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Haystack Pointing System: Radar Coordinate Correction

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

HAYSTACK POINTING SYSTEM: RADAR COORDINATE CORRECTION

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ABSTRACT

In the Haystack Pointing system, errors caused by atmospheric refraction, gravitational deformation of the antenna, skewed axes and resolver error are compensated for by a correction program in the computer which adds the necessary biases to the geometric values of azimuth and elevation to produce an effectively correct aiming of the antenna.

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

HAYSTACK POINTING SYSTEM: RADAR COORDINATE CORRECTION

I. INTRODUCTION

The Radar Coordinate Correction program of the Haystack Pointing system accepts as input a pair of angles (θ, ϕ) which are the azimuth and elevation coordinates of a point at which the antenna is to be pointed. The program modifies these angles by adding corrections derived from tables using the method of table look-up and interpolation and produces as output a pair of antenna pointing angles (θ_c, ϕ_c) which are corrected for gravitational deformation of the antenna, atmospheric refraction, resolver error, and skew of axes.

II. PROGRAM OPERATION*

The program is composed of two parts, the initializing package and the worker package. Entrance to each package from a calling routine is made with an RJP instruction.

The initializing package sets up standard correction tables during system initialization. If the correction program is called via the attention symbol route for reinitialization, the initializing package asks the operator to enter values for the various parameters used in computing the correction tables. See Fig. 1 for typical sequence of questions and answers. A vacuous answer (the carriage return alone) results in use of a prestored "standard" value for that particular parameter. The operator also has the option of omitting from use any or all correction tables. After all parameters have been entered, the package computes the correction values and stores them in the various tables. Control is returned to the calling routine from the initializing package with an EXIT instruction.

If temperature or pressure should vary significantly during an experiment, these values can be re-entered and a new refraction correction table computed without interrupting the experiment. The time necessary to recompute the refraction table after the parameters have been entered via the console is approximately 4 milliseconds.

There are three tables involved in the correction of the pointing angles (see Appendix B). The table REFRACTBL corrects for atmospheric refraction and is a

*Use of this document assumes knowledge of TN-1966-10, "Haystack Pointing System: Control Structure," by J. D. Drinan and A. A. Mathiasen.

```
CORRECTION PGM
INCLUDE REFRACTION TABLE (Y  OR  N)
     Y*

USE STANDARD VALUES (Y  OR  N)
     N*

ENTER TEMP IN DEG C
     XX.X*

ENTER ATM PRESSURE IN MB
     XXX.X*

ENTER PARTIAL PRESSURE IN MB
     XX.X*

INCLUDE AZ TABLE (Y  OR  N)
     Y*

INCLUDE EL TABLE (Y  OR  N)
     N*
```

Fig. 1. Typical question-answer sequence.

function of elevation only. The argument varies from 0^{o} to 90^{o} and is more densely packed for angles below 25^{o}. The parameters associated with this table are temperature in degrees centigrade and atmospheric (i.e., total) and partial pressures in millibars.

The equations used in computing atmospheric refraction corrections are based on the results of a paper published by W. R. Iliff and J. M. Holt.[1] They verified by experiment that the total atmospheric refraction correction angle τ could be accurately estimated by an equation of the form

$$\tau = b_{\phi} \cdot N_s - a_{\phi} \quad ,$$

where N_s is the surface refractivity, a_{ϕ}, b_{ϕ} are functions of the elevation angle

1. W. R. Iliff, and J. M. Holt, "Use of Surface Refractivity in the Empirical Prediction of Total Atmospheric Refraction," J. Research NBS 67D (Radio Prop.) No. 1 (January-February, 1963).

ϕ. The value of the surface refractivity is computed using the Smith and Weintraub equation[2]

$$N_s = \frac{77.6}{T + 273.15}\left[p + \frac{4810e}{T + 273.15}\right] ,$$

where e is the partial pressure of water vapor in millibars, p is the total pressure in millibars, and T is the temperature in degrees centigrade. The values of a_ϕ and b_ϕ will be precomputed and stored as constants in two tables called ATBL and BTBL for values of ϕ ranging from 0^o to 90^o. See Appendix A for calculation of a_ϕ and b_ϕ.

The tables AZTBL and ELTBL are each functions of azimuth and elevation. They correct for antenna sag, resolver error, and skew of axes, with AZTBL containing the corrections for azimuth and ELTBL the corrections for elevation. Each table has associated with it a pair of vectors containing the arguments of azimuth and elevation. They range from 0^o to 90^o in elevation and 0^o to 360^o in azimuth. The arguments can be irregularly spaced. See Appendix B for the table format.

The worker package uses the angle ϕ in a table look-up in REFRACTBL to produce a correction δ_1 for elevation due to refraction. This correction is added to ϕ to produce the angle $\bar{\phi}$. The angles $(\theta, \bar{\phi})$ are used as arguments in separate table look-ups of AZTBL and ELTBL to produce correction values δ_2 and δ_3 for azimuth and elevation, respectively. These values are added to $(\theta, \bar{\phi})$ to produce final corrected angles (θ_c, ϕ_c). While the values of (θ, ϕ) are in revolutions (with a binary point at B27) the table look-up and interpolation are done in degrees with the correction values converted to revolutions (B27) just prior to being added to (θ, ϕ). Control is returned to the calling routine from the correction package with an EXIT instruction. The time required for one pass through the worker package is of the order of 2 milliseconds.

III. TABLE LOOK UP AND INTERPOLATION

The correction value for each table is computed according to the following equations:

2. E. K. Smith and S. Weintraub, "The Constants in the Equation for Atmospheric Refractive Index at Radio Frequencies, "Proc. IRE 41, No. 8, 1035-1037 (1953).

A. δ_1

The values stored in the refraction table REFRACTBLE are τ_i.
The values stored in the elevation argument table REFRACARG are s_i.

$$\delta_1 = \tau_i + \frac{\phi - s_i}{s_{i+1} - s_i}(\tau_{i+1} - \tau_i) \quad ,$$

where $s_i \le \phi < s_{i+1}$.

B. δ_2

The values stored in the azimuth correction table AZTBL are $\delta_{i,j}$.
The values stored in the azimuth argument table AZTBLAZARG are u_j.
The values stored in the elevation argument table AZTBLELARG are v_i.

$$D_{i,j} = \delta_{i,j} + \frac{\theta - u_j}{u_{j+1} - u_j}(\delta_{i,j+1} - \delta_i) \quad .$$

$$\delta_2 = D_{i,j} + \frac{\phi - v_i}{v_{i+1} - v_i}(D_{i+1,j} - D_{i,j}) \quad ,$$

where $u_j \le \theta < u_{j+1}$,

$v_i \le \phi < v_{i+1}$.

C. δ_3

The values stored in the elevation correction table ELTBL are $\epsilon_{i,j}$.
The values stored in the azimuth argument table ELTBLAZARG are x_j.

The values stored in the elevation argument table ELTBLELARG are y_i.

$$E_{i,j} = \epsilon_{i,j} + \frac{\theta - x_j}{x_{j+1} - x_j} (\epsilon_{j,j+1} - \epsilon_i) \quad .$$

$$\delta_3 = E_{i,j} + \frac{\phi - y_i}{y_{i+1} - y_i} (E_{i+1,j} - E_{i,j}) \quad ,$$

where $x_j \leq \theta < x_{j+1}$,

$y_i \leq \phi < y_{i+1}$.

For an elevation angle ϕ greater than 90^o, the correction value δ_k is computed using the angle $180^o - \phi$. The correction value δ_k so obtained is subtracted from the angle ϕ. For a negative angle ϕ, δ_k is computed by means of extrapolation and is added to the elevation angle ϕ.

Interpolation is linear in both elevation and azimuth with an accuracy compatible with the accuracy of the input angles. All operations are carried out in single precision, fixed point arithmetic.

APPENDIX A

The following equations were used in precomputing the values of a_ϕ and b_ϕ which are stored as constants in the correction program. All equations and parameter values were taken from the paper cited in Reference 1.

The refraction correction angle τ, measured in revolutions, is given by

$$\tau = b_\phi \cdot N_s - a_\phi \quad ,$$

where N_s is the surface refractivity. The values of a_ϕ and b_ϕ are given by

$$a_\phi = \frac{A}{(\alpha + B)^C}$$

$$b_\phi = \frac{180}{\pi \cdot 10^6} \left[\cot \alpha - \frac{D}{(\alpha + E)^F} \right] \quad ,$$

where α is the elevation angle measured in degrees. The functions a_ϕ and b_ϕ have the dimensions of degrees and degrees per surface refractivity unit, respectively. As α becomes large, a_ϕ approaches zero and b_ϕ approaches the product of a constant times the cotangent of the elevation angle. The parameters A, B, C, D, E, F are positive constants and were determined empirically.

Their values are as follows:

A = 40.0	D = 42.5
B = 2.7	E = 0.4
C = 4.0	F = 2.64

APPENDIX B

The following discusses the contents and formats of the tables used in the correction program. In all tables, the subscripts (i, j) vary with elevation and azimuth, respectively.

REFRACARG

s_o
s_i

ATBL

a_o
a_i

BTBL

b_o
b_i

REFRACTBL

τ_o
τ_i

The elevation argument s_i is stored as degrees with the binary point at B20. The values of a_i and b_i will be precomputed and stored in these tables as constants, with a binary point at B20. They are functions of elevation angle and are used in computing the refraction correction table REFRACTBL. The refraction correction value τ_i is computed as a function of temperature, atmospheric pressure, vapor pressure, a_i and b_i. The value τ_i is expressed in degrees with the binary point at B20.

