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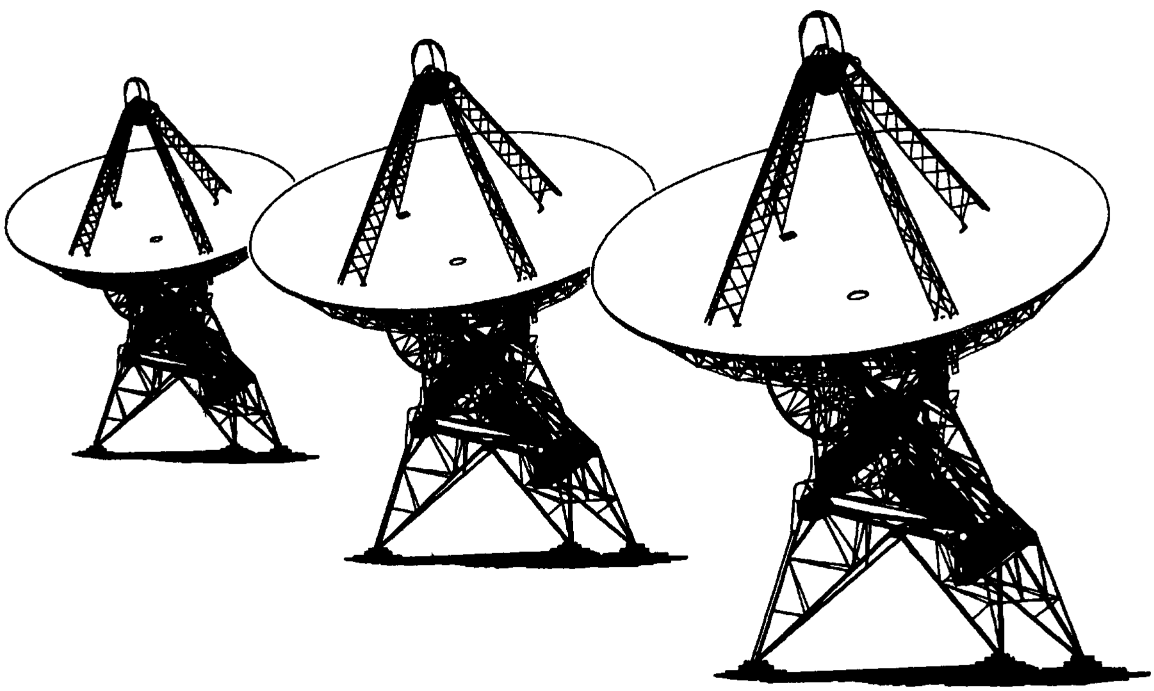
THE NRAO LINE INTERFEROMETER: A MANUAL

E. W. Greisen

National Radio Astronomy Observatory*

Green Bank, West Virginia



*Operated by Associated Universities, Inc., under contract with the National Science Foundation.

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PREFACE TO EDITION 1

This manual is an attempt to describe how to use the NRAO line interferometer while at the telescope and while reducing the data in Charlottesville. This first edition is incomplete in several areas:

(1) The new digital delay system is described in the text, but the effects of this delay system on observing procedures and on data reduction have yet to be fully determined.

(2) The calibration of the autocorrelation quadrant data has not been properly handled in the present programs.

(3) There are as yet no programs to make maps out of the calibrated data.

(4) A number of the subprograms have not been fully debugged including the map editing and display modules and the RF bandpass correction module.

(5) The portions of the various program modules designed to process image and difference band data have not been fully tested.

It is hoped that later editions will correct these deficiencies. In the mean time, all prospective users should consult with the author before attempting to use the telescope and data reduction systems.

Considerable effort has been expended to make this manual and the computer programs both easy to use and free from errors. However, errors undoubtedly remain. These errors can be corrected only if the users will take the trouble to inform the author. The author also solicits any comments and suggestions designed to improve either this manual or the data processing programs.

Eric W. Greisen

April, 1974

ACKNOWLEDGEMENTS

A system as complicated as the NRAO line interferometer can only be developed with the assistance of a large number of people. The very involved on-line computer program was developed by Barry G. Clark and is now in the care of George Conant. The design and construction of the non-digital electronics systems were under the supervision of James Coe, while Ray Hallman and Dwayne Schiebel were responsible for the digital systems. The off-line reduction programs were written principally by the author with the control supervisor being developed and modified by Charles Moore. The CRT communication module was provided by Tom Cram. The present off-line system is based on an earlier system written by Melvin Wright and Charles Moore. The author is grateful to Barry Clark and Robert Brown for their helpful comments on this manuscript and to Donna Beemer for typing it.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

INTRODUCTION

This manual is intended to describe the NRAO line interferometer system with particular emphasis on those aspects of the system which directly affect the user. Chapter I provides a description of the line interferometer and of how to use it during an observing period. Chapter II describes the off-line computer program which carries out the initial processing of the user's data. Chapters III-VIII describe the off-line computer program which may be used to carry out all later processing steps. Appendices A and B review the basic theory of interferometry while Appendices C and N present the gory details of the data formats and the program structure. This manual is not a complete introduction to interferometry or to the use of the NRAO interferometer. For such information the reader should study Chapters I and II of An Introduction to the NRAO Interferometer by R. M. Hjellming.

Line interferometry is simply a combination of conventional continuum interferometry with single-dish total power spectroscopy. There are no fundamental difficulties either in obtaining or in processing the data. However, as with the conventional techniques, there are a great many processing steps which must be taken between the planning of an observing program and the publication of the final results. The NRAO provides the user not only the telescopes themselves, but also the electronics, the personnel to carry out the observations, and the on-line and off-line software needed to obtain and fully process the data. With such support, it would be possible for the NRAO to carry out all of the data acquisition and processing steps with the user only being required to devise the basic idea for the observing program and to write up the results. In the opinion of the author, data obtained in such a fashion would be next to useless. It is not necessary in most circumstances for the user to know how the various processing stages are carried out. However, the user must understand (and be able to control) what is done with his data at every stage in the processing.

It is this philosophy which governs the nature of the principal off-line processing program. This program, HLINEINT, is a heavily overlayed collection of program modules capable of carrying out a wide variety of editing, calibration, mapping, and display tasks. The modules are written in FORTRAN or (only where necessary) in Assembly language. Access to the modules is through a control supervisor called FORTH. This supervisor allows the user a high degree of flexibility in his use of the many processing modules. Although FORTH is, in fact, a powerful computer language, it is not necessary (and probably not even advisable) for the user to have any knowledge of the language. All the user needs to know (or, at least, know how to look up) is a limited vocabulary of control words which allow him to set parameters and to invoke the processing modules. The only FORTH conventions needed by the user are:

(1) Statements are free-format in card columns 1 through 64 and may be separated onto several cards.

(2) Spaces must separate numbers and command words from other numbers and command words.

(3) No blanks may occur within a number, source name or command word (e.g., double word commands are connected by a hyphen).

(4) Positive numbers must be punched <u>without</u> the + sign.

FORTH diagnostic comments are:

(1) OK action completed

(2) ? word not recognized-skip to next command

(3) EMPTY parameter expected and not given

In Appendix F are given a number of examples of the use of the FORTH control supervisor. A complete dictionary of control words is presented in Appendix E.

Chapter I
USING THE LINE INTERFEROMETER

This chapter contains brief descriptions of the hardware and on-line software used by the NRAO line interferometer. Section E is devoted to a discussion of some of the considerations which enter into the planning of an observing session. For an introduction to interferometry and to the use of the NRAO interferometer and for detailed information on the hardware, the user may consult the references given in Section F.

A. The hardware

The line interferometer may be operated at any one of three wavelengths: 21, 11, and 3.7 cm. The RF amplification is provided by Micromega parametric preamplifiers. The observing frequency limits and nominal system temperatures of the three systems are

21 cm	1370 - 1430 MHz	125 °K
11 cm	2660 - 2690, 2700 - 2730 MHz	100 °K
3.7 cm	8060 - 8080, 8090 - 8120 MHz	120 °K

The instantaneous IF bandwidth of all systems is 30 MHz, but this figure applies only to the analogue continuum channels. The total IF bandwidth which applies to the narrow channels is set by the correlator and cannot exceed 10 MHz. The synthesizer frequencies range from 1 to 500 MHz and the IF signals are centered on 10 MHz when they pass through the delay system.

The line interferometer is normally operated as a single sideband instrument. However, because of the different fringe rates, both the "signal" and "image" sidebands may be separately, but simultaneously observed and recorded. The frequency of the signal sideband is given by

$$f_s = 1347.5 \text{ N} \pm (f_{syn} - 130) \text{ MHz}$$

where the + and - signs apply to the upper and lower sidebands, resp., where f_{syn} is the synthesizer frequency, and where N = 1, 2, and 6 for

21, 11, and 3.7 cm, respectively. The frequency of the image sideband is given by

$$f_I = 2695N - f_s \text{ MHz}$$

in both cases. The line interferometer may also be operated as a double sideband instrument. The user should note that the RF bandwidth of the 21-cm receiver restricts operation at that wavelength to a single side-band. Frequency control information is given to the on-line computer program through the FSET data card discussed in Section D.

There are two delay systems used by the line interferometer. One system consists of cable and crystal delay elements and is used only for the analogue continuum (30-MHz bandwidth) channels. The minimum delay increment is 1.953 nanoseconds with a maximum delay of 16 microseconds. Because of the wide bandwidth, this delay system always tracks the delay. Before recording data the user should make certain that this delay system is set to computer control. The other delay system is a digital system built into the correlator. The minimum digital delay increment is 3.125 nanoseconds with a maximum delay, in normal use, of 12.8 microseconds. With this maximum delay, the full 10-MHz bandwidth of the correlator may be used. Maximum delays of 51.2 and 204.8 microseconds are also avail-able. With the larger maximum delays the maximum usable bandwidth becomes 2.5 MHz and 625 kHz, respectively. The larger maximum delays will be of use only after the remote 45-foot telescope becomes available in the line interferometer system. The digital delay system may either track the delays at the appropriate rates or be held fixed during one or more observations ("scans").

B. The correlator

The correlator is shown in Figure I-1 with details shown in Figures I-2 and I-3. The correlator has four filter units labeled A, B, C, and D. The user must connect the desired telescope IF leads to the input connectors of these filter units and must set thumbwheels to indicate

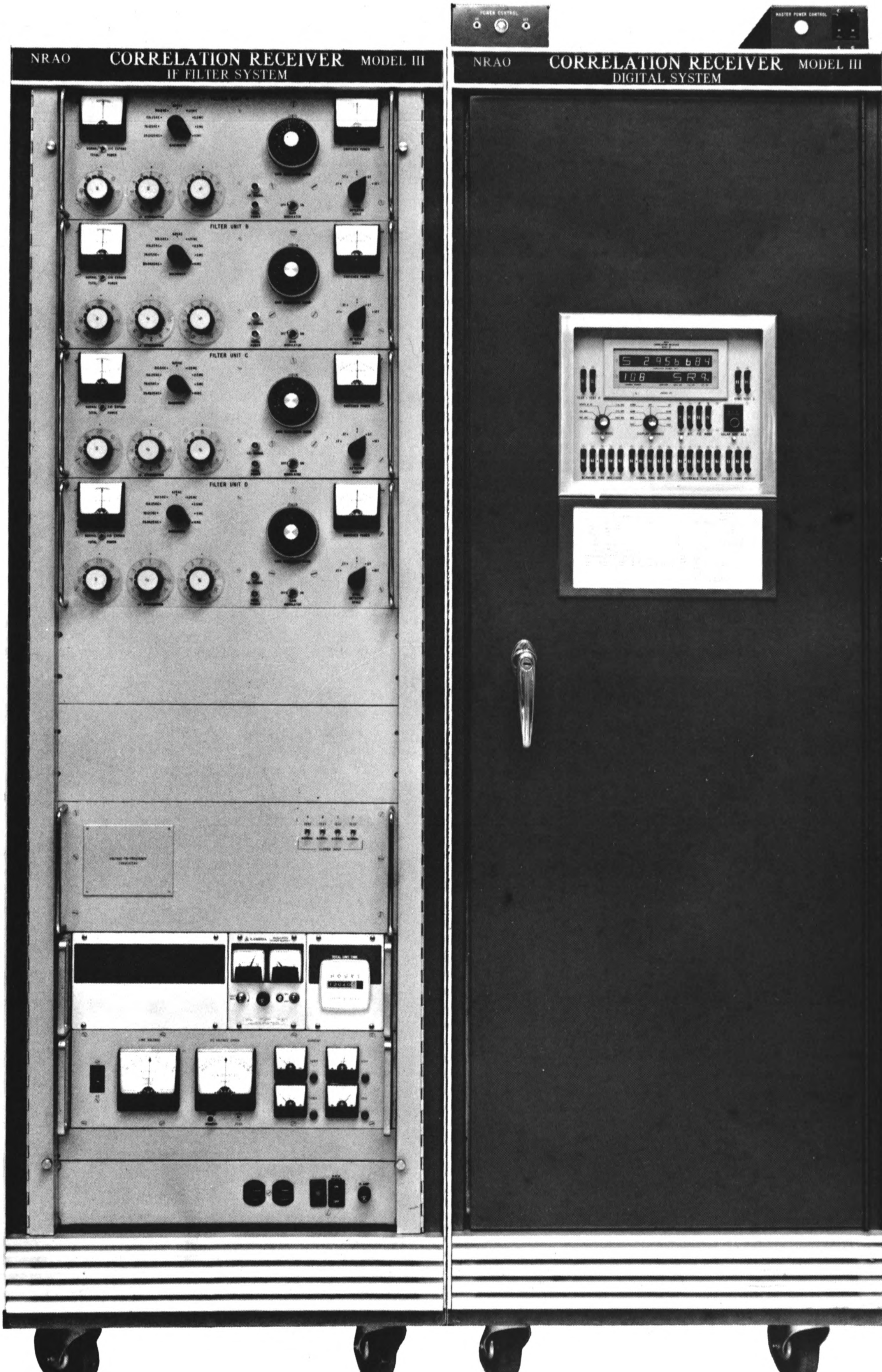


Figure I-1. Correlation Receiver.

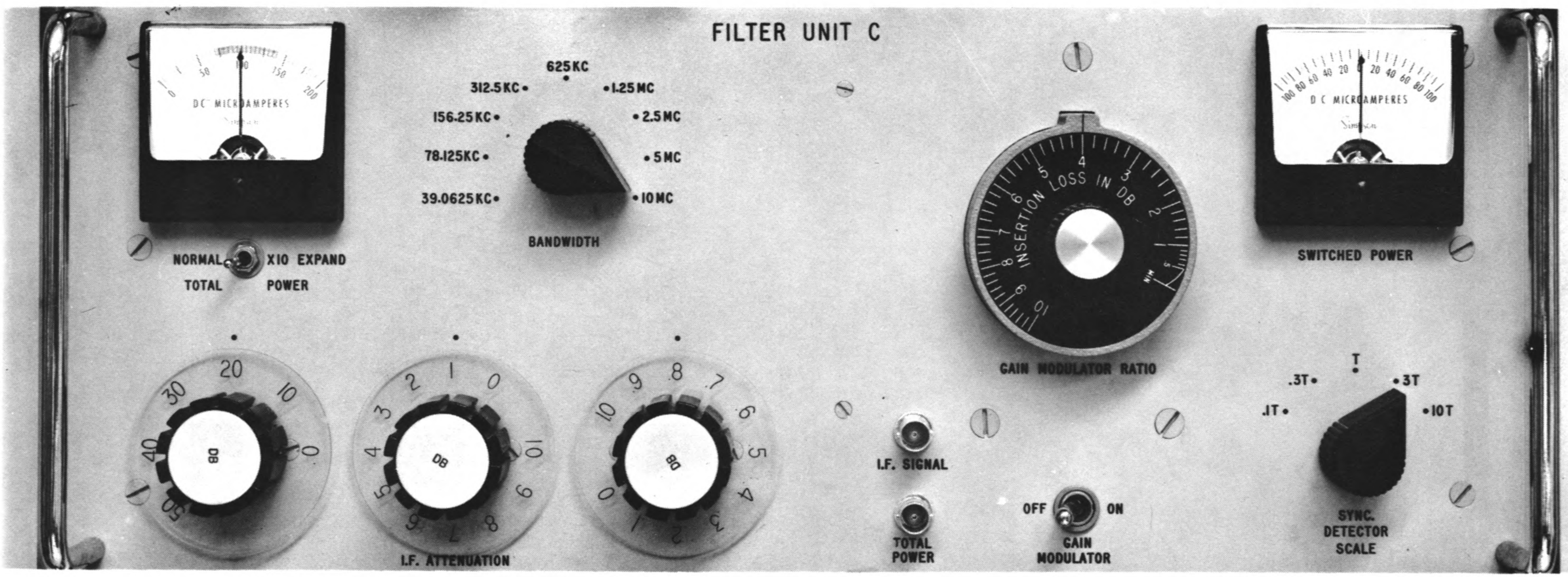


Figure I-2. IF Filter System Controls.

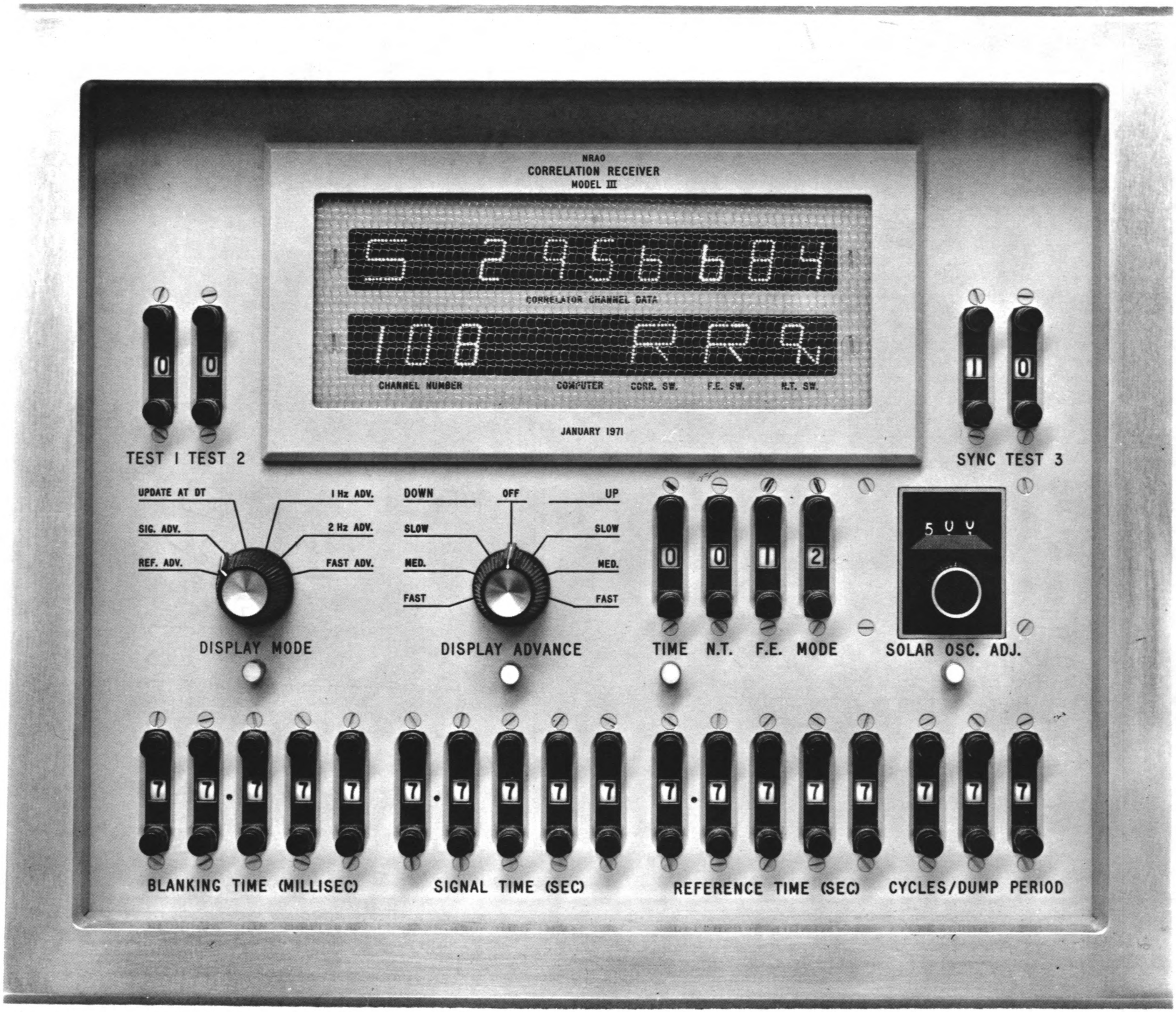


Figure I-3. Digital System Controls.

to the computer which telescope is connected to which filter unit. The input connectors and thumbwheels are located on top of the correlator unit at the back.

The other filter unit controls (Fig. I-2) are found on the upper left front of the correlator. The signal levels should be adjusted using the I.F. ATTENUATION knobs on the filter units so that the TOTAL POWER meters are centered (or are at least in the green area). The total bandwidths of the filter units and thence of the output are set by knobs on the filter units. The available filter widths are 10, 5, 2.5, 1.25, 0.625, 0.3125, 0.15625, 0.078125, and 0.0390625 MHz.

The display and control unit (Fig. I-3) is located on the right hand front of the correlator. The most important control switch is MODE. Modes 1, 2, 3, 4, and 8 are used solely for autocorrelation and are not relevant to the line interferometer. The relevant cross-correlation modes are:

mode 5	1 each	384 channels	input A X B
mode 6	2 each	192 channels	input A X B
			C X D
mode 7	3 each	96 channels	input A X C
			B X A
			C X B
	1 each	96 channels	D X D

Except for the fourth (autocorrelation) quadrant of mode 7, two channels are used in the output spectrum for each frequency, one for the cosine and one for the sine part of the fringe. The spacing between channels is given by B/N where B is the total bandwidth and N is the number of frequency channels (192, 96, or 48). Each channel is equivalent to a filter having a sin x/x shape with a half-power width of 1.21 B/N and a spacing between nulls of 2 B/N. Because of the filters in the correlator, some of the output channels are not reliable. As a rule of thumb, channel I may be regarded as reliable if

$$N/8 < I < N - N/8 \text{ .}$$

The user should, of course, determine for himself the channel range which he regards as reliable.

The correlator controls the switching of the noise tubes needed to determine the system temperatures. The noise tubes add about 20 °K to the system temperatures and are on during the "signal" portion of the switching cycle. For this reason the signal portion of the cycle should be only about 10% of the full cycle. The normal settings of the control switches (see Fig. I-3 although these normal settings are not illustrated) are:

TIME	0
NT	3
FE	0
BLANKING TIME	10.000
SIGNAL TIME	0.09000
REFERENCE TIME	0.89000
CYCLES/DUMP PERIOD	010

The correlator electronics are fairly sensitive to being moved. Thus, the user should check the correlator displays fairly carefully, especially during the first few days after the correlator has been moved to the interferometer. The counts in the various lag channels are displayed as CORRELATOR CHANNEL DATA (see Fig. I-3). The display can be manually or automatically stepped through the channels using the DISPLAY MODE and DISPLAY ADVANCE knobs. The counts in all channels should be very nearly the same. Errors of just a few tenths of a percent can cause large modulations in the output spectra. When there is a strong correlated signal, the counts in the central two or three lag channels of each cross-correlation section will deviate significantly from the usual number of counts. In the autocorrelation quadrant of mode 7, it is the first few lag channels which show the largest deviations.

C. The on-line computer

The principal tasks of the on-line computer are:

(1) point and drive the telescopes,

(2) set the synthesizer,

(3) set and drive the delay systems,

(4) drive the lobe rotator to stop the expected natural fringes,

(5) solve for the sine and cosine parts of the fringes using a phase shifting technique,

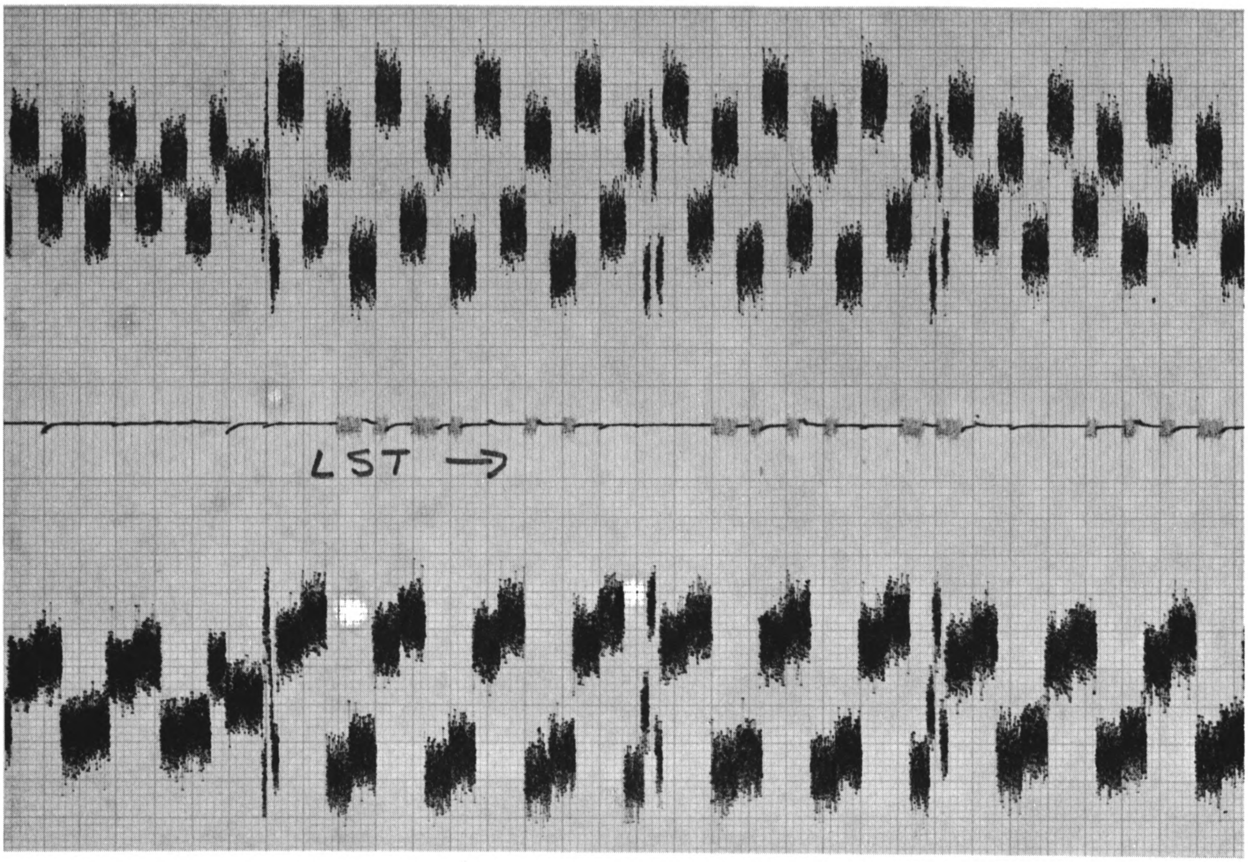
(6) apply the Van Vleck correction and Fourier transform the auto-correlator output,

(7) record the data including the output of numerous monitoring devices,

(8) display the data on two CRT displays.

The data are recorded on seven-track tape with a header record and one or more data records per scan. The formats of these records are listed in Appendix C. The user communicates with the on-line program with a variety of data cards. The telescope operators can communicate with the program from the teletype, but it should not be necessary for the user to do so.

The data are displayed on-line in three ways. The signals in the continuum channels are displayed on chart recorders. Since the fringes are stopped by the lobe rotator, the displayed signals are not the usual sine wave fringe pattern. Instead, the sine portion appears on the R channels and the cosine portion appears on the L channels. The displayed signals have some of the appearance of a square wave because of the regular 90, 180, and 270 degree phase shifts introduced by the computer. (See Fig. I-4.) The on-line program places the values of amplitude and phase from selected channels on a CRT screen set at the operator's console. In addition, the on-line program places a plot of the sine and cosine parts (separately) of all the narrow channels on a second CRT screen. This last display is normally the best monitor of the functioning of the interferometer.



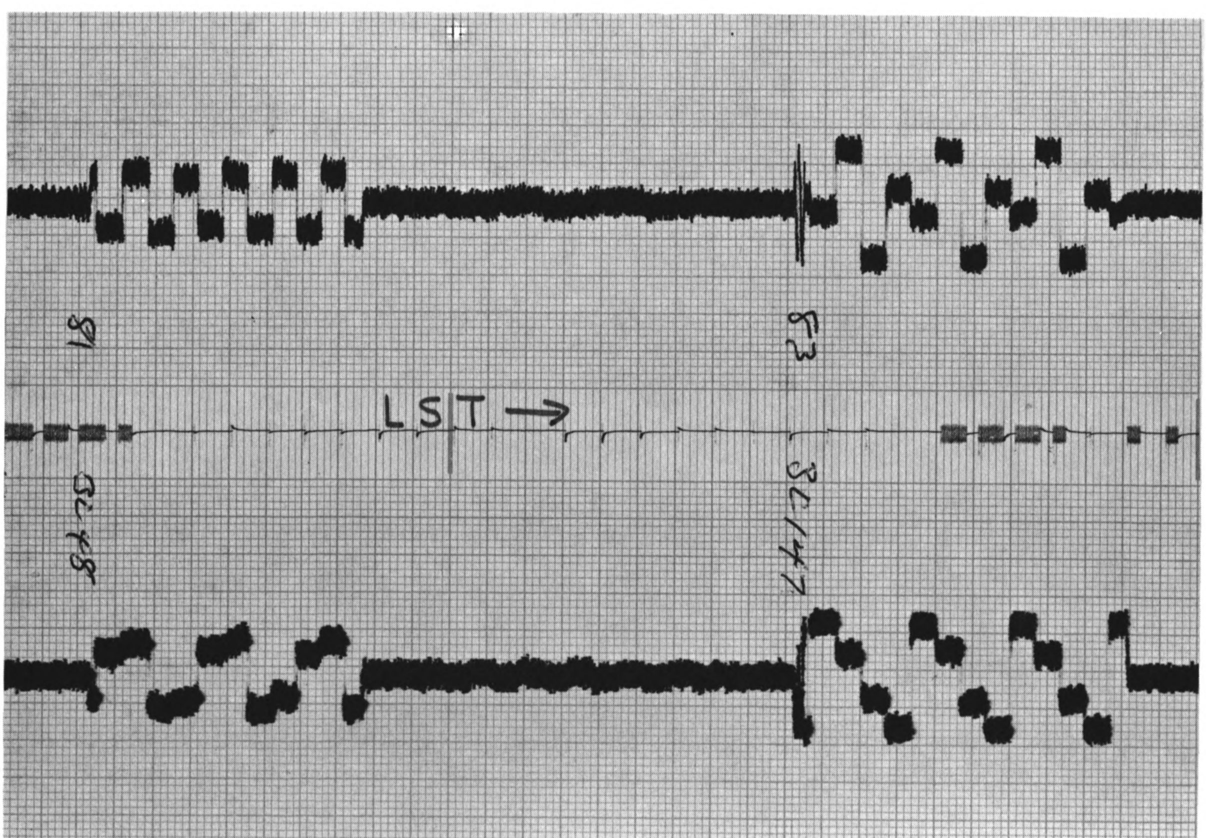


Figure I-4. Sample Chart Record Displays.

There is one detailed convention which the user should understand. The on-line computer records the sums of the narrow channel data in each of the four quadrants (sine and cosine parts separately). The telescope tape computer program, however, alters the nature of these data. Instead of four separate pairs of sums regardless of mode, the telescope tape program creates one, two, and four pairs of averages for modes 5, 6, and 7, respectively. The words in the HLINEINT program (see § III-9) refer to the averages in this form. For example, RX-SUMA refers to the average of the first 48, 96, or 192 frequency channels depending on whether the mode is 7, 6, or 5, respectively. The word RX-SUMB refers to the second 48 or 96 channels for modes 7 or 6. The words RX-SUMC and RX-SUMD have meaning only for mode 7.

D. Card input to the on-line program

The on-line program must first be given information about baseline coordinates, telescope pointing corrections, delay centers, and frequency. Then the program is given any number of cards specifying the scan parameters. The user will normally be responsible only for the frequency card and the scan cards. The observatory personnel will determine the baseline coordinates (from past experience and, perhaps, by measurement), the pointing corrections (from a special sequence of observations), and the delay centers (by experiment). A sample deck for the on-line program is shown in Appendix F, section 1.

1. Baseline coordinates:

Four cards giving the z, x, and y lengths of the baselines (in nanoseconds and in this order) and the baseline numbers are required. The lengths are given with three places after the decimal and the decimal points are punched in columns 8, 28, and 48. The baseline number goes in column 61 and has the meaning

1	BL12	85-1 X 85-2
2	BL13	85-1 X 85-3
3	BL23	85-2 X 85-3
4	BL14	85-1 X 45

Baseline 3 must be given as the difference of baselines 1 and 2: e.g. $BX_3 = BX_1 - BX_2$, etc. Baseline 4 is not used, but the card for baseline 4 must still be entered.

2. Telescope pointing corrections:

   Three cards giving the telescope number followed by 16 pointing parameters per telescope are entered following the baseline cards. The format is (I1, I4, 15I5).

3. Delay centers:

   One card giving the delay centers follows the pointing cards. The units are microseconds X 1024 and the numbers are in octal. The delay center of the delay line in telescope 2 goes in columns 1-6, of telescope 3 in columns 11-16, and of the long delay for the 45 foot in columns 21-31. The numbers must be right justified and leading zeros must be punched.

4. Frequency parameters (FSET card):

Columns	Format	Information	
1 - 4	A4	FSET	
19 - 30	F12.0	line rest frequency in Hz (decimal in col. 30)	
39 - 50	F12.0	signed sum of local oscillator frequencies except synthesizer prior to delay lines in Hz (decimal in col. 50)	
60 - 70	F11.0	signed sum of local oscillator frequencies applied after delay lines in Hz (decimal in col. 70)	
77	A1	S or D	sidebands (single, double)
78	A1	F or V	delays (fixed, variable)
79	A1	S or L	integration time (short, long)
80	A1	S or L	record length (short, long)

Comments:

(a) The line rest frequency is combined with the velocity on the scan card to determine the observing frequency. If you are observing very large redshifts, it is recommended that you define a spurious rest frequency near your passband and difference your source z's from that of your defined "rest frequency".

(b) The frequency entered in columns 39-50 is that LO frequency which is beat to zero by the lobe rotators. As such it is the local oscillator frequency (double sideband or variable delays) or the observing frequency (fixed delays). The numbers to enter are:

for tracked delay, upper sideband as signal band

21 cm	1207500000.
11 cm	2555000000.
3.7 cm	7945000000.

for tracked delay, lower sideband as signal band

21 cm	(1487500000.)
11 cm	2835000000.
3.7 cm	8225000000.

for fixed delay, upper sideband as signal band

21 cm	1217500000.
11 cm	2565000000.
3.7 cm	7955000000.

for fixed delay, lower sideband as signal band

21 cm	(1477500000.)
11 cm	2825000000.
3.7 cm	8215000000.

Do not use the numbers in parentheses.

(c) The LO frequency after the delay line (columns 60 - 70) is 0 for fixed delay and ±010000000. for variable delay with the upper (+) or lower (-) sideband as the signal band.

(d) In column 77 enter S for single sideband operation (even if both sidebands are to be separately recorded). Enter D for double sideband operation to have the computer operate the second lobe rotator to preserve the phase relationship between the sidebands.

(e) In column 78 enter F for fixed delay operation or V for variable (tracked) delay operation. If F is specified, the digital delays are changed by the computer only when a scan card of mode D is encountered.

(f) In column 79 enter S for short integration time records (80 seconds) or L for long records (160 seconds). For baseline 3 only, the effects of correlator bias are not completely eliminated in 80-second integrations. Thus, if S has been specified, the data from baseline 3 should be averaged to 160 seconds before serious use is made of them. (See § III-4 for how to do this averaging.)

(g) In column 80 enter S to have only signal band data recorded or L to have both signal and image band data recorded.

