The Interferometer Fringe Reduction Program -- Version II

B. G. Clark and C. M. Wade

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I. PRINCIPLES OF OPERATION

The mathmatical principles upon which the reduction lies are developed in References 1 and 2 and will not be discussed further here. The particular variant used is the least squares fitting of a sine wave plus a constant, developed in the latter half of Reference 2.

1. Explanation of the Print-Out

a) The heading information for the baseline. This lists the baseline constants h, B_1, B_2, B_3 used for the reduction and the baseline number as well as tape number and date. It also lists the Bessel day numbers used for precessing the source table and the source table data card.

b) The heading for each source. This lists the apparent position of the source, precessed to the hour of observation, the Julian day number of the day upon which the source crosses the meridian, the local oscillator frequency, which is extended in the standard identification data (SID) block by means of manually set switches, and the scan number. The differences between the antenna pointing and the true source position are calculated and printed out under the title "pointing corrections." The coordinate encoders for antenna 1 are not connected, as of this writing, so the pointing corrections for antenna 1 are not correct.

c) The data print-out. There are 13 columns of data printed out for each minute's observation, as follows:

(i) Source number is automatically prefaced with a 3C as most, but not all, of our sources appear in the 3C catalogue. They appear to 1 decimal place.

(ii) N is a running integer number for convenience in plotting. It is the number of minutes after the source appeared at 6^h east hour angle.

(iii) Hour angle = apparent sidereal time - apparent right ascension

(iv) Apparent sidereal time

(v) The amplitude of the least squares sine wave fitted to the data, in units of the number of pulses per tenth second received from the voltage to frequency converter.

(vi) The phase of this least squares sine wave, in degrees, taken to lie between -180 and 180°. The phase is so defined that of two sources, the one with the most positive phase is nearer the northeast pole of the interferometer.

(vii) The fringe frequency in cycles/second

(viii and ix) The parameters describing the location in the spacial frequency plane. The units are wavelengths, u is the effective baseline length in the right ascension direction and v is the effective baseline length in the declination direction.

(x) The RMS deviation of the 600 points from the fitted sine wave, in counts per tenth second.

(xi) The constant component determined in the fitting of a sine wave plus constant.

(xii and xiii) The ALC feed-back voltages averaged over the minute. Mainly of engineering interest.

d) Error messages

(i) "B1 = ..., B2 = ..., is not consistent with IB = ..." An error was made in punching the baseline constants or baseline number in the card input. Exit is called.

(ii) "Date later than 30 June 1967" probably means that the date was punched in the wrong columns in the input card. Exit is called.

(iii) "Tape and card dates disagree." This is followed by the Julian day of the card and tape dates. The program will ignore a one day difference. Three such messages result in a call to Exit, unless Sense Switch 2 is depressed.

(iv) "Source not in table." The machine was unable to match the recorded antenna positions with the source table positions. It then proceeds forward until it encounters the ending SID block, and tries again. If it can identify the source from this block, it proceeds to reduce the data; if not, it is lost.

(v) "Tilt, antenna 1 moved ... and antenna 2 moved ... minutes of arc" occurs if the ending SID positions disagree with the beginning SID positions by more than 1!5.

(vi) "Reduction repeated." The ending SID time differed from that predicted by the beginning SID. The beginning time was changed to fit the second SID and the reduction was repeated, resulting in two sets of cards for this block of data.

(vii) "Ending SID missing." A beginning SID record was encountered directly after a data record, with no ending SID between.

(viii) "Beginning SID does not appear where expected." The record after a second SID was not a beginning SID. The machine scans ahead to the next SID. If it is an ending SID, its identification data are used to reduce the intervening data. If it is a beginning SID, the data are lost.

(ix) "Second SID disagrees with first. Cannot re-reduce." The record number in the ending SID is unbelievably large, so the data are not re-reduced, although the time in the ending SID is not that predicted by the beginning SID.

(x) "I-O check. Return to execution." An I-O check is probably a machine error, though it is possible that the tape may contribute to the condition.

(xi) "...Word record encountered and ignored." Standard data records are 601 words long. Shorter records are discarded with this message. If the record is more than 12 words long, the machine checks to see if it is an SID record before discarding it.

(xii) "Record of length exceeding 601 words. Excess words ignored."

e) The card output. The card deck punched by the program is headed by four cards, the first of which contains the tape number and baseline parameters, the second contains the clock error, and the third contains the last six digits of the Julian day. The fourth card carries two precession constants and four Bessel day numbers (M,N,A,B,C,D) in radians. Then comes the source table, which consists of cards containing source number, and the apparent RA and declination in radians. The source table is terminated with a blank card and is followed with data cards punched with the source number, H.A., Amplitude, u, v, RMS, offset, and N, as explained under the description of the print-out. The last digit of the Julian day of meridian passage is also punched.

2. Small Corrections to the Phase

The amplitudes are corrected for the influence of integration, by division by $\frac{\sin(\Delta/2)}{\Delta/2}$, where Δ is the phase change during the 0.1 second integration interval, and several small corrections are made to the phase, immediately before output. All phase effects greather than 0."2 have been included.

a) The change of the Bessel day numbers with time. The aberrational Bessel day numbers sometimes change 0."35/day. Therefore, the Bessel day numbers are to be read in for 0^h UT and extrapolated by the following formulae:

$$\frac{dA}{dt} \approx .0000002674 \text{ radians/day}$$

(This is general precession only.)

$$\frac{dB}{dt} \approx 0$$

$$\frac{dC}{dt} \approx .000001566 \sin \phi \text{ radians/day},$$

where ϕ is the angle the earth has traveled in its orbit since the vernal equinox and

$$\frac{dD}{dt} \approx -.0000017075 \cos \phi \text{ radians/day}.$$

(These assume that the earth's orbit is circular.)

These corrections are applied after every beginning SID instead of every minute as the others are.

b) Refraction is covered in Reference 3. The coefficient was assumed to be 1.00028 (i.e., dew point $\approx 0°C$).

c) The spherical term of refraction is also covered in Reference 3, and the correction is applied to the data.

d) A term in the phase arises from the approximation of the interferometer function by a sine wave. It is derived as follows: The true interferometer function, f(t) is (Reference 4)

$$f(t) = A \cos 2\pi(B_1 \cos \delta + B_2 \cos \delta \cos \tau + B_3)$$

or approximately, in the vicinity of time t_o

$$f(t) \approx A \cos 2\pi(C + R(t-t_o) + R^1(t-t_o)^2)$$

where

$$R = -B_2 \cos \delta \sin \tau$$

and

$$R^1 = -B_2 \cos \delta \cos \tau$$

$$f(t) \approx A[\cos 2\pi(C + R(t-t_o)) - 2\pi R^1(t-t_o)^2 \sin 2\pi(C + R(t-t_o))]$$

when fitted with the sine wave

$$A_C \cos 2\pi R(t-t_o) + A_S \sin 2\pi R(t-t_o)$$

(neglecting end effects), the result is

$$A_C = A\left[\frac{1}{2} \cos 2\pi C - 2\pi \frac{T^2}{24} R^1 \sin 2\pi C\right]$$

$$A_S = A\left[\frac{1}{2}\sin 2\pi C - 2\pi\frac{T^2}{24}R^1 \cos 2\pi C\right]$$

where T is the interval of observation which results in a phase $2\pi\left\{C + \frac{R^1T^2}{12}\right\}$, i.e., $\frac{2\pi R^1T^2}{12}$ greater than the true phase. For $T = 1^{\text{min}}$, $0^\circ\!.00042837\ B_2 \cos\delta \cos\tau$ must be added to the observed phase.

e) Diurnal aberration. This is discussed in Reference 5. The displacements in α and δ derived there are

$$\Delta\alpha = {}^s0213\ \rho \cos\phi^1 \cos H \sec\delta$$

$$\Delta\delta = {}''320\ \rho \cos\phi^1 \sin H \sin\delta$$

where $\rho \cos\phi^1$ is the distance to the axis of the earth compared to the equatorial radius. If these quantities are inserted in the equations of Reference 4, the phase changes by

$$\Delta\phi = 2\pi(B_1 \cos\delta \sin H \sin\delta + B_2 \cos\delta \sin\tau \cos H \sec\delta - B_2 \cos\tau \sin^2\delta \sin H)\ \text{const.}$$

$$\Delta\phi = 2\pi(B_1 \sin H \sin\delta \cos\delta + B_2 \sin h + B_2 \cos^2\delta \cos\tau \sin H).\ \text{const}$$

The second term is constant for all H and δ and so may be lumped with B_3. The remainder is

$$\Delta\phi = 2\pi \sin H \cos\delta\ (B_1 \sin\delta + B_2 \cos\delta \cos\tau).\ \text{const}$$

$$2\pi \cdot \text{const} = 0^\circ\!.0003289$$

This quantity is added to the observed phase.

II. OPERATING INSTRUCTIONS

1. Card Formats

a) Input cards

i) Baseline parameter card

A) In columns 1-10 the hour angle of the southwest pole of the interferometer, in hours, minutes, seconds and fractions, written with a decimal point after the seconds and no internal spaces.

B) B_1 in columns 11-19 with a decimal point. In wavelengths.

C) B_2 in columns 20-28 in wavelengths, with a decimal point.

D) B_3 in columns 29-37 in fractions of a revolution with a decimal point.

E) The baseline number in column 41

ii) Day card

A) Columns 3-8 YYMMDD where YY is the year, MM is the month, and DD the day. No internal spaces permitted.

B) Columns 11-13 tape number. While tape numbers are less than 100 they appear in columns 12-13.

C) Columns 14-23, 24-33, 34-43 and 44-53 contain the 4 Bessel day numbers for 0h V.T. on the date specified in columns 3-8. In seconds of arc, with sign and decimal point.

D) Column 54-59 clock error with sign (- = slow + = fast) and decimal point.

iii) Source table date in columns 2-7 allows source table to be identified without precessing the positions back to 1950.

This card should be updated every time the source table is modified.

iv) Source table. For each source prepare a card containing:

A) Columns 1-7; the source number with decimal point.

B) Columns 8-21; right ascension in hours, minutes, seconds and fractions, with a decimal point after the seconds, and no internal spaces.

C) Columns 22-35; declination in degrees, minutes, and seconds, with a decimal point after the seconds and a sign in front of degrees. No internal spaces.

