NATIONAL RADIO ASTRONOMY OBSERVATORY*

Tucson, Arizona

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36 Foot Telescope
Computer System Manual

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FOREWORD

This manual documents the third generation PDP-11 computer system for the NRAO 36' radio telescope for observer, operator, and staff alike. This documentation is contained in one volume because of the great amount of over-lapping information for the parties concerned. Hopefully, the reader will realize the manual for what it is: A reference to be used in conjunction with hands-on experience of the computer-receiver-telescope system. The manual is not intended to be a stand-alone teaching aid. The new observer will be properly introduced to the 36' telescope when he arrives for his observation run. However, such an observer would benefit from reading the entire manual prior to his scheduled run in order to know our system capabilities and limitations. After having familiarized himself with the manual, the observer is also encouraged to call our staff to clear up any questions about our system.

For those who would like information on the computer language used on the 36' telescope system, I refer you to the NRAO Computer Division Internal Report No. 17 entitled "Basic Principles of FORTH Language as Applied to a PDP-11 Computer".

I thank those observers and staff members who provided helpful suggestions. I especially appreciate the constructive comments and detailed reading of the manuscript by B. L. Ulich and P. J. Rhodes. Many thanks to Sue Worachek for a fine typing job.

Jan M. Hollis

October 1976

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I. Observer Introduction

A. Introduction to the Computer

1. Overview of On-Site Computational Capabilities and Responsibilities

(a) A single PDP 11/40 Computer is programmed to allow four basic tasks to be performed by the central processor on a time-shared basis. These tasks are:

(1) Data Acquisition
(2) Telescope Tracking
(3) Data Analysis
(4) Program Parameter Monitor (TV Screen)

(b) The program to accomplish (a) above resides on the disk in text form and is available to be compiled into core when necessary.

(c) Data is first recorded on the disk. Additionally, data is recorded on 7 or 9 track tape and the observer may take the tape with him at the end of his observing run. We do not mail tapes for observers. On-line data analysis is accomplished by retrieving data from the disk. Off-line data reduction via the tape is the responsibility of the observer. If ASCII data tapes are desired (see the Tape Utility Check Lists and Information Chapter of this manual), the observer must allow some time at the end of his run for the operator to create these special tapes.

(d) During the course of an observing program, the observer has the use of a Tektronix graphics terminal for data analysis.

(e) Since the telescope operator is responsible for the safety of equipments and personnel at the site, he has sole control of the commands that affect the telescope and the data acquisition at the teletype terminal. This policy is instituted to insure that the operator knows what is going on at all times. The observer must relay his desires regarding the observing program to the operator.

(f) Observers are encouraged to bring IBM cards with the 1950 positions of the sources they intend to observe (proper format is shown below). Our card reader is compatible with an IBM 29 Card Punch with either ASCII or EL character sets (see (h) below).

(g) Proper Source Card Format:

Example:

RA(1950)	DEC(1950)	EPOCH	SOURCE	VELOCITY	CARD
18:00:36.8	-24:22:52	EPOCH	M8	11.2 KM/S	CARD

Notes:

(1) EPOCH and CARD are the same for all sources and source name is limited to 10 characters with no spaces. The word EPOCH means 1950.0.

(2) Do not give plus signs to positive DEC or positive VELOCITY.

(3) Do not leave spaces between (say) the minus sign and the numbers that comprise DEC or VELOCITY.

(4) For example, -02:19:42. and -2:19:42. are equivalent for DEC entries.

(5) It does not matter how many spaces one leaves between RA, DEC, EPOCH, SOURCE and VELOCITY.

(6) Source VELOCITY (e.g., 10.0 KM/S) is optional and would not be necessary for continuum observers; if no VELOCITY is specified, Ø is set into the catalog.

(h) Special Characters Card Code Compatible to Card Reader.

Graphic	Card Punch Code
+	12-8-6
-	11
:	8-2
.	12-8-3

Numbers and letters on both the 26 and 29 IBM punches are the same.

(i) Observer requirements that may not appear in the observing proposal which necessitate software modification will be accommodated if practicable. Adequate advance notice, naturally, is required.

B. Introduction to the Observing Programs

1. Either spectral line or continuum observing may be done at the telescope.

2. Spectral line observing requires the use of filter banks and a 512 channel multiplexer to take the data.

3. Continuum observing requires the use of an analog to digital converter in the omniverter to take the data. Data may be either switched power or total power output of the receiver.

4. Data from either spectral line or continuum observing may be corrected for the effects of attenuation by the earth's atmosphere.

C. Spectral Line Observing

1. The observing program for this type of work is called the SPECTRA Program.

2. Various modes of observing are available in this program such as frequency switching, position switching, frequency plus position switching, load switching, absolute position switching, etc. These various modes, however, require that proper hardware be set up. It is wise to call in advance and insure that the support staff knows what you desire for your observing run.

3. Data analysis is accomplished by the observer at the Tektronix terminal. He may display the data on the screen, one filter bank at a time. He may also perform gaussian fitting to the data, pass smoothing functions through the data, fold data, etc.

4. Technical aspects of the SPECTRA Program are discussed in detail in chapter IX.

D. Continuum Observing

1. There are two observing programs available for this type of work. One is the CONTINUUM Program and the other is the MAPPING Program. Equipment usage and basic signal processing is the same for both. Most observing parameters are also the same.

   (a) CONTINUUM Program

   The CONTINUUM observing program performs scans each consisting of a sequence of integrations on and off the source. For beam switching receivers the "on" and "off" positions correspond to the two beams. At the conclusion of the scan, which normally consists of 21 samples of 10 to 30 seconds integration time each, a mean temperature (TAV) and its error (TAV-RMS) are computed and recorded with the data. This program also allows the observer to perform a series of five scans (FIVE) spaced HP north, south, center, east and west about the source, where HP is half the half-power beam width of the antenna.

   (b) MAPPING Program

   The MAPPING observing program performs raster scans centered on the source. A scan may be either one or two dimensional, and may be at any specified angle (SA) in RA-DEC coordinates, or it may be parallel (HMAP) or perpendicular (VMAP) to the horizon. MAPPING is normally used for extended sources, although it may be used to map a point source, in which case it draws the shape of the antenna beam.

2. The CONTINUUM and/or MAPPING Programs have either a beam switching or load switching capability which must be specified at the teletype prior to commencing observations.

3. There are 3 options for continuum data analysis by the observer at the Tektronix terminal.

   (a) CONTINUUM LOAD

   CONTINUUM is used with data taken with the CONTINUUM Program observing vocabulary. It allows the observer to recall and plot scans, average scans together, and to display the results of the FIVE scan data patterns, with a two-dimensional gaussian fitted to the results to give pointing information. The plotting and averaging functions are also appropriate for MAPPING data which consist of one-dimensional scans of up to 256 points.

   (b) MAPPING LOAD

   MAPPING is designed to display two-dimensional maps, both drawn with contours and with slices (perspective view). Averaging or transforming this data is not possible.

   (c) FOURIER LOAD

   FOURIER is used with one-dimensional maps of 256 points or less. It allows plotting and averaging, and also includes the ability to perform a Fast Fourier Transform (FFT) on the data to obtain the power spectrum. When taking data for FOURIER, you should use a number of samples equal to a power of 2.

4. Technical aspects of both CONTINUUM and MAPPING Programs are discussed in detail in chapters VII and VIII, respectively.

E. 36' Telescope System Block Diagram

1. Figure 1. which follows is a general block diagram of the 36' Telescope system for both spectral line and continuum observing.

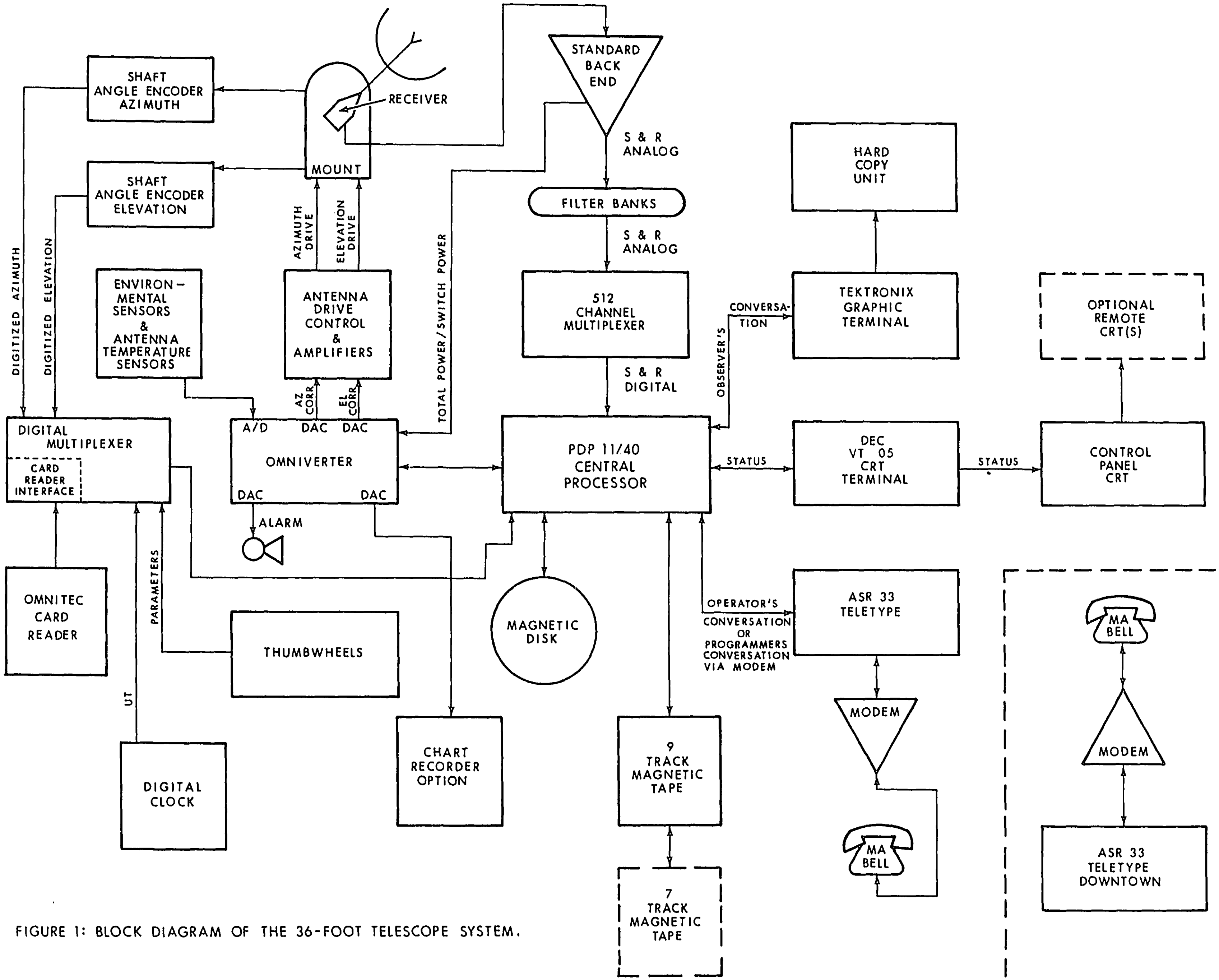


FIGURE 1: BLOCK DIAGRAM OF THE 36-FOOT TELESCOPE SYSTEM.

F. Tektronix Keyboard Information

1. The Tektronix has a PAGE key which is a local control and does not affect the computer. It is relatively useless to an observer. The observer should type the word

   PAGE   cr

   to clear the screen. The program automatically keeps track of the cursor position on the screen. The word PAGE has been defined to clear the screen and position the cursor in the upper left corner.

2. Always erase the screen when you leave the console for any length of time to prevent screen damage.

3. Messages that you type are stored in a temporary location in the computer called the "message buffer". When you hit the RETURN (cr) key, the program will begin to interpret and act on the contents of the message buffer. Thus, you command the computer by typing one or more words followed by "cr". Things you type also appear on the screen, of course, but since the Tektronix has a storage-tube display, things will appear on the screen that are no longer in the message buffer.

4. Two control keys are available to correct typing mistakes by modifying contents of the message buffer:

   (a) The RUB OUT Key

   This key deletes the last character typed, thus effectively backspacing one character. Since partial erasure of the Tektronix storage-tube scope is not possible, the "erased" character still appears, and the cursor will move one space to the right. RUB OUT's that backspace beyond the beginning of the line are ignored. The erased message will still appear.

   (b) The BREAK Key

   This key erases the entire contents of the message buffer. Thus, if you have really fouled up, or changed your mind, BREAK will give you a clean state.

G. Program Loading at the Tektronix

The data reduction and display routines available at the Tektronix terminal are summarized here. The routines are mutually exclusive--that is, they will replace one another automatically. All routines, except CATALOG, need an observing program loaded first at the teletype.

Routine	Description
CATALOG LOAD	To enter source catalog positions, list catalogs and draw rising-setting charts.
SPECTRA LOAD	SPECTRA data reduction.
CONTINUUM LOAD	CONTINUUM data reduction.
MAPPING LOAD	Two-dimensional maps display.
FOURIER LOAD	One-dimensional map display and one-dimensional Fourier analysis package.

H. General Information on Fitting Routines

1. Both continuum and spectral line programs have fitting routines available.

2. FORTH fitting routines are accomplished by a gaussian elimination technique which applies a least squares fitting approximation to observed data. A matrix inversion is performed in lieu of triangulation of the matrix followed by back-elimination.

3. The errors displayed with the variables after the fitting is complete, along with the FCF (Fit Confidence Factor) are completely described in the following reference:

   Introduction to Numerical Analysis by F. B. Hildebrand, McGraw-Hill, 1956, pp. 258-268.

I. TV Screen Information and Examples

1. A short description of most of the various parameters that appear on the TV screen for the various observing programs will be found in the CONTINUUM or SPECTRA Program chapter of this manual under the section concerning Header Variables Recorded on Disk.

2. Pictures of the TV screen may be taken at any time at the Tektronix when an observing program is loaded at the teletype. To accomplish this, type at the Tektronix

   SNAP cr

   The pages that follow are examples of what the TV screen contains for the various observing programs. The operator and observer should agree on all parameters that appear on the TV before taking any observation.

```
      OK

SCAN        SOURCE  HORIZON     LST        UTC     DUT1  1976   OBS  OPR
 1321       URANUS     4:01  13:53:02   22:46:26     50 29 AUG  BLU   WS

               R. A.      DECLINATION             AZIMUTH  ELEVATION
CURRENT     14:07:55.0  -12:27:02.       COMMAND  174:51        45:23
1950.0                                   ACTUAL   174:53:07.   45:26:02.
OFFSET           0:00.0        0:00      ERROR     -0:00:02.   0:00:00.
ECLIPTIC    225:00:00.  -35:15:51.       OFFSET        -2:12        0:39

 TS     TC    ATTN     ATM     MODE       T(AMB)         RCVR   F0   POLZ
 340   14.0  0.118    1.40      00         23 63           15  23.8   0:00
                                      SP
          AZ       EL       HP     T(ANT) %EFF  GAIN0    #C     #CP
+BEAM:   1:38     0:01     0:38   -0.0297  28   7140   3652   4000
-BEAM:  -2:12     0:01

         ERR   FOCUS   SP(V)   TP(V)   SCANS  SAMPLES   SEC   TIME
INPUT    0:05                            5       7      20.0  11:40
ACTUAL   0:01   32.3   0.10  0.0059                     0.0
```

CONTINUUM SNAP

```
OK

SCAN        SOURCE  HORIZON    LST       UTC     DUT1  1976   OBS  OPR
 1218       JUPITER    1:54  7:11:20  16:03:51    50 29 AUG  BLU   WS

               R. A.      DECLINATION            AZIMUTH  ELEVATION
CURRENT      3:54:16.8   19:15:10.       COMMAND 266:26        44:12
1950.0                                   ACTUAL  266:27:20.   44:11:15.
OFFSET          0:07.3        0:52       ERROR     0:00:01.    0:00:02.
ECLIPTIC     45:00:00.   35:15:52.       OFFSET        1:23        0:16

 TS     TC    ATTN     ATM     MODE        T(AMB)         RCVR    F0    POLZ
 269   14.0  0.129    1.43      89          18 82           15   23.8    0:00
                                        SP
            AZ        EL       SIZE   T(ANT) %EFF  GAIN0    GC     GCP  ANGLE
+BEAM:     1:23      0:16      0:10    -0.12   28   7183    4613   4409 153:41
            RA        DEC
RATES:     0:46    -1:27  /8
          ERR    FOCUS    SP(U)    TP(U)    ROWS  COLUMNS     SEC      TIME
INPUT     0:05                               24      24        1 0     9:36
ACTUAL    0:00    25.8    0.10   0.8505                       0.0
```

MAPPING SNAP

```
OK

SCAN        SOURCE  HORIZON     LST       UTC     DUT1  1976    OBS  OPR
 1330         L134     5:33  14:31:37  22:49:32     20  7 SEP  JMH    WS

                R. A.      DECLINATION              AZIMUTH  ELEVATION
CURRENT     15:52:24.7   -4:31:31       COMMAND   148:39        48:45
1950.0      15:51:00.0   -4:26:57       ACTUAL    148:41:13     48:45:46
OFFSET          0:00.0        0:00      ERROR      -0:00:06    -0:00:01
GALACTIC      4.2291     35.7820        OFFSET         0:00         1:30

 TS      TC      ATTN     ATM     MODE       T(AMB)          RCUR   F0    POLZ
 1313  800.0   0.000    1.32       PS         21.74            15  23.8    0:00
                                          SP
      BW  CHANNEL FILTERS  VEL    T(ANT)  FREQUENCY   V(LSR)  IF'S   SB
F1   500    0 -255   288  -26.0   0.328   89.18855    12.93    400    1
F2   100  256 -511                        1.96546687          4750

          ERR    FOCUS    SP(V)    TP(V)    SCANS  SAMPLES    SEC    TIME
INPUT     0:05                                1        2      30.0    1:00
ACTUAL    0:01    34.3    -1.05   1.0175                      21.1
```

SPECTRA SNAP

II. System Trouble Shooting

This chapter deals with those idiosyncrasies of our computer-receiver-telescope system. In most of the following cases nothing is seriously wrong except a switch is in the wrong position or some piece of hardware has spuriously malfunctioned.

A. Disk Problems

1. A disk error occurs but the program keeps running. The following message will be observed displayed at one of the terminals or on the TV screen:

   DSK ERR n

   where n is some number. The following steps should be taken:

   (a) If non-normal sounds are heard from the disk unit, turn off the disk pack and call for digital help.

   (b) If (a) is not necessary the unit is probably ok but log the disk error number n in the trouble log.

2. A disk error occurs as in 1. above, the alarm comes on and the program halts. The following may be seen at one of the terminals or on the TV screen:

   DSK ERR n BK# m

   where m is the block number having difficulty. If the problem occurs in a background task, the above message may not be seen but the alarm and computer halt will occur. The following steps should be taken:

   (a) Repeat the steps in 1. above and additionally record m also in the trouble log.

   (b) Reload the program and continue. If the condition persists, use a new disk pack and/or disk unit.

   (c) If (b) above does not correct the situation, call for digital help.

3. Cannot write on the disk. Note that attempting to change information on the TV screen is equivalent to writing on the disk. The following steps should be taken:

   (a) Insure that WRITE PROTECT is not present on either disk unit.

B. <u>Terminal Problems</u>

1. The Tektronix margin moves too far to the right. The following should be performed:

   (a) At the Tektronix type

   AXES cr

2. The Tektronix seems to have forgotten its vocabulary. The following should be performed:

   (a) At the Tektronix type

   TEKTRONIX cr

3. The Tektronix does not respond. The following should be performed:

   (a) Insure the Tektronix LOCAL-LINE Switch is in the LINE Mode.

   (b) If (a) above fails, type at the teletype

   OBSERVER PROMPT ØOWN cr

   (c) If (b) fails, reload the program.

4. The Tektronix plots erratically. The following should be performed:

   (a) Cycle the two baud rate switches on the back of the Tektronix and leave both at the 9600 setting.

5. The teletype will not respond. The following steps should be performed:

   (a) Check the teletype switch is in the ON-LINE mode.

   (b) Check the MODEM switch is in the TTY position.

   (c) If (a) and (b) fail, type at the Tektronix

   OPERATOR PROMPT ØOWN cr

   (d) If (c) fails, reload the program.

C. Tape Problems

1. Parity errors occur when writing on tape. The following steps should be taken:

   (a) Attempt to repeat the process; if parity errors still occur, use a new tape.

   (b) If parity errors go away after using a new tape, throw away the old tape.

   (c) If parity errors persist, call for digital help. Switch to the backup tape unit.

2. Tape unit does not respond. Perform the following:

   (a) Insure that you have not mounted a tape on the 7 Track unit but have the 9 Track computer routines selected or vice versa.

3. The program halts when creating an ASCII tape. Take the following steps:

   (a) Leave the tape unit alone and reload the program.

   (b) Type

   ```
   NEXT-FILE     cr

   REWIND        cr
   ```

   (c) Conduct a TAPE-LOG on the tape and from this compute which scan has caused the computer to halt.

   (d) Recreate the ASCII tape and leave out the offending scan which probably has garbage in the header information.

D. Data Taking Problems

1. The computer does not respond to a data taking command. Perform the following steps:

   (a) REFRESH the TV screen and then check that the ACTUAL tracking error on the TV screen is less than the INPUT error. For test purposes, when data taking is desired without tracking on source, type

   ```
   EXPEDITE     cr
   ```

   (b) Insure that the receiver is in phase lock. One may defeat the phase lock integrate preventer circuit if desired.

2. Computer does not respond to the SR-ROUTE mode setting command when SPECTRA is loaded at the teletype. Perform the following steps:

   (a) Insure the multiplexer power supply is on.

   (b) Cycle the Computer/Manual Switch on the Multiplexer and leave it in the computer position. This action should free up the Multiplexer.

E. Source Tracking Problems

1. The TRACKER background task stops and the TV LST and UTC times are not changing. Take the following steps:

   (a) Insure that TRACK has been loaded at the teletype.

   (b) Inquire if someone is loading a program. If so, wait until the loading is complete.

   (c) If (a) and (b) are not the cause, reload the program.

2. The 1950 coordinates are suspected of being precessed wrong. Take the following steps:

   (a) Check the Universal Time Clock and reset it if necessary.

   (b) Check the card or catalog entry for correctness.

   (c) Reset DUT1 if necessary by using the verb !DUT1.

   (d) Reset the date again regardless of what the TV screen indicates the date to be.

   (e) Re-enter the source position and REFRESH the TV screen.

   (f) If (a) through (e) fails, seek the source W3 and check the precessed coordinates against our master list.

F. Miscellaneous Problems Associated with the Computer Alarm

1. The computer alarm sounds. Take the following step:

   (a) Type

   HELP cr

   at either the teletype or the Tektronix terminal and the computer will indicate steps to be taken.

III. Operator Observing Program Check Lists

A. CONTINUUM Check List

1. Politely inform the observer not to use the Tektronix terminal until you tell him it is operational.

2. Place the teletype in the On-line mode.

3. Load FORTH at computer console:

   (a) Place HALT/ENABLE switch down.

   (b) Enter 773110 on the octal switches; a bit is on when switch is up.

   (c) Press LOAD ADDRESS - look to ensure 773110 appears in the ADDRESS display lights. (If this does not happen, cycle HALT/ENABLE and START switches simultaneously 3 or 4 times and repeat steps (a) and (b).)

   (d) Place HALT/ENABLE switch up.

   (e) Press START switch down and teletype will respond "?".

4. Load the TELESCOPE vocabulary at the teletype:

   (a) 3 LOAD cr

   (b) TRACK LOAD cr

5. Load the continuum OBSERVING vocabulary at the teletype, the TV screen will update and you and the observer must set any parameters that appear wrong.

   (a) CONTINUUM LOAD cr

   The default is the switched power signal upon loading. If the total power signal is desired, type

   TPDATA cr

   To return to the switched power signal, type

   SPDATA cr

   (b) Mount a fresh tape and type

   NEW-TAPE cr

   Caution: Never type NEW-TAPE when remounting an observer's binary data tape which contains scans he wants to take with him.

(c) Insure the following parameters are set:

(1) n !RCVR cr

where n is the correct receiver number (see Table 1 of chapter VII).

(2) Set the date:

n NOV cr

where n is the correct day's date based on Universal Time. Standard first 3 letter abbreviations for months apply except for December which is designated DCM.

(3) Set the operator and observer initials:

OPR INITIALS nnn cr
OBS INITIALS mmm cr

where nnn is the operator's initials, and mmm is the observer's initials.

(4) Enter AZ-EL offset for the main beam position via the thumbwheels (see chapter V) and type:

MAIN! cr

(5) Enter AZ-EL offset for the reference position via the thumbwheels (see chapter V) and type:

REF! cr

(6) REFRESH cr

insures that your status monitor is current and is the way to check that all your parameters got set correctly.

(7) n DEFAULT ! cr

where n is the data scale factor. For further information see the CONTINUUM Program Chapter under the section entitled "CONTINUUM/MAPPING Data Scale Factor".

6. At the Tektronix:

   (a) CONTINUUM LOAD cr
       SNAP cr

       This will provide a picture of the status monitor at the graphics display; make a hard copy and retain it in case you have to reset any parameters.

   (b) If you have to enter planetary positions for the day, you may do so at the Tektronix. Type

       CATALOG LOAD cr
       PLANETS INDEX cr

       This will provide you a listing of the PLANETS catalog. To enter positions in the catalog, see chapter VI.

   (c) At this point you may turn the Tektronix terminal over to the observer, informing him that he may load

       CATALOG LOAD cr
       or
       CONTINUUM LOAD cr

       and that he may only use the Tektronix terminal for data reduction or entering sources in his personal catalog.

7. At the teletype select the switching mode applicable by typing

   (a) For Beam Switching (the default)

       BS cr

   (b) For Load Switching

       LS cr

8. Perform a calibration:

   (a) Move the telescope to look at blank sky.

   (b) Set the time you want to spend in each phase of the calibration (tenths of seconds):

       100 CSEC ! cr

   (c) CALIBRATE cr

       This will record a scan of 14 samples which has performed a calibration of both switched and total power outputs. For details of this operation, see the continuum calibration page in the CONTINUUM Program chapter.

9. Perform an Extinction:

   (a) A calibration must have been performed prior to performing an extinction. See step 8 above for calibration procedure.

   (b) Release the telescope at any desired position in AUTO-TRACK.

   (c) EXTINCTION   cr

   The antenna will move from 22^{o} elevation to 65^{o} to 22^{o}, making a total of 11 measurements, each measurement SEC long. To obtain the atmospheric attenuation and system temperature from these data, see the CONTINUUM Program chapter.

10. Observation

   (a) The basic continuum observation is a sequence of integrations alternating the reference and main beam on the source.

   (b) Check and if necessary set the following parameters at the teletype:

      (1) SEC

      Duration of a single integration - specified in tenths of seconds. To set a value of 10 seconds, type

      100   SEC   !   cr

      (2) RPT

      The number of repetitions of an OFF-ON-OFF sample sequence; RPT can be no less than 1 and no more than 127. To set a value of 6, type

      6   RPT   !   cr

      (3) %EFF

      Aperture efficiency in units of percent. To set a value of 50%, type

      50   %EFF   !   cr

(4) ATTN

Atmospheric attenuation in units of percent x 10. To set value of 1%, type

10 ATTN ! cr

(5) HEADER

Scan number (values 500-2000 permissible). To set a value of 500, type

500 HEADER ! cr

(6) TC

Noise tube temperature (tenths of K). To set a value of 15.0 K type

150 TC ! cr

(7) HP

This noun is half the HPBW of the telescope. To set a value of 40 seconds of arc, type

40 HP !

(c) Enter source position from catalog, or by card, teletype or thumbwheels (see chapters V and VI).

(d) REFRESH to check all parameters on the monitor display.

(e) SEEK or FOLLOW source (see chapter V).

(f) Observations

(1) n SEQUENCE cr

where n is the number of scans you want to record. Computer will begin taking data. As each scan is finished, it will be recorded and the scan number will be incremented by 1.

(2) FIVE cr

which will take five scans about the source (see chapter VII).

(g) Interrupted Observations (at the teletype only):

(1) Stopping normal observations

To stop an observation, type

STOP cr

Observing will cease. You then have 3 options.

(i) Type any one of the commands in (f) above to begin again; the aborted run will be lost.

(ii) n SCAN SAVE cr

Saves a partial data set for scan n (you may not continue this scan any longer).

(iii) GO cr

Allows you to continue a scan that has been stopped but not saved.

(2) Stopping Calibrations or Extinctions

To stop either a CALIBRATE or EXTINCTION, type

STOP cr

Observing will cease. When using the verb STOP in this case, you may be left in switched power (SP) instead of a desired total power (TP) signal or vice versa. The signal type selected is specified on the TV screen above T(ANT). You may set the signal as appropriate:

(i) Selecting Switch Power Signal

SPDATA cr

(ii) Selecting Total Power Signal

TPDATA cr

B. MAPPING Check List

1. Politely inform the observer not to use the Tektronix terminal until you tell him it is operational.

2. Place the teletype in the On-line mode.

3. Load FORTH at computer console:

   (a) Place HALT/ENABLE switch down.

   (b) Enter 773110 on the octal switches; a bit is on when switch is up.

   (c) Press LOAD ADDRESS - look to ensure 773110 appears in the ADDRESS display lights. (If this does not happen, cycle HALT/ENABLE and START switches simultaneously 3 or 4 times and repeat steps (a) and (b).)

   (d) Place HALT/ENABLE switch up.

   (e) Press START switch down and teletype will respond "?".

4. Load the TELESCOPE vocabulary at teletype.

   (a) 3 LOAD cr

   (b) TRACK LOAD cr

5. Load the mapping OBSERVING vocabulary at teletype; and the TV screen will update and you and the observer must set any parameters that appear wrong.

   (a) MAPPING LOAD cr

   The default is the switched power signal upon loading. If the total power signal is desired, type

   TPDATA cr

   To return to the switched power signal, type

   SPDATA cr

   (b) Mount a fresh tape and type

   NEW-TAPE cr

   Caution : Never type NEW-TAPE when remounting an observer's binary data tape which contains scans he wants to take with him.

(c) Insure the following parameters are set:

(1) n !RCVR cr

where n is the correct receiver number (see Table 1 of chapter VII).

(2) Set the date:

n NOV cr

where n is the correct day's date based on Universal Time. Standard first 3 letter abbreviations for months apply except for December which is designated DCM.

(3) Set the operator and observer initials:

OPR INITIALS nnn cr
OBS INITIALS mmm cr

where nnn is the operator's initials, and mmm is the observer's initials.

(4) Enter AZ-EL offsets for the main beam position via the thumbwheels (see chapter V) and type:

MAIN! cr

(5) n HEADER ! cr

where n is the scan number; values 500 to 2000 only are allowed.

(6) n %EFF ! cr

where n is the aperture efficiency in %. For example, to set a value of 50 percent, type

50 %EFF ! cr

(7) n ATTN ! cr

where n is the atmospheric attenuation in tenths of %. For example,

10 ATTN ! cr

gives a 1% attenuation; see step 9 later for instructions on what to do to measure it.

(8) n DEFAULT ! cr

where n is the data scale factor (see chapter VII).

6. At the Tektronix

   (a) MAPPING LOAD cr

   SNAP cr

   This will provide a picture of the status monitor at the graphics display; make a hard copy and retain it in case you have to reset any parameters.

   (b) If you have to enter planetary positions for the day, you may do so at the Tektronix. Type

   CATALOG LOAD cr

   PLANETS INDEX cr

   This will provide you a listing of the PLANETS catalog. To enter positions in the catalog, see chapter VI.

   (c) At this point you may turn the Tektronix terminal over to the observer, informing him that he may load

   CATALOG LOAD cr
   or
   MAPPING LOAD cr
   or
   CONTINUUM LOAD cr
   or
   FOURIER LOAD cr

   and that he may only use the Tektronix terminal for data reduction or entering sources in his personal catalog.

7. At the teletype select the switching mode applicable by typing:

   (a) For Beam Switching (the default)

   BS cr

   (b) For Load Switching

   LS cr

8. Perform a Calibration:

   (a) Move the telescope to look at blank sky.

   (b) Set the time you want to spend in each phase of the calibration (tenths of seconds):

   100   CSEC   !   cr

   (c) CALIBRATE   cr

   This will record a scan of 14 samples which has performed a calibration of both switched and total power outputs. For details of this operation, see the continuum calibration page in the CONTINUUM Program Chapter.

9. Perform an Extinction (optional):

   (a) A calibration must have been performed prior to performing an extinction. See step 8 above for calibration procedure.

   (b) Release the telescope at any desired position in AUTO-TRACK.

   (c) EXTINCTION   cr

   The antenna will move from 22° elevation to 65° to 22°, making a total of 11 measurements, each measurement SEC long. To obtain the atmospheric attenuation and system temperature from these data, see the CONTINUUM Program Chapter.

10. Observation

(a) The basic mapping observation is a rectangular raster scan about a source. The telescope moves continuously through the raster; its scanning rate is computed by the program so that the specified amount of integration time is used moving through each box. When the end of a scan line is reached, the telescope will move back as rapidly as possible to the beginning position of the next line in the MAP mode. During the "flyback" phase of a MAP no data is taken.

(b) Enter source position from catalog or by card, teletype or thumbwheels. For an extended source, the source position should be the center position.

(c) Check and if necessary set the following parameters at the teletype:

(1) mm:ss CELL ! cr

where CELL is the size of a single integration box in arc dimensions. For example, to set the size of the sample box to 1 minute and 30 seconds of arc, type

1:30 CELL ! cr

(2) n m GRID cr

where GRID is the dimensions of the raster in boxes; n is the number of rows, m is the number of samples per row. The total number of samples (i.e., n x m) should be a power of 2 if one expects to use the one-dimensional Fourier transform package. The operator should inform the observer about this fact. Note the product n x m must be $\leq$ 256. For example, to select a one-dimensional map of 128 points, type

1 128 GRID cr

(3) Two different ways to set the scanning angle of the scan:

(i) nn:mm SA cr

where SA is the scanning angle from 0^o to 360^o; nn is the number of degrees, mm is the number of minutes. For example,

90:00 SA cr

gives a scan in RA only and

00:00 SA cr

gives a scan in DEC only. See the drawings in the MAPPING Program Chapter for further information.

(ii) HORIZONTAL cr

causes SA to be computed for the map so that the scan lines are parallel to the horizon.

VERTICAL cr

causes PA to be computed for the map so that the scan lines are perpendicular to the horizon.

(4) n SEC ! cr

where SEC is the integration time per box; n is in tenths of seconds. For example, to set 1 second of integration time per box, type

10 SEC ! cr

(d) REFRESH cr check all parameters on monitor display.

(e) SEEK or FOLLOW source (see chapter V).

(f) Commanding Maps and/or a Map, type

(1) n MAP cr

where n is the number of maps desired.

(2) n HMAP

where n is the number of HORIZONTAL maps desired.

(3) n VMAP

where n is the number of VERTICAL maps desired.

(g) Interrupted Observations (at the teletype only):

(1) Stopping normal observations

To stop an observation, type

STOP cr

Observing will cease. You then have 3 options.

(i) Type any one of the commands in (f) above to begin again; the aborted run will be lost.

(ii) n SCAN SAVE cr

Saves a partial data set for scan n (you may not continue this scan any longer).

(iii) GO cr

Allows you to continue a scan that has been stopped but not saved.

(2) Stopping Calibrations or Extinctions

To stop either a CALIBRATE or EXTINCTION, type

STOP cr

Observing will cease. When using the verb STOP in this case, you may be left in switched power (SP) instead of a desired total power (TP) signal or vice versa. The signal type selected is specified on the TV screen above T(ANT). You may set the signal as appropriate:

(i) Selecting Switch Power Signal

SPDATA cr

(ii) Selecting Total Power Signal

TPDATA cr

C. SPECTRA Check List

1. Politely inform the observer not to use the Tektronix terminal until you tell him the program is operational.

2. Place the teletype in the On-line mode.

3. Load FORTH at computer console:

   (a) Place HALT/ENABLE switch down.

   (b) Enter 773110 on the octal switches, a bit is on when switch is up.

   (c) Press LOAD ADDRESS - look to ensure 773110 appears in the ADDRESS display lights. (If this does not happen, cycle HALT/ENABLE and START switches simultaneously 3 or 4 times and repeat steps (a) and (b).)

   (d) Place HALT/ENABLE switch up.

   (e) Press START switch down and teletype will respond "?".

4. Load the TELESCOPE vocabulary at teletype.

   (a) 3 LOAD cr

   (b) TRACK LOAD cr

5. Load the spectral line OBSERVING vocabulary at the teletype.

   (a) FILTERS ? cr

   This query will cause the compter to reply with a number (example, FILTERS ? 289). This number must be set correctly before proceeding further; it is the software equivalent of the hardware set-up for the filter banks.

   (b) If it is necessary to set FILTERS based on the results of (1) above, enter

   n FILTERS ! cr

   where n is the correct number obtained from SPECTRA Program Chapter.

   (c) SPECTRA LOAD

   (d) Mount fresh data tape and type:

   NEW-TAPE cr

   Caution: Never type NEW-TAPE when remounting an observer's binary tape which contains scans he wants to take with him.

(e) Check with the observer and then load only one of the following:

```
CHOPPER    LOAD    cr
NO-CAL     LOAD    cr
NOISE      LOAD    cr
VANE       LOAD    cr
```

(f) At the point you and the observer must look at the status monitor and set any parameters that appear wrong.

(1) n !RCVR cr

where n is the correct receiver number (see Table 1 of chapter IX).

(2) If the filter parameters are not correct for any reason, one may type:

```
n    BANK    cr
m    BANK    cr
```

where n and m are integers determined from the filter bank table in the SPECTRA Program Chapter of this manual.

(3) n FREQ 2! cr

where n is sky frequency in GHz with five decimal places (e.g., n = 119.54540).

(4) n KM/S cr

where n is the source velocity with respect to LSR in km / sec units (e.g., n = -41.6).

(5) n LO-IF ! m 1ST-IF ! cr

where n is the local oscillator reference frequency in MHz (e.g., n = 400) and m is the first intermediate frequency in MHz (e.g., m = 4750).

(6) n SB !

where n is the sideband you will be using. See chapter IX for a description of parameters set by choosing an SB. The observer must tell you which sideband to use.

(7) Set the operator and observer initials:

OPR INITIALS nnn cr
OBS INITIALS mmm cr

(8) Set the date:

n OCT cr

where n is the correct date based on Universal Time. Standard first 3 letter abbreviations for months apply except for December which is designated DCM.

(9) n RPT ! cr

where n is the number of repeats of ON-OFF pairs desired in a position switched scan.

(10) Enter RA-DEC and AZ-EL offsets at the same time for the source position via the thumbwheels (see chapter V) and type:

MAIN! cr

(11) Enter RA-DEC and AZ-EL offsets for the reference position via the thumwheels (see chapter V) and type:

REF! cr

(12) REFRESH cr

insures that your status monitor is current and is the way to check that all your parameters got set correctly.

6. Set up the Tektronix terminal for the observer; at the Tektronix perform the following:

(a) SPECTRA LOAD cr

(b) SNAP cr

This will provide a picture of the status monitor on the graphics display; make a hard copy and retain it in case you have to reset any of the observing parameters.

(c) If you have to enter planetary positions for the day, you should type:

```
CATALOG    LOAD     cr
PLANETS    INDEX    cr
```

This will provide you a listing of the planets catalog.

To enter positions in the catalog, see chapter VI.

(d) At this point, you may turn the Tektronix terminal over to the observer, informing him that he may load

```
CATALOG LOAD       cr

          or

SPECTRA LOAD       cr
```

and that he may only use the Tektronix terminal for data reduction or entering sources in his personal catalog in accordance with this manual.

7. Tracking commands at the teletype.

(a) To track a source type (examples):

```
FOLLOW    JUPITER     cr
```

or, for an observer who has ORI-A in 1CAT,

```
1CAT                  cr
SEEK    ORI-A         cr
```

8. Spectra observing commands at teletype.

(a) To do a calibrate:

```
n    TC         !       cr
m    CSEC       !       cr
p    CRPT       !       cr    (necessary for vane calibrate)
CALIBRATE               cr
```

(b) Take data by issuing one of the following commands:

```
n    BS        cr
          or
n    FS        cr
          or
n    PS        cr
          or
n    LS        cr
          or
n    BS+PS     cr
          or
n    FS+PS     cr
          or
n    APS       cr
```

where n is the number of scans desired.

```
PS-MAP         cr
         or
FS-MAP         cr
```

which allow automatic mapping of positions stored in an observer's personal catalog (see chapter X).

