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Title: JPL Physical Optics Program on the MASSCOMP MC500 Computer at Green Bank

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JPL PHYSICAL OPTICS PROGRAM ON THE MASSCOMP MC500 COMPUTER AT GREEN BANK

Sivasankaran Srikanth

The JPL physical optics code consisting of the spherical wave expansion and the scattering programs written by A. Ludwig has been in use at NRAO for a few years now. The original scattering program which computes the scattered pattern from a reflector of arbitrary shape has been modified with the addition of a field plotting routine, multiple-scattering capability, etc. (EDIR No. 221 with Addendum). The above programs with the associated subroutines are in the Pandora system of the IBM 360 at Charlottesville.

In view of the fact that the IBM will soon be phased out, the JPL code has been modified to be compatible with the Unix operating system of the MASSCOMP at Green Bank. This technical note describes the features and commands for using the code. All the field patterns which were earlier plotted on the line printer IBM 3776 2 can now be quickly viewed on the MASSCOMP graphics terminal using the routine 'gp.f'. In case a record of the plot is required, 'plotp' command can be used to get the plot on the MASSCOMP line printer. However, this is much slower than the IBM printer.

Spherical Wave Expansion (SWE) Program

This program computes the coefficients of expansion of the far-zone incident magnetic field pattern in terms of transverse electric (TE) and transverse magnetic (TM) spherical waves. This fortran program is called 'swe.f' in the MASSCOMP. The associated subroutines MULT, LEGEND and VECTOR (described in EDIR 221) have been combined and called 'subs.f'. The input data is in the same format as in the Pandora. The program may be run by typing

sw datafile <CR>

Here datafile is the name of the input data file, an example of which is shown in Appendix A. The command 'sw' is a UNIX shell script which first removes the files DATAIN, DOUT, PATIN, PATOUT, PATDIF, and DISK. Then it copies 'datafile' onto the 'DATIN' and invokes 'swe.f' and 'sub.f'and prints DOUT where the following output of the SWE program are stored.

-- two alphanumeric statements.

-- input pattern: numerical values (if IPLOT1 = -1 or -11).

-- power in input pattern.

-- real and imaginary values of SWE coefficient.

-- fraction of total mode power in the coefficients for each mode order.

-- total coefficient mode power.

-- output pattern: numerical values (if IPLOT2 = -1 or -11).

-- power in output pattern.

Numerical values for the magnitude and phase of the far-zone input field, the output field and the difference between input and output fields are written on files PATIN, PATOUT, and PATDIF, respectively. These patterns can be viewed on the graphics terminal by giving the command

gplot <CR>.

The terminal prompts you to give a value for the variable IP. By typing 1, 2 or 3, the input, output, or the difference pattern can be viewed. The program also stores the SWE coefficients on file DISK to be read by the SCAT program.

Scattering (SCAT) Program

This program reads the spherical wave expansion coefficients from the file DISK, computes the near or far-field, depending on where the reflecting surface is located, and given the scattering surface specified by $\rho(\theta,\phi)$, computes the scattered pattern over a grid of observation points. The program is called 'scat.f' and its attendant subroutines are 'esurf.f'/ 'ssurf.f', 'fint.f', 'sfp.f', 'vec.f' and 'sald.f'. These routines consist of the various subroutines listed below:

esurf.f .... SURF (ELLIPSOID), EDGEEQ

ssurf.f .... SURF, EDGEEQ

fint.f .... FINT

sfp.f .... SETUP, FIELDS, PATHL, VECTOR

vec.f .... VECTOR

sald.f .... SPHANK, ADJUST, LEGEND, DIFF

Here also the input data is in the same format as that in the Pandora system.

The program can be run by the command

sc datafile <CR>

An example of the datafile is shown in Appendix B. The command 'sc' removes a number of files if they exist, copies the datafile on to SCATIN and invokes 'scat.f' and the subroutines mentioned above. It is to be noted here that 'esurf.f' routine has been compiled for executing the SCAT program. This routine computes the surface parameters for an ellipsoidal reflecting surface. The output of the SCAT program is stored in SCATOUT and a list of the output is given below:

-- 2 alphanumeric statements followed by the propagation constant.

-- θ and ϕ for each integration grid segment.

-- integration grid number and value of IEDGE.

-- if edge is encountered in the present grid, the value of θ-edge for IEDGE = 0; θ-edge and ρ-edge as a function of ϕ for IEDGE <> 0.

-- near-field incident pattern power.

} For each integration grid.