5. Scan cards:

Columns	Format	Information
1 - 8	A8	source name
12 - 23	2(I2,1X),F6.3	source right ascension
25 - 36	A1,2(I2,1X),F5.2	source declination
38	A1	epoch code
48	I1	gain code for baseline 1
49	I1	gain code for baseline 2
50	I1	gain code for baseline 3
52	A1	mode
54 - 58	I2,1X,I2	start time (LST) HH MM
60 - 64	I2,1X,I2	stop time (LST) HH MM
66 - 72	F7.1	velocity offset

Comments:

(a) The source name, source position, stop time and velocity offset must be punched on each scan card. Put comments in columns 74 - 80 only.

(b) The source name must be left justified and can contain from one through 8 alphameric characters but must not contain imbedded blanks. If the source is to be a calibrator taken from the standard list (see Appendix D and § V-1), the name must be identical to that given in the standard list.

(c) The code in column 38 specifies the epoch of the punched position with a blank signifying 1950.0. A code of M is given for mean positions at the nearest Besselian year and of D for current positions.

(d) Because of saturation problems with the analogue correlators and because the narrowband data will be stored off-line in half-word integers, it is necessary to assign a gain setting to each source and baseline. Gain codes are 0, 1, 2, and 3 for multiplication by 1.0, 0.1, 0.01, and 0.001, respectively. The multiplication is carried out by the hardware for the continuum data and by the off-line software for the narrowband data. The counts per flux unit (of fringe amplitude) for the narrowband data is typically 8000-10000 at 21-cm while the limit on half-word integers is 32767. Thus, for sources above about 2.5 flux units a gain code of 1 is needed, for sources above 25 flux units a gain code of 2 is needed, etc. For observations with narrow single-channel bandwidths it is advisable to use a gain code of at least 1 at all times since the noise in the data can be on the order of several flux units. (For single channel bandwidth B in kHz, the 3σ deviation is about $14/\sqrt{B}$ flux units.)

(e) The scan mode (not to be confused with the correlator mode) is given in column 52 with a blank indicating a normal observation. Enter U if the velocity offset on the card is topocentric rather than relative to the local standard of rest. Enter C if the frequency of the scan is to be computed using the local standard of rest velocity of the previous scan card together with the velocity offset of the present card. Enter D to set the digital delays and the local standard of rest velocity to the position and stop time of the present card without recording any data.

(f) The start and stop times are given in local sidereal time. If the start time is left blank the scan will start as soon (after the previous scan) as the source has been acquired. The scan will stop at the end of the first 80 (or 160) second integration period ending after the stop time.

(g) The signal band, radial velocity offset is given in km/sec relative to the local standard of rest (except for scan mode U above). The observing frequency is computed using the optical astronomical convention:

$$V_R = cz = c\ \Delta\lambda/\lambda_o = c\ \Delta\nu/\nu$$

WARNING: some observers define a radial velocity V' as

$$V' = c\,\frac{\Delta\nu}{\nu_o} = V_R\ \left(\frac{1}{1 + V_R/c}\right)$$

which, at high values of V_R, differs substantially from V_R. For example, if V_R = 6000 km/sec, V_R-V' = 118 km/sec.

Up to 100 scan cards may be read into the computer at a time. However, when the 100 cards have been used up, more scan cards may be entered without entering cards of the other types.

E. Planning an observing session

It is impossible to describe all of the considerations which will enter into the planning of observing sessions. However, there are some points of sufficient importance and general interest that they should be mentioned.

It is best to plan in great detail the entire sequence of observations well in advance of the observing session. The scan cards should also be punched well in advance. In planning the observations remember that

(1) the telescopes require a driving time of about 45 seconds plus about one minute for every 20 degrees,

(2) the observing sequence should allow 5-10 minutes each day (preferably just before 8 a.m. local time) for telescope tapes to be changed,

(3) the accuracy of the data can be no better than the accuracy of the calibrations, and

(4) the hour angle range of the telescopes is $\pm 5^h\ 40^m$ at positive declinations and $\pm 4^h\ 40^m$ at negative declinations with added restrictions due to the mountains at positive hour angles.

In deciding how long the scans should be, consider

(1) if scans are only one or two records long, the set-up time required by the on-line program will be a significant fraction of the total observing time,

(2) for very narrow bandwidth observations, scans should be fairly short since the observing frequency is held fixed during the scan while the radial velocity of the local standard of rest can change as fast as 0.1 km/sec per hour,

(3) scans should not be too long since, if a parity error occurs in a header record, the entire scan will be lost, and

(4) scans should not be so long as to contain significant changes in the calibrations or the source visibility functions since some of the reduction program modules operate (or, at least,

operate more efficiently) on scans as a whole (i.e. as scan averages).

In order to fully calibrate the data the user will have to make observations of

(1) the corrections to the assumed baseline parameters (a 24-hour set of scan cards is available at the telescope and 4 or more hours of data should be taken for all relevant baselines once during the session),

(2) the slope of phase as a function of frequency (several hours of data should be taken once during the session by observing a single source such as 3C286 at a wide variety of velocities),

(3) the instrumental phase and gain as functions of time (observe a phase and gain calibrator at least once per hour or more often during times when the outside air temperature is changing rapidly), and

(4) the IF bandpass shape (is a slow function of time, but, since this calibration depends on the signal-to-noise ratios of individual channels rather than sums of channels, you should devote a significant fraction of the observing time to observations of continuum bandpass-shape calibrators).

Observation (2) above will also provide information on the RF (front end) bandpass shape. The data may be corrected for the RF bandpass, but such corrections are significant only if observations at one frequency are used to calibrate observations at significantly different frequencies. The choice of calibration sources is up to the user. He should be cautious, however, in using sources which vary in their flux, which may be partially resolved, or which have galactic hydrogen absorption features.

The noise in the system may be estimated from

$$\sigma = 10\ (\text{f.u./°K})\ \frac{1.57\ (T_R + T_A)}{[2\ \tau\ \Delta\nu\ ]^{1/2}}$$

where T_R is the receiver temperature, T_A the antenna temperature, τ the integration time, and $\Delta\nu$ the bandwidth. The factor of 1.57 arises from the one-bit sampling in the correlator. The formula may be expressed as

$$\sigma = 3.5 \left(\frac{T_R + T_A}{125}\right) \frac{1}{[N \Delta\nu/2]^{1/2}} \quad \text{flux units}$$

where N is the number of 80-second records averaged and $\Delta\nu$ is in kHz. The Hjellming reference is commended to the reader for an excellent discussion of noise in interferometric observations.

F. References

1. Interferometry and the NRAO interferometer
   a. Fomalont, E. B. 1973, "Earth-Rotation Aperture Synthesis", Proc. IEEE, 61, 1211.
   b. Hjellming, R. M. 1973, An Introduction to the NRAO Interferometer.

2. The NRAO line interferometer
   a. Coe, J. R. 1971, "3-Element Interferometer 3.7, 11, and 21 cm Receivers", NRAO Electronics Division Internal Report No. 113.
   b. Shalloway, A. M., Mauzy, R., and Greenhalgh, J. 1972, "Correlation Receiver Model III: Operational Description", NRAO Electronics Division Internal Report No. 125.
   c. Wright, M. H. C., Clark, B. G., Moore, C. H. and Coe, J. 1973, "Hydrogen-line Aperture Synthesis at the NRAO: Techniques and Data Reduction", Radio Science, 8, 763.

3. Hydrogen-line absorption profiles
   a. Hughes, M. P., Thomson, A. R., and Colvin, R. S. 1971, Ap. J. Suppl., 23, 323.
   b. Radhakrishnan, V. et al. 1972, Ap. J. Suppl., 24, 1 and following articles.

CHAPTER II. THE TELESCOPE TAPE PROGRAM

On a daily basis the seven-track data tape recorded by the on-line control program is carried from Green Bank to Charlottesville. There the seven-track tape is immediately processed by a program called HLINETAP. It is the responsibility of the user <u>in advance of the observing period</u> to have an observer tape (9 track, 1600 bpi) tape assigned to him and to provide the appropriate computer division personnel (Ann Jackson) with any data cards which may be required by the HLINETAP program.

HLINETAP reads a seven-track telescope tape and writes a nine-track, Fortran-readable observer tape. In so doing, the program converts the data formats, applies the gain settings to the narrow channel data, rearranges the data, and checks for parity errors, length errors, discontinuities in the total power channels and abnormalities in the weather and interferometer control parameters. The user may also elect to:

(1) Have scan average profiles plotted on the printer.

(2) Have the header and first n data records of each scan dumped (as half-word integers) and the n single-record profiles plotted on the printer.

(3) Override the recorded gain settings.

(4) Discard the image band data (when recorded).

(5) Have only a specified scan range of the telescope tape processed by the program.

CARD DECK SETUP:

```
//HLINE  JOB  (acc,P,6,13,3),yourname,MSGLEVEL=(1,1)CLASS=D
//       EXEC  HLINETAP,TN9=iiii,DSN9=aaaaaa,TN7=jjjj,DSP={NEW
                                                          MOD}
//GO.SYSIN  DD  *
      data card of type 1 (control parameters)
      data card of type 2 (FSET parameters)
      data card(s) of type 3 (GAIN override parameters)
/*
```

EXPLANATION:

(a) JCL card parameters

acc:	your computer account number (required)
yourname:	your name without blanks
iiii:	tape number of your observer tape (required)
aaaaaa:	data set name of observer tape (required)
jjjj:	tape number of your telescope tape (required-will be added by Ann Jackson)

DSP parameter: Set to NEW for an unlabeled (or already labeled) tape having no data and set to MOD for an already labeled tape containing data. MOD is the default if the DSP parameter is omitted.

(b) Data cards

The data cards are all optional. However, if a data card of type 2 and/or data cards of type 3 are to appear, then a data card of type 1 must appear.

(i) Data card of type 1 (control):

Columns	Format	Information
2 - 5	A4	Enter 'AVER' if scan average profiles are desired. Leave blank otherwise. Default is blank.
7 - 9	I3	Number of data records dumped and plotted in each scan. Default is 0.
11 - 14	A4	If card of type 2 is desired, enter 'FSET'. Default is blank.
16 - 19	A4	If card(s) of type 3 are desired, enter 'GAIN'. Default is blank.
21 - 24	Z4	Receiver-baseline connection override. Default is 0000. See format notes below.
26 - 30	I5	Minimum scan number to be processed. Default is 0.
32 - 36	I5	Maximum scan number to be processed. Default is 32767.

(ii) Data card of type 2 (FSET):

The FSET card immediately follows the control card and is included only if FSET is punched in columns 11-14 of the control card. The card is identical in format to the FSET card used at the telescopes.

Columns	Format	Information
1 - 4	A4	Enter 'FSET'
19 - 30	F12.0	Line rest frequency in Hertz. Default is 1420405752.
39 - 50	F12.0	Local oscillator frequency (before delay line and excluding the synthesizer) in Hertz. Default is 1217500000.
59 - 70	F12.0	Signed sum of local oscillators applied after the delay line. Default is 0.
77	A1	Set to S or D for single or double side-band. Default is S.
78	A1	Set to V or F for variable or fixed delays. Default is F.
79	A1	Set to S or L for short (80-seconds) or long (160-seconds) records. Default is S.
80	A1	Set to S or L for short (signal band only) or long (both signal and image band) data records. Default is S. If this parameter is set to S, image band data (when present) will be dumped and plotted, but will not be written on the observer tape. If this parameter is set to L, image band data (when present) will appear on the observer tape as a separate data record immediately following the associated signal band data record.

(iii) Data card of type 3 (GAIN):

Include between 1 and 100 cards of this type only if GAIN is punched in columns 16-19 of the CONTROL card. Include cards only for those sources for which a gain override is desired.

Columns	Format	Information
2 - 9	A8	Source name as recorded on tape
11 - 14	Z4	Gain to be applied (see format note below)

FORMAT NOTES:

1. Receiver-baseline connection override

Column of CONTROL card	Information
21	Baseline number to be used for channels 1 - 96.
22	Baseline number to be used for channels 97 - 192.
23	Baseline number to be used for channels 193 - 288.
24	Baseline number to be used for channels 289 - 384.

Where the Baseline number = 1 for baseline 1-2
Baseline number = 2 for baseline 1-3
Baseline number = 3 for baseline 2-3
Baseline number = 4 for the autocorrelator

NOTE: If any of these parameters are to be overridden, <u>all</u> must be overridden.

2. Gain override

Column of GAIN card	Information
11	Gain code number for baseline 1-2
12	Gain code number for baseline 1-3
13	Gain code number for the auto-correlator
14	Gain code number for baseline 2-3

Where the gain code number = 0 for multiplication by 1.000
gain code number = 1 for multiplication by 0.001
gain code number = 2 for multiplication by 0.100
gain code number = 3 for multiplication by 0.010

NOTE: (a) If any of these parameters are to be overridden, <u>all</u> must be overridden.

(b) Be careful with the unusual, but unavoidable, ordering of these gain codes and baselines.

OUTPUT:

(1) Tape: The data are converted in format and reorganized and written on the nine-track observer tape. The organizations of the data are explained in Appendix C.

(2) Cards: The program converts the narrow channel data from integer *4 format to integer *2 format by applying the gains. If the conversion causes an overflow to occur, a card is punched giving the correct value for the particular channel as well as the scan and channel numbers. These cards may be entered in the HLINEINT program (see § III-8) to recover the correct values for the channel amplitudes.

(3) Printer (normal): At the beginning the program prints a summary of the input parameters. At the end the program prints a summary giving the number of headers and data records transferred and the number of headers and data records lost due to lack of data, restarts, parity errors, and missing headers. The initial values of the weather and total power monitors are also printed.

(4) Printer (optional): As previously explained, the user may elect to have single record and scan average profiles plotted. The profiles give the amplitude (scaled from 0 to the peak value present) and the phase (scaled from -180 to 180 degrees). The user may have the header and n records of each scan dumped. The dump occurs prior to format conversion and data reorganization and assumes that all parameters are half-word integers. The narrowband data itself is dumped as full words (prior to the application of the gains) in the proper IBM 360 format.

(5) Printer (error conditions): Whenever a possible error condition is detected, a message is printed. Most of the messages are self explanatory and need no further discussion. The most common message concerns a "discontinuity" in the total power monitors. This message can indicate a serious problem. However, a discontinuity will quite properly occur when the antenna temperature is changed sharply (e.g., when the frequency is changed in or out of the general galactic hydrogen emission line).

CHAPTER III. THE OFF-LINE REDUCTION PROGRAM HLINEINT

A. Disk Data Set Creation

HLINEINT is a heavily-overlayed collection of program modules designed to process the data from the observer tape to the final maps and spectra. The program assumes that the data lie on a disk data set which also contains dictionaries for the FORTH supervisor and indices to the data. The first step the user must take is to create his own disk data set. The short program listed below will do this for you.

```
//CREATE  JOB  (nnn,P,6,13,4),yourname,MSGLEVEL=(1,1),CLASS=B
//        EXEC  FORTGCLG
//FORT.SYSIN  DD  *
C    CREATE  RESERVES  A DISK DATA SET FOR THE
C    USER AND TRANSFERS THE FORTH DICTIONARY
C    INTO IT
        REAL*8  A(128)
        DEFINE  FILE  10(4500,256,U,IA)
        DEFINE  FILE  11(4500,256,U,IB)
        DO  10  I = 1, 100
        READ(10'I)  A
        WRITE(11'I)  A
    10  CONTINUE
        STOP
        END
//GO.FT10F001  DD  DSN=GREISEN.FILE,DISP=SHR
//GO.FT11F001  DD  DSN=GREISEN.yourname,UNIT=SYSDA,
        DCB=(DSORG=DA,RECFM=F,BLKSIZE=1024),
        DISP=(NEW,CATLG),SPACE=(CYL,(30,2),,CONTIG)
//
```

You must replace nnn with your computer user number and yourname with your name ($\leq$ 8 characters). Copies of this program may be obtained from the author. Please be careful using this program because serious problems may occur if GREISEN.FILE is damaged.

B. Job Control Language

HLINEINT is usually operated from card input. The card deck to be used is listed below:

```
//HLINE  JOB  (nnn,P,6,13,4),yourname,MSGLEVEL=(1,1),CLASS=L
//       EXEC  HLINEINT,DISKDSN=yourname
               ,RDSN=readname,RTN=iii,RFILE=m
               ,WDSN=writename,WTN=jjj,WFILE=n
//HLINEGO.READER  DD  *
 FORTH LOAD CARDS LOAD HEX 20 LOAD DECIMAL
 Your cards
 DISCARD GOODBY
//
```

HLINEINT may also be run from the CRT graphics terminal. To do this you must request the operators to assign class G to the large partition (180K) and submit the deck listed below:

```
//HLINE  JOB  (nnn,P,6,13,4),yourname,MSGLEVEL=(1,1),CLASS=G
//       EXEC  HLINEINT,DISKDSN=yourname,CRT=,CMOORE=FORTH

               ,RDSN=readname,RTN=iii,RFILE=m
               ,WDSN=writename,WTN=jjj,WFILE=n
```

EXPLANATION:

Parameter		Optional	Default
DISKDSN	catalogued disk data set name	No	None
RDSN	read tape (FT03F001) data set name	Yes	NULLFILE
RTN	read tape (FT03F001) tape number	Yes	0
RFILE	read tape (FT03F001) file number	Yes	1
WDSN	write tape (FT04F001) data set name	Yes	NULLFILE
WTN	write tape (FT04F001) tape number	Yes	0
WFILE	write tape (FT04F001) file number	Yes	1
CRT	turns CRT on or off	Yes	'DUMMY '
CMOORE	data set name for control program	Yes	JOBS
nnn	your computer user number	No	None

C. Basic Command Vocabulary

The dictionary of command words is divided into several subsets. The basic vocabulary is made available using the HEX 20 LOAD command shown on the previous page. The other vocabularies are called EDITS, CALS, MAPS, LOOKS, and CRTS and overlay one another. These vocabularies must be explicitly loaded when they are required.

Throughout chapters III-VIII a number of conventions will be used in describing the command vocabularies. The $\{\ \}$ notation will be used to show a list of options at least one of which much be given by the user either explicitly or by default. In all cases in which there exists a default or in which the user may select more than one item from the list, the default and the multiple choices will be described. A number of command words require one or more numerical arguments. The arguments are half-word integers - i.e. they contain no decimal point and they lie in the range from -32768 through 32767. The user must provide in the indicated order all arguments needed by the command word. In the following descriptions, command words which are directly used by the user are shown in capital letters while arguments, which must be replaced by the user with numerical values, are shown in small letters. The small letters occasionally have numerical subscripts, but these subscripts serve only to differentiate the letters. For example, the description of the command words XRANGE and XSMOOTH (§ III 10) appears as

```
m1   m2   XRANGE
   m      XSMOOTH
```

but the user would enter something such as

```
10   46   XRANGE
   3      XSMOOTH
```

in using these words. Note that almost all arguments preceed the command word. In a very few cases, each digit of a single numerical argument has separate meaning. Such arguments are shown as, for example,

n1n2n3n4

with the accompanying text explicitly stating that it represents a single number.

The following words are available for use at all times after the HEX 20 LOAD command. These words are used extensively by all the vocabulary subsets and, hence, the user should become thoroughly familiar with them.

(1) To specify the name of the source for which a desired action is to be taken enter

FOR ssssssss

where ssssssss contains between one and eight characters with no imbedded blanks and is the name of the source for which the action is to be taken. To carry out the desired action for all sources enter

FOR ALL-SORC

(2) To move the printer to the top of the next page enter

PAGE

(3) To specify the range of scans over which the desired action is to be carried out enter

$$n1 \qquad n2 \qquad \left\{\begin{matrix}\text{SCANS} \\ \text{SCAN-RANGE}\end{matrix}\right\}$$

where n1 ≤ n2 are the lowest and highest scan numbers in the desired range and where the choice between SCANS and SCAN-RANGE depends on the particular command and will be indicated with each command. To have the action carried out for all scans on the data set enter

$$\text{FULL} \qquad \left\{\begin{matrix}\text{SCANS} \\ \text{SCAN-RANGE}\end{matrix}\right\}$$

If SCANS may be used and only scan n is desired, you may enter either of

n   A-SCAN

n n   SCANS

For the command words that use SCANS and deal with data scans (rather than map or map-spectra "scans"), the action is normally taken for all records within each of the scans. To have the action taken only for certain records within a scan enter

i   RECORD   =   j   NR   =

where i is the record number of the first record for which the action is to be taken and j is the number of (consecutive) records for which the action is to be taken. Remember to give this command sequence after the basic command (but before SCANS or A-SCAN) and that the header record is record number zero. The word

HEADS

is equivalent to 0 RECORD = 1 NR = and restricts the action to header records.

(4) To average records within a scan (and in one case across scan boundaries) enter

n INT =

to average n records at a time or enter

AVERAGE

to average all records within a scan. Note that this parameter simply counts records without regard for the number of 80-second intervals which have already been averaged to form the present records. The averaging process itself does weight the records by their integration times. The peculiar order of n INT = is one of the oddities of the control supervisor which is avoided as much as possible. To give an example:

2 INT =

will average records in pairs before displaying or transferring them - thereby approximately halving the number of data records displayed or transferred.

(5) To specify the form of the data to be displayed enter one and only one of

AMPLITUDE	
PHASE	
REAL	(cosine part of fringe)
IMAGINARY	(sine part of fringe)
VECTOR	(both amplitude and phase)
COMPLEX	(both cosine and sine parts)

(6) To define the range of channels to be included in a particular action or display enter

m n RX

where m is the number of the first channel to be included and n is the number of channels included. (In data scans, the real and imaginary parts count as one channel.) For data scans the most commonly used channel ranges may also be specified using one of the following words:

RX-A	(1 48 RX)
RX-B	(49 48 RX)
RX-C	(97 48 RX)
RX-D	(145 48 RX)
RX-AB	(1 96 RX)
RX-BC	(49 96 RX)
RX-CD	(97 96 RX)
RX-ABC	(1 144 RX)
RX-BCD	(49 144 RX)
RX-ABCD	(1 192 RX)

(7) To specify that the action is to be carried out <u>only</u> on one or more record types enter

HEX   n1n2n3n4   YESTYPE

where n1n2n3n4 is a single hexadecimal number and where the ni are the code numbers of the types of records to be included. To invoke the most common of these include only specifications, use one of

DATA	(1 2 3 4)
HEADER	(1 0 0 0)
SIGNAL	(2 0 0 0)
IMAGE	(3 0 0 0)
DIFFERENCE	(4 0 0 0)
UV	(5 0 0 0)
MAP	(6 7 8 9)
DTBEAM	(6 0 0 0)
CLBEAM	(7 0 0 0)
DTMAP	(8 0 0 0)
CLMAP	(9 0 0 0)
MPSPECT	(A 0 0 0)

Some routines will act solely on those data types specified with this parameter, while others will act on all types except when this parameter is specified.

The code numbers are as follows:

1	data header record
2	data record - signal band
3	data record - image band
4	data record - difference band
5	map of data gridded in the (u,v) plane
6	synthesized beam pattern ("dirty" beam)
7	clean beam pattern
8	synthesized source map ("dirty" map)
9	corrected source map ("clean" map)
A	spectra map

(8) The narrowband data are stored on the observer tape and disk data set as half-word integers. Should a value exceed the limits allowed by this format, the program in which the excess occurs will punch a card of the form

$$\left\{\begin{array}{l}\text{SIGNAL-BAND}\\ \text{IMAGE-BAND}\end{array}\right\}\quad s\quad \text{BSCAN}\quad =\quad c\quad \text{BCHAN}\quad =\quad n1\quad n2\quad \text{BVALUE}\quad \text{NB-OVERFLOW}$$

suitable for entering in some of the later stages of the processing in order to recover the true value. When entering NB-OVERFLOW cards be sure that they are in ascending scan number (s) order. To delete the current list of NB-OVERFLOW values enter

NEW-OVERFLOW

Since the search of the overflow lists can cause large increases in the computer time, the user should employ this option only when necessary and should issue the NEW-OVERFLOW command as soon as the current overflow list is no longer needed. Note: as soon as an overflow occurs, an NB-OVERFLOW card is punched, but the values on that card are not entered in the current overflow lists.

(9) A parameter list and a counter of the number of parameters in the list are used by several of the program modules. To zero the counter enter

LIST

which is usually not required since LIST is incorporated in the definitions of many other words. To enter the number n in the list (and advance the counter) state

n

where the comma must follow each number to be entered in the list. There are several special words which enter the most commonly used numbers into the list. These include

RX-SUMS	(sums of narrow channels)
CONTINUUM	(analogue channels)
BROADBAND	(analogue then narrow band sums)

which first zero the counter and then enter the appropriate numbers into the list and

RX-SUMA	(sum of narrow channels - first baseline)
RX-SUMB	(sum of narrow channels - second baseline)
RX-SUMC	(sum of narrow channels - third baseline)
RX-SUMD	(sum of narrow channels - fourth baseline)
COR-1	(baseline 12 analogue channels)
COR-2	(baseline 13 analogue channels)
COR-3	(baseline 23 analogue channels)

which add the appropriate numbers into the list without zeroing the counter. The maximum number of items which may be entered in the list depends on the program module and will be described in the later chapters.

(10) There are several words which are basic to operations on maps:

(a) To specify the range over which the action is taken, state one or both of

m1 m2 XRANGE

n1 n2 YRANGE

where the operation will be carried out over the ranges from m1 through m2 in the x direction (-RA) and from n1 through n2 in the y direction (-DEC). Note: the mi and ni are in array units, n increases as declination decreases, and severe problems will arise if m1 or n1 exceeds the actual map dimensions. Some routines allow you to specify that the action is to be carried out only for the inner one-fourth of the area. To invoke this option, specify

INNER

and give neither XRANGE nor YRANGE. For example, for a map of dimensions 64 x 128, INNER is equivalent to 17 44 XRANGE 33 96 YRANGE.

(b) Many routines allow you to smooth the maps before carrying out the remainder of the operation. To use this option, state one or both of

m XSMOOTH

n YSMOOTH

where m (n) is the full width of the gaussian convolving function at e-fold points in array locations for the x (y) direction. The limits are

$0 \leq m \leq 10$

$0 \leq n \leq 8$ (x dimension < 512)

$\qquad\quad 4$ (x dimension = 512)

and the default is always m = n = 0 since smoothing is expensive in computer time.

(c) In the computation of optical depths, the optical depth is set to zero except at those array locations where the continuum brightness exceeds k per cent of the peak continuum brightness. To set k, state

k CUTOFF

where k = 20 is always the default.

IV. HLINEINT COMMAND VOCABULARY FOR EDITING

There are a number of routines to carry out data transfer and sorting tasks and to allow the user to edit and alter the data in detail. To load the vocabulary needed for this purpose state

EDITS LOAD

(1) In some data movement tasks an exclude option similar to the include only option (§ III-7) is available. To exclude one or more record types from the action enter

HEX n1n2n3n4 NOTYPE

where n1n2n3n4 is a single hexadecimal number and the ni are the code numbers for the record types to be excluded. To invoke the most common of the exclude specifications enter one of

NO-DATA	(1 2 3 4)
NO-HEADER	(1 0 0 0)
NO-SIGNAL	(2 0 0 0)
NO-IMAGE	(3 0 0 0)
NO-DIFFERENCE	(4 0 0 0)
NO-UV	(5 0 0 0)
NO-MAP	(6 7 8 9)
NO-DTBEAM	(6 0 0 0)
NO-CLBEAM	(7 0 0 0)
NO-DTMAP	(8 0 0 0)
NO-CLMAP	(9 0 0 0)
NO-MPSPECT	(A 0 0 0)

If the include only option is also used, the exclude option is ignored. To set the parameter for no exclusions enter

0 NOTYPE

(2) To rewind a tape enter

$$\left\{\begin{matrix}\text{READ-TAPE}\\ \text{WRITE-TAPE}\end{matrix}\right\} \qquad \text{REWIND}$$

(3) To create a new, or extend an existing, disk data set by moving data from tape, enter

$$\text{options a} \quad \text{OBSERVER-TAPE} \quad \text{options b} \left\{\begin{matrix}\text{ALL}\\ \text{n1 n2}\end{matrix}\right\} \text{SCAN-RANGE}$$

where the options a are

(a) To create a new disk data set code

NEW-DISK

which clears all the old indices

(b) To omit all scans of a particular source code

OMIT-SOURCE ssssssss

where ssssssss is the source name

(c) To control the source number assigned to a particular source code

n INCLUDE ssssssss

where 112 ≤ n ≤ 169 is the desired source number for source name ssssssss. The assignment of source numbers will be done automatically for all sources for which this option has not been invoked. The option can be used to improve the indexing when there are few scans for some sources and many for others. In such cases (and where there are more than 58 sources), it is useful to assign the same source number to several of those sources having only a few scans each.

and where the options b are

(a) To average records before loading onto disk enter

$$\left\{\begin{matrix}\text{n} \quad \text{INT} \quad = \\ \text{AVERAGE}\end{matrix}\right\}$$

where the default is n = 1 (see § III-4).

(b) To include or exclude certain types of records you may specify any one of the include only or exclude options (see § III-7 and IV-1). All types of records are included by default.

(c) To create and place on disk difference band records enter

CREATE-DIFFERENCE

where you must, of course, have both signal and image band records on the tape.

(d) To include <u>only</u> data having specified bandwidths code

n1n2n3n4 BANDWIDTH

where n1n2n3n4 is a single decimal number and where ni refers to the i'th quadrant. If ni = 0 there is no exclusion based on the bandwidth of the i'th quadrant. If ni = 1, 2, 3, 4, 5, 6, 7, 8, or 9 the data record is excluded if the total bandwidth of the i'th quadrant is not 10, 5, 2.5, 1.25, 0.625, 0.3125, 0.15625, 0.078125, or 0.0390625 MHz respectively. The default is to include all bandwidths.

(e) You may enter NB-OVERFLOW cards here, but they will help you only if you are averaging records or creating difference records.

You may wish to enter part of your observer tape with one set of exclusions and part with another set. The word OBSERVER-TAPE resets everything except the tape itself and the lists of omitted sources and overflowed channels. To reset these items code, respectively,

READ-TAPE REWIND
NEW-OMITLIST
NEW-OVERFLOW

(4) To transfer data from disk or tape to tape enter

options a FOR $\left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\}$ $\left\{\begin{matrix}\text{COPY-NINE}\\ \text{WRITE-NINE}\end{matrix}\right\}$

options b $\left\{\begin{matrix}\text{FULL}\\ \text{m1 m2}\end{matrix}\right\}$ SCAN-RANGE

where COPY-NINE transfers data from one tape to another and WRITE-NINE transfers data from the disk data set to tape.

The options at options a are

(a) To omit all scans of a particular source name enter

OMIT-SOURCE ssssssss

where ssssssss is the source name.

The options at options b are

(a) To exclude or include only specific record types in the data transfer (see § III-7 and IV-1) where the default is to include all record types.

(b) To restrict the transfer of data scans to specified bandwidths using

n1n2n3n4 BANDWIDTH

(see § IV-3d) where the default is to include all bandwidths.

NOTE: COPY-NINE may be used when there is no indexed data on the disk data set. In such a case you must

(a) Replace FOR ALL-SORC with 1 SRCNUM =

(b) Replace FOR ssssssss with 169 SRCNUM =
0 ZOURCE ssssssss

(c) Replace FULL with ALL

(5) To transfer data between the disk data set and tape by a more efficient routine use

$$m1 \quad m2 \quad \left\{ \begin{array}{l} \text{FILL-DISK} \\ \text{EMPTY-DISK} \end{array} \right\}$$

where m1 and m2 represent the range of <u>block</u> numbers in the transfer ($100 \leq m1 \leq m2$) and where FILL-DISK transfers data from tape to disk and EMPTY-DISK transfers data from disk to tape. FILL-DISK assumes that the tape is positioned at the start of the data intended to become block m1. The principal use of these routines is to make back-up copies of the entire disk data set (including indices, but <u>not</u> the FORTH dictionaries) which may be used to restore the data set at a later time. It is a good idea to make a back-up copy of the disk data set after various stages in the processing. Then, if something goes wrong during a later stage (e.g. computer failure, user error, <u>et al.</u>), it is possible to restore the data without going back to the beginning.

Option for EMPTY-DISK:

If you wish to empty the full disk to tape, state

100 0 EMPTY-DISK

(6) To copy the disk data set onto itself with various editing options enter

REWRITE options $\begin{Bmatrix} \text{RENUMBER} \\ \text{NO-RENUMBER} \end{Bmatrix}$

where, in rewriting and re-indexing the disk, the scans may either retain their original scan numbers (NO-RENUMBER) or may be renumbered (RENUMBER). Warning: NB-OVERFLOW cards use the scan number. Thus, cards punched before a renumbering cannot be used after a renumbering. The options are

(a) To average data records (see § III-4) with the default set for no averaging.

(b) To exclude or include only specified record types (see § III-7 and IV-1) with all record types included by default.

(c) To omit all scans of a particular source name enter

OMIT-SOURCE ssssssss

where ssssssss is the source name.

(d) To restrict the data scans retained to specified bandwidths enter

n1n2n3n4 BANDWIDTH

(see § IV-3d) where all bandwidths are included by default.

(e) To enter NB-OVERFLOW cards.

(f) To control the indexing of the new data set enter

n INCLUDE ssssssss

where $112 \leq n \leq 169$ is the source number to be assigned to source ssssssss. (See § IV-3)

(g) To average records across scan boundaries (under control of option (a)) enter

m DV =

where, if $m = 0$ records from adjacent scans are not stacked, if $m > 0$ records from adjacent scans may be stacked if the baselines and source names are the same and the velocity offsets are within m meters/sec of each other, and if $m < 0$ records are stacked as for $m > 0$ except that the velocities are not examined. Please note that AVERAGE sets INT to 120. The default is $m = 0$.

(h) To control the renumbering enter

n LOW =

where $n = 1$ is the default and where if $n \geq 0$ the new scan number is set to the old scan number minus the lowest old scan number plus n and if $n < 0$ the scans are renumbered as they are found sequentially on the disk with the new numbers beginning at $|n|$. Note that the associated scan numbers in map headers will not be meaningful after a renumbering.

(i) To create difference-band records from signal and image band records enter

CREATE-DIFFERENCE

where this option should be used with care since it creates more records than were initially present. If the averaging and omission options do not sufficiently compact the data, the program will blow up when it is asked to write on the block from which it must obtain the next (old) data record.

Note that all scans which have been marked invalid (see § IV-9 and § V-14b) will be omitted during the rewrite.

The author suggests that you make a complete back-up copy of the disk data set (see § IV-5) before using the REWRITE routine.

(7) To average ("stack") all of the records of one or more scans together to create a new scan use one of four methods:

(a) To stack scans from n1 through n2 into scan m enter

FOR $\left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\}$ n1 n2 INTO m ASTACK

where only scans having the same source name and the same baselines (in wavelengths $\pm$ 1/8 λ) will contribute to the stack. If ALL-SORC is specified, the source name will be taken as the source name of scan n1.

(b) To stack a list of scans into scan m enter

LIST a1 , a2 , a3 , a4 , INTO m STACK

where only scans having the source name and baselines ($\pm$ 1/8 λ) of scan a1 will contribute to the stack. No more than 20 scans may appear in the list.

(c) To stack scans for all sources from scan n1 through n2

FOR $\left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\}$ n1 n2 INTO m ANYSTACK

where all scans will contribute to the stack. Scan m will be assigned source name ssssssss (or the source name of scan n2 if ALL-SORC is specified), but all source names will contribute to the stack.

(d) To stack scans for all sources from a list of scans enter

$$\text{FOR} \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \text{LIST} \quad a1 \ , \quad a2 \ , \quad a3 \ , \quad \text{INTO} \quad m$$

STACKANY

where all scans will contribute to the stack. The source name is assigned as in (c).

Notes and options:

(a) If $m < 0$, the new scan will be assigned a scan number one higher than the highest scan number previously on the disk data set.

(b) NB-OVERFLOW cards may be entered.

(c) Signal, image, and difference band records, if present, will be averaged separately and placed in the stacked scan as separate records.

(d) If $m > 0$ specifies an already existing scan, that scan (actually only the header and first record(s)) will be replaced by the stacked scan. Difficulties will arise if the scan to be replaced has a different number of records or a different source name than the stacked scan.