IV. Tape and Disk Utility Check Lists & Information

A. How to Mount a 9 Track Tape Checklist

1. Set UNIT SELECT at Ø
2. Select OFF LINE
3. Select BR REL
4. Check/select tape unit PWR on.
5. Mount tape (write ring in or out, as desired) and wind on 4 or 5 turns on the take-up reel.
6. Select LOAD, this draws a vacuum.
7. Select FWD
8. Cycle START switch from STOP to START and the tape goes to load point.
9. Select ON LINE
10. Tape is now properly mounted and one should see the following visual display lights:

LOAD	(system under vacuum)
RDY	(system on line)
LD PT	(tape rewound)
FILE PROT	(if on (off) write ring out (in))
SEL	(this unit selected)

B. <u>How to Dismount a 9 Track Tape Check List</u>

1. REWIND cr

2. Select OFF LINE

3. Select REW

4. Cycle START switch from STOP to START and the tape goes to the load point.

5. Select REV

6. Cycle START switch from STOP to START and the tape completely rewinds and you lose vacuum.

7. Select BR REL

8. Remove the tape.

C. How to Mount a 7 Track Tape Check List

1. Turn on the unit by pushing the POWER button (button light comes on).

2. Select desired density via the toggle switch on the tape controller (use 800 BPI setting unless 556 BPI is especially requested).

3. Mount tape (write ring in or out, as desired) and thread it up as per the diagram found in the lower left hand corner of the unit. Wind on 4 or 5 turns on the take-up reel.

4. Press the LOAD button (button light comes on) and the tape will go to load point.

5. Press ON LINE button (button light comes on) so that the computer can command the tape unit.

6. Note that the RESET button allows one to switch between manual operations, if necessary. Such a case would occur if too many turns were wound on in step 3. causing the tape load point marker to already be wound on. Upon performing step 4. the tape would completely wind on to the take-up reel. To retrieve the situation, press RESET then REVERSE (wait until tape rewinds), then FORWARD.

D. How to Dismount a 7 Track Tape Check List

1. REWIND cr

2. Go off line by pressing the ON LINE button (button light goes out).

3. Press REWIND button (button light comes on) and the tape completely rewinds off the take-up reel.

   Note that if one presses REVERSE instead of REWIND, the tape will return to load point instead of completely rewinding off the take-up reel.

4. Remove the tape.

5. Note that the RESET button allows one to switch between manual operations, if necessary.

E. Verification of Information on a Binary Data Tape Check List

1. One may use this procedure when an observer wants to know what is recorded on his data tape.

2. The desired data tape is mounted with write ring in or out.

3. The Tektronix has the applicable data reduction program loaded (example: SPECTRA LOAD). Use only the Tektronix terminal for the following steps.

4. Select the 9 track tape unit (the default) by typing

   9T cr

   or the 7 track tape unit by typing

   7T cr

5. REWIND cr

   This causes the data tape to rewind to the load point.

6. TAPE-LOG cr

   This command causes one line per scan to be printed out on the Tektronix screen.

7. Make a hard copy.

8. TAPE-LOG cr

   This command will cause the print out to continue where step 6 left off.

9. Repeat steps 6. and 7. until all information is obtained. Note that the screen will stop filling when the end of file mark at the end of all scan is encountered.

F. Program Transfer from Tape to Disk Check List

1. One may use this procedure when only program backup tapes exist (i.e., no backup disk is available).

2. Program is loaded to the 3 LOAD level or higher. Use only the teletype for the following commands.

3. DISCARD cr

4. 15 LOAD 16 LOAD cr

5. In the rare case that the program tape is a 7 track tape, type

   7T cr

   to select the 7 track tape unit.

6. Mount program backup tape desired with write ring out and place it at load point.

7. Change disks (if necessary), installing the disk desired to have the program recorded on it.

8. Ø RELOAD cr

   This command dumps the program on the tape to the disk.

9. Reload the program from the computer at octal address 77311Ø.

G. Program Transfer from Disk to Tape to Disk Check List

1. One may use this procedure if a backup disk and/or tape is desired from an old disk.

2. Program is loaded to the 3 LOAD level or higher. Use only the teletype for the following commands.

3. DISCARD cr

4. 15 LOAD 16 LOAD cr

5. Normally use the 9 track unit for creating program tapes. However, if a 7 track program tape is desired, type

   7T cr

6. Mount fresh tape with write ring in and place it at load point.

7. BACKUP cr

   This command dumps the program on the old disk to the tape.

8. Change disks, leaving the tape just as it is.

9. Ø RELOAD cr

   This dumps the program on the tape to the new disk.

10. Reload the program from the computer at octal address 77311Ø.

H. Transfer of Blocks from Disk to Disk Check List

1. The operator may want to transfer a STATUS block, PLANETS block, and 1CAT or 2CAT block from one disk to another under certain situations. A maximum of 6 blocks only can be transferred using the following method.

2. Program is loaded to 3 LOAD or higher and all operations are performed at the teletype.

3. DISCARD cr

4. ERASE-CORE cr

   This clears the I/O buffers.

5.
```
399   BLOCK   UPDATE   cr
324   BLOCK   UPDATE   cr
325   BLOCK   UPDATE   cr
326   BLOCK   UPDATE   cr
327   BLOCK   UPDATE   cr
328   BLOCK   UPDATE   cr
```

   Note: In this example, the 6 blocks above are transferred off the disk and placed into core and marked for updating.

   399 = STATUS
   324 = PLANETS
   325 = 1CAT
   326 = 2CAT
   327 = 3CAT
   328 = 4CAT

6. Do not HALT the computer but change to the new disk you desire the updated blocks to be written on.

7. FLUSH cr

   This action flushes the core information into the new disk.

8. Reload the program from the computer at octal address 77311Ø.

I. Duplicating a Binary Data Tape Check List

1. One may use this procedure if an observer needs more than one copy of his data tape.

2. Program is loaded to the 3 LOAD level or higher. Use only the teletype for the following commands.

3. DISCARD cr

4. 15 LOAD 16 LOAD cr

5. Select the 7 track tape unit by typing

   7T cr

   if desired. Otherwise the 9 track unit will be the default.

6. Mount fresh tape with write ring in and place it at load point.

7. n m DUMP END-FILE cr

   where n and m are the desired scan range.
   (example)

   500 856 DUMP END-FILE cr

   Caution: Insure that if scan numbers increment by 2, you dump to m + 1.

8. Reload the program from the computer at octal address 773110.

J. Binary Data Transfer from Tape to New Disk Check List

1. One may use this procedure if a disk change has been necessary, but the observer wants his data on the new disk.

2. Program is loaded to the 3 LOAD level or higher. Use only the teletype for the following commands.

3. DISCARD cr

4. 15 LOAD 16 LOAD cr

5. Select the 9 track tape unit (the default) by typing

   9T cr

   or the 7 track tape unit by typing

   7T cr

6. Mount the data tape desired with write ring in or out and place it at load point.

7. Put disk in that you want the data to be recorded on.

8. n RELOAD cr

   Where n is the number of the starting scan; this causes the data to be dumped from the tape to the disk.

9. Reload the program from the computer at octal address 773110.

K. Information for Off-Line Data Reduction for Binary Tapes

1. 9 Track Tape Characteristics

   (a) Binary (twos complement arithmetic)
   (b) 9 Track
   (c) Odd Parity
   (d) Tape density: 800 bits per inch
   (e) Block structure:
       (1) 513 word blocks
       (2) 513th word contains the block number
       (3) Block followed by inter-record gap
   (f) Word structure:
       (1) 16 bits (2 bytes)
       (2) Word bytes are in standard PDP 11 order on the tape (i.e., the low order byte is followed by the high order byte). The only exceptions to this are that the ASCII information and the 513 word of each block is in reverse byte order.
   (g) One end of file mark on the tape at the end of all the scans.

2. 7 Track Tape Characteristics

   (a) Binary (twos complement arithmetic)
   (b) 7 Track
   (c) Odd Parity
   (d) Tape density: 800 or 556 bits per inch
   (e) 16 bit words
   (f) Bit Pattern: These tapes have a 4,6,6 pattern, recording the most significant bits first. There is no unique standard 7 Track pattern for recording 16 bit words; the 4,6,6 pattern is _a_ standard and is compatible with 620 Varian tapes created at KPNO.
   (g) Block structure:
       (1) 513 word blocks
       (2) 513th word contains the block number
       (3) Block followed by inter-record gap

3. Number Formats

   (a) Single precision numbers:
       (1) One word length
       (2) Sign bit followed by 15 significant bits
   (b) Double precision numbers = (DP)
       (1) Comprised of two word lengths
       (2) Sign bit followed by 31 significant bits

(c) Angular measures:

(1) 14 bit fraction of a circle = (.14):
The number read from the tape must be divided by

$$2^{14} = 16384$$

to obtain the fraction of a circle. It is comprised of one word length.

(2) 22 bit fraction of a circle = (.22)
The number read from the tape must be divided by

$$2^{22} = 4194304$$

to obtain the fraction of a circle. It is comprised of two words whose high order portion contains 10 sign bits.

4. Header Variables and Data Format

See the applicable program section of this manual concerning Header Variable Recorded on Disk (and Binary Tape).

5. SPECTRA Scan Format

(a) The first 128 words of a scan are reserved for header information; not all are used at present.

(b) Up to a maximum of 512 data points follow the header information (depending on number and kind of filter banks used).

(c) Note that all scans whose total number of filter bank channels exceed 384 will be spread across 5/4 blocks. In such a case, the next scan's header information will start in the next available block. Note also that if 384 channels are exceeded, scan numbers will increment by 2 in order to have scan numbers agree with block numbers on the disk.

6. CONTINUUM/MAPPING Scan Format

(a) The first 128 words of a scan are reserved for header information; not all are used at present.

(b) CONTINUUM Data has a maximum of 384 data points and resides in one block along with the header information.

(c) MAPPING Data can be of any length and is determined by the grid size; it will spill over into successive blocks; scan numbers will increment (Δn) by the scheme:

$$\Delta n = \text{Truncated Result of } \left[(128+\#\text{data points})/512\right] + 1$$

L. ASCII Data Tape Creation Check List

1. This program is to be used at the end of an observer's run when the data on the disk is desired to be dumped onto a tape in ASCII form. CAUTION! Never try to load an ASCII data tape onto any disk. Only BINARY Data tapes may be used for reloading data on disk. 7 Track ASCII tapes can be provided but it is discouraged since subsequent reading at another computer facility will necessitate a complicated programming effort.

2. Program loaded to 3 LOAD only.

3. Perform all subsequent operations at the Tektronix.

4. 175 LOAD cr

   The computer will reply

   WHAT KIND OF ASCII TAPE DO YOU WANT? TYPE SPECTRA OR CONTINUUM.
   If, for example, a SPECTRA ASCII tape is desired, type

   SPECTRA cr

   and only SPECTRA scans will subsequently be recorded on the tape; later one may go back and type

   CONTINUUM cr

   and place all CONTINUUM scans on a separate file.

5. Select the 7 Track tape unit by typing

   7T cr

   if desired, otherwise the 9 Track tape unit will be the default.

6. Mount fresh tape with write ring in, tape unit on line, and tape at load point.

7. 1ST-FILE cr

8. n m ASCII cr (example, 500 600 ASCII) where n is the low scan number limit and m is the high scan number limit. If more scans are desired to be dumped, continue on to step 9.

9. NEXT-FILE cr

10. n m ASCII cr

11. Repeat steps 9 and 10 as many times as necessary to obtain all scan desired.

12. Be sure to record on a label affixed to the tape reel the file and scan information. (Example):

File #1	SCANS	500	to	899
File #2	SCANS	900	to	1299

13. CAUTION! If parity errors occur, repeat everything starting at step 6. If they persist, you probably have a bad tape. Try it again with a new tape.

14. After you have completed the ASCII tape, one may see how many records were created per file by doing the following steps.

15. REWIND cr

16. TAPE-LOG cr

    This prints out a series of numbers starting a 1 until the first end of file is reached.

17. TAPE-LOG cr

    This does the same as step 16, but for the second file. Keep repeating this step until all files are printed out.

M. Information for Off-line Data Reduction for 9 Track ASCII Tapes

1. Tape Characteristics

   (a) 9 Track
   (b) Odd Parity
   (c) Tape density: 800 bits per inch
   (d) Record (Block) Structure:
       (1) 513 word records followed by inter-record gap
       (2) 513th word contains the record number
       (3) The start of an individual scan contains header information at the beginning of a record followed by as many additional records as necessary for the individual data points. Header and data formats are discussed later.
   (e) Word Structure:
       (1) 16 bits per word (2 bytes)
       (2) Word bytes on the tape have the high order byte followed by the low order byte.
   (f) One end of file mark at the end of all scans.

2. ASCII (American Standard Code for Information Interchange)

   (a) Each character is represented by 8 bits: 7 bits + 1 bit for even parity.

3. Header Information

   (a) The SPECTRA (or CONTINUUM/MAPPING) Head Information Key shows what information is in the header and is to be used as a key to interpret the actual header information in Example 1 (or 2).

   (b) The numbers not in parentheses under the variables in the header keys correspond to the word locations on the binary tape (see applicable Program chapter concerning Header Variables Recorded on Disk and Binary Tape). Numbers in parentheses refer to the field length of the variables. Formats for the variables can be inferred from Examples 1 and 2.

   (c) The individual lines in Example 1 (or 2) represent 64 characters. There are 16 lines for a total of 1024 characters; note that these examples omit the last two characters of a logical record (i.e., each record is 1026 characters). The last two characters are the logical record numbers.

<u>SPECTRA ASCII Header Information Key</u>

SCAN# Ø(8)	'UNIT 13(8)	RCVR 11(8)	TS 65(8)	MODE 12(8)	%EFF 14(8)	TIME 17(9)		Fill Spaces (7)
DATE 4(8)	OBS 24-25(5)	OPR 26-27(5)	SOURCE 28-33(14)	AZ-OFF 8(9)	EL-OFF 9(10)	TC 64(9)		Fill Spaces (4)
'RA 18-19(13)	'DEC 20-21(12)	'AZ 23(10)	SIN(EL) 22(9)	ATTN 66(9)	FILTERS 100(8)			Fill Spaces (3)

'UT
15(8)
	'LST
	16(8)
		#SAMPLES
		34(8)
			#SCANS
			35(8)
				FØ
				75(9)
					PA
					5(10)
								Fill Spaces
								(13)

SEC
69(9)
	TOL
	71(8)
		+LO
		1(8)
			#FB
			2(8)
				VEL
				3(9)
					1ST-IF
					38(8)
						LO-IF
						39(8)
								Fill Spaces
								(6)

SB
42(8)
	SYNTH
	36-37(16)
		FREQ
		40-41(15)
			#PTS
			47(8)
				BANDWIDTH
				49(8)
								Fill Spaces
								(9)

#CH
50(8)
	CHØ
	51(8)
		BW
		52(8)
			RMS
			53(8)
				#CH
				55(8)
					CHØ
					56(8)
						BW
						57(8)
							RMS
							58(8)
								Fill Spaces
								(0)

#CH
60(8)
	CHØ
	61(8)
		BW
		62(8)
			RMS
			63(8)
				DUT1
				80(8)
					BASELINE
					123-124(16)
								Fill Spaces
								(8)

RNAME 94-99(14)	REF OFFSETS:	AZ 110(10)	EL 111(10)	RA 112(10)	DEC 113(10)			Fill Spaces (10)
MAIN OFFSETS:	AZ 106(10)	EL 107(10)	RA 108(10)	DEC 109(10)	RPT 103(8)			Fill Spaces (16)
MAIN:	RA(1950) 81-82(13)	DEC(1950) 83-84(12)	REF:	RA(1950) 85-86(13)	DEC(1950) 87-88(12)			Fill Spaces (14)

Example of SPECTRA ASC II Header Information

Line	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1.						5	1	7								2								6						9	8	0
2.			2	3		F	E	B			M	A	G				W	S									O	R	I	A	O	H
3.					5	:	3	3	:	5	8	.	6				-	5	:	2	3	:	3	2	.					1	7	4
4.					6	:	5	2					8	:	2	6							1	0								1
5.						3	0	.	0							1	0							5	0							
6.								1							1	.	9	7	7	3	1	1	3	0								8
7.						2	5	6								0						2	5	0						1	0	0
8.								0								0								0								0
9.								R	O	R	I	A	O	H						0	:	1	5						-	0	:	0
10.							0	:	1	5						-	0	:	0	7							0	:	0	0		
11.					5	:	3	2	:	4	7	.	0				-	5	:	2	4	:	2	1	.					5	:	3
12.				-	1	0	6	8					-	9	6	8						9	6	0					2	2	5	9
13.					2	3	4	5						3	4	5						4	5	6					-	7	8	9
14.					8	9	0	0						4	5	6						7	8	9						9	0	0
15.					8	7	6	5						3	3	3						2	2	2						5	5	5
16.					9	8	7							6	5	4						4	4	4						7	7	7

Line	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
1.								6							5	0						3	0	.	0							
2.						0	:	1	5						-	0	:	0	7					6	0	0	.	0				
3.	:	0	9					0	.	8	1	6							0	.	0						2	8	8			
4.	.						0		1							0	:	0	0													
5.	2						1	0	.	0					1	4	2	0						4	0	0						
6.	9	.	1	8	9	0	0						5	1	2							5	0									
7.						2	5	6						2	5	6					1	0	0	0						2	0	0
8.						3	2	5												3	5	0	1	0								
9.	7							0	:	0	0							0	:	0	0											
10.					0	:	0	0							1	0																
11.	2	:	4	7	.	0					5	:	2	4	:	2	1	.														
12.								0							1	0						7	7	7								0
13.								9							5	6						4	5	6								0
14.								8							4	5						2	2	2								0
15.								7							3	4						4	5	6								0
16.								6							2	3						4	3	7								9

Notes:
(a) Lines 1-16 above comprise the first block of a SPECTRA scan on an ASC II tape.
(b) Lines 1-11 above contain the header information.
(c) Lines 12-16 begin the data for the first filter bank.
(d) Remaining data for the above scan starts immediately in line 1. of following ASCII blocks until all data is recorded.

Example 1.

<u>CONTINUUM/MAPPING ASCII Header Information Key</u>

SCAN# Ø(8)	'UNIT 13(8)	RCVR 11(8)	TS 65(8)	MODE 12(8)	%EFF 14(8)	TIME 17(9)	Fill Spaces (7)
DATE 4(8)	OBS 24-25(5)	OPR 26-27(5)	SOURCE 28-33(14)	AZ-OFF 8(9)	EL-OFF 9(10)	TC 64(9)	Fill Spaces (4)
'RA 18-19(13)	'DEC 20-21(12)	'AZ 23(10)	SIN(EL) 22(9)	ATTN 66(9)			Fill Spaces (11)

'UT
15(8)
	'LST
	16(8)
		(#ROWS)
		#SAMPLES
		34(8)
			(#SAMPLES/ROW)
			#SCANS
			35(8)
				FØ
				75(9)
					PA
					5(10)
							Fill Spaces
							(13)

FIVE POINT
AZ-OFF
6(10)
	EL-OFF
	7(10)
		RMS
		36(8)
			T
			43(8)
				T-RMS
				44(8)
					BASE
					45(8)
						#C
						68(8)
							Fill Spaces
							(4)

GAINØ
67(9)
	'GAIN
	50(9)
		CELL
		63(10)
			MA
			51(10)
				#PTS
				47(8)
					TOL
					71(8)
							Fill Spaces
							(10)

DUT1 80(8)	SEC 69(9)	TAV 117-118(16)	TAV-RMS 119(8)	HP 46(8)			Fill Spaces (15)

Example of CONTINUUM/MAPPING ASCII Header Information

Line	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
1.					1	2	0	0								3								1	6				1	0	0	0	0								2								1	2							5	.	0							
2.			3	0		N	O	V			J	M	P			P	R	R									S	A	T	U	R	N						0	:	1	5						-	0	:	0	7					1	0	0	.	0				
3.					5	:	3	3	:	5	8	.	6				2	2	:	2	3	:	3	2	.					1	7	3	:	1	7					0	.	6	7	7						2	0	.	0												
4.					7	:	0	5					8	:	3	8							1	0								1	.						0	.	1							0	:	0	0													
5.							0	:	3	2							0	:	0	0						2	3	2					1	0	9	1							8	7						5	5	6				1	0	0	0	0				
6.				1	0	0	0	.	0							0	.	5							0	:	0	0							0	:	0	0							1	0							1	0										
7.						3	5	0							5	.	0												1	0	0	5	0						8	9	1							3	2																
8.						5	6	6				-	1	1	2	5						4	2	6				-	2	0	1	6						4	8	6				-	1	6	8	6						5	8	7				-	1	7	2	1
9.						7	6	3				-	1	5	2	9																																																
10.																																																																
11.																																																																
12.																																																																
13.																																																																
14.																																																																
15.																																																																
16.																																																																

Notes:
(a) Lines 1-16 above comprise the first block of a CONTINUUM/MAPPING scan on ASCII tape.
(b) Lines 1-7 above contain the header information.
(c) Lines 8-9 contain the data.
(d) Lines 10-16 are filled with spaces.

Example 2.

V. TELESCOPE Tracking Information

A. TELESCOPE Tracking Vocabulary

A list of observing nouns and verbs follow which are to be used by the operator at the teletype for commanding the telescope to ultimately track a source, track a fixed position, or command the receiver or subreflector. The words below are available anytime TRACK is loaded; thus, these words are common to CONTINUUM, MAPPING and SPECTRA Programs.

1. AZ-EL

   This verb commands the telescope to a specified azimuth and elevation. The telescope will stay at these specified coordinates. See B.5 which follows for an example of how to use this command.

2. CARD cr

   This verb activates the card reader and the information typed on the card will be read and interpreted as though it were teletype input. It may be used for entering source positions typed on cards (see B.2 below).

3. CASSEGRAIN cr

   This verb will command the telescope to the Cassegrain service position (see B.5 below).

4. 1CAT, 2CAT, ... 5CAT

   These verbs allow any one of the five observer source catalogs to be selected (see chapter VI).

5. CURRENT

   This verb commands the telescope to track a current (i.e., precessed) equatorial source position. See B.2 below for an example of how to use this command.

6. Date Setting

   It is of paramount importance to enter the day's date, as soon as the current observation allows, after Ø hours Universal Time (5 PM MST). For example, to set the date type

   n OCT cr

   where n is the correct day number based on Universal Time. Standard first 3 letter abbreviations for months apply except for December which is designated DCM.

7. DUT1

The noun DUT1 may be regarded as a correction to be added to coordinated Universal Time (UTC) to obtain a better approximation to the mean solar time of the prime meridian obtained from direct astronomical observations which have been corrected for small movements of the earth relative to the axis of rotation. These DUT1 corrections are obtained monthly from the Naval Observatory. To set DUT1 to 0.5 seconds type

    500   !DUT1   cr

To query the parameter DUT1 with only TRACK loaded type

    DUT1   ?   cr

8. EL-HUSH   cr

This verb silences the computer alarm that warns of the low elevation limit. See also the section entitled "Telescope Limits" in this chapter for more information. The alarm will come on again if you are still in the low elevation limit situation and you start observational data taking.

9. EPOCH

This verb commands the telescope to track a 1950 equatorial source position. See B.2 below for an example of how to use this command.

10. EXPEDITE   cr

This verb automatically sets the noun TOL (described below) to a high value. This allows observations to be made without tracking a source. If EXPEDITE is used and normal observations are subsequently resumed, TOL must be reset.

11. FØ

This noun is the temperature independent focus parameter in the empirical focus equation described below for FOCUS. The units of FØ are in tenths of mm. For example to set FØ at 65.5 mm type

    655   FØ   !   cr

To query FØ with only TRACK loaded type

    FØ   ?   cr

12. FOCUS cr

This verb causes the focus of the receiver to be performed via computer control. It can be executed anytime; however, it is automatically done at the beginning of each scan or CALIBRATE before any data is taken. The empirical focus equation, F, in mm units is

$$F = 2.69T_o + 1.36T_1 - 3.82\ T_2 + 1.63 \sin(EL) + F\emptyset$$

where T_o, T_1, and T_2 are the Centigrade temperatures of the antenna North, South, and Center Hub points, respectively; EL is the commanded elevation angle of the telescope and FØ has been previously described above.

13. FOLLOW name cr

This verb selects the PLANETS catalog and causes the telescope to track the planet designated by name. The word name can be any one of the following: SUN, MOON, MERCURY, VENUS, MARS, JUPITER, SATURN, URANUS, PLUTO, SATELLITE or COMET. See chapter VI for more information and also B.4 below.

14. GALACTIC

This verb commands the telescope to track a position in the galactic coordinate system. See B.2 below for an example of how to use this command.

15. ddd:mm PA-RCVR cr

This verb enters the desired position angle offset orientation (specified in degrees and minutes) for prime focus receiver polarization work.

16. POLAR

This verb computes the position angle of the commanded source position, adds the position angle offset specified by the PA-RCVR command, and commands the prime focus receiver box to the proper angle.

17. SEEK name cr

This verb searches the catalog last selected (i.e., 1CAT, 2CAT, PLANETS, etc.) for the source designated by name. If the word name (e.g., ORIONA) is found in the designated catalog, the telescope will begin tracking the coordinates of this source. See chapter VI for more information and also B.3 below.

18. SERVICE cr

This verb will command the telescope to the prime focus service position (see B.5 below).

19. TOL

This noun is the maximum RMS tracking error limit in seconds of arc. If the actual tracking error exceeds this limit, data taking ceases until the actual error falls below the limit. To set, for example, a tracking error limit of 10 seconds of arc type

```
10    TOL    !
```

and to query the value with only TRACK loaded, type

```
TOL    ?
```

The computer sets zero into TOL when the receiver drops out of phase lock to insure that data taking ceases. If you stop a scan during this alarm condition, you must reset TOL.

20. ZENITH

This verb will command the telescope to the bird-bath position (see B.5 below).

B. Source Tracking from the Teletype

1. When the TRACK program is loaded, the computer begins tracking an arbitrary position. Source positions may be entered from the terminal or on cards or on the thumbwheels (see E.2 in this chapter for information concerning the use of the thumbwheel panel). The format for card or terminal input is identical.

2. Stationary Source Tracking Via Card, Thumbwheels, or Terminal

   Stationary source positions may be specified in three ways: current positions, 1950.0 positions (which will be precessed, including nutation and aberration), or galactic positions (from which the others will be computed). Copy the number of digits and position of decimal point exactly from the following examples. The source name must be given; use up to ten characters with no spaces.

   (a) Current positions

RA (hh:mm:ss.s)	DEC (dd:mm:ss.)		Source name
2:41:11.9	-0:08:06.	CURRENT	NGC-1068

   (b) 1950.0 positions

RA (hh:mm:ss.s)	DEC (dd:mm:ss.)		Source name
12:26:33.3	2:19:42.	EPOCH	3C273

   (c) Galactic positions

L_{II} (dd.ffff)	B_{II} (dd.ffff)		Source name
359.9529	-0.0349	GALACTIC	SAG-A

   (d) Epochs other than 1950.0

   The only standard epoch available for precession is 1950.0. However, you may precess positions for other specific days with 16,000 days of 1950.0 by using the following method:

   (1) Type in the date for the position you have:

   1971 A.D. 15 MAR

   then enter the position by card, keyboard, or thumbwheels as a CURRENT position. Write down the 1950.0 coordinates from the display, and then enter the source in your catalog (see the Source Catalog Use and Information chapter of this manual).

(2) Enter the current epoch and todays' date:

1976 A.D. 30 OCT

and SEEK the source (if you put it in your catalog) or enter the 1950.0 position. It will then be precessed to today's date.

(3) Regardless of the form of the input, the current RA/DEC are kept in memory, and 1950.0 RA/DEC and galactic coordinates are computed from them for display. The current RA/DEC are recorded with the data.

3. Stationary Source Tracking Via Observer Catalogs

Several source catalogs are available on the disk (see chapter VI). For example, to select a catalog, just type its name.

```
2CAT     cr     (selects observer's second catalog)
```

To track the stationary source, type SEEK (source name):

```
SEEK     3C273     cr
```

4. Moving Source Tracking (Sun and Planets)

(a) Action Required at the Teletype:

To track a planet whose positions are correctly entered in the PLANETS catalog (see chapter VI), just type FOLLOW then the name of the source. For example:

```
FOLLOW  JUPITER     cr
      or
FOLLOW  COMET       cr
```

5. AZ-EL Positions

To go to an AZ-EL position specified in degrees and minutes (and stay there), type:

```
 AZ        EL

259:59    89:59     AZ-EL    cr
```

The following standard AZ-EL positions have been defined:

SERVICE	(0:00	27:12)
CASSEGRAIN	(223:00	18:00)
ZENITH	(Present AZ,	90:00)

C. Pointing Information

1. In addition to coordinate conversion, the telescope tracking program incorporates pointing corrections. The absolute error in any commanded RA-DEC position should not exceed about 5 arc-sec rms at any point (except within about 2 degrees of the zenith).

2. All corrections are stored in the computer program and applied automatically except for a final offset in azimuth and elevation. This is required in order to place the feedhorn (s) in each box on the electrical axis of the telescope. Once this offset has been determined on any source, it applies all over the sky. The azimuth value is divided by cos (elevation) to make it a constant angular offset.

3. The observer is responsible for measuring the azimuth/elevation pointing offsets. This should be done whenever a receiver box is changed and should be checked once a day at 3 mm and shorter wavelengths. It is most conveniently done by commanding the telescope to point at a strong source, and then entering azimuth and elevation offsets via the thumbwheels (see the section entitled "Source Position Offsets" in this chapter) until the signal is maximized. These offsets are then entered into the program by MAIN! and REF! commands (see E.2 below). The pointing may be checked by doing a continuum FIVE observation and using FIVE POINT data fit. Once the offsets are entered, the pointing is completely determined.

4. A history of pointing corrections (AZ-EL offsets) is kept for each receiver in the Pointing Log Book which is maintained by the resident scientist-observer.

5. The sequence of computed operations is:

   (a) Input RA-DEC position, either 1950 or current.

   (b) If 1950 position, precess to current date.

   (c) If source is a planet, interpolate to current UT.

   (d) Do spherical co-ordinate conversion from RA-DEC to AZ-EL.

   (e) Add azimuth and elevation corrections, Δ_a and Δ_e (see below).

   (f) Add azimuth and elevation beam offsets.

   (g) Command telescope to the correct AZ-EL position.

   (h) Loop to Step (c) once per second. Between loops, position is linearly extrapolated.

6. Pointing Equations

$$\Delta_a = c' \tan(e) + i_A \sin(a-e_A) \tan(e) + a_{off} + c \sec(e)$$

$$\Delta_e = r \cot(e) + b \cos(e) + i_A \cos(a-e_A) + h_{off}$$

where

a = true azimuth

e = true elevation

c' = collimation error of az, el axes

i_A = inclination of azimuth axis

e_A = azimuth of tilt of azimuth axis

a_{off} = azimuth encoder offset

c = collimation error of telescope axis

r = refraction coefficient

b = bending of feed support

h_{off} = elevation encoder offset

D. Telescope Limits

1. 20° is the "horizon" with respect to which the "time until horizon" display is computed. Normally, observing below this is not recommended due to increasing atmospheric attenuation.

2. 16° 30' is the limit at which the siren comes on to warn of approaching elevation tracking limit.

3. 15° 12' is the final track limit; you can drive out of this limit manually or you can AUTO-TRACK out of this limit if you SEEK another source which is above the limit.

4. 14° 26' is the physical limit set by the telescope mount. In extreme circumstances you may request the operator to remove the blocks and reset the limit in (c) above; he will have to obtain special authority to do so.

E. Source Position Offsets

1. General Concepts

(a) The telescope always points either on or off the source when tracking by the following scheme:

TELESCOPE POSITION = CURRENT SOURCE POSITION
± RA-DEC OFFSETS ± AZ-EL OFFSETS
± FIVE POINT OFFSETS

Notes:

(1) If on source, the above offsets are denoted by the mnemonic MAIN.

(2) If off source, the above offsets are denoted by REF.

(3) Not all observing programs make use of the various offsets mentioned above.

(b) AZ-EL Offsets can perform two functions:

(1) Pointing Corrections - these corrections are always required for every receiver and every observing program.

(2) Any additional offsets desired by the observer (additional to the point corrections). That is,

AZ-EL OFFSETS = AZ-EL (Pointing Corrections)
+ AZ-EL (Additional Offsets)

2. How to Use Thumbwheel Offset Panel

(a) For example, consider entering AZ-EL offsets and assume RA-DEC offsets are set to zero.

(b) Energize the panel.

(c) Select bank 1 or 2.

(d) Select AZ-EL offsets on the thumbwheel.

(e) Dial in the correct offsets desired on the bank selected.

(f) Position the toggle switch properly:

UP - Continuously reads the bank selected.
NEUTRAL - No effect.
DOWN - Instantaneously reads the bank selected and spring returns to neutral.

(g) When you perform step (f) above, the values of the bank selected appear on the TV screen and are stored via the program into an array called BEAM.

(h) De-energize the panel.

(i) Having the operator now type MAIN! (or REF!) which causes the values of all offsets (both RA-DEC and AZ-EL) displayed on the TV screen to be transferred from the BEAM array to the working array MAIN (or REF).

(j) Note that any individual offset can be no larger than $2^{\circ}48'$ of arc.

3. CONTINUUM Observing

(a) RA-DEC offsets are set to zero upon loading the CONTINUUM Program; they can be used, however, and are exactly as described in 5.(a) below.

(b) AZ-EL offsets are used as per 1.(b) above.

(c) FIVE POINT offsets are internal to the program (i.e., not set by the Thumbwheel Offset Panel). They depend upon the current value of half the half-power beam width (HP) and are used to perform a FIVE POINT observation about a source.

4. MAPPING Observing

(a) RA-DEC offsets are used to produce a map. However, these offsets are generated internally in the computer and should not be set via the Thumbwheel Offset Panel. The RA-DEC offsets generated are rectangular. That is, the RA coordinate (α) which the telescope seeks is $\alpha + \Delta\alpha/\text{Cos } \delta$, where the angle δ is the source DEC coordinate. The TV screen RA offset displayed will be $\Delta\alpha/\text{Cos } \delta$.

(b) AZ-EL offsets are used as per 1.(b) above.

(c) There is no REF beam in the MAPPING program. One uses only the MAIN beam.

(d) There is no FIVE POINT offset capability.

5. SPECTRA Observing

(a) RA-DEC offsets can be set via the Thumbwheel Offset Panel. RA-DEC Offsets entered via the thumbwheels for the SPECTRA Program cause an offset in the RA ($\Delta\alpha$) to be added directly to the RA of the source (α); that is, the RA coordinate that the telescope will seek is $\alpha + \Delta\alpha$. SPECTRA maps done with these offsets will map on the celestial coordinate system and thus will spatially taper down on approaching the north celestial pole. The TV screen RA offset displayed will be $\Delta\alpha$.

(b) AZ-EL offsets are used as per 1.(b) above.

(c) There is no FIVE POINT offset capability.

VI. Source Catalog Use and Information

A. Loading and Use of Observer Catalogs

1. Source catalogs reside on the disk. Catalog positions for fixed sources are always 1950 positions.

2. You should enter your source positions in your own catalog. One block (Catalog) may contain up to 30 sources.

3. Source positions are entered at the Tektronix. To obtain these routines, type

```
CATALOG    LOAD    cr
```

4. To select a catalog, just type its name. 1CAT, 2CAT, 3CAT, 4CAT, and 5CAT are defined.

```
1CAT    cr  (selects observer's first catalog)
      or
3CAT    cr  (selects observer's third catalog)
```

5. To list your catalog (after selecting it in 4. above), type

```
INDEX   cr
```

6. If you desire to clear the catalog selected in 4. above, type

```
CLEAR   cr
```

7. To enter a position in a catalog, select the catalog as per 4. above and type

```
RA (1950)     DEC (1950)     Source Name     Velocity

2:21:57.0     61:52:45.    EPOCH     W3    -39.0   KM/S
```

The phrase for velocity (e.g., -39.0 KM/S) is optional; if it is omitted, a source velocity of 0.0 km/s will be defaulted. It is a good idea (although not necessary) to enter your positions in order of increasing RA. Alternatively, one may read in sources via the card reader. The format for the cards is described in the Observer Introduction Chapter. Have the operator assist you in the use of the card reader. Source names should be no longer than 10 characters with no spaces. However, using shorter names will save typing time later when the operator seeks your source from the teletype. Each source in a catalog must have a unique name. If one tries to enter two sources with the same name in the same catalog, the second source will not be recorded.

8. To delete a source from the catalog selected in 4. above,

   FIND DR-21 DELETE cr

   will delete the entry for DR-21. Deleting an entry leaves a hole in the catalog, which will be filled by your next entry. To change a position, you must delete the bad position and enter the correct one.

9. When you have finished working on your catalog, type

   FLUSH cr

   to ensure that it is written on the disk.

10. You may obtain a chart showing the positions of the sources in your catalog for any time. Select the catalog as in 4. above and then type

    n CHART cr

    where n is the desired Universal Time given in military style.

    1200 CHART cr

    draws the picture for 12 hours Universal Time. To see where sources are now, type

    NOW cr

11. To put axes on your charts, type

    AXES cr

    The center of the horizontal axis looks due south. The vertical axis is in units of degrees declination. The horizontal axis is in units of time (hours right ascension). Source positions plotted correspond to the first letter in the source name. The horizon plotted is the actual horizon of the site rather than the limited horizon of the telescope.

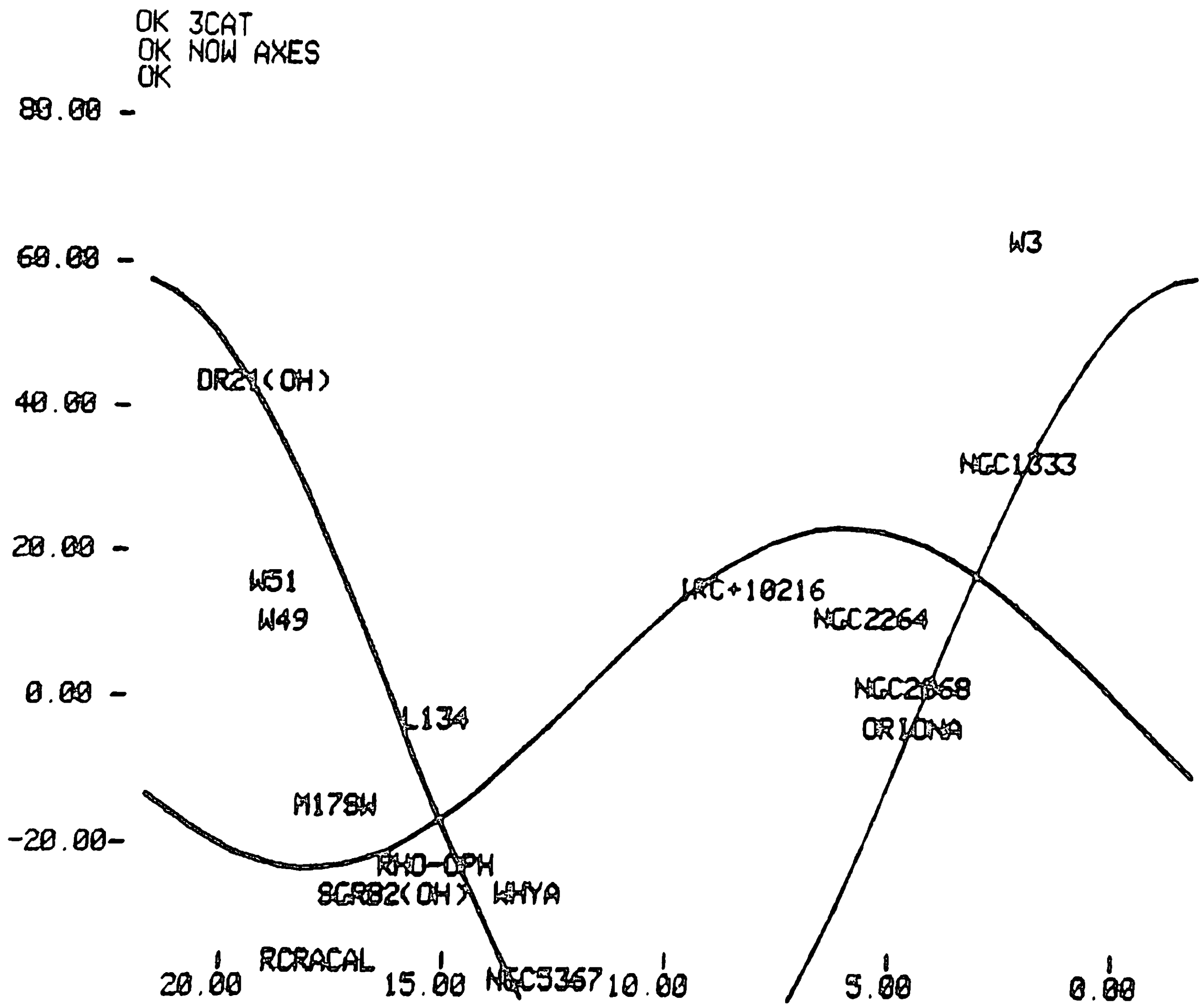
12. See following pages for examples of displays available to your catalog.