AZTBLAZARG

u_o			u_j

AZTBLELARG

v_o
v_i

AZTBL

$\delta_{o,o}$			$\delta_{o,j}$
$\delta_{i,o}$			$\delta_{i,j}$

ELTABLAZARG

x_o		x_j	

ELTBLELARG

y_o
y_i

ELTBL

$\epsilon_{o,o}$		$\epsilon_{o,j}$	
$\epsilon_{i,o}$		$\epsilon_{i,j}$	

The arguments u_j, v_i, x_j, y_i are stored as degrees with the binary point at B20. The correction values $\delta_{i,j}$ and $\epsilon_{i,j}$ will be precomputed and stored in these tables as constants, where $\delta_{i,j}$ is the correction value for azimuth and $\epsilon_{i,j}$ is the correction value for elevation. They represent the corrections necessary to account for errors other than the refraction error. Both $\delta_{i,j}$ and $\epsilon_{i,j}$ are expressed in degrees with the binary point at B20.

APPENDIX C

```
                    ;;;;;;;;;;;;;;;;;;;;;;;;;;   SPURT OUTPUT NO. 110      ;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

                          CORCT               CLARK+PC*27JUN66

CARDS    L1 ID LABEL      TA STATEMENT                          LOC    F JKB Y      NOTES

  .      00000 CORCT         PROGRAM   CLARK+PC*27JUN66
  .      00001 CORCTX        U-TAG     CORCTWORK*CORCTINIT      00000  00116 00002
  .      00002               FD   1*CORCT                       00001  10242 71031
  .      00003 REFRACIND     EQUALS    REFRACIND$
  .      00004 AZELIND       EQUALS    AZELIND$
  .      00005 CORCTINIT     ENTRY                              00002  61000 00000
  .      00006               ENT  A*L(SYSTAT1)*ANOT             00003  11510 63313  IF NOT ZERO, NO QUESTIONS
  .      00007               JP   COR1A                         00004  61000 00016
  .      00010               CL   CPU(REFRACIND)                00005  16060 63161  INCLUDE REFRACTION TABLE
  .      00011               MOVE 3*STNTSUBC*TSUBC              00006  10030 00405  SET UP STANDARD VALUES
                                                                00007  14030 00417
                                                                00010  10030 00406
                                                                00011  14030 00420
                                                                00012  10030 00407
                                                                00013  14030 00421
  .      00012               CL   CPW(AZELIND)                  00014  16070 63162  INCLUDE AZTBL,ELTBL
  .      00013               JP   COR4+2                        00015  61000 00073
  .      00014 COR1A         NO-OP                              00016  12000 00000
  .      00015               RJP  U(INTERCOM)                   00017  65020 63426  ASK IF REFRACTBL INCLUDED
  .      00016               U-TAG     TOUT1*TIN1               00020  00751 00763
  .      00017               ENT  A*W(YESISONE1)                00021  11030 00415
  .      00020               STR  A*U(REFRACIND)                00022  15020 63161
  .      00021               JP   COR2*AZERO                    00023  60400 00045  SET UP FOR NO AND SKIP DOWN

  .      00022               RJP  U(INTERCOM)                   00024  65020 63426  ASK IF STANDARD VALUES OK
  .      00023               U-TAG     TOUT2*TIN2               00025  00765 00776
  .      00024               ENT  A*W(YESISONE2)*ANOT           00026  11530 00416
  .      00025               JP   COR1                          00027  61000 00037  NO,GET CONSOLE INPUT
  .      00026               MOVE 3*STNTSUBC*TSUBC              00030  10030 00405  YES,SET UP FOR STANDARD VALUES

                                                                00031  14030 00417
                                                                00032  10030 00406
                                                                00033  14030 00420
                                                                00034  10030 00407
                                                                00035  14030 00421
  .      00027               JP   COR2                          00036  61000 00045  AND SKIP DOWN
  .      00030 COR1          RJP  U(INTERCOM)                   00037  65020 63426  ENTER TEMPERATURE(TSUBC)
  .      00031               U-TAG     TOUT3*TIN3               00040  01000 01007
  .      00032               RJP  U(INTERCOM)                   00041  65020 63426  ENTER PRESSURE(RHO)
  .      00033               U-TAG     TOUT4*TIN4               00042  01013 01023
  .      00034               RJP  U(INTERCOM)                   00043  65020 63426  ENTER PARTIAL PRESSURE(E)
  .      00035               U-TAG     TOUT5*TIN5               00044  01027 01040
  .      00036 COR2          RJP  U(INTERCOM)                   00045  65020 63426  ASK IF AZ TABLE INCLUDED
  .      00037               U-TAG     TOUT6*TIN6               00046  01044 01054
  .      00040               PUT  L(YESISONE6)*U(AZELIND)       00047  10010 00422
                                                                00050  14020 63162
  .      00041               RJP  U(INTERCOM)                   00051  65020 63426  ASK FOR AZ BIAS
  .      00042               U-TAG     PCSPOUT1*PCSPIN1         00052  01104 01070
  .      00043               ENT  Q*W(AZBIAS)                   00053  10030 01100  B19
  .      00044               MUL  400                           00054  22000 00400  SET A +/-0 AND LSH AQ 8D --B27

  .      00045               DIV  3600                          00055  23000 00550
```

```
00046                STR  Q*W(AZBIASREV)                00056  14030 01102  REVS B27
00047 COR3           RJP  U(INTERCOM)                   00057  65020 63426  ASK IF EL TABLE INCLUDED
00050                U-TAG     TOUT9*TIN9               00060  01056 01066
00051                PUT  L(YESISONE9)*L(AZELIND)       00061  10010 00423
                                                        00062  14010 63162
00052                RJP  U(INTERCOM)                   00063  65020 63426  ASK FOR EL BIAS
00053                U-TAG     PCSPOUT2*PCSPIN2         00064  01123 01074
00054                ENT  Q*W(ELBIAS)                   00065  10030 01101  B19
00055                MUL  400                           00066  22000 00400  B27 IN AQ
00056                DIV  360D                          00067  23000 00550
00057                STR  Q*W(ELBIASREV)                00070  14030 01103  REVS B27
00060 COR4           ENT  A*U(REFRACIND)*ANOT           00071  11520 63161
00061                JP   DONE                          00072  61000 00115
00062                ENT  A*W(TSUBC)                    00073  11030 00417  AT B9
00063                ADD  A*W(KELVIN)                   00074  20030 00410  AT B9
00064                STR  A*W(TSUBK)                    00075  15030 00424  TSUBK AT B9
00065                ENT  Q*W(E)                        00076  10030 00421  AT B9
00066                MUL  W(K1)                         00077  22030 00411  IN AQ AT B18
00067                DIV  W(TSUBK)                      00100  23030 00424  IN Q AT B9
00070                ADD  Q*W(RHO)                      00101  26030 00420  IN Q AT B9
00071                MUL  W(K2)                         00102  22030 00412  IN AQ AT B18
00072                DIV  W(TSUBK)                      00103  23030 00424  IN Q AT B9
00073                STR  Q*W(NSUBS)                    00104  14030 00425  NSUBS AT B9
00074                ENT  B6*L(REFRACSIZE)              00105  12610 00426
00075                ENT  B6*B6-1                       00106  12606 77776
00076                ENT  Q*W(NSUBS)                    00107  10030 00425  NSUBS IN Q AT B9
00077                MUL  W(BTBL+B6)                    00110  22036 00533  NSUBS*B AT B39
00100                RSH  AQ*19D                        00111  03000 00023  IN Q AT B20
00101                SUB  Q*W(ATBL+B6)                  00112  27036 00471
00102                STR  Q*W(REFRACTBL+B6)             00113  14036 00575  TAU(I) IN DEG AT B20
00103                BJP  B6*$-5                        00114  72600 00107
00104 DONE           EXIT                               00115  61010 00002
00105 CORCTWORK      ENTRY                              00116  61000 00000
00106                ENT  A*W(SAZIM)                    00117  11030 63055
00107                ADD  A*W(AZDIFS)*APOS              00120  20630 63120
00110                ADD  A*W(AREV)                     00121  20030 00413
00111                COM  A*W(AREV)*YMORE               00122  04730 00413
00112                SUB  A*W(AREV)                     00123  21030 00413
00113                STR  A*W(CAZIM)                    00124  15030 63060
00114                ENT  A*W(SELEV)                    00125  11030 63056
00115                ADD  A*W(ELDIFS)                   00126  20030 63121
00116                STR  A*W(CELEV)                    00127  15030 63061
00117                ENT  A*W(RANGE)                    00130  11030 63052
00120                ADD  A*W(RDIFS)                    00131  20030 63122
00121                STR  A*W(CRANGE)                   00132  15030 63057