(e) If the new scan is to have a source name which does not already appear in the disk indicies you must enter, before the stacking commands,

j INCLUDE ssssssss

where $112 \leq j \leq 169$ is the source number to be assigned to the new source name ssssssss.

(8) To store a number n into array position m enter

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \quad \text{n} \quad \text{INTO} \quad \text{m} \quad \text{STORE} \quad \text{options} \quad \left\{\begin{matrix}\left\{\begin{matrix}\text{FULL}\\ \text{i1 i2}\end{matrix}\right\} & \text{SCANS}\\ \text{i} & \text{A-SCAN}\end{matrix}\right\}$$

where the options are

(a) To have the action carried out on data header records only enter

HEADS

where, by default, the action is carried out only on data records. (See also § III-3)

(b) To exclude specified record types from the store operation (see § IV-1) where, by default, the store operation is carried out on all data record types.

(9) To mark portions of data records as invalid (so that later operations will ignore them) enter

$$\text{FOR} \quad \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \text{DELETE} \quad \text{"options"} \quad \left\{ \begin{array}{ll} \begin{Bmatrix} n1 \quad n2 \\ \text{FULL} \end{Bmatrix} & \text{SCANS} \\ \qquad n & \text{A-SCAN} \end{array} \right\}$$

where the "options" are

(a) To specify the portions of the data that are to be invalid using one of

RX-SUMS
CONTINUUM
BROADBAND

and/or one or more of

RX-SUMA	COR-1
RX-SUMB	COR-2
RX-SUMC	COR-3
RX-SUMD	COR-4

(see § III-9). This information must be given if anything is to be deleted.

(b) To exclude specified data record types from the deletion (see § IV-1) where all data record types are included by default.

The validity indicators are the RMS parameters for the analogue and RX-SUM data channels. If a particular RX-SUM is marked as invalid, all narrow channels which enter into that RX-SUM are considered invalid.

To reinstate a deleted segment, use MULTIPLY-LIST (see § IV-10) with n = 0, m = -1000, and the ai = 100, 104, 108, 112, 116, 120, 124, and/or 128 (as needed).

(See also § III-3.)

(10) To multiply a list of items by a scalar or vector number

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC} \\ \text{ssssssss}\end{matrix}\right\} \; m \; n \; \text{MULTIPLY-LIST} \quad a1 \;,\; a2 \;,\; a3 \;,$$

$$\text{options} \quad \left\{\begin{matrix} \left\{\begin{matrix}\text{FULL} \\ i1 \quad i2\end{matrix}\right\} & \text{SCANS} \\ i & \text{A-SCAN}\end{matrix}\right\}$$

where the ai are the array element subscripts and there can be no more than 20 such subscripts. The action taken depends on the value of n. If n = 0, the array elements are taken as scalar numbers and multiplied by m/1000. If n ≠ 0, the array elements are taken as complex numbers (with the real part in ARRAY(ai) and the imaginary part in ARRAY(ai+1)) and are multiplied by m/1000 in amplitude and have phase of n tenths of a degree added to them.

The options are

(a) To have the action carried out on data header records only enter

HEADS

where, by default, the action will be carried out on data records only. (See also § III-3.)

(b) To exclude specific data record types from the action (see § IV-1) where, by default, all data record types are included.

(11) To carry out a complex multiplication of a portion of the narrowband data together with corresponding corrections to the continuum, RX-sums, instrumental functions and inverse bandpass multiplier enter

$$\text{FOR} \left\{\begin{array}{c}\text{ALL-SORC}\\ \text{ssssssss}\end{array}\right\} \left\{\begin{array}{ccl} m & n & \text{MULTIPLY}\\ & m & \text{MULT-AMP}\\ & n & \text{ADD-PHASE}\end{array}\right\} \text{ options } \left\{\begin{array}{ll}\left\{\begin{array}{c}\text{FULL}\\ j1\ \ j2\end{array}\right\} & \text{SCANS}\\ \qquad j & \text{A-SCAN}\end{array}\right\}$$

where the amplitudes will be multiplied by m/1000 and where the phases will be increased by n/10 degrees. The options are

(a) To enter NB-OVERFLOW cards.

(b) To specify the range of channels to which the operation is to be applied (see § III-6) with RX-ABCD as the default.

(c) To suppress the action for particular data record types (see § IV-1) where, by default, the action is carried out on all data record types.

(d) To suppress the inverse action from being carried out on the inverse bandpass multiplier enter

NO-HEADER

or, if option (c) is invoked, enter

HEX 1n2n3n4 NOTYPE

(see § IV-1).

The requested action is taken on the appropriate continuum channels and the inverse action is taken on the appropriate instrumental functions only when the channel range specified in option (b) is one or more complete segments of the narrowband data in the recorded mode.

(12) To create a new scan which is the complex sum, difference, product, ratio or logarithm of the ratio of two other scans state

$$\text{n1} \quad \text{n2} \quad \left\{ \begin{matrix} \text{S+S} \\ \text{S-S} \\ \text{S*S} \\ \text{S/S} \\ \text{STS} \end{matrix} \right\} \quad \text{options} \quad \text{m} \quad \text{RSCAN}$$

where the average of scan number n2 is added to, subtracted from, multiplied with, or divided into the average of scan n1. The result scan is stored in scan m with the header record and source name taken from scan n1. If m $\leq$ 0, the result scan will be assigned a scan number one higher than the highest scan number already on disk. Note, if scan m is already on the disk, problems will arise if the original scan m does not have the same source name as scan n1. The options are

(a) NB-OVERFLOW cards may be entered.

(b) The data types on which the action is carried out (separately) may be specified (see § III-7). The default is DATA.

(c) Scan n2 may be smoothed in frequency before the operation is carried out. To do this, state

i SMOOTH

where i is the full width in channels at the e-folding points of the Gaussian smoothing function.

(d) The data in the result scan will be multiplied by two numbers. One of these is

0.5	for +
1.0	for -
1000.0	for /
$\left[\lvert \text{RXSUM}_1 \rvert \cdot \lvert \text{RXSUM}_2 \rvert \right]^{-1/2}$	for *

The other may be set by stating

k AMULT

where the multiplication is by k/1000 and k = 1000 is the default. If k is set to zero, neither of the multiplying numbers will be applied to the data. For the STS operation, the result scan is expressed as 1000.0 * optical depth with scan n2 defined as the continuum. The command AMULT has no effect on the STS operation.

NOTE: The user should be careful in his choice of n1 and n2. The program module does not compare the bandwidths, modes, baselines, etc., of the two scans.

(13) To reverse the sign of the phase or to flip the frequency direction of the profiles enter

$$\text{FOR} \quad \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \begin{Bmatrix} \text{—PHASE} \\ \text{FLIP} \end{Bmatrix} \quad \text{options} \quad \left\{ \begin{matrix} \begin{Bmatrix} \text{FULL} \\ \text{n1 n2} \end{Bmatrix} & \text{SCANS} \\ \text{n} & \text{A-SCAN} \end{matrix} \right\}$$

where the options are

(a) To specify the range of channels over which the action is taken (see § III-6) where RX-ABCD is the default. FLIP requires that this option specify one or more complete segments of the narrowband data in the recorded mode.

(b) To exclude specified data record types from the requested action (see § IV-1) where the default is to include all data types.

(14) There are several detailed editing tasks which can be carried out on maps using the headers only. To invoke the routine

$$\text{FOR} \quad \left\{ \begin{matrix} \overset{\text{state}}{\text{ALL-SORC}} \\ \text{ssssssss} \end{matrix} \right\} \quad \text{operation} \quad \text{option} \quad \left\{ \begin{matrix} \left\{ \begin{matrix} \text{FULL} \\ \text{k1 k2} \end{matrix} \right\} & \text{SCANS} \\ \text{k} & \text{A-SCAN} \end{matrix} \right\}$$

where the operations are

(a) To store value i in header array position j:

i INTO j STORE-MAP

(b) To mark the map as invalid:

DELETE-MAP

(c) To multiply the map by m/1000:

m MULTIPLY-MAP

(d) To multiply I*2 header array positions a1, a2, a3, etc. (up to 20) by m/1000:

m MULT-LIST a1 , a2 , a3 ,

(e) To store the scan numbers of the associated continuum maps (n1 and n2) in the header for later use in computing optical depths:

n1 n2 ENTER-CONTINUUM

where if ni = 0 the header will show no i'th continuum map and if ni < 0 the header will not be changed in regard to the i'th continuum map.

The option is to specify the types of maps for which the action is carried out (see § III-7). By default, the action is carried out for all map types.

NOTE: All operations except (e) apply also to map-spectra headers.

(15) To add a constant to a map enter

$$\text{FOR} \quad \left\{ \begin{array}{c} \text{ALL-SORC} \\ \text{ssssssss} \end{array} \right\} \quad n \quad \text{ADD-MAP} \quad \text{options} \quad \left\{ \begin{array}{cc} \left\{ \begin{array}{c} \text{FULL} \\ \text{k1 k2} \end{array} \right\} & \text{SCANS} \\ \text{k} & \text{A-SCAN} \end{array} \right\}$$

where n is in the units of the map (un-normalized) and where the options are

(a) To restrict the types of maps on which the action is carried out using an include only word (see § III-7). The default is to include all map types.

(b) Because n is a half-word integer, it may not lie in the desired range. To alter the range, enter one or both of

    i   M*
    j   M/

where the value added to the map will be n * i / j (of course, all in floating point). By default, i = j = 1.

(16) To create a map identical to a map already on disk state

n INTO m MOVE-MAP

where n is the scan number of the original map and m is the scan number of the copy. If $m \leq 0$, the scan number of the copy will be one higher than the previous highest scan number.

To alter the array size of an existing map (either to save only a portion of the map or to create a larger map area into which several maps may be added) state

n INTO m i1 i2 i3 i4 MAP-REDUCE

where n is the scan number of the original map, m is the scan number of the resulting map, i1 (i2) is the lowest array point in the x (y) direction which is to be retained, and i3 (i4) is the desired array dimension in the x (y) direction of the resulting map. Note: (1) $n \neq m$, (2) if $m \leq 0$, the resulting map will have scan number one higher than the previous highest scan number, (3) i1 and i2 may be ≤ 0, and (4) i3 and i4 must equal 16, 32, 64, 128, 256 or 512 but i3 is not required to equal i4.

(17) Normally, map array point (1,1) is at the upper left corner and represents the north-east corner. To alter this, state

$$n \quad \mathrm{INTO} \quad m \quad \left\{\begin{array}{l}\mathrm{FLIPX}\\ \mathrm{FLIPY}\\ \mathrm{FLIPXY}\end{array}\right\}$$

where FLIPX reverses east and west, FLIPY reverses north and south and FLIPXY reverses both and where n is the scan number of the map on which the action is taken and m is the scan number under which the altered map is stored. Note: (1) n may equal m, (2) if m < 0 the map is stored under a scan number one higher than the previous highest scan number, and (3) the display programs provided in LOOKS and CRTS will normally ignore the fact that the map has been flipped.

(18) To have one map operate on another by addition, subtraction, multiplication, or division, state

$$\text{n1} \quad \text{n2} \quad \left\{ \begin{array}{c} \text{M+M} \\ \text{M-M} \\ \text{M*M} \\ \text{M/M} \end{array} \right\} \quad \text{options} \quad \text{m} \quad \text{RMAP}$$

and by optical depth state

n1 MTM options m RMAP

where the continuum maps entered in the header of map n1 will be used to compute the optical depths (MTM) and where map n2 will be added to (M+M), subtracted from (M-M), multiplied by (M*M), or divided into (M/M) map n1. The resulting map is stored under scan number m or under scan number one higher than the previous highest scan number (if $m \leq 0$).

The options are:

(a) To have the result map multiplied by k/1000, enter

k AMULT

where k = 1000 by default.

(b) To specify the minimum continuum brightness for computation of the optical depth, use

j CUTOFF

(see § III-10), where j = 20 by default.

NOTE: The maps are presumed (but not tested) to be centered on the same RA and DEC and are required to have the same array spacings. The maps may have different array dimensions and array centers, with the result map having the same array dimensions and centers as map n1. The use of MTM is not recommended in most instances. All display programs contain the option to convert the map to optical depth before display. Such "on-the-spot" conversion allows contour lines at the edge of and off the source to be properly suppressed.

V. HLINEINT Command Vocabulary for Calibration

The principal purpose of HLINEINT is to calibrate the data and to produce maps from them. This section describes the numerous calibration modules. To invoke the necessary vocabulary state

CALS LOAD

(1) In order to calibrate the data it is necessary to mark (in each scan header) the calibrators. To do this, we prepare a list of calibrators by name with associated information (e.g., flux, weight, velocity range, type) and then enter the list in the scans. There are three ways to add sources to the list:

(a) To take sources from a standard list (given in Appendix D), use

STANDARD-CALIBRATORS options CALIST

where, if the standard list is not to be used for one or more of the calibrations, enter one or more of

NOT-PHASE
NOT-GAIN
NOT-BNDPASS

(b) To enter a source in the list state

CALIBRATOR ssssssss options CALIST

where the options are:

(i) If the source is a gain calibrator, you must enter

m FLUX

where m is the flux in milli-flux units (or in units of your choice if STANDARD-CALIBRATORS is not used to provide gain calibrators).

(ii) If the source is not to be used to calibrate all three parameters, enter one or more of

NOT-PHASE
NOT-GAIN
NOT-BNDPASS

(iii) To use a gain calibrator with less than full weight, enter

m WEIGHT

where $0 < m \leq 100$ is the desired weight. The default is $m = 100$.

(iv) If the source is to be used as a calibrator only within a specified velocity range, enter

n1 n2 VEL

where n1 and n2 are in km/sec. Those observations of the source having signal-band velocity offset v (for the center channel) where

$$| v - n1 | \leq n2$$

are the only observations of the source used as calibrators. Note - if $n2 \leq 0$, the velocity of the observation is not checked.

(c) You may wish to mark a source as not being a calibrator for some calibrations within some velocity range. To do this, enter

NOT-CALIBRATOR ssssssss options CALIST

where (i) The velocity range over which the source is not a calibrator is entered with

n1 n2 VEL

as described above.

(ii) If the source is not in the present list (with the velocity range given by option (a)), then the source is taken to be a non-calibrator for all 3 types of calibrations. If the source is in the present list (with the same velocity range), then you <u>must</u> specify the types of calibrations for which the source is not a calibrator using

NOT-PHASE
NOT-GAIN
NOT-BNDPASS

When the list is complete, you must enter it into the scans. To do this state

$\begin{Bmatrix} \text{n1 n2} \\ \text{FULL} \end{Bmatrix}$ ENTER-CALS

where n1 ≤ n2 is the desired scan range for the operation. The maximum number of entries in the list is 100. If you need more than 100 calibrators or wish to have different lists for different scan ranges, you may start a new list, erasing the old one, using

NEW-LIST

The list may contain two or more entries under the same source name. In such a case, the first entry found in the list having a velocity restriction satisfied by the observation is the entry applied to the observation. If the observation satisfies none of the entries having velocity restrictions, then the entry having no velocity restriction (if there is one) is applied to the observation. To give two examples:

CALIBRATOR 3C147 22240 FLUX CALIST

NOT-CALIBRATOR 3C147 0 100 VEL CALIST

creates two entries in the list and specifies that 3C147 is a phase, gain, and bandpass calibrator except when the band center velocity is between -100 and +100 km/sec, while

```
CALIBRATOR    3C48    15630    FLUX    CALIST
CALIBRATOR    3C48    10    70    VEL    NOT-GAIN
NOT-BNDPASS    CALIST
```

creates two entries in the list and specifies that 3C48 is a phase calibrator at all velocities and a gain and bandpass calibrator except when the velocity is between -60 and +80 km/sec.

Because of the importance of order in the creation of the list, it is probably best to use STANDARD-CALIBRATORS before using either CALIBRATOR or NOT-CALIBRATOR.

(2) A one-bit correlator produces a normalized spectrum where the normalization is a function of the system temperatures and, hence, of time, source, and frequency. In order to calibrate fringe amplitudes, it is necessary to determine the normalization factor and correct for it. To do this, state

$$\text{FOR} \left\{\begin{array}{c}\text{ALL-SORC}\\ \text{ssssssss}\end{array}\right\} \left\{\begin{array}{l}\text{FIX-AGC}\\ \text{UNFIX-AGC}\end{array}\right\} \text{options} \left\{\begin{array}{cc}\left\{\begin{array}{c}\text{FULL}\\ \text{n1 n2}\end{array}\right\} & \text{SCANS}\\ \text{n} & \text{A-SCAN}\end{array}\right\}$$

where the options are:

(a) NB-OVERFLOW cards may be entered here

(b) This calibration uses the values of the switched noise tubes. These values may be set using

n1 n2 n3 m **NOISE**

where ni is the noise tube temperature (arbitrary units) of telescope i and m is the normalization factor (usually about the system temperature) in the same units as the ni. The default is 200 200 200 1200 NOISE. If the switched noise tubes were not used, you <u>must</u> state

NO-NOISE

FIX-AGC computes and applies the correction to the data. UNFIX-AGC computes the correction and removes it from the data (restoring them to the original normalized state).

The switched noise tube method of calibration is to be preferred since it makes no assumptions and uses data recorded with each record. The NO-NOISE option must assume that the number of counts/°K in the total power remains constant. The NO-NOISE option determines the "expected" total powers from the first data record in the range of scans and redetermines the "expected" powers each time the mode, bandwidth, or baseline-connection parameters change. Thus, for the NO-NOISE option, it is recommended that you use FOR ALL-SORC and that the range of scans include as many scans as possible between known instrumental discontinuities. To use UNFIX-AGC with this option you must use the same source name(s) and scan range(s) you used with FIX-AGC.

(3) Before instrumental phase may be calibrated, it may be necessary to correct the observed phases for the use of fixed delays and to change the observed phases for changes in the assumed time, source positions, and baseline parameters:

(a) To correct observed phases for the use of fixed delays enter

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \quad \text{DELAY-COR} \quad \left\{\begin{matrix} \left\{\begin{matrix}\text{FULL}\\ \text{n1 n2}\end{matrix}\right\} & \text{SCANS}\\ \text{n} & \text{A-SCAN}\end{matrix}\right\}$$

(b) To change observed phases for a change in the recorded times (and to change the recorded times) enter

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \quad \text{n} \quad \text{CLOCK-COR} \quad \left\{\begin{matrix} \left\{\begin{matrix}\text{FULL}\\ \text{n1 n2}\end{matrix}\right\} & \text{SCANS}\\ \text{n} & \text{A-SCAN}\end{matrix}\right\}$$

where n is the time in milliseconds of LST to be <u>added</u> to the recorded times.

(c) To change the (recorded) assumed source position and to change the observed phases accordingly enter

$$\text{FOR} \quad \text{ssssssss} \quad \text{m1} \quad \text{m2} \quad \text{POSITION-COR} \quad \left\{\begin{matrix} \left\{\begin{matrix}\text{FULL}\\ \text{n1 n2}\end{matrix}\right\} & \text{SCANS}\\ \text{n} & \text{A-SCAN}\end{matrix}\right\}$$

where m1 is the change to be <u>added</u> to the recorded right ascension (in 0.001 seconds of time) and m2 is the change to be <u>added</u> to the recorded declination (in 0.01 seconds of arc).

NB-OVERFLOW cards may be entered for these three correction routines.

(d) To change the (recorded) assumed baseline parameters and to change the observed phases accordingly use the sequence

a1	b1	c1	d1	e1	BL12
a2	b2	c2	d2	e2	BL13
a3	b3	c3	d3	e3	BL23

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC} \\ \text{ssssssss}\end{matrix}\right\} \quad \text{BASELINE-COR} \quad \left\{\begin{matrix}\left\{\begin{matrix}\text{FULL} \\ \text{n1 n2}\end{matrix}\right\} & \text{SCANS} \\ \text{n} & \text{A-SCAN}\end{matrix}\right\}$$

where the ai, bi, ci, and di are the changes to be added to the assumed Xi, Yi, Zi, and Ki baseline parameters, respectively, in units of 1/1024.0 nanoseconds and where the ei are the phase-frequency corrections in units of 1/102.4 fringes/MHz. (These phase-frequency corrections arise from idfferences in the second LO cables connecting the synthesizer to the respective mixers.)

Cards of the BLij type must be given for each baseline for which there are data within the scan range even if the desired changes are all zero. Cards of the BLij type suitable for use with BASELINE-COR are punched by the program module which determines the best-fit corrections to the baseline parameters (see § V-5).

NB-OVERFLOW cards may be entered for use in the BASELINE-COR routine.

(4) If observations at one RF are used to calibrate observations at substantially different RF's, you may wish to correct the data prior to the instrumental function calibration for the effects on the system gain and/or phase of the front end bandpass shape. To carry out this correction, use the sequence

```
FOR {ALL-SORC}  RF-CORRECTIONS
    {ssssssss}
 a   f1   f2   b   RFACOR
 p   f1'  f2'  b'  RFPCOR
{APPLY-RFCOR}  {FULL }  SCAN-RANGE
{ENTER-RFCOR}  {n1 n2}
```

where APPLY-RFCOR causes the action to be based on the RF of each channel separately, ENTER-RFCOR causes the action to be based on the RF of the center channel of each quadrant, and where

10^6 f1 + 10^3 f2	=	RF observing frequency in Hz
a/1000	=	number by which amplitudes are multiplied
p	=	phase in 0.1 degrees added to the data
b	=	baseline number to which the correction is to be applied (if b = 0 the correction is applied to all baselines).

You may enter between 0 and 100 RFACOR and RFPCOR cards, but they must be entered in order of ascending frequency. To determine the actual correction used, a linear interpolation is done between the provided points. If an observation lies outside the provided frequency range, no action is taken on the observation and an error message is printed.

Notes: (a) It is not necessary to enter both RFPCOR and RFACOR cards.

(b) The phase-frequency correction which is proportional to the LO frequency and results from unequal electrical lengths in the LO system is handled as a baseline parameter. This routine is solely for any additional phase (and amplitude) corrections which depend on the observing frequency.

It is up to the user to determine whether or not his data require the use of this routine and, if so, what values to enter into this routine.

(5) The baseline parameters given to the on-line computer program during an observing run are not always perfectly correct. To determine best-fit corrections to the assumed parameters use

BASELINES options SOLVE

which will carry out a least-squares solution for the corrections iterated with a fit of a smooth instrumental phase function. The options are:

(a) To tell the program what scan range(s) to use in determining the solution you <u>must</u> enter at least one (and no more than five) commands of the type

$$\left\{\begin{array}{c}\text{FULL}\\ \text{n1 n2}\end{array}\right\} \quad \text{SCAN-RANGE}$$

where the total time covered by the requested scan range(s) cannot exceed 100 hours.

(b) $\left\{\begin{array}{l}\text{n INT =}\\ \text{AVERAGE}\end{array}\right\}$ with AVERAGE as the default.

Note: Only 200 observations of phase calibrators are allowed. Thus, if n is too small, you may exceed the limit. On the other hand, if the corrections are large, there will be some loss of accuracy if n is too large.

(c) You may specify the type of data to be used in the solution (see § III-7) where SIGNAL is the default. It is suggested that you use only one type of data at a time.

(d) You may wish to give an initial guess, or to enter known values, for some of the corrections. To do this, use one or more cards of the type

$$\text{ai} \quad \text{bi} \quad \text{ci} \quad \text{di} \quad \text{ei} \quad \left\{\begin{array}{c}\text{BL12}\\ \text{BL13}\\ \text{BL23}\end{array}\right\}$$

where the format of this card type is discussed in § V-3c. You must enter values for all 5 parameters on a card, but you do not have to enter all 3 such cards.

(e) The program iterates between a least-squares solution for the corrections and a fitting of a smooth instrumental phase function. To set the number of iterations, state

m ITERATIONS

where m is the desired number of iterations and is defaulted to 5.

(f) The program assumes that you want to solve for all 5 parameters for all 3 baselines. To turn off some of this assumption, state one or more of

NO-X	NO-Z	NO-DF
NO-X1	NO-Z1	NO-DF1
NO-X2	NO-Z2	NO-DF2
NO-X3	NO-Z3	NO-DF3
NO-Y	NO-K	NO-BL1
NO-Y1	NO-K1	NO-BL2
NO-Y2	NO-K2	NO-BL3
NO-Y3	NO-K3	

(g) To compute the smooth instrumental phase function the data are convolved with a convolving function which is by default an exponential. If the data contain real and rapid time variations you may use a Gaussian convolving function by stating

GAUSSIAN

(h) The width of the convolving function may be set by

n TAUP

where n is the convolution time in 0.01 hours and the default is n = 400.

BASELINES---SOLVE will print the corrections determined at each iteration, will show printer plots of the final instrumental functions, and will punch cards suitable for entering in BASELINE-COR (see § V-3c).

(6) To correct the data for the IF bandpass shape, a two stage process is required:

(a) To compute a time-smoothed inverse bandpass multiplier and store it in the scan headers, state

$$\text{FIND-BANDPASS} \quad \text{options} \quad \left\{ \begin{matrix} \text{FULL} \\ \text{n1 n2} \end{matrix} \right\} \quad \text{SCAN-RANGE}$$

where any number of calibrators may occur so long as no more than 199 are to be applied to any one scan and where any number of modes may occur within the scan range so long as with each mode, there is associated a unique bandwidth and baseline-connection set. The options are:

(i) NB-OVERFLOW cards may be entered, but are used only for bandpass calibrator scans.

(ii) You may specify the type of data to be used in determining the calibration (see § III-7), where DATA is the default.

(iii) The time smoothing is done using a convolution function, which is by default an exponential. To specify a convolution function which falls off more rapidly, state

GAUSSIAN

(iv) You may set the width of the convolving function using

m CONTIME

where m is the convolution time in 0.01 hours and where the default is m = 400.

(v) The inverse bandpass multiplier is normally determined for each channel separately. To obtain better signal-to-noise ratio for the calibration, you can smooth channels in frequency using

n SMOOTH

where n is the full width in channels at the e-folding points of the Gaussian smoothing function. Note: if n is too large, real frequency structure in the inverse multiplier will be smoothed away resulting in a loss of accuracy.

(b) To apply the inverse multiplier to the data, state

$$\text{FOR} \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \left\{\begin{matrix}\text{FIX-BANDPASS}\\ \text{UNFIX-BANDPASS}\end{matrix}\right\} \text{ options } \left\{\begin{matrix}\text{FULL}\\ \text{n1 n2}\end{matrix}\right\} \text{SCAN-RANGE}$$

where FIX-BANDPASS corrects the data for the bandpass shape and UNFIX-BANDPASS removes the previously applied correction (in case you change your mind about it). The options are:

(i) NB-OVERFLOW cards may be entered.

(ii) You may specify the type(s) of data on which the action is taken (see § III-7), where the default is DATA.

(7) A two-stage process is also used to correct the data for time varying instrumental phase and gain:

(a) To determine the complex instrumental functions, state

INSTRUMENTAL-FUNCTION options $\left\{\begin{matrix}\text{FULL}\\ \text{n1 n2}\end{matrix}\right\}$ SCAN-RANGE

which determines the instrumental functions, produces printer plots of them, and stores their values in the data records. The scan range should include data having only one mode, bandwidth and baseline connection set. No provision is made for discontinuities in the instrumental functions. Hence, if there are discontinuities, n1 through n2 should only cover the scan range between discontinuities. The options are

(i) You may specify the type of data from which and for which the instrumental functions are determined (see § III-7), where SIGNAL is the default. It is recommended that only one type of data be calibrated at a time.

(ii) You may limit the number of baselines in the particular solution by stating one or more of

RX-SUMA
RX-SUMB
RX-SUMC
RX-SUMD

where the default is all those RX-SUMs relevant to your data.

(iii) In obtaining values needed to determine the instrumental functions, records may be averaged using

n INT =
AVERAGE

where AVERAGE is the default. No averaging is done when the instrumental functions are stored in the data records. Any number of calibrators may occur so long as no more than 99 affect any one scan. However, the program will be more efficient if no more than 99 affect any LST day. Thus, unless very rapid, real time variations occur, the option AVERAGE should be used.

(iv) To compute the time smoothed instrumental function the calibration data are convolved with a convolving function which is, by default, an exponential. If the data contain real and rapid time variations you may use a Gaussian convolving function by stating

GAUSSIAN

(v) The convolution times for phase and gain are set with

n TAUP
m TAUG

respectively, where n and m are in units of 0.01 hours and have default values of 400. If you do not wish to solve for phase or for gain set the appropriate convolution time to zero.

(vi) Normally the determined instrumental functions are simply stored in the correct locations in the data array. You may make the instrumental function determined in this step supplement (by a complex multiplication) the instrumental function determined and stored in a previous step. To do this, state

SUPPLEMENT

The principal intention of this option is to allow the use of different scan ranges for phase and for gain. For example, if there is a discontinuity in phase, but not in gain, between scans 100 and 101, you might want to use the sequence:

```
INSTRUMENTAL-FUNCTION    0    TAUG
  1    100    SCAN-RANGE
 101   200    SCAN-RANGE
INSTRUMENTAL-FUNCTION    0    TAUP    SUPPLEMENT
  1    200    SCAN-RANGE
```

(b) To correct the data with the instrumental function stored in the data records by the previous step state

$$\text{FOR} \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \left\{\begin{matrix}\text{FIX-INSFUNC}\\ \text{UNFIX-INSFUNC}\end{matrix}\right\} \text{ option } \left\{\begin{matrix}\text{FULL}\\ \text{n1 n2}\end{matrix}\right\} \text{SCAN-RANGE}$$

where FIX-INSFUNC applies the correction for the instrumental function and UNFIX-INSFUNC removes a previously applied correction (in case you change your mind about it). The option is

(i) You may specify the types of data to which the correction is applied (see § III-7) where DATA is the default.

VI. HLINEINT Command Vocabulary for Mapping

This chapter describes the vocabulary needed to produce maps from the calibrated data. To load the vocabulary, state

MAPS LOAD

(1)

(2) To convert a set of maps (e.g., T(x,y) at a set of V) into one map of spectra (e.g., T(V,x,y)), enter

CREATE-MPSPECT "options" m RSPECTRA

where m is the scan number under which the resulting spectra-map is stored. If m $\leq$ 0, the spectra map will be stored under scan number one higher than the previous highest scan number. The "options", one of which is required, are

(a) To specify the source name(s) and associated scan range(s) to be included, enter one or more (up to 10) of

$$\text{n1} \quad \text{n2} \quad \text{SOURCE} \quad \left\{ \begin{array}{c} \text{ALL-SORC} \\ \text{ssssssss} \end{array} \right\}$$

where n1 through n2 is the desired scan range for the specified source name and where at least one of these command sequences must be entered.

(b) To specify the base map, enter

n BASE-MAP

where n is the scan number of the desired base map and where the base map is used to provide the scan numbers of the continuum maps and to set the array ranges, centers, spacings, etc. By default the base map is taken as the first valid map found in the first of the scan ranges.

(c) To specify the range of array values (relative to the base scan) to be included (see § III-10a), where the specified ranges may exceed the size of the base map. The full base map area is included by default. The command INNER is not available.

(d) To smooth the original maps before storing the values in the map-spectra (see § III-10b) where, by default, no smoothing is done.

(e) To specify the number of array intervals between points to be included, enter one or both of

m XSKIP
n YSKIP

where m = n = 4 by default. The user is advised to make m and n as large as is reasonable.

Note: The map spectra are stored as normalized brightnesses with up to two continuum brightness values stored at the start of each spectrum to facilitate later comparisons and computations.

VII. HLINEINT Command Vocabulary for Displays

This chapter describes the vocabulary used to obtain printer and Calcomp plotter displays of the data and maps. To load this vocabulary state

LOOKS   LOAD

(1) To have information on the contents of the disk data set printed enter

DISK-CONTENTS

for a brief summary or

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC} \\ \text{ssssssss}\end{matrix}\right\} \quad \left\{\begin{matrix}\text{LIST-SCANS} \\ \text{LIST-UVS} \\ \text{LIST-MAPS} \\ \text{LIST-SPECTRA}\end{matrix}\right\}$$

for a complete summary of particular types of records or

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC} \\ \text{ssssssss}\end{matrix}\right\} \quad \text{LIST-DISK}$$

for a complete summary of all record types.

If ALL-SORC is specified, the program will list the scan and block numbers (for all record types) associated with each source name and then make a sequential list (for the specified record types) of the disk.

(2) To obtain profiles on the printer enter

$$\text{FOR} \quad \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \begin{Bmatrix} \text{PROFILES} \\ \text{SPECTRA} \end{Bmatrix} \quad \text{options} \quad \left\{ \begin{matrix} \begin{Bmatrix} \text{m1 m2} \\ \text{FULL} \end{Bmatrix} & \text{SCANS} \\ \text{m} & \text{A-SCAN} \end{matrix} \right\}$$

where PROFILES gives horizontal plots (channel number runs across the page) and SPECTRA gives vertical plots (channel number runs down the page). The options are

(a) To average the data before plotting (see § III-4) with AVERAGE as the default.

(b) To specify what record types are included (see § III-7) with DATA as the default.

(c) To enter NB-OVERFLOW cards.

(d) To specify the form of the data to be displayed (see § III-5) with VECTOR as the default.

(e) To specify the range of channels to be plotted (see § III-6) with RX-ABCD as the default.

(f) To smooth the data prior to display enter

n SMOOTH

where n = 0 by default and where n is the full width in channels at the e-folding points of the Gaussian smoothing function.

(g) To plot only every j'th channel beginning (in the specified section) with channel j/2 enter

j SKIPCHAN

where j = 1 by default.

(h) To specify a fixed scale for the plots enter

m1 m2 SCALE

where m1 < m2 is the range to be plotted. If m1 ≥ m2, which is the default, the plots will be separately self-scaling. For fixed-scale VECTOR plots, the phase is scaled from -180 to 180 degrees.

(i) To specify the number of printer lines per parameter for horizontal plots enter

m NLINES

where m = 50 by default.

(3) To obtain plotted profiles on the Calcomp enter

$$\text{FOR} \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \text{PLOT} \quad \text{options} \begin{Bmatrix} \begin{Bmatrix} \text{FULL} \\ \text{n1 n2} \end{Bmatrix} & \text{SCANS} \\ \text{n} & \text{A-SCAN} \end{Bmatrix}$$

where each baseline and scan will be plotted separately. The options are

(a) To average the data before plotting (see § III-4) with AVERAGE as the default.

(b) To specify what record types are included (see § III-7) with DATA as the default.

(c) To enter NB-OVERFLOW cards.

(d) To specify the form of the data to be displayed (see § III-5) with VECTOR as the default.

(e) To specify the range of channels to be plotted (see § III-6) with RX-ABCD as the default.

(f) To smooth the data prior to plotting enter

m SMOOTH

where m = 0 is the default and where m is the full width in channels at the e-folding points of the Gaussian smoothing function.

(g) To specify a fixed scale for the lower plots enter

m1 m2 LSCALE

and to specify a fixed scale for the upper plots enter

m3 m4 USCALE

where m1 < m2 and m3 < m4 are the ranges of values plotted. The upper plot is of phase (sine part) if VECTOR (COMPLEX) is specified. There is no upper plot if AMPLITUDE, PHASE, REAL, or IMAGINARY are specified. If m1 ≥ m2 (m3 ≥ m4), which is the default, the lower (upper) plots will be self-scaling. One parameter may be self-scaling while the other is fixed scale.

(h) To specify the size of the plots enter one or both of

m XMULT
n YMULT

where the defaults are m = n = 1000 and where the sizes of the plots are, in inches, 6 * j * n/1000 in the y direction and M * m/1000 in the x direction with j being the number of parameters plotted and m = 12, 9, or 6 as mode = 5, 6, or 7, respectively. The limits are

$$200 \le m \le 8000$$

$$200 \le n \le \begin{Bmatrix} 4200 \\ 2100 \end{Bmatrix} \quad \text{for} \quad \begin{Bmatrix} \text{AMPLITUDE, } \underline{\text{et al.}} \\ \text{VECTOR, COMPLEX} \end{Bmatrix}$$

(4) To obtain profiles on the Calcomp involving more than one scan or baseline per plot enter

FOR $\left\{\begin{array}{l}\text{ALL-SORC} \\ \text{ssssssss}\end{array}\right\}$ MULTI-PLOT n1 , n2 , n3 ,

n4 , n5 , options MPLOT

where the data from between 1 and 13 scans ni will be plotted on the same plot(s). The plots are of scan averages and all valid data are plotted. The data in the scans may have different bandwidths, modes, baseline connections, and baseline parameters. The options are

(a) To enter NB-OVERFLOW cards

(b) To specify what record types are included (see § III-7) with SIGNAL as the default. Data types will always be plotted separately.