-- spillover efficiency.

-- far-field incident pattern numerical values if FIPLOT = -1.

-- far-field incident pattern power.

} For each ϕ.

-- phase center translations, scale factor.

-- far-field scattered pattern numerical values if FSPLOT = -1.

-- far-field scattered pattern power.

} For each Φ.

The near-zone incident magnetic field values as a function of the polar angle are stored in a file NIPLOT. For each value of Φ (up to 2 values) the far-zone incident pattern values are stored in FIPLOT1 and FIPLOT2 and the scattered pattern values in FSPLOT1 and FSPLOT2. If patterns for more than two Φ values are desired, the program can be easily modified to handle the same. The difference between the incident and scattered pattern for angles up to 20° on either side of the pattern maximum are stored in DIFPLOTL and DIFPLOTR.

Using the command

gplot <CR>

the required pattern can be viewed on the graphics terminal by choosing the proper value of IP as per the table below:

IP	Pattern
4	Near-zone incident magnetic field.
5	Far-zone incident electric field for $\Phi = \Phi_1$.
6	Far-zone incident electric field for $\Phi = \Phi_2$.
7	Far-zone scattered electric field for $\Phi = \Phi_1$.
8	Far-zone scattered electric field for $\Phi = \Phi_2$.
9	Difference between incident and scattered fields on the left side of beam maximum.
10	Difference between incident and scattered fields on the right side of beam maximum.

Note: For cross-polarized field the corresponding commands are:

sccr datafile <CR>

gcrplot <CR> [with IP = 7]

Plotting Routine

This routine plots the magnitude and phase of the field pattern versus the polar angle. The routine is called 'gp.f' and is shown in Appendix C. The magnitude is plotted in red and phase in green. The magnitudes are read in volts from the file where the pattern values are stored (e.g., NIPLOT, FSPLOT1), which are converted to dBs before being plotted. The range for the magnitudes is 2 dB to -46 dB. However, for a range of -20 dB to -68 dB, the routine 'gpcr.f' can be used. The command for running the above two routines are:

gplot <CR>

or

gcrplot <CR>.

When this command is given the following message appears on the screen:

ENTER IP: (SWIN-1, SWOUT-2, SWDIF-3,
SCATIN-4, SCATFI1-5, SCATFI2-6,
SCATFS1-7, SCATFS2-8, SCATDIFL-9,
SCATDIFR-10).

By choosing a value for IP, the desired pattern can be viewed on the graphics terminal.

A table of the files from which the input values are read by 'gp.f' or 'gpcr.f' is given below:

IP	File
1	PATIN
2	PATOUT
3	PATDIF
4	NIPLOT
5	FIPLOT1
6	FIPLOT2
7	FSPLOT1
8	FSPLOT2
9	DIFPLOTL
10	DIFPLOTR

All the programs are stored in the sri/Scat directory.

APPENDIX A

```
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SPHERICAL WAVE EXPANSION PROGRAM
    1    67
  6 CM. PATTERN INCIDENT ON FIRST  REFLECTOR (APRAD38.95;L 246CMS)
    81    -1    -1    -1    1    1
     1     1     1
   10.00000
    0.00000    0.00000    0.00000
    1.00       -0.28       0.30
    2.00       -1.15       1.07
    3.00       -2.51       1.88
    4.00       -4.25       2.14
    5.00       -6.36       1.43
    6.00       -8.30       0.24
    7.00      -10.19       0.34
    8.00      -12.09       3.35
    9.0       -14.34       9.09
   10.0       -16.91      15.59
   11.0       -19.58      20.55
   12.0       -21.87      24.63
   13.00      -23.62      32.67
   14.0       -25.60      46.72
   15.0       -28.08      63.11
   16.0       -30.72      76.01
   17.0       -32.42      86.21
   18.0       -33.25     105.04
   19.0       -34.53     134.23
   20.0       -36.75     166.33
   181    41
```

APPENDIX B

```
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ELLIPSOID 38.0 D TILT;N=2,RHO0=2.54,WL=6CM,THETAEDGE=15.5+0.000*COSPHI
    1
  104.7198   -1.6500    0.0        2.1266    38.0000    2.5380    0.0000
   61      74.00       1.00
    1     180.00     180.00
    1
   20       0.00       1.00
   37       0.00      10.00
    0
  15.500
   -2    3.7000     0.0000
    2    0.00     0    -1
   15.5000
```

