G.1 The mainline program POLRUN

The program POLRUN listed below is designed to read data in 80-column format; list headings and virtual heights; run POLAN; and list the calculated real heights. A number of special facilities are also built in, primarily for use in repeated running of test data with different modes of analysis or different start conditions. Input constants which invoke these facilities are outlined in the program comments, and the shortened or "fast-look" output is described in section G.2.2.

Lower case lines in the listing relate to the special test facilities built into the program. For normal use only the lines listed in upper case are required, so a considerably shortened version of POLRUN can be made to read and run normal data. FORTRAN line numbers added during the compilation are shown at the left of each line. Columns 73 to 80 of some lines are used for comments, and are not part of the program code.

```
          c***  P O L R U N  ***   MAINLINE FOR N(H) ANALYSIS USING 'POLAN'.
          c                                                              Feb 1985.
          c     Read (1):   field  (and station heading);
          c     Read (2):   data,  data,  data,   . . .
          c
          c     The data for each ionogram terminates with at least two zero values of
          c         height.  Data for the following ionogram then begins on the next line.
          c     Use 1 blank line to reread a station,field line (1);     2 blanks to exit.
          c------------------------------------------------------------------------------
          c--------                                                Extensions Mar 85.
          c  Set the FIRST amode -ve to use a constant value of amode throughout the run.
          c
          c  Set a final parameter BMODE to loop data with modes =  amode to bmode.
          c
          c-------- Initial data line with FH = 9.  gives quick-check without data lists;
          c                          then FH =-9.  reverts to normal output.
          c
          c-------- Set START > 200.  to use the value  START-200  for all following runs.
          c------------------------------------------------------------------------------
0001            DIMENSION HEAD(25),FV(120),HT(120),  fs(120),hs(120)
0002            BYTE DAT(9)
0003            CALL DATE (DAT)
0004            bmode= 0.
0005            cmode= 0.
0006            modin= 0
0007            stacon= 0.
0008      10       fast = 0.
0009               go to 100
0010      20          fast = 1.
          c                                          read field and mode
0011      100   READ 120,  HEAD, FH,DIP, AMODE, VALLEY, LIST, bmode            read (1)
0012      120   FORMAT (25A1, 4F5.0 , I5, F5.0)
0013            amodl= amode
0014              if (fh.eq. 9.)  go to 20
0016              if (fh.eq.-9.)  go to 10
0018              IF (FH.EQ.0.)  STOP
0020                          if (modin.eq.0.and.amode.lt.0.)  cmode= -amode      constant
0022                          modin= modin+1
0023                          if (cmode.gt.0.)  amode= cmode
          c
0025                      if(fast.gt.1.) print 150
0027      150             format(1h , 60(1h-) )
0028                if (fast.le.1.) PRINT 140, DAT
0030      140       FORMAT (1H1,7X,'P O L A N   OF  APRIL 1985.',67X,9A2)
0031                if (fast.eq.1.)print*,'<<<<<  F A S T   L O O K   R U N  >>>>>'
0033             PRINT 160, HEAD, FH,DIP, AMODE, VALLEY, LIST, bmode
0034      160    FORMAT (1H0,25A1,5X, 'FH =',F5.2,5X, 'DIP =',F6.1,5X,
               1       'AMODE =',F6.2,5X, 'VALLEY=',F6.2, '    LIST =', I3,f8.1)
          c                                          read data
0035      200    if (cmode.eq.0.)  amode= amodl
0037             NH = -3
```

```
      READ 220, HEAD,START, (FV(I),HT(I), I=1,5)                        read(2)-
220   FORMAT (25A1, F5.3, 5(F5.3,F5.2) )
      IF (FV(1).EQ.0.) GO TO 100
               if (start.gt.200.)  stacon= start-200.
               if (stacon .gt. 0.)  start= stacon
      PRINT 240, HEAD, START
240   FORMAT (1H0,25A1,4X,'START ='F7.3)
300      NH = NH+8
         IF(FV(NH)+HT(NH).EQ.0..or.fv(nh).eq.-1..OR.NH.GT.113) GO TO 380     end
         READ 320, (FV(I),HT(I), I=NH+1,NH+8)                           -read(2)
320      FORMAT (8(F5.3,F5.2))
         GO TO 300
c                                        list data.
380         if (fast.eq.0.)  go to 400
            fast = fast+1.
            list= 0
            go to 450
400   L = 1
420      M = MIN0(NH, L+15)
         PRINT 520, 'OFREQ', (FV(I), I=L,M)
         PRINT 520, ' VIRT', (HT(I), I=L,M)
         L = M+1
         IF (L.LE.NH.AND.(FV(M-1).NE.0..OR.FV(M).NE.0.))  GO TO 420
      PRINT 520
c                                        save data
            do 430 i = 1, 120
            fs(i)= fv(i)
430         hs(i)= ht(i)
c---------------------------------------analysis
c
450            if (bmode.ne.0.)  print 480, amode
480            format ('0#### Analysed with  mode =', f6.1,/)
      N=120
      CALL POLAN (N,FV,HT,  FH,DIP, START, AMODE, VALLEY, LIST)
c
c                                        output
            if (fast.ge.1.) print 150
            if (fast.ge.1.) go to 200
      L = 1
500      M = MIN0(N+2, L+15)
         PRINT 520, 'OFREQ', (FV(I), I=L, M)
         PRINT 520, ' REAL', (HT(I), I=L, M)
520      FORMAT (A5, F7.3,7F8.3, 1X,8F8.3)
         L = M+1
         IF (L.LE.N+1 .and.fv(m).ne.-1..and.fv(l).ne.-1.)  GO TO 500
c
            if (bmode.ne.0..and.amode.lt.bmode) go to 600
      PRINT 560
560   FORMAT (1H0,132('='))
      GO TO 200
c                                                          loop with  mode + 1
600         do 620 i= 1, 120
               fv(i)= fs(i)
620            ht(i)= hs(i)
            amode= amode+1
            go to 450
c
      END
```

G.2 STANDARD TEST DATA AND FAST-LOOK OUTPUT

The data listed below are used as input for the mainline program POLRUN. They define a number of model ionograms which test most of the different start, peak and valley procedures in POLAN. The initial line ('FAST LOOK OUTPUT') is normally omitted; when included it produces a shortened printout summarising the overall results for each layer. Fast-Look output obtained from the standard test data is listed in section G.3.2 below, and the normal full output is discussed in G.3.

For normal calculations the first data line gives an overall heading or station identification, followed by the magnetic field constants FH and DIP, the Mode of analysis, and (optional) Valley and List parameters. Following lines contain the ionogram data as (frequency, height) pairs. The first data line has a heading (e.g. the date and time for this ionogram) and a value for the parameter START, followed by 5 data points. Following lines contain 8 (frequency,height) data points each. The end-of-data for each ionogram is signalled by two (or more) zero virtual heights.

Data for the next ionogram follow immediately if the field, mode, valley and list constants are unchanged (as for ionograms 1A, 1B, .. 1G below). A blank line in the data set indicates that field constants are to be changed, and a new line giving FH, DIP, MODE, VALLEY and LIST parameters is read before ionogram data continues. Two blank lines terminate the data file.

The first data set, numbered (00), provides a test of the new single-polynomial modes in POLAN which use a specified number of real-height coefficients to represent each layer. Thus Mode 80 would use 8 terms for each layer. The value Mode = 85 given in the test data specifies 8 real height coefficients for the final layer, and 5 for each preceding layer. LIST = 1 (the last parameter on this line) causes the calculated real-height coefficients to be listed for each layer.

The second data set (01) below is a shortened version of the 2-layer model (1G), run with LIST = 2 to show quickly any major errors in the operation of POLAN. Following data sets (1) through (5) demonstrate and test different aspects of the analysis, mostly with only the normal output listings. The use of these sets is outlined in section G.3.1.

G.2.1 STANDARD TEST DATA FOR POLAN, AS READ BY THE MAINLINE PROGRAM POLRUN

To run this data it must be entered exactly as shown, including blank lines and with numerical data in the correct columns. Virtual heights are shown without decimal points; the 5 digits include 2 decimal places and are read using an F5.2 format.

```
    Fast look output-->    9.0
(00) SINGLE-POLYNOMIALS.  -1.2  20.  85.   0.    1
(4B X VALLEY, much data)   -1.  1.0  9165 1.2  9622 1.6 10022 1.8 10205 2.0 10394
 2.2 10597 2.4 10823 2.6 11084 2.8 11401 2.9 11593 3.0 11818 3.1 12090 3.2 12420
 3.3 12918 3.3513249 3.4 13694 3.4514367 3.5 15712 3535  0.0-425033325-434828397
-444726408-454625351-464524740-474424381-484324184 3.6 27600 3.7 24780 3.8 23682
 3.9 23113 4.0 22799 4.1 22635 4.2 22571 4.3 22577 4.4 22637 4.6 22880 4.8 23250
 5.0 23723 5.2 24295 5.3 24600 5.4 24968 5.5 25333 5.6 25757 5.7 26150 5.8 26686
 5.9 27200 6.0 27797 6.2 29174 6.3 30000 6.4 30957 6.5 32092 6.6 33483 6.7 35282
 6.8 37828 6.9 42200 7.0

(01)FIXED FH; TRACE LIST2 -1.0  30.   0.   0.    2
(1G) E + F; NO FC'S         0. 1000 9700 130010100 170010700 220011700 260013100
 290015600  0.0  0.0 320028000 340026500 360026200 390026900 420028500 460032700
 490041800

(1) STANDARD TEST LAYERS  -1.0  30.   0.   0.
(1A) E LAYER,MODEL START   90. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3.0
(1B)MODEL ABOVE EXTRAPN.  100. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3.0
(1C) START FN AT 90 KM.    0.4 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3.0
(1D) E CUSP , CONTINUOUS    0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 300032000 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(1E)E CUSP,DISCONTINUOUS    0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000-320. 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(1F) E + F; DIRECT START   -1. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000     0 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
```

```
(1G) E + F; NO FC'S          0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500         0 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000

(2)  VALLEYS.              -1.0  30.   0.    0.
(2A)MONOTONIC (NO VALLY)     0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000   10. 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(2B) DIRECT VALLEY CALCN     0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000    0. 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(2C)40KM VALLEY;NO FPEAK     0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000   -8. 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000  -1.
(2D) MAXIMUM VALLEY.         0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000    5. 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(2E) DEEP VALLEY             0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000 -0.5 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(2F) SHALLOW VALLEY          0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000 -.01 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000

(3)PEAKFIT: HM=300,SH=60  -1.0  30.   0.    0.
(3A) CHAPMAN, NO FC'S       -1. 2.8 18729 3.0 20633 3.3 21791 3.6 22720 3.9 23597
 4.2 24478 4.5 25396 4.8 26380 5.0827385 5.3528469 5.6 29615 5.8 30670 6.0 31901
 6.2 33391 6.4 35296 6.6 37973 6.8 42566 6.9 47209
(3B) TRUNCATED:  WITH FO    -1. 5.3522918 5.6 26893 5.8 28532 6.0 30116 6.2 31850
 6.4 33940 6.6 36759 6.8 41468 6.9 46161 7.0
(3C)         WITH FO + FX   -1. 5.3522918 5.6 26893 5.8 28532 6.0 30116 6.2 31850
 6.4 33940 6.6 36759 6.8 41468 6.9 46161 7.0       7.518
(3D)         WITH FX ONLY   -1. 5.3522918 5.6 26893 5.8 28532 6.0 30116 6.2 31850
 6.4 33940 6.6 36759 6.8 41468 6.9 46161 0.0       7.518
(3E)         WITH BAD FC    -1. 5.3522918 5.6 26893 5.8 28532 6.0 30116 6.2 31850
 6.4 33940 6.6 36759 6.8 41468 6.9 46161 6.95

(4) X RAYS  NO PHYS EQUNS -1.2  20.  -5.    0.
(4A)START TEST3A, FIX FB     0.-176627128-185326469-194226085-203225868-212325758
-221625720 1.0 23512 1.1 23556 1.2 23642 1.3023756 1.4 23887 1.5 24031 1.6 24184
 1.7 24344 1.8 24509 1.9 24678 2.0 24850 2.1 25025 2.2 25201 2.3 25380 2.4 25560
 2.5 25741 2.6 25923 2.7 26106 -1.

(4) X RAYS WITH FIXED FB  -1.2  20.   0.    0.
(4A)START TEST3A, FIX FB     0.-176627128-185326469-194226085-203225868-212325758
-221625720 1.0 23512 1.1 23556 1.2 23642 1.3023756 1.4 23887 1.5 24031 1.6 24184
 1.7 24344 1.8 24509 1.9 24678 2.0 24850 2.1 25025 2.2 25201 2.3 25380 2.4 25560
 2.5 25741 2.6 25923 2.7 26106 -1.
(4B) X VALLEY, DATA ERR.    -1. 1.0  9165 1.2  9622 1.6 10022 1.8 10205 2.0 10394
 2.2 10597 2.4 10823 2.6 11084 2.8 11401 2.9 11593 3.0 11818 3.1 12090 3.2 10114
 3.3 12918 3.3513249 3.4 13694 3.4514367 3.5 15712 3535  0.0-425033325-434828397
-444726408-454625351-464524740-474424381-484324184 3.6 27600 3.7 24780 3.8 23682
 3.9 23113 4.0 22799 4.1 22635 4.2 22571 4.3 22577 4.4 22637 4.6 22880 4.8 23250
 5.0 23723 5.2 24295 5.4 24968 5.6 25757 5.8 26686 6.0 27797 6.2 29174 6.3 30000
 6.4 30957 6.5 32092 6.6 33483 6.7 35282 6.8 37828 6.9 42200 7.0

2 PARAMETERS, WITH LIST.  -1.2  20.  0.0 -1.0   -1
(4C) TEST 4B, X VALLEY.     -1. 1.0  9165 1.2  9622 1.6 10022 1.8 10205 2.0 10394
 2.2 10597 2.4 10823 2.6 11084 2.8 11401 2.9 11593 3.0 11818 3.1 12090 3.2 12437
 3.3 12918 3.3513249 3.4 13694 3.4514367 3.5 15712 3535  0.0-425033325-434828397
-444726408-454625351-464524740-474424381-484324184 3.6 27600 3.7 24780 3.8 23682
 3.9 23113 4.0 22799 4.1 22635 4.2 22571 4.3 22577 4.4 22637 4.6 22880 4.8 23250
 5.0 23723 5.2 24295 5.4 24968 5.6 25757 5.8 26686 6.0 27797 6.2 29174 6.3 30000
 6.4 30957 6.5 32092 6.6 33483 6.7 35282 6.8 37828 6.9 42200 7.0

(5)VARYING FB; WITH LIST   1.0  30.   0.    0.     1
(5A) TEST6B NIGHT,DIP 30     0.-168234309-175732046-183230575-190729572-198328863
-206028351 114028970 122028056 130027455 138027046 146026763 154026566 162026430
 170026338 180026268 190026236 200026232 220026281 -1.
```

```
CANBERRA FIELD(WRONG FH) 1.52  57.3   0.   0.    1
(5B) BAD START DATA        0.-255217300-263317300-270617600-275818600 163515000
 169915000 177415100 182816200 185617800 188719600 193418900 200818700 206220000
 208423100 208925200 209629900
```