(c) To specify the form of the data plotted (see § III-5) with VECTOR as the default.

(d) To smooth the data prior to plotting enter

m SMOOTH

where m = 0 is the default and where m is the full width in channels at the e-folding points of the Gaussian smoothing function. Note that the smoothing is by channel number. If different channel separations occur in the data, then different smoothing parameters in velocity will occur.

(e) To specify fixed scales for the lower and/or upper plots enter one or both of

m1 m2 LSCALE
m3 m4 USCALE

(see § VII-3g). The defaults are for self-scaling based on the data of scan n1 only, with a different set of self-determined scales for each data type.

(f) To have all baselines appear on the same plot enter

OVER-WRITE

where, by default, each baseline number is plotted separately (but on the same scales as other baseline numbers of that data type). The autocorrelation quadrant will always be plotted separately.

(g) To specify the size of the plots enter one or both of

m XMULT
n YMULT

where m = n = 1000 by default and where the size of each plot is, in inches, 6 * j * n/1000 in the y direction and M * m/1000 in the x direction, with j being the number of parameters plotted and M = 15, 12, or 9 as mode = 5, 6, or 7, respectively. The limits are

$$200 \le m \le 10000$$

$$200 \le n \le \begin{Bmatrix} 4200 \\ 2100 \end{Bmatrix} \quad \text{for} \quad \begin{Bmatrix} \text{AMPLITUDE, } \underline{\text{et al.}} \\ \text{COMPLEX, VECTOR} \end{Bmatrix}$$

(5) To have position, velocity, bandwidth, and projected baseline information from data headers printed enter

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \quad \text{HEADERS} \quad \left\{\begin{matrix}\left\{\begin{matrix}\text{FULL}\\ \text{m1 m2}\end{matrix}\right\} & \text{SCANS}\\ \text{m} & \text{A-SCAN}\end{matrix}\right\}$$

To obtain a list of calibrator data scans enter

$$\text{LIST-CALIBRATORS} \quad \text{option} \quad \left\{\begin{matrix}\left\{\begin{matrix}\text{FULL}\\ \text{m1 m2}\end{matrix}\right\} & \text{SCANS}\\ \text{m} & \text{A-SCAN}\end{matrix}\right\}$$

where the option is to restrict the list to one source name by stating

$$\text{FOR} \quad \text{ssssssss}$$

To obtain full dumps of data headers and records enter

$$\text{FOR} \quad \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \quad \left\{\begin{matrix}\text{HEX-DUMP}\\ \text{DUMP}\\ \text{DUMP4}\end{matrix}\right\} \quad \text{options} \left\{\begin{matrix}\left\{\begin{matrix}\text{FULL}\\ \text{m1 m2}\end{matrix}\right\} & \text{SCANS}\\ \text{m} & \text{A-SCAN}\end{matrix}\right\}$$

where the dumps are in half-word hexadecimal (HEX-DUMP), half-word integer (DUMP) or full-word integer (DUMP4) formats and where the options are

(a) To average records before dumping (see § III-4) with no averaging as the default.

(b) To specify the record types to be dumped (see § III-7) with DATA as the default.

(c) To restrict the dump to header records only by stating

$$\text{HEADS}$$

(6) To obtain specified information from data headers, state

$$\text{FOR} \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \quad \text{HLOOK} \quad \text{choices} \left\{\begin{matrix}\left\{\begin{matrix}\text{m1 m2}\\ \text{FULL}\end{matrix}\right\} & \text{SCANS}\\ \text{m} & \text{A-SCAN}\end{matrix}\right\}$$

where you must specify one of the choices below:

(a) BASELINES (baselines in ns)

(b) UVS (projected baseline parameters)

(c) VELOCITIES (velocities)

(d) I*2 n1 , n2 , n3 ,

for a list of array values as half-word integers. No more than 16 array points may be done at a time.

(e) I*4 n1 , n2 , n3 ,

for a list of array values as full-word integers taken from <u>full-word</u> locations n1, n2, n3, etc.. No more than 10 array points may be done at a time.

(f) CMPLX $\left\{\begin{matrix}\text{c1} & \# & \text{c2} & \# & \text{c3} & \#\\ \text{a1} & , & \text{a2} & , & \text{a3} & ,\end{matrix}\right\}$ option

for a list of complex numbers from channel numbers ci or array points (for the real part) ai. The option is to specify the type of data displayed (see § III-5) with VECTOR as the default. The limits are 8 complex numbers if VECTOR or COMPLEX are specified and 16 numbers if AMPLITUDE, <u>et al.</u> are specified.

(g) INV-BANDPASS options

to print the inverse bandpass multiplier. The options are to specify the type of data displayed (see § III-5) with VECTOR as the default and to specify the range of channels displayed (see § III-6) with RX-ABCD as the default.

(7) To obtain specified information from data records, state

$$\text{FOR} \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \text{LOOK} \begin{Bmatrix} \text{n} \;\; \text{INT} \;\; = \\ \text{AVERAGE} \end{Bmatrix} \; \text{choices} \begin{Bmatrix} \begin{Bmatrix} \text{m1 m2} \\ \text{FULL} \end{Bmatrix} & \text{SCANS} \\ \text{m} & \text{A-SCAN} \end{Bmatrix}$$

where the averaging default is n = 1 and where you must specify one of the choices below:

(a) TPOWERS

for a list of total powers - all 4 inputs of signal followed by all 4 inputs of signal + noise.

(b) DELAYS

for a list of delay values.

(c) I*2 n1 , n2 , n3 ,

for a list of array values as half-word integers. No more than 16 array points may be done at a time.

(d) I*4 n1 , n2 , n3 ,

for a list of array values as full-word integers taken from full-word locations n1, n2, n3, etc.. No more than 10 array points may be done at a time.

(e) CMPLX $\begin{Bmatrix} \text{c1} & \# & \text{c2} & \# & \text{c3} & \# \\ \text{a1} & , & \text{a2} & , & \text{a3} & , \end{Bmatrix}$ option

for a list of complex numbers from channel numbers ci or array points (for the real part) ai. The limits are 8 points if VECTOR or COMPLEX are specified and 16 points if AMPLITUDE, <u>et al.</u> are specified.

(f)	INSFUNC	option	(instrumental function)
(g)	RX-SUMS	option	(narrow channel sums)
(h)	CONTINUUM	option	(analogue channels)
(i)	BROADBAND	option	(analogue then narrow channel sums)
(j)	CHANNELS	options	

for a list of narrowband channel values.

The options are, for choices (e)-(j), to specify the type of data displayed (see § III-5) with VECTOR as the default and, for choice (j) to specify the range of channels displayed (see § III-6) with RX-ABCD as the default.

(8) To have information from map and spectra-map headers printed, state

$$\text{FOR} \left\{\begin{matrix}\text{ALL-SORC}\\ \text{ssssssss}\end{matrix}\right\} \quad \text{MLOOK} \quad \text{options} \left\{\begin{matrix}\left\{\begin{matrix}\text{FULL}\\ \text{n1 n2}\end{matrix}\right\} & \text{SCANS}\\ \text{n} & \text{A-SCAN}\end{matrix}\right\}$$

where the map type, scan number, source name, center velocity, velocity range, and peak value for each map will be printed. The options are:

(a) To restrict the display to one or more map types use one of the include only words (see § III-7). By default, all map types are included.

(b) To obtain additional information, enter one of the following sequences:

(i) I*2 i1 , i2 , i3 ,

for a list of values from half-word header locations i1, i2, i3, etc. (up to 16).

(ii) R*4 j1 , j2 , j3 ,

for a list of values from full-word floating point header locations j1, j2, j3, etc. (up to 10).

(iii) MDUMP

for a half-word dump of the header.

(iv) MHEX-DUMP

for a hexadecimal dump of the header.

(v) ASSOCIATES

for a list of associated maps (e.g., the dirty and clean beams, continuum maps, et al.).

(vi) POSITIONS

for the position of the map center and information on the size, center, and spacing of the array.

(vii) MAP-DUMP

for a hexadecimal dump of the map header and all map records.

(9) To have a map printed, enter

$$\text{FOR} \left\{ \begin{matrix} \text{ALL-SORC} \\ \text{ssssssss} \end{matrix} \right\} \quad \text{PRINT-MAP} \quad \text{options} \quad \left\{ \begin{matrix} \text{FULL} \\ \text{m1 m2} \end{matrix} \right\} \text{SCAN-RANGE}$$

where the options are

(a) To specify what is printed, enter one of

m DEGREES
m RATIO
m TAU
CONTUR

where m is the number of digits in each printed number and where the plot units are determined as explained in option (b). For TAU, the map is converted to optical depth before printing. For CONTUR, the numbers printed have one digit with alternate numbers blank. The default is 2 RATIO.

(b) To specify a particular step size, state

k STEPSIZE

where k is in °K (for brightness maps under DEGREES), in 0.001 of optical depth (for TAU and for optical depth maps under DEGREES), and in 0.0001 of the peak value (for RATIO and CONTUR). The default scaling of the maps is determined by the specification of option (a) and the peak value present. For example:

(i) If 3 RATIO is specified, then a change of 1 on the print represents a change of 0.001 of the peak value.

(ii) If 3 DEGREES is specified and the peak temperature is 30,000°K, then a change of 1 on the print represents a change of 100°K.

(iii) If 3 TAU is specified and the peak optical depth is 0.9, then a change of 1 on the print is a change in optical depth of 0.001.

(c) To restrict the action to one or more types of maps, specify one of the include only words (see § III-7). The default is to include all map types.

(d) To set the continuum cutoff level (for TAU only), state

k CUTOFF

where k = 20 is the default (see § III-10c).

(e) To specify the range of the array to be printed (see § III-10a) where the whole map is printed by default. The command INNER is not available. The printed maps will occupy as many pages as are needed.

(f) To smooth the map before printing (see § III-10b) where no smoothing is the default.

(g) To have only some of the map points in the specified ranges printed, state one or both of

m XSKIP
n YSKIP

where only, every m'th (n'th) point in the x (y) direction will be printed. By default, m = n = 1.

(10) To produce cross-hatched map profiles on the Calcomp plotter, state

$$\text{FOR} \quad \begin{Bmatrix}\text{ALL-SORC}\\ \text{ssssssss}\end{Bmatrix} \quad \begin{Bmatrix}\text{X-HATCH}\\ \text{Y-HATCH}\\ \text{XY-HATCH}\end{Bmatrix} \quad \text{options} \quad \begin{Bmatrix}\text{FULL}\\ \text{n1 n2}\end{Bmatrix} \quad \text{SCAN-RANGE}$$

where lines at constant declination are produced by X-HATCH and XY-HATCH and lines at constant right ascension are produced by Y-HATCH and XY-HATCH. The options are

(a) To specify the types of maps included (see § III-7) where all maps are included by default.

(b) To specify that the map is to be converted to optical depth before plotting, enter

0 TAU

and to set the continuum cutoff level enter

k CUTOFF

where k = 20 by default (see § III-10c).

(c) To specify the range of the array to be plotted (see § III-10a), when the whole map is plotted by default. The command INNER is available.

(d) To smooth the map before plotting (see § III-10b) where no smoothing is the default.

(e) To specify the number of array intervals between plotted lines (in the direction perpendicular to the lines), state one or both of

m YSKIP
n XSKIP

when YSKIP applies to X-HATCH and XY-HATCH and XSKIP applies to Y-HATCH and XY-HATCH. The default is to have about 16 lines plotted.

(f) To suppress the plotting of axis labels and tick marks, state

NO-AXES

(g) To suppress lines obscured by foreground lines, state

HIDDEN

(h) The vertical displacement due to the value of the map is proportional to [T(x,y)/(Tmax-Tmin)] * TMULT/1000.0, where Tmax (Tmin) is the maximum (minimum) value on the map and where TMULT may be set using

j TMULT

with j = 1000 as the default.

(i) To give some appearance of three-dimensionality, enter

n BACK

to tilt the top back n degrees ($0 \leq n \leq 60$),

m OVER

to rotate the map to the right (around the center of the bottom) by m degrees ($-60 \leq m \leq 60$), and

k PERSPECTIVE

to show the map in pseudo-perspective with the top k/100.0 times farther away than the bottom ($75 \leq k \leq 150$). The defaults are m = n = 0, k = 100.

(j) By default, the scaling of the plotted map is such that the maximum map dimension is ten inches and that equal displacements in x and y on the output represent equal displacements in seconds of arc (prior to the application of BACK and PERSPECTIVE). To multiply the scaling factors so determined by m/1000.0 in the x direction and n/1000.0 in the y direction, enter one or both of

m XMULT
n YMULT

where m = n = 1000 by default.

(11) To produce contour maps on the Calcomp, enter

FOR $\left\{ \begin{matrix} \text{ALL-SORC} \\ \text{ssssssss} \end{matrix} \right\}$ CONTOUR options $\left\{ \begin{matrix} \text{FULL} \\ \text{n1 n2} \end{matrix} \right\}$ SCAN-RANGE

where the contours are computed without interpolation mesh points (in order to conserve computer time) and where the options are

(a) To specify what is plotted and the contour interval, enter one of

$$n \left\{ \begin{matrix} \text{DEGREES} \\ \text{TAU} \\ \text{RATIO} \end{matrix} \right\}$$

where the default is 100 RATIO and where n is the contour interval in °K (for brightness maps under DEGREES), in units of 0.001 of optical depth (for TAU and for optical depth maps under DEGREES), and in units of 0.001 of the peak value of the map (for RATIO). The specification of TAU causes the map to be converted to optical depth before plotting.

(b) To specify what types of maps are included (see § III-7) where the default is to include all map types.

(c) To set the continuum cutoff level (for TAU) state

k CUTOFF

where k = 20 is the default (see § III-10c).

(d) To specify the range of the array to be plotted (see § III-10a) where the whole map is plotted by default. The command INNER is available.

(e) To smooth the map before plotting (see § III-10b) where no smoothing is the default.

(f) By default, the scaling of the plotted map is such that the maximum map dimension is ten inches and that equal displacements in x and y on the output represent equal displacements in seconds of arc (prior to the application of BACK and PERSPECTIVE). To multiply the scaling factors by m/1000.0 in the x direction and by n/1000.0 in the y direction, enter one or both of

m XMULT

n YMULT

where m = n = 1000 by default.

(g) To have the zero contour plotted (it is normally suppressed), state

ZERO

(h) To suppress the plotting of tick marks and axis labels, enter

NO-AXES

(i) Normally contour maps are plotted in two dimensions. However, various three dimensional options are available. These are

n BACK

to tilt the top back n degrees ($0 \leq n \leq 60$),

m OVER

to rotate the map to the right by m degrees ($-60 \leq m \leq 60$),

k PERSPECTIVE

to show the map in pseudo-perspective with the top k/100.0 times farther away than the bottom ($75 \leq k \leq 150$), and

THREE-D

to have the contours displaced vertically in proportion to their value. To set the amount of the vertical displacement enter

j TMULT

where the vertical displacement is proportional to (j/1000.0) * T (x,y)/(Tmax - Tmin). The defaults are n = m = 0, k = 100, and j = 0 (with THREE-D setting j to 1000).

(12) For publication and for attractive slides, contour maps with smoother contours may be required. This routine is very time consuming and, hence, should be used only when necessary. To obtain smoother Calcomp contour maps state

$$\text{FOR} \quad \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \text{SMOOTH-CONTOUR} \quad \text{options} \quad \begin{Bmatrix} \text{FULL} \\ \text{n1 n2} \end{Bmatrix} \quad \text{SCAN-RANGE}$$

where the options are

(a) To specify what is plotted and the contour interval, use one of

$$n \quad \begin{Bmatrix} \text{DEGREES} \\ \text{RATIO} \\ \text{TAU} \end{Bmatrix}$$

where the default is 100 RATIO and where n is the contour interval in °K (for brightness maps under DEGREES), in units of 0.001 of optical depth (for TAU and for optical depth maps under DEGREES), and in units of 0.001 of the peak value of the map (for RATIO). The specification of TAU causes the map to be converted to optical depth before plotting.

(b) To specify what types of maps are included (see § III-7) where the default is to include all map types.

(c) To set the continuum cutoff level (for TAU only), state

k CUTOFF

where the default is k = 20 (see § III-10c).

(d) The smoothness of the plot (and the computer time) are determined by the number of mesh points interpolated between the map array points. To set these numbers state one or both of

m XMESH
n YMESH

where m (n) is the number of mesh intervals between map array points in the x (y) direction. By default, $m = n = 5$. The limits are $1 \leq m, n \leq 19$.

(e) To specify the range of the array to be plotted (see § III-10a) where the whole map is plotted by default. The command INNER is available.

(f) To smooth the map before plotting (see § III-10b) where no smoothing is the default.

(g) To have the zero contour plotted (it is normally suppressed), state

ZERO

(h) To suppress the plotting of tick marks and axis labels, state

NO-AXES

(i) By default, the scaling of the plotted map is such that the maximum map dimension is ten inches and that equal displacements in x and y on the output represent equal displacements in seconds of arc. To multiply the scaling factors so determined by m/1000 in the x direction and by n/1000 in the y direction, enter one or both of

m XMULT
n YMULT

where $m = n = 1000$ by default.

(13) To obtain printer profiles of the spectra in the spectra-map, enter

$$\text{FOR} \quad \begin{Bmatrix}\text{ALL-SORC}\\ \text{ssssssss}\end{Bmatrix} \quad \begin{Bmatrix}\text{MAP-PROFILES}\\ \text{MAP-SPECTRA}\end{Bmatrix} \quad \text{options} \begin{Bmatrix} \begin{Bmatrix}\text{FULL}\\ \text{n1 n2}\end{Bmatrix} & \text{SCANS} \\ \text{n} & \text{A-SCAN}\end{Bmatrix}$$

where MAP-PROFILES (MAP-SPECTRA) gives horizontal (vertical) plots. The options are

(a) To specify which of the spectra are to be plotted, use one of two methods:

(i) by giving a list of array coordinates

m1 , n1 , m2 , n2 ,

where up to six pairs of coordinates (mi, ni) may be entered

or (ii) by specifying the array range and the array spacing between plotted profiles using some or all of

i1	i2	XRANGE
j1	j2	YRANGE
i3		XSKIP
j3		YSKIP

with the default being method (ii) with the entire array included, but with i3 = j3 = 4.

(b) To specify the range of velocities to be plotted using

m n RX

where m is the first channel to be plotted and n is the number of channels to be plotted. By default, all channels are plotted.

(c) To have the spectrum converted to optical depth before plotting enter

0 TAU

where all spectra for which the average continuum brightness is greater than k percent of the peak brightness (of all maps used in making the spectrum map) will be eligible to be plotted. To set k, enter

k CUTOFF

where the default is k = 20.

(d) To set the vertical scale of the plots, enter

n1 n2 MSCALE m TMULT

where the data will be plotted from n1 * (10 * * m) to n2 * (10 * * m) and where, if n2 ≤ n1, the plots will be self-scaling. The default is for self-scaling with m = 0.

(e) To smooth the data in velocity prior to plotting, enter

j VSMOOTH

where j is the full width in channels at e-fold points of the Gaussian smoothing function. The default is j = 0.

(f) To have only every n'th channel printed, enter

n SKIP

where n = 1 by default.

(g) To set the number of lines in horizontal plots (MAP-PROFILES only), enter

k LINES

where k = 50 by default.

(14) To obtain a plot on the Calcomp of the spectra in a spectra-map, enter

$$\text{FOR} \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \text{MAP-PLOT} \quad \text{options} \begin{Bmatrix} \begin{Bmatrix} \text{FULL} \\ \text{n1 n2} \end{Bmatrix} & \text{SCANS} \\ \text{n} & \text{A-SCAN} \end{Bmatrix}$$

where the options are

(a) To specify which of the spectra are to be plotted use one of two methods:

(i) by giving a list of array corrdinates

m1 , n1 , m2 , n2 ,

where up to six pairs of coordinates (mi, ni) may be entered

or (ii) by specifying the array range and the array spacing between plotted spectra using some or all of

i1 i2 XRANGE
j1 j2 YRANGE
i3 XSKIP
j3 YSKIP

with the default being method (ii) with the entire array included, but with i3 = j3 = 4.

(b) To specify the range of velocities to be plotted using

m n RX

where m is the number of the first channel plotted and n is the number of channels plotted. By default, all channels are plotted.

(c) To have the spectrum converted to optical depth before plotting enter

0 TAU

where all spectra for which the average continuum brightness is greater than k percent of the peak brightness (of all maps used in making the spectrum map) will be eligible to be plotted. To set k enter

k CUTOFF

where k = 20 by default.

(d) To set the vertical scaling of the plots, enter

n1 n2 MSCALE m TMULT

where data having values between n1 * (10 * * m) and n2 * (10 * * m) will be plotted and where, if n2 ≤ n1, the plots will be self-scaling. The default is for self-scaling with m = 0.

(e) To smooth the data in velocity prior to plotting, enter

j VSMOOTH

where j is the full width in channels at e-folding points of the Gaussian smoothing function. The default is j = 0.

(f) To have successive plots over-write each other enter

OVER-WRITE

where, by default, the plots do not over-write each other. In any case, plots from separate scans do not over-write each other.

(g) To set the size of the plots enter one or both of

j XMULT
k YMULT

where the defaults are j = k = 1000 and where each spectrum plot is 6.0 * k/1000 inches high and (j/1000)* MAX (6.0, 5.0 * NCHAN/96.) inches wide.

(15) To have a map of spectra plotted on the Calcomp, enter

$$\text{FOR} \left\{ \begin{array}{c} \text{ALL-SORC} \\ \text{ssssssss} \end{array} \right\} \quad \text{MAP-EVERYTHING} \quad \text{options} \left\{ \begin{array}{l} \left\{ \begin{array}{c} \text{FULL} \\ \text{n1 n2} \end{array} \right\} \ \text{SCANS} \\ \quad \text{n} \quad \text{A-SCAN} \end{array} \right\}$$

where the options are

(a) To specify the range of the spectra-map array plotted (see § III-10a) with the whole array plotted by default.

(b) To specify the array spacing between plotted spectra use one or both of

m XSKIP
n YSKIP

where m = n = 4 by default.

(c) To specify the range of velocities plotted use

m n RX

where m is the number of the first channel plotted and n is the number of channels plotted. By default, all channels are plotted.

(d) To have the spectra converted to optical depth before plotting enter

0 TAU

where all spectra for which the average continuum brightness is greater than k percent of the peak brightness (of all maps used in making the spectrum map) will be eligible to be plotted. To set k enter

k CUTOFF

where k = 20 by default.

(e) To smooth the data prior to plotting enter

j VSMOOTH

where j is the full width in channels at the e-folding points of the Gaussian smoothing function. The default is j = 0.

(f) To set the vertical scaling of the plots, enter

n1 n2 MSCALE m TMULT

where data having values between n1 * (10 * * m) and n2 * (10 * * m) will be plotted. If n2 ≤ n1, each of the separate spectra plots will be self-scaling. The default is for self-scaling with m = 0.

(g) To set the size of the plots enter one or more of

i XMULT
j YMULT
k HMULT

where the defaults are i = j = k = 1000 and the limits are 300 ≤ i ≤ 4000, 300 ≤ j ≤ 1000, and 500 ≤ k ≤ 2000. The height of the full plot is set to the full width of the plotting paper, but may be multiplied by j/1000. The height of each spectrum is set so that each spectrum occupies 95% of the distance between spectra and so that all spectra fit on the plot. This height may be multiplied by k/1000. The length of each spectrum and the full plot is set, before application of YMULT and XMULT, so that equal displacements in x and y represent equal displacements in seconds of arc. The lengths may be multiplied by i/1000.

(h) To suppress the plotting of axes enter

NO-AXES

where, by default, axes are plotted in RA and DEC around the whole plot and in T and V next to each spectrum.

VIII. HLINEINT Command Vocabulary for the Interactive CRT

The HLINEINT program may be invoked from the graphics CRT terminals. A series of programs similar to those of the LOOKS vocabulary is available to display data on the CRT screen. In addition the user may invoke all of the procedures described in chapters III-VII. These procedures will place their output on the printer (and Calcomp) as usual rather than on the CRT.

Since interactive processing requires large amounts of real computer time and since HLINEINT requires the large partition, the use of the CRT options will be limited to those times when the IBM 360 computer is not being heavily used by other users. You must consult with the computer operators before submitting your HLINEINT deck calling for the CRT.

To enter a command through the CRT terminal depress (hold down) the CTRL key and type D. To backspace in order to wipe out an error depress CTRL and type Z once for each character you wish to wipe out.

When the HLINEINT program comes up on the CRT, it will display HELLO ?. To load the basic vocabulary enter

FORTH LOAD HEX 20 LOAD

which is the same initializing command as is used with the cards version except that CARDS LOAD is omitted. When you are through using HLINEINT from the CRT enter

DISCARD GOODBY

to stop the program and free the large partition for other users.

Input is required from the user at two points in the program. When new commands are required, the controller will type

OK

When a CRT routine has filled the screen it will place a > sign on the screen and wait for instructions from the user. If you enter the word

STOP

with no leading blanks, the CRT routine will return control to the supervisor without completing the present command. If you enter nothing or some other word, the CRT routine will continue to carry out the present command.

To load the vocabulary needed for the special CRT routines, enter

CRTS LOAD

(1) To have information on the contents of the disk data set displayed on the CRT enter

DISK-CONTENTS

for a brief summary, or

$$\text{FOR} \quad \left\{ \begin{array}{l} \text{ALL-SORC} \\ \text{ssssssss} \end{array} \right\} \quad \left\{ \begin{array}{l} \text{LIST-SCANS} \\ \text{LIST-UVS} \\ \text{LIST-MAPS} \\ \text{LIST-SPECTRA} \end{array} \right\}$$

for a complete summary of particular types of records, or

$$\text{FOR} \quad \left\{ \begin{array}{l} \text{ALL-SORC} \\ \text{ssssssss} \end{array} \right\} \quad \text{LIST-DISK}$$

for a complete summary of all record types.

The information displayed will include

(i) Highest and lowest scan numbers

(ii) Lowest unused block numbers

(iii) Initial block number of each scan

(iv) Scan number and source name

(v) Record type

(vi) In data scans, the number of signal, image, and difference band records

(vii) In uv, map, and map-spectra scans, the map dimensions and velocity

(2) To obtain plots on the CRT of the spectra, enter

FOR $\left\{ \begin{array}{l} \text{ALL-SORC} \\ \text{ssssssss} \end{array} \right\}$ SPECTRA $\left\{ \begin{array}{l} \text{n1 n2} \\ \text{FULL} \end{array} \right\}$ SCAN-RANGE

where each plot will fill the screen and there will be one plot for each record (or record average) for each baseline. The options are

(a) To average records before plotting use

$\left\{ \begin{array}{l} \text{n INT =} \\ \text{AVERAGE} \end{array} \right\}$

where AVERAGE is the default (see § III-4).

(b) To specify the range of channels to be displayed (see § III-6) with RX-ABCD as the default.

(c) To include only specified record types (see § III-7) with DATA as the default.

(d) To specify the format of the data plotted (see § III-5) with VECTOR as the default.

(e) To smooth the data prior to plotting enter

n SMOOTH

where n = 0 is the default and where n is the full width in channels at the e-folding points of the Gaussian smoothing function.

(f) To specify a fixed scale for the plots enter

m1 m2 SCALE

where m1 < m2 is the range to be plotted. If m1 ≥ m2, which is the default, the plots will be separately self-scaling. For fixed-scale VECTOR plots, the phase is scaled from -180 to 180 degrees.

(g) To have successive spectra over-write each other enter

OVER-WRITE

where, by default the screen is cleared before each spectrum is plotted. The user may clear the screen with the page button on the console whenever control has been returned to him (e.g. when > is displayed).

(3) To print information on the CRT screen from header records, enter

FOR {ALL-SORC / ssssssss} HLOOK choices {n1 n2 / FULL} SCAN-RANGE

where you must specify one of the choices below:

(a) BASELINES (baselines in ns)

(b) UVS (projected baseline parameters)

(c) VELOCITIES (velocity offsets)

(d) CALIBRATORS (list calibrators by type)

(e) j1 j2 {DUMP / HEX-DUMP}

for a list of array values from ARRAY(j1) through ARRAY(j2) in half-word integer (DUMP) or hexadecimal (HEX-DUMP) formats. To fit on screen, the limits are

(j2 - j1) < 310 for DUMP

(j2 - j1) < 433 for HEX-DUMP

(f) I*2 n1 , n2 , n3 ,

for a list of array values as half-word integers. No more than 10 array points may be done at a time.

(g) I*4 n1 , n2 , n3 ,

for a list of array values as full word integers taken from full word locations n1, n2, n3, etc.. No more than 7 array points may be done at a time.

(h) CMPLX {c1 # c2 # c3 # / a1 , a2 , a3 ,} {VECTOR / COMPLEX}

for a list of complex numbers from channel numbers ci or half-word integer array points (for the real part) ai. VECTOR is the default and no more than five complex numbers may be done at a time.

(i) INV-BANDPASS $\left\{\begin{array}{l}\text{VECTOR}\\ \text{COMPLEX}\end{array}\right\}$ $\left\{\begin{array}{c}\text{m} \quad \text{n} \quad \text{RX}\\ \text{RX-A}\\ \underline{\text{et al.}}\end{array}\right\}$

to list a range of channels in the inverse bandpass multiplier. The defaults are VECTOR and RX-AB and no more than 160 channels may be displayed at a time.

(4) To print information on the CRT screen from data records, enter

FOR { ALL-SORC / ssssssss } LOOK choices { n1 n2 / FULL } SCAN-RANGE

where you must specify one of the choices below:

(a) TPOWERS (total powers)

(b) DELAYS (delay values)

(c) j1 j2 { DUMP / HEX-DUMP }

for a list of array values from ARRAY(j1) through ARRAY(j2) in half-word integer (DUMP) or hexadecimal (HEX-DUMP) formats. To fit on the screen, the limits are

$(j2 - j1) < 300$ for DUMP

$(j2 - j1) < 420$ for HEX-DUMP

(d) { I*2 / I*4 } n1 , n2 , n3 ,

for a list of array values as half-word integers (I*2) or as full-word integers (I*4). The limits are 10 half-words or 7 full-words at a time.

(e) INSFUNC option (instrumental functions)

(f) RX-SUMS option (narrow channel sums)

(g) CONTINUUM option (analogue fringe values)

(h) CMPLX { c1 # c2 # c3 # / a1 , a2 , a3 , } option

for a list of complex numbers from channel numbers c or half-word array points (for the real part) a.

(i) CHANNELS { m n RX / RX-A / <u>et al.</u> } option

to list a range of narrow band channel data. The default is RX-AB.

The option for choices (e) through (i) is to specify the type of data display (see § III-5). The default is VECTOR. The limits for options (h) and (i) are 5 complex numbers and 150 channels if VECTOR or COMPLEX are specified and 10 complex numbers (with no limit on channels) if AMPLITUDE, PHASE, REAL, or IMAGINARY are specified.

(5) To have information from map and spectra-map headers displayed, state

$$\text{FOR} \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \text{MLOOK} \quad \text{options} \begin{Bmatrix} \text{FULL} \\ \text{n1 n2} \end{Bmatrix} \quad \text{SCAN-RANGE}$$

where the map type, scan number, source name, center velocity and velocity range will be displayed. The options are

(a) To restrict the display to one or more map types, use one of the include only words (see § III-7). By default, the information is displayed for all map types.

(b) To obtain additional information, enter one of the following sequences:

(i) I*2 i1 , i2 , i3 ,
for a list of values from half-word header locations i1, i2, i3, etc. (up to 10).

(ii) R*4 j1 , j2 , j3 ,
for a list of values from full-word floating-point header locations j1, j2, j3, etc. (up to 7).

(iii) MDUMP
for a half-word dump of the header.

(iv) MHEX-DUMP
for a hexadecimal dump of the header.

(v) ASSOCIATES
for a list of associated maps (e.g., the dirty and clean beams, continuum maps, *et al.*).

(vi) POSITIONS
for the position of the map center and information on the size, center, and spacing of the array.

(vii) MAXIMA
for the peak value of each map.

(6) To produce cross-hatched map profiles on the CRT screen, state

$$\text{FOR} \quad \begin{Bmatrix} \text{ALL-SORC} \\ \text{ssssssss} \end{Bmatrix} \quad \begin{Bmatrix} \text{X-HATCH} \\ \text{Y-HATCH} \\ \text{XY-HATCH} \end{Bmatrix} \quad \text{options} \quad \begin{Bmatrix} \text{FULL} \\ \text{n1 n2} \end{Bmatrix} \quad \text{SCAN-RANGE}$$

where lines at constant declination are produced by X-HATCH and XY-HATCH and lines at constant right ascension are produced by Y-HATCH and XY-HATCH. The options are

(a) To specify the types of maps included (see § III-7). The default is to include all map types.

(b) To specify that the map is to be converted to optical depth before plotting, enter

0 TAU

and to set the continuum cutoff level enter

k CUTOFF

where k = 20 by default (see § III-10c).

(c) To specify the range of the array to be plotted (see § III-10a), where the whole map is plotted by default. The command INNER is available.

(d) To smooth the map before plotting (see § III-10b) where no smoothing is the default.

(e) To specify the number of array intervals between plotted lines (in the direction perpendicular to the line) state one or both of

m XSKIP
n YSKIP

where XSKIP applies to Y-HATCH and XY-HATCH and YSKIP applies to X-HATCH and XY-HATCH and where the default is to have about 16 lines plotted.

(f) To suppress the plotting of axes and labels, state

NO-AXES

(g) To have lines obscured by foreground lines suppressed, state

HIDDEN

(h) The vertical displacement due to the value of the map is proportional to [T(x,y)/(Tmax-Tmin)] * TMULT/1000.0, where Tmax (Tmin) is the maximum (minimum) value on the map and where TMULT may be set using

j TMULT

with j = 1000 as the default.

(i) To give some appearance of three-dimensionality, enter

n BACK

to tilt the top back n degrees ($0 \leq n \leq 60$),

m OVER

to rotate the map to the right (around the center of the bottom) by m degrees ($-60 \leq m \leq 60$), and

k PERSPECTIVE

to show the map in pseudo-perspective with the top k/100.0 times farther away than the bottom ($75 \leq k \leq 150$). The defaults are m = n = 0, k = 100.

(j) To set the scaling of the map, enter

n XMULT

where a displacement of 1" in the N-S direction will be equal to a displacement of (n/1000)" in the E-W direction. By default, n = 1000. To have equal (x,y) displacements represent equal array displacements, state

-1 XMULT

(7) To produce contour maps on the CRT screen, enter

$$\text{FOR} \quad \left\{ \begin{matrix} \text{ALL-SORC} \\ \text{ssssssss} \end{matrix} \right\} \quad \text{CONTOUR} \quad \text{options} \quad \left\{ \begin{matrix} \text{FULL} \\ \text{n1 n2} \end{matrix} \right\} \quad \text{SCAN-RANGE}$$

where the options are

(a) To specify what is plotted and the contour interval, enter one of

$$n \quad \left\{ \begin{matrix} \text{DEGREES} \\ \text{TAU} \\ \text{RATIO} \end{matrix} \right\}$$

where the default is 100 RATIO and where n is the contour interval in °K (for brightness maps under DEGREES), in units of 0.001 of optical depth (for TAU and for optical depth maps under DEGREES), and in units of 0.001 of the peak value of the map (RATIO). The specification of TAU causes the map to be converted to optical depth before plotting.

(b) To specify what types of maps are included (see § III-7). The default is to include all map types.

(c) To set the continuum cutoff level (for TAU), state

$$k \quad \text{CUTOFF}$$

where k = 20 is the default (see § III-10c).

(d) To specify the range of the array to be plotted (see § III-10a) where the whole map is plotted by default. The command INNER is available.