The source table is terminated with a blank card. It may contain at most 50 cards. If it has exactly 50 sources, the blank card should be omitted.

b) Output cards

i) Parameter card

A) Tape number I4, columns 13-16

B) h. I3, I2, F5.2 hours, minutes and seconds in columns 19-21, 24-25, and 28-32

C) B_1 in columns 42-49 F8.2

D) B_2 in columns 58-65 F8.2

E) B_3 in columns 74-79 F6.2

Other columns than those listed may have alphabetic characters.

ii) Clock error card. Clock error in columns 1-6, F6.2

iii) Date card. The last 6 digits of the Julian day in columns 1-6.

iv) Precession constant card. Constants M and N in radians in columns 1-12 and 13-24 respectively. F12.10. The Bessel day numbers, also in radians, appear in columns 25-36, 37-48, 49-60, and 60-72, respectively, in E format E12.5.

iv) <u>The punched source table</u>. The source number is punched in columns 3-7, with 1 decimal place, F5.1, the apparent R.A. of date in radians in columns 13-24, the apparent declination in radians in columns 25-36, both with format F12.8. The source table is terminated with a blank card.

v) <u>The data cards</u>.

A) Source number in columns 1-5 F5.1

B) H.A. sign in column 8, hours in column 9, minutes in 11-12, seconds in 14-17. Decimal point in 16

C) Amplitude in columns 18-27. Decimal point in column 25

D) Phase in columns 28-37. Phase in degrees, decimal point in column 34

E) u and v in columns 38-45 and 46 to 53. Decimal points in columns 45 and 53

F) RMS deviation in columns 54-61. Decimal point in columns 58

G) DC offset in columns 62-72. Decimal point in column 70

H) Last digit of Julian day of meridian transit is punched in column 74.

I) The running number N is punched in columns 75-80.

2. <u>Normal Operating Procedure</u>

a) The baseline parameters are first estimated from the survey list of Reference 6, or they are eventually taken from the position-calibration program operating on observations of several point sources.

b) The date, tape numbers, Bessel day numbers and clock error must be punched in the format described above. The Bessel day numbers must be for 0^h U.T. on the date punched.

c) As many stacks of data cards as desired may be stacked one behind the other, separated only by the blank card terminating each source table. The computer operator should be told to put on the tapes in the order corresponding to that of the day cards.

d) The card decks should be filed, marked with the date of reduction and the first card interpreted. The bad cards should then be edited out of this deck before it is placed on tape.

References

1. C. M. Wade, "A Method for Finding the Phase and Amplitude of Interferometer Fringe Patterns," NRAO Internal Report, November 1964

2. B. G. Clark, "On the Reduction of Digital Interferometer Records," NRAO Internal Report, December 1964

3. B. G. Clark, "Refraction," NRAO Internal Report, December 1964

4. C. M. Wade and G. W. Swenson, "Geometrical Aspects of Interferometry," NRAO Internal Report, December 1964

5. Explanatory Supplement American Ephemeris and Nautical Almanac, p. 49

6. C. M. Wade, "Interferometer Constants Predicted from the Survey Data," NRAO Internal Report, January 1965

THE INTERFEROMETER FRINGE REDUCTION PROGRAM. VERSION II.

B. G. Clark and C. M. Wade

III. A Programmers Guide to the Interferometer Fringe Reduction Program

1. Flow Chart
   A greatly simplified flow chart is given in the following pages.

2. Fortran Program Listing

3. Subroutine Listings and Explanations

   a) JD(NY, M, ND) is an arithmetic statement function in the main fringe reduction program which converts from years (NY), months (M), and days (ND) to Julian days.

   b) RADI (RA, DEC, ALPHA, DELTA) converts right ascension (RA) and declination (DEC) from format with hours (or degrees), minutes, seconds, and fractions read as a single floating point number into radians (ALPHA, DELTA). It is permissible to CALL RADI (RA, DEC, RA, DEC), in which case the answers are stored in the input words.

   c) BCDCNV (IW, IPS, IPO, IP1, IP2, IP3, IP4, IP5, IP6) decodes a BCD coded word with the following format:

byte ↓ / bit →	1	2	3	4	5	6
1	IPS		—	I	P1	—
2	IPO		—	I	P2	—
3			—	I	P3	—
4			—	I	P4	—
5			—	I	P5	—
6			—	I	P6	—

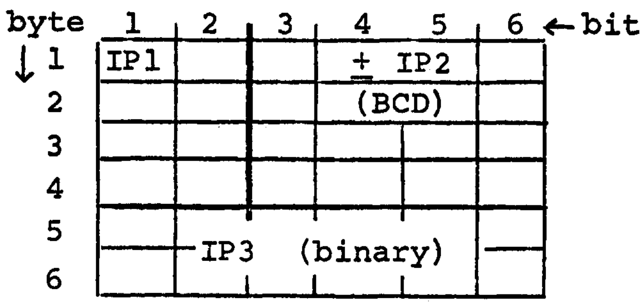
   d) RAD2 (IPS, IP1, IP2, IP3, IP4, IP5, IP6, DEC) when preceded by a call to BCDCNV unfolds the declination word from the tape SID and converts to radians, storing in DEC.

e) RAD3 (IPO, IP1, IP2, IP3, IP4, IP5, IP6, RA) unfolds a right ascension word from a tape SID, and again connects to radians.

f) RAD4 (IPS, IP1, IP2, IP3, IP4, IP5, IP6, RA) unfolds on hour angle word from a tape SID, and converts to radians.

g) RADOUT (ANGLE, ND, NM, FS) converts from an angle in radians (ANGLE) to degrees (ND) (with proper sign), minutes (NM), and seconds (FS).

h) NOCNV (IW, IP1, IP2, IP3) converts a tape data word (IW) with the following format:



i) FCNV (IW, IFREQ) converts a BCD word with the 8 digit format used for SID frequency notation into binary.

j) TREAD (NOTAPE, IW, IFLGWD, NWDS) reads up to 602 words from tape unit NOTAPE (Fortran 1-4. Fortran 0 corresponds to NOTAPE = 10) into memory area IW. The four least significant bits of IFLGWD, from the right, mean redundancy check, end-of-file, end-of-tape, and I-O check, respectively. NWDS is the number of words read from the tape into IW.

k) BSP (NOREC, NOTAPE) backspaces tape NOTAPE by NOREC records. Backspacing should not be done with Fortran BACKSPACE statements.

l) FLOT (IW, DATA, IAGC1, IAGC2, IGAIN) takes the first 601 words in IW, ignores the first two, and treats the others as follows: The word is treated as 3 binary numbers. The first twelve bits is extracted, floated and stored in the DATA array. The second twelve bits is considered AGC information, and these numbers are summed, separate sums being kept for odd seconds

(IAGC1) and even seconds (IAGC2). IGAIN is 1 or 10 depending on wehther bit 25 is a 0 or 1 respectively. The last twelve bits are discarded.

m) SUMS (CDEL, SDEL, DATA, CFT, SFT, SAVG, SUMSQ) takes the 599 word array DATA and generates

$$SAVG = \sum_{i=1}^{599} DATA_i$$

$$SUMSQ = \sum_{i=1}^{599} (DATA_i - \overline{DATA})^2$$

$$CFT = \sum_{i=-299}^{299} (DATA_{0+300} - \overline{DATA}) \cos (i\Delta)$$

$$SFT = \sum_{i=-299}^{299} (DATA_{i+300} - \overline{DATA}) \sin (i\Delta)$$

$\sin \Delta$ = SDEL and $\cos \Delta$ = CDEL must be supplied.

4. Glossary of Variable Names.

This listing does not include such things as the rapidly varying DO parameters, intermediate quantities used for printout only, and the intermediate variables used in decoding BCD words.

A	Amplitude of the fitted sine wave
AC	Cosine component of this amplitude
ALFO ALF1 ALF2 ALF3	Intermediate steps in precessing right ascension
ALPHA	Right ascension of source under reduction
ALT	Altitude difference between elements of the interferometer
ARG	Phase of point source at given position
AS	Sine component of fitted sine wave
BESA BESB BESC BESD	Bessel day numbers, in seconds of arc

BOSA BOSB BOSC BOSD	Bessel day numbers, in radians
B1 B2 B3	B_1 B_2 B_3 See ref. 4
CAB	cos α for Bessel star constants
CDB	cos δ for Bessel star constants
CDEC	cos δ
CDEL	cos Δ Δ = phase change between subsequent integrations
CERR	Clock error in seconds
CFT	Cosine sum - see SUMS subroutine
CHA	cos H
COSA	Cosine of azimuth of baseline
COSP	Intermediate, paralactic, term in spherical term refraction
COSZ	Cosine of zenith distance
CRL	Longitude correction to sidereal time, in seconds
CRLNG(6)	Longitude correction for all 6 baselines
CRO	Central readout time, in radians
CT	Civil time, in fractions of a day (approximate)
CTAU	cos τ
CTM	Civil time of meridian passage of the source
DAT	Date in fractions of a year (approximate)
DATA (599)	The floated correlator outputs
DDEC1 DDEC2	Declination pointing corrections
DD1 DD2	Amount telescopes have moved in declination between beginning and ending SID's.
DEBA DEBC DEBD	Corrections to bring the Bessel day numbers to the time of observation
DEC (50)	Source table declinations
DEC50	Declination from source table cards
DEL	Δ = phase change between subsequent integrations
DELA DELC DELD	Derivatives of the Bessel day numbers
DELTA	Declination of source under reduction
DET	Determinant for the determination of least squares sine wave

DLTO DLT1 DLT2 DLT3	Intermediate steps in precessing declination
DPHI	Zenith phase rotation (in degrees) due to plane term of refraction
DPHO	Coefficient of spherical term of refraction
DRA1 DRA2	Pointing corrections in right ascension
DR1 DR2	Amount telescopes have moved in right ascension between beginning and ending SID's
D1 D2	Total amount telescopes have moved between beginning and ending SID's
ENDH	Ending hours of sidereal time from ending SID
ENDM	Ending minutes of sidereal time from ending SID
ENDPT	Predicted ending time, in minutes = STARTT + RECNO + 1
ENDT	Ending time in minutes of sidereal time
FI	Phase of fitted sine wave, referred to center of minute
FREQ	LO frequency
GAIN	1 or 10, according to gain indicator bit
H	Hour angle of south-west baseline pole, in hours, minutes, seconds
HA	Hour angle H
HOLD1	Antenna 2, declination read from beginning SID
HOLD2	Antenna 2, right ascension read from beginning SID
HP	Hour angle of north-east baseline pole, in radians
IAGC1 IAGC2	ALC feedback levels
IBADDT	Number of times tape date has disagreed with card data
IBASE	Baseline number
IBCODE	Observer's code
IDATE	Card date. Read and printed as YYMMDD, then converted to Julian days
IFLGWD	Flag word from TREAD
IFREQ	LO frequency
IGAIN	1 or 10 according to gain indicator bit
IGOON	= 1 if SS2 set, continues reduction even though dates disagree
ITAPE	Telescope tape number
ITBDAT	Source table date