G.2.2 Fast-look output produced by POLRUN

The initial line in the standard data listing above sets a value of 9.0 for the gyrofrequency. This informs the mainline program POLRUN that listings should be restricted to the overall constants for each layer. The result is a compact output, as reproduced below. The main ionospheric characteristics are shown, and with fixed test data the correctness of the final peak constants verify the correctness of all steps in the calculation. Apart from the last data set (5), and the intermediate layers in 4B and 4C, all critical frequencies should be close to 3.0, 5.0 or 7.0 MHz. Fast-look output from POLRUN is cancelled at any time by specifying a gyrofrequency FH = -9.0. The control values of FH can be accepted only when the program is expecting a station/field line (i.e. at the start of the data or following a blank line), and must always be followed by a normal station/field line.

```
     P O L A N   OF  APRIL 1985.                                                        1 9 - A U G - 8 5
<<<<<  F A S T   L O O K   R U N  >>>>>

(0) SINGLE-POLYNOMIALS.       FH =-1.20      DIP =  20.0     AMODE = 85.00     VALLEY=  0.00    LIST =  1      0.0

(0) X VALLEY, much data.     START = -1.000

Peak  3.532 (+/-0.035) MHz,    Height 116.8 (+/- 0.6) km.    Scale Height 12.3 (+/- 0.8) km.     Slab (to peak) =  16.0 km.
 2  valley 23.2 km wide,    0.09 MHz deep.       devn  1.20 km          8 terms fitting 29 0 + 7 X rays  + 4            hx = 148.4

Peak  6.999 (+/-0.017) MHz,    Height 250.4 (+/- 0.9) km.    Scale Height 59.3 (+/- 1.2) km.     Slab (to peak) =  86.8 km.
--------------------------------------------------------------
--------------------------------------------------------------

(1)FIXED FH; TRACE LIST2      FH =-1.00      DIP =  30.0     AMODE =  0.00     VALLEY=  0.00    LIST =  2      0.0

(1G) E + F; NO FC'S          START =  0.000

Peak  3.046 (+/-0.003) MHz,    Height 125.2 (+/- 0.1) km.    Scale Height 18.2 (+/- 0.0) km.     Slab (to peak) =  23.2 km.
 2  valley 27.6 km wide,    0.11 MHz deep.       devn  1.23 km          5 terms fitting  5 0 + 0 X rays  + 4            hx = 158.3

Peak  5.062 (+/-0.019) MHz,    Height 263.5 (+/- 1.3) km.    Scale Height 68.0 (+/- 1.2) km.     Slab (to peak) = 100.9 km.
--------------------------------------------------------------
--------------------------------------------------------------

(1) STANDARD TEST LAYERS      FH =-1.00      DIP =  30.0     AMODE =  0.00     VALLEY=  0.00    LIST =  0      0.0

(1A) E LAYER,MODEL START     START = 90.000

Peak  3.002 (+/-0.007) MHz,    Height 123.3 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  19.1 km.
--------------------------------------------------------------

(1B)MODEL ABOVE EXTRAPN.     START =100.000

Peak  3.001 (+/-0.007) MHz,    Height 123.9 (+/- 0.2) km.    Scale Height 14.7 (+/- 0.2) km.     Slab (to peak) =  18.3 km.
--------------------------------------------------------------

(1C) START FN AT 90 KM.      START =  0.400

Peak  3.002 (+/-0.007) MHz,    Height 123.5 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  18.9 km.
--------------------------------------------------------------

(1D) E CUSP , CONTINUOUS     START =  0.000

Peak  4.998 (+/-0.037) MHz,    Height 262.7 (+/- 4.4) km.    Scale Height 79.2 (+/- 5.5) km.     Slab (to peak) = 107.0 km.
--------------------------------------------------------------

(1E)E CUSP,DISCONTINUOUS     START =  0.000

Peak  4.998 (+/-0.036) MHz,    Height 262.6 (+/- 4.3) km.    Scale Height 79.8 (+/- 5.3) km.     Slab (to peak) = 106.9 km.
--------------------------------------------------------------

(1F) E + F; DIRECT START     START = -1.000

Peak  3.001 (+/-0.007) MHz,    Height 124.5 (+/- 0.2) km.    Scale Height 14.5 (+/- 0.2) km.     Slab (to peak) =  17.5 km.
 2  valley 32.0 km wide,    0.12 MHz deep.       devn  1.84 km          5 terms fitting  5 0 + 0 X rays  + 4            hx = 164.5

Peak  4.997 (+/-0.030) MHz,    Height 268.5 (+/- 3.3) km.    Scale Height 76.1 (+/- 4.1) km.     Slab (to peak) = 103.7 km.
--------------------------------------------------------------

(1G) E + F; NO FC'S          START =  0.000

Peak  3.007 (+/-0.006) MHz,    Height 123.6 (+/- 0.2) km.    Scale Height 15.2 (+/- 0.2) km.     Slab (to peak) =  19.3 km.
 2  valley 31.5 km wide,    0.12 MHz deep.       devn  1.80 km          5 terms fitting  5 0 + 0 X rays  + 4            hx = 162.8

Peak  4.986 (+/-0.032) MHz,    Height 266.3 (+/- 3.5) km.    Scale Height 74.7 (+/- 4.5) km.     Slab (to peak) = 103.6 km.
--------------------------------------------------------------
```

```
(2)  VALLEYS.                FH =-1.00    DIP =  30.0    AMODE =  0.00    VALLEY=  0.00    LIST =  0     0.0

(2A)MONOTONIC (NO VALLY)     START =  0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.    Slab (to peak) =  19.1 km.

Peak  4.999 (+/-0.036) MHz,   Height 262.1 (+/- 4.3) km.   Scale Height 80.3 (+/- 5.3) km.    Slab (to peak) = 106.5 km.
------------------------------------------------------------

(2B) DIRECT VALLEY CALCN     START =  0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.    Slab (to peak) =  19.1 km.
 2  valley 31.7 km wide,    0.12 MHz deep.       devn  1.88 km         5 terms fitting  5 O + 0 X rays  + 4          hx = 163.1

Peak  4.997 (+/-0.029) MHz,   Height 267.8 (+/- 3.2) km.   Scale Height 76.4 (+/- 4.1) km.    Slab (to peak) = 104.7 km.
------------------------------------------------------------

(2C)40KM VALLEY;NO FPEAK     START =  0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.    Slab (to peak) =  19.1 km.
 2  valley 40.0 km wide,    0.20 MHz deep.       devn  0.82 km         5 terms fitting  5 O + 0 X rays  + 4          hx = 169.3
------------------------------------------------------------

(2D) MAXIMUM VALLEY.         START =  0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.    Slab (to peak) =  19.1 km.
 2  valley 62.8 km wide,    0.42 MHz deep.       devn  6.15 km         5 terms fitting  5 O + 0 X rays  + 4          hx = 188.6

Peak  4.992 (+/-0.038) MHz,   Height 274.5 (+/- 3.7) km.   Scale Height 70.8 (+/- 4.9) km.    Slab (to peak) =  98.5 km.
------------------------------------------------------------

(2E) DEEP VALLEY             START =  0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.    Slab (to peak) =  19.1 km.
 2  valley 40.4 km wide,    0.43 MHz deep.       devn  5.40 km         5 terms fitting  5 O + 0 X rays  + 4          hx = 170.4

Peak  4.996 (+/-0.029) MHz,   Height 271.1 (+/- 3.0) km.   Scale Height 74.5 (+/- 3.9) km.    Slab (to peak) = 102.8 km.
------------------------------------------------------------

(2F) SHALLOW VALLEY          START =  0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.    Slab (to peak) =  19.1 km.
 2  valley  7.7 km wide,    0.01 MHz deep.       devn  3.85 km         5 terms fitting  5 O + 0 X rays  + 4          hx = 148.5

Peak  4.999 (+/-0.027) MHz,   Height 264.9 (+/- 3.1) km.   Scale Height 78.9 (+/- 3.8) km.    Slab (to peak) = 107.0 km.
------------------------------------------------------------
------------------------------------------------------------

(3)PEAKFIT: HM=300,SH=60     FH =-1.00    DIP =  30.0    AMODE =  0.00    VALLEY=  0.00    LIST =  0     0.0

(3A) CHAPMAN, NO FC'S        START = -1.000

Peak  7.003 (+/-0.009) MHz,   Height 300.0 (+/- 0.8) km.   Scale Height 60.3 (+/- 1.1) km.    Slab (to peak) =  76.4 km.
------------------------------------------------------------

(3B) TRUNCATED:  WITH FO     START = -1.000

Peak  7.001 (+/-0.008) MHz,   Height 299.9 (+/- 0.7) km.   Scale Height 60.1 (+/- 1.0) km.    Slab (to peak) =  61.2 km.
------------------------------------------------------------

(3C)        WITH FO + FX     START = -1.000

Peak  7.001 (+/-0.008) MHz,   Height 299.9 (+/- 0.6) km.   Scale Height 60.1 (+/- 0.9) km.    Slab (to peak) =  61.2 km.
------------------------------------------------------------

(3D)        WITH FX ONLY     START = -1.000

Peak  7.001 (+/-0.008) MHz,   Height 299.9 (+/- 0.7) km.   Scale Height 60.1 (+/- 1.0) km.    Slab (to peak) =  61.2 km.
------------------------------------------------------------

(3E)        WITH BAD FC      START = -1.000

Peak  6.968 (+/-0.031) MHz,   Height 297.4 (+/- 2.5) km.   Scale Height 56.3 (+/- 3.8) km.    Slab (to peak) =  59.1 km.
------------------------------------------------------------
------------------------------------------------------------

(4) X RAYS  NO PHYS EQUNS    FH =-1.20    DIP =  20.0    AMODE = -5.00    VALLEY=  0.00    LIST =  0     0.0

(4A)START TEST3A, FIX FB     START =  0.000
 1  start offset = -12.2 km,   slab  84.7 km.      devn  0.00 km     8 terms fitting  6 O + 6 X rays + 0.       hx = 213.8
------------------------------------------------------------
------------------------------------------------------------

(4) X RAYS WITH FIXED FB     FH =-1.20    DIP =  20.0    AMODE =  0.00    VALLEY=  0.00    LIST =  0     0.0

(4A)START TEST3A, FIX FB     START =  0.000
 1  start offset = -29.7 km,   slab   7.3 km.      devn  1.00 km     8 terms fitting  6 O + 6 X rays + 3.       hx = 214.6
------------------------------------------------------------
```

```
(4B) X VALLEY, DATA ERR.       START = -1.000

*****reduce: data error at f, h =   3.100 118.168   3.200  98.716   3.300 127.007

Peak  3.533 (+/-0.005) MHz,    Height 116.1 (+/- 0.2) km.    Scale Height 12.5 (+/- 0.4) km.     Slab (to peak) =  15.4 km.
 3  valley 21.8 km wide,     0.07 MHz deep.        devn  0.60 km        8 terms fitting  5 O + 5 X rays  + 4          hx = 144.3

Peak  7.000 (+/-0.002) MHz,    Height 250.6 (+/- 0.2) km.    Scale Height 59.8 (+/- 0.3) km.     Slab (to peak) =  86.7 km.
-------------------------------------------------------------
-------------------------------------------------------------

2 PARAMETERS, WITH LIST.      FH =-1.20      DIP =  20.0      AMODE =  0.00      VALLEY= -1.00     LIST = -1      0.0

(4C) TEST 4B, X VALLEY.       START = -1.000

Peak  3.533 (+/-0.005) MHz,    Height 116.0 (+/- 0.2) km.    Scale Height 12.5 (+/- 0.4) km.     Slab (to peak) =  15.4 km.
 7  valley 18.4 km wide,     0.04 MHz deep.        devn  0.16 km        8 terms fitting  5 O + 5 X rays  + 4          hx = 142.3

Peak  7.000 (+/-0.002) MHz,    Height 250.1 (+/- 0.2) km.    Scale Height 60.0 (+/- 0.3) km.     Slab (to peak) =  86.9 km.
-------------------------------------------------------------
-------------------------------------------------------------

(5)VARYING FB; WITH LIST      FH = 1.00      DIP =  30.0      AMODE =  0.00      VALLEY=  0.00     LIST =  1      0.0

(5A) TEST6B NIGHT,DIP 30      START =  0.000
 1  start offset = -78.8 km,   slab   0.0 km.      devn  0.83 km     8 terms fitting  6 O + 6 X rays + 3.       hx = 227.3
 2  start offset = -77.9 km,   slab   0.1 km.      devn  0.86 km     8 terms fitting  6 O + 6 X rays + 3.       hx = 227.7
-------------------------------------------------------------
-------------------------------------------------------------

CANBERRA FIELD(WRONG FH)      FH = 1.52      DIP =  57.3      AMODE =  0.00      VALLEY=  0.00     LIST =  1      0.0

(5B) BAD START DATA           START =  0.000
 1  start offset = -56.3 km,   slab -28.9 km.      devn  1.60 km     6 terms fitting  4 O + 2 X rays + 3.       hx = 131.4
x ray weights reduced to 1/4.
 3  start offset = -57.2 km,   slab -24.8 km.      devn  1.58 km     6 terms fitting  4 O + 2 X rays + 3.       hx = 130.6

Peak  2.096 (+/-0.006) MHz,    Height 147.0 (+/- 0.4) km.    Scale Height  9.4 (+/-11.3) km.     Slab (to peak) =  25.9 km.
-------------------------------------------------------------
```

G.3. STANDARD RESULTS AND DISCUSSION

G.3.1 Discussion of the test output

The full output obtained from the standard test data, as produced by the program POLRUN, is listed in section G.3.2 below. It is obtained by running the standard test data of section G.2 after deletion of the initial line which sets FH = 9.0. Results then list the initial virtual-height data and the calculated real-height profile, along with any additional trace information which has been requested by use of a non-zero value for the parameter LIST. The output in G.3.2 was obtained on a PDP11/10 minicomputer without floating point hardware, and required a total running time of 19 minutes.

The first data set (00) uses a reasonably large number of virtual-height points, covering two layers and with extraordinary ray data provided for the intervening valley calculation. This set is basically an expanded version of the X-Valley data of (4B), and gives similar results. It is run here with AMODE = 85, to determine a 5-term real height polynomial for the first layer and an 8-term polynomial for the final layer. Use of LIST = 1 gives the lines "*adjust --- . . " in the output, showing the basic profile constants at each step. Values q1 to q5 are the polynomial coefficients for the first layer, while the final number (1.74) on the same line is the r.m.s. deviation in km of the fit to the virtual-height data. Some further constants are listed on the trace lines beginning "## "; no heading is given for these values at LIST = 1, but headings can be seen in the following block (the lines beginning "##TRACE: " in the (1G) analysis).

The output for set (00) shows the operation of the new single-polynomial modes in POLAN, and the least-squares solution obtained with a highly over-determined data set. The calculations for the final layer, including the valley region, use a real-height polynomial with 8 terms fitted to 29 ordinary-ray data points, 7 extraordinary-ray points, and 4 physical conditions (used to predispose the valley solution to a physically acceptable form). The total of 40 simultaneous equations fitted in the least-squares solution is the limit available in the current version of POLAN. This limit can be increased if required by changing the first dimension of the array B(40,17).

The 8 polynomial coefficients which describe the final layer, as a function of DF = (f - foE), are Q0 to Q7. Q1 to Q7 are as listed by POLAN, when run with LIST = 1. The listed value for Q8 gives the constant offset or real-height shift at the start frequency (foE) of this profile section, which is used in calculating the valley width. For the real-height expression this term is ignored, and the initial constant term Q0 is obtained by adding the listed values of HMAX (for the E layer) and VALLEY WIDTH. This gives the real height at the beginning of the F layer, just above the valley region, and the F-layer profile is

$$h(f) = Q0 + Q1*DF + Q2*DF^2 + Q3*DF^3 + \ldots + Q7*DF^7.$$

The order of the expansion (the number of true polynomial terms in Q) is given by the value of MT listed on the same line, as in the output below.

The second analysis (01) in the standard data set uses a shortened version of the two-layer data (1G), run with LIST = 2. This produces some trace information in a normal start/ first-layer/ valley/ second-layer calculation using the minimum amount of data necesary for a reasonably complete check of the ordinary-ray sections in POLAN. Results from the main data groups (1) to (5) then follow, to test and illustrate different aspects of the operation of POLAN. The virtual heights in groups (1) and (2) are an arbitrary series used to provides a simple, compact data set for test purposes. They are constructed to give critical frequencies of about 3.0 MHz for the E layer and 5.0 for the F layer, so that results can be checked rapidly.

Of the profiles in group 1, (1A), (1B), (1C) and (1F) show the 4 different types of start treatment available for use with ordinary ray data. (1D) and (1E) show calculations across a cusp in the virtual-height data, assuming a continuous variation in profile gradient across the cusp (1D), or allowing a gradient discontinuity at the cusp frequency (1E). (1G) verifies the accuracy of peak and valley calculations when the critical frequencies are not scaled.

Results in group (2) show the different types of valley calculation possible with ordinary-ray data only. In the examples shown these different results are obtained by specifying different values for the virtual height at the critical frequency of the layer. This virtual height defines a valley flag HVAL within POLAN. The corresponding frequency is either a scaled value of foE, as shown in set (2), or is zero if the critical frequency is not scaled. The same results can be obtained, for a series of ionograms in which the virtual height at the layer boundary has the normal zero value, by providing a non-zero value for the input parameter VALLEY. This is read from the station/field card by POLRUN, and passed to POLAN as an input parameter; when the virtual height is zero at a critical frequency, POLAN sets HVAL equal to VALLEY. In most ordinary-ray calculations the width of the valley is determined by applying reasonable physical conditions and limits, and the valley depth bears a fixed relation to the width (as described in section 7.2 of this report).

In (2A) below the E and F layers are assumed to be continuous with no intervening valley. This result gives the lower limit to the range of possible heights for the upper layer, and is obtained by setting HVAL equal to 10.0. (2B) shows the default procedure obtained when HVAL = 0.0. The solution for the valley width is then a least-squares result incorporating desirable physical criteria which specify the continuity of gradient at the top of the valley region, approximate relations between the expected valley width and the height of the underlying peak, and the preference for a smooth (low-order) real-height profile. The "standard" valley width for a peak height of 123.3 km is 21.6 km. A preference for this width is included in the least squares solution, with about the same weight as a virtual-height point; the calculated width is appreciably larger since the data then gives a smoother continuation into the following F layer.