OK 3CAT

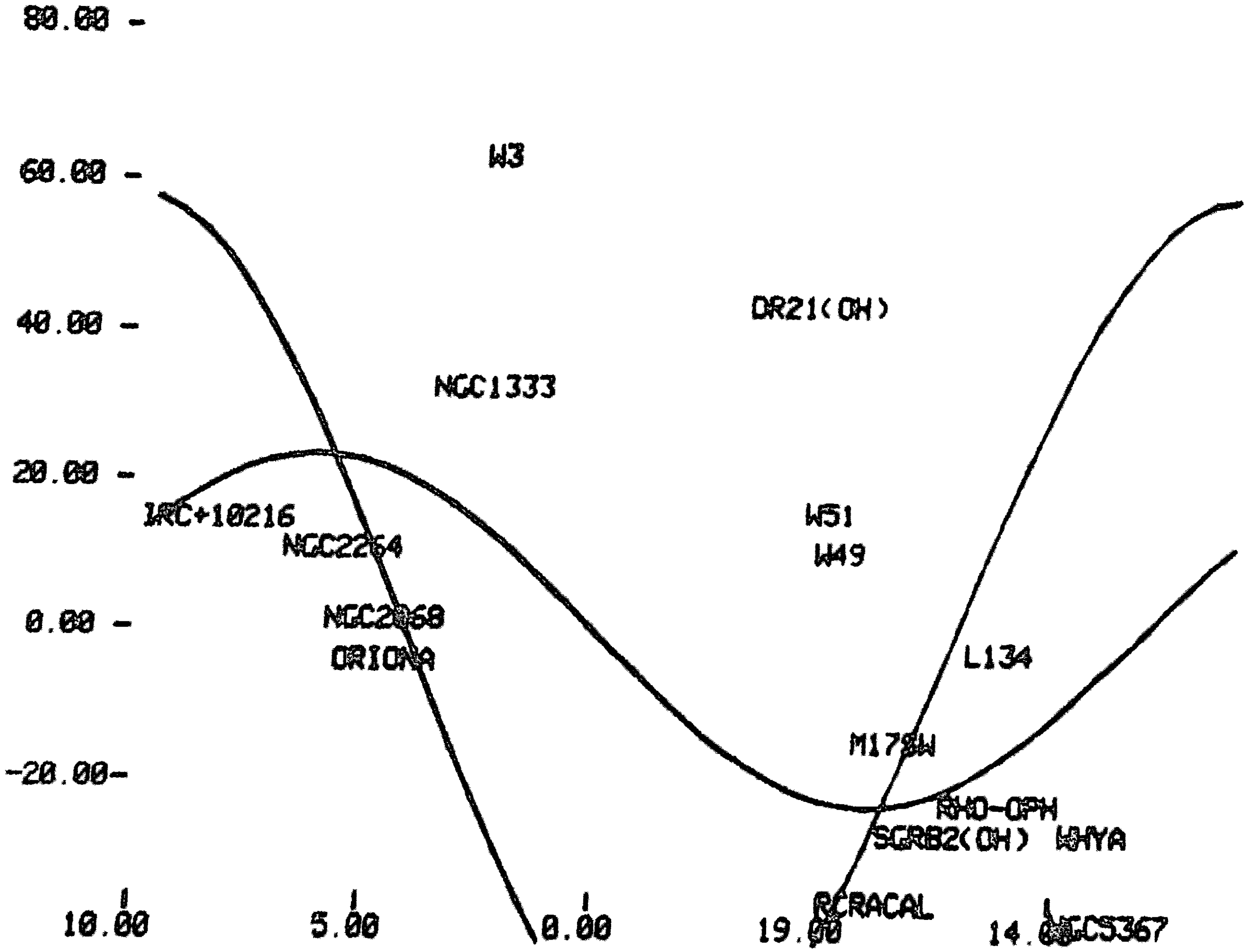
OK INDEX

	1950 RA	1950 DEC	Source Velocity
W3	2:21:51.0	61:52:19.	-41.4
NGC1333	3:26:17.0	31:14:30.	7.5
ORIONA	5:32:47.0	-5:24:21.	9.0
NGC2068	5:44:08.0	0:02:00.	10.7
NGC2264	6:38:28.4	9:32:12.	8.5
IRC+10216	9:45:14.8	13:30:40.	-26.0
WHYA	13:46:12.0	-28:07:06.	38.3
NGC5367	13:54:40.0	-39:44:00.	0.0
L134	15:51:00.0	-4:26:57.	3.0
RHO-OPH	16:23:15.0	-24:19:00.	2.1
SGRB2(OH)	17:44:11.0	-28:22:30.	70.0
M17SW	18:17:26.5	-16:14:54.	19.4
RCRACAL	18:59:32.8	-37:14:08.	5.0
W49	19:07:53.0	9:01:00.	2.3
W51	19:21:27.0	14:24:30.	57.1
DR21(OH)	20:37:14.0	42:12:00.	-3.3

OK


OK 3CAT
OK NOW AXES
OK
80.00
60.00
40.00
20.00
0.00
-20.00
20.00
15.00
10.00
5.00
0.00
W3
DR21(OH)
NGC1333
W51
W49
NGC2264
NGC2068
ORIONA
L134
M17SW
RHO-OPH
SGRB2(OH)
WHYA
RCRACAL
NGC5367

OK 3CAT
OK 0700 CHART AXES
OK



B. Loading and Use of PLANETS Catalog

1. A special source catalog resides on the disk for moving sources. Its name is PLANETS.

2. To make entries in the PLANETS catalog, one must obtain the necessary routines by typing

   CATALOG LOAD cr

   at the Tektronix terminal.

3. To select the PLANETS catalog and display its contents, type

   PLANETS INDEX cr

   You will see that each entry has 3 positions. The correct source position is obtained from an interpolation of these 3 positions. For MERCURY, VENUS, SUN, MARS, JUPITER, SATURN, URANUS, NEPTUNE and PLUTO the 3 positions correspond to yesterday, today, and tomorrow positions at 0000 hours Universal Time. It is the operator's responsibility to enter the tomorrow position for these sources every day at 5 PM MST. Standard pre-punched cards are available for these sources for entering via the card reader.

4. Entering source positions:

   (a) To enter a new position for Jupiter, type

Current RA	Current DEC	Horizontal Parallax			
20:27:40.8	19:53:45.	2	PLANET	JUPITER	cr

   and the oldest entry for JUPITER will be discarded and the new entry above will become the tomorrow position.

   (b) Alternatively, one may read a card with the same information on it as in (a) above via the card reader. To activate the card reader, type

   CARD cr

   Multiple card reads may be done by putting the word CARD in any of the columns at the end of the information on each card to be read. When reading such a deck, there must be two blank cards at the end of the deck for proper read termination.

5. For faster moving sources such as the MOON, COMET or SATELLITE, the 3 positions may be entered at one of the following intervals: 24, 12, 8, 6, 4, 3, 2, or 1 hours.

   (a) To set the interval between positions, type

       6 DH ! cr

   to select the 6 hour interval.

   (b) Now you must set the expected continuum data scale factor (see chapter VIII) for the source by typing

       4 BELONG COMET cr

   This action stores the scale factor (4) into the catalog and also stores in the catalog the value of DH previously set. It is important to follow a setting of DH by the proper use of BELONG. DH and BELONG should only be used with the sources MOON, COMET and SATELLITE.

   (c) Then enter the 3 positions for the source as follows:

Current RA	Current DEC	Horizontal Parallax	UT	Name
21:30:03.8	-09:04:37.	1:15	1 HOURS	COMET
21:33:33.2	-09:57:59.	1:15	7 HOURS	COMET
21:36:51.9	-10:51:36.	1:15	13 HOURS	COMET

   (d) At 13 hours Universal Time, one may then repeat steps (a) and (b) above and then enter the next position for 19 hours Universal Time. When this is done, the 1 hour Universal Time position in the example in (c) above will be discarded.

6. When you have finished working with the PLANETS catalog, type

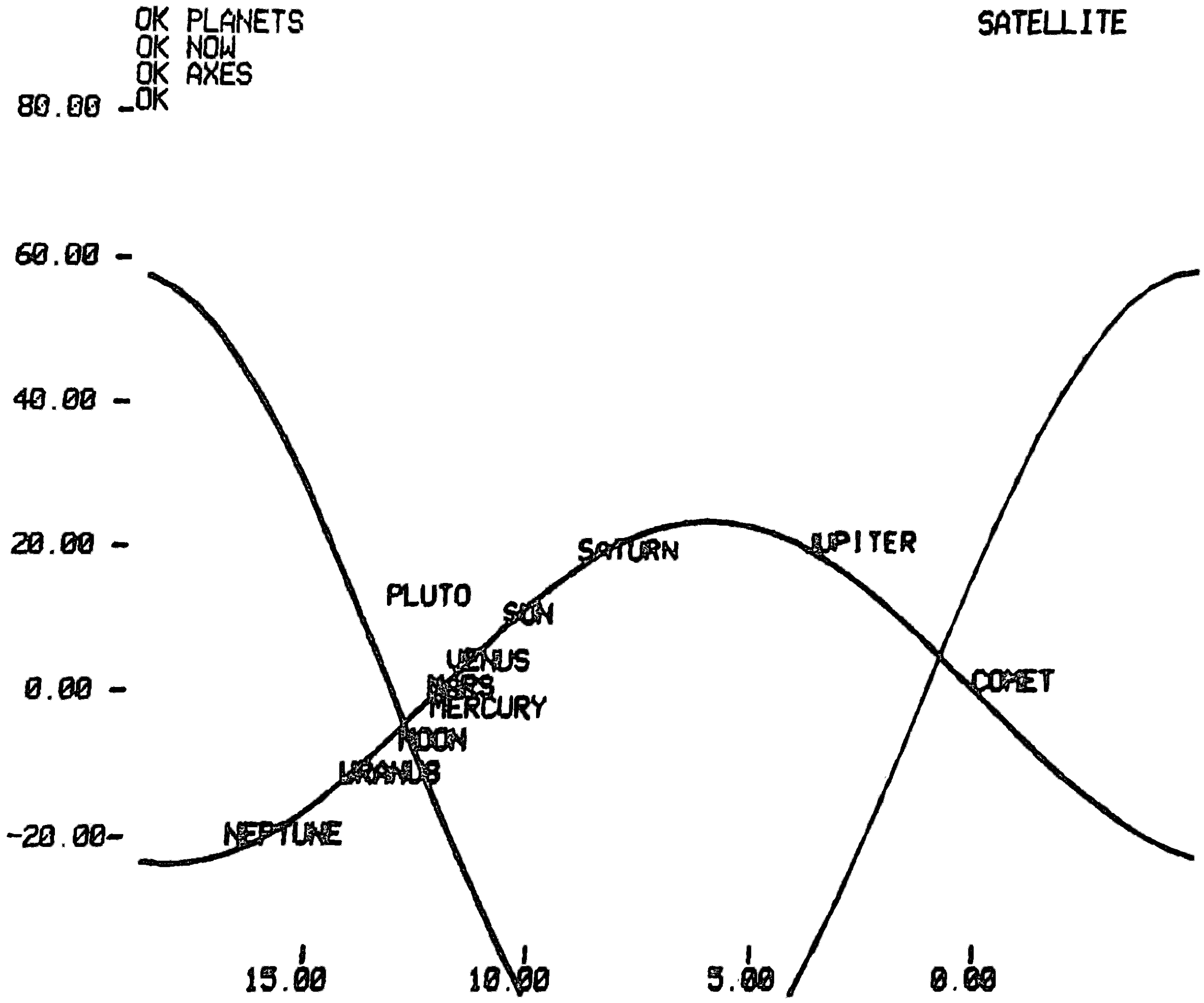
   FLUSH cr

   to insure that it is written on disk.

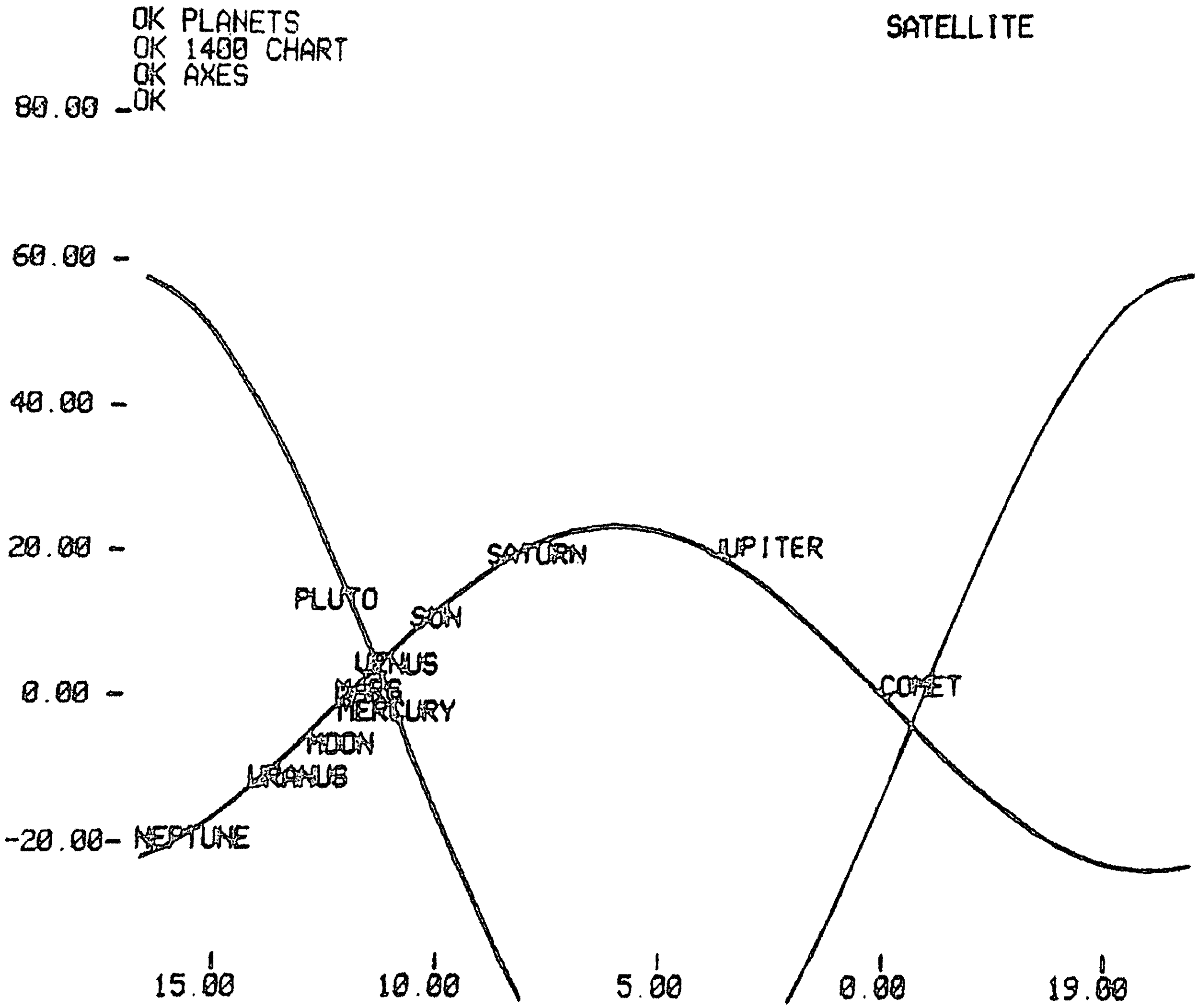
7. For plotting the PLANETS catalog at the Tektronix, items A.10 and A.11 apply.

8. See following pages for examples of displays available to the PLANETS catalog.

```
                           Current       Current
                              RA            DEC
                           ----------    ----------
OK PLANETS INDEX
                    12:03:20.6    -3:03:05.       10
         MERCURY    12:06:13.5    -3:32:11.        0
                    12:08:55.1    -3:59:53.        3
                    11:40:35.2     3:28:04.        6
           VENUS    11:45:04.4     2:57:34.        0
                    11:49:33.3     2:26:58.        2
                    10:26:38.7     9:44:47.        3
             SUN    10:30:17.5     9:23:32.        0
                    10:33:56.0     9:02:08.        0
                    12:50:23.7    -8:05:08.     3676<--- Moon's HP
            MOON    12:47:58.0    -7:53:08.        6<--- UT of Mid Position
                    12:45:32.4    -7:41:05.        1<--- Moon Data Scale Factor
                    12:09:48.7    -0:23:30.        4
            MARS    12:12:09.4    -0:39:22.        0
                    12:14:30.4    -0:55:14.        3
                     3:53:43.5    19:11:28.        2
         JUPITER     3:54:01.3    19:12:14.        0
                     3:54:18.3    19:12:38.        2
                     8:51:30.8    18:12:04.        1
          SATURN     8:52:00.4    18:10:12.        0
                     8:52:29.8    18:08:20.        3
                    14:07:38.0   -12:23:26.        0
          URANUS    14:07:47.1   -12:25:15.        0
                    14:07:56.3   -12:27:03.        4
                    16:39:29.3   -20:37:12.        0
         NEPTUNE    16:39:30.0   -20:37:17.        0
                    16:39:30.9   -20:37:22.        4
                    13:06:55.2    11:48:45.        0
           PLUTO    13:06:50.7    11:49:31.        0
                    13:06:45.0    11:50:16.        4
                     0:00:00.0     0:00:00.       88
           COMET     0:00:00.0     0:00:00.        0
                     0:00:00.0     0:00:00.        4
                     0:00:00.0    90:00:00.        0
       SATELLITE     0:00:00.0    90:00:00.        0
                     0:00:00.0    90:00:00.        4
OK
```



OK PLANETS
OK NOW
OK AXES
OK
SATELLITE
80.00
60.00
40.00
20.00
0.00
-20.00
15.00
10.00
5.00
0.00
SATURN
PLUTO
MERCURY
NEPTUNE


OK PLANETS
OK 1400 CHART
OK AXES
OK
SATELLITE
80.00
60.00
40.00
20.00
0.00
-20.00
PLUTO
SATURN
JUPITER
VENUS
MARS
MERCURY
MOON
URANUS
NEPTUNE
COMET
15.00
10.00
5.00
0.00
19.00

VII. CONTINUUM Program

A. CONTINUUM Observing Vocabulary

A list of observing nouns and verbs follow which are to be used by the operator at the teletype for ultimately obtaining continuum data.

1. ATTN

This noun is the atmospheric attenuation in tenths of percent at the zenith. When ATTN is non-zero it will scale all data up by the factor

$$\exp \quad \{\sec (z) \; * \; ATTN/1000\}$$

where z is the zenith distance to the source in degrees. ATTN may be set to its proper non-zero value (based on the CONTINUUM Program tipping scan data) to account for atmospheric attenuation if the observer desires. For example, to set ATTN to 12.5%, type

```
125    ATTN    !    cr
```

and to query the set value type

```
ATTN   ?   cr
```

Also see the sections entitled "EXTINCTION Data Reduction" and "CONTINUUM/MAPPING Signal Processing" in this chapter for additional information concerning ATTN.

2. BS   cr

This verb selects the beam switching observing mode. For more information see section C.2. in this chapter.

3. #C, #CP

These nouns correspond to the number of bits in the switched power and total power portions, respectively, of a calibration. For more information see the section entitled "Calibration Procedure" in this chapter.

4. CALIBRATE   cr

This verb causes a noise tube calibration to be performed. A CALIBRATE computes #C, #CP, TS and GAINØ described in this section. The noun CSEC relates to CALIBRATE and is described below. See the section entitled "Calibration Procedure" in this chapter for details of calibration methods. For meaningful data a CALIBRATE should always be performed when the program is reloaded for any reason.

5. CSEC

This noun is the number of tenths of seconds to be spent integrating on an individual sample in a CALIBRATE. For example, to set CSEC to 30 seconds, type

```
300    CSEC    !    cr
```

and to query the set value type

```
CSEC    ?    cr
```

6. Date Setting

It is of paramount importance to enter the day's date, as soon as the current observation allows, after Ø hours Universal Time (5 PM MST). For example, to set the date, type

```
n    OCT    cr
```

where n is the correct day number based on Universal Time. Standard first 3 letter abbreviations for months apply except for December which is designated DCM.

7. DUT1

The noun DUT1 may be regarded as a correction to be added to coordinated Universal Time (UTC) to obtain a better approximation to the mean solar time of the prime meridian obtained from direct astronomical observations which have been corrected for small movements of the earth relative to the axis of rotation. These DUT1 corrections are obtained monthly from the Naval Observatory. To set DUT1 to 0.5 seconds, type

```
500    !DUT1    cr
```

To query the parameter DUT1, REFRESH the TV screen.

8. %EFF

This noun is the aperture efficiency in percent. It is used in the computation of flux units in the data reduction routine at the Tektronix terminal. To set a value of 28 percent, type

```
28    %EFF    !
```

and to query the set value REFRESH the TV screen.

9. EXPEDITE cr

This verb automaticallys set the noun TOL (described below) to a high value. This allows observations to be made without tracking a source. If EXPEDITE is used and normal observations are subsequently resumed, TOL must be reset.

10. EXTINCTION cr

This verb causes an atmospheric tipping scan to be performed; the total power data from such a scan can be used to evaluate ATTN. See the section entitled "EXTINCTION Data Taking Procedure" in this chapter for more information.

11. FIVE cr

This verb causes a series of five scans (see SEQUENCE below) about a source to be taken. For more information see the sections in this chapter entitled "FIVE Pointing Data Taking Procedure" and "FIVE Data Fitting". See also SPDATA and TPDATA described in this section.

12. FØ

This noun is the temperature independent focus parameter in the empirical focus equation described below for FOCUS. The units of FØ are in tenths of mm. For example, to set FØ at 65.5 mm, type

    655   FØ   !   cr

To query FØ, REFRESH the TV screen and observe its value.

13. FOCALIZE cr

This verb causes a scan in continuum switched power or total power to be made with each datum point of the scan at a different focus setting; the data from such a scan can be used to evaluate FØ described above. For more information, see the sections in this chapter entitled "FOCALIZE Data Taking Procedure" and "FOCALIZE Data Reduction Procedure". See also FOCUS described below. See also SPDATA and TPDATA described in this section.

14. FOCUS cr

This verb causes the focus of the receiver to be performed via computer control. It can be executed anytime; however, it is automatically done at the beginning of each scan or CALIBRATE before any data is taken. The empirical focus equation, F, in mm units is

$$F = 2.69T_o + 1.36T_1 - 3.82\ T_2 + 1.63\ \sin\ (EL) + F\emptyset$$

where T_o, T_1, and T_2 are the Centigrade temperatures of the antenna North, South, and Center Hub points, respectively; EL is the commanded elevation angle of the telescope and FØ has been previously described above. See FOCALIZE above.

15. GAINØ

This noun is a measure of the receiver total power gain taken during a CALIBRATE and stored away in the calibration scan header information. It is computed by the expression

$$\frac{TS * TP}{TS + TA * \sec(z) * ATTN/1000}$$

where TS is system temperature, TA is the temperature of the atmosphere (245 K default), z is the zenith distance to where the telescope is pointing, and ATTN has been previously described. Additionally, a receiver total power gain measurement is taken at the beginning of each scan and that information is recorded away in the header information for disk and binary tape. See the parameter GAIN in the section entitled "CONTINUUM/MAPPING Header Variables Recorded on Disk (and Binary Tape)" in this chapter.

16. GO cr

This verb will allow a stopped (STOP) scan to continue. See STOP described below.

17. HEADER

This noun refers to the scan number in progress or the next scan to be executed if no scan is currently in progress. The scan number will automatically increment when a scan is completed. Scan numbers start at 500 and can go as high as 2000. To reset the HEADER, for example, to 500, type

500 HEADER !

Be aware that resetting the HEADER parameter to a lower value will cause previous data on the disk to be written over when a data taking observation is performed. To query the reset value of HEADER, REFRESH the TV screen.

18. HP

This noun is half the half-power beam width (HPBW) of the antenna for a given frequency and is in units of seconds of arc. HP is used as the step increment in a FIVE observation about the center position of a source. To set HP to 40 seconds of arc, type

```
40     HP     !
```

and to query the set value, REFRESH the TV screen.

19. LS cr

This verb selects the load switching observing mode. For more information see section C.2. in this chapter.

20. MAIN! cr

This verb is used to store the AZ, EL, RA and DEC main beam offsets displayed on the TV screen (usually via the thumbwheel offset panel) correctly into the program. See chapter V for more details.

21. NS

This noun is the number of samples in a scan. It is automatically set upon initiation of a SEQUENCE or FIVE by the value of RPT. NS will be equal to

```
RPT * 2 + 1
```

Thus, NS can be no less than 3 and no more than 255. NS is always odd. See also RPT below.

22. OBS, OPR

These nouns refer to the initials of the observer and operator, respectively. To set, for example, the observer's initials to WAD, type

```
OBS     INITIALS     WAD     cr
```

To query the set value perform a REFRESH of the TV screen.

23. PL-HUSH cr

This verb silences the computer "RECEIVER OUT OF LOCK" alarm for the duration of the scan in progress.

24. RCVR

This noun refers to the spectral line receiver number. See Table 1 in this chapter for a description of receivers available. To set this noun, for example, to 15, type

15 RCVR ! cr

and then REFRESH the TV screen to query the set value. Alternatively, one may type

15 !RCVR cr

and, in addition to setting 15 into RCVR, you will get all the default values of TS, TC, HP, %EFF, BANDWIDTH, ATTN, and FØ for receiver 15.

25. REF! cr

This verb is used to store the AZ, EL, RA and DEC reference on the TV screen (usually via the thumbwheel offset panel) correctly into the program. See chapter V for more details.

26. REFRESH cr

This verb causes all current values of parameters to be redisplayed on the TV screen.

27. RPT

This noun is the number of OFF-ON-OFF pairs in an observation (single scan). RPT will set NS described previously in this section. The total time required for a single scan in tenths of seconds would be

SEC * NS

See the explanation of SEC below. To set, for example, 5 OFF-ON-OFF pairs for an observation type

5 RPT ! cr

28. n SCAN SAVE cr

This phrase records a stopped scan n properly on disk and tape.

29. SEC

This noun is the number of tenths of seconds to be spent integrating on an individual sample in a data observation. For example, to set SEC to 30 seconds, type

```
300    SEC    !    cr
```

and to query the set value type

```
SEC    ?    cr
```

30. n   SEQUENCE   cr

This verb causes n scans to be taken of a source. Each scan will have alternating observations ON and OFF the source. The first and last data points will be OFF source. See also SPDATA and TPDATA described in this section.

31. SPDATA   cr

This verb selects the switched power data mode for the observing commands SEQUENCE, FIVE and FOCALIZE. When selected, "SP" will appear above T(ANT) on the TV screen.

32. STOP   cr

This verb causes any data taking in progress to cease. Use this word only when absolutely necessary and check the value of TOL after having used STOP.

33. TC

This noun is the double sideband noise tube calibration temperature in tenths of K. To set, for example, TC to 15.0 K type

```
150    TC    !
```

34. THUMB   cr

This verb prints out the values of AZ, EL, RA and DEC offsets stored away in the program by both MAIN! and REF!.

35. T-HUSH   cr

This verb silences the computer alarm for observation without a tape unit.

36. TOL

This noun is the maximum RMS tracking error limit in seconds of arc. If the actual tracking error exceeds this limit, data taking ceases until the actual error falls below the limit. To set, for example, a tracking error limit of 10 seconds of arc, type

10 TOL !

37. TPDATA cr

This verb selects the total power data mode for the observing commands SEQUENCE, FIVE and FOCALIZE. When selected, "TP" will appear above T(ANT) on the TV screen.

38. TS

This noun represents the system temperature. TS is automatically set at the end of a CALIBRATE. For more information see the section entitled "Calibration Procedure" in this chapter.

Continuum Receivers

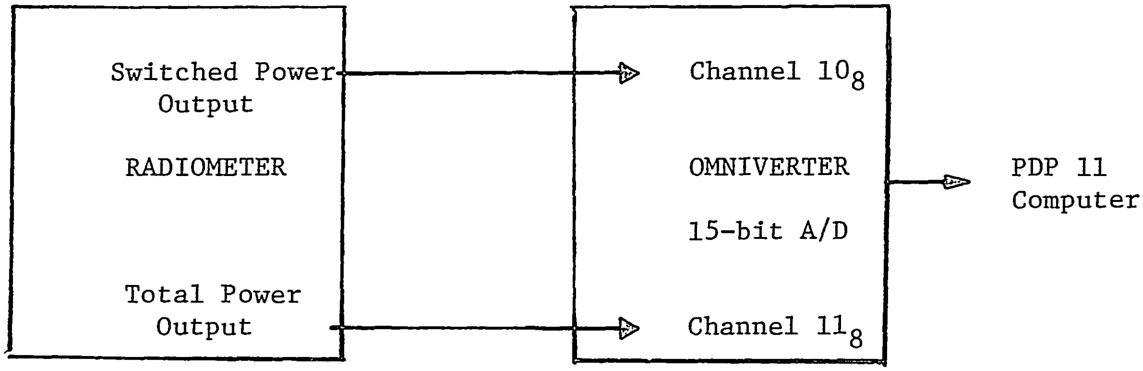
(All temperatures are double sideband)

CODE n	FREQ (GHz)	TS (K)	TC (K)	HP (")	RCVR BAND-WIDTH (MHz)	%EFF (%)	ATTN (%)	FØ (mm)	NOTES
10	31.4	750	15.0	105	500	51	2.5	18.3	NRAO Prime Focus Continuum Receiver
11	31.4	600	15.0	105	2000	44	2.5	28.0	Four Channel Uncooled Cassegrain Continuum Receiver
12	35	300	15.0	95	1000	44	3.0	28.0	33-50/80-120 GHz Dual Channel Cooled Cassegrain Receiver
13	47	200	15.0	70	400	40	12.0	28.0	47 GHz Dual Channel Cooled Cassegrain Paramp
14	90	300	15.0	38	1000	28	7.0	28.0	33-50/80-120 GHz Dual Channel Cooled Cassegrain Receiver
15	90	300	15.0	38	1000	28	7.0	28.0	80-120/127-174 GHz Dual Channel Cooled Cassegrain Receiver
16	150	1000	15.0	30	1000	18	10.0	28.0	80-120/127-174 GHz Dual Channel Cooled Cassegrain Receiver
17	215	10000	100.0	30	1000	10	26.0	81.0	NRAO 1mm Bolometer
18	150	1000	15.0	30	1000	27	10.0	28.0	150 GHz Uncooled Cassegrain Receiver
19	---	--	--	--	--	--	--	--	Any Other NRAO Reciever
99	---	--	--	--	--	--	--	--	User's Own Receiver

Table 1: Setting Continuum Receiver Default Parameters: n !RCVR

B. Radiometer Connection

1. The PDP computer has two input lines for use with the NRAO Standard Back End. These lines transmit the signals used for continuum observing, and for monitoring signals from the spectral line receivers. It is hooked up as follows:



2. Full scale input to the A/D converter is ± 10 volts, and this is converted to a 14-bit-plus-sign digital word every 100 milliseconds. The input is thereby quantized at a 0.6 millivolt level.

3. When setting output levels on the standard back end or connecting other radiometers to the computer, be aware of the quantization level of 0.6 millivolts and the full-scale level of 10 volts, by looking at the monitor display. The switched power ("SP") and total power ("TP") are displayed directly in volts. One can also use the synchronous detector meter on the standard back end in the "DIGITAL OUT" position, where it reads ± 10 volts full scale, or the digital voltmeter on the standard back end.

4. In general, the receiver gain should be as high as possible without going off-scale. For normal continuum work this means maximum receiver gain; the calibration signal (about 15 K) should show about 4 to 6 volts difference between the off and on position.

5. For connecting other radiometers, be aware of the 100 ms sample rate, and adjust your analog time constant accordingly to avoid undersampling. The minimum acceptable time constant is about RC=200 ms.

C. CONTINUUM/MAPPING Signal Processing

1. One of two signal input functions may be selected in the CONTINUUM and/or MAPPING Programs:

   (a) Switched Power: SPDATA

   This signal is the switched power signal; it may be selected by an observer for his regular data taking in lieu of a total power signal discussed later. Upon loading of the data taking program at the teletype, the SPDATA observation signal is the default. For notation purposes SP denotes switched power data in volts.

   (b) Total Power: TPDATA

   This signal is the total power signal which is used in the second 7 samples of a CALIBRATE; it is also the signal used during an EXTINCTION data taking observation. For notation purposes

   $$TP = (V-V_c) + 1.0000$$

   where

   V = Total Power voltage coming from the receiver

   V_c = Reference voltage injected by the standard back end and $V_c = 1.0$

   The computer adds a one volt constant so that the TV screen should display a total power voltage of near 1 volt for all receivers.

2. Two correction factors are applied to the selected signal during an observation (not during a CALIBRATE or an EXTINCTION).

   (a) <u>SCALE</u> - A voltage to temperature scale factor.

      (1) <u>SPDATA</u>

$$\frac{10^{\mathrm{UNIT}}}{\#\;\;\#C\;\;{*C}}\;\frac{TC}{10}$$

      (2) <u>TPDATA</u>

$$\frac{10^{\mathrm{UNIT}}}{\#\;\;\#CP\;\;{*C}}\;\frac{TC}{10}$$

      where

      TC = Calibration temperature provided by Electronics Division

      UNIT = number of decimal places in data. See also the section entitled "CONTINUUM/MAPPING Data Scale Factor" in this chapter.

      # = number of integration points

      #C = number of SP bits corresponding to TC

      #CP = number of TP bits corresponding to TC

      *C = 1 for LS

      *C = 2 for BS

   (b) <u>DIM</u> - A factor which scales up the signal from either (a).(1). or (a).(2). above to correct for atmospheric attenuation. The factor is

      $\exp \{\sec (z) \;*\; \mathrm{ATTN}/1000\}$

   where z is the zenith distance to the source in degrees. Note that this factor will affect your data if ATTN is any non-zero value.

D. CONTINUUM/MAPPING Data Scale Factor

1. When on source, T(ANT) on the TV screen reflects the source signal to the standard back end. The number of decimal places in the quantity T(ANT) is the value of UNIT.

2. The value of UNIT is set automatically under the following circumstances:

   (a) CALIBRATE - UNIT is set to 2 during the calibration; after the calibration is complete, UNIT is restored to the value it was, just prior to the calibration.

   (b) EXTINCTION - UNIT is set to Ø during the extinction; after the extinction is complete, UNIT is restored to the value it was, just prior to the EXTINCTION.

   (c) FOLLOW (Planet) - UNIT is set to one of the values from the following table:

PLANETS	UNIT
MERCURY	3
VENUS	2
SUN	0
MOON	1
MARS	3
JUPITER	2
SATURN	3
URANUS	4
NEPTUNE	4
PLUTO	4

   (d) SEEK, EPOCH, CURRENT, and GALACTIC - UNIT is set to the value of DEFAULT. Upon loading the program DEFAULT is 3. The observer may have the operator change the value of DEFAULT by typing the following:

   ```
   n    DEFAULT    !    cr
   ```

   where n is Ø for the strongest sources and 4 for the weakest sources.

3. The value of UNIT may be manually set by the operator at any time by typing the following:

   ```
   n    UNIT    !    cr
   ```

   One must keep in mind that UNIT will be automatically reset under the conditions in 2 above.

4. Upon RECALL of a particular scan at the Tektronix, the data scale factor (i.e., past value of UNIT) for that scan may be obtained by typing:

   ```
   'UNIT    ?    cr
   ```

E. CONTINUUM/MAPPING Header Variables Recorded on Disk (and Binary Tape)

WORD LOCATION	NAME	DESCRIPTION
Ø	HEADER	Current scan number - 5ØØ to 2ØØØ allowed
4	DAY	Modified JD - from 1 JAN 195Ø
5	PA-RCVR	Position angle of receiver box
6-7	OFFSETS	Five point AZ-EL offsets (low order portion of .22)
8-9	MAIN	AZ-EL main beam offsets (low order portion of .22)
11	RCVR	Receiver ID integer
12	MODE	Observing mode integer
13	'UNIT	Base 10 exponential scale factor for data (0,1,2,3,4)
14	%EFF	Aperture efficiency (%)
15	'UT	UT at beginning of scan (.14)
16	'LST	LST at beginning of scan (.14)
17	TIME	Actual integration time of scan (tenths of seconds)
18-19	'RA	Actual RA (.22)
2Ø-21	'DEC	Actual DEC (.22)
22	SINH	Sine of elevation angle (.14)
23	'AZ	Actual AZ (.14) reckoned from the East
24-25	OBS	Observer initials Character count + 3 characters (ASCII)
26-27	OPR	Operator initials Character count + 3 characters (ASCII)
28-33	NAME	Source name Character count + 11 characters (ASCII)
34-55	NS	Number of rows in first word and number of samples row in second word
36	RMS	Theoretical RMS of receiver (K* 10 EXP(+'UNIT))
43	T	Average temperature of OFF-ON-OFF pairs (K* 10 EXP(+'UNIT))
44	T-RMS	RMS of T in same units as T
45	BASE	Baseline of Off Samples (K* 10 EXP(+'UNIT))
46	HP	Half the HPBW of the antenna ("of arc)
47	#PTS	Number of observational data points
49	BANDWIDTH	Bandwidth of receiver (MHz)
50	GAIN	Receiver gain (tenths of millivolts)
51	SA	Scanning angle with respect to NCP (.14)
63	CELL	Size of sample grid (seconds of arc)
64	TC	Calibration temperature (tenths of K)
65	TS	System temperature (K)

WORD LOCATION	NAME	DESCRIPTION
66	ATTN	Zenith atmospheric attenuation (tenths of %)
67	GAINØ	Receiver gain determined at calibration time, (tenths of millivolts)
68	#C	Number of counts in most recent SP calibration
69	SEC	Tenths of seconds per sample
71	TOL	Tracking tolerance in seconds of arc
75	FØ	Focus offset (tenths of mm)
76	#CP	Number of counts in most recent TP calibration
80	DUT1	UT clock correction in thousandths of a second
117-118	TAV	Average temperature of OFF-ON-OFF sample sequence in K* 10 EXP('UNIT + 1)
119	TAV-RMS	RMS of TAV in same units as TAV
128	--	Starting location of recorded data; all data is single precision.

Notes:

(a) See the Tape and Disk Utility Check Lists & Information Chapter concerning Off-Line Data Reduction for Binary Tapes for the meaning of (.22), (.14) and (DP).

(b) Characters in ASCII are stored in the order 2N436587 . . . where N is a binary number equal to the number of characters in the word.

F. Calibration Procedure

1. The calibration procedure is the same for the CONTINUUM and MAPPING calibrations:

   (a) Move the telescope to look at blank sky.

   (b) Set CSEC to the time you want to spend in each phase of the calibration. 100 CSEC ! is sufficient (10 seconds). Make sure TC is correct for your receiver.

   (c) Type at the teletype,

   CALIBRATE cr

2. The action in 1. above initiates the calibration scan. First a measurement of GAINØ (see the section entitled "CONTINUUM Observing Vocabulary" for an explanation of this parameter) is performed and stored away in the calibration scan header information. Next the program integrates seven samples of switched power and seven samples of total power. The first sample in switched power and the first sample in total power are observations of blank sky. The second switched and total power samples are observations of blank sky plus an energized noise tube. The procedure continues alternately observing a sample with and a sample without the energized noise tube. The last samples (i.e., sample seven for either switched or total power) in switched and total power are without the noise tube energized. When the data taking is complete, the CALIBRATE computes and displays the parameters #C, #CP, and TS from the data.

3. #C is the number of bits which represents the temperature of the noise tube (TC) as determined from the observed change in switched power during the calibration scan. A typical value for #C is approximately 4000 when using a cooled receiver and TC is 15 K.