IW(602)	Buffer holding raw data read from tape
JD	Arithmetic statement function which converts to Julian days
JDATE	Tape date (Julian days)
JSRCE	Number of sources in source table
KDATE	Julian day of meridian passage
KSID	= 1 if source table was searched with no result, 0 otherwise
KTAG	= 0 if tape at load point
M	Months, in dates
N	Running number-number of minutes since object appeared at 6^h east H.A.
ND	Days, in dates
NREC	Record number
NSCAN	Scan number read from tape
NWDS	Number of words read from tape by READ
NY	Years, in dates
OBJECT	Source under reduction
OFFSET	Constant term fitted with sine wave
P	End effect term (see ref. 2)
PHI	Phase of fitted sine wave relative to point source at given position
PRECM PRECN	The general precession constants M and N
Q	End effect term (see ref. 2)
R	Fringe rate in cycles/sec
RA(50)	Source table right ascensions
RA50	Right ascension read from source table cards
RECNO	Record number
RMS	rms deviation of data points from least squares sine wave
SAB	sin α for Bessel star constants
SAVG	Sum of the data points
SDB	sin δ for Bessel star constants
SDEC	sin δ
SDEL	sin Δ, Δ = phase change between subsequent integrations
SFT	Sine sum. See SUMS subroutine
SHA	sin H
SIDDC1 SIDDC2 SIDHA1 SIDH2 SIDRA1 SIDRA2	δ H α — Antenna positions read from beginning SID. SIDRA2 and SIDDC2 may be replaced by the antenna 1 coordinates during the searching of the source table

SID2D1	δ	Ending SID antenna positions
SID2D2		
SID2R1	α	
SID2R2		
SINA	Sine of baseline azimuth	
SRCE(50)	Source numbers for source table	
STARTH	Starting sidereal time - hours	
STARTM	Starting sidereal time - minutes	
STARTT	Starting sidereal time expressed in minutes	
STAU	sin τ (ref. 4)	
SUMSQ	Sum of squares of deviations of data points from mean	
TAU	τ (ref. 4)	
TDB	tan for Bessel star constants	
TH	Hours of time of record	
TM	Minutes of time of record	
U	u (ref. 4)	
V	v (ref. 4)	

References

1. C. M. Wade. "A Method for Finding the Phase and Amplitude of Interferometer Fringe Patterns," NRAO Internal Report, November 1964

2. B. G. Clark, "On the Reduction of Digital Interferometer Records," NRAO Internal Report, December 1964

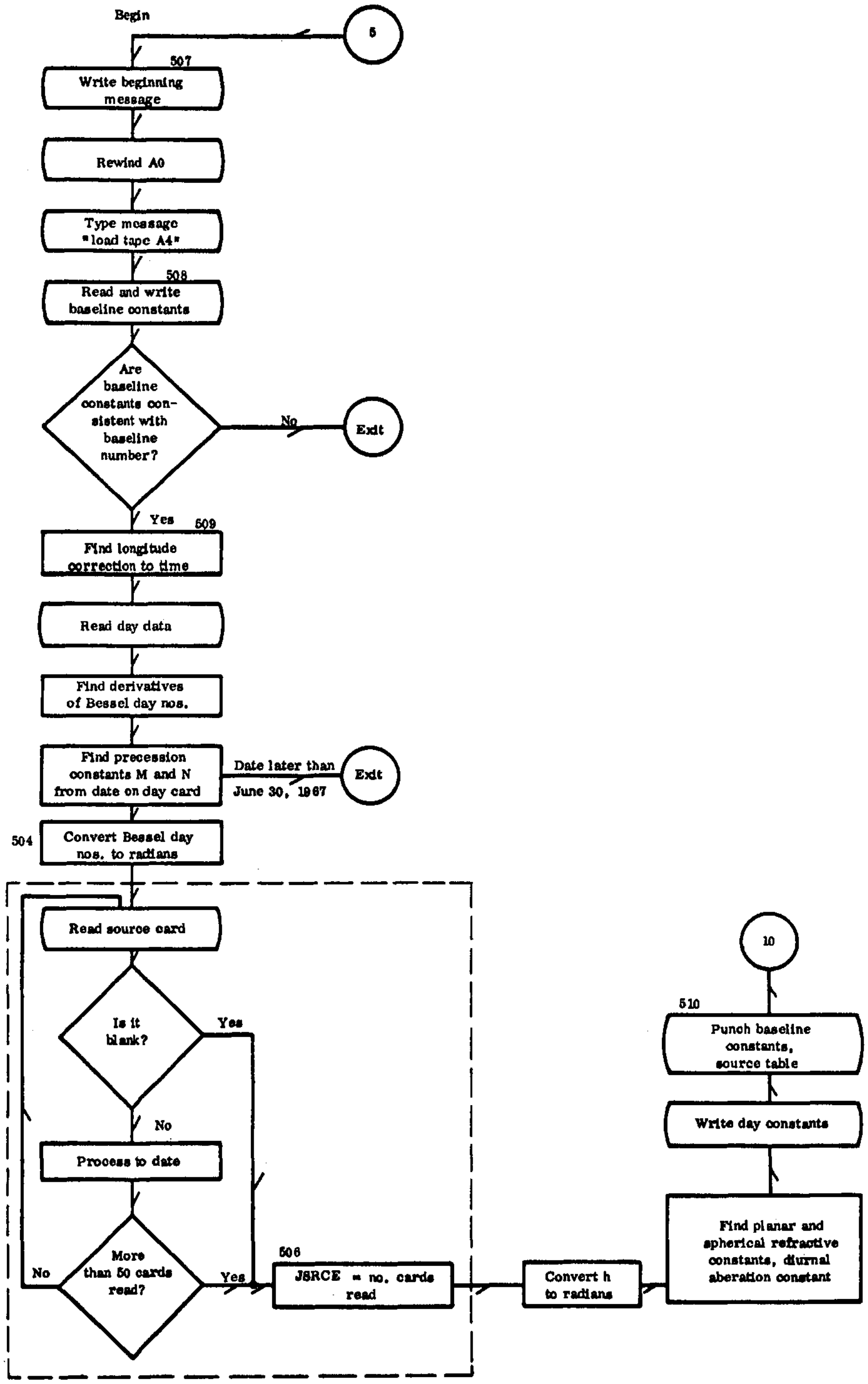
3. B. G. Clark, "Refraction," NRAO Internal Report, December 1964

4. C. M. Wade and G. W. Swenson, "Geometrical Aspects of Interferometry," NRAO Internal Report, December 1964

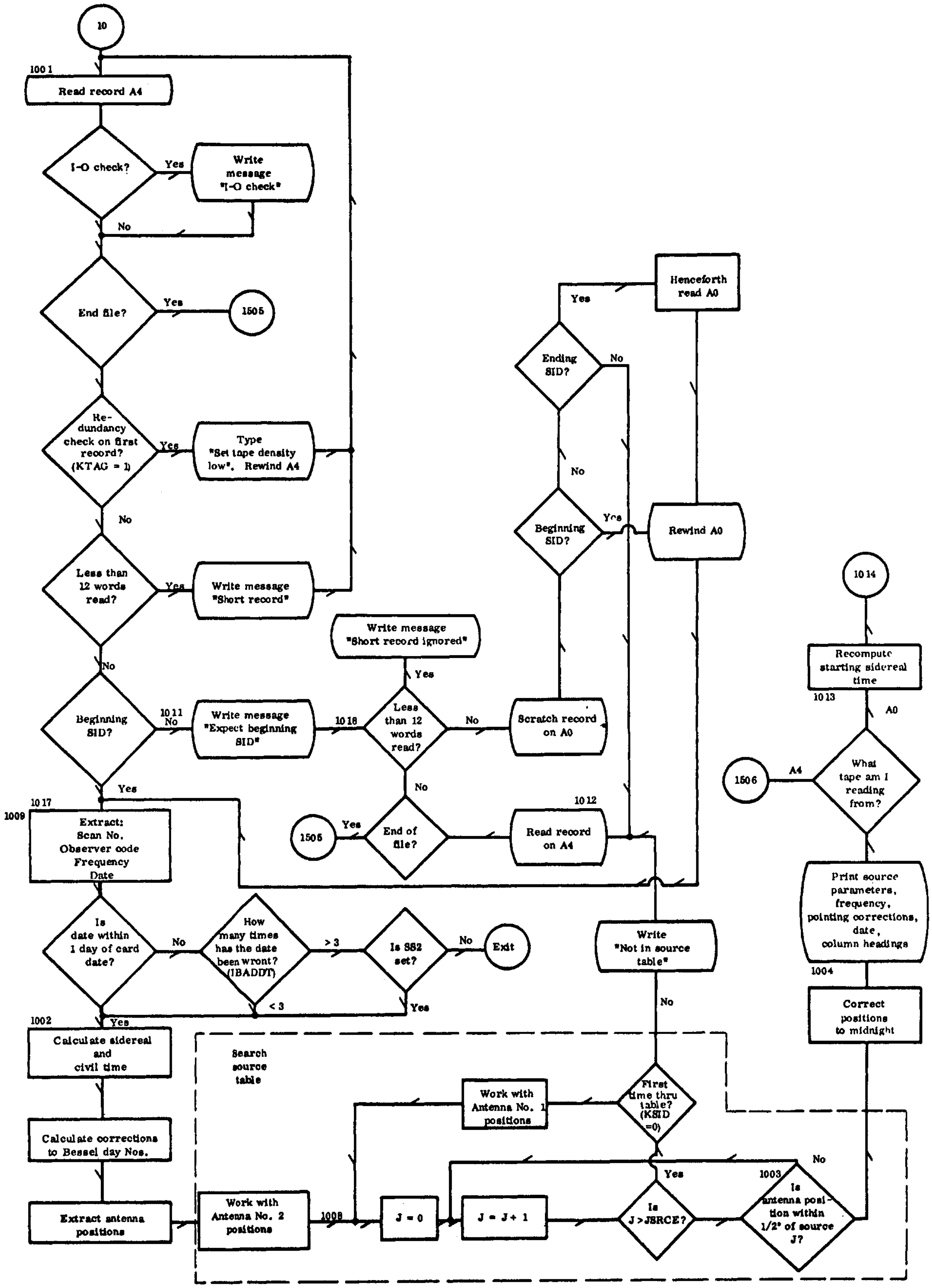
5. <u>Explanatory Supplement American Ephemeris and Nautical Almanac</u>, p. 49.

