100 IF(K.LT.MIN)MIN=K
      IF(IWRITE.LE.0)GO TO 500
      WRITE(6,7)
      DO 110 I=1,NCM
      IF(I.GT.NRGE)GO TO 106
      WRITE(6,4)I,JA(I),JB(I),I1(I),I2(I),I3(I)
      GO TO 110
  106 K=I+JFP
      WRITE(6,4)I,JA(I),JB(I),I1(I),I2(I),I3(I),K,JA(K),JB(K),
     *I1(K),I2(K),I3(K)
  110 CONTINUE
      WRITE(6,5)
  500 RETURN
      END
```

Figure A9 (Cont'd)

APPENDIX 10
SUBROUTINE CMATX

Subroutine CMATX is listed in Figure A.10. It computes C matrix for a general wire configuration similar to subroutine IDANT and ZGS of reference 3, but CMATX also accounts for the components of the C matrix due to reflected and diffracted fields from plates and wedges as expressed in the P(I,J) terms. In the form listed, CMATX does not include effects of wire conductivity. However, if wire surface impedance is to be included, CMATX can be extended by adding the section from statements 200 and 260 of subroutine IDANT[3] before statement 262 of CMATX.

CALL statement:

```
CALL CMATX (ICC,INT,JPP,MD,N,NCM,ND,NLF,NP,NPGP,NRS,NS,AK,CMM,D,
          FMC,CDK,SDK,NFAR,WAVM,AM,XC,YC,ZC,CR,VNP,NOP,NOC,NSGP,
          NPLC,X,Y,Z,IDSEG)
```

Input and output parameters are defined below.

Input:

ICC	Dimension related to the open-circuit impedance matrix C
INT:	Integer denotes the number of integration intervals using Simpson's rule. For general purpose set INT=4
JPP:	Number of modes that have images
MD:	List of dipole modes sharing segment J
N:	Total number of dipole modes
NCM:	Dimension of the compressed C matrix
ND:	List of dipoles sharing segment J
NLD:	Number of lump loads
NP:	Number of points
NPGP:	Number of points on the ground plane
NRS:	Number of real segments

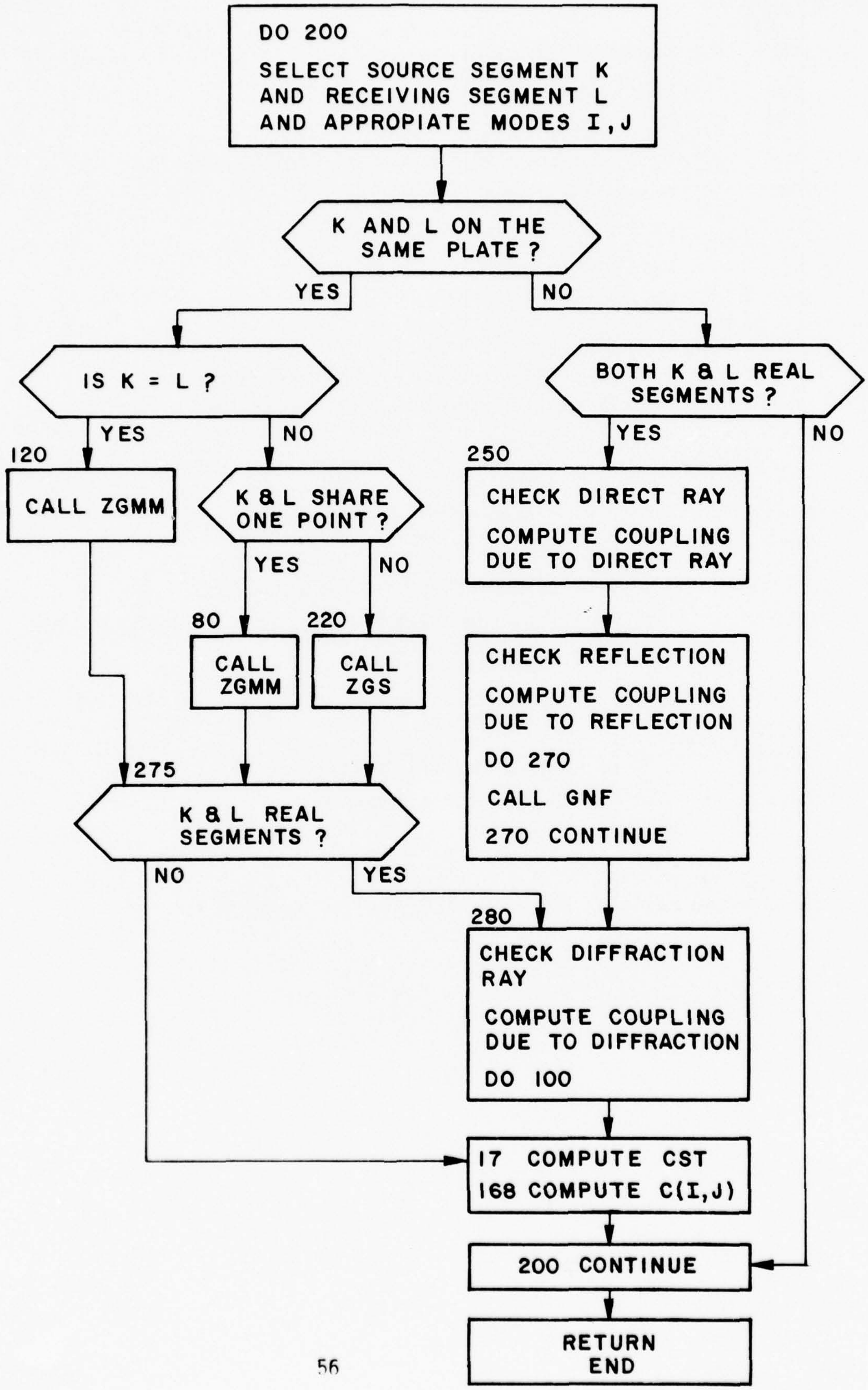
NS:	Number of segments
AK:	$(2\pi/\lambda_0)a$ where a is wire radius
CMM:	Wire conductivity in megamhos/m
D:	List of dimensionless segment lengths kd
FMC:	Frequency in MHz
NFAR:	Far field indicator
WAVM:	Wavelength in meters
AM:	Wire radius in meters
XC,YC,ZC:	Coordinates of the end points
CR:	List of position vectors of corners in meters
VNP:	List of unit vector normal to the plates
NOP:	Number of plates
NOC:	Number of corners
NSGP:	Number of segments on the ground plane
NPLC:	List of corner indices
XC,YC,ZC:	Dimensionless coordinates of end points
IDSEG:	List of plates (numbers) that act as a ground plane for segment J.

Output:

CDK:	List of $\cos(\gamma d)$ for all segments
SDK:	List of $\sin(\gamma d)$ for all segments
C:	Resultant C matrix

Subroutine called: ZGS,ZGMM, REGION,IMAGE,COMED,WEDIFF

SUBROUTINE CMATX