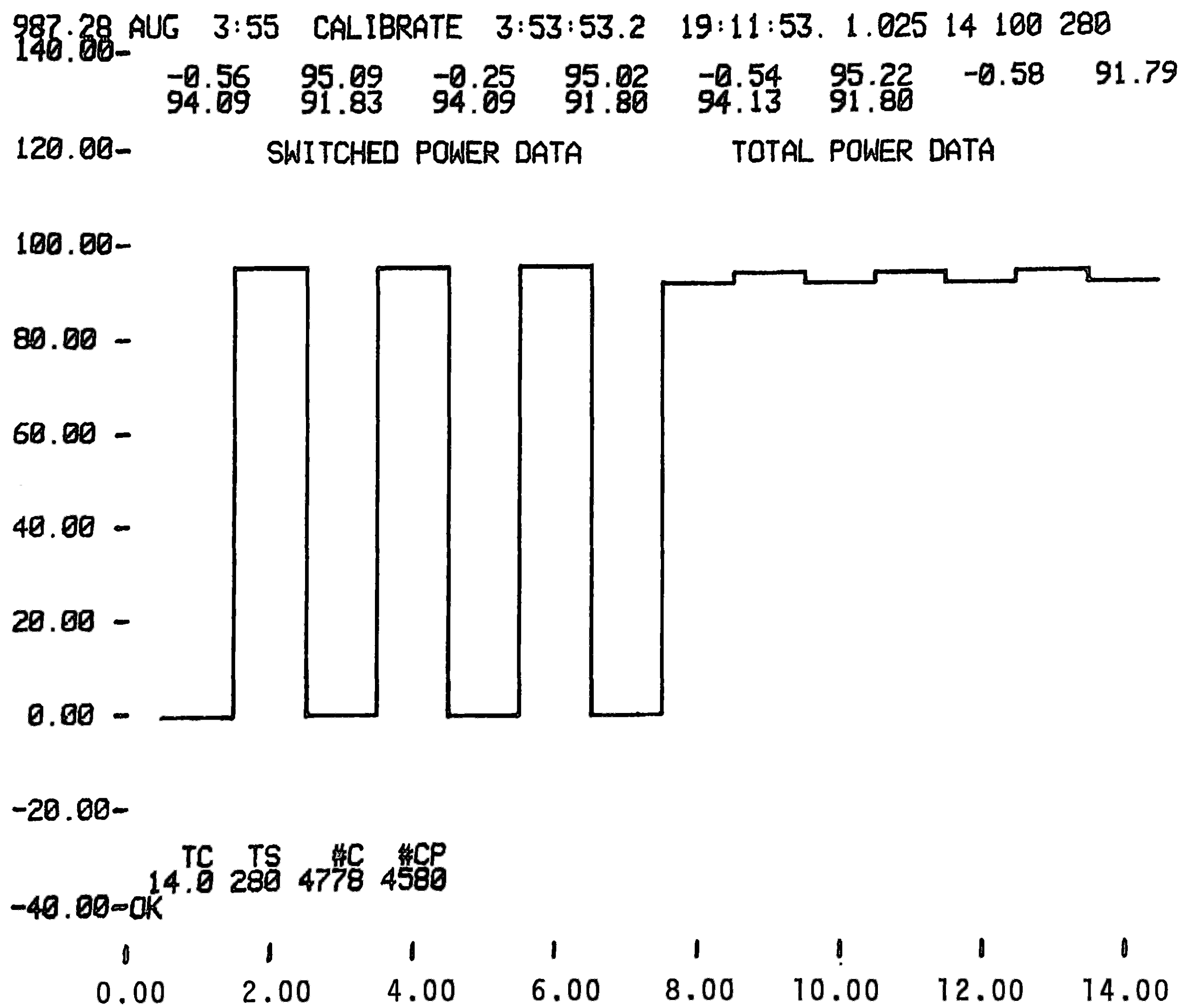
4. #CP is the number of bits which represents the temperature of the noise tube (TC) as determined from the observed change in total power during the calibration scan. A typical value for #CP is approximately 4000 when using a cooled receiver and TC is 15 K.

5. TS is a measure of the system temperature in Kelvins. It is numerically equal to the expression

$$TS = \frac{\langle TP \rangle_{off} \ * \ TC}{10 \ * \ \#CP}$$

   where $\langle TP \rangle_{off}$ represents the average of all the total power observations during the CALIBRATE with the noise tube off.

6. To display the results of a calibration scan, see the verb CAL in the section entitled "CONTINUUM Data Reduction Vocabulary" in this chapter. An example of CAL follows on the next page.



Example: 987 CAL

G. EXTINCTION Data Taking Procedure

1. The continuum data system will take data to later compute the atmospheric extinction if desired. This is done by measuring the effect of atmospheric emission on the total power and fitting an exponential to the data. The sequence of operations, performed at the teletype, is as follows:

   (a) You must have done a calibration. See the section entitled "Calibration Procedure" in this chapter.

   (b) Release the telescope to track something at any desired azimuth. With the CONTINUUM program loaded, type at the teletype

   EXTINCTION   cr

   The antenna will move from 22° elevation to 65° to 22° making a total of 11 measurements, each SEC long. An EXTINCTION integrates 11 values of total power for the telescope oriented for the following values of (1.0/sin EL) in the order given:

   2.6, 2.3, 2.0, 1.7, 1.4, 1.1, 1.4, 1.7, 2.0, 2.3, 2.6

   The data should take the form of the equation

   $$TRS + TA\ \{1 - \exp(-\sec(z) * ATTN/1000)\}$$

   where z is the zenith distance to the point at which the telescope is pointing. The 11 measurements are recorded as a scan. See the section entitled "EXTINCTION Data Reduction Procedure" in this chapter for further information.

   (c) Reload source coordinates, as they have been changed, and continue observing.

H. FIVE Pointing Data Taking Procedure

1. The FIVE procedure will command 5 scans to be performed about a source. The telescope will be positioned on the sky for each of the five scans as shown

```
        N

    E   C   W

        S
```

   The sequential order of the scans will be N, S, C, E, and W. Here C represents the position of the source; N and S represent positions above and below the source in elevation, respectively, by an amount equal to half the half-power beam width (HP); E and W represent positions to the left and right of the source in azimuth, respectively, by an amount equal to HP.

2. To command the observations, the operator at the teletype types

```
FIVE        cr
```

3. To display and reduce the results of a FIVE observation, see the section entitled "FIVE Data Fitting" in this chapter.

I. FOCALIZE Data Taking Procedure

1. An automatic means of taking a single scan, consisting of 14 data points for the determination of the best focus parameter (FØ), is available. The scan causes the focus parameter (FØ) to be changed in steps of the wavelength parameter (WL) and the receiver will be commanded to the new focus via the following scheme:

$$F\emptyset = (F\emptyset)_o + (i-3) * WL \qquad 0 \leq i \leq 6$$
$$F\emptyset = (F\emptyset)_o + (i-10) * WL \qquad 7 \leq i \leq 13$$

   $(F\emptyset)_o$ is the best guess of FØ set prior to commencement of the scan. WL is usually set to the wavelength of the receiver (tenths of mm) and has a default of 3.5 mm. WL should not be set longer than the wavelength of the receiver because the fitting routine (discussed later) fits a simple parabola rather than the more correct gaussian (see the figure which follows on the next page; it is a plot of an empirical focus curve for the 36-foot telescope operating with a receiver at 3.5 mm wavelength). The data is taken via the above scheme while observing on a continuum source and the proper pairs of data points (14 antenna temperatures) are averaged to arrive at a resultant 7 data points to correct for receiver drift. Note that no observations off the source are taken.

2. To accomplish 1. above, the following commands are performed at the teletype with the CONTINUUM Program loaded:

   (a) Set the initial FØ and WL (example):

   ```
   715   FØ   !   cr
    35   WL   !   cr
   ```

   (b) Set SEC (tenths of seconds) for the length of integration time on each sample (example):

   ```
   100   SEC  !   cr
   ```

   (c) Track a strong continuum point source.

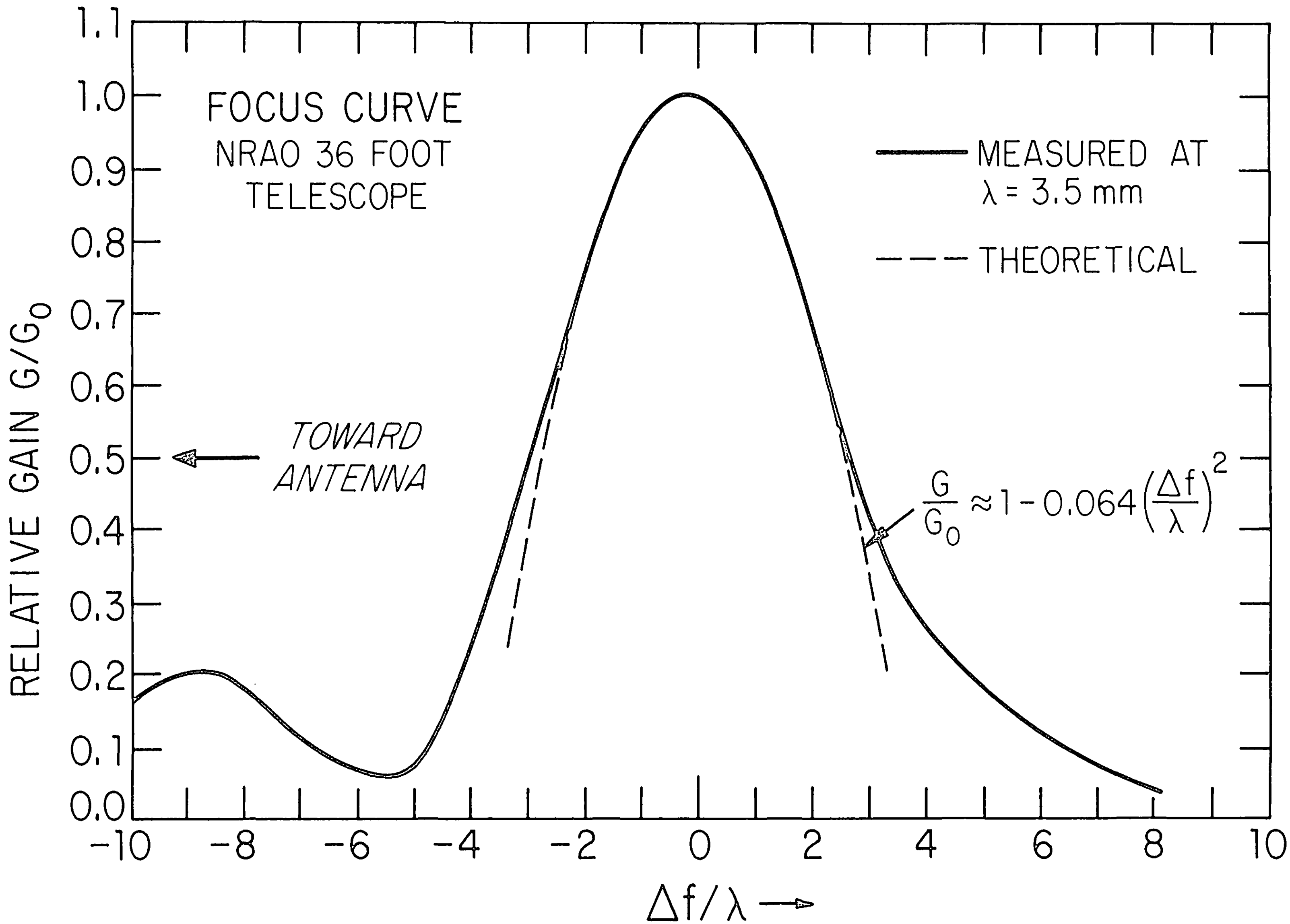
   (d) Type the following phrase to start the automatic data taking process:

   ```
   FOCALIZE       cr
   ```

   (e) As (d) progresses the TV screen will update FØ and the actual FOCUS with each new sample and the bell will ring at the end of each sample.

   (f) Temperatures of the dish (North, South, and Hub) are recorded with the scan prior to the start of data taking and at the end of all data taking.

   (g) When (e) and (f) are finished, the scan will be recorded on disk and tape. To analyze data on the disk, see the section entitled "FOCALIZE Data Reduction Procedure" in this chapter.



36 FOOT TELESCOPE EMPIRICAL FOCUS CURVE

J. CONTINUUM Data Reduction Vocabulary

A list of common data reduction nouns and verbs follow which are to be used by the observer at the Tektronix terminal for displaying and processing continuum data previously recorded on the disk.

1. AUTO cr

This verb allows the computer to automatically select the range on the vertical axes of scans subsequently recalled for plotting from storage on the disk. The computer will attempt to place such scans in the middle third of the Tektronix screen. If the dynamic range of the data is too large, AUTO may not work and the range of the vertical scale must be set by RANGE described below. Once AUTO is selected it will remain in effect until defeated by RANGE or MANUAL, both described below.

2. AVERAGE cr

This verb allows one to display the difference between the average of those scans in the scan table which do not have a minus sign and the average of those scans in the scan table which have a minus sign. The averages are weighted by integration time. To manipulate the contents of the scan table see the section entitled "Using the Scan Table" in this chapter.

3. AVG cr

This verb will determine the mean temperature and its corresponding error from the data in the plot buffer and print out the results. The mean temperature, TAV, is determined from the formula

$$TAV = \frac{\sum\limits_{i=1,3,5..NS}^{NS} T_{i+1} - (T_i + T_{i+2}) / 2}{RPT}$$

where T_i is temperature value associate with the i^{th} datum point and NS is the number of samples in the plot buffer and RPT is the number of OFF-ON-OFF data groups. The first temperature value in the plot buffer is an OFF source datum point. Temperatures in the plot buffer will alternate successively between OFF and ON and the last point will be an OFF.

Since all but the first and last OFF data points will be used twice in the calculation of TAV, the associated error, TAV-RMS, is computed by

$$\text{TAV-RMS} = 2\sqrt{\frac{\sum_{i=1}^{n} (X_i)^2}{(2n+3)(n-1)}}$$

where n equals the value of RPT and X_i is the residual of i^{th} datum point associated with the computation of the mean temperature, TAV. An example follows on a succeeding page.

4. n CAL cr

This verb causes the CALIBRATE data scan n to be properly displayed with axes and labels and the raw data printed out by the PRINT function. Additionally, the quantities TC, TS, #C, and #CP which result from the CALIBRATE are printed out with labels. For more information see the section entitled "Calibration Procedure" in this chapter.

5. COMBINE cr

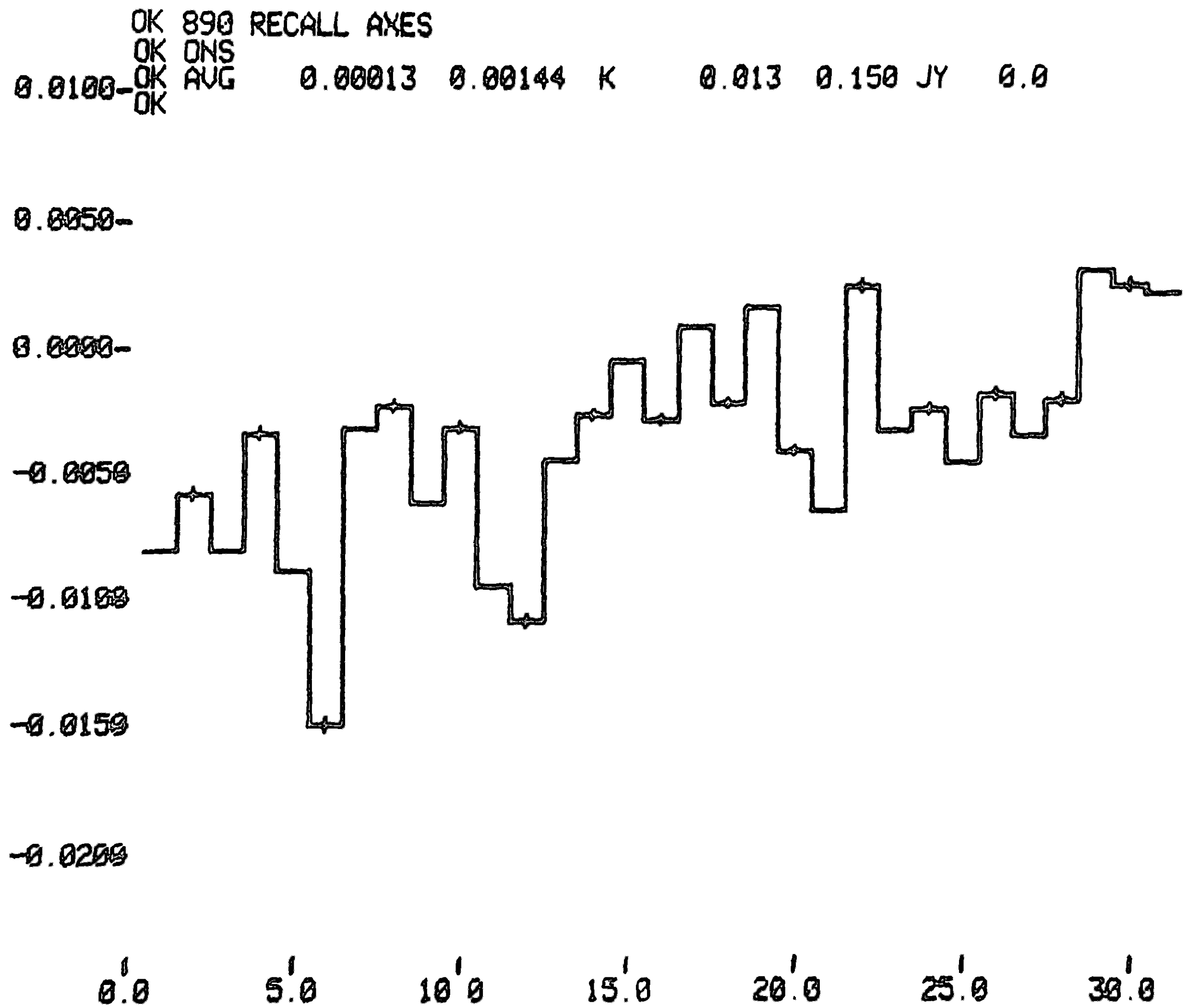
This verb allows one to display the average of those scans in the scan table. For such an operation no scan in the scan table should have a minus sign. The average is weighted by the integration time. To manipulate the contents of the scan table see the section entitled "Using the Scan Table" in this chapter.

6. n F cr

This verb causes FIVE data to be displayed where n is the center scan of the FIVE. Additionally, a two-dimensional gaussian is fit to these data with and without constraints on the azimuthal and elevation beam widths. The resultant fit data is also displayed. For more information see the section entitled "FIVE Data Fitting" in this chapter.

7. n FOCALIZE cr

This verb causes the FOCALIZE data scan n to be properly displayed and a parabolic fit to three selected data points to be performed. For more information see the section entitled "FOCALIZE Data Reduction Procedure" in this chapter.


OK 890 RECALL AXES
OK ONS
OK AVG 0.00013 0.00144 K 0.013 0.150 JY 0.0
OK
0.0100
0.0050
0.0000
-0.0050
-0.0100
-0.0150
-0.0200
0.0
5.0
10.0
15.0
20.0
25.0
30.0

AVG Example

8. n HEAD cr

This verb will print out some pertinent information for scan n on the disk. For example,

730 HEAD cr

will print out the following:

Scan No.	Date	LST	Source Name	Actual RA	Actual DEC	ATMS	NS	TIME	TS
730	8 OCT	13:43	ORIA	5:41:35.2	-2:19:16.	1.347	11	3300	380

Most of the above parameters and units are self-explanatory. ATMS is the number of atmospheres through which the observation was taken. See the section entitled "CONTINUUM/MAPPING Header Variables Recorded on Disk (and Binary Tape)" for additional information.

9. n LOG cr

This verb points out TAV and TAV-RMS for scan n in degrees K and the same quantities in flux units (Jansky) along with the signal-to-noise ratio. For a description of the computation of TAV and TAV-RMS see AVG in this section.

10. n m LOGS cr

This verb performs a LOG for scans n through m inclusive.

11. <LOG> cr

This verb prints out the scan number followed by TAV and TAV-RMS in degrees K for each scan in the scan table. Additionally, the average TAV and its RMS error are computed and displayed in LOG format described above. The RMS error is computed from

$$RMS = \sqrt{\frac{\sum_{i=1}^{n} (X_i)^2}{(n-1)}}$$

where X_i is the residual of the i^{th} data point and n is the number of scans in the scan table.

12. MANUAL cr

This verb causes the computer to "freeze" the vertical axis range for all future plotting. Once MANUAL is selected it will remain in effect until defeated by RANGE or AUTO both described in this section.

13. Plot Options

(a) PAGE cr

This verb erases the screen and positions the cursor at the upper left hand corner.

(b) PLOT cr

This verb will replot the data currently in the plot buffer.

(c) PRINT cr

This verb will print out the values of the function plotted, eight values per line.

(d) AXES cr

This verb will provide horizontal and vertical axes for the data displayed by PLOT.

(e) LABEL cr

This verb will print out the physical quantities of the axes displayed by AXES.

(f) FULL GRID cr

This verb will draw a rectangular grid on the screen.

(g) HISTOGRAM, POINTS, LINE

These verbs allow selection of the desired plotting mode. The program will stay in one plotting mode until another mode is selected by the user.

(h) ONS cr

This verb causes a cross (i.e., +) to be drawn on the displayed continuum graphics at those positions where the ON source data points should be.

14. n m RANGE cr

This verb allows the observer to select the vertical axis on all future plots. The integer numbers n and m are the minimum and maximum vertical axis range values desired. Once RANGE is executed it will remain in effect until defeated by AUTO or MANUAL both described in this section.

15. n S cr

This verb causes the data scan n to be properly displayed with axes and labels. An example follows on a succeeding page.

16. SNAP cr

This verb may be used anytime to take an instantaneous picture of the TV screen.

17. SUM cr

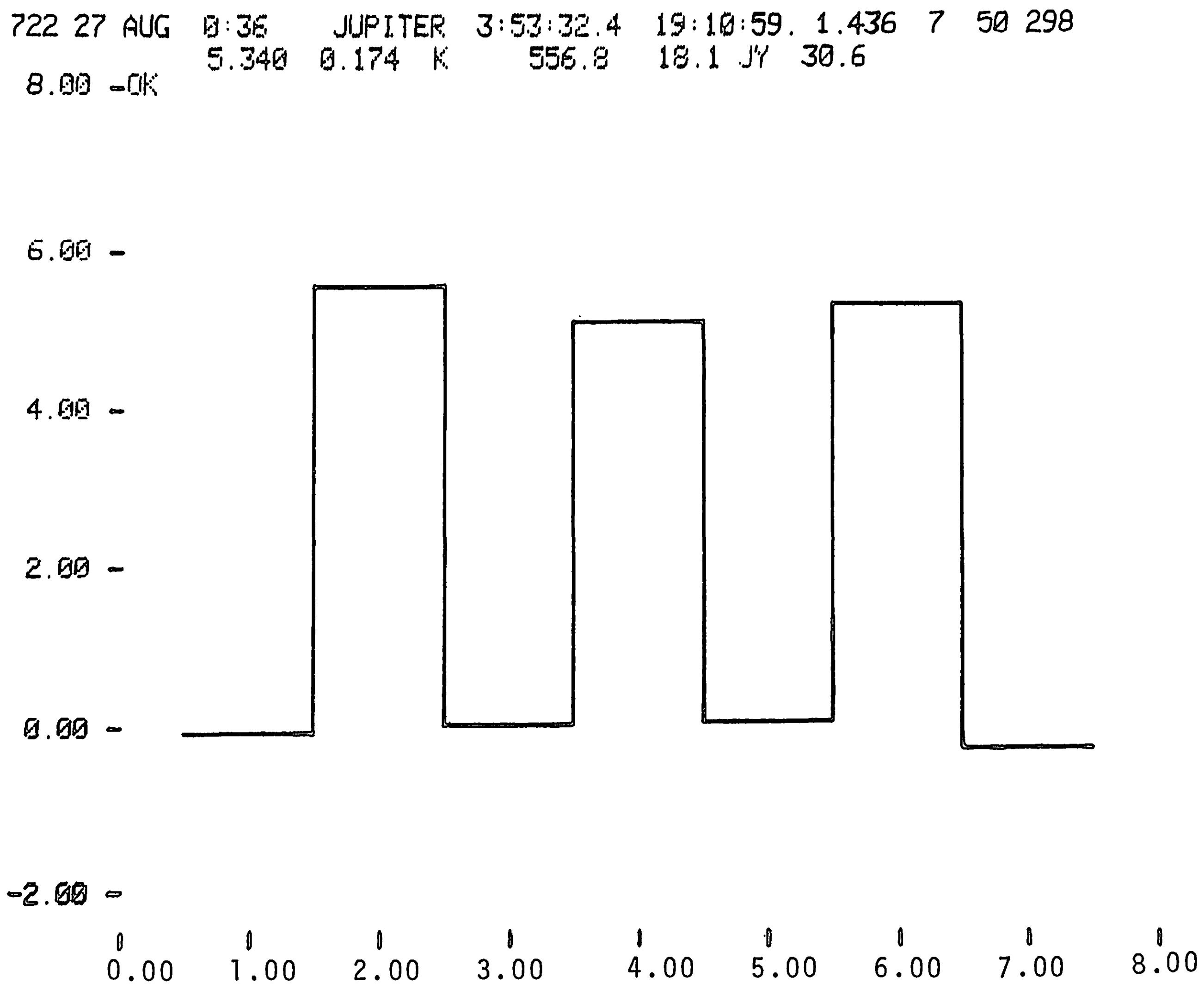
This verb causes a <LOG> to be performed on the contents of the scan table and the results printed out; additionally a COMBINE and subsequent AVG is performed on the contents of the scan table, the resultant graphics displayed and the AVG information printed out. A HEAD is also printed out for the first scan in the scan table. See additionally <LOG>, COMBINE, AVG and HEAD in this section. To manipulate the contents of the scan table, see the section entitled "Using the Scan Table" in this chapter. An example follows on a succeeding page.

18. THUMB cr

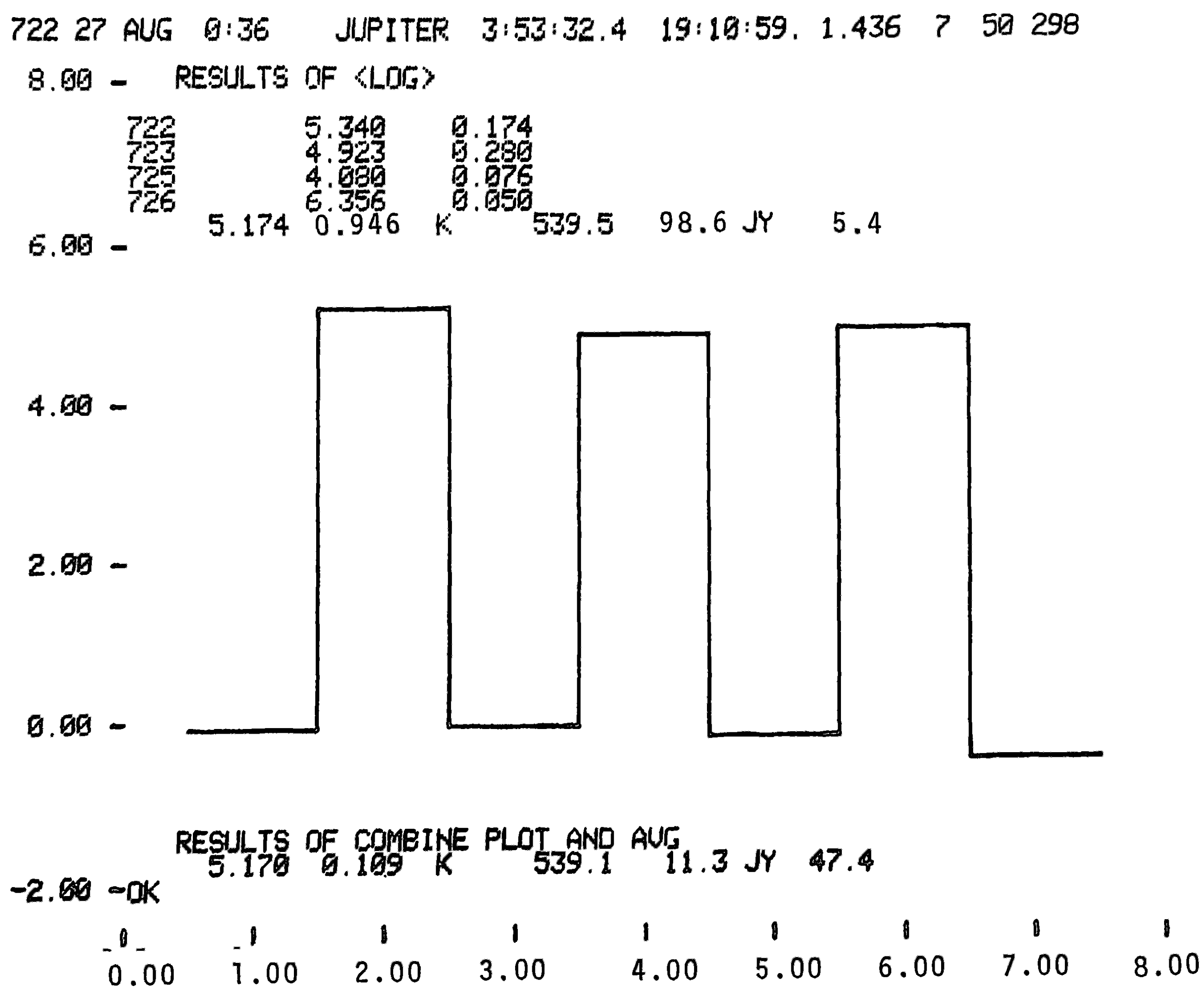
This verb prints out the values of AZ, EL, RA and DEC offsets that the program is currently using for data taking.

19. n TIP cr

This verb causes the EXTINCTION data scan n to be properly displayed in the LINE plotting mode with axes and labels and the raw data printed out by the PRINT function. Additionally, the raw data is iteratively fit six times, the fit results printed out and the fitted data drawn in the HISTOGRAM plotting mode. See LINE, PRINT and HISTOGRAM in this section. For more information see the section entitled "EXTINCTION Data Reduction Procedure" in this chapter.



Example: 722 S


722 27 AUG 0:36 JUPITER 3:53:32.4 19:10:59. 1.436 7 50 298
RESULTS OF <LOG>
722 5.340 0.174
723 4.923 0.280
725 4.080 0.076
726 6.356 0.050
5.174 0.946 K 539.5 98.6 JY 5.4
RESULTS OF COMBINE PLOT AND AVG
5.170 0.109 K 539.1 11.3 JY 47.4
-2.00 -OK
8.00
6.00
4.00
2.00
0.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00

SUM Example

K. Using the Scan Table

1. The stacking words specify which scans you want to see in the off-line display. They manipulate an array of scan numbers called the scan table. All operations are performed at the Tektronix.

2. To empty the table, type

   EMPTY cr

3. To list the scan numbers in the table, type

   STACK cr

   There is a limit of 50 scans in the table.

4. To add a scan to the table, type

   503 A cr

5. To specify that a scan is an OFF, make its scan number negative. Thus,

   503 A -504 A cr

   adds 503 and 504 to the stack, 503 as on ON, 504 as an OFF.

6. Two abbreviations (+N, and ADD) are helpful when adding a contiguous sequence of scans:

   (a) +N adds the next scan to the stack. Thus,

   800 A +N cr

   is an abbreviation for

   800 A 801 A cr

   (b) n ADD adds the next n scan numbers:

   800 A 10 ADD cr

   gives 800 801 802 .... 810 in the scan table.

7. To delete an individual scan from the scan table, type

   504 DELETE cr

   and it will delete scan 504 and print out those scans that remain in the scan table.

8. Placing a scan in the table does not in any way affect its status on disk or tape. It does allow you to use the various data reduction techniques such as COMBINE, F, and <LOG>.

L. EXTINCTION Data Reduction Procedure

1. The EXTINCTION data reduction program fits an equation of the following form to the data from an atmospheric tipping scan:

   TRS + TA {1 - exp(-sec(z) * ATTN/1000}

   where TRS is the temperature of the receiver plus spillover; TA is the mean temperature of the atmosphere; z is the zenith distance in degrees; ATTN is the atmospheric attenuation at the zenith and is described in the section entitled "CONTINUUM Observing Vocabulary" in this chapter. The results of the fitting procedure will determine converged values of TRS and ATTN if the raw data is reasonable.

2. To obtain and use the EXTINCTION fitting routine at the Tektronix terminal, perform the following:

   (a) CONTINUUM LOAD cr

   (b) Set TA

   n TA ! cr

   where n is the value of the temperature in Kelvins. A default value of n = 245 is normal for a Cassegrain receiver; a value of 200 should be used for n for the prime focus receiver. To query TA, type

   TA ? cr

   (c) Recall the EXTINCTION data scan n by typing

   n S cr

   (d) Set an initial guess for ATTN

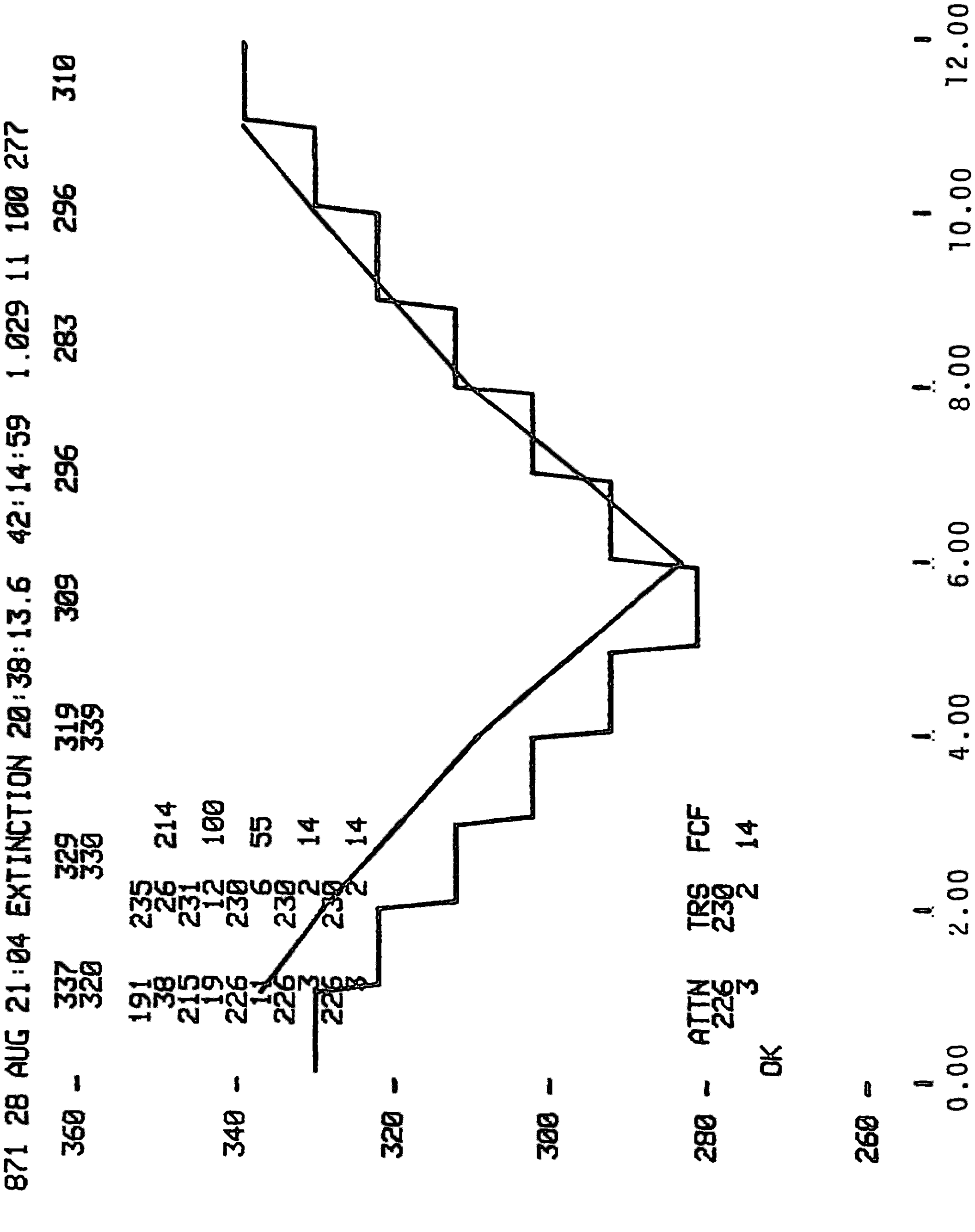
   100 ATTN !

   This will set 10% attenuation, for example.

   (e) Fit the data of scan n by typing

   n TIP cr

   An example of TIP follows on the next page. In the example the values of ATTN and TRS are shown with their respective errors below them; FCF refers to the fit confidence factor and is related to the sum of the squares of the fit residuals.



Example: 871 TIP

M. FIVE Data Fitting

1. After you have completed a sequence of 5 scans about a source (FIVE), you may fit a two-dimensional gaussian beam to the data. It uses an equation of the following form

$$T_i = T_{peak} \ \exp\left[-.693\{(\Delta AZ_i/HP_{az})^2 + (\Delta EL_i/HP_{el})^2\}\right]$$

where T_{peak} is the final fitted peak temperature in Kelvins.

$T_i = T_N, T_S, T_C, T_E$, or T_W

ΔAZ_i = AZ difference from peak to i in arc seconds

ΔEL_i = EL difference from peak to i in arc seconds

HP_{az} = Half the HPBW in AZ in arc seconds

HP_{el} = Half the HPBW in EL in arc seconds

2. To obtain and use the FIVE fitting routines at the Tektronix terminal, perform the following:

(a) CONTINUUM LOAD cr

(b) Fit and display the FIVE data by typing

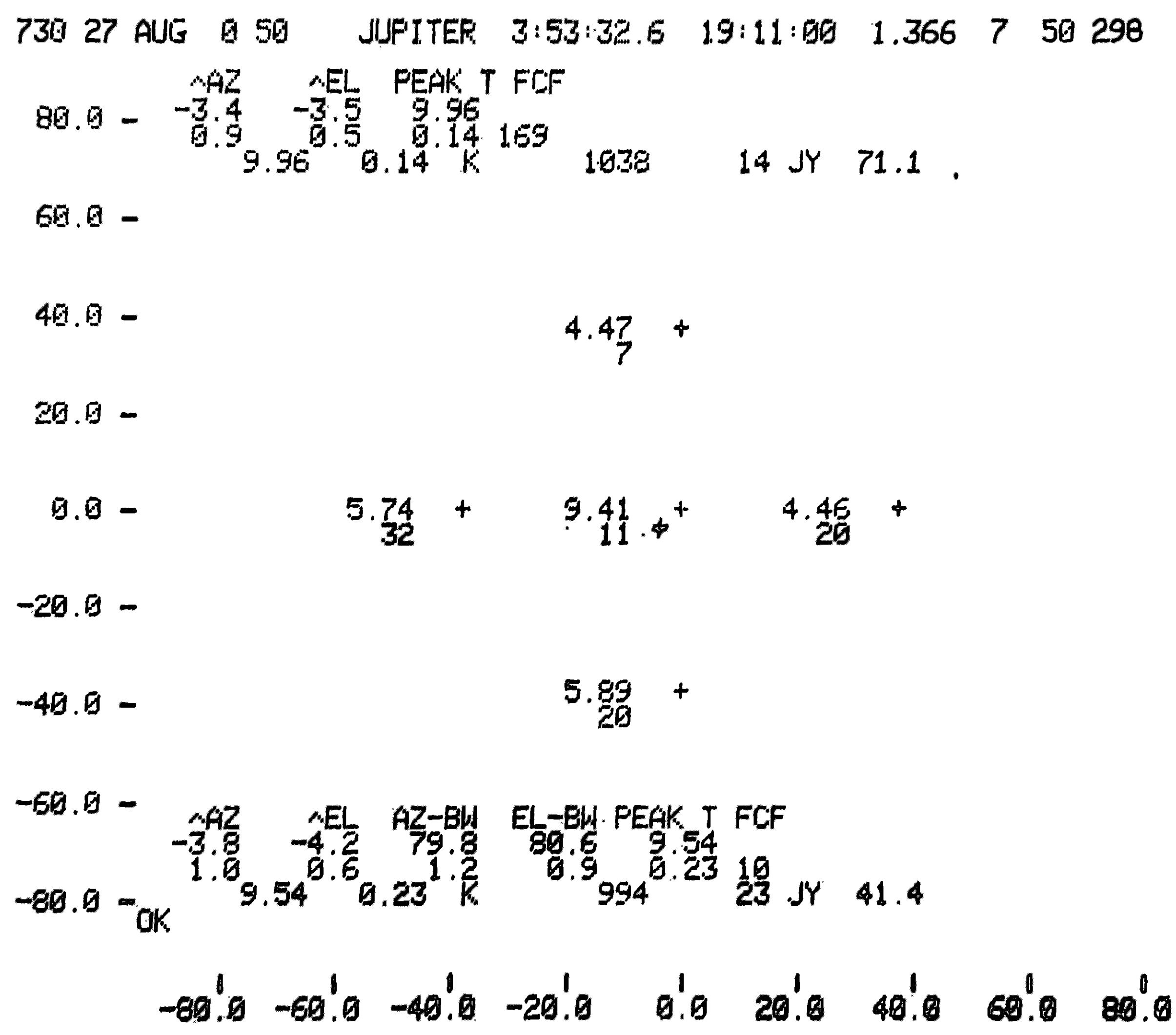
n F

where n is the scan number of the center scan in the FIVE data observations. First the mean temperature, TAV, and its error, TAV-RMS, are displayed for each scan in the FIVE on a graphic representation of the sky in azimuth and elevation offset coordinates. Then a two-dimensional gaussian is fit using the equation in 1. above with the constraint

$$HP_{az} = HP_{el} = HP$$

The results of the fit are printed out; the values of ΔAZ, ΔEL, T_{peak} are shown with their respective errors below them; also shown is the fit confidence factor (FCF) which is related to the sum of the squares of the fit residuals. Next another two-dimensional gaussian fit is performed with no restrictions on the beam widths. This time additional information about the full beam width is printed out.