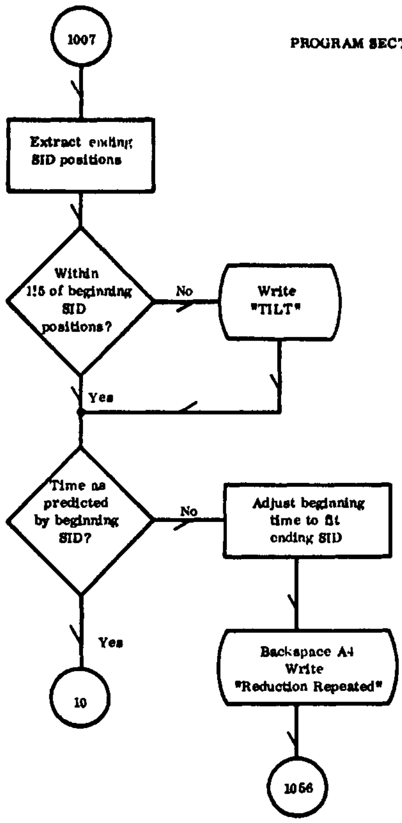
6. C. M. Wade, "Interferometer Constants Predicted from the Survey Data," NRAO Internal Report, January 1965

PROGRAM SECTION 5
PREPARATORY OPERATIONS

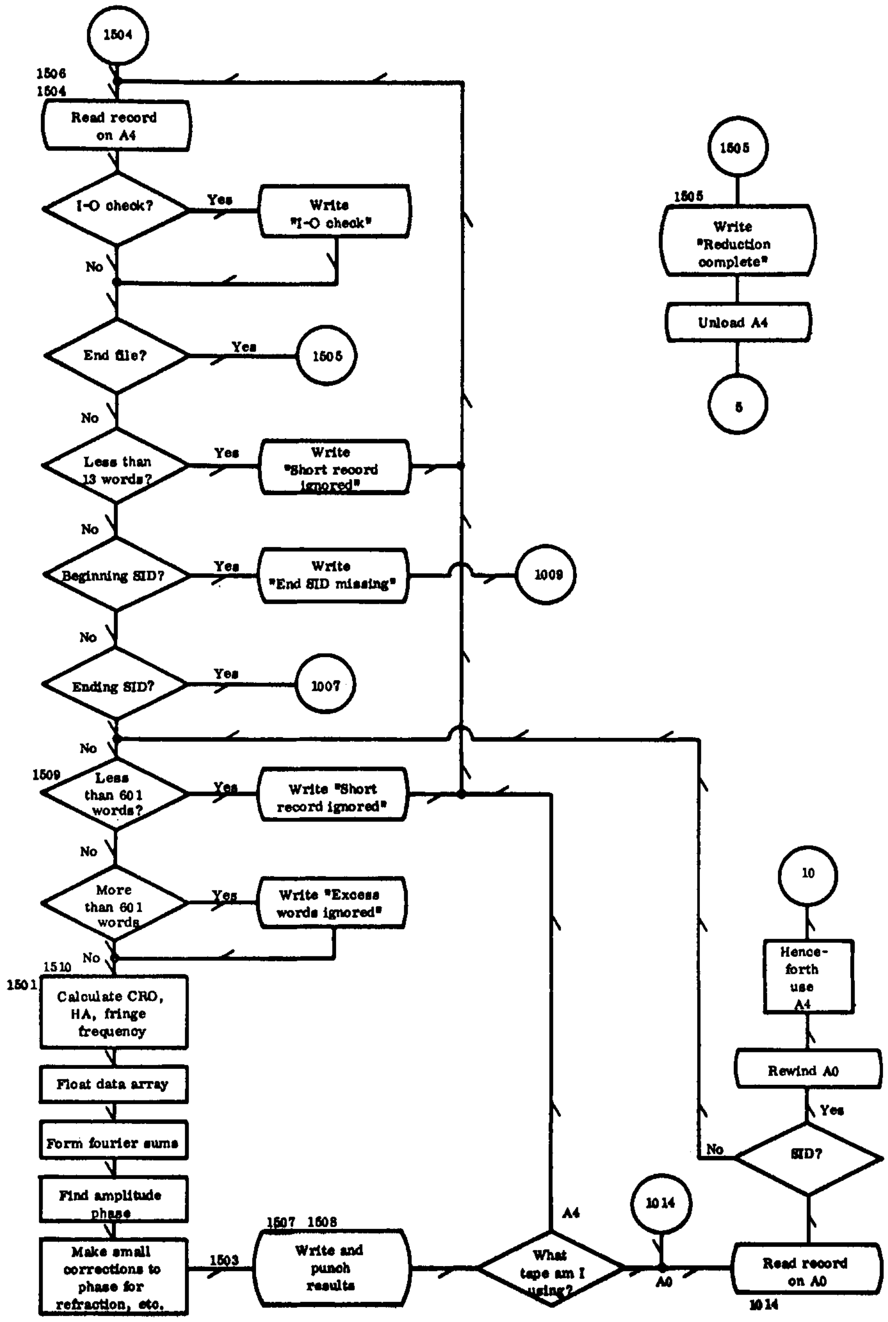


PROGRAM SECTION 10
PROCESSING SID's




1007
Extract ending SID positions
Within 1.5 of beginning SID positions?
No
Write "TILT"
Yes
Time as predicted by beginning SID?
No
Adjust beginning time to fit ending SID
Yes
10
Backspace A4
Write
"Reduction Repeated"
1056