```
      OPTIONS 32K
C**COMPUTE C MATRIX FOR GENERAL WIRE CONFIGURATION
C**SIMILAR TO ICANTX ZGS, BUT ACCOUNT FOR REFLECTION
C**AND DIFFRACTION OF PLATES AND WEDGES. D.L.DOAN
      SUBROUTINE CMATX(ICC,INT,JPP,MD,N,NCM,ND,
     &NED,NP,NPGP,NRS,NS,AK,CMM,D,FMC,CDK,SDK,NFAR,WAVM,
     &AM,XC,YC,ZC,CP,VNP,NOP,NOC,NSGP,NPLC,X,Y,Z,IDSEG)
      COMMON/COM/C
      COMMON/COM2/CGD,SGD,DC
      COMMON/COM3/IA,IB,JA,JB,I1,I2,I3
      COMMON/COM6/VG,ZLD
      COMMON/COM7/P,Q
      LOGICAL TELL
      COMPLEX VG(130),ZLD(130)
      COMPLEX EX1,EY1,EZ1,EX2,EY2,EZ2,GAM,SGD(65),CGD(65)
     &,SGDS,SGDT,CST,P11,P12,P21,P22,ETA,Q(2,2),CGDS
      COMPLEX P(2,2),CIJ,VB1,VB2,CONS1,EDS,EDH,EIS,EIH,QW(2,2)
      COMPLEX C(32,32),ET1,ET2,EI1,EI2,ER1,ER2,ED1,ED2
      COMPLEX R11,R12,R21,R22
      DIMENSION VK(3),VNA(3),VA(3),IDSEG(65)
      DIMENSION XC(70),YC(70),ZC(70),IA(65),IB(65),ND(65),CDK(65),
     &SDK(65),D(65),X(70),Y(70),Z(70),DC(65)
      DIMENSION I1(70),I2(70),I3(70),JA(70),JB(70),MD(65,4)
      DIMENSION VNP(NOP,3),NPLC(NOP,4),CP(NOC,3),VNN(3),VN(3)
      DIMENSION RRT1(3),RRT(3),RS(3),RSA(3),RSB(3),RIA(3),RIB(3),
     &RO(3),C1(3),C2(3),RD(3),VI(3),BN(3),E(3),V3(3),VN3(3)
      DIMENSION VPHNS(3),VPHND(3),VBNS(3),VBND(3),EDN2(3),BN2(3)
C**ND(J)=TOTAL NO. OF DIPOLE MODES SHARING SEGMENT J
C**MD(J,K)=LIST OF DIPOLES SHARING SEGMENT J
C**N=TOTAL NO. OF DIPOLE MODES
C**
      DATA TP/6.28318/
    2 FORMAT(8X,'AK=',F8.6,5X,'DMAX=',F8.4,5X,'DMIN=',F8.4)
      TPL=TP/WAVM
      GAM=CMPLX(0.,TPL)
      ETA=(376.727,.0)
      PI=3.14159265
      DO 10 I=1,NCM
      DO 10 J=1,NCM
   10 C(I,J)=(0.,.0)
      DMAX=0.
      DMIN=100.
      DO 20 J=1,NRS
      DJ=D(J)
      IF(DJ.GT.DMAX)DMAX=DJ
      IF(DJ.LT.DMIN)DMIN=DJ
      CDK(J)=COS(DJ)
      SDK(J)=SIN(DJ)
C     SGD(J)=CMPLX(0.,SDK(J))
C     CGD(J)=CMPLX(CDK(J),0.)
      K=J+NRS
      CDK(K)=CDK(J)
      SDK(K)=SDK(J)
C     SGD(K)=CMPLX(0.,SDK(K))
C     CGD(K)=CMPLX(CDK(K),0.)
```

Figure A10. Subroutine CMATX.

```
   20    CONTINUE
         IF(DMIN.LT.AK)GO TO 21
         IF(DMAX.GT.3.)GO TO 21
         IF(AK.GT.0.1)GO TO 21
         GO TO 22
   21    WRITE(6,2)AK,DMAX,DMIN
         N=0
         RETURN
   22    DO 200 K=1,NS
         NDK=ND(K)
         KA=IA(K)
         KB=IB(K)
         DK=D(K)
         SGDS=CMPLX(0.,SDK(K))
         CGDS=CMPLX(CDK(K),0.)
         DO 200 L=1,NS
         NDL=ND(L)
         LA=IA(L)
         LB=IB(L)
         DL=D(L)
         SGDT=CMPLX(0.,SDK(L))
         NIL=0
         DO 200 II=1,NDK
         I=MD(K,II)
         IF(I.GT.NCM)GO TO 200
         FI=1.
         IF(KB.EQ.I2(I))GO TO 36
         IF(KB.EQ.I1(I))FI=-1.
         IS=1
         GO TO 40
   36    IF(KA.EQ.I3(I))FI=-1.
         IS=2
   40    DO 200 JJ=1,NDL
         J=MD(L,JJ)
         IF(I.GT.J)GO TO 200
         FJ=1.
         IF(LB.EQ.I2(J))GO TO 46
         IF(LB.EQ.I1(J))FJ=-1.
         JS=1
         GO TO 50
   46    IF(LA.EQ.I3(J))FJ=-1.
         JS=2
   50    IF(NIL.NE.0)GO TO 168
         NIL=1
      C**BEGINNING SIMILAR TO ZGS
         CA=(X(LB)-X(LA))/DL
         CB=(Y(LB)-Y(LA))/DL
         CG=(Z(LB)-Z(LA))/DL
         INS=2*(INT/2)
         IF(INS.LT.2)INS=2
         IP=INS+1
         DELT=DL/INS
         T=0.
         P11=(0.,.0)
         P12=(0.,.0)
```

Figure A10 (Cont'd)