00122                ENT  A*W(RANGEDOT)                 00133  11030 63062
00123                ADD  A*W(RDOTDIFS)                 00134  20030 63123
00124                STR  A*W(RANGEDOT)                 00135  15030 63062
00125                ENT  A*W(ELBIASREV)                00136  11030 01103
00126                RPL  A+Y*W(CELEV)                  00137  24030 63061  REVS B27
00127                ENT  Q*A                           00140  10070 00000
00130                MUL  W(TWOPI)                      00141  22030 01133  B26
00131                LSH  AQ*2                          00142  07000 00002  RADIANS B25
00132                ENT  Q*25D                         00143  10000 00031  BINARY POINT
00133                RJP  COS                           00144  65000 01134
00134                STR  A*W(COSELEV)                  00145  15030 01131  B28
00135                ENT  Q*W(AZBIASREV)                00146  10030 01102  B27
00136                MUL  1                             00147  22000 00001
00137                LSH  AQ*28D                        00150  07000 00034
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00140                DIV   W(COSELEV)                    00151  23030 01131  B28
00141                SUB   Q*W(MAXAZBIAS)*QNEG           00152  27730 01132
00142                CL    Q                             00153  10000 00000
00143                ADD   Q*W(MAXAZBIAS)                00154  26030 01132
00144                RPL   Y+Q*W(CAZIM)                  00155  34030 63060
00145                ENT   A*L(SLAVEMODES)*AZERO         00156  11410 63125  TEST FOR SLAVE MODE
00146                JP    AZELINTRP                     00157  61000 00206  YES,SKIP REFRACTION
00147                ENT   A*U(REFRACIND)*ANOT           00160  11520 63161  NO,DO WE CORRECT FOR REFRAC

00150                JP    AZELINTRP                     00161  61000 00206  NO,SKIP REFRACTION
00151                RJP   ELRANGE                       00162  65000 00374  EL IN REV IN Q AT B27
00152                MUL   360D                          00163  22000 00550  DEG AT B27
00153                RSH   AQ*7                          00164  03000 00007  IN Q AT B20
00154                ENT   B6*L(REFRACSIZE)              00165  12610 00426
00155                ENT   B5*REFRACARG                  00166  12500 00427
00156                RJP   GETINC                        00167  65000 00361
00157                STR   A*CPW(AZINC)                  00170  15070 00332  AT B20
00160                STR   Q*W(AZDIF)                    00171  14030 00333  AT B20
00161                ENT   A*B7                          00172  11007 00000
00162                ADD   A*REFRACTBL                   00173  20000 00575
00163                ENT   B6*A                          00174  12670 00000  TABLE POINTER
00164                RJP   AZINTERP                      00175  65000 00343  ANS IN Q AT B20
00165                CL    A*QPOS                        00176  11200 00000
00166                CP    A                             00177  15040 00000
00167                LSH   AQ*7                          00200  07000 00007  IN AQ IN DEG AT B27
00170                DIV   360D                          00201  23000 00550  IN REV AT B27
00171                BSK   B0*L(FLAG)                    00202  71010 00404  IS EL GTR 90 DEG
00172                CP    Q                             00203  14000 00000  YES
00173                STR   Q*W(REFRACCOR$)               00204  14030 63031
00174                RPL   Y+Q*W(CELEV)                  00205  34030 63061  AT B27
00175 AZELINTRP      ENT   A*W(AZELIND)*ANOT             00206  11530 63162  USE EITHER AZTBL OR ELTBL
00176                JP    WORKEXIT                      00207  61000 00272  NO,SO EXIT
00177                RJP   ELRANGE                       00210  65000 00374
00200                MUL   360D                          00211  22000 00550  IN DEG AT B27
00201                RSH   AQ*7                          00212  03000 00007  IN DEG AT B20
00202                STR   Q*W(ELDEG)                    00213  14030 00341  IN DEG AT B20
00203                ENT   Q*W(CAZIM)                    00214  10030 63060  IN REV AT B27
00204                MUL   360D                          00215  22000 00550  IN DEG AT B27
00205                RSH   AQ*7                          00216  03000 00007  IN DEG AT B20
00206                STR   Q*W(AZDEG)                    00217  14030 00342  IN DEG AT B20
00207 AZINTRP        ENT   A*U(AZELIND)*ANOT             00220  11520 63162
00210                JP    ELINTRP                       00221  61000 00246  EXCLUDE AZTBL
00211                PUT   L(AZTBLSIZE)*U(SIZE)          00222  10010 00637  M=EL DIMEN
                                                         00223  14020 00327
00212                PUT   L(AZTBLSIZE+1)*L(SIZE)        00224  10010 00640  N=AZ DIMEN
                                                         00225  14010 00327
00213                PUT   AZTBLELARG*U(ARGLOC)          00226  10000 00641
                                                         00227  14020 00330
00214                PUT   AZTBLAZARG*L(ARGLOC)          00230  10000 00646
                                                         00231  14010 00330
00215                PUT   AZTBL*L(TBLLOC)               00232  10000 00653
                                                         00233  14010 00331
00216                RJP   INTERP                        00234  65000 00273  ANS IN Q IN DEG AT B20
00217                CL    A*QPOS                        00235  11200 00000
00220                CP    A                             00236  15040 00000
00221                LSH   AQ*7                          00237  07000 00007  IN AQ IN DEG AT B27
00222                DIV   360D                          00240  23000 00550  IN Q IN REV AT B27
00223                ADD   Q*W(CAZIM)*QPOS               00241  26630 63060
00224                ADD   Q*W(AREV)                     00242  26030 00413
```

```
00225            COM  Q*W(AREV)*YMORE           00243  04330 00413
00226            SUB  Q*W(AREV)                 00244  27030 00413
00227            STR  Q*W(CAZIM)                00245  14030 63060  IN RANGE 0 TO 1 REV
00230 ELINTRP    ENT  A*L(AZELIND)*ANOT         00246  11510 63162
00231            JP   WORKEXIT                  00247  61000 00272  EXCLUDE ELTBL
00232            PUT  L(ELTBLSIZE)*U(SIZE)      00250  10010 00704  M=EL DIMEN
                                                00251  14020 00327
00233            PUT  L(ELTBLSIZE+1)*L(SIZE)    00252  10010 00705  N=AZ DIMEN
                                                00253  14010 00327
00234            PUT  ELTBLELARG*U(ARGLOC)      00254  10000 00706
                                                00255  14020 00330
00235            PUT  ELTBLAZARG*L(ARGLOC)      00256  10000 00713
                                                00257  14010 00330
00236            PUT  ELTBL*L(TBLLOC)           00260  10000 00720
                                                00261  14010 00331
00237            RJP  INTERP                    00262  65000 00273  ANS IN Q IN DEG AT B20
00240            CL   A*QPOS                    00263  11200 00000
00241            CP   A                         00264  15040 00000
00242            LSH  AQ*7                      00265  07000 00007  IN AQ IN DEG AT B27
00243            DIV  360D                      00266  23000 00550  IN Q IN REV AT B27
00244            BSK  B0*L(FLAG)                00267  71010 00404  IS EL GTR 90 DEG
00245            CP   Q                         00270  14000 00000  YES
00246            RPL  Y+Q*W(CELEV)              00271  34030 63061
00247 WORKEXIT   EXIT                           00272  61010 00116
00250 INTERP     ENTRY                          00273  61000 00000
00251            ENT  B5*L(ARGLOC)              00274  12510 00330  AZ VECTOR
00252            ENT  B6*L(SIZE)                00275  12610 00327  N
00253            STR  B6*L(INTERP1)             00276  16610 00322
00254            ENT  Q*W(AZDEG)                00277  10030 00342  IN DEG AT B20
00255            RJP  GETINC                    00300  65000 00361
00256            STR  A*CPW(AZINC)              00301  15070 00332  AZBAR-AZ(J)
00257            STR  Q*W(AZDIF)                00302  14030 00333  AZ(J+1)-AZ(J)
00260            STR  B7*L(IJ)                  00303  16710 00336  STORE J
00261            ENT  B5*U(ARGLOC)              00304  12520 00330  EL VECTOR
00262            ENT  B6*U(SIZE)                00305  12620 00327  M
00263            ENT  Q*W(ELDEG)                00306  10030 00341  IN DEG AT B20
00264            RJP  GETINC                    00307  65000 00361
00265            STR  A*CPW(ELINC)              00310  15070 00334  ELBAR-EL(I)
00266            STR  Q*W(ELDIF)                00311  14030 00335  EL(I+1)-EL(I)
00267            STR  B7*U(IJ)                  00312  16720 00336  STORE I