PROGRAM SECTION 15
REDUCTION FOR AMPLITUDE AND PHASE



```
$IBFTC IFRP    DECK,LIST,REF
C      INTERFEROMETER FRINGE REDUCTION PROGRAM   IFRP II/1, 1 FEB 1965.
C
C      PROGRAM SECTION 005.  PREPARATORY OPERATIONS.
C
C      JULIAN DAY ARITHMETIC STATEMENT FUNCTION
C
       REAL JD
       JD(NY,M,ND)=(NY*146097)/400+(M*3057)/100+ND+((5-M/3)/5)*(2-(4-MOD(
      1NY,4))/4+(100-MOD(NY,100))/100-(400-MOD(NY,400))/400)+1721028
C
C      PRINT MESSAGE -- LOAD DATA TAPE ON TAPE DRIVE 4.  PLACE THE FOL-
C      LOWING CARDS IN THE CARD READER.
C        1.  BASE LINE CONSTANTS.
C        2.  DATE, TAPE NO., BESSEL DAY NOS., CLOCK ERROR.
C        3.  SOURCE POSITION TABLE.
C
       DIMENSION IW(602),DATA(599),SRCE(50),RA(50),DEC(50),CRLNG(6)
  507  WRITE (6,1005)
 1005  FORMAT(1H ,31HLOAD DATA TAPE ON TAPE DRIVE 4./1H ,45HPLACE THE FOL
      1LOWING CARDS IN THE CARD READER./6X,23H1.  BASELINE CONSTANTS./6X,
      249H2.  DATE, TAPE NO., BESSEL DAY NOS., CLOCK ERROR./6X,26H3.  SOU
      3RCE POSITION TABLE.)
       WRITE(6,2005)
 2005  FORMAT(1H1/1H )
       REWIND 0
       CALL TYPE(1,30HLOAD TAPE ON A4, LOW DENSITY.    )
       IBADDT = 0
       READ(5,3005)H,B1,B2,B3,IBASE
 3005  FORMAT(F10.2,3F9.2,I4)
C
C      VERIFY CONSISTENCY OF CONSTANTS AND SPECIFIED BASELINE.
C
       IF(ABS(B1-1015.*FLOAT(IBASE+3)).GT.30.)GO TO 508
       IF(ABS(B2-2498.*FLOAT(IBASE+3)).GT.30.)GO TO 508
       GO TO 509
  508  WRITE(6,8005) B1,B2,IBASE
 8005  FORMAT(1H0,4HB1 =F9.2,5X,4HB2 =F9.2,32H  IS NOT CONSISTENT WITH IB
      1ASE =I3,18H.  JOB TERMINATED.)
       CALL EXIT
C
C      DETERMINE LONGITUDE CORRECTION IN SECONDS OF TIME.
C
  509  CRLNG(1)=-0.271
       CRLNG(2)=-0.628
       CRLNG(3)=-0.984
       CRLNG(4)=-1.341
       CRLNG(5)=-1.696
       CRLNG(6)=-2.052
       CRL=CRLNG(IBASE)
C
C      READ DAY DATA.  DETERMINE DERIVIATIVES OF BESSEL DAY NOS.
C
       READ(5,4005)IDATE,ITAPE,BESA,BESB,BESC,BESD,CERR
 4005  FORMAT(I8,I5,4F10.3,F6.2)
       NY = IDATE/10000
       M = IDATE/100 - NY*100
       ND = MOD(IDATE,100)
       DAT = (JD(1900+NY,M,ND) - 2438762.)/365.2425
       DAT = AMOD(DAT,1.0)
       DELA = 2.674E-7
```

```
      DELC = 1.5664E-6*COS(6.28319 (DAT-0.4712))
      DELD =1.7075E-6    *COS(6.28319* (DAT-0.7283))
C
C     READ IN SOURCE TABLE WITH 1950.0 MEAN POSITIONS.  CONVERT TO
C     APPARENT POSITIONS FOR DATE OF OBSERVATIONS, IN RADIANS.
C
      IF(IDATE.GT.650630)GO TO 501
      PRECM=46.101/13750.987
      PRECN=20.042/13750.987
      GO TO 504
  501 IF(IDATE.GT.660630)GO TO 502
      PRECM=49.175/13750.987
      PRECN=21.378/13750.987
      GO TO 504
  502 IF(IDATE.GT.670630)GO TO 503
      PRECM=52.248/13750.987
      PRECN=22.714/13750.987
      GO TO 504
  503 WRITE(6,5005)
 5005 FORMAT(1H0,47H DATE LATER THAN 30 JUNE 1967.  JOB TERMINATED.)
      CALL EXIT
  504 BOSA=BESA/206264.81
      BOSB=BESB/206264.81
      BOSC=BESC/206264.81
      BOSD=BESD/206264.81
      READ(5,12005) ITBDAT
12005 FORMAT(I7)
      DO 505 J=1,50
      READ(5,6005)SRCE(J),RA50,DEC50
 6005 FORMAT(F7.1,F14.2,F14.1)
      IF(SRCE(J).LE.0.)GO TO 506
      CALL RAD1(RA50,DEC50,ALF0,DLT0)
      ALF1=ALF0+PRECM+PRECN*SIN(ALF0)*SIN(DLT0)/COS(DLT0)
      DLT1=DLT0+PRECN*COS(ALF0)
      ALF2=0.5*(ALF0+ALF1)
      DLT2=0.5*(DLT0+DLT1)
      ALF3=ALF0+PRECM+PRECN*SIN(ALF2)*SIN(DLT2)/COS(DLT2)
      DLT3=DLT0+PRECN*COS(ALF2)
      SAB=SIN(ALF3)
      CAB=COS(ALF3)
      SDB=SIN(DLT3)
      CDB=COS(DLT3)
      TDB=SDB/CDB
      RA(J)=ALF3+BOSA*(2.30039+SAB*TDB)+BOSB*CAB*TDB+BOSC*CAB/CDB+BOSD*S
     1AB/CDB
      DEC(J)=DLT3+BOSA*CAB-BOSB*SAB+BOSC*(0.43365*CDB-SAB*SDB)+BOSD*CAB*
     1SDB
  505 CONTINUE
      J = 51
  506 JSRCE=J - 1
C
C     CONVERT H TO RADIANS, FOR NORTH-EAST POLE.
C
      CALL RAD1(H,0.,HP,DUMMY)
      HP=HP-3.14159265
C
C     FIND REFRACTION CONSTANTS
C
      ALT = 0.6215244*B1 + 0.7833948*B2*COS(HP)
      DPHI = 360.*0.00028*ALT
      DPHO = 0.115*FLOAT(3*IBASE+9)
```

```
      COSA = B1/(0.7834*SQRT(B1*B1+B2*B2))
      SINA = SQRT(1.-COSA*COSA)
C
C     PRINT CONSTANTS.
C
      WRITE(6,7005)ITAPE,IDATE,H,B1,B2,B3,IBASE,BESA,BESB,BESC,BESD,CERR
     1,ITBDAT
 7005 FORMAT(1H ,4HTAPEI5,5X,I7/1H ,4H H =F9.2/1H ,4HB1 =F9.2/1H ,4HB2 =
     1F9.2/1H ,4HB3 =F9.2/1H ,8HBASELINEI2/1H ,22HBESSEL DAY NOS.    A =
     2F10.3/20X,3HB =F10.3/20X,3HC =F10.3/20X,3HD =F10.3/1H ,11HCLOCK ER
     3RORF7.2/1H ,17HSOURCE TABLE DATEI7/1H ,68H RECORDS MARKED * WERE R
     4EAD FROM TELESCOPE TAPE WITH A PARITY ERROR.)
      WRITE(6,2005)
      IDATE = JD(NY+1900,M,ND)
C
C     PUNCH CONSTANTS.
C
      IH=H/10000.
      IM=ABS(H/100.)
      IM=IM-IABS(IH)*100
      S=AMOD(ABS(H),100.)
      WRITE(7,9005)ITAPE,IH,IM,S,B1,B2,B3,CERR,IDATE,PRECM,PRECN,BOSA,BO
     1SB,BOSC,BOSD
 9005 FORMAT(8X,4HTAPEI4,2HH=I3,2HH I2,2HM F5.2,1HS,5X,3HB1=F8.2,5X,3HB2
     1=F8.2,5X,3HB3=F7.3/F6.2/I6/2F12.10,4E12.5)
      DO 510 I=1,JSRCE
  510 WRITE(7,10005)SRCE(I),RA(I),DEC(I)
10005 FORMAT(2X,F5.1,5X,2F12.8)
      WRITE(7,11005)
11005 FORMAT(1H )
C
C
C     PROGRAM SECTION 010.  LOCATION OF FIRST SID AND EXTRACTION OF SID
C     DATA.
C
C     SEARCH FOR FIRST SID.
C
      KTAG = 0
 1001 CALL TREAD(4,IW,IFLGWD,NWDS)
      IF (IFLGWD.GE.8) WRITE (6,6015)
      IF (IFLGWD.GE.8)  IFLGWD =IFLGWD-8
      IF(IFLGWD.GE.2)  GO TO 1505
      KTAG = KTAG + 1
      IF(KTAG.EQ.1.AND.IFLGWD.EQ.1) KTAG = KTAG + 3
      IF (KTAG .EQ.4) CALL TYPE(1,36HSET A4 TO LOW DENSITY. PRESS START.
     1    )
      IF(KTAG.EQ.4) GO TO 1001
      KTAG = 1
      IF (NWDS.LE.12) WRITE (6,7015) NWDS
      IF (NWDS.LE.12) GO TO 1001
      CALL NOCNV(IW(2),IP1,IP2,IP3)
      IF(IP3.NE.0)GO TO 1011
 1017 ASSIGN 1506 TO KK
      ASSIGN 1504 TO LL
C
C     SCAN NUMBER, OBSERVER CODE, AND FREQUENCY
C
 1009 NSCAN = IP2
      CALL BCDCNV(IW(3),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      IBCODE=IP6+10*IP5+100*IP4+1000*IP3+10000*IP2+100000*IP1
      CALL FCNV(IW(6),IFREQ)
```

```
      FREQ = IFREQ*2 +2600000000
C
C     EXTRACT AND CHECK DATE.
C
      CALL BCDCNV(IW(4),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      JDATE = JD(1900+10*IP1+IP2,10*IP3+IP4,10*IP5+IP6)
      IF(IABS(JDATE-IDATE).LE.1)GO TO 1002
      WRITE(6,1010)  IDATE,JDATE
 1010 FORMAT (1H0,43H TAPE AND CARD DATES DISAGREE.  CARD DATE = , I9,
     115H.  TAPE DATE = ,I9)
      IBADDT = IBADDT + 1
      CALL SSWTCH(2,IGOON)
      IF(IBADDT.GE.3.AND.IGOON.NE.1)  CALL EXIT
      GO TO 1002
C
C     FIND HOURS AND MINUTES OF SID TIME.
C
 1002 CALL BCDCNV(IW(5),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      STARTH=10*IP1+IP2
      STARTM=10*IP3+IP4
C
C     FIND CIVIL TIME
C
      CT = STARTH/24.+STARTM/1440. - CERR/86400. - DAT +.72357
      CT = CT*0.99727
      IF (CT.LT.0.)  CT = CT+ 1.
      IF (CT.GT.1.) CT = CT - 1.
      CT = CT + FLOAT(JDATE-IDATE)
C
C     FIND CORRECTIONS TO BESSSEL DAY NUMBERS
C
      DEBA = DELA*CT
      DEBC = DELC*CT
      DEBD = DELD*CT
C
C     EXTRACT SID COORDINATES FOR ANTENNA 1.
C
      KSID=0
      CALL BCDCNV(IW(7),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      CALL RAD2(IPS,IP1,IP2,IP3,IP4,IP5,IP6,SIDDC1)
      CALL BCDCNV(IW(8),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      CALL RAD3(IP0,IP1,IP2,IP3,IP4,IP5,IP6,SIDRA1)
      CALL BCDCNV(IW(9),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      CALL RAD4(IPS,IP1,IP2,IP3,IP4,IP5,IP6,SIDHA1)
C
C     EXTRACT SID COORDINATES FOR ANTENNA 2.  SEARCH SOURCE TABLE.
C
      CALL BCDCNV(IW(10),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      CALL RAD2(IPS,IP1,IP2,IP3,IP4,IP5,IP6,SIDDC2)
      HOLD1=SIDDC2
      CALL BCDCNV(IW(11),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      CALL RAD3(IP0,IP1,IP2,IP3,IP4,IP5,IP6,SIDRA2)
      HOLD2=SIDRA2
      CALL BCDCNV(IW(12),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      CALL RAD4(IPS,IP1,IP2,IP3,IP4,IP5,IP6,SIDHA2)
 1008 DO 1003 J=1,JSRCE
      IF(ABS (SIDRA2- RA(J)).GT.0.00872665  )GO TO 1003
      IF(ABS (SIDDC2-DEC(J)).GT.0.00872665  )GO TO 1003
      ALPHA=RA(J)
      DELTA=DEC(J)
      OBJECT=SRCE(J)
```