(e) To smooth the map before plotting (see § III-10b) where no smoothing is the default.

(f) To have the zero contour plotted (it is normally suppressed), state

ZERO

(g) To suppress the plotting of axes and labels, enter

NO-AXES

(h) To set the scaling of the map, enter

n XMULT

where a displacement of 1" in the N-S direction will be equal to a displacement of (n/1000.)" in the E-W direction. By default, n = 1000. To have equal (x,y) displacements represent equal array displacements, state

-1 XMULT

(i) Normally, contour maps are plotted in two dimensions. However, various three-dimensional options are available. These are

n BACK

to tilt the top back n degrees ($0 \leq n \leq 60$),

m OVER

to rotate the map to the right by m degrees ($-60 \leq m \leq 60$),

k PERSPECTIVE

to show the map in pseudo-perspective with the top k/100.0 times farther away than the bottom ($75 \leq k \leq 150$), and

THREE-D

to have the contours displaced vertically in proportion to their value. The amount of the vertical displacement may be set by

j TMULT

when the vertical displacement is proportional to

(j/1000) * T(x,y)/(Tmax-Tmin).

The defaults are m = n = 0, k = 100, and j = 0 (with THREE-D setting j to 1000).

(8) To obtain a plot on the CRT of the spectra in a spectra-map, enter

$$\text{FOR} \quad \left\{ \begin{matrix} \text{ALL-SORC} \\ \text{ssssssss} \end{matrix} \right\} \quad \text{MAP-SPECTRA} \quad \text{options} \quad \left\{ \begin{matrix} \text{n1 n2} \\ \text{FULL} \end{matrix} \right\} \quad \text{SCAN-RANGE}$$

where the options are

(a) To specify which of the spectra are to be plotted use one of two methods:

(i) by giving a list of array coordinates

m1 , n1 , m2 , n2 ,

where up to six pairs of coordinates (mi, ni) may be entered

or (ii) by specifying the array range and the array spacing between plotted spectra using some or all of

i1 i2 XRANGE
j1 j2 YRANGE
i3 XSKIP
j3 YSKIP

with the default being method (ii) with the entire array included, but with i3 = j3 = 4.

(b) To specify the range of velocities to be plotted using

m n RX

where m is the first channel plotted and n is the number of channels to be plotted. By default, all channels are plotted.

(c) To have the spectrum converted to optical depth before plotting enter

0 TAU

where all spectra for which the average continuum brightness is greater than k percent of the peak brightness (of all maps used in making the spectrum map) will be eligible to be plotted. To set k, enter

k CUTOFF

where k = 20 by default.

(d) To set the vertical scale of the plots, enter

n1 n2 MSCALE m TMULT

where the data will be plotted from n1 * (10 * * m) to n2 * (10 * * m) and where, if n2 ≤ n1, the plots will be self-scaling. The default is for self-scaling with m = 0.

(e) To smooth the data in velocity prior to plotting, enter

j VSMOOTH

where j is the full width in channels at e-folding points of the Gaussian smoothing function. The default is j = 0.

(f) To have successive plots over-write each other, enter

OVER-WRITE

where, by default, the screen is erased before each spectrum is plotted. The screen is erased before each scan in any case.

APPENDIX A. INTERFEROMETER PHASE

Interferometer phase is a confusing subject with some controversy over its precise meaning. This appendix will present a basic development of the subject as handled by the NRAO line interferometer system.

The basic elements of the interferometer are illustrated in Figure A-1. Let x, y_1, y_2, and z be the electrical lengths of the cables associated with telescope 1 and $x + \Delta x$, $y_1 + \Delta y_1$, $y_2 + \Delta y_2$, and $z + \Delta z$ be the corresponding electrical lengths for telescope 2. Let ω_{LO} be the angular frequency of the first local oscillator, ω_2 be the sum of the angular frequencies of the following local oscillators, ω_{IF} be the angular frequencies to which the final IF amplifiers respond, and let A_u and A_L be the voltages due to the upper and lower sidebands in telescope 1 and B_u and B_L be the corresponding voltages in telescope 2. For telescope 1, the voltages are given by the real part of:

at (a) $A_u \exp i\,[(\omega_{LO} + \omega_2 + \omega_{IF})(t-x/c)]$

$\qquad + A_L \exp i\,[(\omega_{LO} - \omega_2 - \omega_{IF})(t-x/c)]$

at (b) $\exp i\,[\omega_{LO}\,(t-y_1/c)]$

at (c) $A_u \exp i\,[-\,\omega_{LO}(x/c-y_1/c)+(\omega_2 + \omega_{IF})(t-x/c)]$

$\qquad + A_L \exp i\,[-\omega_{LO}(x/c-y_1/c)-(\omega_2 + \omega_{IF})(t-x/c)]$

at (d) $\exp i\,[\omega_2(t-y_2/c)]$

and at (e) $A_u \exp i\,[-\omega_{LO}(x/c-y_1/c)-\omega_2(x/c-y_2/c)+\omega_{IF}(t-x/c-z/c)]$

$\qquad + A_L \exp i\,[-\omega_{LO}(x/c-y_1/c)+\omega_2(x/c-y_2/c)-\omega_{IF}(t-x/c-z/c)]$.

In this development we have assumed that signals of frequencies $2\omega_{LO}$ (at (c)) and $2\omega_2$ (at (e)) are eliminated by IF filters and amplifiers. Note that

$$A_u = A_u(x,y)$$

$$A_L = A_L(x,y)$$

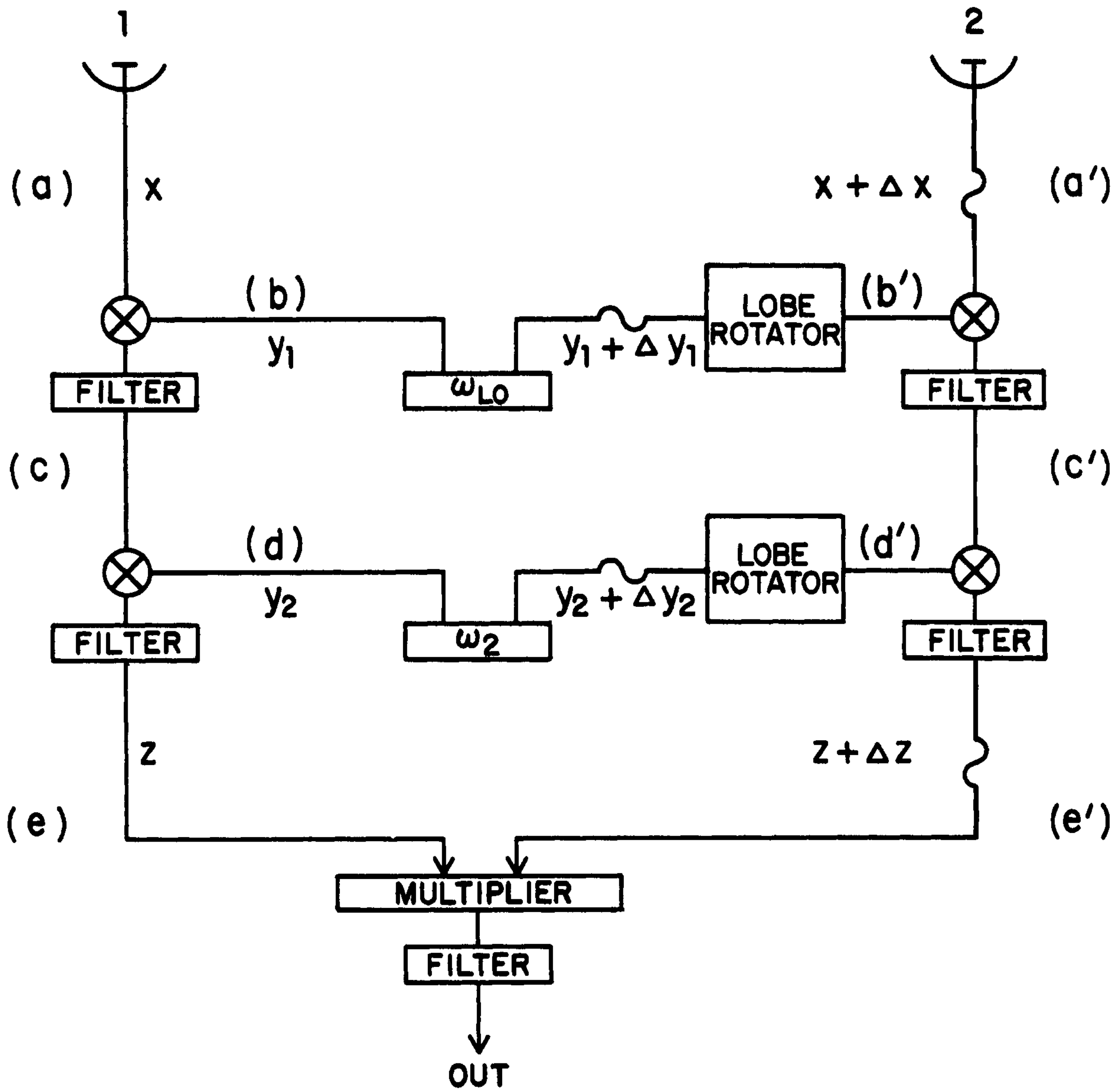


Figure A-1. Receiver Logic

where x and y are coordinates on the sky and that the above expressions should show an integral over x and y.

The signal reaching telescope 2 is delayed by $\tau(x,y)$ seconds compared to that reaching telescope 1. Thus, at (a') the signal is

$$B_u \exp i\,[(\omega_{LO}+\omega_2+\omega_{IF})(t-\tau-x/c-\Delta x/c)]$$

$$+ B_L \exp i\,[(\omega_{LO}-\omega_2-\omega_{IF})(t-\tau-x/c-\Delta x/c)].$$

The lobe rotator at (b') operates at ω_{LO} and at the delay (τ_o) based on the assumed baseline and source parameters. Thus, the voltages are

at (b') $\exp i\,[\omega_{LO}(t-\tau_o-y_1/c-\Delta y_1/c)+\theta]$

at (c') $$B_u \exp i\,[-\theta-\omega_{LO}(\tau-\tau_o)-\omega_{LO}(x/c+\Delta x/c-y_1/c-\Delta y_1/c)$$
$$+(\omega_2+\omega_{IF})(t-\tau-x/c-\Delta x/c)]$$
$$+B_L \exp i\,[-\theta-\omega_{LO}(\tau-\tau_o)-\omega_{LO}(x/c+\Delta x/c-y_1/c-\Delta y_1/c)$$
$$-(\omega_2+\omega_{IF})(t-\tau-x/c-\Delta x/c)]$$

where θ is an additional phase shift applied by the lobe rotator under computer control. The second lobe rotator operates effectively at ω_2 with added phase shift α and, if delay is fixed, an additional phase shift $-\omega_{IFO}\,\tau_o$. Thus, the voltages for tracked delay are

at (d') $\exp i\,[\omega_2(t-\tau_o-y_2/c-\Delta y_2/c)+\alpha]$

and at (e') $$B_u \exp i\,[-\theta-\alpha-(\omega_{LO}+\omega_2)(\tau-\tau_o)-\omega_{LO}(x/c+\Delta x/c-y_1/c-\Delta y_1/c)$$
$$-\omega_2(x/c+\Delta x/c-y_2/c-\Delta y_2/c)$$
$$+\omega_{IF}(t-\tau-x/c-\Delta x/c-z/c-\Delta z/c)]$$
$$+B_L \exp i\,[-\theta+\alpha-(\omega_{LO}-\omega_2)(\tau-\tau_o)-\omega_{LO}(x/c+\Delta x/c-y_1/c-\Delta y_1/c)$$
$$+\omega_2(x/c+\Delta x/c-y_2/c-\Delta y_2/c)$$
$$-\omega_{IF}(t-\tau-x/c-\Delta x/c-z/c-\Delta z/c)]$$

The output power is the real part of AB* with the $2\omega_{IF}$ terms eliminated by the low-pass filter. The result may be expressed as

$$R(\tau) = A_u\ B_u \cos\ [\Phi_u + \theta + \alpha] + A_L\ B_L \cos\ [\Phi_L + \theta - \alpha] \tag{A-1}$$

where, for tracked delay,

$$\begin{aligned}\Phi_{\substack{u\\L}} = (\omega_{LO} \pm \omega_2 \pm \omega_{IF})\ (\tau - \tau_o) + \omega_{LO}(\Delta x/c - \Delta y_1/c) \\ \pm\ \omega_2(\Delta x/c - \Delta y_2/c) \pm \omega_{IF}(\tau_o + \Delta x/c + \Delta z/c).\end{aligned} \tag{A-2}$$

In the table below, four possible pairs of θ and α are shown together with the part of the upper and lower sideband fringes which appear in $R(\tau)$:

θ	α	$R(\tau)$
0	0	Real(u) + Real(L)
90	-90	Real(u) - Real(L)
90	0	-Imag(u) - Imag(L)
0	-90	Imag(u) - Imag(L)

The on-line computer solves for the real and imaginary parts of both upper and lower sidebands by following a phase-shifting sequence similar to that shown in the table. Actually a more complicated sequence is followed in order to eliminate problems with DC offsets.

The output phase terms Φ above deserve further discussion. We note that any assumptions we have made concerning source positions and instrumental parameters affect Φ only as they affect τ_o and the angular frequencies. Let us define some nomenclature as:

$$\begin{aligned}&\text{actual delay} &&\equiv\ d &&= \Delta z/c\\ &\text{delay center} &&\equiv\ d_c &&= -\Delta x/c\\ &\text{requested delay} &&\equiv\ d_r &&= -\tau_o + d_c\end{aligned}$$

where the requested delay is the correct delay when delay is tracked and let the subscript 0 indicate that the parameter is evaluated at the assumed source and instrumental parameters. We note that

$$\tau = B_x \cos\delta \cos h + B_y \cos\delta \sin h + B_z \sin\delta + K \cos\delta$$

and define

$$\omega_{IF} = \omega_{IFO} + \Delta\omega_{IF}$$

Let us first consider the case when delay is tracked. The phase terms become

$$\left(\Phi_{\substack{u\\L}} \right)_T = (\omega_{LO} \pm \omega_2 \pm \omega_{IF})(\tau - \tau_o) + \omega_{LO}\ (\Delta x/c - \Delta y_1/c)$$

$$\pm\ \omega_2\ (\Delta x/c - \Delta y_2/c)$$

The ω_{LO} and most of the ω_2 terms are independent of observation and may be lumped together as an instrumental phase $\phi_{\substack{u\\L}}$. Thus

$$\left(\Phi_{\substack{u\\L}} \right)_T = \phi_{\substack{u\\L}} \pm P\ \omega_s + (\omega_{LO} \pm \omega_2 \pm \omega_{IF})\ (\tau - \tau_o)$$

where ω_s is the angular frequency of the synthesizer and P is the phase-frequency slope $(\Delta x - \Delta y_2)/c$. The fixed delay case is more complicated. The second lobe rotator is operated with an additional phase shift$-\omega_{IFO}\ \tau_o$. This additional phase shift adds a term $\mp\ \omega_{IFO}\ \tau_o$ to equation (A-2). Thus, for fixed delay,

$$\left(\Phi_{\substack{u\\L}} \right)_F = \left(\Phi_{\substack{u\\L}} \right)_T \pm\ \omega_{IFO}\ (d-d_c) \pm \Delta\omega_{IF}\ (d-d_r) \qquad \text{(A-3)}$$

We have now obtained expressions for the measured phase. The off-line program has the capability of "correcting" the measured phase for various "errors" (see Chapter V). These errors are not in the true parameters (e.g. τ) but in the assumed ("expected") fringe which was subtracted by the lobe rotators. If we define the correction ΔP

to parameter P as the amount to be <u>added</u> to parameter P in the correction, we find:

(a) To correct for fixed delay

$$\Delta \Phi_{\substack{u \\ L}} = \mp [\omega_{IFO}(d-d_c) + \Delta\omega_{IF}(d-d_r)]$$

(b) To correct for inequalities in the LO chains

$$\Delta \Phi_{\substack{u \\ L}} = \mp P \ \omega_s$$

(c) To correct for changes in the assumed source position and baseline parameters

$$\Delta \Phi_{\substack{u \\ L}} = -(\omega_{LO} \pm \omega_2 \pm \omega_{IFO} \pm \Delta\omega_{IF}) \ \Delta \ \tau_o$$

where

$$\begin{aligned} \Delta \tau_o = \ & \Delta B_x \ \cos \delta \cos h \\ & + \Delta B_y \ \cos \delta \sin h \\ & + \Delta B_z \ \sin \delta \\ & + \Delta K \ \cos \delta \\ & + \Delta\delta \ (B_z \cos \delta - K \sin \delta - B_x \sin \delta \cos h - B_y \sin \delta \sin h) \\ & + (\Delta\alpha - \Delta t)(B_x \cos \delta \sin h - B_y \cos \delta \cos h). \end{aligned}$$

APPENDIX B. MAPPING

It is well known that the observed visibility function is the complex Fourier transform of the sky brightness distribution. The methods by which the brightness distribution is obtained from the data are the subject of much confusion and debate. It is hoped that this appendix will clarify the Fourier transform methods used by HLINEINT.

(1) Fourier Transformation

The interferometer samples the visibility function along elliptical arcs in the visibility or (u,v)-plane. The sampled function V' may be written as

$$V' = V(u,v) \cdot S(u,v) \qquad (1)$$

where V(u,v) is the smooth visibility function and S is the sampling function given by

$$S(u,v) = \sum_{\text{obs.}i} W_i \; {}^2\delta(u-u_i,\, v-v_i).$$

The W_i are the weights assigned by the user to the individual data points. These weights are usually taken to be proportional to the square root of the integration time and inversely proportional to the local density of data points. A taper may also be introduced using the W_i. All of these weighting factors are accessible to the user of HLINEINT and may be altered to suit the needs of the particular data set.

The simplest procedure for obtaining the brightness map would be to directly Fourier transform equation (1). However, because of the large quantities of data present in many experiments, most observers prefer to use a more efficient Fourier transform algorithm. Such algorithms require that the data occur at regular intervals in the Fourier transform variables (u and v). To convert the observed data (V') to fit this requirement, we must "smooth it to a grid":

$$V'' = \text{III} \cdot (c * (V \cdot S)) \qquad (2)$$

where c is a convolving function, * represents a convolution and III is the rectangular "bed of nails" function

$$III(u,v) = \sum_{i=-\infty}^{\infty} \sum_{j=-\infty}^{\infty} {}^2\delta[(u-i\Delta u),(v-j\Delta v)]$$

Equation (2) may be transformed with an algorithm such as the FFT to obtain

$$T'' = \overline{III} * [\overline{c} \cdot (T*B)] \qquad (3)$$

where T'', $\overline{III}$, $\overline{c}$, T, and B are the Fourier transforms of V'', III, c, V, and S, respectively. The function $\overline{III}$ is another "bed of nails" function which causes the entire pattern to repeat at regular intervals. If, for the moment, we assume that this repetition may be ignored we can obtain a map T'''

$$T''' = \frac{T''}{\overline{c}} \approx T * B. \qquad (4)$$

The synthesized beam pattern ("dirty beam") may be obtained in a similar manner by substituting a delta function at the origin for T:

$$B'' = \overline{III} * (\overline{c}B)$$

or (5)

$$B \approx \frac{B''}{\overline{c}}$$

The HLINEINT transform programs automatically compute T''' rather than T'' and normally also compute the dirty beam B. The two functions may then be entered in the CLEAN subroutines to obtain an estimate of T(x,y).

The smoothing to a grid does cause some problems which we should consider. The function c is a known, analytic function so that there is no problem with division by $\overline{c}$. However it is very dangerous to ignore the convolution with $\overline{III}$. If either T(x,y) or B(x,y) are not heavily concentrated toward the origin, then the repetition of map images can cause significant errors to arise. A careful choice of the convolving function (e.g., a moderately wide gaussian) can reduce the effects of the repetition, but the cost in computing time can be significant. A pill box convolving function uses very little computer time, but has little effect on the errors arising from the repetition.

If the user has only around 100 data points to be transformed for each map, he should seriously consider employing the direct ("brute force") Fourier transform procedure available in HLINEINT. This procedure yields synthesized maps and beams given exactly by

$$T' = T * B$$
$$B = T'(T = {}^2\delta(x,y)) = \overline{S} \; .$$

The direct procedure also allows the user considerable freedom in the selection of map parameters (grid spacings, etc.).

With the FFT, there is very little freedom in the choice of the map parameters. To determine the map parameters let us assume (1) that the source is contained in an area somewhat smaller than $|x| < x_o$, $|y| < y_o$, (2) that the data lie entirely within $|u| < u_T$, $|v| < v_T$ and (3) that we wish m points per synthesized beamwidth in the x-direction and n points in the y-direction. If we wish to use the cleaning procedure, we must compute the beam over an area $4\ x_o \times 4\ y_o$. Plugging in the FFT relationships we find that

$$\Delta u = \frac{1}{4x_o} \qquad \Delta v = \frac{1}{4y_o}$$

$$\Delta x \le \frac{1}{2mu_T} \qquad \Delta y \le \frac{1}{2nv_T} \tag{6}$$

$$M \ge 8\ x_o\ u_T\ m \qquad N \ge 8\ y_o\ v_T\ n$$

where M,N are the x,y dimensions of the transform and the inequality arises from the necessity to have M and N integer powers of 2. If one wishes to synthesize the full beam area using spacings up to

2700 meters, the values of M and N given by equation (6) are several powers of 2 larger than the maximum array size (512 x 512) allowed by the programs. Thus the user will have to compromise in some fashion when he specifies Δx, Δy, M, and N. The user is reminded that the cleaning operation can only be carried out over the central quarter of the map area.

(2) Cleaning

The brightness map obtained by Fourier transformation of the observations is approximately the convolution of the true brightness distribution with the synthesized beam pattern ("dirty beam"). In some cases, the dirty beam is sufficiently clean that the effects of the convolution may be ignored. However, in cases where there are few data points or where there is poor coverage of the (u,v)-plane, the effects of the convolution may be significant.

The procedure called CLEAN may be used to attempt to do a type of deconvolution of the brightness map. In the first step, the source is temporarily assumed to consist of an unknown number, N, of components which are point sources of unknown amplitude and position. The uncorrected source map ("dirty map") is then a sum of N components each of which has the shape of the beam pattern. The decomposition of the map is performed by repeatedly scanning the map for its highest remaining peak (in absolute value) and subtracting from the map an appropriately scaled beam pattern centered on that peak. (Note: in order to do this subtraction, the beam pattern must have been computed for an area four times larger than the area of the map being cleaned.) The process is stopped when the highest remaining peak is less than the expected noise level. See the instructions for the use of CLEAN for a description of several alternative methods by which the user may set this "expected noise level".

The second and final step in the procedure is to restore the components found in the first step to the "noise" map which remained at the end of the first step. Since the point-source model is obviously incorrect for most sources, the components are restored to the map in the form of elliptical gaussians. Usually the elliptical gaussian "clean beam" has the same shape as the central peak of the dirty beam. However, the user may specify other alternatives.

This cleaning procedure is found to work well and to converge rapidly for data having good signal-to-noise ratio. It is a systematic and reliable method of interpolation between the data points in the visibility plane. Since the clean beam has no sidelobes, the procedure also provides a straightforward method of extrapolating the data to antenna spacings somewhat larger than were actually utilized.

APPENDIX C. RECORD FORMATS

(1) Data Header

I*2 WORD	I*4 WORD	PARAMETER AND UNITS	TEL.TAPE WORD
1	--	Integer 1 to identify data header	1
2	--	Scan #	2
3	--	Calibrator weight (≤ 100)	--
4	--	Greenwich sidereal days since 2424832	4
5-6	3	LST (integer $0^s.1$)	5-6 (1)
7-10	--	Source name (EBCDIC)	7-10 (2)
11-12	6	RA (revolutions - 30-place fraction)	11-12
13-14	7	DEC (revolutions - 30-place fraction)	13-14
15	--	Source flux (if > 0 => gain calibrator)	--
16	--	Phase calibrator indicator (> 0 => phase cal.)	--
17	--	Bandpass calibrator indicator (> 0 => BP cal.)	--
18	--	Value of clock corrections applied	--
19	--	Value of RA corrections applied	--
20	--	Value of DEC corrections applied	--
21	--	Baseline correction indicator (> 0 => cor. applied)	--
22	--	Delay not track correction indicator (> 0 => cor. appl.)	--
23	--	Delay center 85-1 (ns * 1.024)	--
24	--	Delay center 85-2 (ns * 1.024)	69
25	--	Delay center 85-3 (ns * 1.024)	70
26	--	Actual analogue delay 85-1 (ns * 1.024)(may be garbage)	73 (3)
27	--	Actual analogue delay 85-2 (ns * 1.024)(may be garbage)	74
28	--	Actual analogue delay 85-3 (ns * 1.024)(may be garbage)	75
29-30	15	$V-V_{LSR}$ (signal band: in 1/c real * 4)	--
31-32	16	$V-V_{LSR}$ (image band: in 1/c real * 4)	--
33-34	17	V_{LSR} (in 1/c real * 4)	33-34 (4)
35-36	18	Synthesizer frequency (Hz)	35-36
37-38	19	Z_{12} (Baseline in λ's * 1024 at Signal-Band	37-38 (5)
39-40	20	Z_{13} Observing frequency)	39-40
41-42	21	Z_{23} "	41-42
43-44	22	Z_{14} "	43-44
45-46	23	X_{12} "	45-46
47-48	24	X_{13} "	47-48
49-50	25	X_{23} "	49-50
51-52	26	X_{14} "	51-52
53-54	27	Y_{12} "	53-54
55-56	28	Y_{13} "	55-56
57-58	29	Y_{23} "	57-58
59-60	30	Y_{14} "	59-60
61-62	31	K_{12} "	61-62
63-64	32	K_{13} "	63-64
65-66	33	K_{23} "	65-66
67-68	34	K_{14} "	67-68

I*2 WORD	I*4 WORD	PARAMETER AND UNITS	TEL.TAPE WORD
69-70	35	λ signal band/λ image band (real * 4)	--
71-72	36	Observing frequency (signal band MHz part)	--
73-74	37	Observing frequency (signal band Hz and kHz part)	--
75-110	38-55	Projected baseline array (λ's * 1024)	--(6)
111-122	--	Reserved	
123	--	AGC correction indicator (> 0 => AGC cor. applied) + 100 * return code	-- 15
124	--	Phase-frequency correction applied (>0=> cor. applied)	--
125	--	Phase frequency correction: BL 12	--
126	--	" " " BL 13	--
127	--	" " " BL 23	--
128	--	" " " BL 14	--
129	--	Bandpass correction multiplier (ch. 1, real part * 1000)	--
130	--	" " " (ch. 1, imag. part * 1000)	--
131-512	--	" " " (chs. 2-192, *1000)	--

NOTES:

(1) Units on telescope tape: BCD $0\overset{s}{.}1$

(2) Units on telescope tape: ANSI

(3) See note 9 for data record formats

(4) Units on telescope tape: 30-bit fraction 1/c

(5) Units on telescope tape: λ * 1024 at LO frequency

(6) B(1,J) = J or 0
B(2,J) = X(J)
B(3,J) = Y(J)
B(4,J) = Z(J) cos δ - K(J) sin δ
B(5,J) = X(J) sin δ
B(6,J) = Y(J) cos δ

where J = 1, 2, 3 = baseline number

(2) Data Record

I*2 WORD	PARAMETER (UNITS)	TEL.TAPE WORD
1	Integer 2, 3, or 4 to identify data record and type	1[1]
2	Scan number	2
3	Switches	3
4	Greenwich sidereal days since 2424832	4
5-6	LST (integer $0^{s}.1$)	5-6
7	MODE + 100 * (# of baselines)	--
8	Receiver baseline connections (recorded or overridden)	--[2]
9	Gains used to scale data	--
10	Recorded gains	10[3]
11	IF selection	11[4]
12	Computer control	12[5]
13	Lock	13[6]
14	Range	14[7]
15	Faults	15[8]
16	Actual analogue delay: 85-1 (in ns * 1.024)	16[9]
17	" " " 85-2 (")	17
18	" " " 85-3 (")	18
19-20	Local oscillator (Hz)	19-20
21-22	Total integration count	21-22
23-24	Total power (signal) input A	23-24[10]
25-26	" " " " B	25-26
27-28	" " " " C	27-28
29-30	" " " " D	29-30
31-32	Total power (signal + noise) input A	31-32
33-34	" " " " B	33-34
35-36	" " " " C	35-36
37-38	" " " " D	37-38
39-56	Compressed autocorrelator words 1572-1603	39-70
39	Receiver bandwidth code - all inputs combined = A + 10B + 100C + 1000D	39-42[11]
40	MODE + 16 (Front-end and noise tube switches) + 256 (Receiver gain modulator)	43-45
41	Sense switches + 256 (Switching sync. control)	46-47
42	Clipper test signals + 16 (Digital test signals)	48-49
43-44	Frequency of local oscillator A (Hz)	51-54[12]
45-46	" " " " B "	55-58
47-48	" " " " C "	59-62
49-50	Blanking time (microseconds)	63-64
51-52	Signal time "	65-66
53-54	Reference time "	67-68
55	Cycles per clump period	69
56	Standard time modes + bandpass application indicator (=0 not applied, = 128 applied)	70

I*2 WORD	PARAMETER (UNITS)	TEL.TAPE WORD
57-78	A/D channels 24-63 (some deleted)	151-190
57	Outside temperature (°C)	170
58	Outside dew point (°C)	171
59	Outside barometric pressure (mm)	172
60	Cable pressure (?)	173
61	Receiver box temperature 85-1	178
62	" " " 85-2	179
63	" " " 85-3	180
64	LO line strecher 85-1	182
65	" " " 85-2	183
66	" " " 85-3	185
67	IF monitor (R) 85-1	151
68	" " " 85-2	153
69	" " " 85-3	155
70	Sync. detector (R) 85-1	159
71	" " " 85-2	161
72	" " " 85-3	163
73	IF monitor (L) 85-1	152
74	" " " 85-2	154
75	" " " 85-3	156
76	Sync. detector (L) 85-1	160
77	" " " 85-2	162
78	" " " 85-3	164
79	"Requested" (correct analogue) delay 85-1 (ns*1.024)	191(9)
80	" " " " 85-2 "	192
81	" " " " 85-3 "	193
82	Digital delay "bandwidth" codes	194(13)
83	Actual digital delay 85-1	195
84	" " " 85-2	196
85	" " " 85-3	197
86	Reserved	
87-88	Instrumental function (Re, Im * 1000) Quadrant 1	--
89-90	" " " " 2	--
91-92	" " " " 3	--
93-94	" " " " 4	--
95	" " application indicator (=1=> applied)	--
96	Integration time (sec/80)	--
97	Continuum: baseline 1: cosine part	71(14)
98	" " ": sine part	72
99	" " ": baseline #	--
100	" " ": RMS ($\Delta F/F$ * 1000)	(74)
101-104	Continuum: baseline 2: (Re, Im, #, RMS)	75-78
105-108	" " 3: "	79-82
109-112	" " 4: "	83-86
113-116	RX-Sum: "Quadrant" 1 (Re, Im, #, RMS)	103-108(15)
117-120	" " 2 "	109-114
121-124	" " 3 "	115-120
125-128	" " 4 "	121-126

I*2 WORD	PARAMETER (UNITS)	TEL.TAPE WORD
129	Narrowband data: cosine (real) part channel 1	275-258(16)
130	" " : sine (imaginary) part channel 1	259-260
131-132	" " : (Re, Im) channel 2	261-264
133-512	" " : (Re, Im) channels 3-192	265-1024

Notes on Data Record Formats

(1) On telescope tape, only the 2 appears. Image band data (if present) is combined in the same data record as signal band data (see below). The codes 2, 3, and 4 refer, respectively, to signal-band, image-band, and difference-band (signal minus image) data.

	WORD	USE	BIT	USE
(2)	8	Receiver baselines	1-4	Baseline # for ch. 1-48
			5-8	" " " " 49-96
			9-12	" " " " 97-144
			13-16	" " " " 145-196
(3)	10	Gains	1-2	Baseline 1-2 RR
			3-4	" 1-2 LL
			5-8	" 1-3
			9-12	" 1-4
			13-16	" 2-3

{0 is x by 1; 1 is x by 0.001; 2 is x by 0.1; 3 is x by 0.01}

	WORD	USE	BIT	USE
(4)	11	IF Selection	1-3	85-1
			4-6	85-2
			6-9	85-3
			10	water vapor cal on

{001 XR-SL; 010 XR-XL; 100 SR-SL}

	WORD	USE	BIT	USE
(5)	12	Computer control	1	telescope: 85-1
			2	" 85-2
			3	" 85-3
			4	receiver: 85-1
			5	" 85-2
			6	" 85-3
			7	delay: 85-1
			8	" 85-2
			9	" 85-3
			10	correlator gain: BL12
			11	" " BL13
			12	polarization and focus motors
			13	correlator gain: BL14
			14	" " BL23
			15	" " BL24
			16	" " BL34

(6)	13	Lock	10	42' out of lock
			11	Master LO "
			12	85-1 LO "
			13	85-2 LO "
			14	85-3 LO "
			15	--
			16	42' LO "
(7)	14	Range	1	85-1 LO phase unlocked
			2	85-2 LO "
			3	85-3 LO "
			4	42' LO "
			5	--
			6	Master LO out of range
			7	IF level "
			8	--
			9	85-1 (R) IF level out of range
			10	" (L) " "
			11-12	85-2 " "
			13-14	85-3 " "
			15-16	42' " "
(8)	15	Faults	1	85-1 box temperature out of range
			2	85-2 " "
			3	85-3 " "
			4	--
			5	85-1 SR receiver fault
			6	SL " "
			7	XR " "
			8	XL " "
			9-12	85-2 " "
			13-16	85-3 " "

(9) On the telescope tape, word 16 is an indicator which (if ≥ 0) indicates that the delay is in 85-1 and if <0 indicates that the delay is in 85-2. Word 17 carries the delay which is in 85-1 or 85-2. The units of telescope tape words 17 and 18 are ns * 2.048.

(10) The total power counts (words 23-38) are scaled by the gains (word 9).

(11) Receiver bandwidth codes are

1	10.0	MHz
2	5.0	MHz
3	2.5	MHz
4	1.25	MHz
5	625.0	kHz
6	312.5	kHz
7	156.25	kHz
8	78.125	kHz
9	39.0625	kHz

(12) On the telescope tape, words 51-70 are in BCD while on the observer tape the parameters are stored as integers.

(13) Four bits are used for each correlator input. The delay bandwidth code is

Code	Max BW	Coarse delay bits	Zero bits	Fine delay bits
0	10 MHz	1 - 8	9 - 12	13 - 16
1	2.5	1 - 10	11 - 12	13 - 16
2	0.625	1 - 12	none	13 - 16

where the delay bits refer to words 195-198 on the telescope tape. The LSB of the coarse delay is 50 ns for all codes. The digital delays are expressed in an uncoded fashion on the observer tape with LSB representing 3.125 ns and are re-arranged by telescope. The bandwidth code is also re-arranged by telescope rather than by correlator input.

(14) On the telescope tape, the recorded parameters are, resp., the cosine part, the sine part, the offset, and the sum of squares. The signal-band data are in words 71-86 and the image-band data are in words 87-102.

(15) On the telescope tape, the recorded parameters are double word sums and are, resp., the cosine part, the sine part, and the sum of squares. The signal band data are in words 103-126 and the image-band data are in words 127-150. On the observer tape the values are averaged and then scaled by the gains (word 9). For modes 5 and 6 some quadrants are combined (see § I-C).

(16) The narrowband data are recorded in double words on the telescope tape. The data are scaled by the gains (word 9) and stored in single words on the observer tape. Signal-band data are in words 257-1024 of the telescope tape and image-band data (if recorded) are in words 1025-1792.