00270            ENT  Q*L(SIZE)                 00313  10010 00327  N
00271            MUL  U(IJ)                     00314  22020 00336  N*I
00272            ENT  Y+Q*L(IJ)                 00315  30010 00336  N*I+J
00273            ADD  A*L(TBLLOC)               00316  20010 00331
00274            ENT  B6*A                      00317  12670 00000  TABLE POINTER
00275            RJP  AZINTERP                  00320  65000 00343
00276            STR  Q*W(AZ1)                  00321  14030 00337  INTERP(1) WITH FIXED EL
00277 INTERP1    ENT  B6*B6+00                  00322  12606 00000  BUMP POINTER BY N
00300            RJP  AZINTERP                  00323  65000 00343
00301            STR  Q*W(AZ2)                  00324  14030 00340  INTERP(2) WITH FIXED EL
00302            RJP  ELINTERP                  00325  65000 00352  ANS IN Q
00303            EXIT                           00326  61010 00273
00304 SIZE       0                              00327  00000 00000  M,N
00305 ARGLOC     0                              00330  00000 00000  EL VECT,AZ VECT
00306 TBLLOC     0                              00331  00000 00000  0,TABLE LOC
00307 AZINC      0                              00332  00000 00000  AZBAR-AZ(J)
00310 AZDIF      0                              00333  00000 00000  AZ(J+1)-AZ(J)
00311 ELINC      0                              00334  00000 00000  ELBAR-EL(I)
00312 ELDIF      0                              00335  00000 00000  EL(I+1)-EL(I)
```

```
00313 IJ          0                                    00336  00000 00000  I,J
00314 AZ1         0                                    00337  00000 00000
00315 AZ2         0                                    00340  00000 00000
00316 ELDEG       0                                    00341  00000 00000
00317 AZDEG       0                                    00342  00000 00000
00320 AZINTERP    ENTRY                                00343  61000 00000
00321             ENT  Q*W(B6+1)                       00344  10036 00001  D(I,J+1)
00322             SUB  Q*W(B6)                         00345  27036 00000  D(I,J+1)-D(I,J)
00323             MUL  W(AZINC)                        00346  22030 00332  *(AZBAR-AZ(J))
00324             DIV  W(AZDIF)                        00347  23030 00333  /(AZ(J+1)-AZ(J))
00325             ADD  Q*W(B6)                         00350  26036 00000  +D(I,J)
00326             EXIT                                 00351  61010 00343
00327 ELINTERP    ENTRY                                00352  61000 00000
00330             ENT  Q*W(AZ2)                        00353  10030 00340
00331             SUB  Q*W(AZ1)                        00354  27030 00337  AZ(2)-AZ(1)
00332             MUL  W(ELINC)                        00355  22030 00334  *(ELBAR-EL(I))
00333             DIV  W(ELDIF)                        00356  23030 00335  /(EL(I+1)-EL(I))
00334             ADD  Q*W(AZ1)                        00357  26030 00337
00335             EXIT                                 00360  61010 00352
00336 GETINC      ENTRY                                00361  61000 00000
00337             STR  B5*L(S+3)                       00362  16510 00365
00340             ENT  B6*B6-2                         00363  12606 77775  DONT TEST LAST ARG
00341             RPT  B6+1*BACK                       00364  70206 00001
00342             ENT  Y-Q*W(00+B6)*ANEG               00365  31736 00000  X(I)-XBAR
00343             NO-OP                                00366  12000 00000  HERE IF OUTSIDE VECTOR
00344             STR  B7*L(S+1)                       00367  16710 00370  B7=I
00345             ENT  B5*B5+00                        00370  12505 00000
00346             ENT  Q*W(B5+1)                       00371  10035 00001
00347             SUB  Q*W(B5)                         00372  27035 00000  X(I+1)-X(I)
00350             EXIT                                 00373  61010 00361
00351 ELRANGE     ENTRY                                00374  61000 00000
00352             CL   L(FLAG)                         00375  16010 00404
00353             ENT  Q*W(QTREV)                      00376  10030 00414
00354             SUB  Q*W(CELEV)*QPOS                 00377  27630 63061  90-EL
00355             ADD  Q*W(QTREV)*SKIP                 00400  26130 00414  180-EL
00356             ENT  Q*W(CELEV)*SKIP                 00401  10130 63061
00357             CL   CPL(FLAG)                       00402  16050 00404
00360             EXIT                                 00403  61010 00374
00361 FLAG        0                                    00404  00000 00000  0 IF EL LTE 90
00362 STNTSUBC    0000026000                           00405  00000 26000  22.0B9
00363 STNRH0      0001750000                           00406  00017 50000  1000.0B9 1013.25 IS 1 ATM
00364 STNE        0000005000                           00407  00000 05000  5.0B9 FOR 10 DEG(C),40PERCENT(
                                                                           RH)
00365 KELVIN      0000421114                           00410  00004 21114  273.15B9
00366 K1          0011312000                           00411  00113 12000  4810.0B9
00367 K2          0000115463                           00412  00001 15463  77.6B9
00370 AREV        1000000000                           00413  10000 00000  1.0B27
00371 QTREV       0200000000                           00414  02000 00000  0.25B27
00372 YESISONE1   0                                    00415  00000 00000
00373 YESISONE2   0                                    00416  00000 00000
00374 TSUBC       0                                    00417  00000 00000  AT B9
00375 RH0         0                                    00420  00000 00000  AT B9
00376 E           0                                    00421  00000 00000  AT B9
00377 YESISONE8   0                                    00422  00000 00000
00400 YESISONE9   0                                    00423  00000 00000
00401 TSUBK       0                                    00424  00000 00000  AT B9
00402 NSUBS       0                                    00425  00000 00000  AT B9
00403             COMMENT   FOR A=40,B=2.7,C=4,D=42.5,E=.4
                  ,F=2.64
```

```
.   00404 REFRACSIZE    0000000042        00426  00000 00042  34B0 NUMBER OF ARGUMENTS
.   00405 REFRACARG     0000000000        00427  00000 00000  0.0B20
.   00406               0002000000        00430  00020 00000  0.5B20
.   00407               0004000000        00431  00040 00000  1.0B20
.   00410               0006000000        00432  00060 00000  1.5B20
.   00411               0010000000        00433  00100 00000  2.0B20
.   00412               0012000000        00434  00120 00000  2.5B20
.   00413               0014000000        00435  00140 00000  3.0B20
.   00414               0016000000        00436  00160 00000  3.5B20
.   00415               0020000000        00437  00200 00000  4.0B20
.   00416               0022000000        00440  00220 00000  4.5B20
.   00417               0024000000        00441  00240 00000  5B20
.   00420               0030000000        00442  00300 00000  6B20
.   00421               0034000000        00443  00340 00000  7B20
.   00422               0040000000        00444  00400 00000  8B20
.   00423               0044000000        00445  00440 00000  9B20
.   00424               0050000000        00446  00500 00000  10B20
.   00425               0060000000        00447  00600 00000  12B20
.   00426               0070000000        00450  00700 00000  14B20
.   00427               0100000000        00451  01000 00000  16B20
.   00430               0110000000        00452  01100 00000  18B20
.   00431               0120000000        00453  01200 00000  20B20
.   00432               0130000000        00454  01300 00000  22B20
.   00433               0140000000        00455  01400 00000  24B20
.   00434               0150000000        00456  01500 00000  26B20
.   00435               0160000000        00457  01600 00000  28B20
.   00436               0170000000        00460  01700 00000  30B20
.   00437               0214000000        00461  02140 00000  35B20
.   00440               0240000000        00462  02400 00000  40B20
.   00441               0264000000        00463  02640 00000  45B20
.   00442               0310000000        00464  03100 00000  50B20
.   00443               0360000000        00465  03600 00000  60B20
.   00444               0430000000        00466  04300 00000  70B20
.   00445               0500000000        00467  05000 00000  80B20
.   00446               0550000000        00470  05500 00000  90B20
.   00447 ATBL          0002417552        00471  00024 17552  .632670B20
.   00450               0001415200        00472  00014 15200  .381470B20
.   00451               0000665064        00473  00006 65064  .213429B20
.   00452               0000407207        00474  00004 07207  .128547B20
.   00453               0000247702        00475  00002 47702  .081973B20
.   00454               0000160024        00476  00001 60024  .054707B20
.   00455               0000115465        00477  00001 15465  .037893B20