```
      P21=(0.,.0)
      P22=(0.,.0)
      R11=(0.,.0)
      R12=(0.,.0)
      R21=(0.,.0)
      R22=(0.,.0)
      Q(1,1)=(0.,.0)
      Q(1,2)=(0.,.0)
      Q(2,1)=(0.,.0)
      Q(2,2)=(0.,.0)
      SGN=-1.
C**LIFT UP THE SOURCES CORRESPONDING TO ENDPOINTS TOUCHING THE
C**GROUND PLANE FOR REFLECTION AND DIFFRACTION TESTS.
C**AFAC,BFAC ACCOUNTS FOR GRAZING INCIDENCE
      IF(KA.GT.NPGP .AND. KB.GT.NPGP)GO TO 210
      IF(KB.LE.NPGP)GO TO 208
      IUSEGK=IUSEG(K)
      RSA(1)=XC(KA)+1.E-06*VNP(IUSEGK,1)
      RSA(2)=YC(KA)+1.E-06*VNP(IUSEGK,2)
      RSA(3)=ZC(KA)+1.E-06*VNP(IUSEGK,3)
      RSB(1)=XC(KB)
      RSB(2)=YC(KB)
      RSB(3)=ZC(KB)
      AFAC=0.5
      BFAC=1.
      GO TO 215
  208 IUSEGK=IUSEG(K)
      RSA(1)=XC(KA)
      RSA(2)=YC(KA)
      RSA(3)=ZC(KA)
      RSB(1)=XC(KB)+1.E-06*VNP(IUSEGK,1)
      RSB(2)=YC(KB)+1.E-06*VNP(IUSEGK,2)
      RSB(3)=ZC(KB)+1.E-06*VNP(IUSEGK,3)
      AFAC=1.
      BFAC=0.5
      GO TO 215
  210 RSA(1)=XC(KA)
      RSA(2)=YC(KA)
      RSA(3)=ZC(KA)
      RSB(1)=XC(KB)
      RSB(2)=YC(KB)
      RSB(3)=ZC(KB)
      AFAC=1.
      BFAC=1.
  215 CAS=(X(KB)-X(KA))/DK
      CBS=(Y(KB)-Y(KA))/DK
      CGS=(Z(KB)-Z(KA))/DK
      CCC=CA*CAS+CB*CBS+CG*CGS
      IDD=IUSEG(K)-IUSEG(L)
      IF(IDD.NE.0)GO TO 240
      IF(K.EQ.L)GO TO 120
      IND=(LA-KA)*(LB-KB)*(LA-KB)*(LB-KA)
      IF(IND.EQ.0)GO TO 80
C**ANTENNA SEGMENTS ON SAME PLATE
  220 CALL ZGS(X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),X(LA),Y(LA),
```

Figure A10 (Cont'd).

```
     &Z(LA),X(LB),Y(LB),Z(LB),AK,DK,CDK(K),SDK(K),DL,SDK(L),INT,
     &Q(1,1),Q(1,2),Q(2,1),Q(2,2))
      GO TO 275
  120 S=0.5
      IF(KA.NE.LA)S=-0.5
      CALL ZGMM(.0,DK,DK*(.5-S),DK*(.5+S),AK,CDK(K),SDK(K),
     &SDK(K),1.0,Q(1,1),Q(1,2),Q(2,1),Q(2,2))
      GO TO 275
C**SEGMENTS K AND L SHARE ONE POINT
   80 KG=0
      JM=KB
      JC=KA
      KF=1
      IND=(KB-LA)*(KB-LB)
      IF(IND.NE.0)GO TO 82
      JC=KB
      KF=-1
      JM=KA
      KG=3
   82 LG=3
      JP=LA
      LF=-1
      IF(LB.EQ.JC)GO TO 83
      JP=LB
      LF=1
      LG=0
   83 SGN=KF*LF
      CPSI=((X(JP)-X(JC))*(X(JM)-X(JC))+(Y(JP)-Y(JC))*(Y(JM)
     &-Y(JC))+(Z(JP)-Z(JC))*(Z(JM)-Z(JC)))/(DK*DL)
      CALL ZGMM(.0,DK,.0,DL,AK,CDK(K),SDK(K),SDK(L),CPSI
     &,QQ(1,1),QQ(1,2),QQ(2,1),QQ(2,2))
      DO 98 KK=1,2
      KP=IABS(KK-KG)
      DO 98 LL=1,2
      LP=IABS(LL-LG)
      Q(KP,LP)=SGN*QQ(KK,LL)
   98 CONTINUE
C**ANTENNA SEGMENTS BELONG TO THE SAME PLATE
C**IF BOTH K&L ARE REAL SEGMENTS, CONSIDER DIFFRACTION EFFECTS
  275 IF(K.LE.NRS .AND. L.LE.NRS)GO TO 280
      GO TO 17
C**REACH HERE IF SEGMENTS ARE ON DIFFERENT PLATES
  240 IF(K.LE.NRS .AND. L.LE.NRS)GO TO 250
      GO TO 200
C**MUTUAL COUPLING DUE TO MONOPOLES FAR APART OR NOT PARALLEL
  250 T=0.
      SGN=-1.
      P11=(0.,0.)
      P12=(0.,0.)
      P21=(0.,0.)
      P22=(0.,0.)
      F11=(0.,0.)
      F12=(0.,0.)
C     GO TO 15
      DO 260 IN=1,IP
```

Figure A10 (Cont'd).

```
      RO(1)=XC(LA)+(T/TPL)*CA
      RO(2)=YC(LA)+(T/TPL)*CB
      RO(3)=ZC(LA)+(T/TPL)*CG
      CALL GNF(XC(KA),YC(KA),ZC(KA),XC(KB),YC(KB),ZC(KB),RO(1),
     &RO(2),RO(3),AM,DC(K),CGDS,SGDS,ETA,GAM,EX1,EY1,EZ1,EX2,
     &EY2,EZ2)
C     WRITE(6,-)IN,EX1,EX2
   12 CALL REGION(RSA,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 13
      EI1=EX1*CA+EY1*CB+EZ1*CG
   13 CALL REGION(RSB,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 14
      EI2=EX2*CA+EY2*CB+EZ2*CG
      CC=3.+SGN
      IF(IN.EQ.1 .OR. IN.EQ.IP)CC=1.
      CC1=CC*SIN(LL-T)
      CC2=CC*SIN(T)
      P11=P11+EI1*CC1
      P12=P12+EI1*CC2
      P21=P21+EI2*CC1
      P22=P22+EI2*CC2
      T=T+DELT
  260 SGN=-SGN
      CST=-(0.,1.)*(DELT/TPL)/(3.*SGOT)
      C(1,1)=CST*P11
      C(1,2)=CST*P12
      C(2,1)=CST*P21
      C(2,2)=CST*P22
C**NEXT CONSIDER MUTUAL AND SELF COUPLINGS DUE TO REFLECTION
C**AND DIFFRACTION MECHANISM
   14 T=0.
      SGN=-1.
      R11=(0.,.0)
      R12=(0.,.0)
      R21=(0.,.0)
      R22=(0.,.0)
C     GO TO 15
      DO 270 IN=1,IP
C**FIRST CONSIDER COUPLINGS DUE TO REFLECTIONS
      ER1=(0.,.0)
      ER2=(0.,.0)
      DO 5 I5=1,NOP
      RO(1)=XC(LA)+(T/TPL)*CA
      RO(2)=YC(LA)+(T/TPL)*CB
      RO(3)=ZC(LA)+(T/TPL)*CG
C     WRITE(6,-)IN,I5
      CALL IMAGE(RSA,RIA,I5,NIMA,VNP,NPLC,CR,NOP,NOC)
      CALL IMAGE(RSB,RIB,I5,NIMA,VNP,NPLC,CR,NOP,NOC)
      CALL REGION(RIA,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(MM.NE.I5)GO TO 51
      IF(.NOT.TELL)GO TO 51
      DO 33 I33 =1,3
   33 RRT1(I33)=RRT(I33)
      CALL REGION(RSA,RRT1,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(TELL )GO TO 51
```

Figure A10 (Cont'd)