(3) Map Header

I*2 WORD	I*4 WORD	PARAMETER AND UNITS	NOTES
1		Identifier code for map type	(1)
2		Scan number	
3		Number of 1024-byte records in map	
4		Scan number of associated dirty beam	
5		" " " " clean beam	
6		" " " " dirty map	
7-10		Source name	
11-12	6	Center position RA (revolutions - 30 place fraction)	
13-14	7	" " DEC (revolutions-30 place fraction)	
15		Array spacing in RA (in 0".01)	
16		" " in DEC (in 0".01)	
17		Number array points in RA	
18		" " " in DEC	
19		Center position RA (in array units * 10)	
20		" " DEC (in array units * 10)	
21		Validity indicator (>0 implies map valid)	
22		Taper: major axis (in 0".1)	
23		" : minor axis (in 0".1)	
24		" : position angle (in 0°.1)	
25		Type of smoothing to grid	(2)
26		Width of smoothing to grid in u (wavelengths)	
27		" " " " " " v (wavelengths)	
28		Velocity width (0.1 km/s)	
29-30	15	Velocity center (REAL * 4, km/sec)	
31-34		Normalizing factor (REAL * 8, is peak value/32767)	
35-36	18	Velocity of second map (REAL * 4, km/sec)	
37		Velocity width of second map (0.1 km/s)	
38		Scan number of associated continuum (first)	
39		" " " " " (second)	
40		Scan number of map base	
41		Optical depth indicator (>0 implies map is of optical depth)	
42		Flipped code	(3)
43		Operand # 1: scan number	
44		Operand # 1: operation code	(4)
45-46		Operand # 2: scan and operation	
47-50		Operands #3, #4: scans and operations	
51-100		Reserved	
101-512		Unused	

(4) Spectra-map Header

I*2 WORD	R*4 WORD	PARAMETER AND UNITS	NOTES
1		Identifier code of 10	
2		Scan number	
3		Number of 1024-byte records in map	
4		Scan number of associated dirty beam	
5		" " " " clean beam	
6		Unused	
7-10		Source name	
11-12	6	Center position RA (revolutions - 30 place fraction)	
13-14	7	" " DEC (revolutions - 30 place fraction)	
15		Array spacing RA (in 0."01)	
16		" " DEC (in 0."01)	
17		Number array points RA	
18		" " " DEC	
19		Center position RA (in array units * 10)	
20		" " DEC (in array units * 10)	
21		Number of points in each spectrum	(5)
22		Number of continuum values with each spectrum	
23-24	12	Velocity of first continuum (REAL * 4, km/s)	
25-26	13	Velocity of second continuum (REAL * 4, km/s)	
27		Unused	
28		Velocity width of single map (0.1 km/s)	
29-30	15	Velocity of first point in spectrum (km/s REAL * 4)	
31-34		Normalizing factor (REAL * 8 is peak value/32767)	
35-36	18	Velocity range of spectrum (REAL * 4, km/s)	
37		Unused	
38		Scan number of first continuum	
39		Scan number of second continuum	
40		Base map scan number	
41		Optical depth indicator (>0 implies map is of optical depth)	
42		Flipped code	(3)
43-62		Reserved	
63-64	32	Velocity of spectrum point #1 (REAL * 4, km/s)	
65-66	33	" " " " #2 "	
67-512	34-256	" " " points #3-#225 "	
513-1024	257-512	Velocity of spectrum points #226-#481	(6)

Notes on Map and Spectra-Map Headers

(1) Identifier codes:

5	(u,v) plane
6	dirty beam
7	clean beam
8	dirty map
9	clean map

(2) Type of smoothing

0	none
1	pill box
2	gaussian

(3) Flipped code

1	map flipped in RA direction
2	map flipped in both directions
3	map flipped in DEC direction

(4) Operation code

0	none
1	addition
2	subtraction
3	multiplication
4	division
5	(optical depth)

(5) The absolute value of A(21) gives the number of points in each spectrum. If $A(21) \leq 0$, the spectra-map scan is assumed to be invalid.

(6) If $|A(21)| > 225$, a second record is used to contain the velocities of the excess spectrum points.

APPENDIX D. STANDARD CALIBRATORS

Warning: Any use of the sources in this list for calibration purposes is done at the user's own risk.

NAME	POSITION (1950.0)						FLUX	CAL. FOR			WEIGHT	
P0106+01	01	06	04.482	+01	19	00.95	(1400)	P			100	
P0114-21	01	14	25.910	-21	07	53.40	3970	P	G		30	
3C48	01	34	49.827	+32	54	20.63	15630	P	G		100	*
NRA091	02	02	07.410	+14	59	50.50	3700	P	G		40	
P0237-23	02	37	52.750	-23	22	04.80	(7200)	P		B	70	
CTA21	03	16	09.145	+16	17	40.70	8030	P	G		80	*
NRA0140	03	33	22.390	+32	08	36.75	3910	P	G		60	
NRA0150	03	55	45.245	+50	49	20.55	(4000)	P			100	
P0413-21	04	13	53.650	-21	03	52.00	2580	P	G		50	
P0420-01	04	20	43.530	-01	27	28.10	(1700)	P			100	
3C119	04	29	07.895	+41	32	08.65	8550	P	G		50	*
3C120	04	30	31.599	+05	14	59.70	(5000)	P			100	
P0438-43	04	38	43.240	-43	38	56.20	6460	P	G	B	20	
P0451-28	04	51	15.140	-28	12	29.90	2440	P	G		50	
3C138	05	18	16.526	+16	35	27.06	9640	P	G		60	*
3C147	05	38	43.503	+49	49	42.87	22240	P	G		80	*
P0605-08	06	05	35.970	-08	34	18.40	2530	P	G		20	
D0727-11	07	27	58.130	-11	34	53.50	(1900)	P			100	
P0735+17	07	35	14.125	+17	49	09.45	(2200)	P			100	
P0736+01	07	36	42.517	+01	44	00.32	(2700)	P			100	
OI363	07	38	00.165	+31	19	02.35	2200	P	G		20	
D0742+10	07	42	48.450	+10	18	32.80	3170	P	G		30	
P0743-00	07	43	21.040	-00	36	55.30	( )	P			100	
P0834-20	08	34	24.650	-20	06	31.40	(3500)	P			100	
P0859-14	08	59	54.960	-14	03	38.60	(3100)	P			100	
P0906+01	09	06	35.190	+01	33	48.10	(1300)	P			100	
DA267	09	23	55.292	+39	15	23.63	2520	P	G		70	
3C236	10	03	05.375	+35	08	48.10	3350	P	G		40	
P1015-31	10	15	53.440	-31	29	12.50	3830	P	G		50	
P1116+12	11	16	20.760	+12	51	06.70	2420	P	G		50	
P1127-14	11	27	35.670	-14	32	54.70	(6000)	P			100	
P1148-00	11	48	10.110	-00	07	12.92	3060	P	G		40	
P1151-34	11	51	49.420	-34	48	46.40	(6450)	P			100	*
3C268.3	12	03	54.090	+64	30	18.70	3820	P	G		100	
P1245-19	12	45	45.220	-19	42	57.60	5390	P	G	B	50	
3C279	12	53	35.824	-05	31	07.69	(11000)	P		B	50	
3C287	13	28	15.940	+25	24	37.25	7310	P	G	B	70	
3C286	13	28	49.653	+30	45	58.79	15440	P	G	B	100	
P1345+12	13	45	06.180	+12	32	20.07	5400	P	G		60	
3C295	14	09	33.640	+52	26	13.50	(22700)			B	100	
3C298	14	16	38.860	+06	42	19.40	5960	P	G	B	30	
3C309.1	14	58	56.644	+71	52	11.17	8390	P	G	B	50	
P1510-08	15	10	08.880	-08	54	46.70	(3950)	P			100	
P1607+26	16	07	09.290	+26	49	18.50	4430	P	G		20	
DA406	16	11	47.930	+34	20	19.85	2920	P	G		70	
3C345	16	41	17.603	+39	54	10.89	(6600)	P			100	
NRA0530	17	30	13.460	-13	02	45.80	(5000)	P			100	
3C371	18	07	18.550	+69	48	57.00	(2400)	P			100	

APPENDIX D
(Continued)

NAME	POSITION (1950.0)						FLUX	CAL. FOR		WEIGHT	
3C395	19	01	02.300	+31	55	13.90	3500	P	G	90	
OV080	19	47	40.130	+07	59	36.90	(1200)	P		100	
3C418	20	37	07.410	+51	08	36.20	(5230)	P		100	*
P2128-12	21	28	52.760	-12	20	23.30	(1800)	P		100	
3C446	22	23	11.050	-05	12	17.50	(5850)	P		100	
3C454.3	22	51	29.510	+15	52	54.54	(11800)	P		100	*

* Marks sources known to have 21-cm absorption features. Fluxes given in parentheses are approximate only.

APPENDIX E. THE HLINEINT VOCABULARY - A SUMMARY

1. Fundamental command sequences

This section of Appendix E lists those command words or sequences which the author expects to be most widely used. The most common option words are fully described in Chapter III and will not be repeated here.

Editing (EDITS LOAD)

OBSERVER-TAPE	:	loads data and maps onto the disk data set.
EMPTY-DISK	:	makes back-up copies of the full disk data set.
REWRITE	:	compresses disk data set by averaging data records and eliminating unwanted data and maps.
STACK	:	creates a new scan out of the average of a list of scans
DELETE	:	marks selected data as invalid.
DELETE-MAP	:	marks selected maps as invalid.
ENTER-CONTINUUM	:	enters continuum map scan numbers in the headers of narrowband maps.

Calibration (CALS LOAD)

STANDARD-CALIBRATORS CALIBRATOR ENTER-CALS	:	marks selected scans as calibration observations.
FIX-AGC	:	corrects amplitudes for normalization effects of the one-bit sampling.
BASELINES SOLVE	:	determines best-fit corrections to the assumed baseline parameters.
BASELINE-COR	:	corrects measured phases for the corrections to the assumed baseline parameters.
FIND-BANDPASS	:	computes the time-smoothed inverse bandpass multiplier and stores it in scan headers.

FIX-BANDPASS	:	applies the inverse bandpass multiplier to the data.
INSTRUMENTAL-FUNCTION	:	computes the instrumental phase and gain as smooth functions of time and stores the values with the data.
FIX-INSFUNC	:	corrects the data for the instrumental phase and gain functions.

Mapping (MAPS LOAD)

CREATE-MPSPECT	:	computes a map of spectra ($T(V,x,y)$) from a set of maps ($T_V(x,y)$)

<u>Displays on printer and plotter (LOOKS LOAD)</u>

LIST-DISK	:	Prints lists of the contents of the disk data set.
PROFILES SPECTRA	:	Prints profiles from data scans.
PLOT	:	Plots profiles from data scans.
LOOK	:	Prints information from data records.
PRINT-MAP	:	Prints maps.
CONTOUR	:	Plots contour maps.
MAP-PROFILES MAP-SPECTRA	:	Prints profiles from spectra-map scans.
MAP-PLOT	:	Plots spectra from spectra-map scans.

<u>Displays on the CRT (CRTS LOAD)</u>

SPECTRA	:	Plots profiles from data scans.
CONTOUR	:	Plots contour maps
MAP-SPECTRA	:	Plots profiles from spectra-map scans.

2. DICTIONARY OF COMMAND WORDS

THIS SECTION OF APPENDIX E PRESENTS AN ALPHABETIC LIST OF ALL COMMAND WORDS DESCRIBED IN CHAPTERS III THROUGH VIII TOGETHER WITH A REFERENCE TO THE CHAPTER AND SECTION IN WHICH THE WORD IS DESCRIBED AND A BRIEF DEFINITION OF THE WORD. THE NUMBER OF HALF-WORD INTEGER ARGUMENTS REQUIRED TO PRECEED THE WORD IS GIVEN IN PARENTHESES FOLLOWING THE DEFINITION. SINCE ORDER AND CONTEXT ARE OF CONSIDERABLE IMPORTANCE IN THE CONTROL LANGUAGE, THE READER SHOULD USE THIS APPENDIX SOLELY AS A CROSS-REFERENCE AND MEMORY AID.

WORD	SECTION	DEFINITION
A-SCAN	III-3	DRIVES SOME ROUTINES THROUGH A SINGLE SCAN (1)
ADD-MAP	IV-15	ESTABLISHES PARAMETERS TO ADD A SPECIFIED CONSTANT TO MAPS (1)
ADD-PHASE	IV-11	ESTABLISHES PARAMETERS TO ADD A SPECIFIED PHASE TO DATA (1)
ALL	IV-3	ENTERS A SCAN RANGE OF 0 THROUGH 32767
ALL-SORC	III-1	SPECIAL SOURCE NAME TO REFER TO ALL SOURCE NAMES
AMPLITUDE	III-5	ESTABLISHES PARAMETER TO HAVE FRINGE AMPLITUDE (ONLY) DISPLAYED
AMULT	IV-12	ESTABLISHES SCALING FACTOR PARAMETER FOR SCAN ON SCAN AND MAP ON MAP OPERATIONS (1)
ANYSTACK	IV-7	CREATES A STACKED SCAN FROM ALL SCANS WITHIN SPECIFIED SCAN RANGE (3)
APPLY-RFCOR	V-4	ESTABLISHES PARAMETERS TO CORRECT DATA FOR FRONT-END BANDPASS SHAPE USING THE RF OF EACH CHANNEL SEPARATELY
ASSOCIATES	VII-8 VIII-5	ESTABLISHES PARAMETER TO HAVE THE SCAN NUMBERS OF ASSOCIATED MAPS DISPLAYED
ASTACK	IV-7	CREATES A STACKED SCAN FROM ALL SCANS WITHIN SPECIFIED SCAN RANGE HAVING A SPECIFIED SOURCE NAME (3)
AVERAGE	III-4	CAUSES ACTIONS TO BE CARRIED OUT USING THE AVERAGE OF ALL RECORDS WITHIN EACH DATA SCAN

BACK	VII-10 VIII-6	ESTABLISHES PARAMETER TO HAVE MAPS DISPLAYED WITH TOP TILTED BACKWARDS BY A SPECIFIED ANGLE (1)
BANDWIDTH	IV-3	ESTABLISHES PARAMETER TO RESTRICT ACTION TO SPECIFIED BANDWIDTH CODE (1)
BASE-MAP	VI-2	ENTERS SCAN NUMBER OF THE MAP FROM WHICH MANY PARAMETERS ARE TAKEN IN CREATING A SPECTRA-MAP (1)
BASELINE-COR	V-3	ESTABLISHES PARAMETERS TO CHANGE PHASES WITH CHANGES IN THE ASSUMED BASELINE PARAMETERS
BASELINES	V-5	ESTABLISHES PARAMETERS FOR A LEAST-SQUARES SOLUTION FOR CORRECTIONS TO THE ASSUMED BASELINE PARAMETERS
BASELINES	VII-6 VIII-3	ESTABLISHES PARAMETERS TO HAVE BASELINE LENGTHS DISPLAYED
BL12 BL13 BL23	V-3	PLACES BASELINE PARAMETER CORRECTIONS FOR SPECIFIED BASELINE IN COMMON (5 EACH)
BROADBAND	III-9	ENTERS A LIST OF ALL CONTINUUM AND RX-SUM ARRAY LOCATIONS INTO COMMON
BVALUE	III-8	ENTERS TRUE VALUE OF AN OVERFLOWED NARROWBAND DATUM INTO COMMON (2)
CALIBRATOR	V-1	SPECIFIES THE FOLLOWING SOURCE NAME TO BE A CALIBRATOR FOR PHASE, GAIN, AND BANDPASS AT ALL VELOCITIES
CALIBRATORS	VIII-3	ESTABLISHES PARAMETERS TO HAVE A LIST OF CALIBRATOR SCANS DISPLAYED
CALIST	V-1	ENTERS SOURCE NAME(S) AND OTHER INFORMATION INTO LIST OF CALIBRATION SOURCES
CALS LOAD	V	LOADS THE VOCABULARY NEEDED TO CARRY OUT CALIBRATION TASKS
CHANNELS	VII-7 VIII-4	ESTABLISHES PARAMETERS TO HAVE NARROWBAND DATA DISPLAYED
CLBEAM	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON MAPS OF CLEAN BEAMS
CLMAP	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON CORRECTED SOURCE ("CLEAN") MAPS

CLOCK-COR	V-3	ESTABLISHES PARAMETERS TO CORRECT PHASES FOR A CLOCK CORRECTION (1)
CMPLX	VII-6 VIII-3	ESTABLISHES PARAMETER TO HAVE A LIST OF COMPLEX NUMBERS DISPLAYED
COMPLEX	III-5	ESTABLISHES PARAMETER TO HAVE BOTH SINE AND COSINE PARTS OF THE FRINGE DISPLAYED
CONTIME	V-6	ESTABLISHES CONVOLUTION TIME PARAMETER FOR BANDPASS CALIBRATION (1)
CONTINUUM	III-9	ENTERS A LIST OF ALL CONTINUUM ARRAY LOCATIONS INTO COMMON
CONTOUR	VII-11 VIII-7	ESTABLISHES PARAMETERS TO HAVE CONTOUR MAPS PLOTTED
CONTUR	VII-9	ESTABLISHES PARAMETERS TO HAVE MAP PRINTED IN ONE-DIGIT, ALTERNATE-BLANK FORMAT
COPY-NINE	IV-4	ESTABLISHES PARAMETERS TO COPY ONE NINE-TRACK TAPE OMTO ANOTHER WITH EDITING
COR-1 COR-2 COR-3	III-9	ENTERS INTO PARAMETER LIST THE ARRAY POSITION FOR CONTINUUM CORRELATOR DATA FROM BASELINE I
CREATE-DIFFERENCE	IV-3	ESTABLISHES PARAMETERS TO HAVE DIFFERENCE RECORDS CREATED DURING DATA TRANSFER
CREATE-MPSPECT	VI-2	ESTABLISHES PARAMETERS TO CREATE A SPECTRA-MAP FROM REGULAR MAPS
CRTS LOAD	VIII	LOADS VOCABULARY NEEDED TO CARRY OUT CRT DISPLAY TASKS
CUTOFF	III-10	ESTABLISHES LOWER LIMIT PARAMETER FOR COMPUTATION OF OPTICAL DEPTH (1)
DATA	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON DATA HEADER AND SIGNAL, IMAGE, AND DIFFERENCE BAND DATA RECORDS
DECIMAL	III(B)	ESTABLISHES THAT SUBSEQUENT NUMBERS ARE IN DECIMAL FORMAT
DEGREES	VII-9	ESTABLISHES PARAMETERS TO HAVE MAPS DISPLAYED IN THEIR PRESENT UNITS (1)

DELAY-COR	V-3	ESTABLISHES PARAMETERS TO CORRECT PHASES FOR USE OF FIXED DELAYS
DELAYS	VII-7 VIII-4	ESTABLISHES PARAMETERS TO HAVE DELAY VALUES DISPLAYED
DELETE	IV-9	ESTABLISHES PARAMETERS TO MARK SPECIFIED DATA AS INVALID
DELETE-MAP	IV-14	ESTABLISHES PARAMETERS TO MARK MAPS AS INVALID
DIFFERENCE	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON DIFFERENCE-BAND DATA RECORDS
DISCARD	III(B) VIII	CLOSES DATA SETS AND UNLOADS VOCABU-LARIES
DISK-CONTENTS	VII-1 VIII-1	DISPLAYS A BRIEF SUMMARY OF THE CONTENTS OF THE DISK DATA SET
DTBEAM	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON MAPS OF SYNTHESIZED ("DIRTY") BEAM PATTERNS
DTMAP	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON SYNTHESIZED ("DIRTY") SOURCE MAPS
DUMP	VII-5 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY A DUMP OF DATA HEADER AND DATA RECORDS IN HALF-WORD INTEGER FORMAT (0,2)
DUMP4	VII-5	ESTABLISHES PARAMETERS TO PRINT A DUMP OF DATA HEADER AND DATA RECORDS IN FULL-WORD INTEGER FORMAT
EDITS LOAD	IV	LOADS VOCABULARY NEEDED TO CARRY OUT EDITING TASKS
EMPTY-DISK	IV-5	COPIES DISK DATA SET ONTO TAPE OVER SPECIFIED RANGE OF BLOCKS (2)
ENTER-CALS	V-1	TRANSFERS INFORMATION FROM THE LIST OF CALIBRATOR SOURCES TO THE DATA HEADERS (2)
ENTER-CONTINUUM	IV-14	ESTABLISHES PARAMETERS TO STORE SCAN NUMBERS OF ASSOCIATED CONTINUUM MAPS IN MAP HEADERS (2)

ENTER-RFCOR	V-4	ESTABLISHES PARAMETERS TO CORRECT DATA FOR FRONT-END BANDPASS SHAPE USING THE RF OF CENTER CHANNELS ONLY
FILL-DISK	IV-5	COPIES TAPE ONTO THE DISK DATA SET OVER SPECIFIED RANGE OF BLOCKS (2)
FIND-BANDPASS	V-6	ESTABLISHES PARAMETERS TO FIND AND STORE THE INVERSE BANDPASS MULTIPLIER FUNCTION
FIX-AGC	V-2	ESTABLISHES PARAMETERS TO CORRECT DATA FOR THE NORMALIZATION EFFECTS OF THE ONE-BIT SAMPLING
FIX-BANDPASS	V-6	ESTABLISHES PARAMETERS TO MULTIPLY THE DATA BY THE PREVIOUSLY STORED INVERSE BANDPASS MULTIPLIER
FIX-INSFUNC	V-7	ESTABLISHES PARAMETERS TO DIVIDE THE DATA BY THE PREVIOUSLY STORED INSTRUMENTAL FUNCTION (THEREBY CALIBRATING THE DATA)
FLIP	IV-13	ESTABLISHES PARAMETERS TO REVERSE THE FREQUENCY ORDER OF THE NARROWBAND CHANNELS
FLIPX FLIPXY FLIPY	IV-17	CREATES NEW MAP SCAN HAVING SPECIFIED SPACE COORDINATES REVERSED (2)
FLUX	V-1	ESTABLISHES THE FLUX OF A GAIN CALIBRATION SOURCE TO BE ENTERED INTO THE LIST OF CALIBRATORS (1)
FOR	III-1	ENTERS THE FOLLOWING SOURCE NAME IN COMMON AND FINDS THE ASSOCIATED SOURCE NUMBER
FULL	III-3	SPECIFIES A SCAN RANGE ENCOMPASSING ALL SCAN NUMBERS ON THE DISK DATA SET
GAUSSIAN	V-5	SPECIFIES THE USE OF A GAUSSIAN CONVOLUTION FUNCTION IN TIME-SMOOTHING
GOODBY	III(B) VIII	THE LAST WORD ENTERED WHEN USING THE PROGRAM - CAUSES NORMAL JOB TERMINATION
HEADER	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON DATA HEADER RECORDS

HEADERS	VII-5	ESTABLISHES PARAMETERS TO HAVE GENERAL HEADER INFORMATION PRINTED
HEADS	III-3	ESTABLISHES PARAMETERS TO LIMIT SCANS COMMANDS TO HEADER RECORDS
HEX	III(B) III-7 IV-1	SPECIFIES THAT FOLLOWING NUMBERS ARE IN HEXADECIMAL FORMAT (RETURNED TO DECIMAL BY YESTYPE & NOTYPE, HOWEVER)
HEX-DUMP	VII-5 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY A DUMP OF DATA HEADER AND DATA RECORDS IN HEXADECIMAL FORMAT (0,2)
HIDDEN	VII-10 VIII-6	ESTABLISHES PARAMETER TO SUPPRESS LINES OBSCURED BY FOREGROUND LINES IN CROSS-HATCH MAP PROFILE DISPLAYS
HLOOK	VII-6 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY INFORMATION FROM DATA HEADER RECORDS
HMULT	VII-15	ESTABLISHES MULTIPLIER FOR HEIGHT OF INDIVIDUAL SPECTRA ON A FULL SPECTRA-MAP PLOT (1)
IMAGE	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON IMAGE BAND RECORDS
IMAGE-BAND	III-8	SPECIFIES THAT THE OVERFLOW IN THE NARROW CHANNEL FOLLOWING OCCURRED IN THE IMAGE BAND DATA
IMAGINARY	III-5	ESTABLISHES PARAMETER TO HAVE ONLY THE SINE PART OF THE FRINGE DISPLAYED
INCLUDE	IV-3	ENTERS FOLLOWING SOURCE NAME IN DISK INDICES WITH SPECIFIED SOURCE NUMBER (1)
INNER	III-10	ESTABLISHES PARAMETERS TO HAVE ACTION CARRIED OUT ON THE CENTRAL ONE-FOURTH OF THE MAP AREAS
INSFUNC	VII-7 VIII-4	ESTABLISHES PARAMETERS TO DISPLAY THE STORED VALUES OF THE INSTRUMENTAL FUNC.
INSTRUMENTAL-FUNCTION	V-7	ESTABLISHES PARAMETERS TO FIND AND STORE THE INSTRUMENTAL PHASE AND GAIN FUNCTIONS
INTO	IV-7	NULL WORD
INV-BANDPASS	VII-6 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY THE INVERSE BANDPASS MULTIPLIER

ITERATIONS	V-5	SPECIFIES THE NUMBER OF ITERATIONS TO BE USED IN SOLVING FOR CORRECTIONS TO THE ASSUMED BASELINE PARAMETERS (1)
I*2	VII-6 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY A LIST OF ARRAY VALUES IN HALF-WORD INTEGER FORMAT
I*4	VII-6 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY A LIST OF ARRAY VALUES IN FULL-WORD INTEGER FORMAT
LINES	VII-13	SPECIFIES THE NUMBER OF LINES IN HORIZONTAL PRINTER PROFILES OF SPECTRA FROM SPECTRA-MAPS (1)
LIST	III-9	RESETS COUNTER OF THE NUMBER OF PARA-METERS IN THE PARAMETER LIST
LIST-CALIBRATORS	VII-1	ESTABLISHES PARAMETERS TO PRINT A LIST OF CALIBRATOR SCANS
LIST-DISK	VII-1 VIII-1	DISPLAYS A LIST OF ALL SCANS ON THE DISK DATA SET
LIST-MAPS	VII-1 VIII-1	DISPLAYS A LIST OF ALL MAP SCANS ON THE DISK DATA SET
LIST-SCANS	VII-1 VIII-1	DISPLAYS A LIST OF ALL DATA SCANS ON THE DISK DATA SET
LIST-SPECTRA	VII-1 VIII-1	DISPLAYS A LIST OF ALL SPECTRA-MAP SCANS ON THE DISK DATA SET
LIST-UVS	VII-1 VIII-1	DISPLAYS A LIST OF ALL (U,V)-PLANE SCANS ON THE DISK DATA SET
LOOK	VII-7 VIII-4	ESTABLISHES PARAMETERS TO OBTAIN LISTS OF INFORMATION FROM DATA RECORDS
LOOKS LOAD	VII	LOADS THE VOCABULARY NEEDED FOR PRINTER AND CALCOMP DISPLAY TASKS
LSCALE	VII-3	ESTABLISHES PARAMETERS FOR A FIXED-SCALE PLOT OF THE LOWER PARAMETER (2)
MAP	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON MAP SCANS (CLEAN AND DIRTY BEAMS AND SOURCE MAPS)
MAP-DUMP	VII-8	ESTABLISHES PARAMETERS TO PRINT A HEXADECIMAL DUMP OF MAP HEADERS AND ALL MAP RECORDS

MAP-EVERYTHING	VII-15	ESTABLISHES PARAMETERS FOR A FULL CALCOMP PLOT OF SPECTRA-MAPS
MAP-PLOT	VII-14	ESTABLISHES PARAMETERS FOR CALCOMP PLOTS OF INDIVIDUAL SPECTRA FROM SPECTRA-MAPS
MAP-PROFILES	VII-13	ESTABLISHES PARAMETERS FOR HORIZONTAL PRINTER PLOTS OF INDIVIDUAL SPECTRA FROM SPECTRA-MAPS
MAP-REDUCE	IV-16	CREATES A NEW MAP SCAN BY EXPANDING OR CONTRACTING AN EXISTING MAP (6)
MAP-SPECTRA	VII-13	ESTABLISHES PARAMETERS FOR VERTICAL PRINTER PLOTS OF INDIVIDUAL SPECTRA FROM SPECTRA-MAPS
MAP-SPECTRA	VIII-8	ESTABLISHES PARAMETERS FOR CRT PLOTS OF INDIVIDUAL SPECTRA FROM SPECTRA-MAPS
MAPS LOAD	VI	LOADS VOCABULARY NEEDED FOR MAPPING TASKS
MAXIMA	VIII-5	ESTABLISHES PARAMETERS TO DISPLAY THE PEAK VALUES OF MAPS
MDUMP	VII-8 VIII-5	ESTABLISHES PARAMETERS TO DISPLAY DUMPS OF MAP AND SPECTRA-MAP HEADERS IN HALF-WORD INTEGER FORMAT
MHEX-DUMP	VII-8 VIII-5	ESTABLISHES PARAMETERS TO DISPLAY DUMPS OF MAP AND SPECTRA-MAP HEADERS IN HEXADECIMAL FORMAT
MLOOK	VII-8 VIII-5	ESTABLISHES PARAMETERS TO DISPLAY INFORMATION FROM MAP AND SPECTRA-MAP HEADERS
MOVE-MAP	IV-16	CREATES A NEW MAP SCAN IDENTICAL TO AN EXISTING MAP SCAN (2)
MPLOT	VII-4	PLOTS SPECTRA ON THE CALCOMP WITH MORE THAN ONE SCAN AND/OR BASELINE PER PLOT
MPSPECT	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON SPECTRA-MAPS
MSCALE	VII-13 VIII-8	ESTABLISHES PARAMETERS TO HAVE A FIXED-SCALE PLOT OF INDIVIDUAL SPECTRA FROM SPECTRA-MAPS (2)

MTM	IV-18	ESTABLISHES PARAMETERS TO CREATE A NEW MAP SCAN FROM AN EXISTING MAP BY CONVERTING TO OPTICAL DEPTH (1)
MULT-AMP	IV-11	ESTABLISHES PARAMETERS TO MULTIPLY THE AMPLITUDES OF THE PRESENT DATA (1)
MULT-LIST	IV-14	ESTABLISHES PARAMETERS TO MULTIPLY MAP HEADER ARRAY VALUES (1)
MULTI-PLOT	VII-4	ESTABLISHES PARAMETERS TO PLOT PROFILES ON THE CALCOMP CONTAINING DATA FROM ONE OR MORE SCANS AND/OR BASELINES
MULTIPLY	IV-11	ESTABLISHES PARAMETERS TO MULTIPLY (BY A COMPLEX NUMBER) THE PRESENT DATA (2)
MULTIPLY-LIST	IV-10	ESTABLISHES PARAMETERS TO MULTIPLY A LIST OF DATA ARRAY VALUES BY A COMPLEX NUMBER (2)
MULTIPLY-MAP	IV-14	ESTABLISHES PARAMETERS TO MULTIPLY THE AMPLITUDE OF MAPS (1)
M+M M-M M*M M/M	IV-18	ESTABLISHES PARAMETERS TO CREATE A NEW MAP SCAN FROM THE SUM, DIFFERENCE, PRODUCT, OR RATIO OF TWO OTHER MAP SCANS (2 EACH)
M/ M*	IV-15	ESTABLISHES SCALING PARAMETERS TO ADD A CONSTANT TO MAPS (1 EACH)
NB-OVERFLOW	III-8	ENTERS PARAMETERS DESCRIBING NARROWBAND DATA WHICH EXCEEDS THE HALF-WORD INTEGER FORMAT INTO THE OVERFLOW LISTS
NEW-DISK	IV-3	CLEARS THE PRESENT DISK INDICES AND ENTERS INITIAL VALUES
NEW-LIST	V-1	CLEARS THE PRESENT LIST OF CALIBRATION SOURCES
NEW-OMITLIST	IV-3	CLEARS THE PRESENT LIST OF SOURCE NAMES TO BE OMITTED DURING DATA TRANSFER
NEW-OVERFLOW	III-8	CLEARS THE PRESENT LIST OF NARROWBAND OVERFLOW INFORMATION
NLINES	VII-2	SPECIFIES THE NUMBER OF LINES IN HORIZONTAL PRINTER PLOTS OF SPECTRA FROM DATA SCANS (1)

NO-AXES	VII-10 VIII-6	SUPPRESSES PLOTTING OF MAP AXIS LABELS AND TICK MARKS
NO-BL1 NO-BL2 NO-BL3	V-5	SUPPRESSES THE SOLUTION FOR CORRECTIONS TO THE ASSUMED PARAMETERS OF BASELINE I
NO-CLBEAM	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON MAPS OF CLEAN BEAM PATTERNS
NO-CLMAP	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON CORRECTED ("CLEAN") SOURCE MAPS
NO-DATA	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON DATA HEADER AND SIGNAL, IMAGE, AND DIFFERENCE BAND DATA RECORDS
NO-DF NO-DF1 NO-DF2 NO-DF3	V-5	SUPPRESSES SOLUTION FOR THE PHASE-FREQUENCY CORRECTION FOR ALL BASELINES OR FOR BASELINE I
NO-DIFFERENCE	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON DIFFERENCE BAND DATA RECORDS
NO-DTBEAM	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON MAPS OF SYNTHESIZED ("DIRTY") BEAM PATTERNS
NO-DTMAP	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON SYNTHESIZED ("DIRTY") SOURCE MAPS
NO-HEADER	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON DATA HEADERS
NO-IMAGE	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON IMAGE BAND DATA RECORDS
NO-K NO-K1 NO-K2 NO-K3	V-5	SUPPRESSES THE SOLUTION FOR THE K BASE-LINE PARAMETER FOR ALL BASELINES OR FOR BASELINE I
NO-MAP	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON MAPS (CLEAN AND DIRTY BEAMS AND SOURCE MAPS)

NO-MPSPECT	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON SPECTRA-MAPS
NO-NOISE	V-2	ESTABLISHES PARAMETERS TO DETERMINE SYSTEM NOISE TEMPERATURES WITHOUT THE USE OF SWITCHED NOISE TUBES
NO-RENUMBER	IV-6	CARRIES OUT IN-PLACE COMPRESSION OF THE DISK DATA SET WITHOUT RENUMBERING SCANS
NO-SIGNAL	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON SIGNAL BAND DATA RECORDS
NO-UV	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON (U,V)-PLANE SCANS
NO-X NO-X1 NO-X2 NO-X3	V-5	SUPPRESSES SOLUTION FOR CORRECTIONS TO THE ASSUMED X BASELINE PARAMETER FOR ALL BASELINES OR FOR BASELINE I
NO-Y NO-Y1 NO-Y2 NO-Y3	V-5	SUPPRESSES SOLUTION FOR CORRECTIONS TO THE ASSUMED Y BASELINE PARAMETER FOR ALL BASELINES OR FOR BASELINE I
NO-Z NO-Z1 NO-Z2 NO-Z3	V-5	SUPPRESSES SOLUTION FOR CORRECTIONS TO THE ASSUMED Z BASELINE PARAMETER FOR ALL BASELINES OR FOR BASELINE I
NOISE	V-2	ESTABLISHES NOISE TUBE AND SYSTEM TEMPERATURE PARAMETERS (4)
NOT-BNDPASS	V-1	MARKS CALIBRATION SOURCE AS NOT TO BE USED FOR BANDPASS CALIBRATION
NOT-CALIBRATOR	V-1	SPECIFIES THE FOLLOWING SOURCE NAME IS NOT TO BE USED AS A CALIBRATOR
NOT-GAIN	V-1	MARKS CALIBRATION SOURCE AS NOT TO BE USED FOR GAIN CALIBRATION
NOT-PHASE	V-1	MARKS CALIBRATION SOURCE AS NOT TO BE USED FOR PHASE CALIBRATION
NOTYPE	IV-1	ESTABLISHES PARAMETER TO PREVENT ACTION FROM BEING CARRIED OUT ON SPECIFIED TYPES OF RECORDS (1)