.   00456               0000067340        00500  00000 67340  .027070B20
.   00457               0000050516        00501  00000 50516  .019850B20
.   00460               0000036367        00502  00000 36367  .014884B20
.   00461               0000027233        00503  00000 27233  .011379B20
.   00462               0000016231        00504  00000 16231  .006982B20
.   00463               0000011201        00505  00000 11201  .004518B20
.   00464               0000006200        00506  00000 06200  .003052B20
.   00465               0000004276        00507  00000 04276  .002135B20
.   00466               0000003114        00510  00000 03114  .001538B20
.   00467               0000001602        00511  00000 01602  .000857B20
.   00470               0000001032        00512  00000 01032  .000514B20
.   00471               0000000526        00513  00000 00526  .000327B20
.   00472               0000000344        00514  00000 00344  .000218B20
.   00473               0000000236        00515  00000 00236  .000151B20
.   00474               0000000160        00516  00000 00160  .000107B20
.   00475               0000000122        00517  00000 00122  .000079B20
.   00476               0000000075        00520  00000 00075  .000059B20
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00477                0000000057                00521  00000 00057  .000045B20
00500                0000000044                00522  00000 00044  .000035B20
00501                0000000024                00523  00000 00024  .000020B20
00502                0000000014                00524  00000 00014  .000012B20
00503                0000000007                00525  00000 00007  .000007B20
00504                0000000005                00526  00000 00005  .000005B20
00505                0000000003                00527  00000 00003  .000003B20
00506                0000000001                00530  00000 00001  .000001B20
00507                0000000000                00531  00000 00000  .0B20
00510                0000000000                00532  00000 00000  .0B20
00511 BTBL           0024206470                00533  00242 06470  .00494700B30
00512                0015560274                00534  00155 60274  .00334948
00513                0011257110                00535  00112 57110  .00228078
00514                0007102446                00536  00071 02446  .00174073
00515                0005566467                00537  00055 66467  .00139933B30
00516                0004614702                00540  00046 14702  .00116581
00517                0004052716                00541  00040 52716  .00099702
00520                0003440024                00542  00034 40024  .00086977
00521                0003120114                00543  00031 20114  .00077064B30
00522                0002651645                00544  00026 51645  .00069133
00523                0002441720                00545  00024 41720  .00062652
00524                0002121160                00546  00021 21160  .00052701
00525                0001670543                00547  00016 70543  .0004542B830
00526                0001504333                00550  00015 04333  .00039884
00527                0001350673                00551  00013 50673  .00035518
00530                0001236714                00552  00012 36714  .00031991
00531                0001056522                00553  00010 56522  .00026639830
00532                0000735352                00554  00007 35352  .00022767
00533                0000637673                00555  00006 37673  .00019830
00534                0000557355                00556  00005 57355  .00017522
00535                0000510263                00557  00005 10263  .00015657B30
00536                0000450006                00560  00004 50006  .00014115
00537                0000414612                00561  00004 14612  .00012816
00540                0000365346                00562  00003 65346  .00011704
00541                0000341167                00563  00003 41167  .00010740B30
00542                0000317374                00564  00003 17374  .00009894
00543                0000253141                00565  00002 53141  .00008163
00544                0000216714                00566  00002 16714  .00006B14
00545                0000167737                00567  00001 67737  .00005719B30
00546                0000144523                00570  00001 44523  .00004800
00547                0000105211                00571  00001 05211  .00003303
00550                0000053523                00572  00000 53523  .00002082
00551                0000025107                00573  00000 25107  .0000100B830
00552                0000000000                00574  00000 00000  .0
00553 REFRACTBL      RESERVE   34D             00575  00000 00000  IN DEGREES AT 820
00554 AZTBLSIZE      0000000005                00637  00000 00005  580 EL,AZ SIZE
00555                0000000005                00640  00000 00005  580
00556 AZTBLELARG     0000000000                00641  00000 00000  0B20
00557                0132000000                00642  01320 00000  22.5B20
00560                0264000000                00643  02640 00000  45B20
00561                0416000000                00644  04160 00000  67.5B20
00562                0550000000                00645  05500 00000  90B20
00563 AZTBLAZARG     0000000000                00646  00000 00000  0B20
00564                0550000000                00647  05500 00000  90B20
00565                1320000000                00650  13200 00000  180B20
00566                2070000000                00651  20700 00000  270B20
00567                2640000000                00652  26400 00000  360B20
00570 AZTBL          7777773524                00653  77777 73524  -.002117820
00571                7777773524                00654  77777 73524  -.002117B20
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.  00572                7777773524
.  00573                7777773524
.  00574                7777773524
.  00575                7777774472
.  00576                7777772571
.  00577                7777765522
.  00600                7777767424
.  00601                7777774472
.  00602                0000001734
.  00603                7777775313
.  00604                7777761113
.  00605                7777765535
.  00606                0000001734
.  00607                0000026074
.  00610                0000013127
.  00611                7777755461
.  00612                7777770426
.  00613                0000026074
.  00614                0000255222
.  00615                0000171353
.  00616                7777755341
.  00617                0000041206
.  00620                0000255222
.  00621 ELTBLSIZE      0000000005
.  00622                0000000005
.  00623 ELTBLELARG     0000000000
.  00624                0132000000
.  00625                0264000000
.  00626                0416000000
.  00627                0550000000
.  00630 ELTBLAZARG     0000000000
.  00631                0550000000
.  00632                1320000000
.  00633                2070000000
.  00634                2640000000
.  00635 ELTBL          0000027060
.  00636                0000016636
.  00637                0000021414
.  00640                0000031636
.  00641                0000027060
.  00642                0000037116
.  00643                0000026675
.  00644                0000031452
.  00645                0000041674
.  00646                0000037116
.  00647                0000066067
.  00650                0000055644
.  00651                0000060423
.  00652                0000070644
.  00653                0000066067
.  00654                0000130353
.  00655                0000120130
.  00656                0000122707
.  00657                0000133130
.  00660                0000130353
.  00661                0000200765
.  00662                0000170543
.  00663                0000173321
.  00664                0000203542

00655  77777 73524  -.002117B20
00656  77777 73524  -.002117B20
00657  77777 73524  -.002117B20
00660  77777 74472  -.001653B20
00661  77777 72571  -.002570B20
00662  77777 65522  -.005048B20
00663  77777 67424  -.004131B20
00664  77777 74472  -.001653B20
00665  00000 01734  .000943B20
00666  77777 75313  -.001271B20
00667  77777 61113  -.007252B20
00670  77777 65535  -.005038B20
00671  00000 01734  .000943B20
00672  00000 26074  .010800B20
00673  00000 13127  .005455B20
00674  77777 55461  -.008986B20
00675  77777 70426  -.003641B20
00676  00000 26074  .010800B20
00677  00002 55222  .084612B20
00700  00001 71353  .059307B20
00701  77777 55341  -.009062B20
00702  00000 41206  .016242B20
00703  00002 55222  .084612B20
00704  00000 00005  5B0 EL•AZ SIZE
00705  00000 00005  5B0
00706  00000 00000  0B20
00707  01320 00000  22.5B20
00710  02640 00000  45B20
00711  04160 00000  67.5B20
00712  05500 00000  90B20
00713  00000 00000  0B20
00714  05500 00000  90B20
00715  13200 00000  180B20
00716  20700 00000  270B20
00717  26400 00000  360B20
00720  00000 27060  .011277B20