```
      CALL GNF(RIB(1),RIB(2),RIB(3),RIA(1),RIA(2),RIA(3),RO(1),
     &RO(2),RO(3),AM,DC(K),CGDS,SGDS,ETA,GAM,EX1,EY1,EZ1,
     &EX2,EY2,EZ2)
      ER1=ER1+EX2*CA+EY2*CB+EZ2*CG
   51 CALL REGION(RIB,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(MM.NE.15)GO TO 5
      IF(.NOT.TELL)GO TO 5
      DO 34 I34=1,3
   34 RRT1(I34)=RRT(I34)
      CALL REGION(RSB,RRT1,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 5
      CALL GNF(RIB(1),RIB(2),RIB(3),RIA(1),RIA(2),RIA(3),RO(1),
     &RO(2),RO(3),AM,DC(K),CGDS,SGDS,ETA,GAM,EX1,EY1,EZ1,
     &EX2,EY2,EZ2)
      ER2=ER2+EX1*CA+EY1*CB+EZ1*CG
  666 FORMAT(6I5)
    5 CONTINUE
      ET2=ER2
C**
      CC=3.+SGN
      IF(IN.EQ.1 .OR. IN.EQ.IP)CC=1
      CC1=CC*SIN(PL-T)
      CC2=CC*SIN(T)
      R11=R11+ET1*CC1
      R12=R12+ET1*CC2
      R21=R21+ET2*CC1
      R22=R22+ET2*CC2
      T=T+DELT
  270 SGN=-SGN
  280 T=0.
      SGN=-1.
      R11=(0.,0.)
      R12=(0.,0.)
      R21=(0.,0.)
      R22=(0.,0.)
C     GO TO 17
      DO 100 IN=1,IP
C***NEXT FIND DIFFRACTED FIELD PARALLEL TO EXPANSION MONOPOLE
C***DUE TO END POINTS OF TEST MONOPOLE
   16 ED1=CMPLX(0.,0.)
      ED2=CMPLX(0.,0.)
      RO(1)=XC(LA)+(T/TPL)*CA
      RO(2)=YC(LA)+(T/TPL)*CB
      RO(3)=ZC(LA)+(T/TPL)*CG
C     GO TO 15
      DO 6 I6=1,NOP
C     WRITE(6,-)IN,I5,I6
      DO 6 J6=1,4
      K1=J6+1
      IF(J6.EQ.4)K1=1
      K2=NPLC(I6,J6)
      K3=NPLC(I6,K1)
      DO 7 J7=1,3
      C1(J7)=CR(K2,J7)
      C2(J7)=CR(K3,J7)
```

Figure A10 (Cont'd).

```
 7    CONTINUE
C***AVOID CONSIDER THE SAME EDGE TWICE
      CALL COMED(I6,C1,C2,CR,NPLC,NCED,-1,NOP,NOC)
      IF(NCED.GT.0)GO TO 6
      EIS=CMPLX(0.,.0)
      EIH=CMPLX(0.,.0)
      EDS=CMPLX(0.,.0)
      EDH=CMPLX(0.,.0)
      CALL WEDIFF(RSA,C1,C2,RO,RD,I6,-1,AM,WAVM,NCM,VNP,CR,NPLC,
     &NOP,NOC,VBNS,VPHNS,CONS1,VB1,VB2,IDIF,VBND,VPHND)
      IF(IDIF.LE.0)GO TO 8
      CALL GNF(RSA(1),RSA(2),RSA(3),RSB(1),RSB(2),RSB(3),RD(1),
     &RD(2),RD(3),AM,DC(K),CGDS,SGDS,ETA,GAM,EX1,EY1,EZ1,EX2,
     &EY2,EZ2)
      EIS=EX1*VBNS(1)+EY1*VBNS(2)+EZ1*VBNS(3)
      EIH=EX1*VPHNS(1)+EY1*VPHNS(2)+EZ1*VPHNS(3)
      EDS=-(VB1-VB2)*EIS*CONS1*AFAC
      EDH=-(VB1+VB2)*EIH*CONS1*AFAC
      ED1=ED1+EDS*(VBND(1)*CA+VBND(2)*CB+VBND(3)*CG)+
     &         EDH*(VPHND(1)*CA+VPHND(2)*CB+VPHND(3)*CG)
 8    EIS=CMPLX(0.,.0)
      EIH=CMPLX(0.,.0)
      EDS=CMPLX(0.,.0)
      EDH=CMPLX(0.,.0)
      CALL WEDIFF(RSB,C1,C2,RO,RD,I6,-1,AM,WAVM,NCM,VNP,CR,NPLC,NOP,
     &NOC,VBNS,VPHNS,CONS1,VB1,VB2,IDIF,VBND,VPHND)
      IF(IDIF.LE.0) GO TO 6
      CALL GNF(RSA(1),RSA(2),RSA(3),RSB(1),RSB(2),RSB(3),RD(1),
     &RD(2),RD(3),AM,DC(K),CGDS,SGDS,ETA,GAM,EX1,EY1,EZ1,
     &EX2,EY2,EZ2)
      EIS=EX2*VBNS(1)+EY2*VBNS(2)+EZ2*VBNS(3)
      EIH=EX2*VPHNS(1)+EY2*VPHNS(2)+EZ2*VPHNS(3)
      EDS=-(VB1-VB2)*EIS*CONS1*BFAC
      EDH=-(VB1+VB2)*EIH*CONS1*BFAC
      ED2=ED2+EDS*(VBND(1)*CA+VBND(2)*CB+VBND(3)*CG)
     &         +EDH*(VPHND(1)*CA+VPHND(2)*CB+VPHND(3)*CG)
 6    CONTINUE
C**
 15   ET1=ED1
      ET2=ED2
C**
      CC=3.+SGN
      IF(IN.EQ.1 .OR. IN.EQ. IP)CC=1
      CC1=CC*SIN(FL-T)
      CC2=CC*SIN(T)
      P11=P11+ET1*CC1
      P12=P12+ET1*CC2
      P21=P21+ET2*CC1
      P22=P22+ET2*CC2
      T=T+DELT
 100  SGN=-SGN
 17   CST=-(0.,1.)*(DELT/TPL)/(3.*SGUT)
C**
      P(1,1)=CST*(R11+P11)
      P(1,2)=CST*(R12+P12)
```

Figure A10 (Cont'd)