OBSERVER-TAPE	IV-3	ESTABLISHES PARAMETERS TO TRANSFER DATA AND MAPS FROM TAPE TO THE DISK DATA SET WHILE AUGMENTING THE DISK INDICES AND EDITING
OMIT-SOURCE	IV-3	PLACES FOLLOWING SOURCE NAME IN LIST OF SOURCE NAMES TO BE OMITTED DURING DATA TRANSFER
OVER	VII-10 VIII-6	ESTABLISHES PARAMETER TO ROTATE MAP DISPLAYS (1)
OVER-WRITE	VII-4	ESTABLISHES PARAMETER TO ALLOW PLOTTED SPECTRUM TO OVERWRITE THE PREVIOUS PLOTTED SPECTRUM
PAGE	III-2	ADVANCES PRINTER TO TOP OF NEXT PAGE
PERSPECTIVE	VII-10 VIII-6	ESTABLISHES PARAMETERS TO DISPLAY MAPS IN PSEUDO-PERSPECTIVE (1)
PHASE	III-5	ESTABLISHES PARAMETER TO HAVE ONLY FRINGE PHASE DISPLAYED
PLOT	VII-3	ESTABLISHES PARAMETERS TO PLOT SPECTRA FROM DATA SCANS ON THE CALCOMP
POSITION-COR	V-3	ESTABLISHES PARAMETERS TO CHANGE PHASES FOR CHANGES IN THE ASSUMED SOURCE POSITION (2)
POSITIONS	VII-8 VIII-5	ESTABLISHES PARAMETERS TO DISPLAY ARRAY AND POSITION INFORMATION FROM MAP HEADERS
PRINT-MAP	VII-9	ESTABLISHES PARAMETERS TO PRINT MAPS
PROFILES	VII-2	ESTABLISHES PARAMETERS TO PRINT HORIZONTAL PLOTS OF SPECTRA FROM DATA SCANS
RATIO	VII-9	ESTABLISHES PARAMETERS TO DISPLAY MAPS IN RELATIVE UNITS (1)
READ-TAPE	IV-2	SPECIFIES ACTION IS TO BE TAKEN ON THE INPUT TAPE
REAL	III-5	ESTABLISHES PARAMETER TO HAVE ONLY THE COSINE PART OF THE FRINGE DISPLAYED
RENUMBER	IV-6	CARRIES OUT AN IN-PLACE COMPRESSION OF THE DISK DATA SET WHILE RENUMBERING THE SCANS

REWIND	IV-2	CAUSES SPECIFIED TAPE TO REWIND
REWRITE	IV-6	ESTABLISHES PARAMETERS TO COMPRESS THE DISK DATA SET IN PLACE
RF-CORRECTIONS	V-4	ESTABLISHES PARAMETERS TO ENTER AND APPLY CORRECTIONS FOR FRONT-END BANDPASS SHAPE
RFACOR	V-4	ENTERS AMPLITUDE CORRECTION INTO LIST OF CORRECTIONS FOR FRONT-END BANDPASS SHAPE (4)
RFPCOR	V-4	ENTERS PHASE CORRECTION INTO LIST OF CORRECTION FOR FRONT-END BANDPASS SHAPE (4)
RMAP	IV-18	CREATES NEW MAP SCAN AS THE RESULT OF TWO MAPS OPERATING ON EACH OTHER (1)
RSCAN	IV-12	CREATES NEW DATA SCAN AS THE RESULT OF TWO SCANS OPERATING ON EACH OTHER (1)
RX	III-6	ESTABLISHES CHANNEL RANGE PARAMETERS OVER WHICH ACTION IS TO TAKE PLACE
RX-A	III-6	RX FOR QUADRANTS 1
RX-AB		RX FOR QUADRANTS 1 AND 2
RX-ABC		RX FOR QUADRANTS 1, 2, AND 3
RX-ABCD		RX FOR QUADRANTS 1, 2, 3, AND 4
RX-B		RX FOR QUADRANTS 2
RX-BC		RX FOR QUADRANTS 2 AND 3
RX-BCD		RX FOR QUADRANTS 2, 3, AND 4
RX-C		RX FOR QUADRANTS 3
RX-CD		RX FOR QUADRANTS 3 AND 4
RX-D		RX FOR QUADRANTS 4
RX-SUMA RX-SUMB RX-SUMC RX-SUMD	III-9	ENTERS IN PARAMETER LIST THE ARRAY LOCATION OF THE I'TH NARROWBAND DATA SUM
RX-SUMS	III-9	CLEARS PARAMETER LIST AND ENTERS ARRAY LOCATIONS OF ALL NARROWBAND DATA SUMS
R*4	VII-8 VIII-5	ESTABLISHES PARAMETERS TO PRINT LIST OF FLOATING POINT ARRAY VALUES
SCALE	VII-2 VIII-2	ESTABLISHES PARAMETERS TO HAVE A FIXED-SCALE PLOT (2)
SCAN-RANGE	III-3	CAUSES ACTION TO BE TAKEN OVER SPECIFIED SCAN RANGE (2)

SCANS	III-3	CAUSES ACTION TO BE TAKEN OVER SPECIFIED SCAN RANGE WITH CONTROL OVER WHICH RECORDS ARE INVOLVED POSSIBLE (2)
SIGNAL	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY ON SIGNAL BAND RECORDS
SIGNAL-BAND	III-8	ESTABLISHES PARAMETER TO INDICATE THAT THE OVERFLOW BEING ENTERED OCCURRED IN SIGNAL OR DIFFERENCE BAND DATA
SKIP	VII-13	ESTABLISHES PARAMETER TO SKIP CHANNELS BETWEEN PLOTTED POINTS IN PRINTER PLOTS OF SPECTRA FROM SPECTRA-MAPS (1)
SKIPCHAN	VII-2	ESTABLISHES PARAMETER TO SKIP CHANNELS BETWEEN PLOTTED POINTS IN PRINTER PLOTS OF SPECTRA FROM DATA SCANS (1)
SMOOTH	IV-12 V-6 VII-2 VIII-2	ESTABLISHES PARAMETER TO SMOOTH SPECTRA FROM DATA SCANS IN FREQUENCY (1)
SMOOTH-CONTOUR	VII-12	ESTABLISHES PARAMETERS TO PLOT CONTOUR MAPS ON THE CALCOMP WITH AN INTERPOLATION MESH FOR PRETTIER OUTPUT
SOLVE	V-5	CARRIES OUT LEAST-SQUARES SOLUTION FOR CORRECTIONS TO THE ASSUMED BASELINE PARAMETERS
SOURCE	VI-2	ENTERS FOLLOWING SOURCE NAME AND THE ASSOCIATED SCAN RANGE FOR INCLUSION IN CREATING A SPECTRA-MAP (2)
SPECTRA	VII-2	ESTABLISHES PARAMETERS TO PRINT VERTICAL PROFILE PLOTS OF SPECTRA FROM DATA SCANS
SPECTRA	VIII-2	ESTABLISHES PARAMETERS TO PLOT SPECTRA FROM DATA SCANS ON THE CRT
STACK	IV-7	PRODUCES A STACKED SCAN FROM ALL SCANS IN A LIST HAVING SPECIFIED BASELINES AND SOURCE NAME (1)
STACKANY	IV-7	PRODUCES A STACKED SCAN FROM ALL SCANS IN A LIST (1)
STANDARD-CALIBRATORS	V-1	ENTERS INTO A LIST OF CALIBRATORS ALL SOURCES IN A STANDARD LIST WHICH ARE PRESENT ON THE DISK DATA SET

STORE	IV-8	ESTABLISHES PARAMETERS TO STORE A NUMBER IN A SPECIFIED ARRAY LOCATION FOR DATA SCANS (2)
STORE-MAP	IV-14	ESTABLISHES PARAMETERS TO STORE A NUMBER IN A SPECIFIED ARRAY LOCATION IN MAP AND SPECTRA-MAP HEADERS (2)
SUPPLEMENT	V-7	ESTABLISHES PARAMETER TO HAVE PRESENT INSTRUMENTAL FUNCTION SUPPLEMENT RATHER THAN REPLACE THE PREVIOUSLY STORED INSTRUMENTAL FUNCTION
S+S S-S S*S S/S STS	IV-12	ESTABLISHES PARAMETERS TO CREATE A NEW SCAN FROM THE SUM, DIFFERENCE, PRODUCT, RATIO, OR LOGARITHM OF THE RATIO OF TWO OTHER SCANS (2)
TAU	VII-9 VIII-6	ESTABLISHES PARAMETERS TO CONVERT MAPS (OR SPECTRA FROM SPECTRA-MAPS) TO OPTICAL DEPTH BEFORE DISPLAY (1)
TAUG	V-7	ESTABLISHES CONVOLUTION TIME FOR INSTRUMENTAL GAIN CALIBRATION (1)
TAUP	V-7	ESTABLISHES CONVOLUTION TIME FOR INSTRUMENTAL PHASE CALIBRATION (1)
THREE-D	VII-11 VIII-7	ESTABLISHES PARAMETER TO DISPLACE CONTOUR LINES VERTICALLY IN PROPORTION TO THEIR VALUE
TMULT	VII-10 VIII-6	ESTABLISHES SCALE FACTOR FOR VERTICAL DISPLACEMENTS OF CROSS-HATCH AND CONTOUR LINES IN MAP DISPLAYS (1)
TMULT	VII-13 VIII-8	ESTABLISHES MULTIPLYING FACTOR TO HAVE FIXED-SCALE PLOTS OF SPECTRA FROM SPECTRA-MAPS (1)
TPOWERS	VII-7 VIII-4	ESTABLISHES PARAMETERS TO DISPLAY TOTAL POWER COUNTERS
UNFIX-AGC	V-2	ESTABLISHES PARAMETERS TO REMOVE A PREVIOUSLY APPLIED CORRECTION FOR THE NORMALIZATION EFFECTS OF THE ONE-BIT SAMPLING
UNFIX-BANDPASS	V-6	ESTABLISHES PARAMETERS TO DIVIDE THE DATA BY THE PREVIOUSLY DETERMINED AND APPLIED INVERSE BANDPASS MULTIPLIER

UNFIX-INSFUNC	V-7	ESTABLISHES PARAMETERS TO MULTIPLY THE DATA BY THE PREVIOUSLY DETERMINED AND APPLIED INSTRUMENTAL FUNCTION (THEREBY RESTORING THE DATA TO AN UNCALIBRATED STATE)
USCALE	VII-3	ESTABLISHES PARAMETERS FOR A FIXED-SCALE PLOT OF THE UPPER PARAMETER (2)
UV	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY FOR (U,V)-PLANE SCANS
UVS	VII-6 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY PROJECTED BASELINE INFORMATION
VECTOR	III-5	ESTABLISHES PARAMETER TO HAVE BOTH FRINGE AMPLITUDE AND PHASE DISPLAYED
VEL	V-1	SPECIFIES VELOCITY CENTER AND RANGE (2)
VELOCITIES	VII-6 VIII-3	ESTABLISHES PARAMETERS TO DISPLAY VELOCITY INFORMATION FROM DATA SCANS
VSMOOTH	VII-13 VIII-8	ESTABLISHES PARAMETER TO SMOOTH SPECTRA FROM SPECTRA-MAPS IN VELOCITY BEFORE DISPLAY (1)
WEIGHT	V-1	SPECIFIES THE WEIGHT OF THE GAIN CALI-BRATOR BEING ENTERED IN THE CALIBRATOR LIST (1)
WRITE-NINE	IV-4	ESTABLISHES PARAMETERS TO TRANSFER DATA AND MAP SCANS FROM DISK TO TAPE WITH EDITING
WRITE-TAPE	IV-2	SPECIFIES ACTION IS TO BE TAKEN ON THE OUTPUT TAPE
X-HATCH XY-HATCH Y-HATCH	VII-10 VIII-6	ESTABLISHES PARAMETERS TO DISPLAY CROSS-HATCHED MAP PROFILES WITH THE SPECIFIED LINES
XMESH	VII-12	ESTABLISHES THE NUMBER OF INTERPOLATION MESH INTERVALS BETWEEN MAP ARRAY POINTS IN THE X DIRECTION (1)
XMULT	VII-3 VIII-6	ENTERS SCALE MULTIPLIER IN THE X DIREC-TION FOR CALCOMP PLOTS AND FOR CRT MAP DISPLAYS (1)
XRANGE	III-10	ESTABLISHES PARAMETERS TO LIMIT THE RANGE OF A MAP IN THE X DIRECTION OVER WHICH ACTION IS CARRIED OUT (2)

XSKIP	VI-2 VII-9 VIII-6	SPECIFIES NUMBER OF ARRAY INTERVALS IN THE X-DIRECTION BETWEEN THE MAP ARRAY POINTS INCLUDED IN THE ACTION (1)
XSMOOTH	III-10	ESTABLISHES PARAMETER TO SMOOTH MAPS IN THE X DIRECTION (1)
YESTYPE	III-7	ESTABLISHES PARAMETER TO HAVE ACTION CARRIED OUT ONLY FOR SPECIFIED RECORD TYPES (1)
YMESH	VII-12	ESTABLISHES THE NUMBER OF INTERPOLATION MESH INTERVALS BETWEEN MAP ARRAY POINTS IN THE Y DIRECTION (1)
YMULT	VII-3	ENTERS SCALE MULTIPLIER IN THE Y DIRECTION FOR CALCOMP POTS (1)
YRANGE	III-10	ESTABLISHES PARAMETERS TO LIMIT THE RANGE OF A MAP IN THE Y DIRECTION OVER WHICH AN ACTION IS CARRIED OUT (2)
YSKIP	VI-2 VII-9 VIII-6	SPECIFIES NUMBER OF ARRAY INTERVALS IN THE Y DIRECTION BETWEEN THE MAP ARRAY POINTS INCLUDED IN ACTION (1)
YSMOOTH	III-10	ESTABLISHES PARAMETER TO SMOOTH MAPS IN THE Y DIRECTION (1)
ZERO	VII-11 VIII-7	ESTABLISHES PARAMETER TO HAVE THE ZERO CONTOUR ALSO PLOTTED
-PHASE	IV-13	ESTABLISHES PARAMETERS TO REVERSE THE SIGN OF THE PHASE
,	III-9	ENTERS A NUMBER INTO THE PARAMETER LIST (1)
#	VII-6 VIII-3	CONVERTS A CHANNEL NUMBER TO THE APPROPRIATE ARRAY LOCATION AND ENTERS IT IN THE PARAMETER LIST (1)

APPENDIX F. SAMPLE DECKS

THIS APPENDIX IS DEVOTED TO ILLUSTRATIONS OF SOME TYPICAL CARD DECKS. THESE SAMPLES ARE NOT INTENDED AS RECIPES TO BE FOLLOWED CLOSELY BY USERS, BUT RATHER AS AIDS TO UNDERSTANDING THE REST OF THIS MANUAL. CARDS SHOWN IN THIS APPENDIX WITH C IN COLUMN 1 ARE INCLUDED FOR EXPLANATORY PURPOSES, BUT WOULD NOT APPEAR IN THE ACTUAL DECKS.

1. THE ON-LINE PROGRAM

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00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

C   BASELINE COORDINATES

   3382.403           -2527.746           -7955.482           1
   2635.963           -1959.529           -6187.479           2
   0746.440           -0568.217           -1768.003           3
  81820.176          -65465.403          -53469.054           4

C   TELESCOPE POINTING CORRECTIONS

1  87  118  -61    3   28  -58   21   44 -101  -42   48   -2  -18    4   44 -101
2 -75  102   17  156   15  -20   14   39 -101   70  -14  -20   41   35   39 -101
3 -96  131   -8   44   39    5    8   39 -101   47    4  -60  -22   70   39 -101

C   DELAY CENTERS

000000    000000    00000350730

C   FSET FOR FIXED DELAY AND SIGNAL BAND ONLY AT 21 CM

FSET                01420405752.        01217500000.        +000000000.     SFSS

C   SCAN CARDS
C   D-MODE CARD SETS DELAY TO MIDDLE OF SOURCE SEQUENCE.  DELAY THEN STAYS FIXED
C   HERE I USE DIFFERENT SOURCE NAMES FOR DIFFERENT VELOCITY OFFSETS

3C123       04 33 55.24  +29 34 14.0            111 D       03 05 +000.0
3C48        01 34 49.82  +32 54 20.7            111         02 10 +060.0
3C123-L     04 33 55.24  +29 34 14.0            111         02 22 -060.0
3C123-A     04 33 55.24  +29 34 14.0            111         02 30 -018.0
3C123-B     04 33 55.24  +29 34 14.0            111         02 39 +008.0
3C123-H     04 33 55.24  +29 34 14.0            111         02 47 +050.0
3C123-A     04 33 55.24  +29 34 14.0            111         02 56 -018.0
3C123-B     04 33 55.24  +29 34 14.0            111         03 04 +008.0
3C147       05 38 43.50  +49 49 42.9            111         03 14 +040.0
3C123-L     04 33 55.24  +29 34 14.0            111         03 25 -060.0
3C123-A     04 33 55.24  +29 34 14.0            111         03 33 -018.0
3C123-B     04 33 55.24  +29 34 14.0            111         03 42 +008.0
3C123-H     04 33 55.24  +29 34 14.0            111         03 50 +050.0
3C123-A     04 33 55.24  +29 34 14.0            111         03 59 -018.0
3C147       05 38 43.50  +49 49 42.9            111         04 11 +040.0
3C161       06 24 43.05  -05 51 13.9            111 D       05 22 +000.0
3C147       05 38 43.50  +49 49 42.9            111         04 23 +040.0
3C161-L     06 24 43.05  -05 51 13.9            111         04 36 -030.0
3C161-A     06 24 43.05  -05 51 13.9            111         04 44 +006.0
3C161-B     06 24 43.05  -05 51 13.9            111         04 53 +032.0
3C161-H     06 24 43.05  -05 51 13.9            111         05 01 +070.0
3C161-A     06 24 43.05  -05 51 13.9            111         05 10 +006.0
3C161-B     06 24 43.05  -05 51 13.9            111         05 18 +032.0
3C147       05 38 43.50  +49 49 42.9            111         05 30 +040.0
3C161-L     06 24 43.05  -05 51 13.9            111         05 43 -030.0

00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

3C161-A    06 24 43.05  -05 51 13.9            111         05 51 +006.0
3C161-B    06 24 43.05  -05 51 13.9            111         06 00 +032.0
3C161-H    06 24 43.05  -05 51 13.9            111         06 08 +070.0
3C161-A    06 24 43.05  -05 51 13.9            111         06 17 +006.0
3C147      05 38 43.50  +49 49 42.9            111         06 31 +040.0
3C123      04 33 55.24  +29 34 14.0            111 D       07 45 +000.0
3C147      05 38 43.50  +49 49 42.9            111         06 42 +040.0
3C123-L    04 33 55.24  +29 34 14.0            111         06 53 -060.0
3C123-A    04 33 55.24  +29 34 14.0            111         07 01 -018.0
3C123-B    04 33 55.24  +29 34 14.0            111         07 10 +008.0
3C123-H    04 33 55.24  +29 34 14.0            111         07 18 +050.0
3C123-A    04 33 55.24  +29 34 14.0            111         07 27 -018.0
3C123-B    04 33 55.24  +29 34 14.0            111         07 35 +008.0
3C147      05 38 43.50  +49 49 42.9            111         07 45 +040.0
3C123-L    04 33 55.24  +29 34 14.0            111         07 56 -060.0
3C123-A    04 33 55.24  +29 34 14.0            111         08 04 -018.0
3C123-B    04 33 55.24  +29 34 14.0            111         08 13 +008.0
3C123-H    04 33 55.24  +29 34 14.0            111         08 21 +050.0
3C123-A    04 33 55.24  +29 34 14.0            111         08 30 -018.0
3C123-B    04 33 55.24  +29 34 14.0            111         08 38 +008.0
3C123-L    04 33 55.24  +29 34 14.0            111         08 47 -060.0
3C147      05 38 43.50  +49 49 42.9            111         08 59 +040.0




C   TO ENTER NEW FSET CARD ONE MUST ENTER ALL THE REST OF THE LEADING CARDS

   3382.403           -2527.746           -7955.482        1
   2635.963           -1959.529           -6187.479        2
   0746.440           -0568.217           -1768.003        3
  81820.176          -65465.403          -53469.054        4
1  87  118  -61    3   28  -58   21   44 -101  -42   48   -2  -18    4   44 -101
2 -75  102   17  156   15  -20   14   39 -101   70  -14  -20   41   35   39 -101
3 -96  131   -8   44   39    5    8   39 -101   47    4  -60  -22   70   39 -101
000000    000000    00000350730

C   FSET CARD FOR TRACKED DELAY AND BOTH SIDEBANDS AT 11 CM

FSET              2702799000.         02555000000.         +010000000.      SVSL

C   SCAN CARDS
C   D-MODE USED ONLY TO SET VLSR FOR FOLLOWING C-MODE CARD

W49        19 08 16.6   +09 00 29.0            112 D       16 46 +0.000
3C286      13 28 49.653 +30 45 58.79           111 C 16 00 16 10 +040.0
W49H       19 08 16.6   +09 00 29.0            112         16 26 +200.0
W49        19 08 16.6   +09 00 29.0            112         16 46 +40.00
W49L       19 08 16.6   +09 00 29.0            112         16 56 -200.0
W49        19 08 16.6   +09 00 29.0            112         17 16 +040.0
3C454.3    22 51 29.510 +15 52 54.54           111 C       17 30 +040.0
W49H       19 08 16.6   +09 00 29.0            112         17 44 +200.0
W49        19 08 16.6   +09 00 29.0            112         18 04 +40.00
W49L       19 08 16.6   +09 00 29.0            112         18 14 -200.
W49        19 08 16.6   +09 00 29.0            112         18 34 +040.0
W49H       19 08 16.6   +09 00 29.0            112         18 44 +200.0
3C454.3    22 51 29.510 +15 52 54.54           111 C       18 58 +040.0

00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

2. THE TELESCOPE TAPE PROGRAM

```
C   SAMPLE DECKS FOR THE PREVIOUS TWO EXAMPLES.  GAIN OVERRIDES ARE NEEDED FOR
C   THE FIRST CASE ONLY.  DUMPS OF THE FIRST TWO RECORDS OF EACH SCAN ARE NEEDED
C   IN THE SECOND CASE.  BOTH CASES HAVE SCAN-AVERAGE PROFILES PRINTED.  THE
C   TAPE IS NEW FOR THE FIRST CASE WHILE THE SECOND CASE ADDS DATA TO THE TAPE.


C   FIRST JOB

00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

//HLINE  JOB    (269,P,6,13,3),GREISEN,MSGLEVEL=(1,1),CLASS=C
//       EXEC   HLINETAP,TN9=3684,DSN9=SAMPLE,TN7=1281,DSP=NEW
//GO.SYSIN  DD *
 AVER           GAIN            21743
 3C161-L  3333
 3C161-A  3333
 3C161-B  3333
 3C161-H  3333
 3C123-L  3333
 3C123-A  3333
 3C123-B  3333
 3C123-H  3333
//

C   SECOND JOB

//HLINE  JOB    (269,P,6,13,3),GREISEN,MSGLEVEL=(1,1),CLASS=D
//       EXEC   HLINETAP,TN9=3684,DSN9=SAMPLE,TN7=1283
//GO.SYSIN  DD *
 AVER   2 FSET              21744 22421
FSET                2702799000.         02555000000.        +010000000.       SVSL
//

00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

3. HLINEINT

THE SAMPLE DECKS SHOWN BELOW ILLUSTRATE ONLY A VERY FEW OF THE MANY ACTIONS AND OPTIONS AVAILABLE TO THE USER. THE DECKS SHOWN ARE BROKEN INTO ONLY A FEW JOBS. USERS WILL NORMALLY BREAK THE DATA PROCESSING INTO A CONSIDERABLE NUMBER OF JOBS IN ORDER TO BE CERTAIN ABOUT EACH PROCESSING STEP BEFORE GOING ON TO THE NEXT STEP.

```
C   CREATE DDS - BEGIN CALIBRATIONS


//HLINE   JOB   (269,P,6,13,4),GREISEN,MSGLEVEL=1,CLASS=L
//        EXEC  HLINEINT,DISKDSN=GREISEN,RDSN=SAMPLE,RTN=3684
//HLINEGO.READER DD *
 FORTH  LOAD  CARDS  LOAD  HEX  20  LOAD  DECIMAL

C   EDITS LOAD NOT REQUIRED IMMEDIATELY AFTER 20 LOAD
C   MOVE DATA TO DISK - AVERAGE SOME OF SECOND SET

 NEW-DISK
 OMIT-SOURCE  3C119   OMIT-SOURCE  3C20-C
 OBSERVER-TAPE  21100  21743  SCAN-RANGE
 READ-TAPE  REWIND
 NEW-OMITLIST  OBSERVER-TAPE  2  INT  =
 21744  22421  SCAN-RANGE

C   LIST DISK CONTENTS

 LOOKS LOAD
 FOR  ALL-SORC  LIST-DISK

C   CORRECT FOR FIXED DELAYS

 CALS LOAD
 FOR  ALL-SORC  DELAY-COR  21100  21743  SCANS

C   CORRECT AMPLITUDES FOR ONE-BIT SAMPLING  (NOTE - THE NAME
C   ALL-SORC IS ALREADY SET)

 FIX-AGC  FULL  SCANS

C   MARK CALIBRATOR SCANS FOR 21 CM DATA

 STANDARD-CALIBRATORS  CALIST
 CALIBRATOR  3C48  15630  FLUX  CALIST
 CALIBRATOR  3C147  22240  FLUX  CALIST
 CALIBRATOR  3C380  NOT-GAIN  CALIST
 NOT-CALIBRATOR  3C48  0  50  VEL  CALIST
 NOT-CALIBRATOR  3C147  0  30  VEL  CALIST
 CALIBRATOR  3C454.3  15440  FLUX  50  WEIGHT  CALIST
 CALIBRATOR  3C123-L  NOT-PHASE  NOT-GAIN  CALIST
 CALIBRATOR  3C123-H  NOT-PHASE  NOT-GAIN  CALIST
 CALIBRATOR  3C161-L  NOT-PHASE  NOT-GAIN  CALIST
 21100  21743  ENTER-CALS
```

```
NEW-LIST  STANDARD-CALIBRATORS  NOT-GAIN  CALIST
CALIBRATOR  3C286  10100  FLUX  CALIST
CALIBRATOR  3C147  12700  FLUX  CALIST
CALIBRATOR  3C454.3  11240  FLUX  20 WEIGHT  CALIST
 21744  22421  ENTER-CALS

C   LIST CALIBRATORS TO CHECK MARKING

 LOOKS LOAD
 LIST-CALIBRATORS  FULL SCANS

C   TRY FOR BASELINE SOLUTIONS

 CALS LOAD
 BASELINES
 2  INT  =        7  ITERATIONS  21233
 21274  SCAN-RANGE   NO-K  NO-DF   SOLVE

C   SEPARATE PHASE-FREQUENCY TO REDUCE ERRORS  (21 CM)

 BASELINES  2  INT  =  3  ITERATIONS
 21380  21420  SCAN-RANGE  NO-K  NO-X  NO-Y  NO-Z  NO-DF1
 SOLVE

C   USE ONLY ONE SIDEBAND  (11 CM)

 BASELINES  21744  21785  SCAN-RANGE  22301  22340
 SCAN-RANGE  IMAGE  NO-K  NO-BL1  SOLVE

C   END OF JOB

 DISCARD  GOODBY

//


C  JOB TO CHECK OUT INSTRUMENTAL AND BANDPASS CALIBRATION


//HLINE  JOB  (269,P,6,13,4),GREISEN,MSGLEVEL=(1,1),CLASS=L
//      EXEC  HLINEINT,DISKDSN=GREISEN
//HLINEGO.READER  DD  *
 FORTH  LOAD  CARDS  LOAD  HEX  20  LOAD  DECIMAL

C  SATISFACTORY BASELINE CORRECTIONS HAVE BEEN FOUND AFTER
C  SEVERAL TRIES  -  CORRECT  DATA

 -151   -1  -90  0  -685   BL12
 -124   10  -93  0  -632   BL13
  -23  -10    6  0   -44   BL23
 FOR  ALL-SORC  BASELINE-COR  FULL  SCANS

C   TRY BANDPASS CALIBRATION

 FIND-BANDPASS
 21100  21232  SCAN-RANGE
 21233  21274  SCAN-RANGE
 21275  21379  SCAN-RANGE
```

```
 21380  21402  SCAN-RANGE
 21403  21743  SCAN-RANGE
 IMAGE   21744  22421  SCAN-RANGE

C   LOOK FOR DISCONTINUITIES IN INSTRUMENTAL FUNCTION -

 INSTRUMENTAL-FUNCTION  4  INT  =  GAUSSIAN
 21100  21232  SCAN-RANGE  21275  21743  SCAN-RANGE
 IMAGE  21744  22421  SCAN-RANGE
 SIGNAL  21744  22421  SCAN-RANGE

C   LOOK AT EFFECT OF INVERSE BANDPASS MULTIPLIER (BEFORE)

 LOOKS LOAD
 FOR ALL-SORC  HLOOK  INV-BANDPASS  21100  21105 SCANS
 21442  A-SCAN
 FOR  3C123-A  PROFILES
 21210  A-SCAN    21500  21510  SCANS

C   APPLY AND RE-EXAMINE

 CALS LOAD
 FOR  3C123-A  FIX-BANDPASS  21210  21210  SCAN-RANGE
 21500  21510  SCAN-RANGE
 LOOKS LOAD
 FOR  3C123-A  PROFILES  21210  A-SCAN
 21500  21510  SCANS

C   RESTORE  DATA TO UNCALIBRATED STATE

 CALS  LOAD
 FOR  3C123-A  UNFIX-BANDPASS  21210  21210  SCAN-RANGE
 21500  21510  SCAN-RANGE

C   END OF JOB

 DISCARD   GOODBY

//


C   JOB TO CALIBRATE, SAVE, AND COMPRESS DATA


//HLINE  JOB  (269,P,6,13,4),GREISEN,MSGLEVEL=1,CLASS=L
//       EXEC  HLINEINT,DISKDSN=GREISEN,WTN=3249,WDSN=SAVED,
//             WFILE=2
//HLINEGO.READER  DD  *
 FORTH  LOAD  CARDS  LOAD  HEX  20  LOAD  DECIMAL

C   APPLY PREVIOUS BANDPASS CALIBRATION

 CALS LOAD
 FOR  ALL-SORC
 FIX-BANDPASS
 FULL
 SCAN-RANGE
```

```
C   RECOMPUTE INSTRUMENTAL FUNCTION WITH FINAL PARAMETERS

 INSTRUMENTAL-FUNCTION  GAUSSIAN  4  INT  =
 200  TAUP  350  TAUG  21100  21149  SCAN-RANGE
 21150  21232  SCAN-RANGE
 21275  21293  SCAN-RANGE
 21294  21332  SCAN-RANGE

C   AND SO FORTH (21 CM)
C   11 CM DATA HAS DISCONTINUITIES IN PHASE ONLY (HOPEFULLY)

 INSTRUMENTAL-FUNCTION  4  INT  =
 GAUSSIAN  300  TAUP  0  TAUG  IMAGE
 21744  22143  SCAN-RANGE  22144  22421  SCAN-RANGE
 SIGNAL  21744  22143  SCAN-RANGE
 22144  22300  SCAN-RANGE  22301  22421  SCAN-RANGE
 0  TAUP  400  TAUG  SUPPLEMENT
 IMAGE  21744  22421  SCAN-RANGE
 SIGNAL  21744  22421  SCAN-RANGE

C  APPLY INSTRUMENTAL FUNCTION JUST STORED

 FOR  ALL-SORC  FIX-INSFUNC  FULL  SCAN-RANGE
 LOOKS  LOAD
 FOR ALL-SORC  LOOK  BROADBAND  FULL  SCANS

C  SAVE CALIBRATED DATA

 EDITS  LOAD
 100  0  EMPTY-DISK

C  REWRITE DISK TO AVERAGE SCANS AND TO CREATE 11 CM DIFFERENCE
C  RECORDS WHILE DROPPING OTHER 11 CM RECORDS

 REWRITE
 AVERAGE  NO-IMAGE  CREATE-DIFFERENCE
 NO-RENUMBER

C   CAN'T SAY NO-SIGNAL WITHOUT LOSING 21 CM DATA
C   SO NOW DELETE 11 CM SIGNAL AND REWRITE AGAIN

 FOR  ALL-SORC  DELETE  BROADBAND  NO-DIFFERENCE
 21744  22421  SCANS
 REWRITE  NO-RENUMBER

C  END OF JOB

 DISCARD  GOODBY

//
```

```
C   JOB USING CRT TO TEST AND MAKE DISPLAYS


C   CARD INPUT:

//HLINECRT  JOB  (269,P,6,13,4),GREISEN,MSGLEVEL=1,CLASS=G
//          EXEC  HLINEINT,DISKDSN=GREISEN,CRT=,CMOORE=FORTH


C   REST OF JOB IS ENTERED ON GRAPHICS CRT

 FORTH  LOAD  HEX  20  LOAD  DECIMAL

C   STACK SOME SCANS: NEW NUMBERS WILL BE 22422 - 22424

 FOR  3C123-A  21100  21743  INTO  -1  ASTACK
 FOR  3C123-B  21100  21743  INTO  -1  ASTACK
 FOR  3C161-B  21100  21743  INTO  -1  ASTACK

C   TRY VARIOUS PLOTS

 CRTS  LOAD
 FOR  ALL-SORC  SPECTRA  22422  22424  SCAN-RANGE
 SPECTRA  RX-AB  OVER-WRITE AMPLITUDE
      0  4000  SCALE  22422  22424  SCAN-RANGE
 RX-CD  22422  22424  SCAN-RANGE
 PHASE  RX-ABCD  -400  1000  SCALE  22422  22424  SCAN-RANGE

C   PARAMETERS LOOK GOOD - DO CALCOMP MULTI-BASELINE PLOT

 LOOKS LOAD
  FOR  ALL-SORC  MULTI-PLOT
  22422  ,  22423  ,  3  SMOOTH  0  4000  LSCALE
  -400  1000  USCALE  OVER-WRITE  542 YMULT
  765  XMULT  MPLOT
  LIST  22424 ,  MPLOT

C   LOOK OVER EVERYTHING

 CRTS LOAD
 FOR  ALL-SORC  SPECTRA  21744  22421  SCAN-RANGE

C   (WILL PROBABLY STOP THIS ONE OUT OF BOREDOM PART OF THE
C   WAY THROUGH)
C   DROP  TEMPORARY  STACKS  AND  END  JOB

 EDITS  LOAD
 FOR  ALL-SORC  DELETE  BROADBAND  22422  22430  SCANS
 DISCARD  GOODBY
```

```
C    JOB TO DISPLAY MAPS AND ILLUSTRATE USE OF FORTH LANGUAGE


//HLINE  JOB   (269,P,6,13,4),GREISEN,MSGLEVEL=1,CLASS=L
//         EXEC  HLINEINT,DISKDSN=GREISEN
//HLINEGO.READER  DD  *
 FORTH  LOAD  CARDS  LOAD  HEX  20  LOAD  DECIMAL

C  REPETITIVE ACTION DESIRED

 : GO     24000  24153   SCANS :

C  EDIT MAP HEADERS

 FOR  ALL-SORC
 DELETE-MAP   HEX  6780 YESTYPE  GO
 543  ADD-MAP  GO
 24000  24153  ENTER-CONTINUUM  GC
 0  INTO  4  STORE-MAP  GO
 0  INTO  5  STORE-MAP  GO
 0  INTO  6  STORE-MAP  GO

C   DISPLAY MAPS - OLD GO DEFINITION DESTROYED BY LOOKS LOAD

 LOOKS  LOAD
 :  GO    15  CUTOFF   33  85  XRANGE  21  110  YRANGE
      24000  24153  SCAN-RANGE  ;
 FOR  ALL-SORC  PRINT-MAP  3  TAU  GO
 XY-HATCH  HIDDEN  30  OVER  150  PERSPECTIVE  0  TAU  GO
 CONTOUR  200  TAU  GO