00721  00000 16636  .007231B20
00722  00000 21414  .008557B20
00723  00000 31636  .012602B20
00724  00000 27060  .011277B20
00725  00000 37116  .015212B20
00726  00000 26675  .011167B20
00727  00000 31452  .012492B20
00730  00000 41674  .016537B20
00731  00000 37116  .015212B20
00732  00000 66067  .026420B20
00733  00000 55644  .022374B20
00734  00000 60423  .023700B20
00735  00000 70644  .027745B20
00736  00000 66067  .026420B20
00737  00001 30353  .043193B20
00740  00001 20130  .039147B20
00741  00001 22707  .040473B20
00742  00001 33130  .044518B20
00743  00001 30353  .043193B20
00744  00002 00765  .062978B20
00745  00001 70543  .058933B20
00746  00001 73321  .060258B20
00747  00002 03542  .064303B20
```

```
.  00665                0000200765                                  00750  00002 00765  .062978B20
.  00666 TOUT1          FD   0*A                                    00751  06000 00000
.  00667                -0   $+1                                    00752  77777 00753
.  00670                FD   0*INCLUDE REFRACTION TABLE(Y OR N)      00753  16231 02132
                                                                    00754  11120 52712
                                                                    00755  13270 61031
                                                                    00756  16242 30531
                                                                    00757  06072 11251
                                                                    00760  36052 42705
                                                                    00761  23400 00000
.  00671                -0                                          00762  77777 77777
.  00672 TIN1           FD   0*Y                                    00763  36000 00000
.  00673                1    YESISONE1                              00764  00001 00415
.  00674 TOUT2          FD   0*A                                    00765  06000 00000
.  00675                -0   $+1                                    00766  77777 00767
.  00676                FD   0*USE STANDARD VALUES(Y OR N)          00767  32301 20530
                                                                    00770  31062 31106
                                                                    00771  27110 53306
                                                                    00772  21321 23051
                                                                    00773  36052 42705
                                                                    00774  23400 00000
.  00677                -0                                          00775  77777 77777
.  00700 TIN2           FD   0*Y                                    00776  36000 00000
.  00701                1    YESISONE2                              00777  00001 00416
.  00702 TOUT3          FD   0*A                                    01000  06000 00000
.  00703                -0   $+1                                    01001  77777 01002
.  00704                FD   0*ENTER TEMP IN DEG C                  01002  12233 11227
                                                                    01003  05311 22225
                                                                    01004  05162 30511
                                                                    01005  12140 51000
.  00705                -0                                          01006  77777 77777
.  00706 TIN3           FD   0*X9                                   01007  35710 00000
.  00707                11   TSUBC                                  01010  00011 00417
.  00710                7777741777                                  01011  77777 41777  -30.0B9
.  00711                0000074000                                  01012  00000 74000  60.0B9
.  00712 TOUT4          FD   0*A                                    01013  06000 00000
.  00713                -0   $+1                                    01014  77777 01015
.  00714                FD   0*ENTER ATM PRESSURE IN MB             01015  12233 11227
                                                                    01016  05063 12205
                                                                    01017  25271 23030
                                                                    01020  32271 20516
                                                                    01021  23052 20700
.  00715                -0                                          01022  77777 77777
.  00716 TIN4           FD   0*X9                                   01023  35710 00000
.  00717                11   RH0                                    01024  00011 00420
.  00720                0001604000                                  01025  00016 04000  900.0B9
.  00721                0002114000                                  01026  00021 14000  1100.0B9
.  00722 TOUT5          FD   0*A                                    01027  06000 00000
.  00723                -0   $+1                                    01030  77777 01031
.  00724                FD   0*ENTER PARTIAL PRESSURE IN MB         01031  12233 11227
                                                                    01032  05250 62731
                                                                    01033  16062 10525
                                                                    01034  27123 03032
                                                                    01035  27120 51623
                                                                    01036  05220 70000
.  00725                -0                                          01037  77777 77777
.  00726 TIN5           FD   0*X9                                   01040  35710 00000
.  00727                11   E                                      01041  00011 00421
.  00730                0000000000                                  01042  00000 00000  0.0B9
```

```
00731                0000226000                          01043  00002 26000  150.0B9
00732 TOUT6          FD    0*A                           01044  06000 00000
00733                -0    $+1                           01045  77777 01046
00734                FD    0*INCLUDE AZ TABLE(Y OR N)     01046  16231 02132
                                                         01047  11120 50637
                                                         01050  05310 60721
                                                         01051  12513 60524
                                                         01052  27052 34000
00735                -0                                  01053  77777 77777
00736 TIN6           FD    0*Y                           01054  36000 00000
00737                1     YESISONE6                     01055  00001 00422
00740 TOUT9          FD    0*A                           01056  06000 00000
00741                -0    $+1                           01057  77777 01060
00742                FD    0*INCLUDE EL TABLE(Y OR N)     01060  16231 02132
                                                         01061  11120 51221
                                                         01062  05310 60721
                                                         01063  12513 60524
                                                         01064  27052 34000
00743                -0                                  01065  77777 77777
00744 TIN9           FD    0*Y                           01066  36000 00000
00745                1     YESISONE9                     01067  00001 00423
00746 PCSPIN1        FD    1*X19                         01070  35617 10505
00747                10    AZBIAS                        01071  00010 01100
00750                7773777777                          01072  77737 77777  -2.0B19
00751                0004000000                          01073  00040 00000  2.0
00752 PCSPIN2        FD    1*X19                         01074  35617 10505
00753                10    ELBIAS                        01075  00010 01101
00754                7773777777                          01076  77737 77777  -2.0B19
00755                0004000000                          01077  00040 00000  2.0
00756 AZBIAS         0                                   01100  00000 00000  DEG B19
00757 ELBIAS         0                                   01101  00000 00000  DEG B19
00760 AZBIASREV      0                                   01102  00000 00000  REVS B27
00761 ELBIASREV      0                                   01103  00000 00000  REVS B27
00762 PCSPOUT1       FD    1*A                           01104  06050 50505
00763                0     PCMSGOUT1                     01105  00000 01112
00764                FD    1*X3B19                       01106  35630 76171
00765                0     AZBIAS                        01107  00000 01100
00766                FD    1*A                           01110  06050 50505
00767                -0    PCMSGOUT1A                    01111  77777 01115
00770 PCMSGOUT1      FD    2*AZ BIAS =                   01112  06370 50716