(2C) specifies a 40 km wide valley between the two layers, by setting HVAL equal to -8.0 (this is minus one fifth of the desired width). The condition "Valley Width = 40.0 km" is then included in the least-squares solution with a comparatively large weight. The r.m.s deviation listed for the valley calculation is smaller in this run, since the data provide a smoother fit with this wider valley. (2C) also shows the use of a data frequency of -1.0 to terminate the profile before a layer peak. In (2D) an upper-limit result is obtained for the height of the upper layer by setting HVAL = 5.0. This initially requests a valley width of 5 times the standard value (or over 100 km). Such a large value is not normally compatible with the virtual height data, and gives unacceptable gradients above the valley region. When this occurs POLAN reduces the valley width progressively until an acceptable solution is obtained. (2E) and (2F) use small negative values of HVAL to specify the depth of the valley, in MHz. The values given are modified to some extent to ensure that they do not approach the value of foE.

The data set (3) consists of accurate virtual heights for a Chapman layer with a critical frequency of 7.0 MHz, a peak height of 250.0 km and a scale height of 60.0 km. The layer was truncated below 2.8 MHz in calculating the data for (3A), and below 5.35 MHz for (3B) to (3E), so no allowance is required for ionisaton below these starting frequencies. Results obtained using the "direct start" in POLAN therefore give a direct check on the accuracy of the profile calculation (using a fairly small number of points), and on the peak fit procedure with different types of critical frequency data.

Group (4) checks the operation of the start and valley calculations using extraordinary ray data. The virtual heights are calculated from a profile consisting of two overlapping Chapman layers, with an overall critical frequency of 7.0 MHz, a peak height of 250.0 km and a scale height of 60.0 km. The gyrofrequency is independent of height (so a negative value is given for the input parameter FH). (4A) is a straightforward start calculation, with the layer peak omitted by using a final frequency of -1. (4B) shows the standard extraordinary-ray valley calculation in which only a single valley parameter is calculated from the data. Thus the listed value for the valley depth is not an independent result, but is a simple function of the calculated width (as described in section 9.2). Only the first 5 of the extraordinary-ray data points have been used in the calculation, since these cover the optimum frequency range of about 0.5 MHz above the critical frequency of the lower layer. The remainder of the X-ray data are ignored by POLAN since their inclusion would not increase the accuracy of the calculation. (4B) also shows the detection of a simple data error, in the virtual height at 3.2 MHz. This error is detected in the "reduction" phase in POLAN and the point is automatically deleted from the calculations.

Results (4C) are for the same data set as (4A), but are run with the input parameter VALLEY = -1 to give the two-parameter valley analysis. This run also has LIST = -1 to give a trace of the start, peak and valley calculations. The two-parameter valley calculation in (4C) tries successive values of valley depth, calculating the optimum valley width each time, to find the combination which gives the smallest r.m.s error when fitted to the combined data (O-ray heights, X-ray heights and three "physical conditions"). Depths of about 0.1 and 0.5 MHz are tried first, and iteration then continues from whichever of these trial values gave the smaller r.m.s deviation. The minimum deviation finally found is 0.16 km; significantly less than the value of 0.6 km for the one-parameter valley fitted to the same data in (4B). With accurate model data, as here, the two-parameter procedure gives good results. With most practical ionograms, however, the accuracy of the data is not sufficient for a meaningful determination of two valley parameters and the default single-parameter analysis should be used in POLAN.

The "*adjust" lines in (4C) give a trace line for the first step, and then from just before the peak. Headings for the trace data are not printed at LIST = -1, but they can be seen in the following output (5). The second "*adjust" line shows that the profile section below the peak began at the 14th data point, fitting the virtual heights at frequencies from 3.3 to 3.5 MHz with a r.m.s. error of 0.01 km. In the second valley calculation the initial curvature of the real-height polynomial was positive, as shown by the positive value of the coefficient q(2). A "physical condition" built into POLAN requires that the curvature be negative just above a valley, so the subroutine ADJUST added the equation $q(2) = -2.0$ km/MHz^2 into the least-squares solution. This gave a new result with q(2) equal to -1.5, and the r.m.s. fit error slightly increased (from 4.68 to 4.83 km). Following the valley calculation, four of the real-height steps had high-order coefficients which were considered oscillatory. This was fixed by adding the constraint $q(mq) = 0.0$ into the least-squares solution, where mq is the index of the highest-order coefficient. Calculated coefficients would also be classified as oscillatory in the last calculated real-height polynomial, but no action was taken at this point since rapid changes in gradient are normal just below a peak.

Data sets (5A) and (5B) use the normal height-varying gyrofrequency. The start calculation in (5A) gives an unacceptably large value for the initial real-height gradient q(1) at the first frequency FA, so this is reduced from 671 to 258 km/MHz. The start calculation is iterated once to adjust for the variation of gyrofrequency with height. On the second calculation the calculated value for the thickness of the underlying slab of low-density ionisation was negative (-0.02 km), so the least-squares solution was recalculated with the added condition SLAB = 0.1. This small change caused a negligible increase in the r.m.s. fitting error.

The calculation of (5B) is for an ionogram processed with an incorrect value of gyrofrequency. The program had some difficulty in fitting a physically acceptable profile to the combined ordinary and extraordinary ray start data. This is shown primarily by the repeated reduction of the starting height (the reduction of the coefficient qm by the start/valley processing subroutine STAVAL) to avoid negative real height gradients at higher frequencies. Eventually the program decided that the two data sets were incompatible. The weight given to the extraordinary-ray data in the analysis was therefore divided by four and a reasonable solution obtained, although an unphysical variation was still required at frequencies below the first data point.