C   THIS JOB WILL TIE UP THE PLOTTER FOR MANY HOURS
C   END OF JOB

 DISCARD  GOODBY

//
```

APPENDIX N. PROGRAM DETAILS FOR THE OVERLY CURIOUS

This appendix should be read only by those who must supplement the basic programs with their own modifications and additions.

1. Common Areas

The telescope tape program uses one named common /AVCOM/ to pass parameters to the averaging routine. The main program HLINEINT uses three common areas:

(1) /USER/ contains the control supervisor and passes parameters from the user to the subroutines.

(2) /PRIME/ contains the data record being processed and the summing arrays for averaging data and is sometimes used as scratch storage.

(3) /MAPCOM/ contains all or parts of one or more maps currently being processed.

The variables in common are listed below with their half-word locations, dimensions, types, and normal uses.

LOCATION	NAME(Dimension)	TYPE	USE
/AVCOM/			
1	SOURCE	R*8	Source name
5	SCAN	I*2	Scan number
6	MODE	I*2	Mode
7	VLSR	R*4	LSR velocity
9	VOFFS	R*4	(V-VLSR) signal band
11	VOFFI	R*4	(V-VLSR) image band
13	H	R*8	Hour angle
17	B(6,3)	I*4	Projected baseline array
53	RECORD	I*4	Record number
55	IGNORE(12)	L*1	Instrumental parameter checks
61	CHSKIP(384)	L*1	Plot normalization checks
/PRIME/			
1	ASKIP	R*4	Dummy
3	A(512)	I*2	Data or map record
515	AVS(512)	I*4	Summing array signal band
1539	AVI(512)	I*4	Summing array image band
2563	AVD(512)	I*4	Summing array difference band
3587	AVH(512)	I*4	Summing array headers

/MAPCOM/

1	A1(2048)	R*4	pieces of maps
4097	A2(2048)	R*4	
8193	A3(2048)	R*4	
12289	A4(2048)	R*4	

/USER/

1	ISKIP(4144)	I*2	main FORTH area
4145	CNTRLA	I*2	invoked subroutine number
4146	JSKIP(251)	I*2	secondary FORTH area
4397	CNTRLB	I*2	invoked subroutine secondary number
4398	ENTRY	I*2	entry point into subroutine
4399	AVAIL	I*2	first unused block on disk
4400	NAVAIL	I*2	next available source number
4401	SCANLO	I*2	lowest scan number on disk
4402	SCANHI	I*2	highest scan number on disk
4403	NR	I*2	number of records per scan in SCANS loop
4404	PARAM	I*2	entry point into RWDISK
4405	LOW	I*2	value or scan range
4406	HIGH	I*2	
4407	SCAN	I*2	scan number
4408	RECORD	I*2	record number
4409	SNAME	R*8	source name (desired)
4413	SRCNUM	I*2	source number (desired)
4414	INT	I*2	number of records to be averaged; contour interval
4415	TYPE1	I*2	exclude data type indicator; indicator of data format
4416	TYPE2	I*2	include only data type indicator
4417	TYPE3	I*2	NB-OVERFLOW data type
4418	BSCAN	I*2	NB-OVERFLOW scan number
4419	BVALUE	I*4	NB-OVERFLOW true data value
4421	BCHAN	I*2	NB-OVERFLOW channel number; cutoff level of continuum map
4422	FLOW	I*2	number of first channel; miscellaneous
4423	DV	I*2	number of channels; miscellaneous
4424	ARG(4)	I*2	number miscellaneous parameters; desired map ranges
4428	NPLIST	I*2	number of parameters in PLIST; type of cross-hatch plot
4429	PLIST(20)	I*2	parameter list entered with comma; numerous plot parameters

2. Organization of the disk data set

(a) Blocks 0-99 contain the FORTH dictionaries and commands used in the execution of the program.

(b) Blocks 100 and 101 contain the list of source names and source numbers. The list begins at word 3 of each block and requires 4 words for the source name and 1 word for the source number for each source.
Word 1 of block 100 contains NAVAIL.
Word 2 of block 100 contains AVAIL.
Word 1 of block 101 contains SCANLO.
Word 2 of block 101 contains SCANHI.

(c) Blocks 102-111 contain a list of all scan numbers together with the block numbers at which they begin. A scan will be found in block number N where

$$N = 102 + MOD(SCAN,10)$$

(d) Blocks 112-169 contain a list of scan numbers with associated block numbers separated by source. Scan numbers for source N are found in block N. Note, this forces source numbers to be $112 \leq N \leq 169$. The first two words of each block are used to give the block number of a second block also used (when needed) to list scans for the given source.

(e) Blocks 170 and up contain the data headers and records, u-v plane and brightness maps, maps of beam patterns, and spectra-maps.

More than one source may be assigned to a given source number, either by the user or by the programs. No error is made because the programs which receive the data from the access program (RWDISK) check the source name before processing the data.

The user must establish his own disk data set and transfer the needed FORTH into it. The method used to do this is explained elsewhere in this manual. The user's disk data set should be catalogued with a DSNAME of

GREISEN.username

3. THE CATALOGUED PROCEDURES

```
      ******  HLINETAP  ******

//HLINETAP PROC DSP=MOD

//LKED      EXEC PGM=IEWLF440,PARM='MAP,LIST'
//SYSPRINT DD   SYSOUT=A
//SYSLIB    DD   DSN=FORT.FORTLIB,DISP=SHR
//          DD   DSN=FORT.GPSLMOD,DISP=SHR
//SYSUT1    DD   UNIT=DISK,SPACE=(CYL,(1,1,1))
//SYSLMOD   DD   DSN=&&GOSET(MAIN),DISP=(NEW,PASS),
//               UNIT=DISK,SPACE=(CYL,(1,1,1))
//MODS      DD   DSN=GREISEN.MODS,DISP=SHR
//SYSLIN    DD   DSN=GREISEN.MODS(INCTELTP),DISP=SHR

//GO        EXEC PGM=*.LKED.SYSLMOD,COND=(1,LT,LKED)
//STEPLIB   DD   DSN=FORT.LINKLIB,DISP=SHR
//FT04F001 DD   DSN=&DSN9,DISP=&DSP,VOL=SER=&TN9,UNIT=TAPE,
//               DCB=(RECFM=VS,BLKSIZE=1032)
//FT05F001 DD   DDNAME=SYSIN
//FT06F001 DD   SYSOUT=A
//FT07F001 DD   SYSOUT=B
//DDP116    DD   LABEL=(2,BLP),UNIT=TAPE7,VOL=SER=&TN7,
//               DCB=(RECFM=F,BLKSIZE=5376,DEN=1),DISP=OLD
//          PEND
```

****** HLINEINT ******

```
//HLINEINT PROC RDSN=NULLFILE,WDSN=NULLFILE,RFILE=1,WFILE=1,
//              RTN=0,WTN=0,CRT='DUMMY ',CMOORE=JOBS

//HLINELKD EXEC PGM=IEWLF440,PARM='MAP,LIST,OVLY'
//SYSPRINT DD   SYSOUT=A
//SYSLIB   DD   DSN=FORT.FORTLIB,DISP=SHR
//         DD   DSN=FORT.GPSLMOD,DISP=SHR
//SYSUT1   DD   UNIT=DISK,SPACE=(CYL,(1,1,1))
//SYSLMOD  DD   DSN=&&GOSET(MAIN),DISP=(NEW,PASS),
//              UNIT=DISK,SPACE=(CYL,(1,1,1))
//JOBS     DD   DSN=MOORE.&CMOORE,DISP=SHR
//MODS     DD   DSN=GREISEN.MODS,DISP=SHR
//SYSLIN   DD   DSN=GREISEN.MODS(INCHLINE),DISP=SHR

//HLINEGO  EXEC PGM=*.HLINELKD.SYSLMOD,COND=(1,LT,HLINELKD)
//STEPLIB  DD   DSN=FORT.LINKLIB,DISP=SHR
//FT03F001 DD   DISP=OLD,UNIT=(TAPE,,DEFER),VOL=SER=&RTN,
//              DCB=(RECFM=VS,BLKSIZE=1032),LABEL=&RFILE,
//              DSN=&RDSN
//FT04F001 DD   DISP=OLD,UNIT=(TAPE,,DEFER),VOL=SER=&WTN,
//              DCB=(RECFM=VS,BLKSIZE=1032),LABEL=&WFILE,
//              DSN=&WDSN
//FT05F001 DD   DDNAME=SYSIN
//FT06F001 DD   SYSOUT=A
//FT07F001 DD   SYSOUT=B
//FT10F001 DD   UNIT=DISK,DISP=(NEW,DELETE),
//              DCB=(BUFNO=2,RECFM=F,BLKSIZE=4096),
//              SPACE=(4096,(32,32))
//PLOTTAPE DD   SYSOUT=O,SPACE=(CYL,(0,5),RLSE)
//DISK     DD   DSN=GREISEN.&DISKDSN,DISP=SHR
//SCOPE    DD   &CRT.UNIT=TEK1
//         PEND
```

4. FORTH as a computer language

FORTH is a powerful computer language based on its flexible and efficient ability to define one word as a sequence of other words. Thus in each application of FORTH one creates a hierarchy of definitions beginning with simple codes which mimic the assembly language and building up to mnemonic commands (such as those listed in Appendix E) which carry out a multitude of complicated tasks. The entire HLININT program could have been written in FORTH and would have been more efficient and more flexible than the present version. However, since FORTRAN is a widely known language and FORTH is not, it was felt that some flexibility and efficiency should be sacrificed in favor of comprehensibility. Thus, FORTH is used mainly as an interface between the user and the many FORTRAN modules. The user of HLINEINT may find some aspects of FORTH useful.

(a) To define a word (WORD) as other words, enter

```
: WORD AWORD BWORD CWORD ;
```

where : indicates the start of the definition and ; indicates the end of the definition and where AWORD, BWORD, and CWORD are previously defined. FORTH places this definition after the definitions already loaded and when it encounters the word as a command searches the dictionary beginning with the most recently defined word. Thus a definition sequence such as

```
:  STACK      ENTRY  =  GO  ;
:  ANYSTACK   1   STACK  ;
:  STACK      2   STACK  ;
```

is perfectly normal and commonly used. Some care must be used in HLINEINT if you would like to define a new word. The FORTH dictionaries EDITS, CALS, MAPS, LOOKS, and CRTS overlay each other. Thus, if you define your word while using EDITS and later you enter CALS LOAD you will lose your definition. For this reason you should not put commands like CALS LOAD in a definition. Another command which is tricky to use in definitions is the word FOR. You may use this word, but the source name cannot appear in the definition. Thus,

```
: GO   FOR   11000  11200  INTO  -1  ASTACK  ;
 GO   3C123
 GO   3C48
```

will work, but

```
: GO   FOR  ALL-SORC   PLOT   RX-AB  ;
  GO   11000  11010   SCANS
  GO   11061  11063   SCANS
```

will not.

(b) FORTH handles numbers from a stack. When a number is read it is placed at the top of the stack. There are several useful operators which handle numbers on a stack. The most common are:

STACK BEFORE			OPERATION	STACK AFTER		
3^{rd}	2^{nd}	top		3^{rd}	2^{nd}	top
N3	N2	N1	+	--	N3	(N1+N2)
N3	N2	N1	-	--	N3	(N2-N1)
N3	N2	N1	*	--	N3	(N2*N1)
N3	N2	N1	/	--	N3	(N2/N1)
N3	N2	N1	SWAP	N3	N1	N2
	N2	N1	DUP	N2	N1	N1
N3	N2	N1	DROP	--	N3	N2
	N2	N1	OVER	N2	N1	N2
N3	N2	N1	.	--	N3	N2
N3	N2	A1	=	--	--	N3
	N2	A1	@	--	N2	N1
N3	N2	N1	MINUS	N3	N2	(-N1)
N3	N2	N1	MOD		N3	(MOD(N2,N1))

where the Ni are numbers and the Ai are addresses. There are a great many other operations possible, but please consult the author before using them.

(c) Values in common area /USER/ may be accessed to have them printed or to alter or use their values. To put the address of the common variable on the stack enter the name of the variable. Thus, the sequence

10 SCAN =

puts the value 10 in the common location called SCAN and the sequence

SCAN @ .

causes the value of SCAN to be printed. One useful application would be in a situation where you want information from all scans higher than 100. To do this for spectra, state

FOR ALL-SORC SPECTRA 101 SCANHI @ SCANS

The common variables are listed earlier in this appendix.

A word of caution about the common variables AVAIL, NAVAIL, SCANHI, and SCANLO is in order. These variables describe the disk data set and are stored with the data set. To obtain in common the current values of these variables state

OPEN

and, if you change the variables and wish the new values to be stored on the disk, state

CLOSE

after you have changed the variables. You are warned that a number of routines in the basic program (including all those using SCAN-RANGE) issue an OPEN command.

(d) References

Unfortunately there are no up-to-date, readily available, and comprehensive references on the FORTH language. There are several internal reports which may be obtained from the NRAO Computer Division. The best of these is entitled: "FORTH: An Application-oriented Language Programmers' Guide" by E. D. Rather and C. H. Moore. There are also two versions of "FORTH: A New Way to Program a Mini-Computer" by C. H. Moore.

5. TELTAP: Program Modules

This program consists of a large main program with a set of fairly small subroutines to carry out a few special tasks. All the programs and subroutines are stored in GREISEN.MODS with member names identical to the subroutine names. The set of INCLUDE cards needed for this program is also stored in this library with member name INCTELTP. All routines described below are in FORTRAN and are normal subroutine subprograms except as noted.

1. ANSI (ADDRESS,COUNT): converts variable at address from count ANSI characters to count EBCDIC characters (Assembly language).
2. AVER(A,ENTRY): sum and average data records.
3. BITS(ADDRESS,FIRSTBIT,#BITS): acquires the requested number of bits from the address given by ADDRESS plus FIRSTBIT (Assembly language).
4. CONNEC(MODE,SCOPES): converts the recorded baseline connection code to an easily interpreted baseline number -quadrant connection code (Integer function).
5. GAINS(CON,GAIN): alters the recorded gain code of the auto-correlation quadrant (Integer function).
6. LO: entry LO : converts recorded bit levels (4,2,2,1) to normal bit levels (8,4,2,1) for the local oscillator

   entry LST : converts LST recorded in BCD with missing bits to integer * 4 in units of 0.1 seconds.

   entry R8 : converts 30-place decimal fractions from DDP116 format to REAL*8

   entry I4 : converts from DDP116 (30-bit) to IBM360 (32-bit) format for INTEGER*4 variables

   (all are Assembly language function subprograms)
7. PROFS(A): converts the data in A to amplitude and phase and produces a printer line profile down the page.

8. RANGE(...): checks a set of variables for discontinuities and for reasonableness of value.
9. RED: entry RED116 (...): reads seven-track tape, converts DDP116 data to IBM format by squeezing out unused bits, and returns information on record length, parity errors, etc.

   : entry REDEND(LAST): checks for end of volume vs end of data set conditions.

   : entries CNVLO, CNVAE, TAPEND are not used

   (All are in Assembly language)
10. STEADY(I,A): produces error message when a change is noted in the valid bits of computer control, lock, range, and faults data words.
11. SEX(ADDRESS): converts the INTEGER*4 number at address from 0.01 seconds to sexigesimal EBCDIC in order to print positions. (Assembly language)
12. TELTAP: obtains control information from cards (or by default), obtains header and data records from RED116 (7-track tape), converts data formats, rearranges data, inserts defaults, writes observer tape, and (if requested) produces dumps of tape records and prints line profiles of tape records and scan averages. (Main program)

6. HLINEINT: OVERLAY SYSTEM AND PROGRAM MODULES

HLINEINT CONSISTS OF A LARGE NUMBER OF SUBROUTINES ARRANGED IN A HEAVILY OVERLAYED FASHION. EACH SUBROUTINE IS STORED ON THE CATALOGUED PARTITIONED DATA SET GREISEN.MODS WITH A MEMBER NAME IDENTICAL TO THE SUBROUTINE NAME (EXCEPT FOR SOME MULTIPLE ENTRY PROGRAMS AND A VERY FEW OTHER EXCEPTIONS). THE SET OF OVERLAY, INCLUDE, INSERT, AND ENTRY CARDS NEEDED BY THE LINKAGE EDITOR IS ALSO STORED ON THIS LIBRARY WITH MEMBER NAME INCHLINE.

THE OVERLAY SYSTEM OF THIS PROGRAM IS SKETCHED IN FIGURE N.1. IN THE FIGURE, OVERLAY POINTS ARE REPRESENTED BY HORIZONTAL LINES AND ARE NAMED WITH (CIRCLED) CAPITAL LETTERS. BELOW IS GIVEN A BRIEF DESCRIPTION OF EACH OF THE SUBROUTINES. THEY ARE LISTED IN ALPHABETICAL ORDER BY MEMBERNAME. ALL OF THE ROUTINES ARE IN FORTRAN AND ARE NORMAL SUBROUTINE SUBPROGRAMS EXCEPT AS NOTED. FOR FURTHER DETAILS AND LISTINGS OF THE PROGRAMS THE USER SHOULD CONSULT THE AUTHOR.

ACPLOT(ENTRY): PRODUCES PRINTER PLOTS OF AUTOCORRELATION SPECTRA BOTH ACROSS AND DOWN THE PAGE

AITKX(IT,MVECT): LINEAR VECTOR INTERPOLATION FUNCTION (COMPLEX FUNCTION)

AITKXD(IT,INSFUN,NDISC,TDISC): LINEAR VECTOR INTERPOLATION FUNCTION FOR VECTORS OF UNIT AMPLITUDE WITH PROVISION FOR DISCONTINUITIES (COMPLEX FUNCTION)

ANSI(ADDRESS,COUNT): CONVERTS ANSI TO EBCDIC CHARACTER CODE (ASSEMBLY LANGUAGE)

AVERTP(ENTRY): SUMS AND AVERAGES DATA RECORDS (LOGICAL FUNC.)

AVHEAD(ENTRY): SUMS AND AVERAGES DATA HEADER RECORDS (LOGICAL FUNCTION)

AVRAG(ENTRY): CONTROLS DATA ACQUISITION FROM THE DISK DATA SET AND THE AVERAGING BY AVERTP (INTEGER FUNCTION)

BASLIN(ENTRY): DETERMINES CORRECTIONS TO THE ASSUMED BASELINE PARAMETERS BY LEAST SQUARES METHOD ITERATED AGAINST THE FIT OF A SMOOTH PHASE FUNCTION

BITS(WORD,FBIT,NBIT): ACQUIRES NBIT BITS BEGINNING AT BIT FBIT IN WORD (ASSEMBLY LANGUAGE, INTEGER FUNCTION)

BNDPAS: FINDS A TIME-SMOOTHED INVERSE BANDPASS MULTIPLIER FUNCTION AND STORES VALUES IN DATA HEADERS

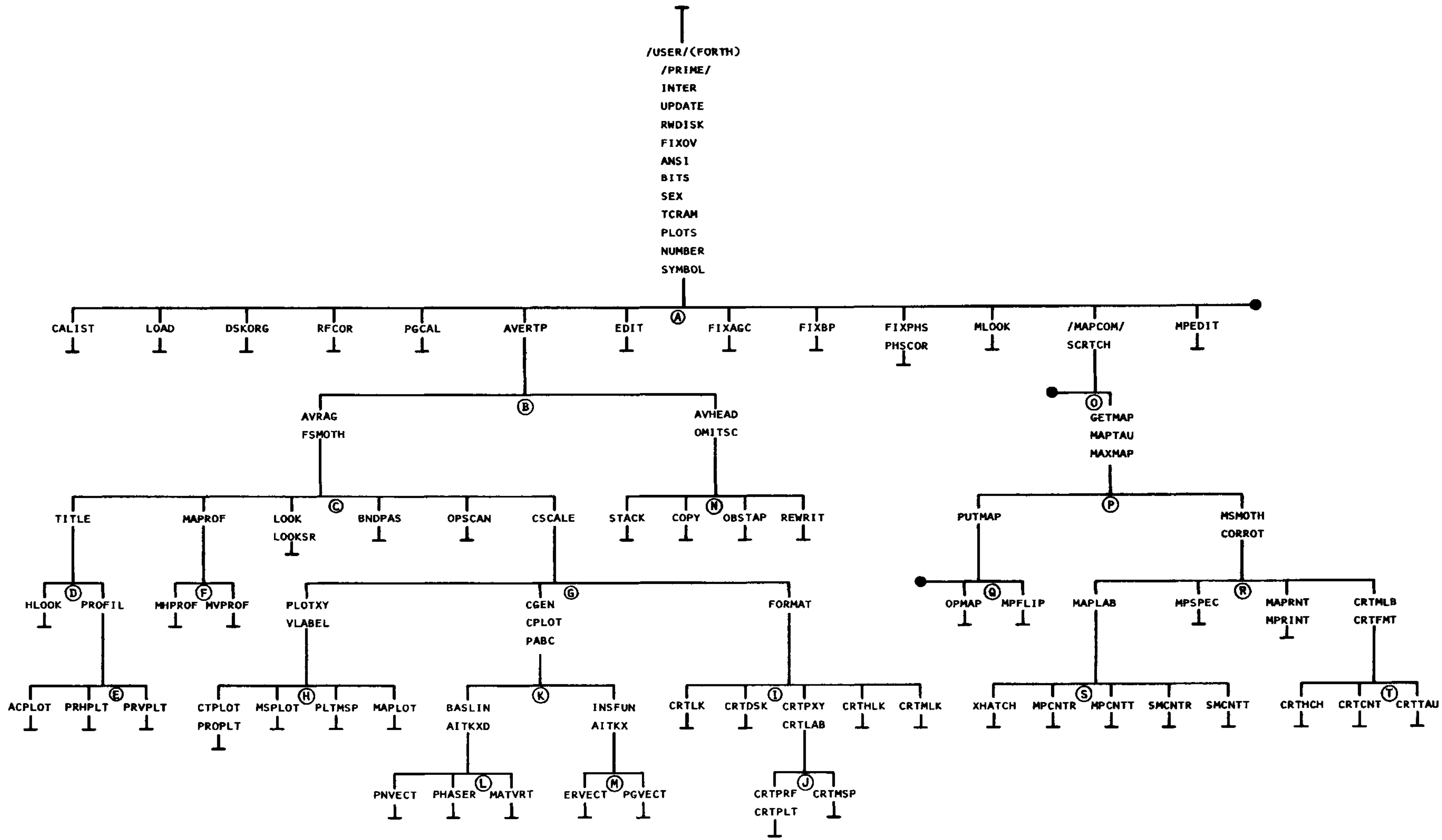

Figure N-1. HLINEINT Overlay System

CALIST(ENTRY): FORMS A LIST OF CALIBRATION SOURCE INFORMATION AND PLACES APPROPRIATE INDICATORS IN HEADERS OF CALIBRATION SCANS

CGEN(X): EXPONENTIAL OR GAUSSIAN CONVOLUTION FUNCTION (REAL FUNCTION)

COPY(ENTRY): COPIES DATA AND MAP SCANS FROM TAPE OR DISK TO TAPE WITH VARIOUS DELETION OPTIONS

CORROT(ENTRY,X,Y): PERFORMS COORDINATE ROTATIONS

CPLOT(K,A1,A2,A3,A4,A5,A6): CENTERS AXIS LABELS AND CALLS PLOTA PLOTB, AND PLOTC TO PRODUCE PRINTER PLOTS OF INSTRUMENTAL FUNCTIONS

CRTCNT(ENTRY): PLOTS CONTOUR MAPS ON THE CRT

CRTDSK(ENTRY): PRODUCES LISTS ON THE CRT OF THE CONTENTS OF THE DISK DATA SET

CRTFMT: (ENTRIES IFORM,FFORM,AFORM) CONVERTS INPUT NUMBER TO EBCDIC CHARACTERS IN SPECIFIED FORMAT

CRTHCH(ENTRY): PLOTS CROSS-HATCH MAP PROFILES ON THE CRT WITH OR WITHOUT PRIOR CONVERSION TO OPTICAL DEPTH

CRTHLK(ENTRY): PRODUCES CRT LISTS OF INFORMATION FROM DATA HEADER RECORDS

CRTLAB(NCODE,UMIN,UMAX,UINT,NDEC): PLOTS AND LABELS AXES ON CRT PLOTS OF SPECTRA

CRTLK(ENTRY): PRODUCES CRT LISTS OF INFORMATION FROM DATA RECORDS

CRTMLB(ENTRY,AMN,AMX,IXA,IXB,IYA,IYB): PLOTS AND LABELS AXES OF CRT PLOTS OF MAPS

CRTMLK(ENTRY): PRODUCES CRT LISTS OF INFORMATION FROM MAP HEADERS

CRTMSP(ENTRY): PLOTS INDIVIDUAL SPECTRA FROM SPECTRA-MAPS ON THE CRT

CRTPLT(VOFFS,DVS,VOFFI,DVI,SOURCE,QFLAG): PREPARES DATA FOR CRT SPECTRAL PLOTS AND CALLS PLOTTING ROUTINES

CRTPRF: OBTAINS DATA FOR USE BY CRTPLT

CRTPXY(NCODE,X,Y,NP,XUMIN,XUMAX,YUMIN,YUMAX): PRODUCES A LINE PLOT ON THE CRT OF Y(I) = F(X(I))

CRTTAU: PLOTS CONTOUR MAPS WITH BLANKING ON THE CRT AFTER CONVERSION TO OPTICAL DEPTH

CSCALE(N,SMIN,SMAX,SLO,SHI,UNIT): DETERMINES THE MAJOR SCALE DIVISION AND LIMITS FOR PLOTTING WHICH CONTAIN THE RANGE OF THE PLOTTING VARIABLE

CTPLOT(QFLAG): OBTAINS DATA FOR CALCOMP PLOTS OF SPECTRA FROM INDIVIDUAL SCANS

DSKORG(ENTRY): PRINTS LISTS OF THE CONTENTS OF THE DISK DATA SET

EDIT(ENTRY,QFLAG): CONDUCTS VARIOUS DETAILED EDITING TASKS ON DATA SCANS INCLUDING MULTIPLICATION, STORING, DELETION, AND REVERSING THE SIGN OF THE PHASE AND THE ORDER OF THE NARROW CHANNELS

ERVECT(....): COMPUTES A SMOOTH COMPLEX ERROR FUNCTION FROM A SET OF PHASE VECTORS AND A SET OF GAINS

FIXAGC(ENTRY,QFLAG): CORRECTS DATA FOR THE NORMALIZATION EFFECT OF THE ONE-BIT SAMPLING

FIXBP(ENTRY): APPLIES TO, OR REMOVES FROM, THE DATA THE INVERSE BANDPASS MULTIPLIER STORED IN THE HEADER RECORDS

FIXOV(ENTRY,J,A2): STORES A LIST OF NARROWBAND DATA POINTS WHICH OVERFLOW THE HALF-WORD INTEGER FORMAT AND CHECKS THE LIST TO PROVIDE A CORRECT VALUE WHEN NEEDED

FIXPHS(ENTRY,QFLAG): COMPUTES CHANGES IN MEASURED PHASES DUE TO CHANGES IN ASSUMED CLOCK, BASELINE, AND POSITION PARAMETERS AND DUE TO THE USE OF FIXED DELAYS AND THEN CALLS PHSCOR TO EFFECT THE CHANGES

FORMAT: (ENTRIES IFORMT, FFORMT, AFORMT, XFORMT) CONVERTS INPUT NUMBER TO EBCDIC CHARACTERS IN THE SPECIFIED FORMAT

FSMOTH(ICODE): CONVOLVES THE INPUT SPECTRUM IN FREQUENCY WITH A TRUNCATED GAUSSIAN

GETMAP(ENTRY,BLOCK): TRANSFERS MAPS FROM THE DISK DATA SET TO THE SCRATCH DISK AREA WITH FORMAT CONVERSION AND CHECKS ON THE DESIRABILITY OF THE MAPS (LOGICAL FUNCTION)

HLOOK(ENTRY,QFLAG): PRINTS LISTS OF INFORMATION FROM DATA HEADER RECORDS

INSFUN: DETERMINES A TIME-SMOOTHED INSTRUMENTAL PHASE AND GAIN FUNCTION AND STORES THE VALUES IN THE DATA RECORDS

INTER: CALLS THE NEEDED PRINCIPAL SUBROUTINES, OBTAINS DATA FOR THE SCANS LOOP, AND CONTROLS THE OPENING AND CLOSING OF THE CRT AND CALCOMP DATA SETS

LOAD(ENTRY): MOVES DATA AND MAPS BETWEEN DISK AND TAPE WITH NO EDITING

LOOK(ENTRY,QFLAG): OBTAINS AND CHECKS DATA NEEDED BY LOOKSR

LOOKSR(ENTRY,SRC): PRINTS LISTS OF INFORMATION FROM DATA RECORDS AND FULL DUMPS OF HEADER AND DATA RECORDS

MAPLAB(ENTRY,AMN,AMX,XA,XB,YA,YB,AMULT): PLOTS AND LABELS AXES FOR CALCOMP PLOTS OF MAPS

MAPLOT(ENTRY): PLOTS A WHOLE SPECTRA-MAP ON THE CALCOMP

MAPRNT(ENTRY): OBTAINS AND CONVERTS MAPS TO THE FORMATS NEEDED BY MPRINT

MAPROF(ENTRY): OBTAINS SPECTRA FROM SPECTRA-MAPS FOR PLOTTING ON THE PRINTER

MAPTAU(BLOCK0,BLOCK1,BLOCK2,BLOCK3): CONVERTS MAP TO OPTICAL DEPTH AND PRODUCES A BLANKING ARRAY

MATVRT(N,K,A,B,FLAG): OBTAINS THE INVERSE (B) OF MATRIX A

MAXMAP(ICODE,AMX,AMN,BLOCK): FINDS THE MAXIMUM AND MINIMUM VALUES ON A MAP

MHPROF(I1,I2,I3,TLOW,THIGH,ICODE): PRINTS HORIZONTAL PROFILES OF INDIVIDUAL SPECTRA FROM SPECTRA-MAPS

MLOOK(ENTRY,QFLAG): PRINTS LISTS OF INFORMATION FROM MAP HEADER RECORDS

MPCNTR(ENTRY): PLOTS CONTOUR MAPS ON THE CALCOMP

MPCNTT: PLOTS CONTOUR MAPS WITH BLANKING ON THE CALCOMP AFTER CONVERSION TO OPTICAL DEPTH

MPEDIT(ENTRY,QFLAG): CARRIES OUT DETAILED EDITING TASKS ON MAP HEADERS INCLUDING MULTIPLICATION, STORING, AND DELETION

MPFLIP(ENTRY): CARRIES OUT DETAILED EDITING TASKS ON MAPS INCLUDING REVERSING AXIS DIRECTIONS, EXPANDING OR CONTRACTING THE MAPS, AND ADDITION OF A CONSTANT

MPRINT(ENTRY,BLOCK,TMAX): PRINTS MAPS IN INTEGER FORMAT

MPSPEC(ENTRY): CREATES SPECTRA-MAPS (T(V,X,Y)) FROM SETS OF MAPS (T(X,Y))

MSMOTH(BLOCK): CONVOLVES INPUT MAP WITH A TWO-DIMENSIONAL TRUNCATED GAUSSIAN

MSPLOT: OBTAINS AND PLOTS SPECTRA ON THE CALCOMP FOR PLOTS INVOLVING MORE THAN ONE SCAN AND/OR BASELINE

MVPROF(I1,I2,I3,TLOW,THIGH,ICODE): PRINTS VERTICAL PROFILES OF INDIVIDUAL SPECTRA FROM SPECTRA-MAPS

OBSTAP(ENTRY): TRANSFERS DATA AND MAPS FROM TAPE TO DISK WHILE CREATING OR EXTENDING THE DISK INDICES AND CARRYING OUT OTHER EDITING TASKS

OMITSC(ENTRY): STORES A LIST OF SOURCES TO BE OMITTED DURING DATA TRANSFER AND CHECKS NAMES AGAINST THE LIST (LOGICAL FUNCTION)

OPMAP(ENTRY): CREATES NEW MAP FROM THE SUM, DIFFERENCE, PRODUCT, RATIO, OR LOGARITHM OF THE RATIO OF TWO OTHER MAPS

OPSCAN(ENTRY): CREATES NEW DATA SCAN FROM THE SUM, DIFFERENCE, PRODUCT, RATIO, OR LOGARITHM OF THE RATIO OF TWO DATA SCAN AVERAGES

PABC: (ENTRIES PLOTA, PLOTB, AND PLOTC) PRODUCES PRINTER PLOTS OF THE INSTRUMENTAL FUNCTIONS (ASSEMBLY LANGUAGE)

PGCAL(ENTRY): APPLIES TO, OR REMOVES FROM, THE DATA THE INSTRUMENTAL FUNCTION STORED IN THE DATA RECORDS

PGVECT(....): DETERMINES A TIME-SMOOTHED COMPLEX INSTRUMENTAL FUNCTION FROM A SET OF PHASE VECTORS AND A SET OF GAINS

PHASER(....): DETERMINES A TIME-SMOOTHED ERROR FUNCTION FOR INSTRUMENTAL PHASE

PHSCOR(MODE,JJ,PHASE,DPHASE): CHANGES OBSERVED PHASES USING INPUT CONSTANT AND SLOPE

PLOTXY(....): PLOTS LINE PLOT OF SPECTRA ON THE CALCOMP IN THE FORM Y(I) = F(X(I))

PLTMSP(ENTRY): PLOTS INDIVIDUAL SPECTRA FROM SPECTRA-MAPS ON THE CALCOMP

PNVECT(....): DETERMINES A TIME-SMOOTHED INSTRUMENTAL PHASE FUNCTION

PRHPLT: PRINTS HORIZONTAL PROFILES OF INDIVIDUAL SPECTRA FROM DATA SCANS

PROFIL(ENTRY,QFLAG): OBTAINS DATA FOR PLOTTING PROFILES ON THE PRINTER

PROPLT(VOFFS,DVS,VOFFI,DVI,SOURCE): PREPARES DATA FOR PLOTS OF SPECTRA ON THE CALCOMP AND CALLS PLOT ROUTINES

PRVPLT: PRINTS VERTICAL PROFILES OF INDIVIDUAL SPECTRA FROM DATA SCANS

PUTMAP(ENTRY,BLOCK): MOVES MAPS FROM SCRATCH DISK TO THE DISK DATA SET WITH NORMALIZATION AND FORMAT CONVERSION (LOGICAL FUNCTION)

REWRIT(ENTRY): CREATES IN PLACE A NEW DISK DATA SET FROM THE OLD ONE WHILE CONDUCTING VARIOUS EDITING TASKS

RFCOR(ENTRY): STORES AND APPLIES PHASE AND AMPLITUDE CORRECTIONS AS FUNCTIONS OF OBSERVING FREQUENCY

RWDISK(ENTRY): CREATES DISK DATA SET INDICES AND CAUSES THE READING FROM, AND WRITING ON, DISK USING THE INDICES

SCRTCH(ENTRY,BLOCK,FBLOCK,NBLOCK): MOVES 8K MAP BLOCKS BETWEEN SCRATCH DISK AND COMMON /MAPCOM/

SEX(S2): CONVERTS INTEGER POSITION (0.01 SEC) TO EBCDIC SEXAGESIMAL FORMAT (ASSEMBLY LANGUAGE)

SMCNTR(ENTRY): PLOTS CONTOUR MAPS ON CALCOMP USING INTERPOLATION MESH TO OBTAIN SMOOTHER PLOT

SMCNTT: PLOTS CONTOUR MAPS WITH BLANKING ON CALCOMP AFTER CONVERSION TO OPTICAL DEPTH USING INTERPOLATION MESH TO OBTAIN SMOOTHER PLOT

STACK(ENTRY): PRODUCES A NEW DATA SCAN WHICH IS THE AVERAGE OF ANY NUMBER OF DATA SCAN AVERAGES

TCRAM: (ENTRIES VCTR, CHAR, FLSH, CRTOPN, CRTRD, PLACE, WAIT, PROMPT) SUBROUTINE WRITTEN BY TOM CRAM COMMUNICATES WITH THE CRT IN ORDER TO READ AND WRITE CHARACTERS, WRITE DARK AND BRIGHT VECTORS, AND CONDUCT OTHER ACTIONS WITH THE CRT (ASSEMBLY LANGUAGE)

TITLE(ENTRY): PRINTS SOURCE POSITION, VELOCITY, BANDWIDTH, AND BASELINE INFORMATION FROM DATA SCANS

UPDATE: (ENTRIES UPDATE AND DISK) TRANSFERS BLOCKS BETWEEN THE DISK DATA SET AND COMMON /PRIME/ (ASSEMBLY LANGUAGE)

VLABEL(....): PLOTS AND LABELS AXES FOR CALCOMP SPECTRA PLOTS

XHATCH(ENTRY): PLOTS CROSS-HATCH MAP PROFILES ON THE CALCOMP WITH OR WITHOUT CONVERSION TO OPTICAL DEPTH