                                                         01113  06300 54405
00771                -0                                  01114  77777 77777
00772 PCMSGOUT1A     FD    2*CHANGE TO                   01115  10150 62314
                                                         01116  12053 12405
00773                -0                                  01117  77777 77777
00774 PCMSGOUT2      FD    2*EL BIAS =                   01120  12210 50716
                                                         01121  06300 54405
00775                -0                                  01122  77777 77777
00776 PCSPOUT2       FD    1*A                           01123  06050 50505
00777                0     PCMSGOUT2                     01124  00000 01120
01000                FD    1*X3B19                       01125  35630 76171
01001                0     ELBIAS                        01126  00000 01101
01002                FD    1*A                           01127  06050 50505
01003                -0    PCMSGOUT1A                    01130  77777 01115
01004 COSELEV        2000000000                          01131  20000 00000  1.0B28
01005 MAXAZBIAS      0020000000                          01132  00200 00000  1/32 REV B27
01006 TWOPI          3110375524                          01133  31103 75524  6.28318531B26
01007 COS            JP    COS                           01134  61000 01134  ARBITRARY
01010                ENT   B7*L(COS)                     01135  12710 01134  STORE EXIT
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.  01011              STR  B7*L(SIN)              01136  16710 01145
.  01012              ENT  B7*1                   01137  12700 00001  FLAG
.  01013              STR  B7*L(SIN+42D)          01140  16710 01217
.  01014              JP   COS+7*APOS             01141  60600 01143
.  01015              CP   A                      01142  15040 00000
.  01016              JP   SIN+2*ANOT             01143  60500 01147
.  01017              ENT  A*W(SIN+60D)           01144  11030 01241  COS (0) 1
.  01020 SIN          JP   SIN                    01145  61000 01145  ARBITRARY
.  01021              STR  B0*L(SIN+42D)          01146  16010 01217  FLAG
.  01022              STR  A*W(SIN+68D)*APOS      01147  15630 01251
.  01023              CP   A                      01150  15040 00000  SET POSITIVE
.  01024              RPT  29D                    01151  70000 00035
.  01025              LSH  A*1*ANEG               01152  06700 00001  SHIFT UNTIL BIT 29 1
.  01026              JP   L(SIN)                 01153  61010 01145  SIN(X) 0
.  01027              LSH  A*29D                  01154  06000 00035  SHIFT RIGHT 1
.  01030              SUB  Q*B7*QPOS              01155  27607 00000  QNEG IMPLIES X EXCEEDS PI/2

.  01031              JP   SIN+34D                01156  61000 01207
.  01032              COM  Q*30D*YMORE            01157  04300 00036  PREVENT ILLEGITIMATE SHIFT
.  01033              ENT  Q*30D                  01160  10000 00036  MAX SHIFT 30
.  01034              STR  Q*L(SIN+13D)           01161  14010 01162  SOTRE SHIFT COUNT
.  01035              RSH  A*0                    01162  02000 00000  SCALE ARGUMENT AT 28
.  01036              COM  A*W(SIN+59D)*YMORE     01163  04730 01240  COMPARE WITH PI/2
.  01037              JP   SIN+37D                01164  61000 01212  REDUCE TO 1ST QUADRANT
.  01040              BSK  B0*L(SIN+42D)          01165  71010 01217  SKIP IF SINE
.  01041              SUB  A*W(SIN+59D)*SKIP      01166  21130 01240  PI/2-X TO A
.  01042              ENT  Q*W(SIN+68D)*QPOS      01167  10230 01251  CHECK SIGN
.  01043              CP   A                      01170  15040 00000  A BEARS PROPER SIGN
.  01044              STR  A*W(SIN+68D)           01171  15030 01251  STORE SIGNED ARGUMENT
.  01045              ENT  Q*A                    01172  10070 00000  SCALED AT 28
.  01046              MUL  W(SIN+68D)             01173  22030 01251  X 2 AT 28+28 56
.  01047              RSH  AQ*29D                 01174  03000 00035  SQUARED AT 27
.  01050              STR  Q*W(SIN+69D)           01175  14030 01252  STORE X 2
.  01051              ENT  Q*W(SIN+64D)           01176  10030 01245  C9
.  01052              ENT  B7*3                   01177  12700 00003  LOOP 4 TIMES
.  01053              MUL  W(SIN+69D)             01200  22030 01252  SUM POLYNOMIAL
.  01054              ENT  Q*A                    01201  10070 00000
.  01055              ADD  Q*W(SIN+60D+B7)        01202  26037 01241
.  01056              BJP  B7*SIN+27D             01203  72700 01200
.  01057              MUL  W(SIN+68D)             01204  22030 01251
.  01060              LSH  AQ*2                   01205  07000 00002  SCALE AT 28
.  01061              JP   L(SIN)                 01206  61010 01145  RETURN
.  01062              COM  Q*X77741*YLESS         01207  04240 77741  CHECK FOR LEGIT SHIFT
.  01063              ENT  Q*X77741               01210  10040 77741  -30
.  01064              STR  Q*CPL(SIN+13D)         01211  14050 01162
.  01065              RSH  AQ*2                   01212  03000 00002
.  01066              DIV  W(SIN+59D)             01213  23030 01240  FORM X/(PI/2)
.  01067              ENT  A*0                    01214  11000 00000  CLEAR A
.  01070              LSH  AQ*L(SIN+13D)          01215  07010 01162
.  01071              LSH  AQ*2                   01216  07000 00002  INTEGER TO A, FRACTION IN Q

.  01072              ADD  A*0                    01217  20000 00000  0 FOR SIN , 1 FOR COS
.  01073              RSH  AQ*2                   01220  03000 00002
.  01074              ENT  LP*W(SIN+67D)*ANOT     01221  40530 01250
.  01075              ENT  LP*W(SIN+60D)*ANOT     01222  40530 01241
.  01076              JP   SIN+51D                01223  61000 01230
.  01077              SUB  LP*W(SIN+66D)          01224  42030 01247
.  01100              ENT  Q*W(SIN+68D)*QPOS      01225  10230 01251  ACCORD SIGN
.  01101              CP   A                      01226  15040 00000
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.   01102      JP    L(SIN)                01227  61010 01145
.   01103      ENT   LP*W(SIN+65D)*ODD     01230  40330 01246
.   01104      JP    SIN+56D               01231  61000 01235
.   01105      14200      0                01232  14200 00000  CP,Q,QPOS
.   01106      SUB   Q*W(SIN+66D)*SKIP     01233  27130 01247
.   01107      ADD   Q*W(SIN+66D)          01234  26030 01247
.   01110      MUL   W(SIN+59D)            01235  22030 01240
.   01111      LSH   AQ*2                  01236  07000 00002  SCALE AT 28
.   01112      JP    SIN+18D               01237  61000 01167  RETURN
.   01113      31103      75524            01240  31103 75524  PI/2 AT 28
.   01114      20000      00000            01241  20000 00000  C1 1*0 AT 28
.   01115      52525      25600            01242  52525 25600  C3-0*1666  665669E00B31
.   01116      10420      71732            01243  10420 71732  C5 0.833302518E-2B34
.   01117      76301      15701            01244  76301 15701  C7-.1980741431E-3B37
.   01120      00127      23405            01245  00127 23405  C9 0.2601886909E-5B40
.   01121      60000      00000            01246  60000 00000
.   01122      40000      00000            01247  40000 00000
.   01123      17777      77777            01250  17777 77777
.   01124      0     0                     01251  00000 00000  TEMPORARY
.   01125      0     0                     01252  00000 00000  TEMPORARY
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LABEL	LOC	LABEL	LOC	LABEL	LOC
ACQAZIM	63071	ACQELEV	63075	ACQUI	63427
ACTUALTIME	63142	ADSCN	63416	AEBOXLINES	63507
AESCN	63417	ALNGOFFSET	63517	ALNGACRSCN	63506
ARCOFAZIM	63524	ARCOFDEC	63526	ARCOFELEV	63522
ARCOFRA	63530	AREV	00413	ARGLOC	00330
ASTRODEC	63106	ASTRORA	63105	ATBL	00471
AUPEREQUAT	63341	AUTOSWITCH	63025	AUTOT	63437
AZ1	00337	AZ2	00340	AZBIAS	01100
AZBIASREV	01102	AZDEG	00342	AZDIF	00333
AZDIFS	63120	AZELOTIME	63532	AZELBXSCAN	63500
AZELIND	63162	AZELIND$	63162	AZELINTRP	00206
AZIM	63053	AZIMOFFSET	63512	AZIMOUT	64000
AZIMOVER	63325	AZIMADD	63442	AZIMERROR$	63027
AZIMIN	75000	AZINC	00332	AZINTERP	00343
AZINTRP	00220	AZMTHSCAN	63501	AZTBL	00653
AZTBLAZARG	00646	AZTBLELARG	00641	AZTBLSIZE	00637
AZTRACKERR	63022	BODYSIZE	63462	BLASTOFF	63146
BTBL	00533	COCON	63414	CONVERTIME	63135
COR1	00037	COR1A	00016	COR2	00045
COR3	00057	COR4	00071	CORCT	63420
CORCTINIT	00002	CORCTWORK	00116	CORCTX	00000
COS	01134	COSORIENT	63065	COSAZEL	63070
COSELEV	01131	CAZIM	63060	CELBODY	63113
CELCOMPGM	63424	CELEV	63061	CELTIME	63133
CHCOR	63422	CHPAR	63431	CRANGE	63057
CRSSOFFSET	63516	DONE	00115	DOPFREQ$	63166
DOPPOUT	66000	DOPPADD	63444	DOPPL	63164
DOPPLER$	63165	DOPSWITCH$	63163	DATANALYZE	63425
DAY	63150	DEC	63003	DECOFFSET	63515
DECDOT	63010	DECLINSCAN	63505	DELTATEE	63316
DRIFTAZIM$	63534	DRIFTELEV$	63535	DRIFTSCAN$	63533
DSECONDS	63141	DUMSECTTG	63154	DYDMP	63421
E	00421	ELBIAS	01101	ELBIASREV	01103
ELDEG	00341	ELDIF	00335	ELDIFS	63121
ELEV	63054	ELEVOFFSET	63513	ELEVOUT	65000