```
      P(2,1)=CST*(R21+P21)
      P(2,2)=CST*(R22+P22)
  166 CIJ=FI*FJ*P(IS,JS)+FI*FJ*Q(IS,JS)
      IF(J.GT.NCM)GO TO 190
      C(I,J)=C(I,J)+CIJ
      IF(I.NE.J)C(J,I)=C(J,I)+CIJ
      GO TO 200
  190 JG=J-NCP
      C(I,JG)=C(I,JG)-CIJ
  200 CONTINUE
C**LOAD IMPEDANCE INSERTED HERE IN C MATRIX
  262 IF(NLD.LE.0)GO TO 300
      DO 282 I=1,NCM
      JJA=JA(I)
      J1=JJA
      II2=I2(I)
      II1=I1(I)
      IF(II2.EQ.IB(J1))J1=J1+NRS
      IF(I.LE.NPGP)GO TO 272
      JJB=JB(I)
      J2=JJB
      IF(II2.EQ.IB(J2))J2=J2+NRS
      C(I,I)=C(I,I)+ZLD(J1)+ZLD(J2)
      JJJ=JJA
      DO 268 K=1,2
      NDJ=ND(JJJ)
      DO 266 JJ=1,NDJ
      J=MD(JJJ,JJ)
      IF(J.EQ.I)GO TO 266
      IF(I2(J).NE.II2)GO TO 266
      FI=1.
      IF(K.EQ.2)GO TO 264
      IF(I1(J).NE.II1)FI=-1.
      C(I,J)=C(I,J)+FI*ZLD(J1)
      GO TO 266
  264 IF(I3(J).NE.I3(I))FI=-1.
      C(I,J)=C(I,J)+FI*ZLD(J2)
  266 CONTINUE
  268 JJJ=JJB
      GO TO 282
  272 IF(IB(J1).LE.NPGP)J1=J1+NRS
      C(I,I)=C(I,I)+2.*ZLD(J1)
      NDJ=ND(JJA)
      DO 278 JJ=1,NDJ
      J=MD(JJA,JJ)
      IF(J.EQ.I)GO TO 278
      IF(I2(J).NE.II2)GO TO 278
      FI=1.
      IF(I1(J).NE.II1)FI=-1.
      C(I,J)=C(I,J)+2.*FI*ZLD(J1)
  278 CONTINUE
  282 CONTINUE
  300 RETURN
      END
```

Figure A10 (Cont'd)

APPENDIX 11
SUBROUTINE CIFFLD

This subroutine is listed in Figure A.11 and is essentially the same as subroutine IFFELD of reference 2, except for the CALL CZFF statement, where CZFF calculates the far zone field of a monopole above the satellite structures (see Appendix A.11).

Let (r,θ,ϕ) denote the spherical coordinates of the distant observer, and let E (I), I (I) denote the electric field intensities of dipole mode I with unit current. Then

$$EPP(I) = r\, e^{jkr}\, E_{\phi}(I)$$
$$ETT(I) = r\, r^{jkr}\, E_{\theta}(I)$$

Summing the fields due to all modes I yield

$$EPH = \sum_{1}^{N} CJ(I)EPP(I)$$

$$ETH = \sum_{1}^{N} CJ(I)ETT(I)$$

where CJ(I) denote the terminal current of mode I

CALL statement

```
CALL CIFFLD (INS,MD,N,ND,NRS,CDK,CJ,DC,EPH,ETH,G,CPP,GTT,PH,SDK,
        TH,XC,YC,ZC,WAVM,AM,NPGP,NCM,VNP,NPLC,CR,NOP,NOC,IDSEG)
```

All symbols have been defined in previous subroutines.

```
C**SUBROUTINE SIMILAR TO IFFLD
      SUBROUTINE CIFFLD(INS,MD,N,NP,NS,CDK,CJ,DC,
     &EPH,ETH,G,GPP,GTT,PH,SDK,TH,XC,YC,ZC,WAVM,AM,NPGP,
     &NCM,VDP,NPLC,CR,NOP,NOC,IDSEG)
      COMMON/COM3/IA,IB,JA,JB,I1,I2,I3
      DIMENSION VDP(NOP,3),NPLC(NOP,4),CR(NOC,3),IDSEG(65)
      COMPLEXEPH,ETH,CJI,ET1,ET2,EP1,EP2
      DIMENSION  MD(65,4),ND(65)
      COMPLEXCJ(1),EPP(32),ETT(32)
      DIMENSIONCDK(1),SDK(1),DC(1),XC(1),YC(1),ZC(1)
      DIMENSIONI1(70),I2(70),I3(70),IA(65),IB(65),JA(70),JB(70)
      DATA CJI/(0.,-0.5*0888E-2)/
      THR=.0174533*TH
      CTH=COS(THR)
      STH=SIN(THR)
      PHR=.0174533*PH
      CPH=COS(PHR)
      SPH=SIN(PHR)
      DO 130 I=1,NCM
      ETT(I)=(0.,.0)
  130 EPP(I)=(0.,.0)
      DO 140 K=1,NS
      KA=IA(K)
      KB=IB(K)
      CALL CZFF(XC(KA),YC(KA),ZC(KA),XC(KB),YC(KB),ZC(KB),DC(K),KA,KB,
     &WAVM,AM,CDK(K),SDK(K),CTH,STH,CPH,SPH,ET1,ET2,EP1,EP2,NPGP,
     &NCM,VDP,NPLC,CR,NOP,NOC,IDSEG(K),MD)
    7 FORMAT(4X,'AFTER CZFF')
      NDK=ND(K)
      DO 140 II=1,NDK
      I=MD(K,II)
      FI=1.
      IF(KB.EQ.I2(I))GO TO 136
      IF(KB.EQ.I1(I))FI=-1.
      EPP(I)=EPP(I)+FI*EP1
      ETT(I)=ETT(I)+FI*ET1
      GO TO 140
  136 IF(KA.EQ.I3(I))FI=-1.
      EPP(I)=EPP(I)+FI*EP2
      ETT(I)=ETT(I)+FI*ET2
  140 CONTINUE
      EPH=(0.,.0)
      ETH=(0.,.0)
  200 DO 260 I=1,NCM
      ETH=ETH+CJ(I)*ETT(I)
  260 EPH=EPH+CJ(I)*EPP(I)
      APP=CABS(EPH)
      ATT=CABS(ETH)
      GPP=APP*APP/(30.*G)
      GTT=ATT*ATT/(30.*G)
      RETURN
      END
```

Figure A11. Subroutine CIFFLD.

APPENDIX 12
SUBROUTINE CZFF

CZFF is listed in Figure A.12.

Submatrix CZFF calculates the far zone field of a monopole above a satellite body modeled by flat plates. CZFF includes contributions from incident, reflected, singly diffracted and doubly diffracted fields. All phase terms of these fields are referred to the origin of the coordinate system before summation.

Between statement of 26 and 30 the direct incident field region is defined and the incident field computed by calling subroutine GFF (reference 3). The fields due to reflected rays are computed in loop Do 5. Do 6 defines diffraction region and computer singly diffracted fields. Doubly diffracted fields are evaluated between statements 80 and 40. Finally the total field arrives at the observation point due to each end of the monopole is the sum of the above field components. Summation is performed between statement 40 and RETURN.

CALL statement:

```
CALL CZFF (XC(KA),YC(KA),ZC(KA),XC(KB),YC(KB),ZC(KB),DC(K),KA,KB,
        WAVM,AM,CDK(K),SDK(K),CTH,STH,CPH,SPH,ET1,ET2,EP1,EP2,NPGP,
        NCM,VNP,NPLC,CR,NOP,NOC,IDSEG(K),MD)
```

ET1,EP1 are θ and ϕ components of the far field due to endpoint 1, ET2, EP2 and those due to endpoint 2. Other symbols have been different previously.