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C
C      CORRECT POSITIONS TO MEAN FOR DAY
C
       SAB = SIN(ALPHA)
       CAB = COS(ALPHA)
       SDB = SIN(DELTA)
       CDB = COS(DELTA)
       TDB = SDB/CDB
       ALPHA =ALPHA+DEBA*(2.30039+SAB*TDB)+DEBC*CAB/CDB+DEBD*SAB/CDB
       DELTA = DELTA + DEBA*CAB+DEBC*(0.43365*CDB-SAB*SDB)+DEBD*CAB*SDB
       SDEC=SIN(DELTA)
       CDEC=COS(DELTA)
       GO TO 1004
 1003  CONTINUE
       CALL RADOUT(HOLD1 ,ND,NM,FS)
       SIDRA2=HOLD2 /15.
       CALL RADOUT(SIDRA2,NDD,NMM,FSS)
       IF(KSID.EQ.1) GO TO 1006
       KSID=1
       SIDDC2=SIDDC1
       SIDRA2=SIDRA1
       GO TO 1008
 1006  WRITE(6,2010)NDD,NMM,FSS,ND,NM,FS
 2010  FORMAT(1H0,24HSOURCE NOT IN TABLE.  RAI3,I3,F6.2,3X,3HDECI4,I3,F4.
      1 0)
       GO TO 1012
C
C      FIND DATE OF MERIDIAN PASSAGE
C
 1004  HA = 10000.*STARTH+100.*STARTM+CRL-CERR
       CALL RAD1(HA,0.,HA,DUMMY)
       HA = HA-ALPHA
       IF (HA.GT.3.5) HA = HA -6.28318531
       IF(HA.LT.-3.5)  HA = HA +6.28318531
       CTM = CT - HA/6.28318531
       MCT = CTM + 7.5
       MCT = MCT - 7
       KDATE = JDATE + MCT
C
C      PRINT SOURCE NAME AND APPARENT POSITION, AND RCVR FREQUENCY
C
       DUMMY=ALPHA/15.
       CALL RADOUT(DUMMY,ND,NM,FS)
       CALL RADOUT(DELTA,NDD,NMM,FSS)
       WRITE(6,3010)OBJECT,ND,NM,FS,NDD,NMM,FSS
 3010  FORMAT(///1H0,2H3CF6.1,6H  RA =I3,I3,F7.3,8H   DEC =I4,I3,F6.2)
       WRITE(6,8010) KDATE
 8010  FORMAT ( 6H DATE  ,I9)
       FREQ = FREQ/1000.
       WRITE (6,7010) FREQ
 7010  FORMAT(11X,14HLO FREQUENCY =, F10.1, 5H KC/S)
C
C      DETERMINE POINTING CORRECTIONS.
C
       DRA1=13751.*(SIDRA1-ALPHA)
       DRA2=13751.*(HOLD2-ALPHA)
       DDEC1=3437.75*(SIDDC1-DELTA)
       DDEC2=3437.75*(HOLD1-DELTA)
       WRITE(6,5010)IBCODE,DRA1,DDEC1,NSCAN,DRA2,DDEC2
 5010  FORMAT(1H ,14HOBSERVERS CODE,I7,19X,29HPOINTING CORRECTIONS.  DRA1
      1 =,F6.1,8H SECONDS/64X,6HDDEC1=,F6.1,8H MINUTES/1H ,11HSCAN NUMBER
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```
      2,I6,46X,6HDRA2 =,F6.1,8H SECONDS/64X,6HDDEC2=,F6.1,8H MINUTES)
C
C      PRINT COLUMN HEADINGS.
C
       WRITE(6,4010)
 4010 FORMAT(1H0,116H SOURCE     N     HOUR ANGLE       TIME         AMP
     1   PHASE      FREQ       U          V            RMS   OFFSET AGC1 AGC2/
     2)
       GO TO KK,(1506,1013)
C
C      FIRST SID NOT PROCESSED
C
 1011 WRITE (6,11010)
11010 FORMAT (// 47H BEGINNING SID DOES NOT APPEAR WHERE EXPECTED.  //)
       GO TO 1018
 1012 CALL TREAD(4,IW,IFLGWD,NWDS)
       CALL NOCNV(IW(2),IP1,IP2,IP3)
       IF (IFLGWD.GE.8) IFLGWD = IFLGWD-8
       IF (IFLGWD.GE.2) GO TO 1505
 1018 IF (NWDS.LE.12) WRITE(6,7015) NWDS
       IF (NWDS.LE.12) GO TO 1012
       WRITE (0) IW,IFLGWD,NWDS
       CALL NOCNV(IW(2),IP1,IP2,IP3)
       NREC = IP3
       IF (IP3.EQ.0) REWIND 0
       IF (IP3.EQ.0) GO TO 1017
       IF(IP1.NE.1) GO TO 1012
       REWIND 0
       ASSIGN 1013 TO KK
       GO TO 1009
 1013 STARTM = STARTM - FLOAT(NREC)-1.
       IF (STARTM.LT.0.) STARTH = STARTH - 1.
       IF (STARTM.LT.0.) STARTM = STARTM + 60.
       IF (STARTH.LT. 0.) STARTH = STARTH + 24.
       ASSIGN 1506 TO KK
 1014 ASSIGN 1014 TO LL
       READ (0) IW,IFLGWD,NWDS
       CALL NOCNV(IW(2),IP1,IP2,IP3)
       RECNO = IP3
       IF (IP1.NE.1) GO TO 1509
       ASSIGN 1504 TO LL
       REWIND 0
       GO TO 1001
 1016 WRITE (6,10010)
10010 FORMAT (20H ENDING SID MISSING.   )
       GO TO 1009
C
C      EXTRACT 2ND SID POSITIONS AND COMPARE THEM WITH 1ST SID.
C
 1007 CALL BCDCNV(IW(7),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
       CALL RAD2(IPS,IP1,IP2,IP3,IP4,IP5,IP6,SID2D1)
       CALL BCDCNV(IW(8),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
       CALL RAD3(IP0,IP1,IP2,IP3,IP4,IP5,IP6,SID2R1)
       CALL BCDCNV(IW(10),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
       CALL RAD2(IPS,IP1,IP2,IP3,IP4,IP5,IP6,SID2D2)
       CALL BCDCNV(IW(11),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
       CALL RAD3(IP0,IP1,IP2,IP3,IP4,IP5,IP6,SID2R2)
       DR1=ABS(SIDRA1-SID2R1)
       DD1=ABS(SIDDC1-SID2D1)
       DR2=ABS(HOLD2-SID2R2)
       DD2=ABS(HOLD1-SID2D2)
```

```
      IF(DR1.LT.0.0005.AND.DR2.LT.0.0005.AND.DD1.LT.0.0005.AND.DD2.LT.0.
     10005) GO TO 1001
      D1=SQRT(DD1*DD1+CDEC*CDEC*DR1*DR1)*3437.75
      D2=SQRT(DD2*DD2+CDEC*CDEC*DR2*DR2)*3437.75
      WRITE(6,6010)D1,D2
 6010 FORMAT(1H0,5HTILT.//1H ,15HANTENNA 1 MOVEDF10.1,20H AND ANTENNA 2
     1MOVEDF10.1,40H MINUTES OF ARC DURING THIS OBSERVATION./)
      CALL BCDCNV(IW(5),IPS,IP0,IP1,IP2,IP3,IP4,IP5,IP6)
      ENDH = 10*IP1 + IP2
      ENDM = 10*IP3 + IP4
      ENDT = 60.*ENDH + ENDM
      STARTT = 60.*STARTH + STARTM
      ENDPT = STARTT +       RECNO  + 1.
      IF (ENDPT.GE.1440.) ENDPT = ENDPT - 1440.
      IF(ENDPT.EQ.ENDT) GO TO 1001
      NOREC = RECNO
      IF (NOREC.GE.150) WRITE (6,12010)
12010 FORMAT(84H SECOND SID DISAGREES WITH FIRST.  CANNOT REREDUCE BECAU
     1SE OF ERRORS IN SECOND SID.    )
      IF (NOREC.GE.150) GO TO 1001
      CALL BSP(NOREC+1,4)
      STARTH = ENDH
      STARTM = ENDM -       RECNO  - 1.
      IF (STARTM.LT.0.) STARTH = STARTH - 1.
      IF (STARTM.LT.0.) STARTM = STARTM + 60.
      IF (STARTH.LT. 0.) STARTH = STARTH + 24.
      WRITE (6,9010)
 9010 FORMAT(// 42H REDUCTION REPEATED.  REMOVE EXCESS CARDS.  //10(6X,
     1 1H*)//)
      GO TO 1504
C
C
C     PROGRAM SECTION 015.  DATA READ-IN, REDUCTION FOR AMPLITUDE AND
C     PHASE, OUTPUT OF RESULTS.
C
 1506 CONTINUE
 1504 CALL TREAD(4,IW,IFLGWD,NWDS)
      IF(IFLGWD.GE.8)  WRITE(6,6015)
 6015 FORMAT (33H I-O CHECK.  RETURN TO EXECUTION.)
      IF(IFLGWD.GE.8)   IFLGWD = IFLGWD-8
      IF(IFLGWD.GE.2) GO TO 1505
C
C     TRANSFER IF FIRST SID.
C
      CALL NOCNV(IW(2),IP1,IP2,IP3)
      RECNO=IP3
      IF (NWDS .GT. 15) GO TO 1509
      IF(IP3.EQ.0)GO TO 1016
C
C     TRANSFER IF SECOND SID.   CHECK RECORD LENGTH
C
      IF(IP1  .EQ.1)GO TO 1007
 1509 IF(NWDS.LT.601) WRITE(6,7015) NWDS
 7015 FORMAT(1H ,I3,37H WORD RECORD ENCOUNTERED AND IGNORED.    )
      IF (NWDS.LT.601) GO TO 1504
      IF (NWDS.EQ.602) WRITE(6,8015)
 8015 FORMAT (61H RECORD OF LENGTH EXCEEDING 601 WORDS.  EXCESS WORDS IG
     1NORED.  )
C
C     FIND CRO TIME IN RADIANS.
C
```

```
 1510 TM=STARTM+RECNO
      TH = STARTH + AINT(TM/60.)
      IF(    TH.GE.24.)    TH=TH - 24.
      TM = AMOD(TM,60.)
 1501 CRO=10000.*    TH+100.*TM-CERR+CRL+29.94
      CALL RAD1(CRO,0.,CRO,DUMMY)
C
C     FIND HOUR ANGLE AND QUANTITIES DEPENDING ON IT.
C
      HA=CRO-ALPHA
      IF (HA.GT.3.5) HA = HA -6.28318531
      IF(HA.LT.-3.5)  HA = HA +6.28318531
      TAU=HA-HP
      STAU=SIN(TAU)
      CTAU=COS(TAU)
      U=B2*STAU
      V=B1*CDEC-B2*SDEC*CTAU
      R=U*CDEC/13750.987
      DEL= .628318531*R
      SDEL=SIN(DEL)
      CDEL=COS(DEL)
      N = 229.183118*HA+360.5
C
C     CONVERT DATA ARRAY TO FLOATING POINT AND TRUNCATE TO GIVE COR-
C     RELATOR OUTPUT ONLY.
C
      CALL FLOT(IW,DATA,IAGC1,IAGC2,IGAIN)
      GAIN = IGAIN
      IAGC1 =(IAGC1+150)/300
      IAGC2 = (IAGC2+149)/299
C
C     FORM SUMS FOR REDUCTION.
C
      CALL SUMS(CDEL,SDEL,DATA,CFT,SFT,SAVG,SUMSQ)
C
C     FIND PHASE, AMPLITUDE, RMS, OFFSET.
C
      P=SIN(599.*DEL)/(599.*SDEL)
      Q=SIN(299.5*DEL)/(599.*SIN(0.5*DEL))
      DET=0.5*(1.+P)-Q*Q
      AC=CFT/(599.*DET)
      AS=2.*SFT/((1.-P)*599.)
      FI=ATAN2(AS,AC)
      A=SQRT(AC*AC+AS*AS)
      A = A*DEL/(2.*SIN(DEL/2.))
      RMS=SQRT((SUMSQ    -AC*CFT-AS*SFT)/599.)
      OFFSET=(SAVG-Q*CFT/DET)/599.
      ARG=B1*SDEC+B2*CDEC*CTAU+B3
      PHI = 57.2958*FI-360.*AMOD(ARG,1.)
C
C     CORRECT FOR REFRACTION AND FRINGE RATE CHANGE
C
      SHA = SIN(HA)
      CHA = COS(HA)
      COSZ = 0.6215244*SDEC + 0.7833948*CDEC*CHA
      COSP = (0.7833948*SDEC-0.6215244*CDEC*CHA)*COSA+CDEC*SHA*SINA
      PHI = PHI + DPHO*COSP/(COSZ*COSZ) +4.2836825E-4 *B2*CDEC*CTAU
     1+0.0003289*CDEC*SHA*ARG
      PHI = PHI - DPHI/COSZ
 1503 IF(PHI.GT.180.)PHI=PHI-360.
      IF(PHI.LT.-180.)PHI=PHI+360.
```