G.3.2 FULL TEST OUTPUT

Following lines are as obtained from a PDP11/10 computer, using 24-bit floating point accuracy. With other machines slight variations can be expected in those quantities which are not well defined. For example in start calculations using extraordinary ray data the heights in the unobserved region (at frequencies below fmin) may vary, in a way which changes the calculated heights in the observed range by less than about 0.1 km

```
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(00) SINGLE-POLYNOMIALS.      FH =-1.20    DIP =  20.0     AMODE - 85.00     VALLEY=  0.00    LIST =  1     0.0

(4B X VALLEY, much data)    START = -1.000

FREQ  1.000   1.200   1.600   1.800   2.000   2.200   2.400   2.600    2.800   2.900   3.000   3.100   3.200   3.300   3.350   3.400
VIRT 91.650  96.220 100.220 102.050 103.940 105.970 108.230 110.840  114.010 115.930 118.180 120.900 124.200 129.180 132.490 136.940

FREQ  3.450   3.500   3.535  -4.250  -4.348  -4.447  -4.546  -4.645   -4.744  -4.843   3.600   3.700   3.800   3.900   4.000   4.100
VIRT143.670 157.120   0.000 333.250 283.970 264.080 253.510 247.400  243.810 241.840 276.000 247.800 236.820 231.130 227.990 226.350

FREQ  4.200   4.300   4.400   4.600   4.800   5.000   5.200   5.300    5.400   5.500   5.600   5.700   5.800   5.900   6.000   6.200
VIRT225.710 225.770 226.370 228.800 232.500 237.230 242.950 246.000  249.680 253.330 257.570 261.500 266.860 272.000 277.970 291.740

FREQ  6.300   6.400   6.500   6.600   6.700   6.800   6.900   7.000    0.000   0.000   0.000   0.000   0.000
VIRT300.000 309.570 320.920 334.830 352.820 378.280 422.000   0.000    0.000   0.000   0.000   0.000   0.000

*adjust-----  lk jm mt    ha     fa    fm      ql       2       3       4       5
*adjust  ---   1  5  5   91.65  1.00  3.50    13.26  -26.39   31.35  -15.25    2.65     1.74

Peak  3.532 (+/-0.035) MHz,    Height 116.8 (+/- 0.6) km.    Scale Height 12.3 (+/- 0.8) km.     Slab (to peak) =  16.0 km.
##  3.3:  19  19  8  7  123.54  3.53  3.53  19  49  29   0   0   7   4  85  10  125.96  3.53  7.00 17.21   6.77   1.00  18.39   0.07
*adjust  ---  19  8  7  123.54  3.53  6.90    48.10  -73.10    99.94  -76.02    31.93   -6.90    0.60    14.60     1.20
 1  valley 21.4 km wide,    0.07 MHz deep.          devn  1.20 km          8 terms fitting 29 0 + 7 X rays  + 4           hx = 147.3
##  3.3:  19  19  8  7  124.33  3.53  3.50  48  49  29   0   0   7   4  85  10  125.96  3.53  7.00 17.21   7.56   1.00  21.37   0.09
*adjust  ---  19  8  7  124.33  3.53  6.90    42.77  -60.98    84.72  -65.61    28.04   -6.15    0.54    15.66     1.20
 2  valley 23.2 km wide,    0.09 MHz deep.          devn  1.20 km          8 terms fitting 29 0 + 7 X rays  + 4           hx = 148.4

Peak  6.999 (+/-0.017) MHz,    Height 250.4 (+/- 0.9) km.    Scale Height 59.3 (+/- 1.2) km.     Slab (to peak) =  86.8 km.

FREQ  1.000   1.200   1.600   1.800   2.000   2.200   2.400   2.600    2.800   2.900   3.000   3.100   3.200   3.300   3.350   3.400
REAL 91.650  93.474  95.109  96.044  97.274  98.710 100.191 101.581  102.869 103.532 104.276 105.182 106.355 107.935 108.929 110.092

FREQ  3.450   3.500   3.532   3.511   3.446   3.446   3.532   3.500    3.700   3.800   3.900   4.000   4.100   4.200   4.300   4.400
REAL111.450 112.962 116.771 120.548 124.326 133.722 139.986 142.626  145.794 148.390 150.654 152.745 154.758 156.745 158.729 160.712

FREQ  4.600   4.800   5.000   5.200   5.300   5.400   5.500   5.600    5.700   5.800   5.900   6.000   6.200   6.300   6.400   6.500
REAL164.650 168.505 172.285 176.087 178.044 180.064 182.164 184.359  186.655 189.056 191.562 194.171 199.718 202.700 205.893 209.407

FREQ  6.600   6.700   6.800   6.900   6.999   6.815   6.384   5.842    0.017 527.071
REAL213.409 218.156 224.008 231.336 250.440 280.856 312.872 346.621    0.861  59.312

=================================================================================================================================


     P O L A N   OF  APRIL 1985.                                                            1 9 - A U G - 8 5

(01)FIXED FH; TRACE LIST2     FH =-1.00     DIP =  30.0     AMODE =  0.00     VALLEY=  0.00    LIST =  2     0.0

(1G) E + F; NO FC'S            START =  0.000

FREQ  1.000   1.300   1.700   2.200   2.600   2.900   0.000   3.200    3.400   3.600   3.900   4.200   4.600   4.900    0.000    0.000
VIRT 97.000 101.000 107.000 117.000 131.000 156.000   0.000 280.000  265.000 262.000 269.000 285.000 327.000 418.000    0.000    0.000

#ARGS: N,fl,hl= 120    1.00  97.00      fb,dip,start=  -1.00  30.00   0.00      amode,valley,list=   0.00   0.00   2

#FRQ    1.00    1.30    1.70    2.20    2.60    2.90    0.00    3.20    3.40    3.60    3.90    4.20    4.60    4.90    0.00
#HTS   97.00  101.00  107.00  117.00  131.00  156.00    0.00  280.00  265.00  262.00  269.00  285.00  327.00  418.00    0.00
##-----------------------------------------------------

##TRACE:  kr   lk jm mt    ha     fa    frm  krm  kv  nf  nr  nl  nx  ms mode mod    hs     fc    fcc    sh   parht    hval vwidth vdepth
##  2.2:   1    1  8  7   82.71  0.50  0.50   1  29   4   0   0   0   1   5   5   93.43  0.00  0.00  0.00  19.10    1.00   0.00   0.00
##  3.3:   1    1  4  4   82.71  0.50  0.50   1  29   4   0   0   0   1   5   5   93.43  0.00  0.00  0.00   0.00    0.00   0.00   0.00

*adjust-----  lk jm mt    ha     fa    fm      ql       2       3       4
*adjust  ---   1  4  4   82.71  0.50  1.70    35.28  -71.11   75.48  -26.78    0.94
*adjust  ---   3  5  5   90.34  1.00  2.60     9.01    1.08   -1.08    0.48    0.17    0.13
*adjust  ---   4  5  5   93.10  1.30  2.90     9.11    0.72    2.45   -3.90    2.04    0.08

Peak  3.046 (+/-0.003) MHz,    Height 125.2 (+/- 0.1) km.    Scale Height 18.2 (+/- 0.0) km.     Slab (to peak) =  23.2 km.

##-----------------------------------------------------

##TRACE:  kr   lk jm mt    ha     fa    frm  krm  kv  nf  nr  nl  nx  ms mode mod    hs     fc    fcc    sh   parht    hval vwidth vdepth
##  2.2:   9    4  5  5   93.10  1.30  3.05   9  37   5   0   0   0   0   5   5  120.27  3.05  0.00 18.18   9.86    0.00   0.00   0.00
##  3.3:   9    9  5  4  137.69  3.05  3.05   9  37   5   0   0   0   4   5   5  136.51  3.05  0.00 25.45  12.48    1.00  22.60   0.09
*adjust  ---    9  5  4  137.69  3.05  4.20    39.85    -6.70    -0.20     2.01     13.16     1.36
##  4.3:   9    9  5  4  137.69  3.05  3.05   9  37   5   0   0   0   4   5   5  136.51  3.05  0.00 25.45  12.48    1.00  25.65   0.09
##  3.3:   9    9  5  4  138.83  3.05  3.05   9  37   5   0   0   0   4   5   5  136.51  3.05  0.00 25.45  13.62    1.00  25.65   0.11
*adjust  ---    9  5  4  138.83  3.05  4.20    35.73    -1.85    -2.31     2.13     14.00     1.23
##  4.3:   9    9  5  4  138.83  3.05  3.05   9  37   5   0   0   0   4   5   5  136.51  3.05  0.00 25.45  13.62    1.00  27.62   0.11
 2  valley 27.6 km wide,    0.11 MHz deep.          devn  1.23 km          5 terms fitting  5 0 + 0 X rays  + 4           hx = 158.3
```

```
*adjust ---  15  5  5  165.16  3.40  4.60    35.65    15.21   -20.53     1.61     5.73     7.04
*adjust ---  16  5  5  171.85  3.60  4.90    40.93    17.07   -66.74    63.23   -14.72     1.64

Peak  5.062 (+/-0.019) MHz,    Height 263.5 (+/- 1.3) km.    Scale Height 68.0 (+/- 1.2) km.     Slab (to peak) = 100.9 km.

FREQ  0.500   0.750   1.000   1.300   1.700   2.200   2.600   2.900    3.046   3.019   2.935   2.935   3.046   3.200   3.400   3.600
REAL 82.714  88.165  90.338  93.104  96.946 102.324 108.000 115.342  125.206 132.016 138.827 147.225 152.823 158.267 165.162 171.848

FREQ  3.900   4.200   4.600   4.900   5.062   4.929   4.617   4.225    0.019 320.663
REAL184.506 195.182 211.613 233.127 263.453 298.315 335.013 373.696    1.299  67.984
========================================================================================================================


     P O L A N   OF  APRIL 1985.                                                                      1 9 - A U G - 8 5

(1) STANDARD TEST LAYERS      FH =-1.00      DIP =  30.0      AMODE =  0.00      VALLEY=  0.00      LIST =  0      0.0

(1A) E LAYER,MODEL START      START = 90.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   0.000   0.000   0.000
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   0.000   0.000   0.000   0.000

Peak  3.002 (+/-0.007) MHz,    Height 123.3 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  19.1 km.

FREQ  0.500   0.750   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.002   2.923   2.738   2.505   0.007
REAL 90.000  93.678  95.227  96.684  98.702 101.119 103.808 106.940  109.780 113.397 118.245 123.349 130.985 139.022 147.494   0.170
========================================================================================================================

(1B)MODEL ABOVE EXTRAPN.      START =100.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   0.000   0.000   0.000
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   0.000   0.000   0.000   0.000

Peak  3.001 (+/-0.007) MHz,    Height 123.9 (+/- 0.2) km.    Scale Height 14.7 (+/- 0.2) km.     Slab (to peak) =  18.3 km.

FREQ  0.500   0.750   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.001   2.922   2.738   2.505   0.007
REAL 96.000  96.770  97.531  98.552 100.156 102.314 104.822 107.821  110.590 114.146 118.954 123.942 131.468 139.390 147.740   0.163
========================================================================================================================

(1C) START FN AT 90 KM.       START =  0.400

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   0.000   0.000   0.000
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   0.000   0.000   0.000   0.000

Peak  3.002 (+/-0.007) MHz,    Height 123.5 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  18.9 km.

FREQ  0.400   0.700   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.002   2.923   2.738   2.505   0.007
REAL 90.000  94.011  95.598  97.024  98.967 101.333 103.989 107.096  109.924 113.530 118.371 123.454 131.070 139.086 147.537   0.168
========================================================================================================================

(1D) E CUSP , CONTINUOUS      START =  0.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000 320.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500   4.700   4.900   5.000   0.000
VIRT320.000 380.000 480.000   0.000   0.000

Peak  4.998 (+/-0.037) MHz,    Height 262.7 (+/- 4.4) km.    Scale Height 79.2 (+/- 5.5) km.     Slab (to peak) = 107.0 km.

FREQ  0.500   0.750   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000   3.200   3.400   3.600   3.800
REAL 90.000  93.678  95.227  96.684  98.702 101.119 103.808 106.940  109.801 109.582 123.291 124.793 152.238 160.712 166.558 171.890

FREQ  4.100   4.300   4.500   4.700   4.900   4.998   4.866   4.559    4.171   0.037 331.443
REAL180.890 189.103 199.137 213.625 236.187 262.677 303.307 346.077  391.160   4.404  79.232
========================================================================================================================

(1E)E CUSP,DISCONTINUOUS      START =  0.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000-320.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500   4.700   4.900   5.000   0.000
VIRT320.000 380.000 480.000   0.000   0.000

Peak  4.998 (+/-0.036) MHz,    Height 262.6 (+/- 4.3) km.    Scale Height 79.8 (+/- 5.3) km.     Slab (to peak) = 106.9 km.

FREQ  0.500   0.750   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000   3.200   3.400   3.600   3.800
REAL 90.000  93.678  95.227  96.684  98.702 101.119 103.808 106.940  109.801 109.602 121.985 130.010 149.715 159.643 165.587 171.099

FREQ  4.100   4.300   4.500   4.700   4.900   4.998   4.867   4.559    4.172   0.036 331.299
REAL180.144 188.468 198.602 213.141 235.734 262.625 303.543 346.614  392.015   4.321  79.792
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1F) E + F; DIRECT START      START = -1.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000 165.000   0.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500   4.700   4.900   5.000   0.000
VIRT320.000 380.000 480.000   0.000   0.000

Peak  3.001 (+/-0.007) MHz,   Height 124.5 (+/- 0.2) km.   Scale Height 14.5 (+/- 0.2) km.   Slab (to peak) = 17.5 km.
 2  valley 32.0 km wide,   0.12 MHz deep.        devn  1.84 km        5 terms fitting  5 0 + 0 X rays  + 4        hx = 164.5

Peak  4.997 (+/-0.030) MHz,   Height 268.5 (+/- 3.3) km.   Scale Height 76.1 (+/- 4.1) km.   Slab (to peak) = 103.7 km.

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   3.001   2.970   2.877   2.877   3.001   3.200   3.400
REAL100.000 100.504 101.691 103.455 105.800 108.672 111.371 114.869 119.637 124.508 130.266 136.025 148.318 156.513 164.539 170.599

FREQ  3.600   3.800   4.100   4.300   4.500   4.700   4.900   4.997   4.865   4.557   4.170   0.030 320.872
REAL175.372 181.957 190.431 198.211 207.910 221.480 242.982 268.507 307.536 348.619 391.925   3.269  76.109
=================================================================================================================

(1G) E + F; NO FC'S          START =  0.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   0.000   3.200   3.400   3.600   3.800   4.100   4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000 165.000   0.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500   4.700   4.900   0.000   0.000
VIRT320.000 380.000 480.000   0.000   0.000

Peak  3.007 (+/-0.006) MHz,   Height 123.6 (+/- 0.2) km.   Scale Height 15.2 (+/- 0.2) km.   Slab (to peak) = 19.3 km.
 2  valley 31.5 km wide,   0.12 MHz deep.        devn  1.80 km        5 terms fitting  5 0 + 0 X rays  + 4        hx = 162.8

Peak  4.986 (+/-0.032) MHz,   Height 266.3 (+/- 3.5) km.   Scale Height 74.7 (+/- 4.5) km.   Slab (to peak) = 103.6 km.

FREQ  0.500   0.750   1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   3.007   2.977   2.886   2.886   3.007
REAL 90.000  93.678  95.227  96.684  98.702 101.119 103.808 106.940 109.780 113.397 118.239 123.588 129.550 135.512 147.249 155.073

FREQ  3.200   3.400   3.600   3.800   4.100   4.300   4.500   4.700   4.900   4.986   4.855   4.548   4.162   0.032 319.549
REAL162.782 168.905 173.802 180.573 189.203 197.059 206.827 220.439 242.001 266.267 304.572 344.895 387.398   3.483  74.699
=================================================================================================================


     P O L A N   OF  APRIL 1985.                                                        1 9 - A U G - 8 5
(2)  VALLEYS.              FH =-1.00    DIP =  30.0    AMODE =  0.00    VALLEY=  0.00    LIST =  0     0.0

(2A)MONOTONIC (NO VALLY)     START =  0.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000 165.000  10.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500   4.700   4.900   5.000   0.000
VIRT320.000 380.000 480.000   0.000   0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.   Slab (to peak) = 19.1 km.

Peak  4.999 (+/-0.036) MHz,   Height 262.1 (+/- 4.3) km.   Scale Height 80.3 (+/- 5.3) km.   Slab (to peak) = 106.5 km.

FREQ  0.500   0.750   1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   3.002   3.200   3.400   3.600   3.800
REAL 90.000  93.678  95.227  96.684  98.702 101.119 103.808 106.940 109.780 113.397 118.245 123.349 146.626 157.741 163.947 169.724

FREQ  4.100   4.300   4.500   4.700   4.900   4.999   4.867   4.559   4.172   0.036 329.915
REAL179.023 187.443 197.655 212.264 234.917 262.115 303.288 346.629 392.315   4.305  80.291
=================================================================================================================

(2B) DIRECT VALLEY CALCN     START =  0.000

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000 165.000   0.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500   4.700   4.900   5.000   0.000
VIRT320.000 380.000 480.000   0.000   0.000

Peak  3.002 (+/-0.007) MHz,   Height 123.3 (+/- 0.2) km.   Scale Height 14.9 (+/- 0.2) km.   Slab (to peak) = 19.1 km.
 2  valley 31.7 km wide,   0.12 MHz deep.        devn  1.88 km        5 terms fitting  5 0 + 0 X rays  + 4        hx = 163.1

Peak  4.997 (+/-0.029) MHz,   Height 267.8 (+/- 3.2) km.   Scale Height 76.4 (+/- 4.1) km.   Slab (to peak) = 104.7 km.

FREQ  0.500   0.750   1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800   2.950   3.002   2.972   2.880   2.880   3.002
REAL 90.000  93.678  95.227  96.684  98.702 101.119 103.808 106.940 109.780 113.397 118.245 123.349 129.217 135.084 147.082 155.081

FREQ  3.200   3.400   3.600   3.800   4.100   4.300   4.500   4.700   4.900   4.997   4.865   4.558   4.170   0.029 324.047
REAL163.112 169.244 174.105 180.807 189.391 197.227 206.978 220.583 242.115 267.831 307.013 348.257 391.733   3.230  76.407
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(2C)40KM VALLEY;NO FPEAK      START =  0.000

FREQ  1.000    1.200    1.500    1.800    2.100    2.400    2.600    2.800     2.950    3.000    3.200    3.400    3.600    3.800    4.100    4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000  -8.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500    4.700  -1.000    0.000    0.000
VIRT320.000 380.000   0.000    0.000    0.000

Peak  3.002 (+/-0.007) MHz,    Height 123.3 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  19.1 km.
 2  valley 40.0 km wide,     0.20 MHz deep.        devn  0.82 km          5 terms fitting  5 O + 0 X rays  + 4           hx = 169.3

FREQ  0.500    0.750    1.000    1.200    1.500    1.800    2.100    2.400     2.600    2.800    2.950    3.002    2.953    2.802    2.802    3.002
REAL 90.000   93.678   95.227   96.684   98.702  101.119  103.808  106.940   109.780  113.397  118.245  123.349  130.817  138.286  153.338  163.373

FREQ  3.200    3.400    3.600    3.800    4.100    4.300    4.500    4.700    -1.000    0.000    4.865
REAL169.323  174.115  178.206  184.465  192.577  200.146  209.713  223.022     0.000    0.000  307.013
======================================================================================================

(2D) MAXIMUM VALLEY.          START =  0.000

FREQ  1.000    1.200    1.500    1.800    2.100    2.400    2.600    2.800     2.950    3.000    3.200    3.400    3.600    3.800    4.100    4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   5.000 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500    4.700    4.900    5.000    0.000
VIRT320.000 380.000 480.000    0.000    0.000

Peak  3.002 (+/-0.007) MHz,    Height 123.3 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  19.1 km.
 2  valley 62.8 km wide,     0.42 MHz deep.        devn  6.15 km          5 terms fitting  5 O + 0 X rays  + 4           hx = 188.6

Peak  4.992 (+/-0.038) MHz,    Height 274.5 (+/- 3.7) km.    Scale Height 70.8 (+/- 4.9) km.     Slab (to peak) =  98.5 km.

FREQ  0.500    0.750    1.000    1.200    1.500    1.800    2.100    2.400     2.600    2.800    2.950    3.002    2.901    2.577    2.577    3.002
REAL 90.000   93.678   95.227   96.684   98.702  101.119  103.808  106.940   109.780  113.397  118.245  123.349  134.040  144.730  169.600  186.180

FREQ  3.200    3.400    3.600    3.800    4.100    4.300    4.500    4.700     4.900    4.992    4.861    4.554    4.167    0.038  304.494
REAL188.590  190.148  191.697  196.326  202.862  209.646  218.522  231.371   252.247  274.507  310.791  348.985  389.245    3.658   70.756
======================================================================================================

(2E) DEEP VALLEY              START =  0.000

FREQ  1.000    1.200    1.500    1.800    2.100    2.400    2.600    2.800     2.950    3.000    3.200    3.400    3.600    3.800    4.100    4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000  -0.500 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500    4.700    4.900    5.000    0.000
VIRT320.000 380.000 480.000    0.000    0.000

Peak  3.002 (+/-0.007) MHz,    Height 123.3 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  19.1 km.
 2  valley 40.4 km wide,     0.43 MHz deep.        devn  5.40 km          5 terms fitting  5 O + 0 X rays  + 4           hx = 170.4

Peak  4.996 (+/-0.029) MHz,    Height 271.1 (+/- 3.0) km.    Scale Height 74.5 (+/- 3.9) km.     Slab (to peak) = 102.8 km.

FREQ  0.500    0.750    1.000    1.200    1.500    1.800    2.100    2.400     2.600    2.800    2.950    3.002    2.901    2.573    2.573    3.002
REAL 90.000   93.678   95.227   96.684   98.702  101.119  103.808  106.940   109.780  113.397  118.245  123.349  134.084  144.819  156.200  163.788

FREQ  3.200    3.400    3.600    3.800    4.100    4.300    4.500    4.700     4.900    4.996    4.864    4.557    4.170    0.029  318.254
REAL170.410  175.708  180.028  186.663  194.820  202.367  211.871  225.084   246.195  271.053  309.277  349.513  391.926    3.011   74.539
======================================================================================================

(2F) SHALLOW VALLEY           START =  0.000

FREQ  1.000    1.200    1.500    1.800    2.100    2.400    2.600    2.800     2.950    3.000    3.200    3.400    3.600    3.800    4.100    4.300
VIRT100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000  -0.010 280.000 260.000 250.000 250.000 265.000 290.000

FREQ  4.500    4.700    4.900    5.000    0.000
VIRT320.000 380.000 480.000    0.000    0.000

Peak  3.002 (+/-0.007) MHz,    Height 123.3 (+/- 0.2) km.    Scale Height 14.9 (+/- 0.2) km.     Slab (to peak) =  19.1 km.
 2  valley  7.7 km wide,     0.01 MHz deep.        devn  3.85 km          5 terms fitting  5 O + 0 X rays  + 4           hx = 148.5

Peak  4.999 (+/-0.027) MHz,    Height 264.9 (+/- 3.1) km.    Scale Height 78.9 (+/- 3.8) km.     Slab (to peak) = 107.0 km.

FREQ  0.500    0.750    1.000    1.200    1.500    1.800    2.100    2.400     2.600    2.800    2.950    3.002    2.999    2.992    2.992    3.002
REAL 90.000   93.678   95.227   96.684   98.702  101.119  103.808  106.940   109.780  113.397  118.245  123.349  125.047  126.744  129.348  131.084

FREQ  3.200    3.400    3.600    3.800    4.100    4.300    4.500    4.700     4.900    4.999    4.867    4.559    4.172    0.027  331.351
REAL148.468  159.500  166.219  173.830  183.372  191.700  201.851  215.826   237.690  264.903  305.370  347.969  392.871    3.105   78.915
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      P O L A N   OF  APRIL 1985.                                                          1 9 - A U G - 8 5
(3)PEAKFIT: HM=300,SH=60       FH =-1.00      DIP =  30.0      AMODE =  0.00      VALLEY=  0.00     LIST =  0      0.0

(3A) CHAPMAN, NO FC'S          START = -1.000

FREQ  2.800    3.000    3.300    3.600    3.900    4.200    4.500    4.800     5.080    5.350    5.600    5.800    6.000    6.200    6.400    6.600
VIRT187.290 206.330 217.910 227.200 235.970 244.780 253.960 263.800  273.850 284.690 296.150 306.700 319.010 333.910 352.960 379.730