```
      OPTIONS 32K
      SUBROUTINE CZFF(XC1,YC1,ZC1,XC2,YC2,ZC2,DCK,KA,KB,WAVM,AP,
     *CDKK,SDKK,CTH,STH,CPH,SPH,ET1,ET2,EP1,EP2,NPGP,NCM,VNP,
     *NPLC,CR,NOP,NOC,IDSEGK,ML)
C** THIS SUBROUTINE CALCULATES THE FAR ZONE FIELD OF A MONOPOLE
C** NEAR OR ON A CONDUCTING BODY MODELLED BY FLAT PLATES
C** SUBROUTINES CALLED:REGION,IMAGE,GFF,COMEU,WEDIFF,GNF,CROSSP
C** OUTPUT:ET1,ET2,EP1,EP2
C**D.L.DOAN,MAY 76.
      LOGICAL TELL
      COMPLEX ET1,ET2,EP1,EP2,GAM,ETA,CGDS,SGDS,EIS,EIH,EDS,EDH
      COMPLEX EIT1,EIP1,ERT1,ERP1,EDT1,EDP1,EIT2,EIP2,ERP2
      COMPLEX ERT2,EDT2,EDP2,EDDT1,EDDT2,EDDP1,EDDP2
      COMPLEX VB1,VB2,CDOS1,EX1,EY1,EZ1,EX2,EY2,EZ2
      DIMENSION RP(65,4)
      DIMENSION VI(3), RO2(3),DN(3),EDN(3),VBDS2(3),VPHS2(3)
      DIMENSION VNP(NOP,3),NPLC(NOP,4),CR(NOC,3),VNN(3),VN(3)
      DIMENSION RPT(3),RO(3),C1(3),C2(3),PP(3),RET1(3),PDD(3),G(3)
      DIMENSION C3(3),C4(3),RSA(3),RSB(3),ETA(3),ETB(3)
      DIMENSION VPHNS(3),VPHND(3),VBNS(3),VBND(3),VPHND2(3)
      DIMENSION VBND2(3),VTHN(3),VTH(3),EDN2(3),VB3(3),V3(3),VPHL(3)
      DATA TP/6.2831853/,PI/3.14159265/
      TPL=TP/WAVM
      ETA=(376.727,0.)
      GAM=CMPLX(0.,TPL)
      CGDS=CMPLX(CDKK,0.)
      SGDS=CMPLX(0.,SDKK)
      RO(1)=STH*CPH
      RO(2)=STH*SPH
      RO(3)=CTH
      RSA(1)=XC1
      RSA(2)=YC1
      RSA(3)=ZC1
      RSB(1)=XC2
      RSB(2)=YC2
      RSB(3)=ZC2
      AFAC=1.0
      BFAC=1.0
C** GROUND PLANE ENDPOINT IS LIFTED UP FOR REFLECTION AND DIFFRACTION
C**TEST, THE MONOPOLE SEGMENT IS ABOVE PLATE IDSEGK
      IF(KA.GT.NPGP .AND. KB.GT.NPGP)GO TO 26
      IF(KB.LE.NPGP)GO TO 22
      RSA(1)=XC1+1.E-06*VNP(IDSEGK,1)
      RSA(2)=YC1+1.E-06*VNP(IDSEGK,2)
      RSA(3)=ZC1+1.E-06*VNP(IDSEGK,3)
      AFAC=0.5
      GO TO 26
   22 RSB(1)=XC2+1.E-06*VNP(IDSEGK,1)
      RSB(2)=YC2+1.E-06*VNP(IDSEGK,2)
      RSB(3)=ZC2+1.E-06*VNP(IDSEGK,3)
      BFAC=0.5
C** DEFINE DIRECT FIELD REGION AND COMPUTE DIRECT INCIDENT FIELD
   26 EIT1=(0.,0.)
      EIP1=(0.,0.)
      EIT2=(0.,0.)
```

Figure A12. Subroutine CZFF.

```
      FIP2=(0.,.0)
      FRT1=(0.,.0)
      FRP1=(0.,.0)
      FRT2=(0.,.0)
      FRP2=(0.,.0)
      FDT1=(0.,.0)
      FDP1=(0.,.0)
      FDT2=(0.,.0)
      FDP2=(0.,.0)
      VPHN(1)=-SPH
      VPHN(2)=CPH
      VPHN(3)=0.
      CALL CROSSF(VPHN,RO,VTHN,VTH)
      FDPT1=(0.,.0)
      FDPT2=(0.,.0)
      FDPP1=(0.,.0)
      FDPP2=(0.,.0)
      CALL GFF(RSA(1),RSA(2),RSA(3),RSB(1),RSB(2),RSB(3),DCK,CGDS,
     *SGDS,CTH,STH,CPH,SPH,GAM,ETA,ET1,ET2,EP1,EP2)
      CALL REGION(RSA,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 29
      FIT1=ET1*AFAC
      FIP1=EP1*AFAC
   29 CALL REGION(RSB,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 30
      FIT2=ET2*BFAC
      FIP2=EP2*BFAC
C** DEFINE REFLECTION REGION AND FIND REFLECTED FIELD
   30 DO 5 IS=1,NOP
      CALL IMAGE(RSA,RIA,IS,NIMA,VNP,NPLC,CR,NOP,NOC)
      CALL IMAGE(RSB,RIB,IS,NIMA,VNP,NPLC,CR,NOP,NOC)
      CALL GFF(RIB(1),RIB(2),RIB(3),RIA(1),RIA(2),RIA(3),DCK,CGDS,
     *SGDS,CTH,STH,CPH,SPH,GAM,ETA,ET1,ET2,EP1,EP2)
      CALL REGION(RIA,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,1,NOP,MM,NOP,NOC)
      IF(MM.NE.IS)GO TO 32
      IF(.NOT.TELL) GO TO 32
      DO 31 I=1,3
   31 RRT1(I)=RRT(I)
      CALL REGION(RSA,RRT1,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 32
      CALL REGION(RRT1,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 32
      FRT1=ET1*AFAC
      FRP1=EP1*AFAC
   32 CALL REGION(RIB,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,1,NOP,MM,NOP,NOC)
      IF(MM.NE.IS)GO TO 5
      IF(.NOT.TELL)GO TO 5
      DO 33 I=1,3
   33 RRT1(I)=RRT(I)
      CALL REGION(RSB,RRT1,RRT,CR,VNP,-1,-1,TELL,NPLC,-1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 5
      CALL REGION(RRT1,RO,RRT,CR,VNP,-1,-1,TELL,NPLC,1,NOP,MM,NOP,NOC)
      IF(TELL)GO TO 5
      FRT2=ET2*BFAC
      FRP2=EP2*BFAC
```

Figure A12 (Cont'd).