(c) An example of the verb F follows on the next page.



Example: 730 F

N. FOCALIZE Data Reduction Procedure

1. To analyze the FOCALIZE data scan taken at the teletype, one must use the Tektronix with the CONTINUUM LOAD program loaded.

2. Type

   n FOCALIZE cr

   where n is the scan number of the FOCALIZE scan.

3. Performance of 2. above causes the data to be plotted out and a 3 point parabolic fit to be applied to the data maximum and the two data points on either side of the maximum to arrive at a best FØ. An example follows on the next page.

4. One may fit any 3 successive points of the data if necessary by selecting the first point (B) and typing the phrase ?FØ (example):

   n B ! ?FØ cr

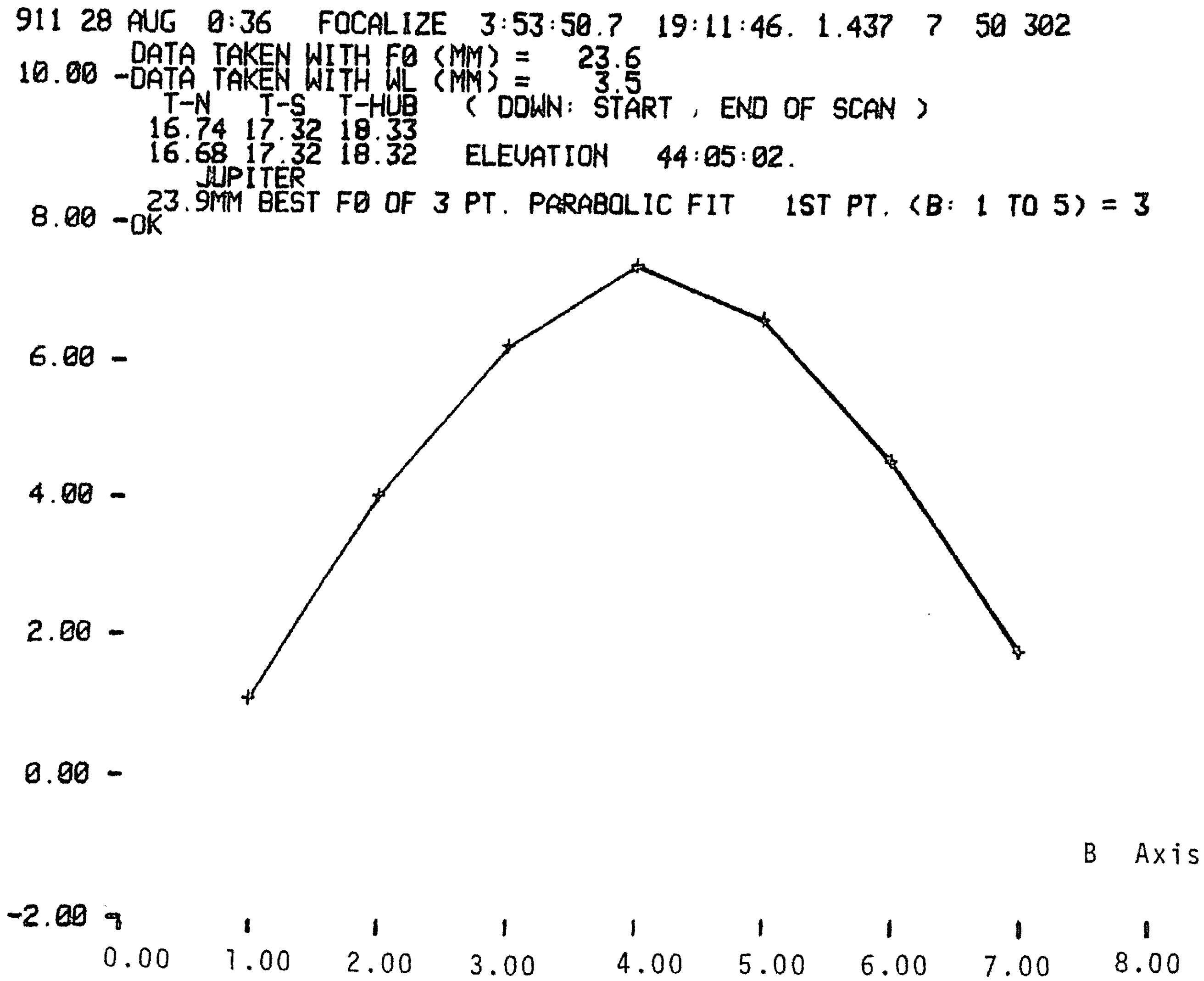
   where $1 \leq n \leq 5$.

5. The 3 point parabolic fit is accomplished by determing a and b of the equation

$$TA = a\ (F\emptyset)^2 + b\ (F\emptyset) + c$$

   and then solving for the extremum in the equation

$$d(TA)\ /\ d(F\emptyset) = 2a\ (F\emptyset) + b = 0$$



Example: 911 FOCALIZE

VIII. MAPPING Program

A. MAPPING Program Introduction

1. CONTINUUM and MAPPING Programs' Common Features:

There are several features common to both the CONTINUUM Program and the MAPPING Program. In the interest of avoiding duplicating documentation, the following is a list of sections in the CONTINUUM Program chapter of this manual that apply to the MAPPING Program:

(a) VII. A. CONTINUUM Observing Vocabulary
(b) VII. B. Radiometer Connection
(c) VII. C. CONTINUUM/MAPPING Signal Processing
(d) VII. D. CONTINUUM/MAPPING Data Scale Factor
(e) VII. E. CONTINUUM/MAPPING Header Variables Recorded on Disk (and Binary Tape)
(f) VII. F. Calibration Procedure
(g) VII. G. EXTINCTION Data Taking Procedure

2. Features of MAPPING Observations:

In the following explanation of the general features of the MAPPING Observations, some parameters and command words are inserted for the reader's benefit so that he may refer to the more detailed explanation of these words in the MAPPING Program Vocabulary section.

The vocabulary loaded at the teletype with MAPPING LOAD provides a flexible means of making rectangular raster scans about a source. The source position is specified in the normal way (see Telescope Tracking Information); for an extended source it should be the center position. The observer must specify the size of a single integration box in seconds of arc (CELL), the dimensions of the raster in boxes (GRID), the scanning angle (SA), and the integration time in each box in tenths of seconds (SEC). The scanning angle may be set in degrees; 90^{o} gives a map in right ascension, 0^{o} gives a map in declination. HORIZONTAL will cause the SA to be computed so that the scan lines are parallel to the horizon; VERTICAL will set the SA so that the scan lines are perpendicular to the horizon.

The telescope moves continuously through the raster; its scanning rate is computed by the program so that the specified amount of integration time is used moving through each box. When the end of a scan line is reached, the telescope will move back as rapidly as possible to the beginning position of the next line in the MAP, HMAP, or VMAP mode. During this "flyback" phase, no data is taken. The later pages in this chapter show the scanning patterns for several types of maps, showing the antenna motion and the interpretation of the scanning angle.

B. MAPPING Observing Vocabulary

The CONTINUUM Observing Vocabulary in chapter VII applies also to the MAPPING Program with the exceptions of the words FIVE, FOCALIZE, NS, HP, RPT and SEQUENCE. In addition the list of observing nouns and verbs which follow apply only to the MAPPING Program and are to be used by the operator at the teletype for ultimately obtaining continuum mapping data.

1. CELL

This noun is the size of a single mapping sample box and is in units of arc minutes and seconds. For example, to set the size of the box to 1 minute 30 seconds of arc, type

1:30 CELL ! cr

and to query the value set, REFRESH the TV screen and observe its value.

2. n m GRID cr

This verb sets the number of rows (n) and number of columns (m) in the sample grid. If the one-dimensional Fourier transform data reduction package is to be used, set n to 1 and m to a power of 2 less than or equal to 256. To produce a two-dimensional map of 3 rows and 4 columns, for example, type

3 4 GRID cr

and to query the values set, REFRESH the TV screen.

3. HORIZONTAL cr

This verb calculates the proper value for SA (described below) such that a subsequent map made using the verb MAP will move the telescope parallel to the Horizon. The calculation is for one point in time and does not update itself as time progresses. See also HMAP and SA. To see the value computed by HORIZONTAL, REFRESH the TV screen.

4. NR

This noun denotes the number of scan numbers (blocks on disk or records on tape) to be used for a map. It is automatically set when GRID is used. To query NR type

NR ? cr

after having used GRID. The value of NR is the scan number increment. For example, if the present scan in progress is 608 and NR is 5, then the next scan will be 613.

5. n MAP, n HMAP, n VMAP

   These verbs allow n maps to be performed on a source. HMAP and VMAP have been defined to preclude the operator from having to type HORIZONTAL and VERTICAL, respectively, before each map in the series of n maps.

6. SA

   This noun is the scanning angle for a map. See the section entitled "MAPPING Scanning Angle (SA) Convention" in this chapter for more information. See also HORIZONTAL and VERTICAL in this section. To manually set a scanning angle of 10 degrees and 30 minutes, type

   ```
   10:30    SA    cr
   ```

   and to query the set parameter, REFRESH the TV screen.

7. VERTICAL cr

   This verb calculates the proper value for SA (described above) such that a subsequent map made using the verb MAP will move the telescope perpendicular to the Horizon. The calculation is for one point in time and does not update itself as time progresses. See also VMAP and SA. To see the value of SA computed by VERTICAL, REFRESH the TV screen.

C. Source Position Angle (PA)

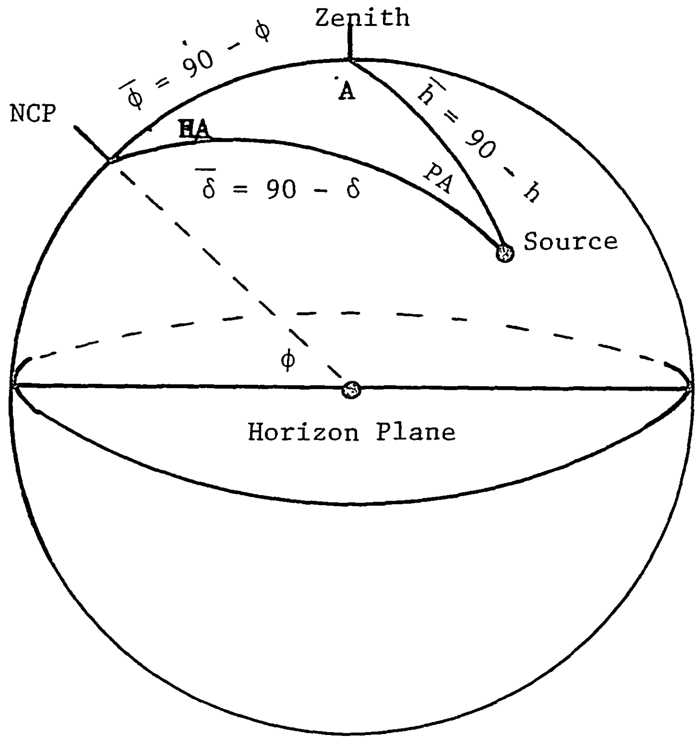
1. The angle between constant elevation and constant declination is the position angle (PA) of the source. The value of the position angle can be obtained from either of the expressions

$$\sin PA = \frac{\cos \phi \sin A}{\cos \delta}$$

or

$$\cos PA = \frac{\sin \phi - \sin \delta \sin h}{\cos \delta \cos h}$$

where ϕ is the latitude, δ is the declination of the source, and h is the elevation angle of the source. The above relations can be obtained from the spherical triangle shown:



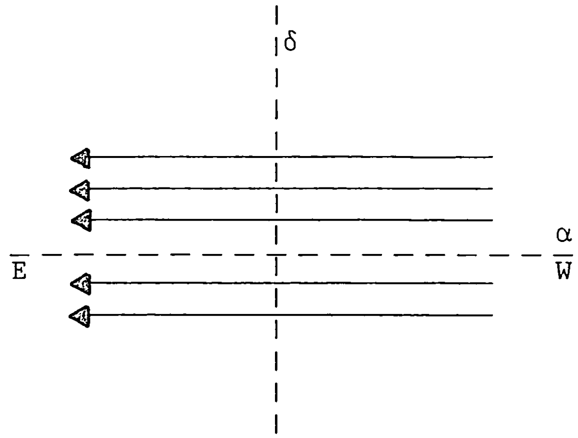
2. The MAPPING Program uses PA whenever HMAP, VMAP, HORIZONTAL or VERTICAL commands are used. For example, if you set the position angle of the source into the program scanning angle (SA) by typing

HORIZONTAL cr

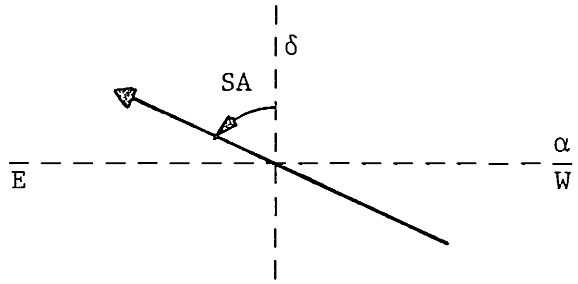
a subsequent MAP scan will perform its raster oriented parallel to the horizon (i.e., a scan in azimuth). Do not confuse the position angle of the source (PA) with the MAPPING program scanning angle (SA) variable. There is a difference.

D. <u>MAPPING Scanning Angle (SA) Convention</u>

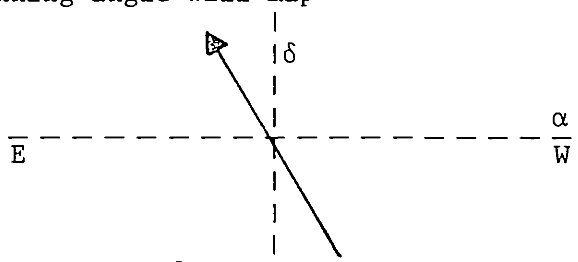
1. A 90^o scanning angle will produce rows in right ascension separated in declination.



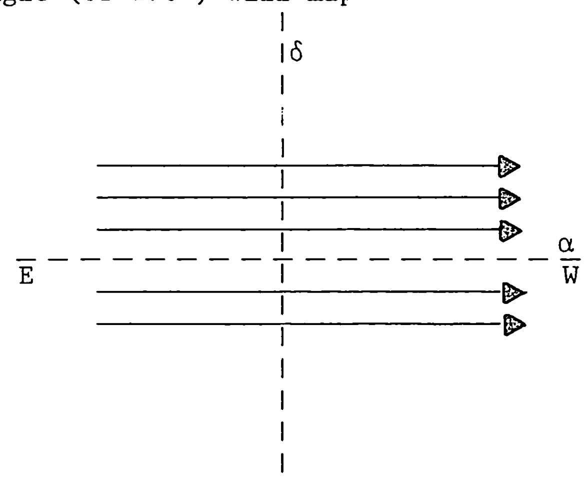
2. The scanning angle measures the tilt of rows to the declination axis.



3. A 30^o scanning angle will map

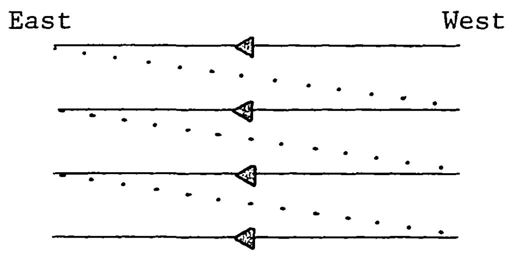


4. A -90^o angle (or 270^o) will map



E. <u>How MAPPING Takes and Records Data</u>

1. For a two-dimensional map with a scanning angle of 90:00, the telescope will scan as shown:



Data will be taken only on the sold lines; the dashed lines denote the flyback phase of the telescope.

2. Data is always recorded in one long array under one scan number using as many blocks as necessary. Additionally, the data is recorded in the order in which the data was taken. Depending on the length of the map, the next scan number may not be consecutive.

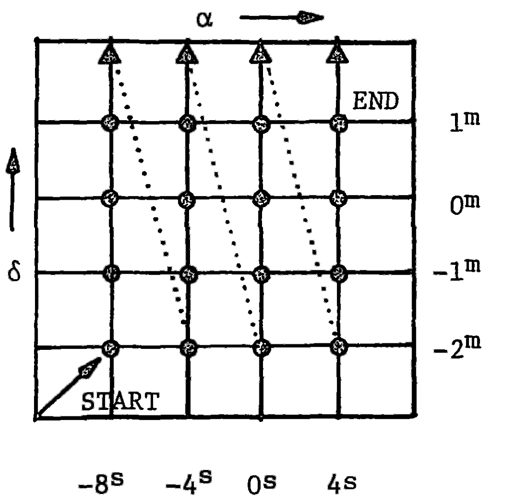
3. For a MAPPING scan, the TV screen will display the RA-DEC offsets only if the integration time of an individual sample is 5 seconds (SEC = 50) or larger. In 4. which follows, various two-dimensional mapping examples are shown. The offsets that would be displayed on the TV screen are denoted by solid circles in the examples.

4. MAPPING Examples

(a) 1 MAP with the following conditions:

```
 4  4   GRID
1:00    CELL  !
0:00    SA
```

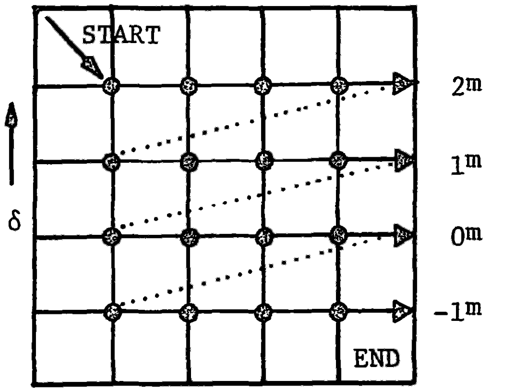
The program continually takes data along the solid arrows.



(b) 1 MAP with the following conditions:

```
  4  4   GRID
 1:00    CELL  !
90:00    SA
```

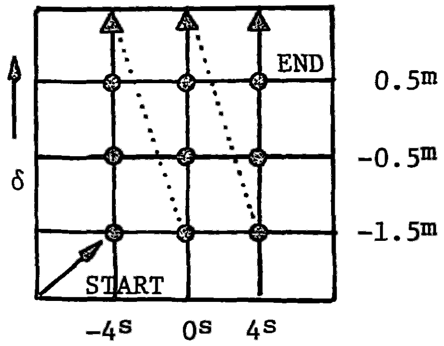
The program continually takes data along the solid arrows.



(c) 1 MAP with the following conditions:

```
 3  3   GRID
1:00    CELL  !
0:00    SA
```

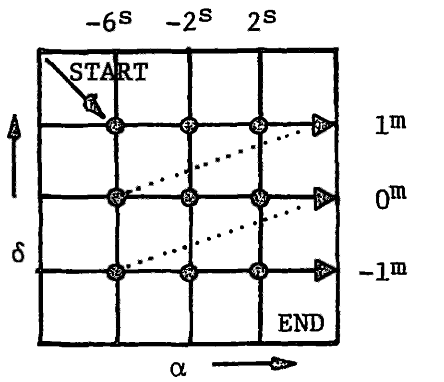
The program continually takes data along the solid arrows.



(d) 1 MAP with the following conditions:

```
  3  3   GRID
 1:00    CELL  !
90:00    SA
```

The program continually takes data along the solid arrows.



F. MAPPING Display and Data Analysis Routines Available

1. There are two vocabularies available at the Tektronix terminal for displaying and analyzing data taken with the MAPPING observing routines:

   (a) FOURIER is designed for one-dimensional maps. It includes the ability to display maps at various scales and do Fourier transforms.

   (b) MAPPING is designed to draw perspective views and contour maps from two-dimensional data.

2. These routines are described in the following pages. To obtain either, type

```
FOURIER      LOAD      cr
              or
MAPPING      LOAD      cr
```

G. MAPPING LOAD Data Display Vocabulary

A list of common data display nouns and verbs follow which are to be used by the observer at the Tektronix terminal for displaying the mapping continuum data previously recorded on the disk.

1. DIST

This noun allows one to change the view distance of those graphics provided by KONTOUR and PLOT, both described in this section. To query DIST one types

```
DIST   ?   cr
```

and to set DIST to a diifferent value n, type

```
n   DIST   !   cr
```

The default value for DIST is 2048. If DIST is reset, one must replot the contour or perspective view.

2. KONTOUR   cr

This verb draws a two-dimensional contour map of mapping scan n. The plotting order reflects the data acquisition order. The proper sequence of commands for obtaining such a display is

```
90    PITCH    0    YAW    cr
n    RECALL                cr
m    SPACE    !            cr
ℓ    h    LEVEL            cr
AXES                       cr
KONTOUR                    cr
```

PITCH, YAW and RECALL are described in this section. The noun SPACE is set to the desired contour spacing (m). The verb LEVEL allows map clipping such that no contours will be plotted outside the range of ℓ (low) and h (high) integers. An example follows on a succeeding page.

3. n   MAP   cr

This verb will cause mapping data scan n to be displayed graphically on the Tektronix screen. For either two or one-dimensional data, the data displayed will be plotted across the screen in the order recorded at data taking time. One has to first set the vertical RANGE for the data which can be estimated from the results of MAP-PRINT before using the MAP verb. Both MAP-PRINT and RANGE are described in this section. An example of MAP follows on a succeeding page.

4. n MAP-PRINT cr

This verb will cause the values of all data points in mapping scan n to be printed out (eight values per line) in the order recorded at data taking time. Maximum and minimum values may be used to set RANGE for the MAP command; both RANGE and MAP are described in this section.

5. n PITCH m YAW cr

These verbs set the integer viewing angles n and m for perspective maps. A value of Ø PITCH gives an edge-on view from the side. A value of Ø YAW gives a view from the back. A nice oblique view for PLOT would be 30 PITCH 30 YAW. For KONTOUR maps one must set 90 PITCH 0 YAW. Both PLOT and KONTOUR are described in this section.

6. PLOT cr

This verb draws a perspective view consisting of slices through data scan n. The plotting order reflects the data acquisition order. The proper sequence of commands for obtaining such a display is

```
m   PITCH   0   YAW   cr
n   RECALL            cr
ℓ   h   RANGE         cr
AXES                  cr
PLOT                  cr
```

PITCH, YAW, RECALL, RANGE and AXES are described in this section. An example follows on a succeeding page.

7. Plot Options

(a) PAGE cr

This verb erases the screen and positions the cursor at the upper left hand corner.

(b) AXES cr

This verb will provide horizontal and vertical axes for the data displayed.

(c) LABEL cr

This verb will print out the physical quantities of the axes displayed by AXES.

(d) FULL GRID cr

This verb will draw a rectangular grid on the screen.

8. n m RANGE cr

This verb allows the observer to select the vertical axis of a PLOT. The integer numbers n and m are the minimum and maximum vertical axis range values desired.

9. n RECALL cr

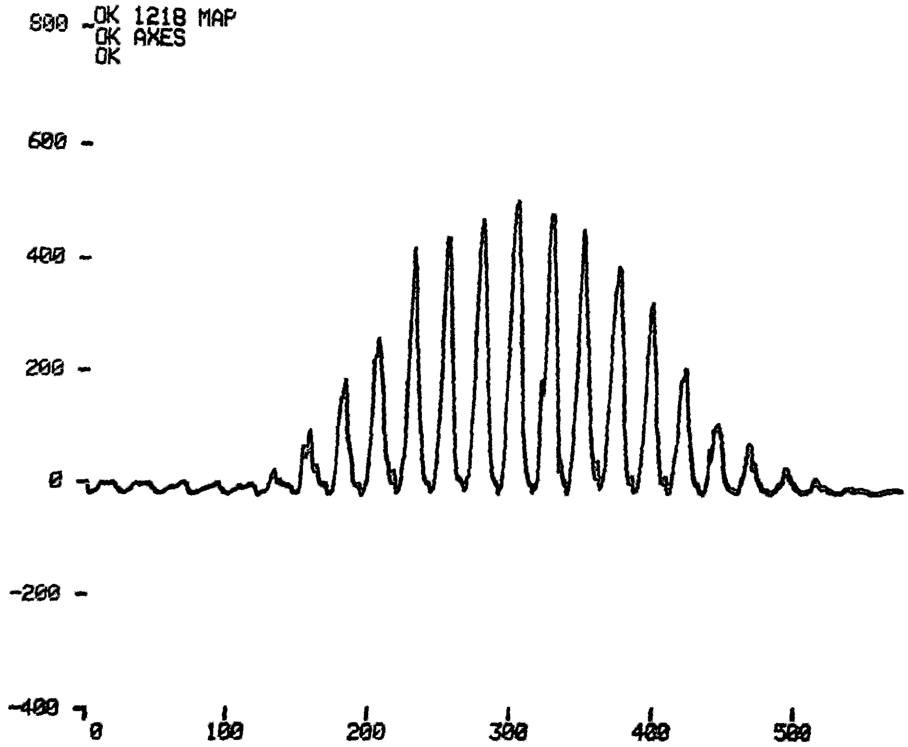
This verb does not display any data but does set up the data for mapping scan n properly for subsequent use by the verbs PLOT and KONTOUR, both described in this section.

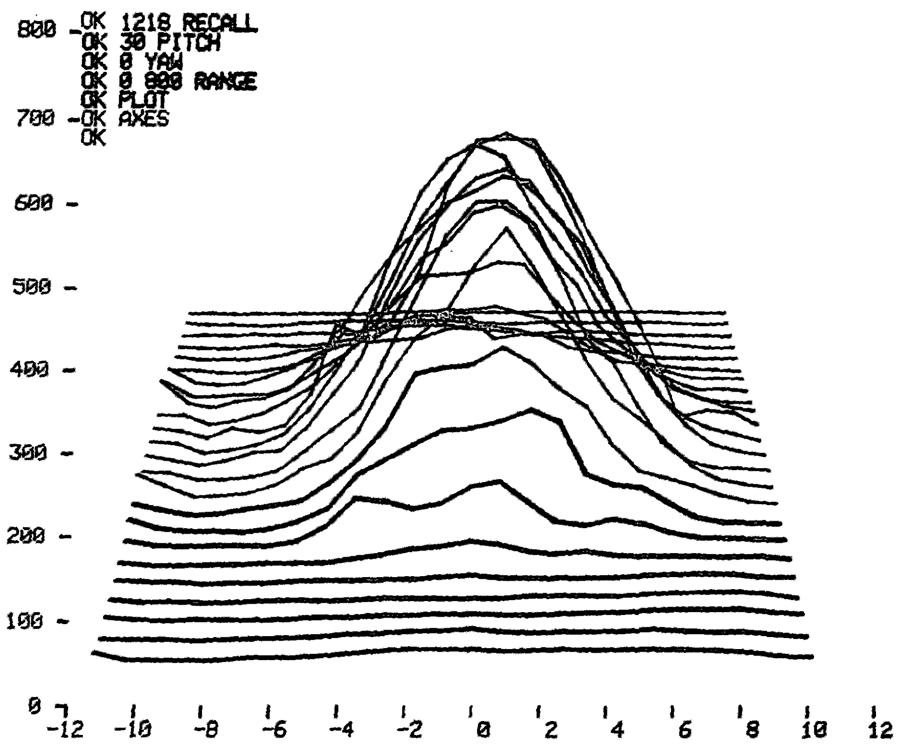
10. SNAP cr

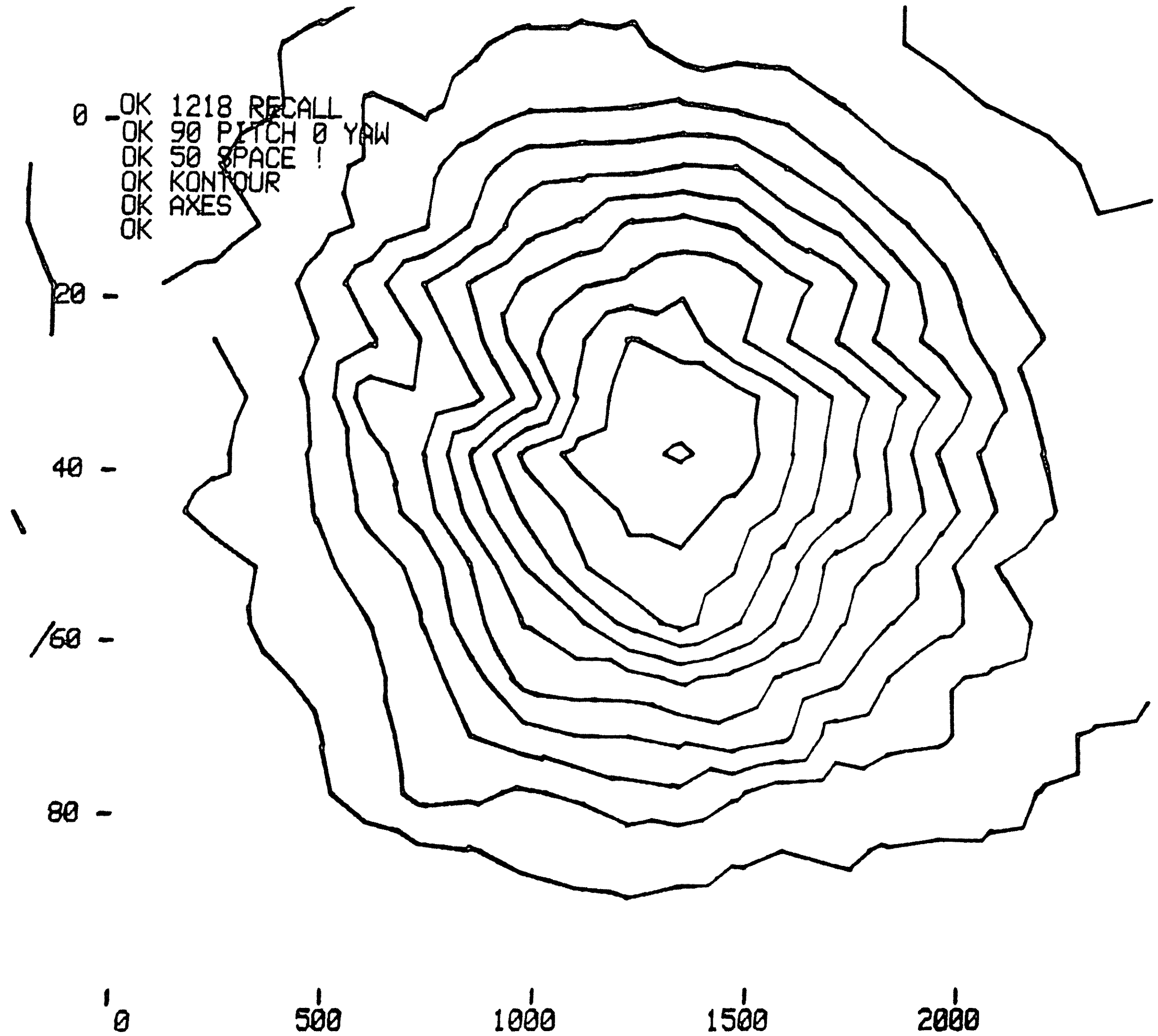
This verb may be used anytime to take an instantaneous picture of the TV screen.

11. THUMB cr

This verb prints out the values of AZ, EL, RA, and DEC offsets that the program is currently using for data taking.


OK 1218 MAP
OK AXES
OK
800
600
400
200
0
-200
-400
0
100
200
300
400
500


OK 1218 RECALL
OK 30 PITCH
OK 0 YAW
OK 0 800 RANGE
OK PLOT
OK AXES
OK
800
700
600
500
400
300
200
100
0
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12


OK 1218 RECALL
OK 90 PITCH 0 YAW
OK 50 SPACE !
OK KONTOUR
OK AXES
OK
0
20
40
60
80
0
500
1000
1500
2000

H. FOURIER LOAD Data Reduction Vocabulary

A list of common data reduction nouns and verbs follow which are to be used by the observer at the Tektronix terminal for displaying and processing continuum data by Fourier analysis previously recorded on the disk.

1. AVERAGE   cr

   This verb allows one to display the difference between the average of those scans in the scan table which do not have a minus sign and the average of those scans in the scan table which have a minus sign. The averages are weighted by integration time. To manipulate the contents of the scan table, see the section entitled "Using the Scan Table" in this chapter.

2. COMBINE   cr

   This verb allows one to display the average of those scans in the scan table. For such an operation no scan in the scan table should have a minus sign. The average is weighted by the integration time. To manipulate the contents of the scan table, see the section entitled "Using the Scan Table" in this chapter.

3. 1 FFT EXAMINE   cr

   This active phrase causes the Fourier transform to be computed and displayed for the data last recalled using the RECALL function described also in this section. That is, the phrase transforms from the X,Y to the U,V plane. One may follow the above phrase with

   -1 FFT EXAMINE   cr

   to obtain the inverse transform. RECALL puts data in a work storage area and the use of FFT operates on these data and replaces it. To see the original data you must RECALL it again, thus destroying the results of FFT. An example of 1 FFT EXAMINE follows on a succeeding page.

4. Plot Options

(a) PAGE cr

This verb erases the screen and positions the cursor at the upper left hand corner.

(b) PLOT cr

This verb will replot the data currently in the plot buffer.

(c) PRINT cr

This verb will print out the values of the function plotted, eight values per line.

(d) AXES cr

This verb will provide horizontal and vertical axes for the data displayed by PLOT.

(e) LABEL cr

This verb will print out the physical quantities of the axes displayed by AXES.

(f) FULL GRID cr

This verb will draw a rectangular grid on the screen.

(g) HISTOGRAM, POINTS, LINE

These verbs allow selection of the desired plotting mode. The program will stay in one plotting mode until another mode is selected by the user.

5. n m RANGE cr

This verb allows the observer to select the vertical axis on all future plots. The integer numbers n and m are the minimum and maximum vertical axis range values desired.

6. n RECALL cr

This verb will graphically display the data of scan n. For more information to augment the display see "Plot Options" in this section. An example of RECALL follows on a succeeding page.

7. SMOOTH

This verb will apply a seven-point smoothing function to the data in the plot buffer. The default value of this function is a three-point boxcar function (i.e., 0, 0, 33, 34, 33, 0, 0) which can also be obtained by typing

BOXCAR cr

Additionally, a three-point Hanning smoothing function (i.e., 0, 0, 23, 54, 23, 0, 0) can be selected by typing

HANNING cr

8. SNAP cr

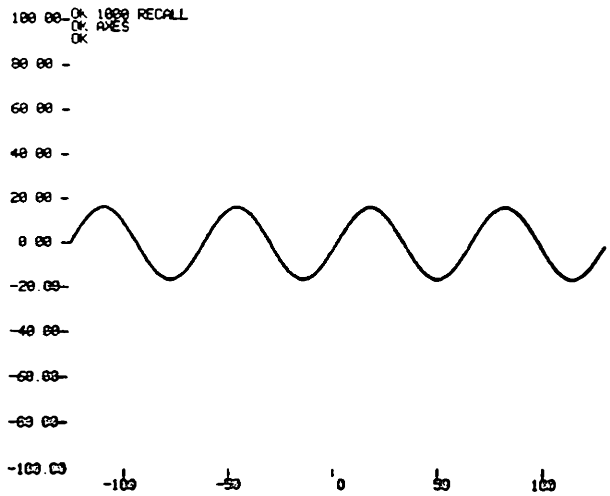
This verb may be used anytime to take an instantaneous picture of the TV screen.

9. THUMB cr

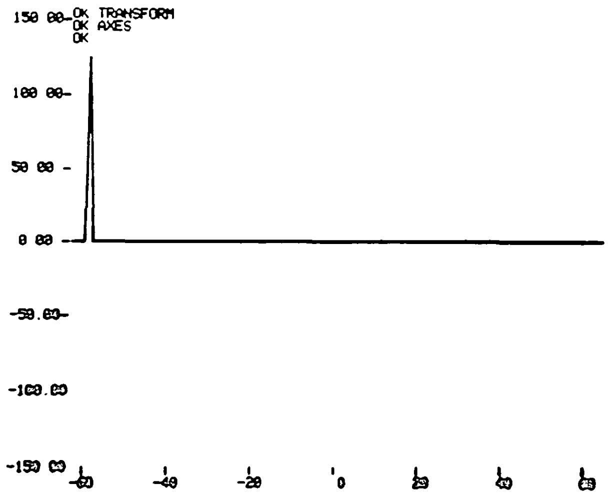
This verb prints out the values of AZ, EL, RA, and DEC offsets that the program is currently using for data taking.

10. TRANSFORM cr

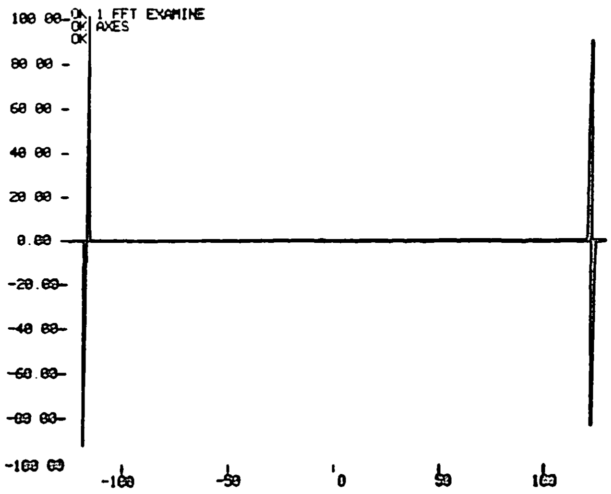
This verb computes and plots the power spectrum of the data last recalled using the RECALL function described also in this section. The number of points plotted will be half the number of points in the original data. RECALL puts data in a work storage area and TRANSFORM operates on these data and replaces it. To see the original data you must RECALL it again, thus destroying the transform. An example of TRANSFORM follows on a succeeding page.



OK 1000 RECALL
OK AXES
OK
100 00
80 00
60 00
40 00
20 00
0 00
-20.00
-40 00
-60.00
-80 00
-100.00
-100
-50
0
50
100



OK TRANSFORM
OK AXES
OK
150 00
100 00
50 00
0 00
-50.00
-100.00
-150 00
-60
-40
-20
0
20
40
60



OK 1 FFT EXAMINE
OK AXES
OK
100 00
80 00
60 00
40 00
20 00
0.00
-20.00
-40 00
-60.00
-80 00
-100 00
-100
-50
0
50
100

IX. SPECTRA Program

A. SPECTRA Observing Vocabulary

A list of observing nouns and verbs follow which are to be used by the operator at the teletype for ultimately obtaining spectral line data.