ELEVADD	63443	ELEVERROR$	63030	ELEVIN	76000
ELINC	00334	ELINTERP	00352	ELINTRP	00246
ELRANGE	00374	ELTBL	00720	ELTBLAZARG	00713
ELTBLELARG	00706	ELTBLSIZE	00704	ELTRACKERR	63023
ELVTNSCAN	63502	EQUATOR	63323	ESTSHIFTED	63143
EXPNAME	63350	FIRSTELEV	63104	FIRSTHRU	63153
FLAG	00404	FLATTENING	63337	FRAMESIZE	63101
FREQUENCY	63317	GEOCENLAT	63322	GEODETLAT	63321
GETINC	00361	GMTMODU24	63145	GMTSHIFTED	63144
HOLDNOHOLD	63511	HOURMINUTE	63137	HOURREG	63151
HEIGHT	63326	ID10RADIO	66777	ID11RADIO	67776
ID12RADIO	67777	ID13RADIO	70775	ID14RADIO	70776
ID15RADIO	71776	ID16RADIO	71777	ID17RADIO	72776
ID18RADIO	72777	ID19RADIO	73776	ID1CELCOR	63000
ID1ENTPNT	63410	ID1RADCOR	63050	ID1RADIO	63440
ID1RECRD	63210	ID1SYSENT	77576	ID1SYSNAM	77676
ID1SYSPAR	63310	ID1TIME	63130	ID20RADIO	73777
ID21RADIO	74776	ID22RADIO	74777	ID23RADIO	75776

ID24RADIO	75777	ID25RADIO	76775	ID26RADIO	76776
ID2CELCOR	63001	ID2ENTPNT	63411	ID2RADCOR	63051
ID2RADIO	63441	ID2RECRD	63211	ID2SYSENT	77577
ID2SYSNAM	77677	ID2SYSPAR	63311	ID2TIME	63131
ID3RADIO	63776	ID4RADIO	63777	ID5RADIO	64776
ID6RADIO	64777	ID7RADIO	65776	ID8RADIO	65777
ID9RADIO	66776	IJ	00336	INAZIMADD	63446
INELEVADD	63447	INTER	63413	INTERAZIM	72000
INTERCOM	63426	INTERDOPP	74000	INTERELEV	73000
INTERLCKSW	63460	INTERP	00273	INTERP1	00322
INTERRANGE	76777	K1	00411	K2	00412
KELVIN	00410	KMPERNM	63342	KYBRDLEVEL	63110
KYBRDSPEC1	63344	KYBRDSPEC2	63345	KYBRDSPEC3	63346
KYBRDSPEC4	63347	LONGITUDE	63320	LINECOUNT$	63127
LSPERAU	63336	MOONSW$	63343	MODESWITCH	63024
MAINSWITCH	63334	MAXAZBIAS	01132	MCPFILLER	71000
MCPGM	63412	MILLSTNADD	63451	MINREG	63152
MSFREQ	63332	NMPERAU	63340	NSUBS	00425
POLE	63324	PCMSGOUT1	01112	PCMSGOUT1A	01115
PCMSGOUT2	01120	PCSPOUT1	01104	PCSPOUT2	01123
PCSPIN1	01070	PCSPIN2	01074	PERIODAZIM	63523
PERIODDEC	63525	PERIODELEV	63521	PERIODRA	63527
PLOTAZIM$$	63020	PLOTELEV$$	63021	PLOTP	63436
PLANP	63434	PREVIOUSTM	63461	PRINRECSW	63160
PRLOG	63423	QTREV	00414	RA	63002
RAOFFSET	63514	RADOT	63007	RADARMODE	63312
RADC8XSCAN	63503	RADECOTIME	63531	RADIODEC	63541
RADIOMETER	63102	RADIORA	63540	RADINDIC	63157
RADIUS	63006	RADIUSDOT	63011	RANGE	63052
RANGEOUT	70777	RANGEADD	63445	RANGEDOT	63062
RASCTNSCAN	63504	RDOTDIFS	63123	RDBOXLINES	63510
RDIFS	63122	RDMTR	63430	RDXXX	63433
RECORDSIZE	63112	RECAZIM	67000	RECELEV	70000
RECFILE	63212	RECRD	63415	RECRDSWTCH	63155
REFRACARG	00427	REFRACCOR$	63031	REFRACIND	63161
REFRACIND$	63161	REFRACSIZE	00426	REFRACTBL	00575
RELEASESW	63156	RHO	00420	SAZIM	63055
SCELTIME	63134	SDEC	63005	SECONDS	63140
SELEV	63056	SIDERTIME	63012	SIN	01145
SINORIENT	63064	SINAZEL	63066	SIZE	00327
SKIP	63331	SLAVE	63126	SLAVEOPTS	63124
SLAVEMODES	63125	SRA	63004	SRADTIME	63136
STNE	00407	STNRHO	00406	STNTSUBC	00405
SYNCAINBCW	63543	SYNCAZBCW$	63545	SYNCEINBCW	63544
SYNCELBCW$	63546	SYNCTIMING	63542	SYSCOMREG1	63452
SYSCOMREG2	63453	SYSCOMREG3	63454	SYSCOMREG4	63455
SYSCOMREG5	63456	SYSCOMREG6	63457	SYSENTRIES	77600
SYSNAMES	77700	SYSTAT1	63313	SYSTAT2	63314
SYSTATD	63315	TOUT1	00751	TOUT2	00765
TOUT3	01000	TOUT4	01013	TOUT5	01027
TOUT6	01044	TOUT9	01056	TBLLOC	00331
TIMECORR	63107	TIMEMODE	63103	TIMEP	63435
TIMETOHOLD	63520	TIN1	00763	TIN2	00776
TIN3	01007	TIN4	01023	TIN5	01040
TIN6	01054	TIN9	01066	TRACKINDIC	63026
TRUERANGE	63063	TRUETIME	63132	TSUBC	00417
TSUBK	00424	TTYSTATUS	63111	TWOPI	01133
TWOSECDOP	63017	VELOFLIGHT	63335	VIZDEC1	63014
VIZDEC2	63016	VIZRA1	63013	VIZRA2	63015

WORKEXIT	00272	WFORD	63432	WFADD	63450
WFFREQ	63333	YEARMONTH	63147	YESISONE1	00415
YESISONE2	00416	YESISONE6	00422	YESISONE9	00423
YRTRAN	63327	ZRTRAN	63330		

SPURT OUTPUT NO. 112

CORCT CLARK+PC*27JUN66

LABEL	LOC	LABEL	LOC	LABEL	LOC
CORCTX	00000	CORCTINIT	00002	COR1A	00016
COR1	00037	COR2	00045	COR3	00057
COR4	00071	DONE	00115	CORCTWORK	00116
AZELINTRP	00206	AZINTRP	00220	ELINTRP	00246
WORKEXIT	00272	INTERP	00273	INTERP1	00322
SIZE	00327	ARGLOC	00330	TBLLOC	00331
AZINC	00332	AZDIF	00333	ELINC	00334
ELDIF	00335	IJ	00336	AZ1	00337
AZ2	00340	ELDEG	00341	AZDEG	00342
AZINTERP	00343	ELINTERP	00352	GETINC	00361
ELRANGE	00374	FLAG	00404	STNTSUBC	00405
STNRHO	00406	STNE	00407	KELVIN	00410
K1	00411	K2	00412	AREV	00413
QTREV	00414	YESISONE1	00415	YESISONE2	00416
TSUBC	00417	RHO	00420	E	00421
YESISONE6	00422	YESISONE9	00423	TSUBK	00424
NSUBS	00425	REFRACSIZE	00426	REFRACARG	00427
ATBL	00471	BTBL	00533	REFRACTBL	00575
AZTBLSIZE	00637	AZTBLELARG	00641	AZTBLAZARG	00646
AZTBL	00653	ELTBLSIZE	00704	ELTBLELARG	00706
ELTBLAZARG	00713	ELTBL	00720	TOUT1	00751
TIN1	00763	TOUT2	00765	TIN2	00776
TOUT3	01000	TIN3	01007	TOUT4	01013
TIN4	01023	TOUT5	01027	TIN5	01040
TOUT6	01044	TIN6	01054	TOUT9	01056
TIN9	01066	PCSPIN1	01070	PCSPIN2	01074
AZBIAS	01100	ELBIAS	01101	AZBIASREV	01102
ELBIASREV	01103	PCSPOUT1	01104	PCMSGOUT1	01112
PCMSGOUT1A	01115	PCMSGOUT2	01120	PCSPOUT2	01123
COSELEV	01131	MAXAZBIAS	01132	TWOPI	01133
COS	01134	SIN	01145	ID1CELCOR	63000
ID2CELCOR	63001	RA	63002	DEC	63003
SRA	63004	SDEC	63005	RADIUS	63006
RADOT	63007	DECDOT	63010	RADIUSDOT	63011
SIDERTIME	63012	VIZRA1	63013	VIZDEC1	63014
VIZRA2	63015	VIZDEC2	63016	TWOSECDOP	63017
PLOTAZIM$$	63020	PLOTELEV$$	63021	AZTRACKERR	63022
ELTRACKERR	63023	MODESWITCH	63024	AUTOSWITCH	63025
TRACKINDIC	63026	AZIMERROR$	63027	ELEVERROR$	63030
REFRACCOR$	63031	ID1RADCOR	63050	ID2RADCOR	63051
RANGE	63052	AZIM	63053	ELEV	63054
SAZIM	63055	SELEV	63056	CRANGE	63057
CAZIM	63060	CELEV	63061	RANGEDOT	63062
TRUERANGE	63063	SINORIENT	63064	COSORIENT	63065
SINAZEL	63066	COSAZEL	63070	ACQAZIM	63071
ACQELEV	63075	FRAMESIZE	63101	RADIOMETER	63102
TIMEMODE	63103	FIRSTELEV	63104	ASTRORA	63105
ASTRODEC	63106	TIMECORR	63107	KYBRDLEVEL	63110
TTYSTATUS	63111	RECORDSIZE	63112	CELBODY	63113
AZDIFS	63120	ELDIFS	63121	RDIFS	63122
RDOTDIFS	63123	SLAVEOPTS	63124	SLAVEMODES	63125
SLAVE	63126	LINECOUNT$	63127	ID1TIME	63130

ID2TIME	63131	TRUETIME	63132	CELTIME	63133
SCELTIME	63134	CONVERTIME	63135	SRADTIME	63136
HOURMINUTE	63137	SECONDS	63140	DSECONDS	63141
ACTUALTIME	63142	ESTSHIFTED	63143	GMTSHIFTED	63144
GMTMOD24	63145	BLASTOFF	63146	YEARMONTH	63147
DAY	63150	HOURREG	63151	MINREG	63152
FIRSTHRU	63153	DUMSECTTG	63154	RECRDSWTCH	63155
RELEASESW	63156	RADINDIC	63157	PRINRECSW	63160
REFRACIND$	63161	REFRACIND	63161	AZELIND	63162
AZELIND$	63162	DOPSWITCH$	63163	DOPPL	63164
DOPPLER$	63165	DOPFREQ$	63166	ID1RECRD	63210
ID2RECRD	63211	RECFILE	63212	ID1SYSPAR	63310
ID2SYSPAR	63311	RADARMODE	63312	SYSTAT1	63313
SYSTAT2	63314	SYSTATD	63315	DELTATEE	63316
FREQUENCY	63317	LONGITUDE	63320	GEODETLAT	63321
GEOCENLAT	63322	EQUATOR	63323	POLE	63324
AZIMOVER	63325	HEIGHT	63326	YRTRAN	63327
ZRTRAN	63330	SKIP	63331	MSFREQ	63332
WFFREQ	63333	MAINSWITCH	63334	VELOFLIGHT	63335
LSPERAU	63336	FLATTENING	63337	NMPERAU	63340
AUPEREQUAT	63341	KMPERNM	63342	MOONSW$	63343
KYBRDSPEC1	63344	KYBRDSPEC2	63345	KYBRDSPEC3	63346
KYBRDSPEC4	63347	EXPNAME	63350	ID1ENTPNT	63410
ID2ENTPNT	63411	MCPGM	63412	INTER	63413
COCON	63414	RECRD	63415	ADSCN	63416
AESCN	63417	CORCT	63420	DYDMP	63421
CHCOR	63422	PRLOG	63423	CELCOMPGM	63424
DATANALYZE	63425	INTERCOM	63426	ACQUI	63427
RDMTR	63430	CHPAR	63431	WFORD	63432
RDXXX	63433	PLANP	63434	TIMEP	63435
PLOTP	63436	AUTOT	63437	ID1RADIO	63440
ID2RADIO	63441	AZIMADD	63442	ELEVADD	63443
DOPPADD	63444	RANGEADD	63445	INAZIMADD	63446
INELEVADD	63447	WFADD	63450	MILLSTNADD	63451
SYSCOMREG1	63452	SYSCOMREG2	63453	SYSCOMREG3	63454
SYSCOMREG4	63455	SYSCOMREG5	63456	SYSCOMREG6	63457
INTERLCKSW	63460	PREVIOUSTM	63461	BODYSIZE	63462
AZELBXSCAN	63500	AZMTHSCAN	63501	ELVTNSCAN	63502
RADCBXSCAN	63503	RASCTNSCAN	63504	DECLINSCAN	63505
ALNGACRSCN	63506	AEBOXLINES	63507	RDBOXLINES	63510
HOLDNOHOLD	63511	AZIMOFFSET	63512	ELEVOFFSET	63513
RAOFFSET	63514	DECOFFSET	63515	CRSSOFFSET	63516
ALNGOFFSET	63517	TIMETOHOLD	63520	PERIODELEV	63521
ARCOFELEV	63522	PERIODAZIM	63523	ARCOFAZIM	63524
PERIODDEC	63525	ARCOFDEC	63526	PERIODRA	63527
ARCOFRA	63530	RADECOTIME	63531	AZELOTIME	63532
DRIFTSCAN$	63533	DRIFTAZIM$	63534	DRIFTELEV$	63535
RADIORA	63540	RADIODEC	63541	SYNCTIMING	63542
SYNCAINBCW	63543	SYNCEINBCW	63544	SYNCAZBCW$	63545
SYNCELBCW$	63546	ID3RADIO	63776	ID4RADIO	63777
AZIMOUT	64000	ID5RADIO	64776	ID6RADIO	64777
ELEVOUT	65000	ID7RADIO	65776	ID8RADIO	65777
DOPPOUT	66000	ID9RADIO	66776	ID10RADIO	66777
RECAZIM	67000	ID11RADIO	67776	ID12RADIO	67777
RECELEV	70000	ID13RADIO	70775	ID14RADIO	70776
RANGEOUT	70777	MCPFILLER	71000	ID15RADIO	71776
ID16RADIO	71777	INTERAZIM	72000	ID17RADIO	72776
ID18RADIO	72777	INTERELEV	73000	ID19RADIO	73776
ID20RADIO	73777	INTERDOPP	74000	ID21RADIO	74776

ID22RADIO	74777	AZIMIN	75000	ID23RADIO	75776
ID24RADIO	75777	ELEVIN	76000	ID25RADIO	76775
ID26RADIO	76776	INTERRANGE	76777	ID1SYSENT	77576
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13. ABSTRACT

In the Haystack Pointing system, errors caused by atmospheric refraction, gravitational deformation of the antenna, skewed axes and resolver error are compensated for by a correction program in the computer which adds the necessary biases to the geometric values of azimuth and elevation to produce an effectively correct aiming of the antenna.

14. KEY WORDS
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