FREQ  6.800    6.900    0.000    0.000    0.000
VIRT425.660 472.090    0.000    0.000    0.000

Peak  7.003 (+/-0.009) MHz,     Height 300.0 (+/- 0.8) km.    Scale Height 60.3 (+/- 1.1) km.     Slab (to peak) =  76.4 km.

FREQ  2.800    3.000    3.300    3.600    3.900    4.200    4.500    4.800     5.080    5.350    5.600    5.800    6.000    6.200    6.400    6.600
REAL187.290 190.368 194.957 199.552 204.200 208.948 213.847 218.963  223.999 229.177 234.350 238.836 243.733 249.194 255.474 263.082

FREQ  6.800    6.900    7.003    6.819    6.387    5.845    0.009 464.260
REAL273.208 280.503 300.047 330.960 363.501 397.802    0.756  60.283
=====================================================================================================================================

(3B) TRUNCATED:  WITH FO       START = -1.000

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    7.000    0.000    0.000    0.000
VIRT229.180 268.930 285.320 301.160 318.500 339.400 367.590 414.680  461.610    0.000    0.000    0.000    0.000

Peak  7.001 (+/-0.008) MHz,     Height 299.9 (+/- 0.7) km.    Scale Height 60.1 (+/- 1.0) km.     Slab (to peak) =  61.2 km.

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    7.001    6.817    6.386    5.843    0.008 372.057
REAL229.180 234.349 238.837 243.734 249.194 255.474 263.082 273.208  280.505 299.922 330.742 363.185 397.383    0.685  60.102
=====================================================================================================================================

(3C)          WITH FO + FX     START = -1.000

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    7.000    7.518    0.000    0.000
VIRT229.180 268.930 285.320 301.160 318.500 339.400 367.590 414.680  461.610    0.000    0.000    0.000    0.000

Peak  7.001 (+/-0.008) MHz,     Height 299.9 (+/- 0.6) km.    Scale Height 60.1 (+/- 0.9) km.     Slab (to peak) =  61.2 km.

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    7.001    6.817    6.385    5.843    0.008 371.943
REAL229.180 234.349 238.837 243.734 249.194 255.474 263.082 273.208  280.506 299.904 330.712 363.141 397.324    0.626  60.076
=====================================================================================================================================

(3D)          WITH FX ONLY     START = -1.000

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    0.000    7.518    0.000    0.000
VIRT229.180 268.930 285.320 301.160 318.500 339.400 367.590 414.680  461.610    0.000    0.000    0.000    0.000

Peak  7.001 (+/-0.008) MHz,     Height 299.9 (+/- 0.7) km.    Scale Height 60.1 (+/- 1.0) km.     Slab (to peak) =  61.2 km.

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    7.001    6.817    6.386    5.843    0.008 372.116
REAL229.180 234.349 238.837 243.734 249.194 255.474 263.082 273.208  280.505 299.931 330.758 363.208 397.414    0.684  60.115
=====================================================================================================================================

(3E)          WITH BAD FC      START = -1.000

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    6.950    0.000    0.000    0.000
VIRT229.180 268.930 285.320 301.160 318.500 339.400 367.590 414.680  461.610    0.000    0.000    0.000    0.000

Peak  6.968 (+/-0.031) MHz,     Height 297.4 (+/- 2.5) km.    Scale Height 56.3 (+/- 3.8) km.     Slab (to peak) =  59.1 km.

FREQ  5.350    5.600    5.800    6.000    6.200    6.400    6.600    6.800     6.900    6.968    6.785    6.356    5.816    0.031 355.909
REAL229.180 234.349 238.837 243.734 249.194 255.474 263.082 273.208  280.541 297.380 326.269 356.679 388.733    2.495  56.335
=====================================================================================================================================


      P O L A N   OF  APRIL 1985.                                                          1 9 - A U G - 8 5
(4) X RAYS  NO PHYS EQUNS      FH =-1.20      DIP =  20.0      AMODE = -5.00      VALLEY=  0.00     LIST =  0      0.0

(4A)START TEST3A, FIX FB       START =  0.000

FREQ -1.766   -1.853   -1.942   -2.032   -2.123   -2.216    1.000    1.100     1.200    1.300    1.400    1.500    1.600    1.700    1.800    1.900
VIRT271.280 264.690 260.850 258.680 257.580 257.200 235.120 235.560  236.420 237.560 238.870 240.310 241.840 243.440 245.090 246.780

FREQ  2.000    2.100    2.200    2.300    2.400    2.500    2.600    2.700    -1.000    0.000    0.000    0.000    0.000
VIRT248.500 250.250 252.010 253.800 255.600 257.410 259.230 261.060    0.000    0.000    0.000    0.000    0.000

 1  start offset = -12.2 km,    slab  84.7 km.       devn  0.00 km    8 terms fitting  6 0 + 6 X rays + 0.      hx = 213.8

FREQ  0.300    0.600    0.800    1.000    1.100    1.200    1.300    1.400     1.500    1.600    1.700    1.800    1.900    2.000    2.100    2.200
REAL111.204 195.916 203.734 209.360 211.702 213.835 215.813 217.669  219.431 221.116 222.746 224.324 225.857 227.353 228.820 230.261

FREQ  2.300    2.400    2.500    2.600    2.700   -1.000    0.000    2.700
REAL231.679 233.079 234.462 235.830 237.185    0.000    0.000 261.060
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P O L A N   OF  APRIL 1985.                                                          1 9 - A U G - 8 5

(4) X RAYS WITH FIXED FB      FH =-1.20      DIP =  20.0      AMODE =  0.00      VALLEY=  0.00     LIST =  0      0.0

(4A)START TEST3A, FIX FB      START =  0.000

FREQ -1.766  -1.853  -1.942  -2.032  -2.123  -2.216   1.000   1.100    1.200   1.300   1.400   1.500   1.600   1.700   1.800   1.900
VIRT271.280 264.690 260.850 258.680 257.580 257.200 235.120 235.560  236.420 237.560 238.870 240.310 241.840 243.440 245.090 246.780

FREQ  2.000   2.100   2.200   2.300   2.400   2.500   2.600   2.700   -1.000   0.000   0.000   0.000   0.000
VIRT248.500 250.250 252.010 253.800 255.600 257.410 259.230 261.060    0.000   0.000   0.000   0.000   0.000

 1  start offset = -29.7 km,   slab   7.3 km.       devn  1.00 km    8 terms fitting  6 0 + 6 X rays + 3.      hx = 214.6

FREQ  0.300   0.600   0.800   1.000   1.100   1.200   1.300   1.400    1.500   1.600   1.700   1.800   1.900   2.000   2.100   2.200
REAL171.109 178.418 201.891 209.706 212.223 214.528 216.631 218.539  220.321 222.010 223.626 225.186 226.701 228.178 229.624 231.042

FREQ  2.300   2.400   2.500   2.600   2.700  -1.000   0.000   2.700
REAL232.439 233.818 235.180 236.528 237.864   0.000   0.000 261.060
==================================================================================================================================

(4B) X VALLEY, DATA ERR.      START = -1.000

FREQ  1.000   1.200   1.600   1.800   2.000   2.200   2.400   2.600    2.800   2.900   3.000   3.100   3.200   3.300   3.350   3.400
VIRT 91.650  96.220 100.220 102.050 103.940 105.970 108.230 110.840  114.010 115.930 118.180 120.900 101.140 129.180 132.490 136.940

FREQ  3.450   3.500   3.535  -4.250  -4.348  -4.447  -4.546  -4.645   -4.744  -4.843   3.600   3.700   3.800   3.900   4.000   4.100
VIRT143.670 157.120   0.000 333.250 283.970 264.080 253.510 247.400  243.810 241.840 276.000 247.800 236.820 231.130 227.990 226.350

FREQ  4.200   4.300   4.400   4.600   4.800   5.000   5.200   5.400    5.600   5.800   6.000   6.200   6.300   6.400   6.500   6.600
VIRT225.710 225.770 226.370 228.800 232.500 237.230 242.950 249.680  257.570 266.860 277.970 291.740 300.000 309.570 320.920 334.830

FREQ  6.700   6.800   6.900   7.000   0.000
VIRT352.820 378.280 422.000   0.000   0.000


*****reduce: data error at f, h =   3.100 118.168   3.200  98.716   3.300 127.007

Peak  3.533 (+/-0.005) MHz,    Height 116.1 (+/- 0.2) km.   Scale Height 12.5 (+/- 0.4) km.     Slab (to peak) =  15.4 km.
 3  valley 21.8 km wide,    0.07 MHz deep.        devn  0.60 km        8 terms fitting  5 0 + 5 X rays  + 4          hx = 144.3

Peak  7.000 (+/-0.002) MHz,    Height 250.6 (+/- 0.2) km.   Scale Height 59.8 (+/- 0.3) km.     Slab (to peak) =  86.7 km.

FREQ  1.000   1.200   1.600   1.800   2.000   2.200   2.400   2.600    2.800   2.900   3.000   3.100   3.300   3.350   3.400   3.450
REAL 91.650  92.912  95.221  96.337  97.465  98.628  99.854 101.179  102.655 103.477 104.379 105.388 107.964 108.811 109.825 111.103

FREQ  3.500   3.533   3.516   3.466   3.466   3.533   3.600   3.700    3.800   3.900   4.000   4.100   4.200   4.300   4.400   4.600
REAL112.912 116.056 119.454 122.853 131.856 137.859 141.026 144.325  147.001 151.608 154.165 156.557 158.707 160.112 161.673 165.224

FREQ  4.800   5.000   5.200   5.400   5.600   5.800   6.000   6.200    6.300   6.400   6.500   6.600   6.700   6.800   6.900   7.000
REAL168.872 172.635 176.507 180.550 184.821 189.388 194.348 199.861  202.897 206.180 209.781 213.807 218.443 224.042 231.355 250.563

FREQ  6.816   6.385   5.843   0.002 526.654
REAL281.250 313.553 347.604   0.195  59.843
==================================================================================================================================


P O L A N   OF  APRIL 1985.                                                          1 9 - A U G - 8 5

2 PARAMETERS, WITH LIST.      FH =-1.20      DIP =  20.0      AMODE =  0.00      VALLEY= -1.00     LIST = -1      0.0

(4C) TEST 4B, X VALLEY.      START = -1.000

FREQ  1.000   1.200   1.600   1.800   2.000   2.200   2.400   2.600    2.800   2.900   3.000   3.100   3.200   3.300   3.350   3.400
VIRT 91.650  96.220 100.220 102.050 103.940 105.970 108.230 110.840  114.010 115.930 118.180 120.900 124.370 129.180 132.490 136.940

FREQ  3.450   3.500   3.535  -4.250  -4.348  -4.447  -4.546  -4.645   -4.744  -4.843   3.600   3.700   3.800   3.900   4.000   4.100
VIRT143.670 157.120   0.000 333.250 283.970 264.080 253.510 247.400  243.810 241.840 276.000 247.800 236.820 231.130 227.990 226.350

FREQ  4.200   4.300   4.400   4.600   4.800   5.000   5.200   5.400    5.600   5.800   6.000   6.200   6.300   6.400   6.500   6.600
VIRT225.710 225.770 226.370 228.800 232.500 237.230 242.950 249.680  257.570 266.860 277.970 291.740 300.000 309.570 320.920 334.830

FREQ  6.700   6.800   6.900   7.000   0.000
VIRT352.820 378.280 422.000   0.000   0.000

*adjust  ---   1  4  4   91.65  1.00  2.20     6.58     -1.53      0.87    -0.11      0.00
*adjust  ---  14  5  5  107.95  3.30  3.50    15.36     30.93     42.58  -801.96   5289.89      0.01

Peak  3.533 (+/-0.005) MHz,    Height 116.0 (+/- 0.2) km.   Scale Height 12.5 (+/- 0.4) km.     Slab (to peak) =  15.4 km.
##  3.3:  19  19  8  7  124.19  3.53  3.53  19  51   5   0   0   5   4   5   5  125.04  3.53  0.00 17.49   8.15  -1.00  18.02   0.10
*adjust  ---  19  8  7  124.19  3.53  4.00     44.47    -98.63   208.01  -186.64     33.05     0.01     0.00    16.74     1.26
 1  valley 24.9 km wide,    0.10 MHz deep.        devn  1.26 km        8 terms fitting  5 0 + 5 X rays  + 4          hx = 146.4
##  3.3:  19  19  8  7  134.19  3.53  3.80  29  51   5   0   0   5   4   5   5  125.04  3.53  0.00 17.49  18.16  -1.00  24.89   0.51
*adjust  ---  19  8  7  134.19  3.53  4.00     22.63    188.03 -1556.22  4050.19 -3457.04     0.11     0.01    20.61     4.68
*adjust  q(2) 19  8  7  134.19  3.53  4.00     28.16     -1.50  -373.01  1225.07 -1136.40     0.03     0.00    22.65     4.83
 2  valley 40.8 km wide,    0.51 MHz deep.        devn  4.83 km        8 terms fitting  5 0 + 5 X rays  + 4          hx = 160.6
##  3.3:  19  19  8  7  125.92  3.53  3.80  29  51   5   0   0   5   4   5   5  125.04  3.53  0.00 17.49   9.89  -1.00  40.81   0.14
*adjust  ---  19  8  7  125.92  3.53  4.00     34.87    -44.05   -31.28   323.86  -366.20     0.02     0.00    18.62     2.11
 3  valley 28.5 km wide,    0.14 MHz deep.        devn  2.11 km        8 terms fitting  5 0 + 5 X rays  + 4          hx = 149.2
```

```
## 3.3: 19 19 8 7 122.73 3.53 3.80 29 51 5 0 0 5 4 5 5 125.04 3.53 0.00 17.49 6.70 -1.00 28.51 0.07
*adjust --- 19 8 7 122.73 3.53 4.00 57.50 -181.48 552.19 -884.51 560.82 0.00 0.00 14.98 0.64
 4 valley 21.7 km wide, 0.07 MHz deep. devn 0.64 km 8 terms fitting 5 0 + 5 X rays + 4 hx = 144.2
## 3.3: 19 19 8 7 121.53 3.53 3.80 29 51 5 0 0 5 4 5 5 125.04 3.53 0.00 17.49 5.50 -1.00 21.68 0.04
*adjust --- 19 8 7 121.53 3.53 4.00 74.45 -280.53 900.96 -1506.86 991.44 -0.00 -0.00 13.10 0.17
 5 valley 18.6 km wide, 0.04 MHz deep. devn 0.17 km 8 terms fitting 5 0 + 5 X rays + 4 hx = 142.4
## 3.3: 19 19 8 7 120.53 3.53 3.80 29 51 5 0 0 5 4 5 5 125.04 3.53 0.00 17.49 4.50 -1.00 18.60 0.03
*adjust --- 19 8 7 120.53 3.53 4.00 95.25 -410.79 1356.03 -2298.54 1525.22 -0.00 -0.00 11.24 0.52
 6 valley 15.7 km wide, 0.03 MHz deep. devn 0.52 km 8 terms fitting 5 0 + 5 X rays + 4 hx = 141.0
## 3.3: 19 19 8 7 121.45 3.53 3.80 29 51 5 0 0 5 4 5 5 125.04 3.53 0.00 17.49 5.42 -1.00 15.74 0.04
*adjust --- 19 8 7 121.45 3.53 4.00 75.82 -287.05 917.63 -1527.44 1000.91 -0.00 -0.00 12.94 0.16
 7 valley 18.4 km wide, 0.04 MHz deep. devn 0.16 km 8 terms fitting 5 0 + 5 X rays + 4 hx = 142.3
*adjust --- 25 5 5 142.28 3.70 4.10 33.30 33.12 267.78 -1970.09 2702.96 5.60
*adjust mq 25 5 5 142.28 3.70 4.10 37.04 48.12 -250.82 262.60 0.00 5.90
*adjust --- 26 5 5 145.25 3.80 4.20 49.23 33.04 -1086.35 3839.31 -4069.23 1.89
*adjust mq 26 5 5 145.25 3.80 4.20 43.62 9.75 -302.23 473.68 -0.00 3.37
*adjust --- 27 5 5 150.03 3.90 4.30 32.90 -91.52 446.99 -960.17 632.09 0.40
*adjust --- 28 5 5 152.70 4.00 4.40 23.67 1.00 184.36 -1305.47 1922.99 0.26
*adjust mq 28 5 5 152.70 4.00 4.40 26.27 11.41 -178.86 272.24 0.00 1.33
*adjust --- 29 5 5 155.19 4.10 4.60 27.44 -24.70 -352.84 1601.50 -1716.00 0.39
*adjust mq 29 5 5 155.19 4.10 4.60 24.81 -49.74 111.49 -79.64 -0.00 1.80
*adjust --- 30 5 5 157.42 4.20 4.80 15.64 -33.19 286.63 -688.81 516.52 0.35
*adjust --- 31 5 5 158.93 4.30 5.00 16.11 10.49 -25.86 34.76 -17.74 0.27
*adjust --- 32 5 5 160.57 4.40 5.20 17.53 6.38 -17.16 22.62 -10.41 0.12
*adjust --- 33 5 5 164.24 4.60 5.40 18.48 0.93 0.98 -1.97 1.56 0.02
*adjust --- 34 5 5 167.98 4.80 5.60 18.96 1.08 -0.96 3.25 -1.63 0.00
*adjust --- 35 5 5 171.81 5.00 5.80 19.35 1.25 1.58 -0.82 0.58 0.00
*adjust --- 36 5 5 175.74 5.20 6.00 20.01 2.03 1.14 -0.05 0.38 0.00
*adjust --- 37 5 5 179.84 5.40 6.20 20.96 2.77 1.40 -0.30 0.97 0.00
*adjust --- 38 5 5 184.15 5.60 6.30 22.24 3.60 1.47 1.07 0.60 0.00
*adjust --- 39 5 5 188.75 5.80 6.40 23.86 4.89 3.13 -1.06 3.41 0.00
*adjust --- 40 5 5 193.75 6.00 6.50 26.17 6.83 3.89 0.86 5.33 0.00
*adjust --- 41 5 5 199.29 6.20 6.60 29.43 9.97 6.74 2.03 14.42 0.00
*adjust --- 42 5 5 202.34 6.30 6.70 31.62 12.34 10.61 -3.02 35.98 0.00
*adjust --- 43 5 5 205.63 6.40 6.80 34.36 16.02 17.69 -22.07 101.98 0.00
*adjust --- 44 5 5 209.25 6.50 6.90 37.80 22.43 40.71 -142.42 407.89 0.02

Peak 7.000 (+/-0.002) MHz, Height 250.1 (+/- 0.2) km. Scale Height 60.0 (+/- 0.3) km. Slab (to peak) = 86.9 km.

FREQ 1.000 1.200 1.600 1.800 2.000 2.200 2.400 2.600 2.800 2.900 3.000 3.100 3.200 3.300 3.350 3.400
REAL 91.650 92.912 95.221 96.337 97.465 98.628 99.854 101.179 102.655 103.477 104.379 105.388 106.551 107.954 108.803 109.815

FREQ 3.450 3.500 3.533 3.522 3.490 3.490 3.533 3.600 3.700 3.800 3.900 4.000 4.100 4.200 4.300 4.400
REAL111.094 112.903 116.031 118.741 121.450 129.215 134.392 138.453 142.279 145.247 150.026 152.702 155.188 157.417 158.925 160.573

FREQ 4.600 4.800 5.000 5.200 5.400 5.600 5.800 6.000 6.200 6.300 6.400 6.500 6.600 6.700 6.800 6.900
REAL164.244 167.980 171.813 175.744 179.837 184.151 188.755 193.748 199.289 202.339 205.635 209.248 213.285 217.933 223.542 230.865

FREQ 7.000 6.816 6.385 5.843 0.002 528.279
REAL250.135 280.891 313.266 347.392 0.202 59.976

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 P O L A N  OF APRIL 1985.                                                    1 9 - A U G - 8 5

(5)VARYING FB; WITH LIST FH = 1.00 DIP = 30.0 AMODE = 0.00 VALLEY= 0.00 LIST = 1 0.0

(5A) TEST6B NIGHT,DIP 30 START = 0.000

FREQ -1.682 -1.757 -1.832 -1.907 -1.983 -2.060 1.140 1.220 1.300 1.380 1.460 1.540 1.620 1.700 1.800 1.900
VIRT343.090 320.460 305.750 295.720 288.630 283.510 289.700 280.560 274.550 270.460 267.630 265.660 264.300 263.380 262.680 262.360

FREQ 2.000 2.200 -1.000 0.000 0.000
VIRT262.320 262.810 0.000 0.000 0.000

## 3.3: 1 -1 8 7 222.48 0.68 0.68 1 30 6 0 0 6 3 5 5 157.72 0.00 0.00 0.00 0.00 0.00 0.00 0.34

*adjust----- lk jm mt ha fa fm q1 2 3 4 5 6 7
*adjust --- -1 8 7 222.48 0.68 1.54 671.21 -1820.61 2601.79 -1886.29 549.49 -0.48 23.97 -100.46 0.18
*adjust q(1) -1 8 7 222.48 0.68 1.54 258.00 -14.87 -812.62 1120.14 -466.12 3.87 0.03 -78.82 0.83
 1 start offset = -78.8 km, slab 0.0 km. devn 0.83 km 8 terms fitting 6 0 + 6 X rays + 3. hx = 227.3
## 3.3: 1 -1 8 7 222.48 0.68 1.62 13 30 6 0 0 6 3 5 5 157.72 0.00 0.00 0.00 0.00 0.00 0.00 0.34

*adjust----- lk jm mt ha fa fm q1 2 3 4 5 6 7
*adjust --- -1 8 7 222.48 0.68 1.54 683.33 -1885.72 2735.83 -2010.02 592.42 -0.61 23.28 -99.94 0.18
*adjust q(1) -1 8 7 222.48 0.68 1.54 259.00 -34.06 -759.75 1062.99 -444.18 3.95 -0.02 -77.89 0.86
*adjust slab -1 8 7 222.48 0.68 1.54 259.00 -34.30 -759.12 1062.38 -443.96 3.95 0.10 -77.87 0.86
 2 start offset = -77.9 km, slab 0.1 km. devn 0.86 km 8 terms fitting 6 0 + 6 X rays + 3. hx = 227.7
*adjust --- 4 5 5 220.82 1.14 1.46 61.18 -164.51 281.66 54.21 -571.81 0.17
*adjust --- 5 5 5 224.83 1.22 1.54 39.70 -95.52 341.38 -866.98 919.40 0.03
*adjust mq 5 5 5 224.83 1.22 1.54 40.24 -94.78 240.20 -278.59 0.00 0.17
*adjust --- 6 5 5 227.53 1.30 1.62 29.38 -44.32 110.69 -257.90 280.74 0.03
*adjust mq 6 5 5 227.53 1.30 1.62 29.55 -44.05 79.49 -77.75 0.00 0.06
*adjust --- 7 5 5 229.64 1.38 1.70 23.99 -26.80 35.50 -27.31 2.79 0.00
*adjust --- 8 5 5 231.40 1.46 1.80 20.32 -19.20 27.69 -37.59 30.88 0.00
*adjust --- 9 5 5 232.92 1.54 1.90 17.72 -13.93 16.66 -13.94 5.66 0.00
*adjust --- 10 5 5 234.26 1.62 2.00 15.78 -10.43 12.29 -10.10 3.04 0.00
*adjust --- 11 5 5 235.46 1.70 2.20 14.33 -7.85 9.56 -10.97 6.62 0.00

FREQ 0.342 0.684 0.912 1.140 1.220 1.300 1.380 1.460 1.540 1.620 1.700 1.800 1.900 2.000 2.200 -1.000
REAL144.514 144.614 195.484 220.823 224.825 227.529 229.639 231.404 232.919 234.255 235.457 236.820 238.070 239.235 241.377 0.000
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P O L A N   OF  APRIL 1985.                                                          1 9 - A U G - 8 5

CANBERRA FIELD(WRONG FH)     FH = 1.52     DIP =  57.3     AMODE =  0.00     VALLEY=  0.00     LIST =  1      0.0

(5B) BAD START DATA             START =  0.000

FREQ -2.552  -2.633  -2.706  -2.758   1.635   1.699   1.774   1.828    1.856   1.887   1.934   2.008   2.062   2.084   2.089   2.096
VIRT173.000 173.000 176.000 186.000 150.000 150.000 151.000 162.000  178.000 196.000 189.000 187.000 200.000 231.000 252.000 299.000

FREQ  0.000   0.000   0.000   0.000   0.000
VIRT  0.000   0.000   0.000   0.000   0.000

## 3.3:  1  -1  6  5  140.00  0.98  0.98   1  32   4   0   0   2   3   5   5  125.00  0.00  0.00  0.00   0.00   0.00   0.00   0.49

*adjust-----  lk jm mt     ha      fa     fm       ql        2         3          4          5
*adjust  ---  -1  6  5  140.00  0.98  1.83   221.40  -370.44    188.70      4.95      31.11   -26.45      0.86
*adjust  q(1) -1  6  5  140.00  0.98  1.83   185.00  -293.15    127.86     20.61      37.63   -24.99      0.90
 1 staval: qm reduced from -25.0 to -37.5, to avoid -ve slope at f,h =   1.78 149.32       (devn increases  0.90 to  1.04).
 1 staval: qm reduced from -37.5 to -56.3, to avoid -ve slope at f,h =   1.63 142.46       (devn increases  1.04 to  1.60).
 1  start offset = -56.3 km,   slab -28.9 km.      devn  1.60 km    6 terms fitting  4 0 + 2 X rays + 3.       hx = 131.4
## 3.3:  1  -1  6  5  140.00  0.98  1.77   7  32   4   0   0   2   3   5   5  125.00  0.00  0.00  0.00   0.00   0.00   0.00   0.49

*adjust-----  lk jm mt     ha      fa     fm       ql        2         3          4          5
*adjust  ---  -1  6  5  140.00  0.98  1.83   214.87  -356.89    179.92      6.31      31.80   -27.12      0.88
*adjust  q(1) -1  6  5  140.00  0.98  1.83   183.00  -289.02    126.09     20.36      37.62   -25.77      0.91
x ray weights reduced to 1/4.
## 3.3:  1  -1  6  5  140.00  0.98  1.77   7  32   4   0   0   2   3   5   5  125.00  0.00  0.00  0.00   0.00   0.00   0.00   0.49

*adjust-----  lk jm mt     ha      fa     fm       ql        2         3          4          5
*adjust  ---  -1  6  5  140.00  0.98  1.83   224.38  -376.30    192.58      4.27      32.71   -26.54      0.86
*adjust  q(1) -1  6  5  140.00  0.98  1.83   186.00  -295.22    129.92     19.87      38.29   -25.40      0.90
 3 staval: qm reduced from -25.4 to -38.1, to avoid -ve slope at f,h =   1.78 149.13       (devn increases  0.90 to  1.04).
 3 staval: qm reduced from -38.1 to -57.2, to avoid -ve slope at f,h =   1.63 142.01       (devn increases  1.04 to  1.58).
 3  start offset = -57.2 km,   slab -24.8 km.      devn  1.58 km    6 terms fitting  4 0 + 2 X rays + 3.       hx = 130.6
*adjust  ---   4  5  5  130.05  1.63  1.86     5.41   100.54  -578.13  -312.53  9182.29      0.19
*adjust   mq   4  5  5  130.05  1.63  1.86    16.14   -91.84   196.99  1161.92     0.00      1.23
*adjust  ---   5  5  5  130.64  1.70  1.89    18.31   -60.28 -1652.52 22427.66-55031.02      0.60
*adjust   mq   5  5  5  130.64  1.70  1.89     8.78   -18.48   433.59  1175.09    -0.00      1.31
*adjust  ---   6  5  5  131.48  1.77  1.93    13.48    49.51  1698.23 11198.33*********      0.33
*adjust   mq   6  5  5  131.48  1.77  1.93     1.73   198.83  3267.20-18075.41    -0.00      1.15
*adjust  ---   7  5  5  132.72  1.83  2.01    30.63   547.52  2228.52-80385.20289600.78      0.29
*adjust   mq   7  5  5  132.72  1.83  2.01    48.64   467.27 -5647.71 16041.62     0.00      3.31
*adjust  ---   8  5  5  133.95  1.86  2.06    67.92   319.19-11162.69 75243.77*********      0.74
*adjust   mq   8  5  5  133.95  1.86  2.06    82.57  -500.84  1808.54 -1521.55    -0.00      2.08
*adjust  ---   9  5  5  136.25  1.89  2.08    51.17  -449.82  6925.57-50407.77130897.91      0.10
*adjust   mq   9  5  5  136.25  1.89  2.08    29.71   462.12 -5446.93 17481.21     0.00      3.34
*adjust  ---  10  5  5  138.14  1.93  2.09    27.27    37.51  3825.57-64558.02281487.09      2.55
*adjust   mq  10  5  5  138.14  1.93  2.09    50.56    34.80 -5240.16 31660.72     0.00      3.19
*adjust  ---  11  5  5  140.71  2.01  2.10   -31.64  2428.56-11689.19******************      0.10
*adjust  q(1) 11  5  5  140.71  2.01  2.10     2.00  1614.82-12298.23******************      0.60

Peak  2.096 (+/-0.006) MHz,    Height 147.0 (+/- 0.4) km.    Scale Height  9.4 (+/-11.3) km.     Slab (to peak) =  25.9 km.

FREQ  0.491   0.981   1.308   1.635   1.699   1.774   1.828   1.856    1.887   1.934   2.008   2.062   2.084   2.089   2.096   2.096
REAL107.611  82.805 121.347 130.053 130.637 131.485 132.718 133.948  136.248 138.143 140.707 142.695 144.632 145.498 147.227 147.045

FREQ  2.041   1.912   1.749   0.006  14.097
REAL151.844 156.897 162.223   0.409   9.360
```