APPENDIX C

```
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C        GRAPHICS ROUTINE
C        THIS ROUTINE PLOTS THE OUTPUT OF THE SPHERICAL
C        WAVE EXPANSION & THE SCAT PROGS.
C        ENTER IP FOR THE REQUIRED PLOTS AS FOLLOWS
C        SWE: INCIDENT(1);  OUTPUT(2); DIFFERENCE(3)
C        SCAT: INCI.(NEAR)(4); INCI.(FAR)PHI1(5)
C          INCI.(FAR)PHI2(6); SCATT.(FAR)PHI1(7);
C          SCATT.(FAR)PHI2(8); DIFF.(LEFT)(9); DIFF(RT)(10)
         INTEGER AXIS, MAG, PHA, I, USED, JPLT
         REAL SX(150),SY(150),SZ(150),XL,YB,XR,YT
         CHARACTER FORM*66, NAME*20, VAR*3, VAS*4, VAT*3
C
         WRITE(6,10)
         READ *,IP
         IF(IP .EQ. 1)GO TO 310
         IF(IP .EQ. 2)GO TO 320
         IF(IP .EQ. 3)GO TO 330
         IF(IP .EQ. 4)GO TO 340
         IF(IP .EQ. 5)GO TO 350
         IF(IP .EQ. 6)GO TO 360
         IF(IP .EQ. 7)GO TO 370
         IF(IP .EQ. 8)GO TO 380
         IF(IP .EQ. 9)GO TO 390
         IF(IP .EQ. 10)GO TO 400
310      KIT=10
         OPEN(KIT,FILE='PATIN',STATUS='OLD')
         GO TO 90
C
320      KIT=11
         OPEN(KIT,FILE='PATOUT',STATUS='OLD')
         GO TO 90
C
330      KIT=13
         OPEN(KIT,FILE='PATDIF',STATUS='OLD')
         GO TO 90
C
340      KIT=16
         OPEN(KIT,FILE='NIPLOT',STATUS='OLD')
         GO TO 90
C
350      KIT=17
         OPEN(KIT,FILE='FIPLOT1',STATUS='OLD')
         GO TO 90
C
360      KIT=21
         OPEN(KIT,FILE='FIPLOT2',STATUS='OLD')
         GO TO 90
C
370      KIT=18
         OPEN(KIT,FILE='FSPLOT1',STATUS='OLD')
         GO TO 90
C
380      KIT=22
         OPEN(KIT,FILE='FSPLOT2',STATUS='OLD')
         GO TO 90
C
```

```
390     KIT=19
        OPEN(KIT,FILE='DIFPLOTL',STATUS='OLD')
        GO TO 90
C
400     KIT=20
        OPEN(KIT,FILE='DIFPLOTR',STATUS='OLD')
C
90      REWIND KIT
        READ(KIT,20)FORM
        READ(KIT,25)NAME
        WRITE(6,30)FORM
        WRITE(6,35)NAME
        READ(KIT,40)JPLT
C
        READ(KIT,50)(SX(I),SY(I),SZ(I),I=1,JPLT)
        DO 130 I=1,JPLT
        SY(I)=20.*ALOG10(SY(I))
130     CONTINUE
C
        DIF=SX(JPLT)-SX(1)
        IF(DIF .LE. 30.0)THEN
         DEL=1.0
         DEM=DEL
        ELSEIF(DIF.GT.30.0 .AND. DIF.LE.70.0)THEN
         DEL=5.0
         DEM=DEL/2.0
        ELSE
         DEL=10.0
         DEM=DEL/2.0
        ENDIF
        N1=SX(1)/10
        FN1=N1*10.0
        NF=SX(JPLT)/10
        FNF=NF*10.0+DEL
C
        IF(DIF .LE. 29.0)THEN
         DEN=5.0*DEL
         ELSEIF(DIF .EQ. 30.0)THEN
         DEN=10.0*DEL
         ELSEIF(DIF.GE.31.0 .AND. DIF.LE.49.0)THEN
         DEN=2.0*DEL
         ELSEIF(DIF.GE.50.0 .AND. DIF.LE.70.0)THEN
         DEN=4.0*DEL
         ELSEIF(DIF.GE.71.0 .AND. DIF.LE.99.0)THEN
         DEN=2.0*DEL
         ELSE