```
  5     CONTINUE
C** DEFINE DIFFRACTION REGION AND FIND DIFFRACTED FIELD
        DO 5 I6=1,NOP
        AGRAZE=1.
        DO 6 J6=1,4
        K1=J6+1
        IF(J6.EQ.4)K1=1
        K2=NPLC(I6,J6)
        K3=NPLC(I6,K1)
        DO 7 J7=1,3
        C1(J7)=CR(K2,J7)
  7     C2(J7)=CR(K3,J7)
C            *AVOID CONSIDER THE SAME EDGE TWICE*
        CALL COMED(I6,C1,C2,CR,NPLC,NCED,-1,NOF,NOC)
        IF(NCED.GT.0)GO TO 6
        CALL WEDIFF(RSA,C1,C2,RO,RD,T6,1,AM,WAVM,NCM,VNP,CR,NPLC,
       &NOP,NOC,VBNS,VPHNS,CONS1,VB1,VB2,IDIF,VBND,VPHND)
        IF(IDIF.LE.0)GO TO 8
        CALL GMF(RSA(1),RSA(2),RSA(3),RSB(1),RSB(2),RSB(3),RD(1),RD(2),
       &RD(3),AM,DCK,CGDS,SGDS,ETA,GAM,EX1,EY1,EZ1,EX2,EY2,EZ2)
        EIS=EX1*VBNS(1)+EY1*VBNS(2)+EZ1*VBNS(3)
        EIH=EX1*VPHNS(1)+EY1*VPHNS(2)+EZ1*VPHNS(3)
        EDS=-(VB1-VB2)*EIS*CONS1*AFAC*AGRAZE
        EDH=-(VB1+VB2)*EIH*CONS1*AFAC*AGRAZE
        EDT1=EDT1+EDS*(VBND(1)*VTHN(1)+VBND(2)*VTHN(2)+VBND(3)*
       &VTHN(3))+EDH*(VPHND(1)*VTHN(1)+VPHND(2)*VTHN(2)+VPHND(3)*
       &VTHN(3))
        EDP1=EDP1+EDS*(VBND(1)*VPHN(1)+VBND(2)*VPHN(2)+VBND(3)*
       &VPHN(3))+EDH*(VPHND(1)*VPHN(1)+VPHND(2)*VPHN(2)+VPHND(3)*
       &VPHN(3))
  8     CALL WEDIFF(RSB,C1,C2,RO,RD,T6,1,AM,WAVM,NCM,VNP,CR,NPLC,
       &NOP,NOC,VBNS,VPHNS,CONS1,VB1,VB2,IDIF,VBND,VPHND)
        IF(IDIF.LE.0)GO TO 6
        CALL GMF(RSA(1),RSA(2),RSA(3),RSB(1),RSB(2),RSB(3),RD(1),
       &RD(2),RD(3),AM,DCK,CGDS,SGDS,ETA,GAM,EX1,EY1,EZ1,EX2,EY2,
       &EZ2)
        EIS=EX2*VBNS(1)+EY2*VBNS(2)+EZ2*VBNS(3)
        EIH=EX2*VPHNS(1)+EY2*VPHNS(2)+EZ2*VPHNS(3)
        EDS=-(VB1-VB2)*EIS*CONS1*BFAC*AGRAZE
        EDH=-(VB1+VB2)*EIH*CONS1*BFAC*AGRAZE
        EDT2=EDT2+EDS*(VBND(1)*VTHN(1)+VBND(2)*VTHN(2)+VBND(3)*
       &VTHN(3))+EDH*(VPHND(1)*VTHN(1)+VPHND(2)*VTHN(2)+VPHND(3)*
       &VTHN(3))
        EDP2=EDP2+EDS*(VBND(1)*VPHN(1)+VBND(2)*VPHN(2)+VBND(3)*
       &VPHN(3))+EDH*(VPHND(1)*VPHN(1)+VPHND(2)*VPHN(2)+VPHND(3)*
       &VPHN(3))
  6     CONTINUE
C**
C** COMPUTE DOUBLE DIFFRACTED FIELD
C**------------------------------------
  80    DO 40 I40=INSEGK,INSEGK
        DO 42 J42=1,4
        K1=J42+1
        IF(J42.EQ.4)K1=1
        K2=NPLC(I40,J42)
```

Figure A12 (Cont'd).

```
            K3=NPLC(I40,K1)
            DO 44 J44=1,3
            C1(J44)=CR(K2,J44)
     44     C2(J44)=CR(K3,J44)
            CALL COMED(I40,C1,C2,CR,NPLC,NCED,-1,NOP,NOC)
            IF(NCED.GT.0)GO TO 42
            DO 47 I46=1,3
     47     VNP(I46)=VNP(I40,I46)
            CALL COMED(I40,C1,C2,CR,NPLC,NCED,NOP,NOP,NOC)
      C** SET UP 2ND EDGE WHERE DOUBLE DIFFRACTION MAY TAKE PLACE
            IF(NCED-0)42,42,48
     48     DO 52  J52=1,4
            K1=J52+1
            IF(J52.EQ.4)K1=1
            K2D=NPLC(NCED,J52)
            K3D=NPLC(NCED,K1)
            DO 54 J54=1,3
            C3(J54)=CR(K2D,J54)
            C4(J54)=CR(K3D,J54)
     54     VN(J54)=VNP(NCED,J54)
            IF((K2D.EQ.K2).AND.(K3D.EQ.K3))GO TO 52
            IF((K2D.EQ.K3).AND.(K3D.EQ.K2))GO TO  52
            F=SQRT((C4(1)-C3(1))**2+(C4(2)-C3(2))**2+(C4(3)-C3(3))**2)
            DO 55 I55=1,3
     55     EDN2(I55)=(C4(I55)-C3(I55))/F
      C** DETERMINE DIRECTION OF GRAZING RAY
            COSB2=0.
            DO 56 I56=1,3
            COSB2=COSB2+EDN2(I56)*RO(I56)
     56     CONTINUE
            CALL CROSSP(EDN2,VN,VN3,V3)
            IF(COSB2.GE.0.999999)GO TO 52
            SINB2=SQRT(1.-COSB2**2)
            DO 58 I58=1,3
     58     G(I58)=COSB2*EDN2(I58)+SINB2*VN3(I58)
      C** FIRST DIFFRACTION
      C** FIRST FIND FIRST AND SECOND DIFFRACTION POINTS
            CALL DIFPTF(RSA,C1,C2,VNN,G,VI,SP,ANI,RD,IDX,
           *VPHNS,VPHND,VBNS,VBND,PHS,PHD,BN,EDN)
            IF(IDX.EQ.-1)GO TO 81
            CALL DIFPTF(RD,C3,C4,VN,RO,VT,S,ANI2,RD2,IDX,
           *VPHNS,VPHND,VBNS,VBND,PHS,PHD,BN,EDN)
            IF(IDX.EQ.-1) GO TO 81
            CALL WEDIFF(RSA,C1,C2,RD2,RD,I40,-1,AM,WAVM,NCM,VNP,CR,NPLC,
           *NOP,NOC,VBNS,VPHNS,CONS1,VB1,VB2,IDIF,VBND,VPHND)
            IF(IDIF.LE.0)GO TO 81
            CALL GNF(RSA(1),RSA(2),RSA(3),RSB(1),RSB(2),RSB(3),RD(1),
           *RD(2),RD(3),AM,DCK,CGPS,SGPS,ETA,GAM,EX1,EY1,EZ1,EX2,EY2,EZ2)
            EIS=EX1*VBNS(1)+EY1*VBNS(2)+EZ1*VBNS(3)
            EIH=EX1*VPHNS(1)+EY1*VPHNS(2)+EZ1*VPHNS(3)
            EDS=-(VB1-VB2)*EIS*CONS1*AFAC
            EDH=-(VB1+VB2)*EIH*CONS1*AFAC
            CALL WEDIFF(RD,C3,C4,RO,RD2,NCED,1,AM,WAVM,NCM,VNP,CR,NPLC,
           *NOP,NOC,VBNS2,VPHNS2,CONS1,VB1,VB2,IDIF,VBND2,VPHND2)
            IF(IDIF.LE.0)GO TO 81
```

Figure A12 (Cont'd).