APPENDIX H. THE SIMPLIFIED PROGRAM SPOLAN

H.1 CONSTRUCTION

SPOLAN provides a much shorter and simpler version of POLAN, for use when full extraordinary ray starting and valley corrections are not required and parabolic layer peaks are acceptable. SPOLAN accepts the same input parameters and gives the same types of analysis. The simplified version of POLRUN listed in section H.3 can be used with either program. Values of AMODE in the range 11 to 20 should not be used with SPOLAN, which does not have an optional 12-point integration. Larger values of AMODE can be used, as in POLAN. Thus AMODE = 85 will use an 8-term real-height expression for the final layer, and 5 terms for lower layers. SPOLAN achieves this by setting the parameters for the first and second layers into the 11th and 12th elements of the mode-defining arrays IT, IV and IR.

Apart from the absence of extraordinary ray calculations, some other simplifications in SPOLAN cause slight differences in the calculated real heights. 5-point gaussian integration is used throughout, so that SPOLAN is faster than POLAN but will be less accurate at high latitudes. At low and medium latitudes the difference is normally negligible with single-layer ionograms. When a second layer is present there will be larger changes in the calculated real heights of the upper layer. These are caused by the slightly different form assumed for the peak of the first layer, and differences in the size and shape of the assumed valley between layers. Since the true valley is not known, however, these differences have little physical significance.

Start procedures.
As in POLAN, a positive value (greater than 44 km) for the parameter START is used to input a model starting height for use at the fixed starting frequency of 0.5 MHz. If START is zero, the first few virtual heights are used to obtain an extrapolated starting height (as described in section 6.2, page 24). Setting START = -1.0 gives a direct start from the first data point FV(1), HT(1) with no allowance for underlying ionisation.

An additional start procedure has been introduced in SPOLAN to give a simple but worthwhile allowance for low-density ionisation below the night-time F layer. This procedure is invoked when the parameter START is negative (and less than -44.0). It uses a single extraordinary-ray virtual height to calculate a suitable starting height as described in section 8.6.2 (page 50). For each recording site a table is prepared giving the extraordinary-ray frequency f_x to be used, as a function of the minimum observed ordinary-ray frequency fmin. The virtual height h'_x of the extraordinary ray at the frequency f_x is measured for each ionogram (with some cautious extrapolation if the trace does not extend down to f_x). Setting the parameter START equal to $-h'_x$ then causes SPOLAN to calculate a model starting height using equations 28 and 29 on page 51, for a starting frequency f_s of 0.5 MHz. The calculated profile is the same as if the equations in section 8.6.2 were applied manually to the measured value of h'_x, and the starting height obtained entered as the (positive) value of START.

The Peak and Valley calculations in SPEAK.
POLAN uses a rather complex procedure for least-squares fitting of a true Chapman-layer peak to all available data. In SPOLAN the critical frequency of a layer should preferably be scaled from the ionogram. The analysis then includes a parabolic peak expression in the real-height function fitted to the virtual-height data. If the critical frequency is not scaled it is determined by fitting a parabolic expression to the last 3 points on the calculated profile. In both cases results are modified to avoid most of the systematic error which occurs from use of the parabolic approximation (particularly in the calculated values of scale height, as discussed in Titheridge, 1985a). This correction is achieved by changing the constants 0.25 (in the critical frequency calculation) and 0.5 (in the scale height) to 0.263 and 0.55 respectively.

A simple model valley is added between layers. This corresponds approximately to the standard model used by POLAN, with a valley width equal to HMAX/2 - 40 km where HMAX is the height of the underlying peak. The depth of the valley also corresponds approximately to the "standard" value, increasing from 0.05 MHz at a width of 10 km to 0.3 MHz at a width of 60 km. The valley does not include the initial parabolic section used by POLAN, but has a linear variation of electron density between the points listed in the output. The width and depth of the valley can be altered by giving a non-zero value for the input parameter VALLEY, or for the 'virtual height' at the critical frequency of a layer. These changes are the same as those used in POLAN. Thus a value of VALLEY between 0.0 and 5.0 multiplies the width of the model valley by this factor; a negative value VALLEY = -D produces a valley width equal to -5D km; and any decimal part of VALLEY is used to specify the valley depth in MHz.

The subroutine COEFIS calculates the coefficients for the real and virtual height equations, in the same way as the POLAN subroutine COEFIC. The much shorter form of COEFIS is due to the use of 5-point gaussian integrals at all times, the use of equal weighting for all equations, and use of a constant gyrofrequency. **The subroutine SSOLVE** uses the same accurate procedure as in POLAN but does not include the facility for altering a solution. **The function SGIND** calculates the values of group refractive index using the same equations as in POLAN, but for the ordinary ray only and assuming a fixed value of gyrofrequency. Thus for SPOLAN the given value of gyrofrequency FH is always the value in the ionosphere; this corresponds to the use of -FH in POLAN.