         DEN=3.0*DEL
        ENDIF
C
        CALL MGIASNGP(0,0)
        CALL MGRGETVCOOR(2,XL,YB,XR,YT,USED)
C
        CALL MGIDEFW(3)
        CALL MGRPW(3,2,.2,.05,.8,.95)
        CALL MGRVCOOR(3,SX(1),-46.0,SX(JPLT),2.0)
C
```

```
      CALL MGIDEFW(4)
      CALL MGRPW(4,2,.2,.05,.8,.95)
      CALL MGRVCOOR(4,SX(1),-180.0,SX(JPLT),180.0)
C
      CALL MGIDEFW(5)
      CALL MGRPW(5,2,0.0,0.05,0.2,0.95)
      CALL MGRVCOOR(5,0.0,-46.0,5.0,2.0)
C
      CALL MGIDEFW(6)
      CALL MGRPW(6,2,0.8,0.05,1.0,0.95)
      CALL MGRVCOOR(6,0.0,-180.0,5.0,180.0)
C
      CALL MGIFREESETS()
      AXIS=MGISTATSET(MGFCNS("Yellow"))
      MAG=MGISTATSET(MGFCNS("Red"))
      PHA=MGISTATSET(MGFCNS("Green"))
      CALL MGIFIXSETS()
C
      CALL MGIV(2)
      CALL MGISET(MAG)
      CALL MGIFETCHGF(10,'7x9')
      CALL MGIGFS(30,20,11,'AMPLIT(DBS)')
      CALL MGISET(PHA)
      CALL MGIGFS(520,20,10,'PHASE(DEG)')
      CALL MGISET(AXIS)
      CALL MGIGFS(300,460,5,'THETA')
C
      CALL MGIV(5)
      CALL MGISET(MAG)
      DO 150 A=-38.75,1.25,8.0
      VARX=A+0.75
      WRITE(VAR,160) IFIX(VARX)
      CALL MGRGFS(3.8,A,3,VAR)
150   CONTINUE
C
      CALL MGIV(6)
      CALL MGISET(PHA)
      DO 170 B=-127.0,173.0,60.0
      VARY=B+7.0
      WRITE(VAS,40) IFIX(VARY)
      CALL MGRGFS(0.1,B,4,VAS)
170   CONTINUE
C
      CALL MGIV(3)
      CALL MGISET(AXIS)
      CALL MGRL(SX(1),0.0,SX(JPLT),0.0)
      CALL MGRL(SX(1),-46.0,SX(1),2.0)
      CALL MGRL(7.14,-12.5,7.14,-10.5)
      CALL MGRL(6.89,-11.5,7.39,-11.5)
      IF(DEL .EQ. 1.0)THEN
       START=SX(1)
       ENDP=SX(JPLT)
      ELSE
       START=FN1
       ENDP=FNF
      ENDIF
```

```
C
      DO 200 CC=START, ENDP, DEN
      DD=CC-DEM
      VARZ=CC
      WRITE(VAT,160) IFIX(VARZ)
      CALL MGRGFS(DD,0.7,3,VAT)
200   CONTINUE
      DO 100 T = START, ENDP, DEL
      CALL MGRL(T,-0.5,T,0.5)
100   CONTINUE
C
      DO 110 T = -46.0,2.0,4.0
      CALL MGRL(SX(1),T,SX(1)+0.5,T)
110   CONTINUE
C
      CALL MGIV(4)
      CALL MGISET(AXIS)
      CALL MGRL(SX(JPLT),-180.0,SX(JPLT),180.0)
C
      DO 120 T=-180.0,180.0,20.0
      IF(T .EQ. 0.0)THEN
      DIS=1.0
      ELSE
      DIS=0.5
      ENDIF
      CALL MGRL(SX(JPLT)-DIS,T,SX(JPLT),T)
120   CONTINUE
C
      CALL MGIV(3)
      CALL MGISET(MAG)
      CALL MGRLS(I-1,SX,SY)
C     CALL MGIFETCHGF(0,"7x9")
C     CALL MGRGFC(-50,50,M)
C
      CALL MGIV(4)
      CALL MGISET(PHA)
      CALL MGRLS(I-1,SX,SZ)
      STOP
C
10    FORMAT(/,T2,'ENTER: IP (SWIN-1  SWOUT-2  SWDIF-3  SCATNI-4  SC
     BATFI1-5  SCATFI2-6',/,T13,'SCATFS1-7  SCATFS2-8  SCATDIFL-9  SCATD
     BIFR-10)')
20    FORMAT(/A66)
30    FORMAT(1H1,A66)
25    FORMAT(A20)
35    FORMAT(1H1,A20)
40    FORMAT(I4)
50    FORMAT(F10.2,F12.6,F8.2)
160   FORMAT(I3)
      END
```