1. ATTN

This noun is the atmospheric attenuation in tenths of percent at the zenith. When ATTN is non-zero it will scale all data up by the factor

exp {sec (z) * ATTN/1000}

where z is the zenith distance to the source in degrees. When observing while using CHOPPER or VANE Calibration methods, ATTN should be set to zero since these calibration methods inherently correct the data for the effects of atmospheric attenuation. However, for NOISE or NO-CAL methods, ATTN may be set to its proper non-zero value (based on the CONTINUUM Program tipping scan data) to account for atmospheric attenuation if the observer desires. For example to set ATTN to 12.5%, type

```
125    ATTN    !    cr
```

and to query the set value type

```
ATTN    ?           cr
```

Also see section F.6 in this chapter for additional information concerning ATTN.

2. BW, #CH, CHØ

These nouns correspond to the filter bank information on the TV screen and are, respectively, the filter bank channel resolution in kHz, the number of channels in the filter bank, and the starting channel number of the filter bank as it relates to the 512 channel multiplexer. To set and query these nouns see the section entitled "Selecting Filter Bank Parameters" in this chapter.

3. CALIBRATE   cr

This verb causes a spectral line calibration to be performed. The nouns CRPT and CSEC relate to CALIBRATE and are described below. See the sections entitled "SPECTRA Calibration Options" and "SPECTRA Calibration and Observation Data Recording" in this chapter for details of various calibration methods. For meaningful data a CALIBRATE should always be performed when the program is reloaded for any reason.

4. CRPT

This noun is the number of ON-OFF pairs in a VANE Calibration. See also the section entitled "SPECTRA Calibration Options" in this chapter. For example, to set CRPT to 10 type

```
10    CRPT    !    cr
```

and to query the set value type

```
CRPT    ?    cr
```

5. CSEC

This noun is the number of tenths of seconds to be spent integrating on an individual sample in a CALIBRATE. For example, to set CSEC to 30 seconds, type

```
300    CSEC    !    cr
```

and to query the set value type

```
CSEC    ?    cr
```

6. Date Setting

It is of paramount importance to enter the day's date, as soon as the current observation allows, after Ø hours Universal Time (5 PM MST) before another synthesizer setting is calculated by performing a REFRESH. Our program computes today's and tomorrow's velocity of the earth in its orbit upon entering the date. When a REFRESH is performed, the UT clock is read and the velocity of the earth in its orbit is interpolated from those values calculated at date change time. Those parameters necessary for the computation of the earth's rotation velocity are computed every second by the tracking program. For example, to set the date type

```
n    OCT    cr
```

where n is the correct day number based on Universal Time. Standard first 3 letter abbreviations for months apply except for December which is designated DCM.

7. DUT1

The noun DUT1 may be regarded as a correction to be added to coordinated Universal Time (UTC) to obtain a better approximation to the mean solar time of the prime meridian obtained from direct astronomical observations which have been corrected for small movements of the earth relative to the axis of rotation. These DUT1 corrections are obtained monthly from the Naval Observatory. To set DUT1 to 0.5 seconds type

    500   !DUT1   cr

To query the parameter DUT1, REFRESH the TV screen.

8. EXPEDITE   cr

This verb automatically sets the noun TOL (described below) to a high value. This allows observations to be made without tracking a source. If EXPEDITE is used and normal observations are subsequently resumed, TOL must be reset.

9. FØ

This noun is the temperature independent focus parameter in the empirical focus equation described below for FOCUS. The units of FØ are in tenths of mm. For example, to set FØ at 65.5 mm type

    655   FØ   !   cr

To query FØ, REFRESH the TV screen and observe its value.

10. FILTERS

This noun is the load block number on the disk which contains the software which is equivalent to the hardware set-up for the filter banks. This parameter must be set correctly before SPECTRA is loaded at the teletype. To determine the allowed values of FILTERS, see the section entitled "Operation of Filter Banks in Series or Parallel" in this chapter. For example, to set FILTERS to 288 type

    288   FILTERS   !   cr

and to query the set value type

    FILTERS   ?   cr

11. FOCUS cr

This verb causes the focus of the receiver to be performed via computer control. It can be executed anytime; however, it is automatically done at the beginning of each scan or CALIBRATE before any data is taken. The empirical focus equation, F, in mm units is

$$F = 2.69T_o + 1.36T_1 - 3.82\ T_2 + 1.63 \sin (EL) + F\emptyset$$

where T_o, T_1, and T_2 are the Centigrade temperatures of the antenna North, South, and Center Hub points, respectively; EL is the commanded elevation angle of the telescope and FØ has been previously described above.

12. FREQ

This noun is the rest frequency of the line observation. Its value will be used in the computation of the synthesizer (SYNTH) setting described below. For example, to set a rest frequency of 89.18855 GHz, type

89.18855 FREQ 2! cr

It is necessary to always show exactly 5 decimal places in the setting of this parameter. To query FREQ it is best to REFRESH the TV screen after having set FREQ.

13. FSKY cr

This verb will print out the Doppler corrected frequency (GHz) of the observation in progress.

14. HEADER

This noun refers to the scan number in progress or the next scan to be executed if no scan is currently in progress. The scan number will automatically increment when a scan is completed. Scans increment by 2 if more than 384 channels of the multiplexer are used. Scan numbers start at 500 and can go as high as 2000. To reset the HEADER, for example, to 500 type

500 HEADER !

Be aware that resetting the HEADER parameter to a lower value will cause previous data on the disk to be written over when a data taking observation is performed. To query the reset value of HEADER, REFRESH the TV screen.

15. LO-IF, 1ST-IF

These nouns refer to the Local Oscillator Intermediate Frequency and First Intermediate Frequency, respectively. For more information see the section entitled "SPECTRA Program Frequency Conventions" in this chapter. To set, for example, the LO-IF to 400 MHz and the 1ST-IF to 4750 MHz type

```
 400    LO-IF    !    cr
4750    1ST-IF   !    cr
```

To query the reset values REFRESH the TV screen.

16. MAIN! cr

This verb is used to store the AZ, EL, RA and DEC main beam offsets displayed on the TV screen (usually via the thumbwheel offset panel) correctly into the program. See chapter V for more details.

17. OBS, OPR

These nouns refer to the initials of the observer and operator, respectively. To set, for example, the observer's initials to LES type

```
OBS    INITIALS    LES    cr
```

To query the set value perform a REFRESH of the TV screen.

18. Observing Commands

(a) n APS cr

This verb refers to the absolute position switching data command; the verb causes n scans to be taken where the telescope shifts alternately between two positions on the celestrial coordinate system and the receiver samples at a fixed frequency. Also see the section entitled "Absolute RA-DEC Position Switching" in this chapter for more information.

(b) n BS cr

This verb refers to the beam switching data command; the verb causes n scans to be taken where the telescope is tracking on source but a cycling ferrite switch in the receiver (at a fixed frequency) alternately samples one of two feedhorns at a rate specified by the hardware. Alternatively, instead of the ferrite switch the subreflector can be used to achieve beam switching. The subreflector may be cycled a maximum of ± 2.5 arc minutes at 5 Hz.

(c) n FS cr

This verb refers to the frequency switching data command; the verb causes n scans to be taken where the receiver is on the source but is shifting in frequency at a rate and amount specified by the hardware.

(d) n LS cr

This verb refers to the load switching data command; the verb causes n scans to be taken where the telescope is on source but the receiver (at a fixed frequency) is alternately looking at the source and a load (chopper wheel) at a rate specified by the hardware.

(e) n PS

This verb refers to the position switching data command; the verb causes n scans to be taken where the telescope shifts alternately between two offset positions and the receiver samples at a fixed frequency. See chapter V for a complete description of offsets used by the telescope in the SPECTRA program.

(f) n FS+PS, n BS+PS, n LS+PS

These verbs cause n scans to be taken where FS, BS, or LS, respectively, is combined with PS.

(g) FS-MAP, PS-MAP

These verbs cause a designated source catalog to be automatically observed in either the FS or PS mode. For more information see the section entitled "Spectral Line Mapping" in this chapter.

19. PL-HUSH cr

This verb silences the computer "RECEIVER OUT OF LOCK" alarm for the duration of the scan in progress.

20. RCVR

This noun refers to the spectral line receiver number. See Table 1 in this chapter for a description of receivers available. To set this noun, for example, to 5 type

```
5 RCVR   !   cr
```

and then REFRESH the TV screen to query the set value. Alternatively, one may type

```
5   !RCVR   cr
```

and, in addition to setting 5 into RCVR, you will get all the default values of TS, TC, %EFF, BANDWIDTH, and FØ for receiver 5.

21. REF! cr

This verb is used to store the AZ, EL, RA and DEC reference on the TV screen (usually via the thumbwheel offset panel) correctly into the program. See chapter V for more details.

22. REFRESH cr

This verb causes all current values of parameters to be redisplayed on the TV screen. This action also causes a synthesizer calculation to be performed and the result displayed. See the section entitled "Using the Computer to Determine Synthesizer Setting" in this chapter for more details.

23. RPT

This noun is the number of ON-OFF pairs in a PS type observation (single scan). The total time required for a single scan in tenths of seconds would be

```
RPT    * 2 *    SEC
```

See the explanation of SEC below. To set, for example, 5 ON-OFF pairs for an observation type

```
5    RPT    !    cr
```

24. SB

This noun is the number of the sideband configuration being used in the synthesizer calculation. See the sections entitled "Sideband Parameter Selection" and "Using the Computer to Determine Synthesizer Setting" in this chapter for more details. To set SB to 2, for example, type

```
2 SB    !    cr
```

and to query the set value REFRESH the TV screen.

25. n SCAN SAVE cr

This phrase records a stopped scan n properly on disk and tape.

26. SEC

This noun is the number of tenths of seconds to be spent integrating on an individual sample in a data observation. For example, to set SEC to 30 seconds, type

```
300    SEC    !    cr
```

and to query the set value type

```
SEC    ?    cr
```

27. STOP cr

This verb causes any data taking in progress to cease. Use this word only when absolutely necessary and check the value of TOL after having used STOP.

28. SYNTH

This noun is the value of the synthesizer automatically computed by a REFRESH of the TV screen. The value of the synthesizer displayed on the TV screen is always a computed value and not the value of the synthesizer set into the synthesizer panel by the operator.

29. TC

This noun is the spectral line calibration temperature in tenths of K. To set, for example, TC to 800.0 K type

```
8000     TC     !
```

30. THUMB cr

This verb prints out the values of AZ, EL, RA and DEC offsets stored away in the program by both MAIN! and REF!.

31. T-HUSH cr

This verb silences the computer alarm for observation without a tape unit.

32. TOL

This noun is the maximum RMS tracking error limit in seconds of arc. If the actual tracking error exceeds this limit, data taking ceases until the actual error falls below the limit. To set, for example, a tracking error limit of 10 seconds of arc type

```
10     TOL     !
```

and REFRESH the TV screen to see the value set. The computer sets zero into TOL when the receiver drops out of phase lock to insure that data taking ceases. If you stop a scan during this alarm condition, you must reset TOL.

33. TS

This noun usually represents the value of the average GAINS (see section entitled "SPECTRA Calibration and Observation Data Recording" in this chapter) and is related to the single sideband system temperature for VANE, CHOPPER, and NOISE calibration methods. TS is automatically set at the end of these calibration methods. For NO-CAL TS must be set by the operator to a value measured by hot and cold loads. To set TS to 1200 K type

    1200   TS   !

and to query the value set, REFRESH the TV screen.

34. VEL

This noun is the source velocity in tenths of km/sec with respect to the local standard of rest. See the sections entitled "Automatic Source Velocity Setting" and "Computer Determined Synthesizer Setting and Actual Synthesizer Setting" to see how to set VEL and how the program uses it.

Spectral Line Receivers

(All temperatures are single sideband)

CODE n	FREQ (GHz)	TS (K)	TC (K)	%EFF (%)	RCVR BAND-WIDTH (MHz)	FØ (mm)	NOTES
1	33-50	600	800.0	42	500	28.0	33-50/80-120 GHz Dual Channel Cooled Cassegrain Receiver
2	47	400	800.0	40	200	28.0	47 GHz Dual Channel Cooled Cassegrain Paramp
3	80-120	600	800.0	28	500	28.0	33-50/80-120 GHz Dual Channel Cooled Cassegrain Receiver
4	80-120	600	800.0	28	500	28.0	80-120/127-174 GHz Dual Channel Cooled Cassegrain Receiver
5	127-174	2000	800.0	18	500	28.0	127-174 GHz Dual Channel Cooled Cassegrain Receiver
6	31-116	1500	800.0	38	100	37.0	Old NRAO Prime Focus Line Receiver
7	---	--	--	--	---	--	Any Other NRAO Receiver
99	---	--	--	--	---	--	User's Own Receiver

Table 1: Setting Spectral Line Receiver Default Parameters: n !RCVR

B. Automatic Source Velocity Setting

1. It is possible for an observer to enter the velocity of his sources in the source catalogs 1CAT, 2CAT, etc. He must type the phrase (examples)

10.5	KM/S
-10.5	KM/S

   after the source name either on the IBM source card or when entering a new source at the keyboard of the Tektronix terminal (see chapter VI).

2. Once 1. above is performed, it is possible for the operator to SEEK an observer's source from the proper catalog and have the computer automatically set the source velocity parameter VEL.

3. To accomplish 2. above, it is necessary for the operator to type at the teletype, once SPECTRA is loaded,

   VEL-AUTO cr

4. Once 3. is performed, it does not have to be performed again unless the SPECTRA program is reloaded or the operator defeats the VEL-AUTO feature by typing

   VEL-MANUAL cr

5. As usual, one must REFRESH the TV screen to compute synthesizer settings.

6. If a source card is read via the card reader from the teletype with the KM/S phrase described in 1. above, it will have no effect in CONTINUUM or MAPPING, but will set VEL in SPECTRA.

7. If the operator desires to override the source velocity displayed on the TV screen in either the VEL-AUTO or the VEL-MANUAL mode, he types at the teletype (examples)

200.3	KM/S	cr
-200.3	KM/S	cr

C. Absolute RA-DEC Position Switching

1. It is possible to position switch between any two source positions on the celestial coordinate system. No RA-DEC offsets are used and, in fact, these offsets are set to zero when an absolute RA-DEC position switched observation begins. Only the AZ-EL pointing offsets remain in effect (see chapter V).

2. The observer first must have his sources (both the main position and the reference position) entered properly in his source catalog. For example, let the main source name be W3 and the reference source name be RW3.

3. With SPECTRA loaded properly at the teletype, the operator first seeks the reference source and then the main source. The order is important because the main source will be observed first during the position switched observation. Thus, the telescope can immediately start going to the main position and the parameters for the synthesizer calculation will be displayed correctly for the main source on the TV screen.

```
REF    SEEK    RW3    cr
       SEEK     W3    cr
```

   Notice that when one seeks the reference source, the program blanks out on the TV screen what main source was last sought and displays the name of the reference source under it. This is a visual aid reminder to the operator to seek the main source last.

4. The observer should instruct the operator to set the number of pairs (RPT parameter) of position switched data and the number of seconds (SEC parameter) he desires to observe on the main source. SEC should be several minutes long in order that the data taking time be maximized when compared to the time it takes to switch between sources that are separated by tens of degrees.

5. When ready to observe, the operator at the teletype, types

```
n    APS    cr
```

   where n is the number of desired absolute position switched scans.

6. To eliminate the reference position source name from the TV screen, type

```
XREF    REFRESH    cr
```

D. Spectral Line Mapping

1. A spectral line mapping procedure is available in either the frequency switching mode ('FS) or position switching mode ('PS). The map points are specified by the observer in 1950 coordinates and entered in any one of his source catalogs. RA and DEC offsets are set to zero and not used in spectral line mapping (see chapter V). If position switching is to be used, the reference position must be entered in any of the observer's catalogs other than the catalog containing the map points. Upon issuing the proper data taking commands, the telescope observes sequential map points in the catalog; each map point observation is recorded on disk and tape as one scan. If it is desirable to calibrate before the catalog is completely searched, one may stop (STOP) the procedure at the end of any scan and perform the calibration. Issuing the proper command (FS-MAP or PS-MAP), will start the spectral line map again where it left off. If a scan is stopped before completion and then the spectral line map started again, the next sequential map point will be observed; that is, the stopped scan map point will be skipped.

2. The observer first must have his map points entered properly in his source catalog. If a reference position is necessary, it must be entered in a different observer catalog. For example, let the map point catalog be 1CAT and the reference position be in 2CAT and let the reference position name be RW3.

3. SPECTRA must be properly loaded at the teletype and all the following commands typed at the teletype.

4. If the position switching mode is to be used, type

   ```
   2CAT      REF      SEEK      RW3      cr
   ```

   Notice that when one seeks the reference source, the program blanks out on the TV screen the space allocated for the main source and displays the name of the reference under it.

5. Insure you are in VEL-MANUAL mode and set source velocity (e.g., -41.3 km/sec) by typing

   ```
   VEL-MANUAL      -41.3      KM/S      cr
   ```

6. Type the following to select the map point catalog, initialize spectral line map parameters, and set the number of scans (n) desired between calibrations.

   ```
   1CAT      PREP           cr
   n         #SCANS    !        cr
   ```

7. To begin the data taking, type, as appropriate,

```
FS-MAP          cr
          or
PS-MAP          cr
```

8. Wait until the nth scan is complete and perform the CALIBRATE as usual.

9. Repeat step 7. and the mapping process will continue where it left off in the catalog (1CAT). The mapping process will stop automatically when all entries in 1CAT have been observed.

10. The parameter NEXT is an integer which points to the next map point to be observed; map points are numbered from Ø. To interrogate NEXT, type:

    ```
    NEXT     ?       cr
    ```

    One may set NEXT to skip over map points by typing

    ```
    n      NEXT      !       cr
    ```

    NEXT is incremented automatically by 1 to point to the next unobserved map point when performing a scan; thus, if an unfinished scan is stopped and mapping begun again, the map point whose scan was stopped will be skipped. Never set NEXT to the same (or larger) value as the number of sources in the map point catalog.

11. One may reset #SCANS anytime if it is desirable to increase or decrease the number of scans performed between system calibrations.

E. SPECTRA Calibration Options

1. Cassegrain Receivers

(a) VANE Calibrations use a vane which is position switched in front of the feed and away from the feed. The duration of on or off sample is determined by setting CSEC at the teletype. The number of pairs of on - off samples is determined by setting CRPT at the teletype. Signal-Reference is generated by the subreflector control panel at a 5 Hz rate.

(b) NOISE calibrations use a noise tube in the subreflector to raise the level of the signal coming from the background sky. The noise tube is fired at a 5 Hz rate to generate signal-reference. The duration of the calibration (total) is determined by setting CSEC at the teletype.

2. Prime Focus Receivers

(a) CHOPPER calibrations use a rotating chopper wheel to chop the signal from the sky in front of the feed. Signal-reference comes from the wheel's rotation at the 5 Hz rate. The duration of the calibration is determined by setting CSEC at the teletype.

F. SPECTRA Calibration and Observation Data Recording

1. At the conclusion of a scan, the data is recorded on both disk and tape. The tape data is used for backup and is available for off-line processing. The disk copy is used for the on-line data reduction routines available at the Tektronix terminal.

2. The numbers recorded for each channel are calibrated antenna temperatures; the units are

$$K * 10^{\text{'UNIT}}$$

where 'UNIT is stored in the header of the scan.

3. Calibration Data for CHOPPER, NOISE, or VANE Calibration

S_{ci} = Calibration signal for channel i.

R_{ci} = Calibration reference (sky) for channel i.

TC = Signal sideband calibration temperature, in tenths of K.

Z_i = ZERO check at the beginning of the calibration for channel i.

$$C_i = \frac{R_{ci} - Z_i}{S_{ci} - R_{ci}} * TC$$

where the array C_i is called the GAINS array.

$$TS = \langle C_i \rangle$$

where TS represents the average GAINS across all channels of the multiplexer, ignoring any eliminated channels. TS is not used in any calculations.

4. Dummy Calibration for NO-CAL

For NO-CAL observations, one must perform a dummy CALIBRATE to eliminate selected defective channels. See the section entitled "Software Elimination of Defective Spectral Line Channels" in this chapter for more information. For NO-CAL observations, TS must be set to a value measured externally, presumably using hot and cold loads.

5. Observing Data

S_i = Signal (ON position or signal frequency) for channel i.

R_i = Reference for channel i.

Z_i = ZERO check recorded at the beginning of the scan for channel i.

C_i = Calibration value, derived in 3 above.

TC = Single sideband calibration temperature.

TS = Single sideband system temperature, measured or set as in 3 above.

$$T_i = \frac{S_i - R_i}{R_i - Z_i} * TS \qquad \text{for NO-CAL}$$

$$T_i = \frac{S_i - R_i}{R_i - Z_i} * C_i \qquad \text{for CHOPPER, NOISE, VANE}$$

6. Correcting Data for Atmospheric Attenuation

For NOISE or NO-CAL methods, ATTN may be set to its proper non-zero value (based on the CONTINUUM Program tipping scan data) to account for atmospheric attenuation if the observer desires. If you are using CHOPPER or VANE and perform your calibration at nearly the same elevation as your source, this correction is inherently included in the measured C_i and needn't be applied separately. Thus, insure ATTN is zero when using CHOPPER or VANE. When ATTN is non-zero, it will scale all data up by the factor

exp {sec (z) * ATTN/1000}

where z is the zenith distance to the source in degrees.

7. BASELINE Removal from Raw Data

The raw data has a constant baseline subtracted from it over all channels of the multiplexer used. This baseline subtraction is necessary to accommodate the finite dynamic range of the computer single precision word. The value of BASELINE is determined from the entire raw data for non-PS observation and is an average of the individual baselines in individual samples of a PS or APS observation. The double precision constant BASELINE is stored in the header of each scan. See the word BL in the section entitled "SPECTRA Data Reduction Vocabulary" in this chapter for the proper way to interrogate the value of BASELINE for each scan.

8. Data Scaling in SPECTRA

(a) Spectral line data are scaled automatically at the end of each non-PS observation, or at the end of the first PS observation pair. At this time the program will set UNIT to the largest number of decimal places (between 0 and 4) that will accommodate all data points. The value used will be stored in the data as 'UNIT.

(b) Since this automatic scaling means that scans on the same source may have varying scales, all plotting routines will normalize data to a single scale, called Y DECIMALS. Y DECIMALS is the number of decimal places printed out in the values on your ordinate axis. This will normally be the same as 'UNIT for the scans being plotted, but may not: if the numbers fall near the extremes of the range, the normalizing process may cause the plot to overflow. In such a case, you should set Y DECIMALS to 'UNIT - 1 and recall the data again (you may not just re-plot it, as the normalizing needs to be re-done). For example, suppose you recall scan 534 as follows:

```
534    F                (scan looks noisy)

'UNIT    ?    3         (534 was recorded in units of .001K)

2      Y DECIMALS    !  (setting Y DECIMALS down 1)

534    F                (now gives a much smoother picture)
```

Additionally, if the data looks truncated (quantized) and 'UNIT is larger than Y DECIMALS, one may then increase Y DECIMALS to the value of 'UNIT in order to remove the quantization from the plot. In such instance, you must always follow a reset of Y DECIMALS by a fresh recall of the data.

G. SPECTRA Header Variables Recorded on Disk (and Binary Tape)

WORD LOCATION	NAME	DESCRIPTION
Ø	HEADER	Current scan number - 5ØØ to 2ØØØ allowed
1	+LO	Local Oscillator offset (tenths of MHz)
2	#FB	Number of filter banks used (1, 2 or 3)
3	VEL	Source velocity with respect to LSR (tenths of km/sec)
4	DAY	Modified JD - from 1 JAN 195Ø
5	PA-RCVR	Position angle of receiver box (.14)
8-9	MAIN	AZ-EL main beam offsets (Low order portion of .22)
11	RCVR	Receiver ID integer
12	MODE	Observing mode integer
13	'UNIT	Base 10 exponential scale factor for data (0,1,2,3,4)
14	%EFF	Aperture Efficiency (%)
15	'UT	UT at beginning of scan (.14)
16	'LST	LST at beginning of scan (.14)
17	TIME	Actual integration time of scan (tenths of seconds)
18-19	'RA	Actual RA (.22)
2Ø-21	'DEC	Actual DEC (.22)
22	SINH	Actual Sine of elevation angle (.14)
23	'AZ	Actual AZ (.14) reckoned from the East
24-25	OBS	Observer initials Character count + 3 characters (ASCII)
26-27	OPR	Operator initials Character count + 3 characters (ASCII)
28-33	NAME	Source name Character count + 11 characters (ASCII)
34-35	NS	Number of samples in first word and number of scans in second word
36-37	SYNTH	Synthesizer setting (DP) (tens of Hz)
38	1ST-IF	(MHz)
39	LO-IF	(MHz)
4Ø-41	FREQ	Sky frequency (DP) (tens of kHz)
42	SB	Sideband integer
47	#PTS	Number of Multiplexer channels used
49	BANDWIDTH	Bandwidth of the receiver (MHz)
50,55,60	#CH	Number of channels in each filter bank
51,56,61	CHØ	Starting channel in each filter bank
52,57,62	BW	Bandwidth per channel in each filter bank (kHz
53,58,63	RMS	Theoretical RMS of each filter bank (K* 10 EXP(+'UNIT))
64	TC	Calibration temperature (tenths of K)
65	TS	System temperature (K)
66	ATTN	Zenith atmospheric attenuation (tenths of %)
69	SEC	Tenths of seconds per sample

WORD LOCATION	NAME	DESCRIPTION
71	TOL	Tracking Tolerance in seconds of arc
75	FØ	Focus offset (tenths of mm)
80	DUT1	UT clock corrections in thousandths of a second
81-82	X50	RA(1950) Source in APS (.22)
83-84		DEC(1950) Source in APS (.22)
85-86		RA(1950) Ref in APS (.22)
87-88		DEC(1950) Ref in APS (.22)
94-99	RNAME	Ref name (See NAME)
100	FILTERS	Software load block for filter banks
103	RPT	Number of pairs in PS or APS scan
106-109	SOURCE	AZ,EL,RA,DEC main position offsets
110-113	REFERENCE	AZ,EL,RA,DEC reference position offsets
123-124	BASELINE	Baseline (DP) for data to prevent data overflow (K* 10 EXP(+'UNIT))
128		Starting location of recorded data; all data is single precision.

Notes:

(a) See the Tape and Disk Utility Check Lists & Information Chapter concerning Off-Line Data Reduction for Binary Tapes for the meaning of (.22), (.14) and (DP).

(b) Characters in ASCII are stored in the order 2N436587 . . . where N is a binary number equal to the number of characters in the word.

H. Computer Control of Signal/Reference Routing

1. Signal/reference switching may be controlled by the computer (e.g., position switching, noise-tube calibration), the multiplexer (5, 2.5 or 1.25 Hz) or by external equipment (e.g. chopper wheel, cassegrain subreflector). Phase information may also be routed to various destinations. The word SR-ROUTE (used at the teletype) has been defined to control this:

   (source) (destination) SR-ROUTE cr

2. The option codes are:

   SOURCES

0	Computer control
1	Multiplexer - 5Hz
2	Multiplexer - 2.5 Hz
3	Multiplexer - 1.25 Hz
4	External
8	Zero Check

   DESTINATIONS

0	Receiver LO system
1	Noise tube modulator
2	Gain modulator
3	Null
7	Standard Bank End (SBE)

3. CALIBRATE and observing modes (explained below) designate standard routings; you need to type

   (source) (destination) SR-ROUTE

   only to override these defaults.

4. To run the chopper signal/reference to the standard back end for pointing, type

   4 7 SR-ROUTE cr

5. When you begin an observation, one of the observing modes below is automatically selected for you. The mode sets the routing of the S/R switching information and the SWITCH factor (1 or 2) for relative integration times, as shown in the table below. MODE is stored in the header.

OBSERVING MODES

Name	Description	SWITCH	MODE	Source	Destination
'FS	Frequency switching	1	1	1	0
'PS	Position switching	1	2	0	0
'FS+PS	Frequency & position switching	2	3	1	0
'BS	Beam switching	1	4	4	3
'BS+PS	Beam & position switching	2	5	4	3
'LS	Load switching	1	6	4	2

For example, in the table above,

```
'FS     cr
```

is equivalent to

```
1    0    SR-ROUTE    cr
```

Thus the source of the switching signal is the 5Hz pulse from the multiplexer, and it will drive the receiver LO system.

6. Do not confuse 'FS (the observing mode) with FS (the observation command). Similarly, 'PS, 'LS, 'FS+PS, etc. with PS, LS, FS+PS, etc., respectively.

I. Selecting Filter Bank Parameters

1. The following table lists the filter banks most commonly used with their starting channel and total number of channels.

Filter Banks

CODE	BW (KHz)	# Channels	Starting Channel
Ø	100	256	Ø
1	100	256	256
2	250	256	Ø
3	250	256	256
4	1000	256	Ø
5	1000	256	256
6	500	256	Ø
7	500	256	256
8	30	128	256

2. To select a desired filter bank configuration from the above table, at the teletype type the code number of the filter bank followed by the verb BANK. For example, if you are using the 256 x 1000 KHz filter bank and the 256 x 250 KHz filter bank, type:

```
4    BANK
3    BANK
```

This initializes the filter parameters required for correct data display. The values set are displayed on the monitor.

3. If a filter bank is to be used which does not have an entry in 1. above, one may manually set its parameters at the teletype. For example, suppose we have a 256 x 2000 KHz filter bank and we want to have it in the first 256 channel slot of the multiplexer. For this situation type

```
F1  2000 BW  !  256  #CH  !  0  CHØ  !  cr
```

On the other hand, if we had wanted it in the second slot, we would have typed

```
F2  2000  BW  !  256  #CH  !  256  CHØ  cr
```

J. Operation of Filter Banks in Series or Parallel

1. Two 256 Channel Filter Banks in Operation

(a) This is using all 512 channels of the multiplexer. The following must be adhered to:

(1) The 256 channel filter bank in the first slot (i.e., 0-255).

(2) The 256 channel filter bank in the second slot (i.e., 256-511).

(3) FILTERS must be set prior to SPECTRA LOAD at the teletype by typing

n FILTERS ! SPECTRA LOAD cr

where n is obtained from the first column of the following table.

FILTERS	First Filter Bank	Second Filter Bank
286	Parallel	Series
287	Parallel	Parallel
288	Series	Series
289	Series	Parallel

2. One 256 Channel Filter Bank and One 128 Channel Filter Bank in Operation

(a) This is using only 384 channels of the 512 channel multiplexer

(1) The 256 channel filter bank in the first slot (i.e., 0-255).

(2) The 128 channel filter bank in the second slot (i.e., 256-383).

(3) FILTERS must be set prior to SPECTRA LOAD at the teletype by typing

n FILTERS ! SPECTRA LOAD cr

where n is obtained from the first column of the following table.

FILTERS	First Filter Bank	Second Filter Bank
284	Series	Series
285	Parallel	Series

K. SPECTRA Program Frequency Conventions

1. For graphs at the Tektronix, all horizontal axes in the spectral line program are in terms of frequency units (MHz) and the displayed units are relative to the midpoint (labelled Ø.Ø) of the horizontal axis. This midpoint is actually 150 MHz. The entire graph displays the frequency in the filter bank. The frequency tick marks on the graph lie between channels in the filter bank.

2. The following Receiver Tuning Aid Table displays the relationship bewteen various frequencies on both the cooled cassegrain receiver and the prime focus receivers in the allowable sideband configurations.

Receiver Tuning Aid Table

Computer Parameters			Receiver Tuning Indications and Parameters					Tektronix CRT Horizontal Axis (Arrows Imply Direction on Screen or Line Shift)						
SB	1ST-IF	LO-IF	Lock-Light	Search Phase		2ND LO	3RD LO	FB	IF	f(Sky)	VELOC-ITY	Increase f(Sky)	Increase SigLO **	Increase Offset Osc. ***
Integer	(MHz)	(MHz)	(ON)	SigLO > CompLO	SigLO < CompLO	(MHz)	(MHz)	(MHz)	(MHz)	(MHz)	(km/s)	Shift	Shift	Shift
0 USB	-1390 -4750*	+400	L	+	-	1540 6080*	- 1480*	>>> >>>	<<< >>>	<<< >>>	>>> <<<	>>> <<<	<<< >>>	<<<
1 LSB	+1390 +4750*	+400	L	+	-	1540 6080*	- 1480*	>>> >>>	<<< >>>	>>> <<<	<<< >>>	<<< >>>	>>> <<<	<<<
2 USB	-1390 -4750*	-400	U	-	+	1540 6080*	- 1480*	>>> >>>	<<< >>>	<<< >>>	>>> <<<	>>> <<<	<<< >>>	<<<
3 LSB	+1390 +4750*	-400	U	-	+	1540 6080*	- 1480*	>>> >>>	<<< >>>	>>> <<<	<<< >>>	<<< >>>	>>> <<<	<<<

Explantory Notes for Receiver Tuning Aid Table:

1. The observer should insure that 1ST-IF, Second LO, and Third LO have not been changed from the above values due to some interference consideration. If these values are different from those above, arrows may not be the same as shown above.
2. * means the quantity applies to Cooled Cassegrain Receiver.
3. ** means it is assumed that the Comparison LO remains constant.
4. f stands for frequency.
5. FB stands for Filter Bank.
6. IF stands for Intermediate Frequency.
7. Kly stands for Klystron.
8. LO stands for Local Oscillator.
9. LO-IF stands for Lock IF.
10. f(Sky) stands for Rest frequency of the line + Doppler shift.
11. f(Kly) is known as the 1ST LO and is equivalent to f(Sky) + 1ST-IF.
12. f(Lock) is equal to f(Kly) + LO-IF.
13. N(Computer) is harmonic number used by computer and is equivalent to the truncated result of $\left(f(\text{Lock}) \text{ in MHz}/2000\right) + 1$. The + 1 insures the calculation is well within 2 GHz lock system range.
14. *** means that the entry applies to Cooled Cassegrain Receiver channel number 2.

L. Sideband Parameter Selection

1. The sideband parameter (SB) is selected using the following scheme:

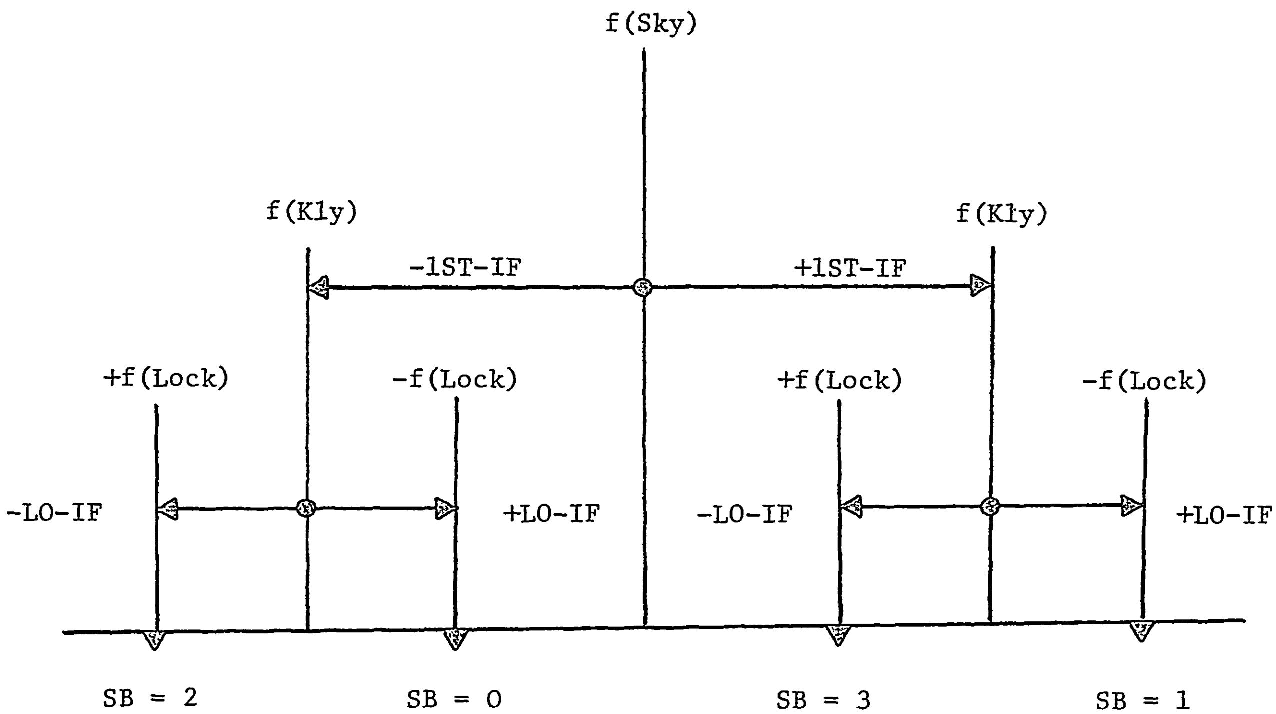
SB	Sign of 1ST-IF	Sign of LO-IF
0	-	+
1	+	+
2	-	-
3	+	-

2. Sideband is set at the teletype by typing

   n SB ! cr

   When SB is set, it determines the proper signs for 1ST-IF and LO-IF. Thus when you have to set 1ST-IF and/or LO-IF, do not give these parameters negative signs. 1ST-IF and LO-IF are single precision parameters and are set in accordance with the SPECTRA Observing Vocabulary section of this chapter.

3. Graphically, SB means the following:



M. Computer Determined Synthesizer Setting and Actual Synthesizer Setting

1. Computer Determined Synthesizer Setting

The frequency calculation parameters used are displayed on the TV monitor and stored in the header of each scan at the beginning of the scan. The program computes the local oscillator setting based on source position and velocity, line frequency, date and Universal Time. After the date, time and source position have been entered in the normal fashion, the operator performs the following at the teletype:

(a) Enter the line frequency in GHz, with 5 decimals: (Note all five decimal places must be given)

```
89.18855   FREQ   2!   cr
```

(b) Enter any source velocity with respect to the local standard of rest in tenths of km/sec.:

```
10.0   KM/S   cr
```

(c) Now you may type

```
n   SB   !   cr
```

to select a sideband, where $0 \leq n \leq 3$ (see Sideband Parameter Selection in this chapter).

(d) Now type

```
REFRESH   cr
```

to obtain on the monitor the synthesizer setting closest to a 2 GHz harmonic for the requested sideband.

(e) Subtract 1.80000000 from the displayed number to obtain the number punched into the keys on the synthesizer.

(f) The synthesizer computation has three steps:

(1) Compute the line-of-sight component (v_o) of the sum of the orbital velocity of Earth, the rotational velocity of Earth and the velocity of the sun. This value is displayed on the monitor under V(LSR).

(2) Correct the line frequency (FREQ) for Doppler shift due to LSR plus the velocity of the source (v):

$$f' = f * \left[1 - \frac{(v+vo)}{c} \right]$$

(3) For the sideband

$$f'' = f' \pm \text{1ST-IF} \pm \text{LO-IF}$$

compute the 2 GHz harmonic

$$n = \text{TRUNCATED RESULT of} \left[\frac{f''}{2\ \text{GHz}} \right] + 1$$

2. Actual Synthesizer Setting

The computer will record the synthesizer setting as read by the frequency counter into the scan header information. This recorded setting is the actual frequency to be used in the observation and it may not agree with the computed synthesizer setting described above. Possible reasons for this could be that the observer has computed his own setting and has entered it in lieu of the computed setting or that the synthesizer panel has been mispunched on entering the computed setting. The synthesizer setting recorded with the data is the value returned when the scan is recalled at the Tektronix with F and S verbs described in the section entitled "SPECTRA Data Reduction Vocabulary" in this chapter.

N. Software Elimination of Defective Spectral Line Channels

1. It is possible to eliminate a maximum of 30 defective channels from the spectral line calibration process. The calibration values (GAINS) for those channels which have been designated eliminated will be set to zero <u>when the next calibration is performed</u>. Subsequent spectral line observations will have the defective channel values set to the value of zero. For NO-CAL observations, one must perform a dummy CALIBRATE to eliminate defective channels just as one would for VANE or CHOPPER calibrations.

2. When SPECTRA is again loaded for any reason, the program insures that no channels are eliminated. Thus the operator must insure that defective channels are eliminated if the hardware demands it. Data accuracy can be lost if elimination is not done since a defective channel may affect data scaling.

3. To determine what channels are to be eliminated, use the following methods at the Tektronix with SPECTRA loaded:

   (a) <u>Method #1</u>

   (1)
```
        FIRST GAINS      cr
    (or)
        SECOND GAINS     cr
    (or)
        n      F         cr
    (or)
        n      S         cr
```

   where n is the appropriate scan number and F, S, FIRST, SECOND and GAINS are described in "SPECTRA Data Reduction Vocabulary" in this chapter.