H.2 TEST RESULTS

H.2.1 The test data

The data listed below are a subset of those used by POLAN and given in section G.2. Extraordinary ray tests have been eliminated, except for the data set (4A) which was adapted to illustrate the single-point start correction. Corresponding results given in H.2.2 are sufficient to verify the operation of SPOLAN. The full set of test data in G.2 can be run with SPOLAN with no change apart from the elimination of extraordinary-ray data.

```
(1) STANDARD TEST LAYERS  -1.0  30.   0.   0.
(1A) E LAYER,MODEL START   85.  100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3.0
(1C) START FN AT 90 KM.    0.4 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3.0
(1F) E + F; DIRECT START   -1. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000      0 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(1G) E + F; NO FC'S         0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500           0 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000

(2)  VALLEYS.             -1.0  30.   0.   0.
(2A)MONOTONIC (NO VALLY)    0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000  10. 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(2C)40KM VALLEY;NO FPEAK    0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000  -8. 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000  -1.
(2E) DEEP VALLEY            0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000 -0.5 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000
(2F) SHALLOW VALLEY         0. 100010000 120010200 150010500 180011000 210011500
 240012200 260013000 280014100 295016500 3000 -.01 320028000 340026000 360025000
 380025000 410026500 430029000 450032000 470038000 490048000 5000

(3)PEAKFIT: HM=300,SH=60  -1.0  30.   0.   0.
(3A) CHAPMAN, NO FC'S      -1.  2.8 18729 3.0 20633 3.3 21791 3.6 22720 3.9 23597
 4.2 24478 4.5 25396 4.8 26380 5.0827385 5.3528469 5.6 29615 5.8 30670 6.0 31901
 6.2 33391 6.4 35296 6.6 37973 6.8 42566 6.9 47209
(3B) TRUNCATED:  WITH FO   -1.  5.3522918 5.6 26893 5.8 28532 6.0 30116 6.2 31850
 6.4 33940 6.6 36759 6.8 41468 6.9 46161 7.0
(3E)        WITH BAD FC    -1.  5.3522918 5.6 26893 5.8 28532 6.0 30116 6.2 31850
 6.4 33940 6.6 36759 6.8 41468 6.9 46161 6.95

(4) X RAY START.          -1.2  20.
(4A)Start Test with h'x: -271.  1.0 23512 1.1 23556 1.2 23642 1.3023756 1.4 23887
 1.5 24031 1.6 24184 1.7 24344 1.8 24509 1.9 24678 2.0 24850 2.1 25025 2.2 25201
 2.3 25380 2.4 25560 2.5 25741 2.6 25923 2.7 26106 -1.
```

NOTE:- For a shortened (peaks only) output precede normal data with the line:
For fast-look output: 9.0

H.2.2 Output produced by SPOLAN

```
SPOLAN   of  Dec 1984.                                                                                  1 8 - S E P - 8 5
(1) STANDARD TEST LAYERS      fb =-1.00     dip = 30.0     amode =  0.0      valley= 0.00   list=  0

(1A) E LAYER,MODEL START       start =  85.0

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   0.000   0.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   0.000   0.000   0.000   0.000

Peak  3.000 Mhz.    Height 122.7 km.        Scale Height  14.8 km.

FREQ  0.500   0.800   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000

REAL 85.000  90.016  92.510  94.505  96.991  99.693 102.648 105.913  108.817 112.595 117.296 122.682  14.814


(1C) START FN AT 90 KM.        start =   0.4

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   0.000   0.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   0.000   0.000   0.000   0.000

Peak  3.000 Mhz.    Height 123.5 km.        Scale Height  14.6 km.

FREQ  0.400   0.760   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000

REAL 90.000  93.783  95.588  96.890  98.855 101.191 103.928 107.011  109.833 113.535 118.184 123.490  14.591


(1F) E + F; DIRECT START       start =  -1.0

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
      4.500   4.700   4.900   5.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   0.000 280.000 260.000 250.000 250.000 265.000 290.000
    320.000 380.000 480.000   0.000   0.000

Peak  3.000 Mhz.    Height 124.7 km.        Scale Height  14.3 km.
            Valley width  22.4 km,         Depth 0.11 Mhz.
Peak  5.000 Mhz.    Height 273.9 km.        Scale Height  85.6 km.

FREQ  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   2.888   3.000   3.200   3.400   3.600   3.800
      4.100   4.300   4.500   4.700   4.900   5.000

REAL100.000 100.428 101.646 103.450 105.840 108.666 111.358 114.946  119.522 124.709 139.464 147.064 159.746 167.240 172.382 177.133
    185.442 193.077 203.204 217.348 239.826 273.913  85.647


(1G) E + F; NO FC'S            start =   0.0

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   0.000   3.200   3.400   3.600   3.800   4.100   4.300
      4.500   4.700   4.900   0.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000   0.000 280.000 260.000 250.000 250.000 265.000 290.000
    320.000 380.000 480.000   0.000   0.000

Peak  3.002 Mhz.    Height 123.7 km.        Scale Height  15.1 km.
            Valley width  21.9 km,         Depth 0.11 Mhz.
Peak  5.000 Mhz.    Height 273.3 km.        Scale Height  84.8 km.

FREQ  0.500   0.800   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.002   2.892   3.002   3.200   3.400
      3.600   3.800   4.100   4.300   4.500   4.700   4.900   5.000

REAL 90.000  93.315  95.011  96.462  98.523 100.930 103.705 106.822  109.555 113.201 118.128 123.705 138.128 145.558 160.234 168.125
    173.112 177.838 185.999 193.518 203.401 217.527 239.675 273.349   84.755
```

```
(2) VALLEYS.                 fb =-1.00     dip = 30.0     amode =  0.0     valley= 0.00   list= 0

(2A)MONOTONIC (NO VALLY)      start =   0.0

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
      4.500   4.700   4.900   5.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000  10.000 280.000 260.000 250.000 250.000 265.000 290.000
    320.000 380.000 480.000   0.000   0.000

Peak  3.000 Mhz.     Height 123.4 km.        Scale Height  14.6 km.
Peak  5.000 Mhz.     Height 270.1 km.        Scale Height  87.2 km.

FREQ  0.500   0.800   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000   3.200   3.400   3.600   3.800
      4.100   4.300   4.500   4.700   4.900   5.000

REAL 90.000  93.315  95.011  96.462  98.523 100.930 103.705 106.822  109.659 113.374 118.033 123.353 147.067 158.212 164.403 170.314
    179.403 187.693 198.069 212.556 235.358 270.065  87.205


(2C)40KM VALLEY;NO FPEAK      start =   0.0

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
      4.500   4.700  -1.000   0.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000  -8.000 280.000 260.000 250.000 250.000 265.000 290.000
    320.000 380.000   0.000   0.000   0.000

Peak  3.000 Mhz.     Height 123.4 km.        Scale Height  14.6 km.
          Valley width  40.0 km,           Depth 0.20 Mhz.

FREQ  0.500   0.800   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000   2.800   3.000   3.200   3.400
      3.600   3.800   4.100   4.300   4.500   4.700

REAL 90.000  93.315  95.011  96.462  98.523 100.930 103.705 106.822  109.659 113.374 118.033 123.353 149.753 163.353 169.067 173.944
    178.105 181.956 189.566 196.714 206.222 219.971 198.745


(2E) DEEP VALLEY              start =   0.0

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
      4.500   4.700   4.900   5.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000  -0.500 280.000 260.000 250.000 250.000 265.000 290.000
    320.000 380.000 480.000   0.000   0.000

Peak  3.000 Mhz.     Height 123.4 km.        Scale Height  14.6 km.
          Valley width  21.7 km,           Depth 0.50 Mhz.
Peak  5.000 Mhz.     Height 274.4 km.        Scale Height  85.4 km.

FREQ  0.500   0.800   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000   2.500   3.000   3.200   3.400
      3.600   3.800   4.100   4.300   4.500   4.700   4.900   5.000

REAL 90.000  93.315  95.011  96.462  98.523 100.930 103.705 106.822  109.659 113.374 118.033 123.353 137.659 145.029 160.751 168.719
    173.576 178.282 186.337 193.950 203.934 218.016 240.453 274.444   85.405


(2F) SHALLOW VALLEY           start =   0.0

freq  1.000   1.200   1.500   1.800   2.100   2.400   2.600   2.800    2.950   3.000   3.200   3.400   3.600   3.800   4.100   4.300
      4.500   4.700   4.900   5.000   0.000

virt100.000 102.000 105.000 110.000 115.000 122.000 130.000 141.000  165.000  -0.010 280.000 260.000 250.000 250.000 265.000 290.000
    320.000 380.000 480.000   0.000   0.000

Peak  3.000 Mhz.     Height 123.4 km.        Scale Height  14.6 km.
          Valley width  21.7 km,           Depth 0.01 Mhz.
Peak  5.000 Mhz.     Height 272.4 km.        Scale Height  86.1 km.

FREQ  0.500   0.800   1.000   1.200   1.500   1.800   2.100   2.400    2.600   2.800   2.950   3.000   2.990   3.000   3.200   3.400
      3.600   3.800   4.100   4.300   4.500   4.700   4.900   5.000

REAL 90.000  93.315  95.011  96.462  98.523 100.930 103.705 106.822  109.659 113.374 118.033 123.353 137.659 145.029 156.674 164.281
    169.805 174.732 183.357 191.089 201.366 215.613 238.174 272.432   86.078
```

(3)PEAKFIT: HM=300,SH=60 fb =-1.00 dip = 30.0 amode = 0.0 valley= 0.00 list= 0

(3A) CHAPMAN, NO FC'S start = -1.0

freq 2.800 3.000 3.300 3.600 3.900 4.200 4.500 4.800 5.080 5.350 5.600 5.800 6.000 6.200 6.400 6.600
6.800 6.900 0.000 0.000 0.000

virt187.290 206.330 217.910 227.200 235.970 244.780 253.960 263.800 273.850 284.690 296.150 306.700 319.010 333.910 352.960 379.730
425.660 472.090 0.000 0.000 0.000

Peak 7.000 Mhz. Height 300.8 km. Scale Height 59.5 km.

FREQ 2.800 3.000 3.300 3.600 3.900 4.200 4.500 4.800 5.080 5.350 5.600 5.800 6.000 6.200 6.400 6.600
6.800 6.900 7.000

REAL187.290 190.368 194.957 199.552 204.200 208.948 213.847 218.961 223.996 229.173 234.345 238.829 243.726 249.185 255.459 263.046
273.177 280.736 300.833 59.543

(3B) TRUNCATED: WITH FO start = -1.0

freq 5.350 5.600 5.800 6.000 6.200 6.400 6.600 6.800 6.900 7.000 0.000 0.000 0.000

virt229.180 268.930 285.320 301.160 318.500 339.400 367.590 414.680 461.610 0.000 0.000 0.000 0.000

Peak 7.000 Mhz. Height 300.8 km. Scale Height 59.5 km.

FREQ 5.350 5.600 5.800 6.000 6.200 6.400 6.600 6.800 6.900 7.000

REAL229.180 234.340 238.835 243.729 249.191 255.465 263.060 273.261 280.744 300.772 59.457

(3E) WITH BAD FC start = -1.0

freq 5.350 5.600 5.800 6.000 6.200 6.400 6.600 6.800 6.900 6.950 0.000 0.000 0.000

virt229.180 268.930 285.320 301.160 318.500 339.400 367.590 414.680 461.610 0.000 0.000 0.000 0.000

Peak 6.950 Mhz. Height 292.8 km. Scale Height 50.5 km.

FREQ 5.350 5.600 5.800 6.000 6.200 6.400 6.600 6.800 6.900 6.950

REAL229.180 234.340 238.835 243.729 249.191 255.465 263.059 273.277 280.725 292.830 50.550

SPOLAN of Dec 1984. 18-SEP-85

(4) X RAY START. fb =-1.20 dip = 20.0 amode = 0.0 valley= 0.00 list= 0

(4A)Start Test with h'x: start =-271.0

freq 1.000 1.100 1.200 1.300 1.400 1.500 1.600 1.700 1.800 1.900 2.000 2.100 2.200 2.300 2.400 2.500
2.600 2.700 -1.000 0.000 0.000

virt235.120 235.560 236.420 237.560 238.870 240.310 241.840 243.440 245.090 246.780 248.500 250.250 252.010 253.800 255.600 257.410
259.230 261.060 0.000 0.000 0.000

OFREQ 0.500 0.800 1.000 1.100 1.200 1.300 1.400 1.500 1.600 1.700 1.800 1.900 2.000 2.100 2.200 2.
300
2.400 2.500 2.600 2.700

REAL167.560 189.238 201.459 205.596 208.622 211.409 213.725 215.941 217.886 219.822 221.588 223.339 224.982 226.609 228.166 229.707
231.202 232.681 234.132 235.561 231.152

H.3 LISTINGS

In the program listings below, lines essential to normal program logic are printed in upper case. Lines dealing mainly with exceptions to normal operation, or with the production of additional trace listings, are in lower case. Trace listings are invoked when the input parameter LIST is non-zero; corresponding program lines are indicated by >>> in columns 76 to 78.