```
      IF(ABS(PHI).GT.180.)GO TO 1503
C
C     OUTPUT OF RESULTS.
C
      HAHA=HA/15.
      CALL RADOUT(HAHA,L1,L2,Z)
      HOHO=CRO/15.
      CALL RADOUT(HOHO,L11,L22,ZZ)
      A = A*GAIN
      RMS = RMS*GAIN
      OFFSET = OFFSET*GAIN
      IF(IFLGWD.EQ.1) GO TO 1507
      WRITE(6,1015)OBJECT,N,L1,L2,Z,L11,L22,ZZ,A,PHI,R,U,V,RMS,OFFSET
     1,IAGC1,IAGC2
 1015 FORMAT(1H ,2H3CF6.1,I5,I4,I3,F6.2,I4,I3,F6.2,F9.1,F11.2,F10.5,2F9.
     10,F11.2,F8.1,2I5)
      GO TO 1508
 1507 WRITE(6,5015)OBJECT,N,L1,L2,Z,L11,L22,ZZ,A,PHI,R,U,V,RMS,OFFSET
     1,IAGC1,IAGC2
 5015 FORMAT(1H ,2H3CF6.1,I5,I4,I3,F6.2,I4,I3,F6.2,F9.1,F11.2,F10.5,2F9.
     10,F11.2,F8.1,2I5,3H  *)
 1508 WRITE(7,4015)OBJECT,L1,L2,Z,A,PHI,U,V,RMS,OFFSET,KDATE,N
 4015 FORMAT(F5.1,I4,I3,F5.1,F10.2,F10.3,2F8.0,F8.2,F11.2,1X,I1,I6)
      GO TO LL,(1504,1014)
C
C     REDUCTION COMPLETE.  RETURN TO START FOR NEXT BLOCK OF DATA, OR
C     CALL EXIT IF TAPE IS FINISHED.
C
 1505 WRITE(6,2015)ITAPE
 2015 FORMAT(1H1,17HREDUCTION OF TAPEI5,14H IS COMPLETE.  )
      WRITE(6,3015)
 3015 FORMAT(1H1/1H )
      CALL UNLOAD(4)
      GO TO 507
      END
```

```
$IBMAP FLOT
*       CALL-    CALL FLOT(IW,DATA,IAGC1,IAGC2,IGAIN)
*       IW IS 601 ELEMENT ARRAY  FIRST TWO ARE IGNORED
*       DATA IS 599 ELEMENT ARRAY
        ENTRY    FLOT
FLOT    SAVE     1
        CLA      3,4                 GET LOCATION OF IW
        ADD      =601                ADD 601
        STA      PICK                STORE ADDRESS
        STA      PICKW
        STA      PICKX
        STA      PICKY
        STA      PICKZ
        CLA      4,4                 GET LOCATION OF DATA
        ADD      =599
        STA      DROP                STORE ADDRESS
        AXT      599,4
PICK    CAL      **,4                GET WORD
        LGR      9                   SHOVE OVER
        ANA      =0777700000         BLANK REST
        ORA      =0214000000000      FLOAT
        FAD      =0200000000000      NORMALIZE
DROP    STO      **,4                STORE IN DATA
        TIX      PICK,4,1            DO AGAIN
*       GET AGCS
        STZ      IAGC1
        STZ      IAGC2
        AXT      599,4
        AXT      9,1
PICKX   CAL      **,4
        ANA      SIV
        ADD      IAGC2
        STO      IAGC2
        TXI      *+1,4,-1
        TIX      PICKX,1,1
        AXT      10,1
PICKY   CAL      **,4         2
        ANA      SIV          2
        ADD      IAGC1        2
        STO      IAGC1        2
        TIX      *+2,4,1      1
        TRA      STOP
        TIX      PICKY,1,1    1
        AXT      10,1
PICKZ   CAL      **,4
        ANA      SIV
        ADD      IAGC2
        STO      IAGC2
        TIX      *+2,4,1
        TRA      STOP
        TIX      PICKZ,1,1
        TRA      PICKY-1
STOP    LAC      FLOT,4
        CLA      IAGC1
        ARS      12
        STO*     4,4
        CLA      IAGC2
        ARS      12
        STO*     5,4
        AXT      599,1
PICKW   CLA      **,1
```

```
        SSP
        ARS      8
        ANA      =8
        STO      IAGC1
        ARS      3
        ADD      IAGC1
        ADD      =1
        STO*     6,4
        RETURN   FLOT
IAGC1   BSS      1
IAGC2   BSS      1
SIV     OCT      77770000
        END
```

```
$IBMAP FCNV
*       CALL-    CALL FCNV(IWD,IFREQ)
        PMC
        ENTRY    FCNV                      CONVERTS FREQUENCY WORD
*
ODDBIT  MACRO    SIV                       GETS THE UNCONVENTIONAL DIGITS
        ANA      =0303                     GETS THE BITS YOU WANT
        LRS      2                         PUTS LOW ORDER IN MQ
        ARS      4                         PARKS HIGH ORDER AT END OF AC
        LLS      2                         PUTS ALL IN AC
        ENDM
*
CNV     MACRO    N,OPP                     SHIFTS,BLANKS,AND ACCUMULATES
        CLA      WORK                      GETS THE INPUT WORD
        ARS      N                         PUT DIGIT OF INTEREST ON RIGHT
        OPP      SIV                       BLANKS UNWANTED BITS
        LRS      3
        ADD      PROD                      MULTIPLIES
        LLS      3                         BY TEN
        ADD      PROD                      AND
        ADD      PROD                      ACCUMULATES
        STO      PROD
        ENDM     CNV
*
FCNV    SAVE                               NOW GET TO WORK
        CLA*     3,4                       INPUT WORD
        STO      WORK                      INPUT WORD
        STZ      PROD                      CLEAR WORKING SPACE
        CNV      16,ODDBIT                 MOST SIGNIFICANT DIGIT
        CNV      4,ODDBIT                  OTHER HIDDEN DIGIT
        CNV      30,ANA                    HUNDRED THOUSANDS DIGIT
        CNV      24,ANA                    TEN THOUSANDS DIGIT
        CNV      18,ANA                    THOUSANDS DIGIT
        CNV      12,ANA                    HUNDREDS DIGIT
        CNV      6,ANA                     TENS
        CNV      0,ANA                     THAT-S ALL,FOLKS.
        CLA      PROD                      GET THAT ANSWER
        STO*     4,4                       PUT IT AWAY
        RETURN   FCNV                      AND GO HOME
SIV     OCT      17                        MASK FOR 4 BIT BCD
WORK    BSS      1                         HOME OF INPUT WORD
PROD    BSS      1                         ACCUMULATE CONVERTED NUMBER
        END
```

```
$IBMAP BSP
*        CALL-    CALL BSP(N,TAPENO)
         ENTRY    BSP
BSP      SAVE     1,2,4                SAVE REGISTERS
         CLA*     3,4                  GET NUMBER OF RECORDS
         PAX      ,1                   X1
         CLA*     4,4                  GET TAPE NUMBER
         PAC      ,2                   X2
         TXL      NOP,2,TP             TAPENO MUST BE LESS THAN 5 OR GO HOME
BSPW     TCOA     *                    DELAY
         BSR      X,2
         TIX      BSPW,1,1             DO AGAIN
         TCOA     *                    MAKE SURE ITS DONE
NOP      RETURN   BSP                  GO HOME
TP       OCT      77773                COMPLEMENT OF 5
X        BOOL     1220
         END
```

```
$IBFTC RAD1     DECK,LIST
      SUBROUTINE RAD1(RA,DEC,ALPH,DELT)
      F=0.
      ANGLE=RA
 9001 JDEG=ANGLE/10000.
      FDEG=JDEG
      JMIN=ANGLE/100.
      FMIN=JMIN-100*JDEG
      RADS=(ANGLE-40.*FMIN-6400.*FDEG)/206264.81
      IF(F.NE.0.)GO TO 9002
      ALPH=15.*RADS
      F=1.
      ANGLE=DEC
      IF(DEC.GE.0.)GO TO 9001
      F=-1.
      ANGLE=-ANGLE
      GO TO 9001
 9002 DELT=F*RADS
      RETURN
      END
```

```
$IBFTC RAD2     DECK,LIST
      SUBROUTINE RAD2(NS,N1,N2,N3,N4,N5,N6,DECRAD)
      DECRAD=36000*N1+3600*N2+600*N3+60*N4+10*N5+N6
      DECRAD=DECRAD/206264.806
      IF(NS.NE.0)DECRAD=-DECRAD
      RETURN
      END
```

```
$IBFTC RAD3     DECK,LIST
      SUBROUTINE RAD3(N0,N1,N2,N3,N4,N5,N6,RARAD)
      RARAD=360000*N0+36000*N1+6000*N2+600*N3+100*N4+10*N5+N6
      RARAD=RARAD/137509.87
      RETURN
      END
```

```
$IBFTC RAD4     DECK,LIST
      SUBROUTINE RAD4(NS,N1,N2,N3,N4,N5,N6,HARAD)
      HARAD=36000*N1+6000*N2+600*N3+100*N4+10*N5+N6
      HARAD=HARAD/137539.87
      IF(NS.NE.0)HARAD=-HARAD
      RETURN
      END
```

```
$IBFTC RADOUT  DECK,LIST
      SUBROUTINE RADOUT(RAD,ND,NM,FS)
      ND=57.29578*RAD
      NM=3437.7468*RAD
      FS=206264.806*RAD-60.*FLOAT(NM)
      NM=NM-60*ND
      IF(RAD.GE.0.) GO TO 9011
      NM=-NM
      FS=-FS
 9011 RETURN
      END
```

```
$IBMAP BCDCNV
*       CALL-    CALL BCDCNV(NNOS,NS,N0,N1,N2,N3,N4,N5,N6)
        ENTRY    BCDCNV
BCDCNV  SAVE
        CAL*     3,4                GET INPUT WORD
        LGR      35                 PUT ALL BUT SIGN IN MQ
        STO*     4,4                STORE SIGN
        PXA                         CLEAR AC
        LGL      5                  FIRST DIGIT AFTER SIGN HAS BEEN BLANKED
        STO*     6,4                IS THE THIRD OUTPUT
        PXA
        LGL      2                  THE FIRST TWO BITS OF THE NEXT DIGIT
        STO*     5,4                ARE THE SECOND OUTPUT
        PXA
        LGL      4                  THE LAST FOUR BITS OF THIS DIGIT
        STO*     7,4                ARE THE FOURTH OUTPUT
        PXA
        LGL      6                  THE REST OF THE DIGITS
        STO*     8,4                ARE TAKEN ENTIRE
        PXA                         AND PUT IN OUTPUTS
        LGL      6                  IN ORDER
        STO*     9,4
        PXA
        LGL      6
        STO*     10,4
        PXA
        LGL      6
        STO*     11,4
        PXA
        RETURN   BCDCNV
        END
FINISH
$IBSYS
```