```
C** CHANGE TO COORDINATE OF 2ND EDGE
      AA1=0.
      AA2=0.
      AA3=0.
      AA4=0.
      DO 70 I=1,3
      AA1=AA1+VBND2(I)*VBNS(I)
      AA2=AA2+VPHND2(I)*VBNS(I)
      AA3=AA3+VBND2(I)*VPHNS(I)
   70 AA4=AA4+VPHND2(I)*VPHNS(I)
C** INCIDENT FIELD ON EDGE 2
      EIS=(EDS*AA1+EDH*AA2)*0.5
      EIH=(EDS*AA3+EDH*AA4)*0.5
      CONS1=CONS1*((SP+S)/(S*SP))*CEXP(CMPLX(0.,TPI*(SP-(SP*S)/(SP+S))*
     *SIN(ANI)**2))
      EDS=-(VB1-VB2)*EIS*CONS1
      EDH=-(VB1+VB2)*EIH*CONS1
      EDPT1=EDPT1+EDS*(VBND2(1)*VTHN(1)+VBND2(2)*VTHN(2)+VBND2(3)*
     *VTHN(3))+EDH*(VPHND2(1)*VTHN(1)+VPHND2(2)*VTHN(2)+VPHND2(3)*
     *VTHN(3))
      EDPP1=EDPP1+EDS*(VBND2(1)*VPHN(1)+VBND2(2)*VPHN(2)+VBND2(3)*
     *VPHN(3))+EDH*(VPHND2(1)*VPHN(1)+VPHND2(2)*VPHN(2)+VPHND2(3)*
     *VPHN(3))
   81 CALL DIFFTF(RSB,C1,C2,VBN,B,VT,SP,ANI,RO,IDX,
     *VPHNS,VPHND,VBNS,VBND,PHS,PHD,BE,EDN)
      IF(IDX.EQ.-1)GO TO 52
      CALL DIFFTF(RD,C3,C4,VN,RO,VT,S,ANI2,RD2,IDX,
     *VPHNS,VPHND,VBNS,VBND,PHS,PHD,BE,EDN)
      IF(IDX.EQ.-1) GO TO 52
      CALL WEDIFF(RSB,C1,C2,RD2,RD,I40,-1,AN,WAVM,DCM,VEP,CR,NELC,
     *NOP,NOC,VBNS,VPHNS,CONS1,VB1,VB2,IDIF,VBND,VPHND)
      IF(IDIF.LE.0)GO TO 52
      CALL GNF(RSA(1),RSA(2),RSA(3),RSB(1),RSB(2),RSB(3),RD(1),
     *RD(2),RD(3),AM,DCM,CEPS,SOFS,ETA,GAM,EX1,EY1,EZ1,EX2,EY2,EZ2)
      EIS=EX2*VBNS(1)+EY2*VBNS(2)+EZ2*VBNS(3)
      EIH=EX2*VPHNS(1)+EY2*VPHNS(2)+EZ2*VPHNS(3)
      EDS=-(VB1-VB2)*EIS*CONS1*BFAC
      EDH=-(VB1+VB2)*EIH*CONS1*BFAC
      CALL WEDIFF(RD,C3,C4,RO,RD2,NCED,1,AN,WAVM,DCM,VEP,CR,NPLC,
     *NOP,NOC,VBNS2,VPHNS2,CONS1,VB1,VB2,IDIF,VBND2,VPHND2)
      IF(IDIF.LE.0)GO TO 52
C** CHANGE TO COORDINATE OF 2ND EDGE
      AA1=0.
      AA2=0.
      AA3=0.
      AA4=0.
      DO 84 I=1,3
      AA1=AA1+VBND2(I)*VBNS(I)
      AA2=AA2+VPHND2(I)*VBNS(I)
      AA3=AA3+VBND2(I)*VPHNS(I)
   84 AA4=AA4+VPHND2(I)*VPHNS(I)
C** INCIDENT FIELD ON EDGE 2
      EIS=(EDS*AA1+EDH*AA2)*0.5
      EIH=(EDS*AA3+EDH*AA4)*0.5
      CONS1=CONS1*((SP+S)/(S*SP))*CEXP(CMPLX(0.,TPI*(SP-(SP*S)/(SP+S))*
```

```
      *SIN(ANI)**2))
      EDS=-(VB1-VB2)*EIS*CONS1
      EDH=-(VB1+VB2)*EIH*CONS1
      EDDT2=EDDT2+EDS*(VBND2(1)*VTHN(1)+VBND2(2)*VTHN(2)+VBND2(3)*
     *VTHN(3))+EDH*(VPHND2(1)*VTHN(1)+VPHND2(2)*VTHN(2)+VPHND2(3)*
     *VTHN(3))
      EDDP2=EDDP2+EDS*(VBND2(1)*VPHN(1)+VBND2(2)*VPHN(2)+VBND2(3)*
     *VPHN(3))+EDH*(VPHND2(1)*VPHN(1)+VPHND2(2)*VPHN(2)+VPHND2(3)*
     *VPHN(3))
   52 CONTINUE
   42 CONTINUE
   40 CONTINUE
C**IN SUMMING ALL FIELDS THE COMMON FACTOR EXP(-JKS)/S IS OMITTED
C**HOWEVER CARE IS TAKEN TO INSURE COMMON PHASE REFERENCE FOR EXP(-JKS)
C**NAMELY,THE ORIGIN OF COORDINATE SYSTEM
      ET1=EIT1+ERT1+EDT1+EDDT1
      ET2=EIT2+ERT2+EDT2+EDDT2
      EP1=EIP1+ERP1+EDP1+EDDP1
      EP2=EIP2+ERP2+EDP2+EDDP2
      RETURN
      END
```

Figure A12 (Cont'd).

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