H.3.1. The mainline program, and the main subroutine SPOLAN

```
c  ** SPOLAN.FOR **    -  POLRUN  with  simplified  POLAN.
c                                                                Oct 1984.
c       Read-(1): field,           -(2): data, data, ...
c       1 blank to reread station/field data,  2 blanks to end.
c
c J.E. Titheridge,  Physics Dept,  University of Auckland,  New Zealand.
c-------------------------------------------------------------------------
        dimension head(6), fv(100), ht(100)
        byte dat(9)
        call date(dat)
        lf= 0
 20     lf= 1-lf
c                                                  read field and mode
 100    READ 120,  HEAD, FH,DIP, AMODE, VALLEY,LIST
 120    format (6a4,1x, 4f5.0, i5)
           if (fh.eq.0.)  stop
           if (fh.eq.9.) go to 20
        print 140, dat, head, fh,dip, amode, valley,list
 140    format ('1SPOLAN   of  dec 1984.',84x,9a2 /1h0,6a4,6x,'fb =',F5.2,
       1 5x'dip =',f5.1,5x,'amode =',f5.1,5x,'valley=',f5.2,'   list=',i3)
c - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
c                                                  read data
 200    READ 220, HEAD, START, (FV(I),HT(I), I = 1,5)
 220    format (6a4,f6.3,5(f5.3,f5.2))
        if (fv(1).eq.0.) go to 100
        print 240, head, start
 240    format (/1h0,6a4,6x,'start =',f6.1)
        N = -3
 300       N = N+8
           IF (HT(N).EQ.0.  .OR. N.GT.87) GO TO 400
           READ 320, (FV(I),HT(I), I = N+1,N+8)
 320       format (8(f5.3,f5.2))
           GO TO 300
c                                                  list data.
 400    if (lf.eq.0)  go to 500
        print 620, 'freq',  (fv(i),i = 1,n)
        print 620, 'virt',  (ht(i),i = 1,n)
        print 620
c                                                  analysis
 500    N = 99
        CALL SPOLAN (N,FV,HT, FH,DIP, START,AMODE, VALLEY,LIST*lf)
c
c                                                  output
        if (lf.eq.0)  go to 640
        PRINT 620, 'FREQ',  (FV(I), I = 1,N)
        PRINT 620, 'REAL',  (HT(I), I = 1,N+1)
 620    format (1h0,a4, f7.3,7f8.3,1x,8f8.3 / (4x8f8.3,1x8f8.3))
 640    print 620
        GO TO 200
        END
```

```
      SUBROUTINE SPOLAN (N,FV,HT, FB,DIP, START,AMODE, VALLEY,LLIST)
c                                                                  Oct 1984.
c  Generalised polynomial analysis;  overlapping, single or least squares.
c  Simplified POLAN for ordinary ray only,
c                   using a maximum of 12 terms (NT) fitting 24 points (NR+NV).
c
c  Call with  N  equal to the dimension of the data arrays  FV, HT.
c       The number of valid data points must be less than   N - 12.
c       Input data is terminated by two zero values of  HT.
c  Ionospheric layers are separated by a zero height, with  FV  equal to zero
c       or to a scaled critical frequency for the lower layer.
c       (The zero height may be replaced by some value < 40 km, to specify a
c       non-standard form for the valley for the current ionogram; such values
c                            are interpreted as described under VALLEY below).
c  FB and DIP give the gyrofrequency (in MHz) and the magnetic dip angle (in
c                                                 degrees) in the ionosphere.
c
c  START =-1.  gives a direct start from the first point FV(1),HT(1)
c        = 0   uses an extrapolated starting height, at a frequency of 0.5 MHz.
c        > 44  gives a model starting height, at 0.5 MHz
c        <-44  gives an X-ray virtual height to calculate the start correction.
c      0 < START < 44  defines a start frequency, to use at H = 90 (20) 170 km.
c
c  AMODE specifies the mode of analysis, as in POLAN.
c      0 gives the default Mode 5 analysis (the simplest least squares mode)
c      1, 2 = linear, parabolic lamination analysis.
c      3, 4 = overlapping cubic, quadratic sections.
c      5 to 9 are least squares calulations with IT terms fitting IV virtual
c        heights and !IR! known real heights, where IT, IV and IR are in DATA.
c        10 gives a single polynomial analysis (up to 12 terms fitting 24 hts).
c        I*10+J uses I terms for final layer, J for lower layers.
c
c  VALLEY = 0  gives the standard full valley, with a width equal to twice the
c                                               local (neutral) scale height.
c  VALLEY = 0.1 to 5.0 multiplies the "standard' width by this factor.
c           The resulting profile may give a negative gradient above the valley.
c  VALLEY = 10 gives no valley between layers.
c            Negative values of VALLEY specify a valley width of 5*INT(-VALLEY) km.
c   Any decimal part of VALLEY specifies the depth (in MHz) for a linear valley.
c
c  LLIST = 1 TO 6 gives increasing printed (trace) output.
c                     Use  LLIST  negative to start trace at first sub-peak section.
c-----------------------------------------------------------------------
       dimension  fv(9), ht(9),  it(12), iv(12), ir(12)
       common /pol/ b(49,13),q(12), fa,ha,fc, nl,mt, jv
       data IT / 1, 2, 3, 4, 5, 6, 6, 6, 7, 33, 12,12 / !number of terms in poly.
       data IV / 1, 1, 2, 3, 4, 5, 7, 8,13, 24, 24,24 /!no of virt heights fitted
       data IR / 0,-1,-1, 1,-2,-3,-4,-4,-6, -3, -3,-3 /!no of real heights fitted
          sq(x) = sqrt(1.-x*x)
          list = llist
          a = sgind(abs(fb), -abs(dip))                              setfield
             if (list.ne.0) print 1, fb,dip,start,amode,valley,llist      >>>
1            format ('0args ='5f8.2,i5)
       IF (START.GT.-44.)  GO TO 2
c                                         Calculate start height from X-ray h'.
          A= FV(1)/FB
          D= (A*2.16+0.38)*A -0.53
          E= (A*2.94-5.63)*A +2.81
          C= D+E*COS(.041*ABS(DIP)-.25)
          START= HT(1)+FB*C*(HT(1)+START)
c                                         Move data up 10 (or 12) places
2      IS = 12
       IF (START.LT. 0.)  IS = 10
       DO 3  J = IS, N-1
          I = N-J
          FV(IS+I)= FV(I)
3         HT(IS+I)= HT(I)
       FA = FV(1)
       HA = HT(1)
       IS = IS-10
```

```
      IF (START.LT.0.)  GO TO 5                                          direct
c                                     Add two start points
      FA = 0.5
      HA = HT(1) - ABS(HT(3)-HT(1)) *FV(1)/(FV(3)-FV(1))             extrapn.
      IF (START.GE.44.)  HA = AMIN1(START, (HA+HT(1))/2.)               model
      HA = AMAX1( AMIN1(HA, HT(1)/2+50.) , HT(1)/4.+55.)                limit
c
      IF (START.GE.44..OR.START.LE.0.)  GO TO 4
         FA = AMOD(START,10.)                                         model F
         HA = (START-FA)*20. + 90.
4     FV(12)= FV(1)*.6 + FA*.4
      HT(12)= HT(1)*.8 + HA*.2
      FV(11)= FA
      HT(11)= HA                                                      virtual
      FV(2) = FV(12)
      FV(1) = FA
      HT(1) = HA                                                         real
c                 KR= Real ht index,  KR+JV= Virtual ht,  LK= Last reduced ht.
5     JV = 10
      KR = 1
      LK = 1
      MOD= ABS(AMODE)
      IF (MOD.EQ.0)  MOD= 5
         it(12)= mod/10                                                nterms
         it(11)= mod-it(12)*10                                       lstlayer
         if (mod.gt.12)  mod= 12                                     one poly
c                                     Set initial analysis constants
10    NT = IT(MOD) - MOD/5 +mod/11*2                ! order of polynomial
      NV = MOD + MOD/6 + MOD/8                      ! virtual hts to use
         IF (MOD.GE.10)  NV = 24                    ! maximum
      NH = MAXO(1, NT-1+MOD/8)                      ! real hts  to  calc.
      NNR= 0
                if(list.ge.4)print99,(fv(jj),jj=11,26),(ht(jj),jj=11,26)   >>>
      GO TO 18
c************************** Real Height Calculation ******************
c For each cycle:-   Calculate one polynomial, with NT terms, from point
c       FA = FV(KR), HA = HT(KR) to fit next NV virtual and NR real hts.
c    Calculate a further NH real heights,  and set  KR  =  KR + NH.
c                     (NR negative to include one real height below HA).
c
c    If a critical frequency (HT < 40) is found in KR+1 to KR+NV+1,
c                           calculate up to critical (with parabolic peak).
c*********************************************************************
c                                     Constants for normal steps
15    NT = IT(MOD)                                                   numterms
      NV = IV(MOD)                                                   fit virt
      NH = MAXO(1,MOD-6)                                             calc hts
      NNR= IR(MOD)
18    NR = IABS(NNR)                                                 fit real
      NL = MINO(1,NR-NNR)                                            back hts
      KR = KR-NR+NL                                                    origin
      FCC= 0.
c                                     check for critical frequency
      DO 20  NF = 1, NV
         MF = KR+NF+JV                                               top freq
         FM = FV(MF)
         IF (FM.LE.FA)  GO TO 400                                       error
20       IF (HT(MF+1).LE.40.)  GO TO 30                                  peak
      GO TO 50
c                                                   use data to peak
30          FCC= FV(MF+1)
            if (mod.gt.10.and.ht(mf+2).gt.ha)  nt= it(11)            lstlayer
            IF (FCC.EQ.0.)  FCC= .2                                   calc FC
            LIST= IABS(LLIST)                                        trace on
            NH = NF-NR+NL                                            hts left
50    MF = MF-JV
      MV = MF-KR                                                     virtleft
      if(list.ge.3)print98,fa,ha,fm,fc,lk,kr,mf,mod,nh,nt,mt,nr,nl,nv,mv   >>>
98          format('  fa,ha='2f7.2, 4x'fm,fc='2f6.2,5x, 'lk,kr,mf='3i3,4x
     1         'mod,nh='2i3, 4x'nt,mt='2i3, 4x'nr,nl='2i3, 4x'nv,mv='2i3)
```

```
                  if(list.ge.4)print99,(fv(jj),jj=11,26), (ht(jj),jj=11,26)    >>>
 99                        format (16f8.2)
       IF (KR.EQ.1)  GO TO 100                                                 1st step
c                                      Reduce virtual heights
c                                            (1) polynomial reduction
       CALL COEFIS (KR, -MV, FV, HT)                                           prevpoly
                           if(list.ge.4) print99, (ht(jj),jj=11,26)              >>>
c                                            (2) step reduction loop
       MF1= MF+JV+1
 80    LK = LK +1                                                              loopslab
          FL = FA
          FA = FV(LK)
          HA = HT(LK)
          DH = HA - HT(LK-1)
          DO 90  I = MF1, N-1                                                  loopfreq
             HV = HT(I)
                if (hv.eq.0..and.ht(i+1).eq.0.)  go to 92                      end freq
                if (hv.le.30.)  go to 90                                       skippeak
             F  = FV(I)
             TAV= ( SQ(FA/F) + SQ(FL/F) ) /2.
             HT(I)= HV - SGIND(F,TAV) * DH                                       reduce
                           if(list.ge.5) print99,fl,fa,dh,ha,f,hv,ht(i)
 90       CONTINUE
 92    continue
          if (fa.eq.fc)  mf1= kr+jv+1                                            valley
       IF (LK.LT.KR)  GO TO 80                                                 nextslab
c------------------------------------------------------------------------------
c                                 - - - - - - Calculate new profile - - - - - -
 100   MT = MIN0(NT, MV+NR)                                                     terms
            if (mod.eq.10)  mt = min0((mv+2)*73/100, 12)
       FC = FCC
       if(list.ge.2)print98,fa,ha,fm,fc,lk,kr,mf,mod,nh,nt,mt,nr,nl,nv,mv      >>>
                           if(list.ge.4) print99, (ht(jj),jj=11,26)              >>>
c                                      Calculate Coefficients
       CALL COEFIS (KR, MV, FV, HT)
                     if (list.lt.6)  go to 190
                     do 160 j=1,mv*2
 160                          print 170, j,(b(j,jj),jj=1,mt+1)                   >>>
 170                          format (' matrix b row'i2,11f10.3)
 190                         continue
c
       CALL SSOLVE (MV+NR, MT,  B, Q)
                           if (list.ge.1) print 199, fa,ha,(q(j),j=1,mt)          >>>
 199                       format (2f7.2,' Coefts Q1,..,MT=',12F8.2)
c                                      Store  real  heights
       KR = KR+NR-NL                                                           lastreal
       DO 220  I = 1, NH
          HR = HA
          DO 210  J = 1, MT
 210         HR = B(MV+NR+I,J)*Q(J) + HR
          KR = KR+1
          HT(KR)= HR                                                            real ht
 220      FV(KR)= FV(KR+JV)
       IF (FC.EQ.0.)  GO TO  15                                                   loop
       if (fc.lt.0.)  go to 400                                                    end
c                                      Calculate parabolic peak
       KVP= KR+JV+1
       HVAL= HT(KVP)
       if (hval.eq. 0.) hval= valley
       if (ht(kvp+1).eq.0.)  hval= 9.9                                         end data
       CALL  SPEAK (N, FV, HT, FC, KR, HVAL)                                   set peak
C
       JV= KVP-KR
       IF (HT(KVP+1).GT.80.)  GO TO 10
C------------------------------------------------------------------------------
 400   N = KR
       RETURN
       END
```

H.3.2. The subroutines COEFIS, SPEAK, SSOLVE and SGIND, in the file SOLSUB.FOR

```
cc      S O L S U B .FOR.  Link with SPOLAN.
c
        SUBROUTINE  COEFIS (KR, MV,  FV, HT)
c                                                 Simplified Coefic, for 0 ray only.
c  Calculate coefficients  b(i,j)  for polynomial     h-ha  =  q(j)*(f-fa)**j,
c          where fa = fv(kr),   ha = ht(kr),   j = 1 to mt.
c          Includes parabolic peak if fc > 1.
c    Virtual heights, freqs are  ht(iv), fv(iv).  Reals are ht(iv-jv),fv(iv-jv).
c
c    First/last mv rows of b give virtual/real ht coefs at freqs  kv+1 to kv+mv.
c    mv -ve to reduce virtual heights by delay in the prev section fa to fv(kr).
c-----------------------------------------------------------------------
        common /pol/  b(49,13), q(12),   fa, ha, fc,  nl, mt, jv
        dimension  tr(5),w(5),  gauss(5),fnr(5), fv(9), ht(9)
        data tr  / .046910077,.23076534,.50       ,.76923466,.95308992/
        data  w  / .11846344,.23931434, .28444444,.23931434,.11846344/
c-----------------------------------------------------------------------
           sq(x)  =  sqrt(1.-x*x)
        NF = IABS(MV)                                              freqs.
        KV = KR+JV
c                    - - - - - - - - - cycle frequencies - - - - - - - -
        DO 100  I = 1-NL, NF
        IV = KV + I
           if (i.eq.0)  iv = iv-1                                  prev ht
        F = FV(IV)
           if (i.eq.0)  go to 30                                   realonly
c                                  integration limits  TA to TA+TD
        TA = 0.                                                    reflectn
        if (mv.lt.0)  ta = sq(fv(kr)/f)                            upperlim
        TD = SQ(FA/F)-TA
c                                  store group indices
        SUMP = 0.
        DO 20  IR = 1, 5
           T  = TR(IR)*TD + TA
           FN = SQ(T) *F
           GAUSS(IR) = SGIND(F,T) *T *W(IR)/FN *TD
              if (fc.gt.fa)  sump = gauss(ir)*fn/sq(fn/fc) + sump     peak sum
20         FNR(IR) = FN-FA
c
c                                  store coefficients in array b:
30      IREAL = I + NF + NL                                        realequn
        DO 90  J = 1, MT
           REALHT = (F-FA)**J                                      realpoly
           SUMVRT = 0.
           IF (J.LT.MT .OR. FC.LT.FA)  GO TO 60                    not peak
c                                        parabolic peak term q(mt)
              if (f.lt.fc)  realht = sq(fa/fc) - sq(f/fc)
              sumvrt = sump *(f/fc)**2                             delay
              if (i.ne.0)  go to 80
60         if (i.eq.0)  go to 90                                   realonly
c                                  form polynomial integrals
           DO 70 IR = 1,5
              A = GAUSS(IR)
              GAUSS(IR) = A*FNR(IR)
70            SUMVRT = SUMVRT + A
           SUMVRT = J*SUMVRT*F*F                                   delay
c                                  store integrals
80         B(I,J) = SUMVRT + REALHT                                virtual
              if (mv.lt.0)  ht(iv) = ht(iv) - q(j)*sumvrt           reduce
90      B(IREAL,J) = REALHT                                         real
c
        IF (I.GT.0)  B(I,MT+1) = HT(IV) - HA                       v r.h.s.
100     B(IREAL,MT+1) = HT(IV-JV) - HA                             r r.h.s.
c                    - - - - - - - - - - - - - - - - - - - - - - - - -
        RETURN
        END
```

```
      SUBROUTINE  SPEAK (N, FV, HT,  FC, KR, HVAL)
c
c   Calculation of parabolic peak for  SPOLAN,  using the last 3 calcd real hts.
c      (If FC was scaled, these heights were obtained with a poly+parabola fit.)
c                 The last calcd height is at  fv(kr), ht(kr).
c
      dimension fv(9), ht(9)
         sq(x) = sqrt(1-x*x)
c
      FM = FV(KR)
      HR = HT(KR)
      FN = FV(KR-2)
      HN = HT(KR-2)
      IF (FC.GT..2)  GO TO 20
c                             calculate fc from gradient fit, when not scaled.
c                      (the factor 0.263 replaces parabolic 0.25, for Chapman)
         fnn= fn**2
         dh = ht(kr-1) - hn
         c  = (fv(kr-1)**2 - fnn) / dh
         d  = (c - (fm*fm-fnn)/(hr -hn) ) / (hr -ht(kr-1))
         fc = sqrt(fnn + .263*d* (c/d+dh)**2)
c                           Calculate the Scale Height.  .55 corrects to chap.
20    SH = 0.554*(HR-HN) /( SQ(FN/FC) -SQ(FM/FC) )
      HM = HR + 2.*SH*SQ(FM/FC)
      KR = KR+1
      FV(KR)= FC
      HT(KR)= HM
c                                                           list  peak
      print 40,  fc, hm, sh
40    format(' Peak'F7.3,' Mhz.    Height'F6.1,' km.',
     1                7X,'Scale Height',F6.1,' km.')
      ht(kr+1) = sh
      if (hval.ge.9.9) return                                          novalley
c
c        Add a simple linear valley above the peak, if there is another layer,
c        using the default Polan value:-  vwidth = sha *2. = hmax/2. - 40. km.
      VAL= HM/2.-40.                                                   standard
         if (hval.gt.0..and.hval.le.5.)  val= val*hval                    scale
         if (hval.le.-1.)  val= 5*int(-hval)                           absolute
      VDEPTH= VAL/200.
         if (hval.lt.int(hval))  vdepth= int(hval)-hval
      KR = KR+2
      FV(KR-1)= FC-VDEPTH
      HT(KR-1)= HM+VAL*.66
      FV(KR) = FC
      HT(KR) = HM +VAL
c
      print 80, val, vdepth
80    format (13x,'Valley width',f6.1,' km,       Depth',f5.2,' Mhz.')
      RETURN
      END

      SUBROUTINE  SSOLVE (M,N, B,Q)
c                            for simplified polan  (SPOLAN)  of june 1978.
c
c Solve m simult equns in n unknowns, in array b(m,n+1). Result in q(n).
c----------------------------------------------------------------------
      dimension  b(49,13), q(12)
      NP = N +1
c                                  Householder transformations
      DO 4  K = 1, NP
      SUM = 0.
      if (k.gt.m)  go to 7
         DO 1  I = K, M
1        SUM = SUM + B(I,K)**2
      if (k.eq.np) go to 7
        A = B(K,K)
        D = SIGN(SQRT(SUM),A)
        B(K,K) = A + D
        C = A*D + SUM
```

```
C
         DO 3  J = K+1, NP
            SUM = 0.
               DO 2  I = K, M
2              SUM = SUM + B(I,K)*B(I,J)
            SUM = SUM/C
               DO 3  I = K, M
               B(I,J) = B(I,J) -B(I,K)*SUM
3        CONTINUE
c
4       B(K,K) = -D
c---------------------------------------------------------------------
c                                  Back substitution
7       B(NP,NP) = SUM
        DO 10  II = 1, N
           I = NP-II
           SUM = B(I,NP)
           IF (II.EQ.1)  GO TO 10
              DO 8  J = I+1, N
8             SUM = SUM - B(I,J)*Q(J)
10         Q(I) = SUM/B(I,I)
        RETURN
        END

        FUNCTION SGIND (F,T)
c                                                      Ordinary ray only.
c Gives  (group index -1.)  to full machine accuracy,  up to reflection.
c       f = wave frequency;       t = sqrt(1. - x)   where  x = (fn/f)**2.
c
c Initialise by call sgind(fb,-dip) to set gyrofreq (mhz) and dip (deg).
c---------------------------------------------------------------------
        data  fbsin,fcsct  /  2*0. /
        IF (T.GE.0.)  GO TO 6
            dip = -.01745329*t
            fbsin = f *sin(dip)
            fcsct = (f*cos(dip))**2 *.5/fbsin
            return
c---------------------------------------------------------------------
6       G1 = F*T*T +1.E-19
        G2 = FCSCT/G1
        G3 = SQRT(G2*G2 +1.)
        G4 = FBSIN/(G2 + G3)
        G5 = F + G4
        G2 = (F*G2*G4/G1-.5*FBSIN)*(F-G1)/(G3*G5) + G5
        SGIND = G2/SQRT((G1 + G4) *G5) -1.
        RETURN
        END
```