   (2) PAGE PRINT

   (3) Use the appropriate template on the following page to determine the channels to be eliminated.

   (b) <u>Method #2</u>

   (1) It is possible for the computer to interrogate GAINS and/or a spectral line scan recalled at the Tektronix for the presence of possible defective channels. The method (SPIKE) acts on the plot buffer and checks for any channel which is larger by a specified amplitude (AMP) than its two adjacent neighbor channels; the method ignors discontinuous steps.

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64
65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88
89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104
105	106	107	108	109	110	111	112
113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128
129	130	131	132	133	134	135	136
137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152
153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176
177	178	179	180	181	182	183	184
185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208
209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224
225	226	227	228	229	230	231	232
233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248
249	250	251	252	253	254	255	256

FIRST - 256 Channel Filter Bank Template for PRINT

257	258	259	260	261	262	263	264
265	266	267	268	269	270	271	272
273	274	275	276	277	278	279	280
281	282	283	284	285	286	287	288
289	290	291	292	293	294	295	296
297	298	299	300	301	302	303	304
305	306	307	308	309	310	311	312
313	314	315	316	317	318	319	320
321	322	323	324	325	326	327	328
329	330	331	332	333	334	335	336
337	338	339	340	341	342	343	344
345	346	347	348	349	350	351	352
353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368
369	370	371	372	373	374	375	376
377	378	379	380	381	382	383	384
385	386	387	388	389	390	391	392
393	394	395	396	397	398	399	400
401	402	403	404	405	406	407	408
409	410	411	412	413	414	415	416
417	418	419	420	421	422	423	424
425	426	427	428	429	430	431	432
433	434	435	436	437	438	439	440
441	442	443	444	445	446	447	448
449	450	451	452	453	454	455	456
457	458	459	460	461	462	463	464
465	466	467	468	469	470	471	472
473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488
489	490	491	492	493	494	495	496
497	498	499	500	501	502	503	504
505	506	507	508	509	510	511	512

SECOND - 256 Channel Filter Bank Template for PRINT

(2) To interrogate, for example, possible defective channels in the first 256 channels of a CALIBRATE, type:

```
FIRST    GAINS    AXES    cr

m        AMP      !       cr

SPIKE

n

o

p
```

Parameter m is the amplitude limit which the computer uses to check if any channel exceeds this limit. If the AXES command has 2 (or 3) places to the right of the decimal point then n set to 300 (or 3000) produces a 3 Kelvin amplitude limit. The values n, o and p are the possible defective channel numbers returned by the computer on execution of SPIKE.

4. Eliminate/interrogate defective channels at the teletype as follows:

(a) To designate, for example, 3 defective channels (say 119, 409, and 460) for elimination, one first tells the computer how many defective (BAD) channels there are and then tells the computer which channels to eliminate (ELIM). These operations can be done only at the teletype:

```
                BAD     cr

119   409   460   ELIM    cr
```

Note in this example that ELIM has to be provided 3 numbers; if the teletype responds ELIM ? you failed to provide ELIM the proper number of defective (BAD) channels. Always follow a BAD command with an ELIM command.

(b) At any time after the performance of 4(a). above, one may interrogate at the teletype which channels are designated as eliminated:

```
BAD?      cr

460

409

119
```

(c) If more channels subsequently become defective, repeat the process in 4(a). above for all defective channels.

(d) One may regain the use of all channels (good or bad) without reloading the program by typing:

```
0     BAD      cr

0     ELIM     cr
```

(e) After performance of 4(a). or 4(d). above, <u>one must perform a CALIBRATE</u> to cause elimination.

O. SPECTRA Data Reduction Vocabulary

A list of common data reduction nouns and verbs follow which are to be used by the observer at the Tektronix terminal for displaying and processing spectral line data previously recorded on the disk.

1. AUTO cr

   This verb allows the computer to automatically select the range on the vertical axes of scans subsequently recalled for plotting from storage on the disk. The computer will attempt to place such scans in the middle third of the Tektronix screen. If the dynamic range of the data is too large, AUTO may not work and the range of the vertical scale must be set by RANGE described below. Once AUTO is selected it will remain in effect until defeat by RANGE or MANUAL, both described below.

2. FIRST AVERAGE, A1, SECOND AVERAGE, A2

   These verbs allow one to display the difference between the average of those scans in the scan table which do not have a minus sign and the average of those scans in the scan table which have a minus sign. The averages are weighted by integration time. FIRST AVERAGE and A1 both act on the first filter bank of the designated scans in the scan table. A1, however, plots out the result with labels. SECOND AVERAGE and A2 are the words necessary for the second filter bank data of the scans in the scan table. To manipulate the contents of the scan table see the section entitled "Using the Scan Table" in this chapter.

3. BL cr

   This verb will display the baseline which has been subtracted from accumulated data that has been stored on the disk as an individual scan. One must recall the data (via F or S described below) and then type

   BL cr

   The value of the baseline subtracted will be the same for both the first and the second filter bank data for the scan plotted. The units of the value will be in Kelvins and the number of decimal places will be the precision to which your data for that particular scan were recorded.

4. FIRST COMBINE, C1, SECOND COMBINE, C2

These verbs allow one to display the average of those scans in the scan table. For such an operation no scan in the scan table should have a minus sign. The average is weighted by the integration time. FIRST COMBINE and C1 both act on the first filter bank of the designated scans in the scan table. C1, however, plots out the result with labels. SECOND COMBINE and C2 are the words necessary for the second filter bank data of the scans in the scan table. To manipulate the contents of the scan table see the section entitled "Using the Scan Table" in this chapter.

5. n FLAG cr

This verb will draw a vertical flag perpendicular to the horizontal frequency axis at the designated frequency n. The value of n should correspond to the units displayed on the horizontal axis but disregarding the decimal point on such units. For example, if the axis unit reads 5.00 (MHz) and you want to flag this frequency type

```
500    FLAG    cr
```

6. FOLD cr

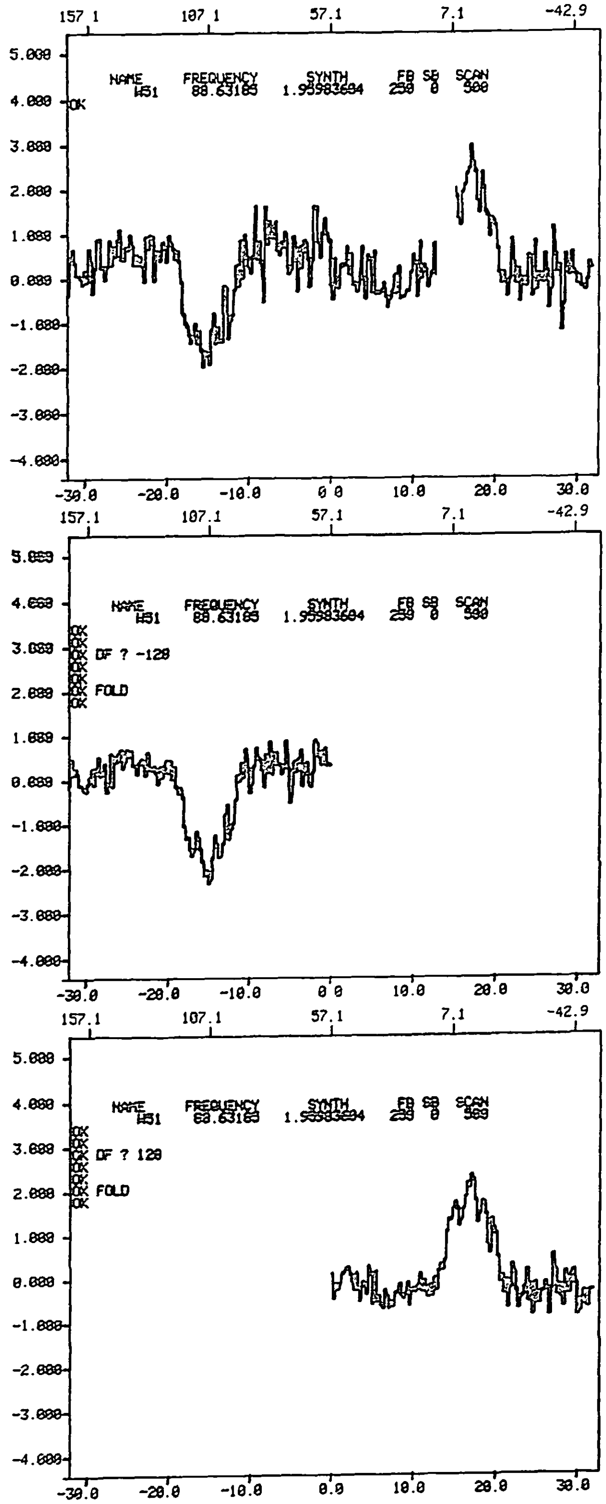
This verb will cause the function in the plot buffer to be shifted a specified amount to the left or right; the resultant function is then subtracted from the original unshifted function and the result divided by 2. For example, to shift a function 128 data points to the left and plot the results, type

```
-128    DF    !    cr

FOLD               cr

XX                 cr
```

where XX is defined elsewhere in this section. To shift to the right by 128 data points one must set DF to a positive (unsigned) 128. See a succeeding page for examples of the verb FOLD.

7. FIRST GAINS, SECOND GAINS

These verbs plot out the gain corrections (i.e., the C_i array described in the section entitled "SPECTRA Calibration and Observation Data Recording" in this chapter) derived from the last CALIBRATE. FIRST GAINS and SECOND GAINS refer to the first and second filter bank data, respectively.



FOLD Examples

8. HALVES cr

This verb will cause the function in the plot buffer to be shifted a specified amount to the left or right; the resultant function is then added to the original data and the result divided by 2. For example, to shift a function 128 data points to the left and plot the results, type

```
-128    DF    !    cr

HALVES             cr

XX                 cr
```

where XX is defined elsewhere in this section. To shift to the right by 128 data points one must set DF to a positive (unsigned) 128. See a succeeding page for examples of the verb HALVES.

9. n HEAD cr

This verb will print out some pertinent information for scan n on the disk. For example,

```
730    HEAD    cr
```

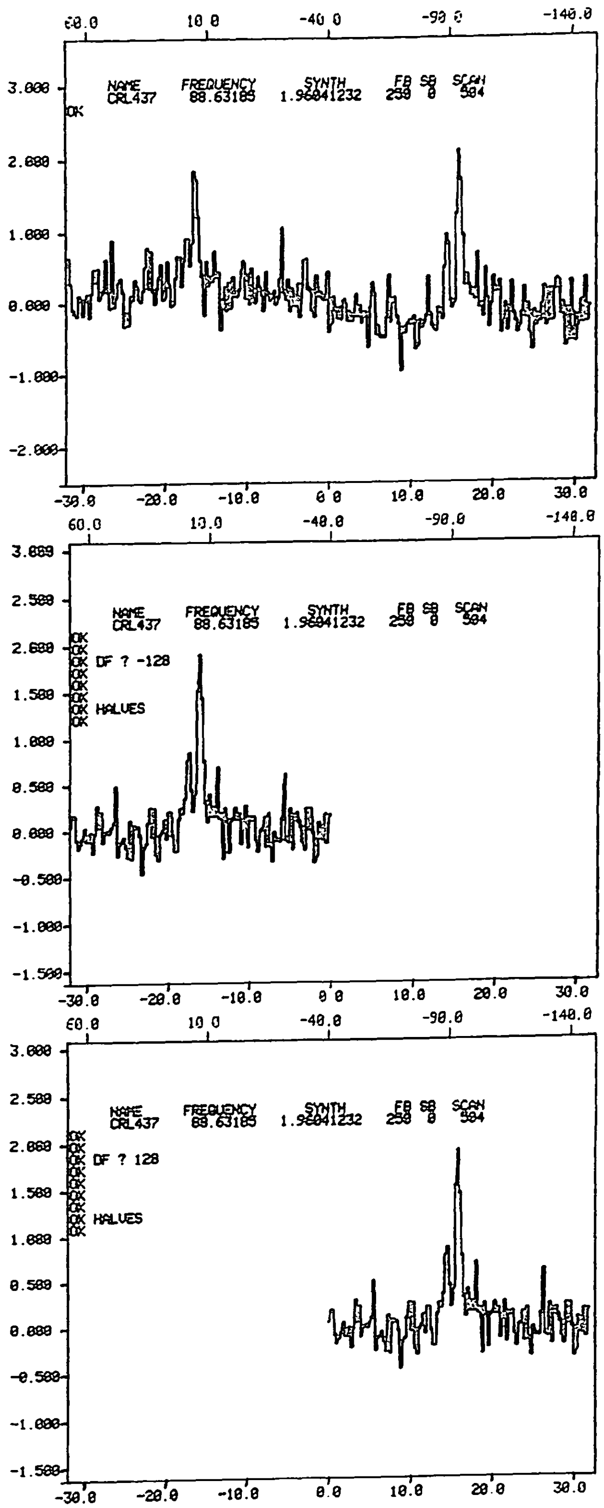
will print out the following:

Scan No.	Date	LST	Source Name	Actual RA	Actual DEC	ATMS	NS	TIME	TS
730	8 OCT	13:43	ORIA	5:41:35.2	-2:19:16.	1.347	1	300	1500

Most of the above parameters and units are self-explanatory. ATMS is the number of atmospheres through which the observation was taken. See the section entitled "SPECTRA Header Variables Recorded on Disk (and Binary Tape)" for additional information.

10. MANUAL cr

This verb causes the computer to "freeze" the vertical axis range for all future plotting. Once MANUAL is selected it will remain in effect until defeated by RANGE or AUTO both described in this section.



HALVES Examples

11. PB cr

This verb will determine the mean and RMS of any data in the plot buffer and print out the results. The RMS is determined as follows:

$$\text{RMS} = \sqrt{\frac{\sum_{i=1}^{n} (X_i)^2}{(n-1)}}$$

where n = the number of points in the plot buffer and X_i is the residual of the i^{th} datum point. An example follows on a succeeding page.

12. Plot Options

(a) PAGE cr

This verb erases the screen and positions the cursor at the upper left hand corner.

(b) PLOT cr

This verb will replot the data currently in the plot buffer.

(c) PRINT cr

This verb will print out the values of the function plotted, eight values per line.

(d) AXES cr

This verb will provide horizontal and vertical axes for the data displayed by PLOT.

(e) LABEL cr

This verb will print out the physical quantities of the axes displayed by AXES.

(f) VELOCITY cr

This verb will draw a velocity axes at the top of the screen.

(g) BOX cr

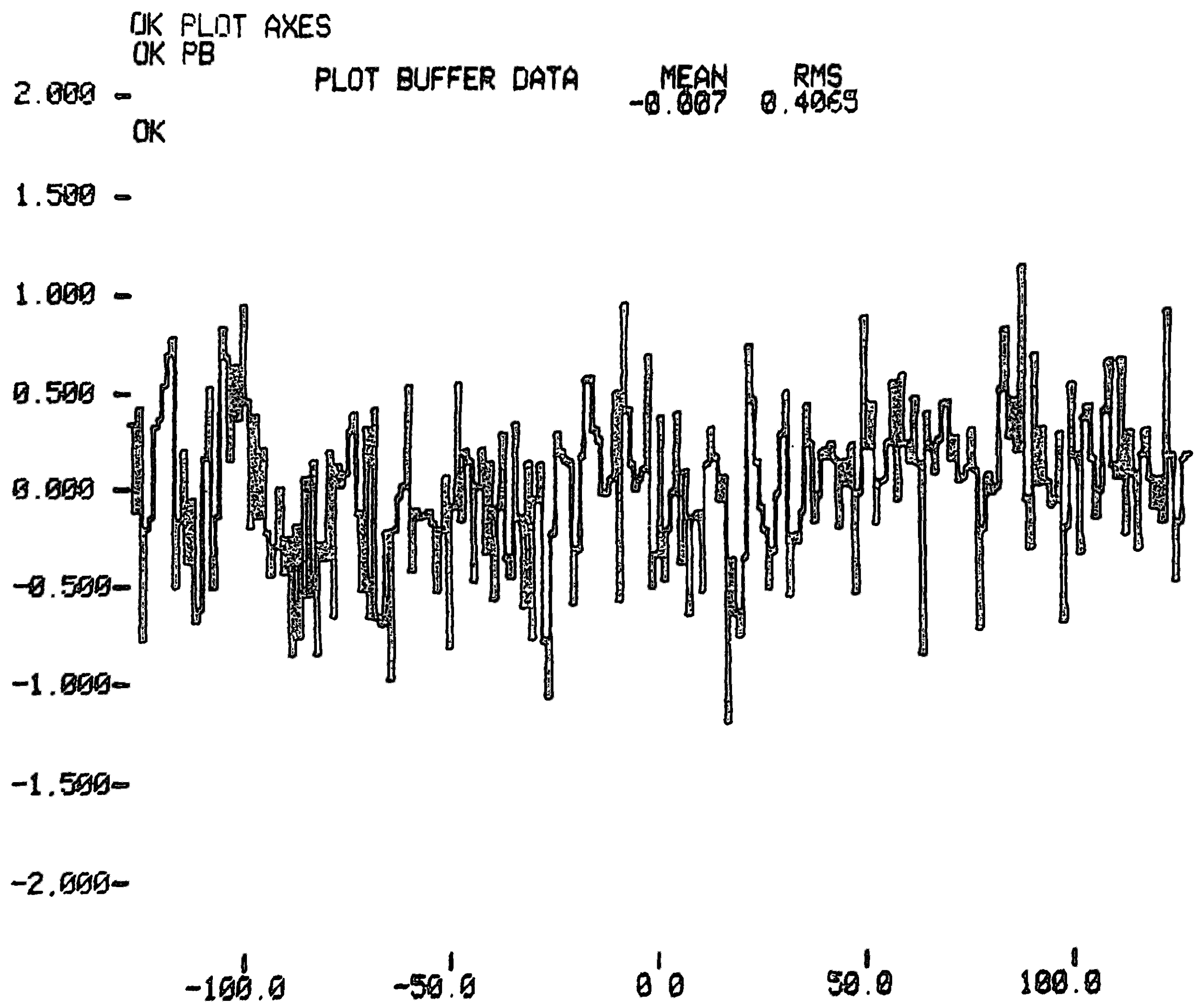
This verb will draw a box around the data plotted on the screen.

(h) FULL GRID cr

This verb will draw a rectangular grid on the screen.

(i) HISTOGRAM, POINTS, LINE

These verbs allow selection of the desired plotting mode. The program will stay in one plotting mode until another mode is selected by the user.


OK PLOT AXES
OK PB
PLOT BUFFER DATA
MEAN
-0.007
RMS
0.4069
OK
2.000
1.500
1.000
0.500
0.000
-0.500
-1.000
-1.500
-2.000
-100.0
-50.0
0 0
50.0
100.0

PB Example

13. FIRST Q, SECOND Q

These verbs allow plotting of a non-position switched scan in progress. The data plotted is raw and unscaled. FIRST Q refers to the first filter bank data and SECOND Q to the second filter bank.

14. n m RANGE cr

This verb allows the observer to select the vertical axis on all future plots. The integer numbers n and m are the minimum and maximum vertical axis range values desired. Once RANGE is executed it will remain in effect until defeated by AUTO or MANUAL both described in this section.

15. Recalling an Individual Scan (F,S)

The verbs F or S are used to recall the data of the first or second filter bank, respectively, in an individual scan. To recall the first filter bank data of scan 604, for example, type

```
604 F
```

and the data will be plotted with labels. Only one filter bank may be recalled at a time. One may use F and S to display a position switched scan in progress after the first ON-OFF pair has been recorded on the disk.

16. FIRST SHOW, SECOND SHOW

This verb allows all scans in the stack to be plotted one above the other on the screen. The amount each scan is displaced vertically from its neighbor is determined by the parameter SHIFT. Thus, you must usually set the vertical range of your plots by the use of RANGE to be able to use SHOW. To set the vertical displacement to 2000 units of the vertical axis, for example, type

```
2000    SHIFT    !
```

17. SMOOTH cr

This verb will apply a seven-point smoothing function to the data in the plot buffer. The default value of this function is a three-point boxcar function (i.e., 0, 0, 33, 34, 33, 0, 0) which can be selected by typing

BOXCAR cr

A three-point Hanning smoothing function (i.e., 0, 0, 23, 54, 23, 0, 0) can be selected by typing

HANNING cr

You can define any seven-point smoothing function yourself by typing (example)

0 10 15 50 15 10 0 SHAPE cr

where the 7 arguments define the function and must total to 100. Thus, having specified the smoothing function by means of BOXCAR, HANNING or the proper use of SHAPE, typing

SMOOTH cr

will cause the smoothing function to act on the contents of the plot buffer. One may perform repeated SMOOTH operations on the same plot buffer data. Each time SMOOTH is executed, the number of data points at each edge of the data function is reduced by one. To restore the full range of data points plotted, type

ALL XX cr

The data plotted at the edges of the spectrum in this case will be meaningless due to the effect of repeated SMOOTH operations and should be ignored.

18. SNAP cr

This verb may be used anytime to take an instantaneous picture of the TV screen.

19. n m SPREAD cr

This verb allows one to select a portion of the horizontal axis for plotting. Here n and m are integer limits of the range you want to see in units of the horizontal axis with no decimal point. After having used SPREAD, XX (described below) will plot out the result with proper axes. If the plot goes off the screen on both sides, type

p g LIMIT cr

where p and g are integer limits of the horizontal axis. Note that if in the AUTO mode p and g are often a factor of ten larger than n and m.

20. THUMB cr

This verb prints out the values of AZ, EL, RA and DEC offsets that the program is currently using for data taking.

21. TILT cr

This verb will remove a linear baseline. You must state the height of the baseline from left-most to right-most edge of the filter. For example,

1000 SLOPE ! TILT cr

will remove a negative slope of 1000 vertical axis limits. On the other hand,

-1000 SLOPE ! TILT cr

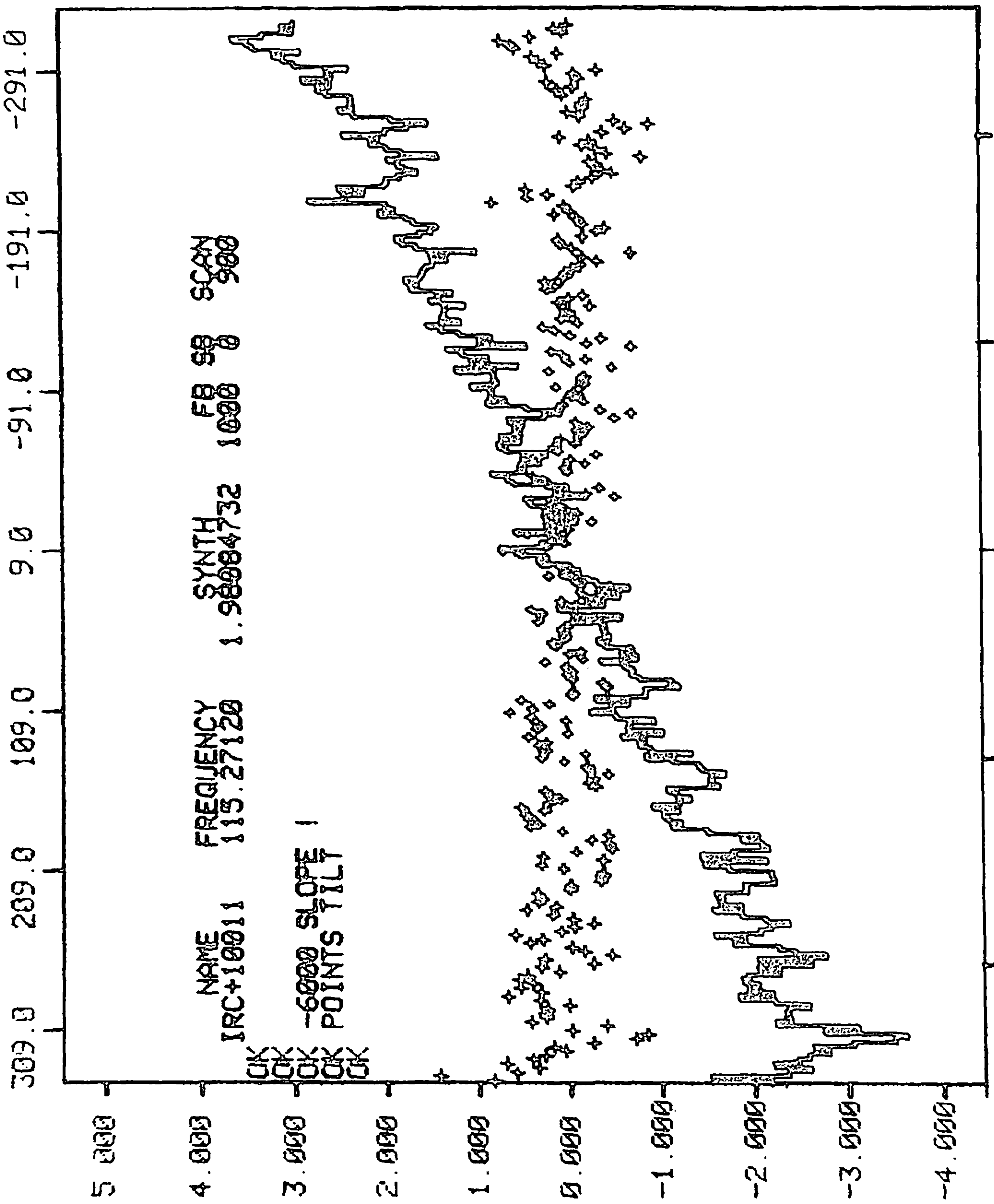
will remove a positive slope of 1000 vertical axis units. A graphic example follows on a succeeding page.

22. XX cr

This verb replots with labels anything in the plot buffer and it additionally prints out all scan numbers in the scan table. It is wise to note that the scan numbers printed out on execution of XX may not have any relation to the plot buffer data.

23. FIRST ZERO, SECOND ZERO

These verbs plot out the zero check corrections (i.e., the Z_i array described in the section entitled "SPECTRA Calibration and Observation Data Recording" in this chapter) which is taken at the beginning of any scan or CALIBRATE. FIRST ZERO and SECOND ZERO refer to the first and second filter bank data, respectively.



TILT Example

P. Using the Scan Table

1. The stacking words specify which scans you want to see in the off-line display. They manipulate an array of scan numbers called the scan table. All operations are performed at the Tektronix.

2. To empty the table, type

   EMPTY   cr

3. To list the scan numbers in the table, type

   STACK   cr

   There is a limit of 50 scans in the table.

4. To add a scan to the table, type

   503 A   cr

5. To specify that a scan is an OFF, make its scan number negative. Thus,

   503 A   -504 A   cr

   adds 503 and 504 to the stack, 503 as an ON, 504 as an OFF.

6. Three abbreviations (+N, -N, ADD) are helpful when adding a contiguous sequence of scans:

   (a) +N adds the next scan to the stack as an ON.

   (b) -N adds the next scan to the stack as an OFF. Thus,

       800   A   +N   +N   -N   -N   -N   cr

       is an abbreviation for

       800 A 801 A 802 A -803 A -804 A -805 A cr

   (c) n ADD adds the nest n scan numbers:

       800   A   10   ADD   cr

       gives 800 801 802 ..... 810 in the scan table.

7. To delete an individual scan from the scan table, type

   504   DELETE   cr

   and it will delete scan 504 and print out those scans that remain in the scan table.

8. Placing a scan in the table does not in any way affect its status on disk or tape. It does allow you to use the various data reduction techniques such as COMBINE and AVERAGE.

Q. <u>Shifted Spectral Lines: Using COMBINE and AVERAGE</u>

1. AVERAGE is designed to average scans which are designated as ONS in the scan table and average scans which are designated as OFFS in the scan table and then subtract these averages and display the result graphically at the Tektronix. See the section entitled "Using the Scan Table" in order to see how to designate ONS and OFFS. Insure you have at least one ON and one OFF before using AVERAGE.

2. COMBINE is designed to average scans which are designated as ONS (only) in the scan table. It then displays the results at the Tektronix.

3. COMBINE and AVERAGE must be preceeded by FIRST or SECOND to insure the correct horizontal axis range is set. To ease the typing burden C1, C2, A1 and A2 have been defined to preclude typing FIRST COMBINE, SECOND COMBINE, FIRST AVERAGE, and SECOND AVERAGE, respectively.

4. The observer may shift the spectral line observed with respect to the filter bank by interacting with the hardware in accordance with receiver tuning procedures documented by Electronics Division. If this is performed, one may COMBINE or AVERAGE scans of differing spectral line shifts by using the offset parameter +LO for each scan.

5. To accomplish 4. above, recall the scan with shifted data and set +LO to correspond to the amount of the shift on the horizontal axis disregarding the decimal point on the values of the horizontal axis. For example, type

	600	F (or S)		cr
	AXES			cr
	-50	+LO	!	cr
(or)	50	+LO	!	cr

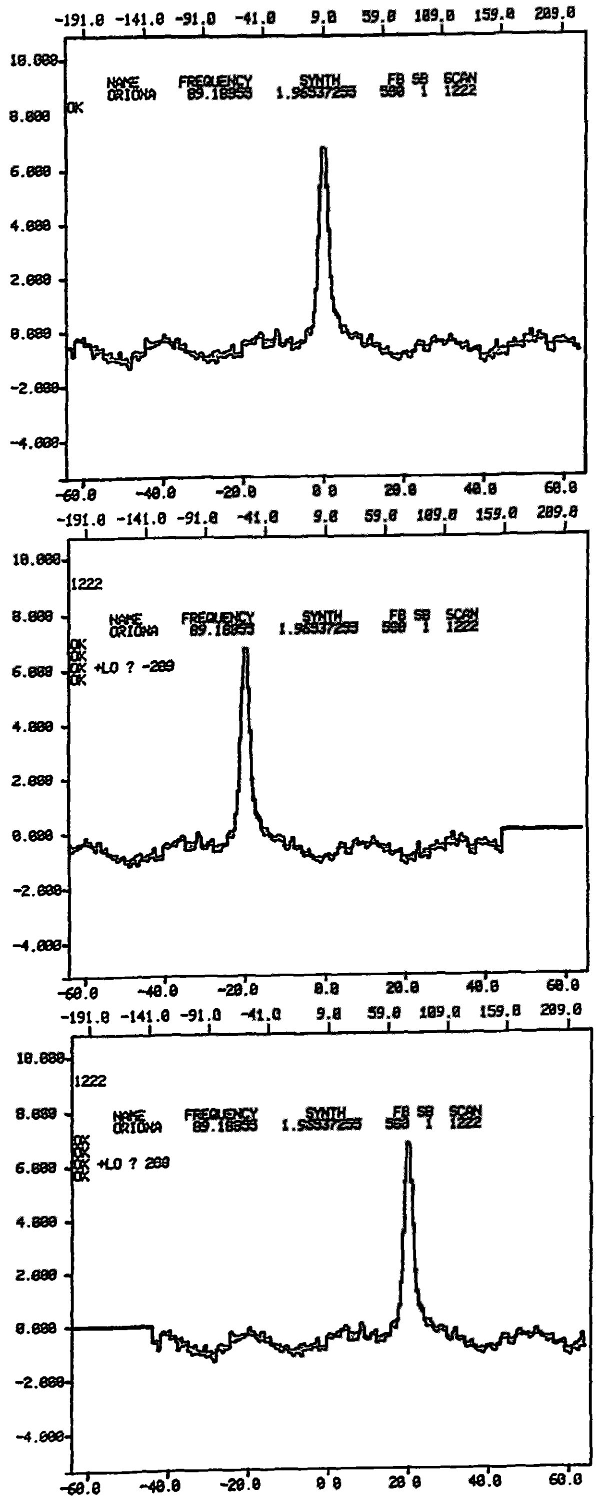
   Negative values of +LO will designate the scan to be shifted to the left on the TV screen; unsigned values of +LO will designate the scan to be shifted to the right on the TV screen.

6. One must repeat 5. above for each and every scan taken with shifted data.

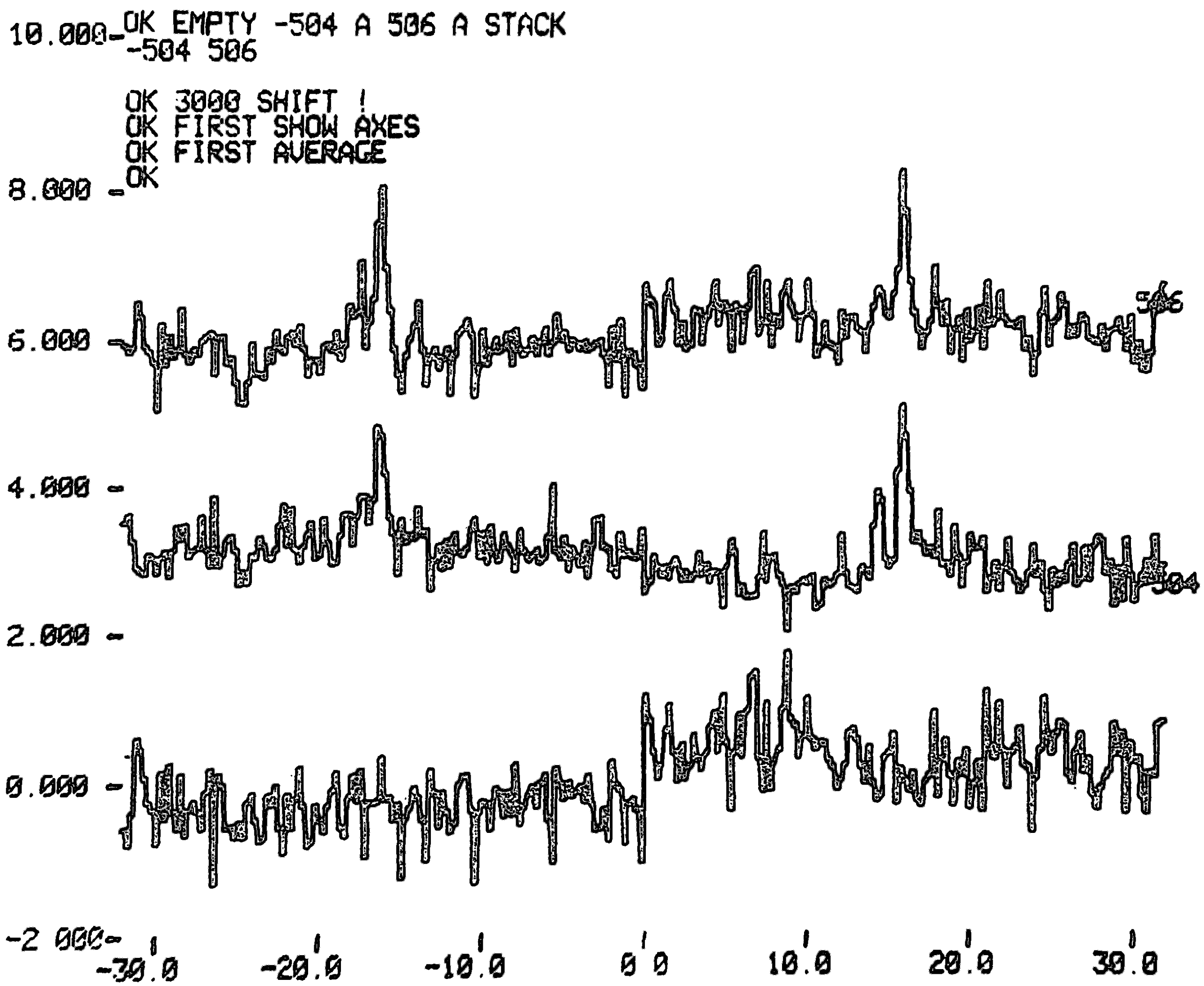
7. When scans that have had their respective +LO set to a non-zero value and the functions COMBINE and/or AVERAGE are used on these scans, data will be shifted prior to the mathematics of the COMBINE or AVERAGE.

8. To test this function to your satisfaction, place only one scan in the STACK and change its value of +LO as per 5. above and use the AVERAGE or COMBINE function on this one scan to see how the data shifts. An example follows on a succeeding page.

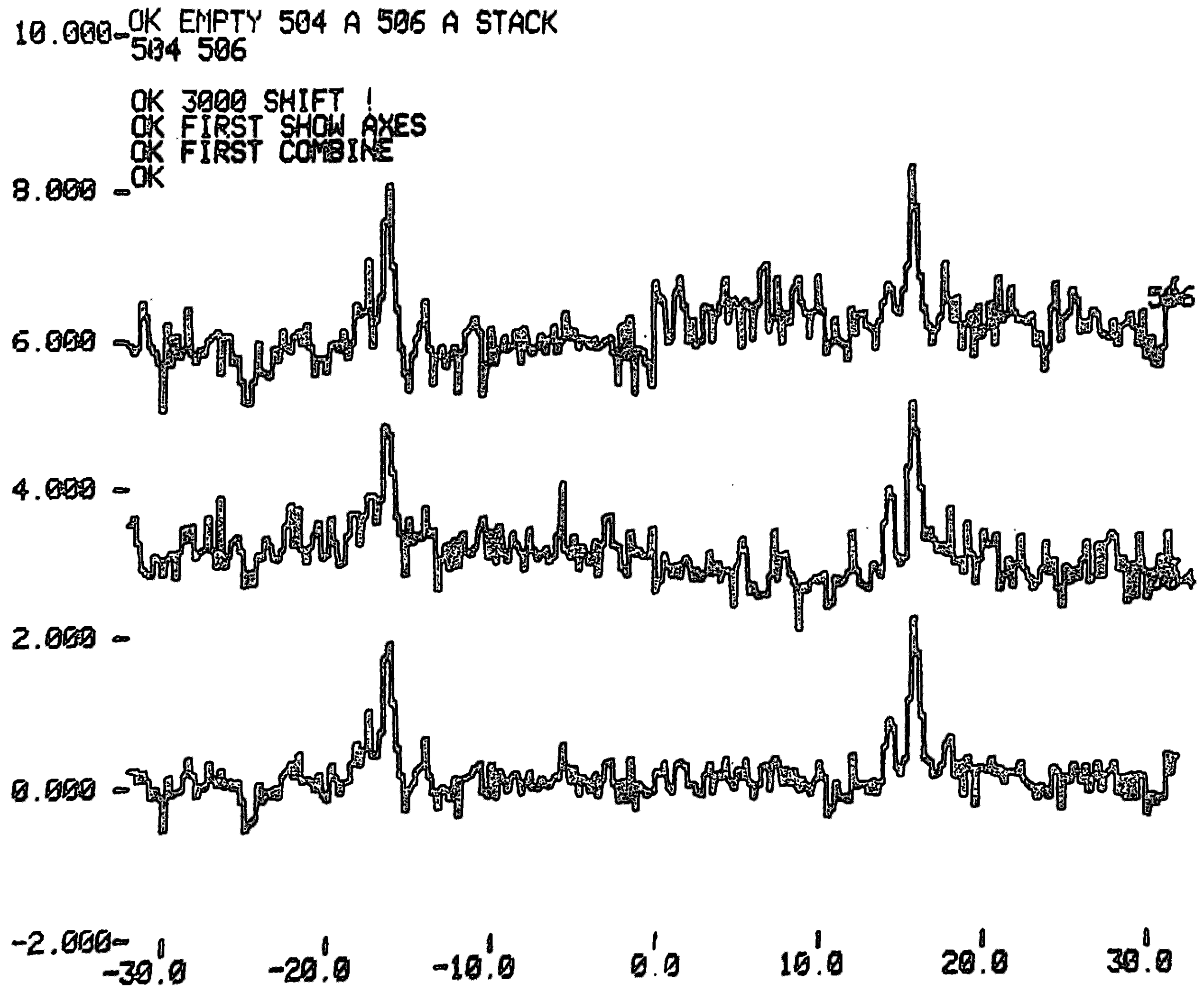
9. Note that no shift is effected when the words F, S, or SHOW are used.



Spectral Line Shift Examples



AVERAGE and SHOW Examples



COMBINE and SHOW Examples

R. Gaussian Fitting Options

1. At the Tektronix, recall scan n by typing

   n F (or S) cr

2. Based on 1. above, set the following initial guesses to the single (double) Gaussian in units of the axes (disregarding decimal points):

   (a) n HEIGHT ! cr

   where n is height of main Gaussian.

   (b) m WIDTH ! cr

   where m is half width of main Gaussian.

   (c) o CENTER ! cr

   where o is the center of the main Gaussian.

   (d) p BASE ! cr

   where p is the baseline of the main Gaussian.