```
$IBMAP NOCNV
*      CALL-    CALL NOCNV(NNOS,NSID,NSCAN,NREC)
       ENTRY    NOCNV
NOCNV  SAVE                       SAVE REGISTERS
       CAL*     3,4               GET NNOS
       LGR      35                PUT ALL BUT SIGN IN MQ
       STO*     4,4               STORE SIGN
       PXA                        CLEAR AC
       LGL      5                 LEFT DIGIT
       STO      THOS
       PXA                        CLEAR AC
       LGL      6                 HUNDREDS DIGIT
       STO      HUNS
       PXA                        CLEAR AC
       LGL      6                 TENS DIGIT
       STO      TENS
       PXA                        ONCE MORE
       LGL      6                 UNITS DIGIT
       STO      UNITS
       PXA                        CLEAR LAST OF SCAN NUMBER FROM AC
       LGL      12                BRING IN RECORD NUMBER
       STO*     6,4               STORE REC NO
       LDQ      TENS
       MPY      =10               I AM NOW
       STQ      TENS              CONVERTING
       LDQ      HUNS              THE BCD
       MPY      =100              TO BINARY
       STQ      HUNS
       LDQ      THOS
       MPY      =1000
       LLS      35                PUT THOSANDS IN AC
       ADD      HUNS
       ADD      TENS
       ADD      UNITS             NOW I HAVE THE SCAN NUMBER,
       STO*     5,4               WHICH I STORE
       RETURN   NOCNV
THOS   BSS      1
HUNS   BSS      1
TENS   BSS      1
UNITS  BSS      1
       END
```

```
$IBMAP SUMS
*       SUMS -  DATA POINTS SUMMATION, ETC. ROUTINE
*
*       CALL -  CALL SUMS(CDEL,SDEL,DATA,CFT,SFT,SAVG,SUMSQ)
*
        ENTRY   SUMS
 SUMS   SAVE    1,2,4
        LAC     SUMS,4                  PICK UP COMPL. OF LOC. TSL+1
        STZ     SSQ                      CLEAR WORKING CELLS
        STZ*    7,4                      (7,4 = SAVG)
        CLA     4,4                      PICK UP LOC OF DATA BLOCK
        ADD     TAG01                    INSERT IR 1 TAG, UP ADDRESS BY 599
        STO     DATA1                    STORE OFF AS REFERENCE CELL
        CLA     4,4                      LOC. OF DATA BLOCK AGAIN
        ADD     TAG02                    INSERT IR 2 TAG, UP ADDRESS BY 298
        STO     DATA2                    STORE OFF AS REFERENCE CELL
        AXT     599,1
 S0034  CLA*    7,4                      (SAVG)
        FAD*    DATA1
        STO*    7,4                      SAVG = SUM OF DATA POINTS
        LDQ*    DATA1
        FMP*    DATA1
        FAD     SSQ
        STO     SSQ                      SSQ = SUM OF SQUARES OF DATA POINTS
        TIX     S0034,1,1
        CLA*    7,4                      (SAVG)
        FDP     LIT04
        STQ     AVG                      AVG = SAVG/599.
        LDQ*    7,4
        FMP     AVG
        FSB     SSQ
        CHS
        STO*    8,4                      SUMSQ = SSQ-AVG*SAVG
        AXT     300,1
        CLA*    DATA1
        FSB     AVG
        STO*    5,4                      CFT = (DATA+299)-AVG
        STZ*    6,4                      SFT = 0
        CLA     LIT01
        STO     C                        C = 1.
        STZ     S                        S = 0
        CLA     AVG
        FAD     AVG
        STO     AV2                      AV2 = 2.*AVG
        AXT     299,1
        AXT     0,2
 S0036  CLA     C
        STO     C1
        LDQ     S
        FMP*    3,4                      S*SDEL
        STO     D0+2
        LDQ*    2,4
        FMP     C                       C*CDEL
        FSB     D0+2
        STO     C                        C = C*CDEL-S*SDEL
        LDQ     C1
        FMP*    3,4                      C1*SDEL
        STO     D0+2
        LDQ     S
        FMP*    2,4                      S*CDEL
        FAD     D0+2
```

```
         STO     S                      S = S*CDEL+C1*SDEL
         CLA*    DATA2
         FAD*    DATA1
         FSB     AV2
         STO     DO                     DATA(1)+DATA(J)-AV2
         LDQ     DO
         FMP     C
         FAD*    5,4
         STO*    5,4                    CFT = CFT+C*(DATA(1)+DATA(J))
         CLA*    DATA1
         FSB*    DATA2
         STO     DO                     DATA(J)-DATA(1)
         LDQ     DO
         FMP     S
         FAD*    6,4
         STO*    6,4                    SFT = SFT+S*(DATA(J)-DATA(I))
         TXI     *+1,2,1                PICK UP DATA(I) FROM +298 TO +0
         TIX     S0036,1,1              PICK UP DATA(J) FROM +300 TO +598
         RETURN  SUMS
*
 C       PZE     **                     WORKING CELL
 C1      PZE     **                     WORKING CELL
 S       PZE     **                     WORKING CELL
 AVG     PZE     **                     AVERAGE OF DATA POINTS
 AV2     PZE     **                     SQUARE OF AVG
 SSQ     PZE     **                     SUM OF SQUARES
 DATA1   PZE     **                     DATA(J)
 DATA2   PZE     **                     DATA(I)
 TAG01   PZE     599,1                  DUMMY DATA(J) REF.
 TAG02   PZE     298,2                  DUMMY DATA(I) REF.
 LIT01   DEC     1.
 LIT04   DEC     599.
         EVEN
 DO      BSS     4                      WORKING STORAGE FOR FP NUMBERS
         END
```

```
$*      RUN ID  E1575
$IBMAP TREAD
       PMC
*      TREAD - 602-WORD BINARY TAPE READ ROUTINE FOR CHANNEL A
*      MODIFIED MAR 12 1965   BY B CLARK
*
*      CALL -  CALL TREAD(TAPENO,BUFFER,FLAGWD,NOWRDS)
*
*              FLAGWD WILL BE SET FROM 0 TO 15.  THE 4 LOW-ORDER BITS
*              HAVE THE FOLLOWING SIGNIFICANCE -
*
*              0 - RECORD HAS BEEN READ, NO PROBLEMS
*              1 - RECORD HAS PERSISTENT REDUNDANCY FAILURE (3 REREADS)
*              2 - RECORD IS END-OF-FILE
*              4 - RECORD IS END-OF-TAPE
*              8 - PERSISTENT  I-O CHECK
*
 RTBA  OPD     076200001220,*,1,2,0
 BSRA  OPD     076400001220,*,1,2,0
       ENTRY   TREAD
 TREAD SAVE    1,2
TRSKIP LAC     TREAD,4
       ENB     =0
       STZ*    4,4                 RESET FLAG WORD
       CLA     3,4                 PICK UP STARTING LOCATION OF BUFFER
       ORA     TRDCC               BUILD DATA CHANNEL COMMAND
       STO     TRCMD
       CLA*    2,4                 PICK UP TAPE NUMBER
       PAC     0,1                COMPL. INTO IR 1
TRTCO  AXT     Y,2            LOAD INDEX FOR TIMING DELAY
       TCOA    *              DELAY IF IN OPERATION
       SEN     X,1            CHECK UP ON TAPE UN+T
       RCHA    TRSEN          CHANNEL COMMAND FOR SENS
       CAL     TRSENS         STATUS WORD
       ARS     30             GET SIGN BIT OUT IN THE OPEN
       ANA     =076            GET STATUS INFO-MAT+ON
       TZE     *+3            ALL CLEAR
       TIX     TRTCO+1,2,1    UNIT NOT READY
       TRA     TRREDY         AND ISNT GETTING READY
       RTBA    0,1                 READ SELECT APPROPRIATE BINARY TAPE
       RCHA    TRCMD               CALL FOR INPUT
       TCOA    *                   DELAY TIL CHANNEL IS FREE
       SCHA    TRCNT
       TCOA    *
       TRCA    TRERR               TEST FOR REDUNDANCY CHECK
 TRRTN CLA*    4,4                 NO, PICK UP FLAG WORD
       TEFA    *+2                 TEST FOR END-OF-FILE
       TRA     *+2                 NO
       ORA     TR002               YES, SET E-O-F FLAG
       ETTA                        TEST FOR END-OF-TAPE
       ORA     TR004               YES, SET E-O-T FLAG
       STO*    4,4                 NO, REPLACE FLAG WORD
       IOT
       TRA     TRERR2
       CLA     TR003
       STO     TRRPT               RESET TAPE REREAD COUNTER
       STO     TRRPT2
       ENB     TRREN
       CLA     TRCNT
       ARS     18
       ANA     TRSIV
       CHS
       ADD     =602
       STO*    5,4
TRRET  RETURN  TREAD               RETURN
```

```
 TRERR LXA     TRRPT,2               PICK UP REPEAT COUNTER
       TNX     TRER3,2,1             TEST IF 3 REREAD ATTEMPTS
       SXA     TRRPT,2               NO
       BSRA    0,1                   BACKSPACE TAPE
       TRA     TRTCO                 GO TO DELAY AND REREAD
 TRER3 CLA     TR001                 3 REREAD FAILURES
       STO*    4,4                   SET REDUNDANCY FLAG
       TRA     TRRTN                 GO TO TEST FOR END CONDITS AND RETURN
TRERR2 LXA     TRRPT2,2
       TNX     TRER4,2,1
       SXA     TRRPT2,2
       BSRA    0,1
       TRA     TRTCO
TRER4  CLA     TR008
       CRA*    4,4
       STO     4,4
       TRA     TRRET
TRREDY TSL     TYPE          TELL OPERATOR UNREADY TAPE
       TXI     *+4,0,2
       BCI     1,TRRED
       PZE     TR001
       PZE     TRMSG
       TRA     TRTCO         SEE IF OPERATOR HELPED ANY
*
 TR001 PZE     1                     REDUNCY FLAG
 TR002 PZE     2                     END-OF-FILE FLAG
 TR003 PZE     3                     FOR RESETTING TAPE REREAD COUNTER
 TR004 PZE     4                     END-OF-TAPE FLAG
TR008  PZE     8
 TRCMD PZE     **                    CONSTRUCTED DATA CHANNEL COMMAND
 TRDCC PTH     **,0,602              DUMMY 602-WORD DATA CHANNEL COMMAND
 TRRPT PZE     3                     REPEAT COUNTER FOR TAPE REREADS
TRRPT2 PZE     3
TRCNT  BSS     1
TRSIV  OCT     7777
TRREN  OCT     000001000001         REENABLE TRAPS
TRSEN  IORD    TRSENS,,1     CHANNEL COMMAND FOR SENS
TRSENS BSS     1             LOCATION OF SENS DATA
TRMSG  BCI     7,TAPE NOT READY. PRESS START WHEN READY.
       OCT     777777777777
       EXTERN  TYPE
X      BOOL    1220
Y      BOOL    77777
       END
```