   (e) q % ! cr

   where q is the relative percent of the secondary Gaussian height as compared to the main Gaussian height.

   (f) r DF ! cr

   where r is the relative horizontal axis unit difference of the secondary Gaussian peak as compared to the main Gaussian peak.

3. If the Gaussian is a double one, type the following phrase for obtaining the first iteration (DF and % are not determined by the fit):

   GAUSS DOUBLE ITERATE cr

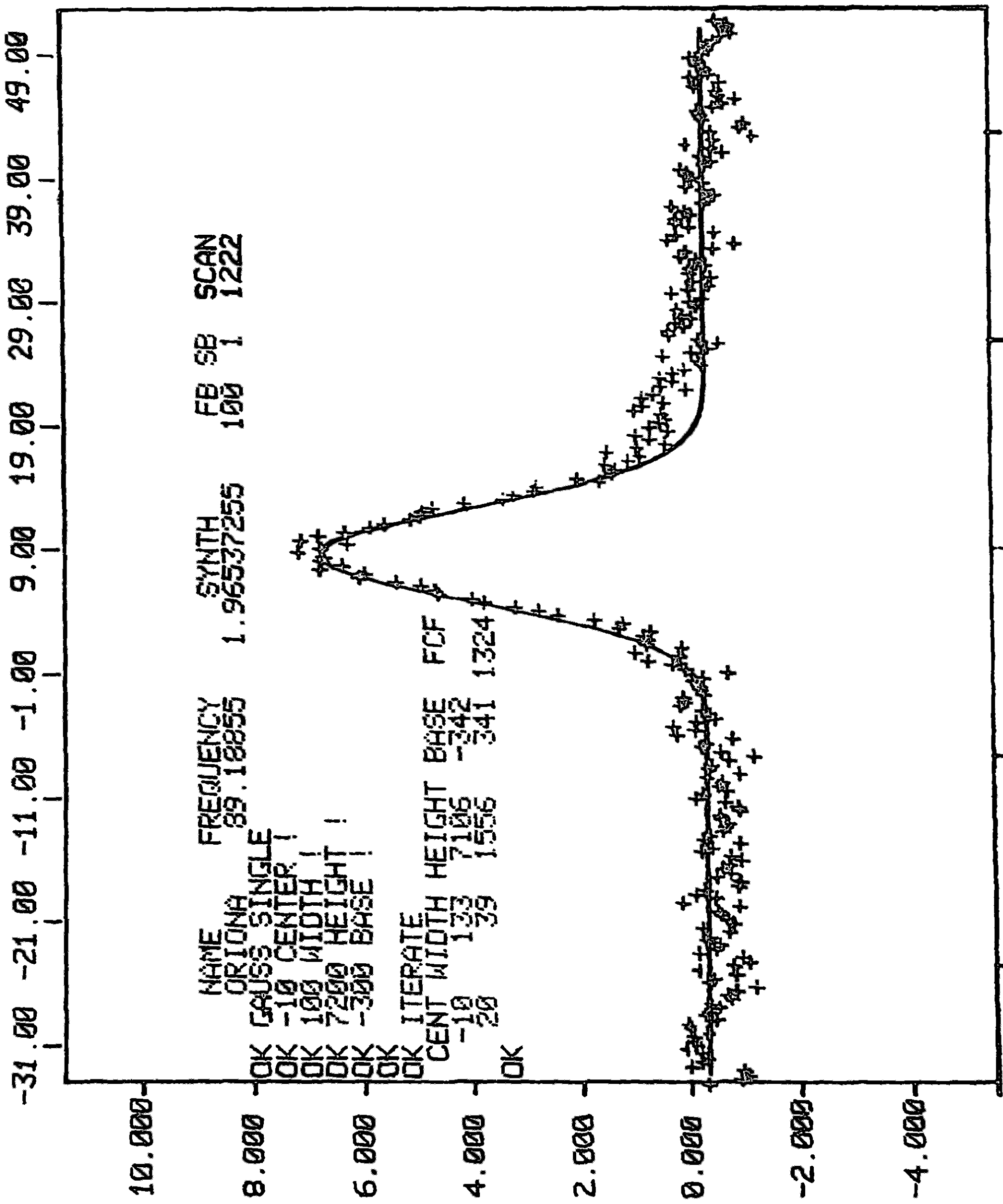
4. If the Gaussian is a single one, type the following phrase for obtaining the first iteration:

   GAUSS SINGLE ITERATE cr

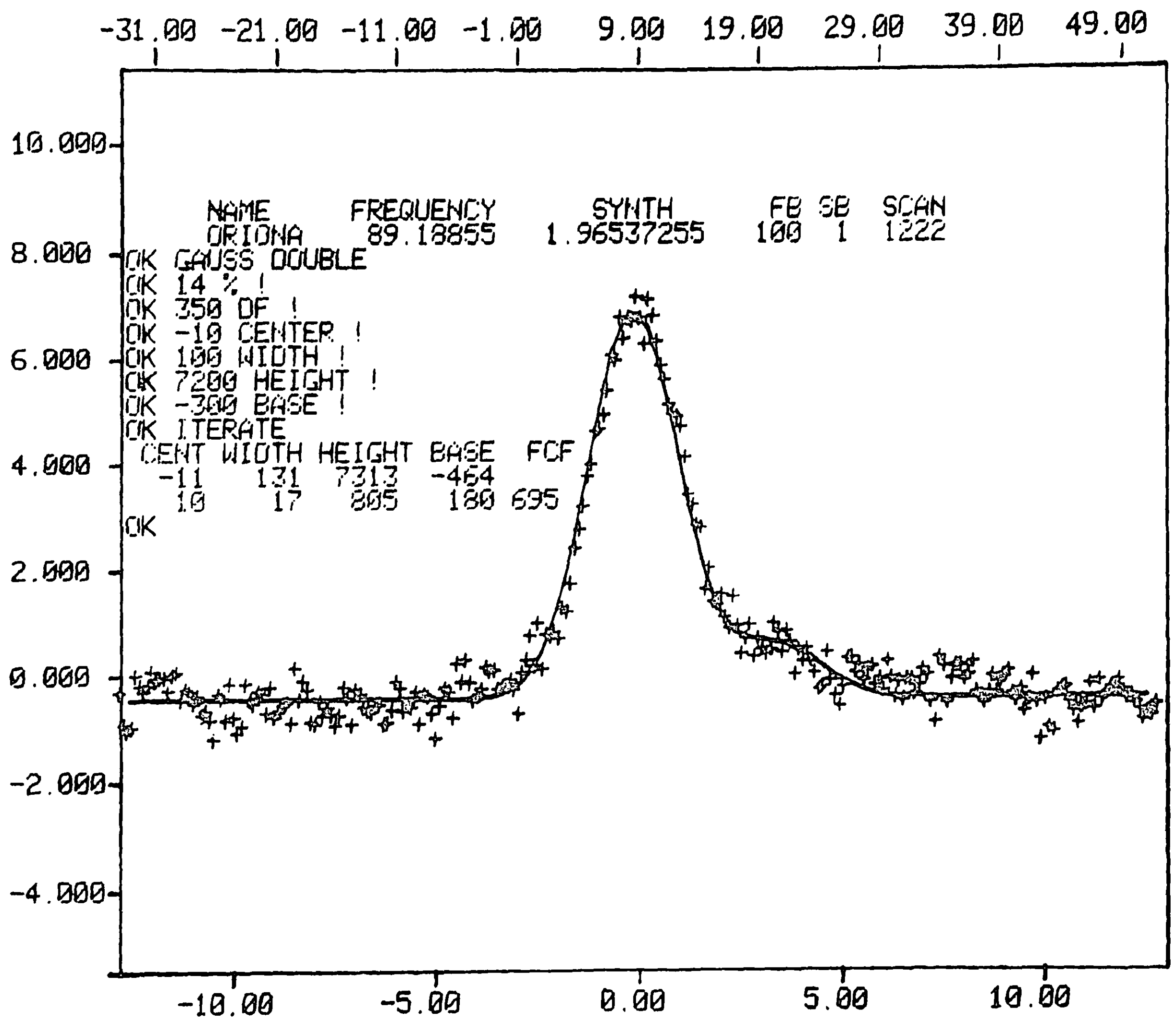
5. For further iterations on either 3. or 4. above, type the following:

   ITERATE cr

6. Examples follow on succeeding pages.



SINGLE GAUSS Example



DOUBLE GAUSS Example

X. Diagnostics

A. Disk Diagnostics

1. Have 3 LOAD or higher loaded at the teletype.

2. At the Tektronix, perform the following:

   210 LOAD 217 LOAD cr

3. Replace the disk with the one upon which diagnostics are to be performed.

4. The following vocabulary is now available at the Tektronix:

   (a) FORMAT cr

   will format the disk cartridge.

   (b) VERIFY cr

   will check the entire disk for checksum errors; it will abort with the phrase VERIFY ? if one is encountered. You may then query the disk status registers to investigate the problem.

   (c) STATUS cr

   will return the value of the disk status register.

   (d) DRIVE cr

   will return the value of the drive status register.

   (e) CHECKSUM cr

   will return the value of the checksum bit.

B. Tape Diagnostics

1. Have 3 LOAD or higher loaded at the teletype.

2. At the Tektronix, perform the following:

   210 LOAD 218 LOAD cr

3. Mount and place on line the desired tape to be checked.

4. The following vocabulary is now available at the Tektronix:

   (a) WRITES cr

   will continually call block 2000 off disk into an I/O buffer and then write it out onto the tape; each time it does this it will print out the value of the tape status word. To cease this operation, press the cr key.

   (b) REWIND READS cr

   will rewind the tape and then read each block off tape, bringing it into an I/O buffer, each time it does this it will print out the value of the tape status word. To cease this operation, press the cr key.

   (c) n PATTERN cr

   will load each word of block 2000 on disk with the number n.

   (d) .PATTERN cr

   will print out the first 256 words of block 2000, having fetched it from disk.

   (e) .TAPE cr

   will fetch the next available block from tape, place it in an I/O buffer, and then print out the first 256 words.

C. Telescope Drive Diagnostics

1. At the teletype, perform and/or insure the following:

   (a) 3 LOAD TRACK LOAD or higher loaded.

   (b) Command the telescope to the following AZ-EL position and set it to AUTO-TRACK:
   180:00 45:00 AZ-EL cr

   (c) TELESCOPE Ø AZ SPLIT cr

2. At the Tektronix, perform the following:

   210 LOAD 216 LOAD cr

3. If drive velocities are to be monitored, connect the azimuth tachometer to channel 20_8 and the elevation tachometer to channel 21_8 of the omniverter analog to digital outputs.

4. The following vocabulary is now available at the Tektronix:

   (a) AZ cr

   sets diagnostics up to move telescope in azimuth only when a STEP, VELOCITY, or ALT command is given.

   (b) EL cr

   same as AZ except telescope is set up to move only in elevation.

   (c) n "/ DELTA ! cr

   n is the step size in seconds of arc desired. DELTA is the step size parameter.

   (d) STEP cr

   commands the telescope to move by the amount DELTA and monitors the position error for 5 seconds. It will plot 1000 points of position error.

   (e) ALT cr

   alternately does a positive and negative STEP until the cr key is pressed.

(f) VELOCITY cr

Monitors 1000 points of telescope drive velocity (200 points/second).

(g) n PHASE cr

Plots drive velocity versus position error for n points.

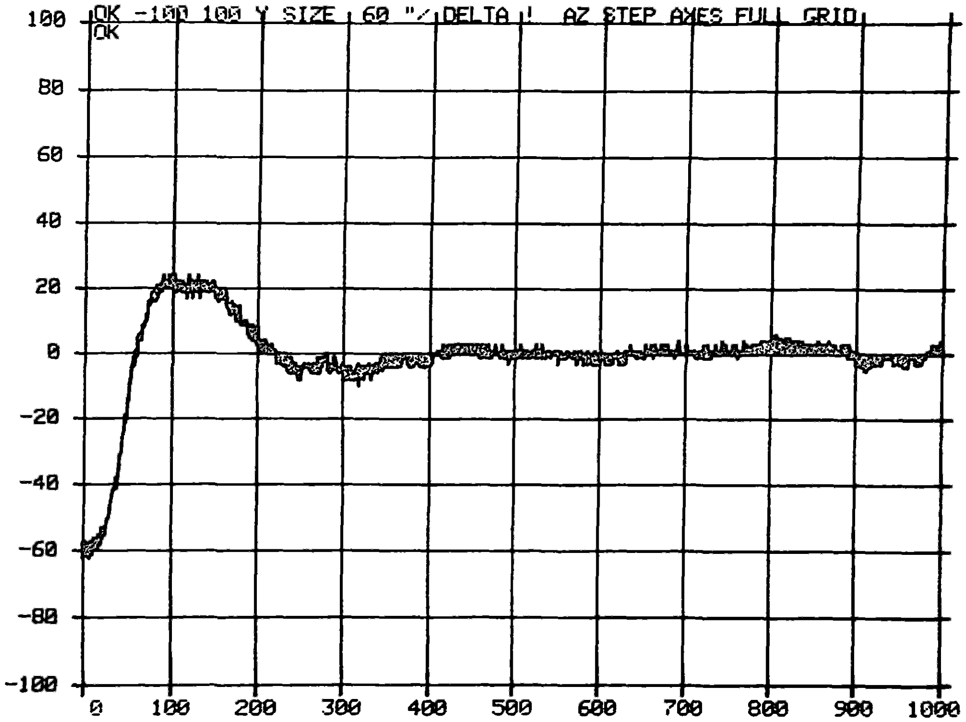
(h) n m Y SIZE

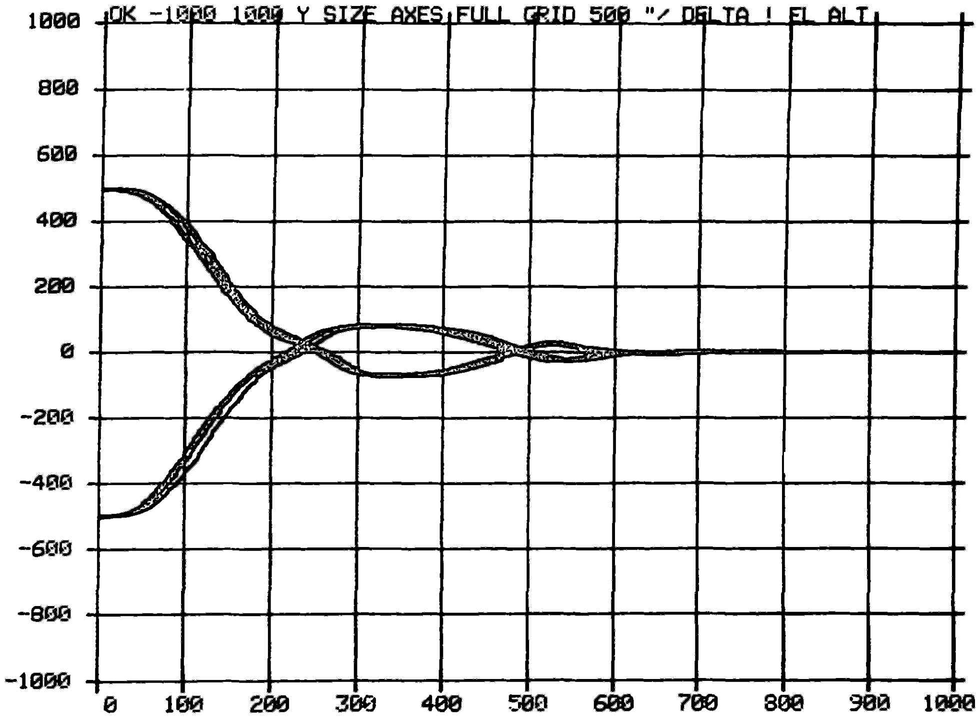
will change the vertical axis scale.

(i) n m X SIZE

will change the horizontal axis scale.

5. See following page for examples of drive diagnostic displays.





Drive Diagnostics Examples

D. Omniverter Diagnostics

1. Have 3 LOAD or higher loaded at the teletype.

2. At the Tektronix, perform the following:

   210 LOAD 214 LOAD cr

3. The following vocabulary is now available at the Tektronix:

   (a) 0 A/D ! cr

   Set A/D channel to be tested.

   (b) 30 D/A ! cr

   Set D/A channel to be tested.

   (c) n BIT cr

   Sets a designated bit pattern on the D/A and leaves that pattern /2 on the stack (for successive use).

   (d) n -BIT cr

   Same as BIT, but with minus sign set on.

   (e) RAMP cr

   Sends a ramp out the D/A, reads it on the A/D and plots the result.

E. Multiplexer and/or Filter Bank Diagnostics

1. Have at least SPECTRA LOAD loaded at the teletype.

2. At the Tektronix, perform the following:

   210 LOAD 215 LOAD cr

3. Cease observing at the teletype.

4. Accumulation of 512 Channel Data at the Tektronix Terminal.

   This procedure can be used to check the long-term time dependence of all channels of the multiplexer and/or filter banks. Essentially, one sample of 512 channel data from the multiplexer is taken; these data are subtracted from all subsequent 512 channel data samples and the absolute values of these subtractions are accumulated in an array which can be plotted at the Tektronix on demand.

   (a) Install a 20 db pad in the zero check input.

   (b) Establish the plot axes by typing

			PAGE	cr
0	512	X	SIZE	cr
0	10000	Y	SIZE	cr
			AXES	cr

   (c) Start data accumulation by typing

   ACC cr

   (d) To plot out what has accumulated so far, type

   APLOT cr

5. Sampling One Channel in Time at the Tektronix.

This procedure can be used to check the short-term time dependence of one channel in the multiplexer and/or filter bank. Repetitive samples of a selected channel are plotted against time.

(a) Select the channel to be sampled by typing

```
n    ITH    !    cr
```

where $1 \leq n \leq 512$.

(b) Select the number of samples to be performed on the channel selected by typing (example)

```
1000    NS    !    cr
```

(c) Set up the plot axes and begin taking data by typing

```
ONE    cr
```

6. Plotting One Sample of 512 Channel Data at the Tektronix Terminal.

(a) Establish the plot axes by typing

```
                        PAGE    cr
  0      512     X      SIZE    cr
-1000    1000    Y      SIZE    cr
                        AXES    cr
```

(b) Take one sample by typing

```
GO    cr
```

(c) Plot the sample taken by typing

```
RAW    cr
```

F. SPECTRA Diagnostics

1. At the teletype, have SPECTRA loaded as per the SPECTRA Operator's Check List. Do not, however, have CHOPPER, NO-CAL, etc. loaded.

2. At the teletype, type

   282 LOAD cr

3. At the Tektronix, type

   SPECTRA LOAD 226 LOAD cr

4. The following vocabulary is now available at the teletype for taking data:

   (a) B cr

   selects position switching mode, resets the Signal and Reference arrays, and does 100 samples of Signal followed by 100 samples of Reference. Set EXPEDITE if necessary prior to using B.

   (b) SS cr

   selects position switching mode, resets the Signal and Reference arrays, and does 100 samples of Signal. Set EXPEDITE if necessary prior to using SS.

   (c) RR cr

   does 100 samples of Reference; use after SS.

   (d) TAT cr

   prints out the number of Signal samples last taken followed by the number of Reference samples last taken.

   (e) RESET cr

   resets the Signal and Reference arrays; must be used prior to using INTEGRATE. It is contained within the words B and SS.

   (f) n INTEGRATE cr

   will integrate for n samples; an observing mode must be specified prior to its use (i.e., 'FS and 'PS).

5. The following vocabulary is available for data display at the Tektronix after having performed one of the data taking actions in 4. above.

(a) FIRST S-AVG AXES cr
(or)
SECOND S-AVG AXES cr

displays the Signal array data.

(b) FIRST R-AVG AXES cr
(or)
SECOND R-AVG AXES cr

displays the Reference array data.

(c) FIRST S-R AXES cr
(or)
SECOND S-R AXES cr

displays Signal minus Reference data.

(d) FIRST S-R/R AXES cr
(or)
SECOND S-R/R AXES cr

displays the quantity Signal minus Reference divided by Reference.

INDEX

Common CONTINUUM Display Recipes

1. Recall scan n of various types

n	CAL	(CALIBRATE)
n	F	(FIVE POINTS)
n	FOCALIZE	(FOCALIZE)
n	S	(SEQUENCE)
n	TIP	(EXTINCTION)

2. Put 10 consecutive scans in STACK and average

```
EMPTY
n      A
9      ADD
PAGE
COMBINE
AXES
AVG
```

3. Display the difference between two sets (n and m) of scans

```
EMPTY
 n1   A     n2    A   .....
-m1   A    -m2    A   .....
PAGE
AVERAGE
AXES
AVG
```

4. Query offsets now in the program

```
THUMB
```

5. Print out average temperature and its error for scan n or for each of scans n through m

```
     n    LOG
n    m    LOGS
```

6. Compute and print out an average temperature and its error for all scans in the STACK.

```
EMPTY
n1    A
n2    A    etc.
<LOG>
```

Common MAPPING Display Recipes

1. Display a two-dimensional countour map of scan n

```
90      PITCH      0      YAW
n       RECALL
m       SPACE      !
ℓ       h          LEVEL
AXES
KONTOUR
```

2. Display a perspective view of scan n

```
m       PITCH      o      YAW
n       RECALL
ℓ       h          RANGE
AXES
PLOT
```

3. Recall and plot the mapping array of scan n

```
PAGE
n       MAP-PRINT
PAGE
ℓ       h       RANGE
AXES
n       MAP
```

Common FOURIER Display Recipes

1. Recall scan n and perform Fourier Transforms

```
ℓ       h       RANGE
PAGE
n       RECALL
AXES
PAGE
TRANSFORM                   (power spectrum)
AXES
PAGE
n       RECALL
PAGE
 1      FFT     EXAMINE     (Fourier Transform)
AXES
PAGE
-1      FFT     EXAMINE     (Inverse Fourier Transform)
AXES
```

Common SPECTRA Display Recipes

1. Recall scan n and FOLD (or HALVES) data shifted by m channels

```
n   F (or S)
m  DF   !
FOLD (or HALVES)
XX
```

2. Put 10 consecutive scans in STACK and average

```
EMPTY
n   A
9   ADD
C1 (or C2)
```

3. Display the difference between two sets (n and m) of scans

```
EMPTY
 n1   A   n2   A   ...
-m1   A  -m2   A   ...
A1 (or A2)
```

4. Display 5 scans on the same plot

```
-1000    20000   RANGE
 2000    SHIFT   !
PAGE
AXES
FIRST (or SECOND)    SHOW
```

5. Remove a linear baseline from scan n

```
n   F (or S)
m   SLOPE   !
TILT
TILT    etc.
XX
```

6. Display GAINS or ZERO

```
PAGE
FIRST    GAINS    (or ZERO)
AXES
MANUAL
POINTS
SECOND   GAINS    (or ZERO)
HISTOGRAM
AUTO
```

7. Query offsets now in the program

```
THUMB
```

8. Average scan n with scan m where m is shifted -5 MHz with repect to n

```
m    F (or S)
-50   +LO   !
EMPTY
n    A    m    A
C1   (or C2)
```

9. Expand a portion of the plot for scan n

```
n   F (or S)
low   high   SPREAD
XX
low   high   LIMIT
XX
```

The low and high for SPREAD and LIMIT may not be the same; LIMIT low and high may be a factor of 10 larger than that for SPREAD.

10. Fit a gaussian to scan n

```
n  F (or S)
GAUSS     SINGLE (or DOUBLE)
n1        CENTER     !
n2        WIDTH      !
n3        HEIGHT     !
n4        BASE       !
n5        DF         !   (for DOUBLE only)
n6        %          !   (for DOUBLE only)
ITERATE
ITERATE      etc.
XX
ITERATE
```

Epilogue

"But you're out of your mind,"
they said with a shrug
"The director is happy...
What's one little bug."

But the programmer was determined,
the others went home.
He spread out the program,
deserted...........alone.

When the cleaning men came,
the whole room was cluttered
with dumps and punched cards,
"I'm close," he muttered.

The mumbling got louder.
"Simple deduction,
I've got it. It's right.
Just change one instruction."

It still wasn't perfect
as year followed year.
The observers would comment,
"Is that guy still here."

He died at the console
of hunger and thirst.
Next day he was buried
face down nine edge first.

The last bug in sight
was an ant passing by,
saluted his tombstone
and whispered, "Nice try."

Author Unknown

Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

September 23, 1977

To: Distribution List

From: Jan M. Hollis

Subject: #1 Change Memo for the 36-ft Telescope Computer System Manual (October 1976)

The 1977 Summer Shutdown precipitated several significant changes to our spectral line and continuum data taking programs. All observing programs after 1 September 1977 are affected by these changes.

We are now able to take two-channel continuum data by loading

TWO LOAD cr

at the teletype. All subsequent data taking commands in this new program are just like those in the CONTINUUM program which still exists for single-channel work. Obviously, however, twice as much data is recorded in the TWO program and thus the parameter RPT must be no more than 63 for TWO observations (RPT can be no more than 127 for CONTINUUM observations, see page 80-81 of the manual). In TWO the terms TC1 and TC2 refer to noise tube temperatures for each channel and can be set like TC for CONTINUUM (see page 82 of the manual). Data Reduction of TWO observations at the Tektronix can be performed just like CONTINUUM observations. However one must select the channel for subsequent data reduction (e.g., F,S, SUM, etc.) by typing either

1ST cr

or 2ND cr

when CONTINUUM is loaded at the Tektronix. This selection remains in effect until the alternate command is executed. Upon loading CONTINUUM at the Tektronix, 1ST is the default.

In the spectral line data taking program SPECTRA, a more efficient position switching data-taking routine for both PS and APS observations is now in effect. The computer takes data in the following sequence:

#1 Sample - OFF then ON
#2 Sample - ON then OFF
#3 Sample - OFF then ON
#4 Sample - ON then OFF
#5 Sample - OFF then ON
#6 Sample - ON then OFF
etc.

Thus, the number of samples (determined by the parameter RPT, see page 135 of the manual) should be selected as an even number for minimizing the switching of the telescope.

Both the teletype and Tektronix terminals have been programmed to echo a "/" character when the RUBOUT key is pressed to delete the last character typed. Moreover the BREAK key, which will erase the entire line currently typed, now responds with a "/OK" at either terminal.

On page 2 of the manual a decimal point should appear in the example for proper source card format

-24:22:52. vice -24:22:52

On page 8 of the manual the reference at the bottom of the page should be:

Introduction to Numerical Analysis (Second Edition) by F. B. Hildebrand, McGraw-Hill, 1974, pp. 457-462 for non-linear least squares fitting fitting; pp. 320-326 for computation of errors on least squares fitting.

Unfortunately due to the advent of the TWO program, some header variables have been re-arranged for SPECTRA, CONTINUUM and MAPPING programs. The attached 7 pages should be substituted for pages 50 through 53 and 89,90,147, and 148 in the manual. Tapes created prior to 1 September 1977 are not completely compatible with the new tape format. However old binary data tapes can be used on our present system for data display and reduction.

SPECTRA ASCII Header Information Key

SCAN# Ø(8)	'UNIT 13(8)	RCVR 11(8)	DUT1 80(8)	MODE 12(8)	%EFF 14(8)	TIME 17(9)		Fill Spaces (7)
DATE 4(8)	OBS 24-25(5)	OPR 26-27(5)	SOURCE 28-33(14)	AZ-OFF 8(9)	EL-OFF 9(10)	TOL 71(8)		Fill Spaces (5)
'RA 18-19(13)	'DEC 20-21(12)	'AZ 23(10)	SIN(EL) 22(9)	ATTN 66(9)	FILTERS 100(8)			Fill Spaces (3)
'UT 15(8)	'LST 16(8)	#SAMPLES 34(8)	#SCANS 35(8)	FØ 75(9)	PA 5(10)			Fill Spaces (13)
SEC 69(9)	TC 64(9)	+LO 1(8)	#FB 2(8)	VEL 3(9)	1ST-IF 38(8)	LO-IF 39(8)		Fill Spaces (5)
SB 42(8)	SYNTH 36-37(16)	FREQ 40-41(15)	#FTS 47(8)	BANDWIDTH 49(8)				Fill Spaces (9)
#CH 50(8)	CHØ 51(8)	BW 52(8)	RMS 53(8)	#CH 55(8)	CHØ 56(8)	BW 57(8)	RMS 58(8)	Fill Spaces (0)
#CH 60(8)	CHØ 61(8)	BW 62(8)	RMS 63(8)	TS 83(8)	BASELINE 123-124(11)			Fill Spaces (14)
RNAME 94-99(15)	REF OFFSETS:	AZ 110(10)	EL 111(10)	RA 112(10)	DEC 113(10)			Fill Spaces (10)
MAIN OFFSETS:	AZ 106(10)	EL 107(10)	RA 108(10)	DEC 109(10)	RPT 103(8)			Fill Spaces (16)
MAIN:	RA(1950) 114-115(13)	DEC(1950) 116-117(12)	REF:	RA(1950) 118-119(13)	DEC(1950) 120-121(12)			Fill Spaces (14)

CONTINUUM/MAPPING ASCII Header Information Key

SCAN# Ø(8)	'UNIT 13(8)	RCVR 11(8)	DUT1 80(8)	MODE 12(8)	%EFF 14(8)	TIME 17(9)	Fill Spaces (7)
DATE 4(8)	OBS 24-25(5)	OPR 26-27(5)	SOURCE 28-33(14)	MAIN BEAM AZ-OFF 8(9)	EL-OFF 9(10)	TOL 71(8)	Fill Spaces (5)
'RA 18-19(13)	'DEC 20-21(12)	'AZ 23(10)	SIN(EL) 22(9)	ATTN 66(9)			Fill Spaces (11)

'UT
15(8)
	'LST
	16(8)
		(ROWS)
		#SAMPLES
		34(8)
			(#SAMPLES/ROW)
			#SCANS
			35(8)
				FØ
				75(9)
					PA
					5(10)
							Fill Spaces
							(13)

FIVE POINT
AZ-OFF
6(10)
	EL-OFF
	7(10)
		#PTS
		47(8)
			HP
			46(8)
				SEC
				69(9)
							Fill Spaces
							(19)

REF BEAM AZ-OFF 110(10)	EL-OFF 111(10)	CELL 63(10)	MA 51(10)				Fill Spaces (24)

CH #1:	TS
	83(8)
		TC
		64(9)
			#C
			67(8)
				#CP
				81(8)
					BASE
					123(8)
						RMS
						36(8)
							Fill Spaces
							(15)

CH #2:	TS
	84(8)
		TC
		65(9)
			#C
			68(8)
				#CP
				82(8)
					BASE
					124(8)
						RMS
						37(8)
							Fill Spaces
							(15)

	T1 117-118(11)	ET1 119(8)	T2 114-115(11)	ET2 116(8)			Fill Spaces (26)

```
 1234567890123456789012345678901234567890123456789012345678901234

 1      512         2        4       46          2        28     600.0
 2   26 AUG  LES   DOM        DR21(OH)       0:30      -1:00        10
 3    20:38:15.2   42:18:10.       7:13     0.983        0.0      288
 4     5:43   20:34        20        1       34.0       0:00
 5      30.0    800.0        0         2       -3.3     4750      400
 6        1        1.99548111      88.63185      512      500
 7      256        0     1000        9       256      256      250       19
 8        0        0        0        0         0          63
 9               REF     30:30      -1:00       0:00       0:00
10       0:30      -1:00        0:00       0:00       10
11    20:37:14.0   42:12:00.   20:37:14.0   42:42:00.
12
13
14
15
16

 1234567890123456789012345678901234567890123456789012345678901234
```

```
 1234567890123456789012345678901234567890123456789012345678901234

 1      536         2        4       46          1        28       5.0
 2   26 AUG  WAD  PJR         JUPITER      0:36       0:17          5
 3     6:04:14.1   23:02:06.      78:46     0.457        7.5
 4    10:27   25:19         5        5       34.0       0:00
 5       0:00       0:38       10       38       5.0
 6      10:36       0:17       0:00       0:00
 7      283       7.0     3449     2400    -1290         1
 8      482       7.0     1975     1440     -940         1
 9        2755       283        2745       283
10
11
12
13
14
15
16

 1234567890123456789012345678901234567890123456789012345678901234
```

OK

New Examples for pages 51 and 53.

E. CONTINUUM/MAPPING Header Variables Recorded on Disk (and Binary Tape)

WORD LOCATION	NAME	DESCRIPTION
Ø	HEADER	Current scan number - 5ØØ to 2ØØØ allowed
4	DAY	Modified JD - from 1 JAN 195Ø
5	PA-RCVR	Position angle of receiver box
6-7	OFFSETS	Five point AZ-EL offsets (low order portion of .22)
8-9	MAIN	AZ-EL main beam offsets (low order portion of .22)
11	RCVR	Receiver ID integer
12	MODE	Observing mode integer
13	'UNIT	Base 10 exponential scale factor for data (0,1,2,3,4)
14	%EFF	Aperture efficiency (%)
15	'UT	UT at beginning of scan (.14)
16	'LST	LST at beginning of scan (.14)
17	TIME	Actual integration time of scan (tenths of seconds)
18-19	'RA	Commanded RA (.22), no offset applied
20-21	'DEC	Commanded DEC (.22), no offset applied
22	SINH	Sine of commanded elevation angle (.14)at start of scan
23	'AZ	Commanded AZ (.14) reckoned from the North at start of scan
24-25	OBS	Observer initials Character count + 3 characters (ASCII)
26-27	OPR	Operator initials Character count + 3 characters (ASCII)
28-33	NAME	Source name, Ch count + 11 characters (ASCII)
34-35	NS	Number of rows in first word and number of samples row in second word
36	RMS	Theoretical RMS of CH #1 receiver (K* 10 EXP(+'UNIT))
37	RMS	Theoretical RMS of CH #2 receiver (K* 10 EXP(+'UNIT))
46	HP	Half the HPBW of the antenna ("of arc)
47	#PTS	Number of observational data points
49	BANDWIDTH	Bandwidth of receiver (MHz)
51	SA	Scanning angle with respect to NCP (.14)
63	CELL	Size of sample grid (seconds of arc)
64	TC	CH #1 cal temperature (tenths of K)
65	TC	CH #2 cal temperature (tenths of K)

WORD LOCATION	NAME	DESCRIPTION
66	ATTN	Zenith atmospheric attenuation (tenths of %)
67	#C	Number of CH #1 SP counts = to TC of CH #1
68	#C	Number of CH #2 SP counts = to TC of CH #2
69	SEC	Tenths of seconds per sample
71	TOL	Tracking tolerance in seconds of arc
75	FØ	Focus offset (tenths of mm)
80	DUT1	UT clock correction in thousandths of a second
81	#CP	Number of CH #1 TP counts = to TC of CH #1
82	#CP	Number of CH #2 TP counts = to TC of CH #2
83	TS	CH #1 system temperature (K)
84	TS	CH #2 system temperature (K)
110-111	REF	AZ-EL REF position offsets (low order portion of .22)
114-115	T2	Average temperature (DP) of CH #2 data in K* 10 EXP ('UNIT + 1)
116	ET2	RMS of T2 in same units as T2
117-118	T1	Average temperature (DP) of CH #1 data in K* 10 EXP ('UNIT + 1)
119	ET1	RMS of T1 in same units as T1
123	BASE	CH #1 uncorrected base
124	BASE	CH #2 uncorrected base
128	--	Starting location of recorded data; all data is single precision

Notes:

(a) See the Tape and Disk Utility Check Lists & Information Chapter concerning Off-Line Data Reduction for Binary Tapes for the meaning of (.22), (.14) and (DP).

(b) Characters in ASCII are stored in the order 2N436587 . . . where N is a binary number equal to the number of characters in the word.

G. SPECTRA Header Variables Recorded on Disk (and Binary Tape)

WORD LOCATION	NAME	DESCRIPTION
Ø	HEADER	Current scan number - 5ØØ to 2ØØØ allowed
1	+LO	Local Oscillator offset (tenths of MHz)
2	#FB	Number of filter banks used (1, 2 or 3)
3	VEL	Source velocity with respect to LSR (tenths of km/sec)
4	DAY	Modified JD - from 1 JAN 195Ø
5	PA-RCVR	Position angle of receiver box (.14)
8-9	MAIN	AZ-EL main beam offsets (Low order portion of .22)
11	RCVR	Receiver ID integer
12	MODE	Observing mode integer
13	'UNIT	Base 10 exponential scale factor for data (0,1,2,3,4)
14	%EFF	Aperture Efficiency (%)
15	'UT	UT at beginning of scan (.14)
16	'LST	LST at beginning of scan (.14)
17	TIME	Actual integration time of scan (tenths of seconds)
18-19	'RA	Commanded RA (.22), no offset applied
2Ø-21	'DEC	Commanded DEC (.22), no offset applied
22	SINH	Sine of commanded elevation angle (.14) at start of scan
23	'AZ	Commanded AZ (.14) reckoned from the North at start of scan
24-25	OBS	Observer initials Character count + 3 characters (ASCII)
26-27	OPR	Operator initials Character count + 3 characters (ASCII)
28-33	NAME	Source name Character count + 11 characters (ASCII)
34-35	NS	Number of samples in first word and number of scans in second word
36-37	SYNTH	Synthesizer setting (DP) (tens of Hz)
38	1ST-IF	(MHz)
39	LO-IF	(MHz)
4Ø-41	FREQ	Sky frequency (DP) (tens of kHz)
42	SB	Sideband integer
47	#PTS	Number of Multiplexer channels used
49	BANDWIDTH	Bandwidth of the receiver (MHz)
50,55,60	#CH	Number of channels in each filter bank
51,56,61	CHØ	Starting channel in each filter bank
52,57,62	BW	Bandwidth per channel in each filter bank (kHz)
53,58,63	RMS	Theoretical RMS of each filter bank (K* 10 EXP(+'UNIT))
64	TC	Calibration temperature (tenths of K)
66	ATTN	Zenith atmospheric attenuation (tenths of %)
69	SEC	Tenths of seconds per sample

WORD LOCATION	NAME	DESCRIPTION
71	TOL	Tracking Tolerance in seconds of arc
75	FØ	Focus offset (tenths of mm)
80	DUT1	UT clock corrections in thousandths of a second
83	TS	System temperature (K)
94-99	RNAME	Ref name (See NAME)
100	FILTERS	Software load block for filter banks
103	RPT	Number of pairs in PS or APS scan
106-109	SOURCE	AZ,EL,RA,DEC main position offsets
110-113	REFERENCE	AZ,EL,RA,DEC reference position offsets
114-115	X50	RA(1950) Source in APS (.22)
116-117		DEC(1950) Source in APS (.22)
118-119		RA(1950) Ref in APS (.22)
120-121		DEC(1950) Ref in APS (.22)
123-124	BASELINE	Baseline (DP) for data to prevent data overflow (K* 10 EXP(+'UNIT))
128	--	Starting location of recorded data; all data is single precision.

Notes:

(a) See the Tape and Disk Utility Check Lists & Information Chapter concerning Off-Line Data Reduction for Binary Tapes for the meaning of (.22), (.14) and (DP).

(b) Characters in ASCII are stored in the order 2N436587 . . . where N is a binary number equal to the number of characters in the word.

Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

November 29, 1977

To: Distribution List

From: Jan M. Hollis

Subject: #2 Change Memo for the 36-ft Telescope Computer System Manual (October 1976)

A new disk error detection scheme has been implimented in the latest version of our software. Henceforth, any disk error on either a READ or WRITE operation will cause that operation to be repeated until it is successful. If the operation is not successful after a maximum of 3 attempts, an error message will print out at the teletype (even if the error occurred at the Tektronix or in a non-terminal background task). The form of the error message is (example):

$000399   000200   140304

The $ character is just a unique flag to let the reader of the teletype output know that a fatal disk error has occurred. The next number (399) is the disk decimal block number involved in the error. The following number is the octal contents of the disk error register. The last number is the octal contents of the disk status register. The meaning of the contents of the disk error and status registers can be decoded by referring to the PDP-11 Peripherals and Interfacing Handbook for the RK05 disk unit. After the teletype prints out the fatal disk error message, the computer alarm will come on and the computer will halt on its own to prevent any successive disk operations. The operator will have to reload the program after such an error. If the conditon persists, it may be necessary to use a new disk and/or disk unit. If using a new disk and/or disk unit fails, call for digital help. The above description replaces sections II. A. 1. and II. A. 2. on page 13 of the manual.

The SPECTRA program has several new convenience definitions to display calibration data (G1 and G2) and zero checks (Z1 and Z2). The definitions of G1, G2, Z1 and Z2 are used analogously to C1 and C2 as described on page 164 of the manual. Additionally, in the interests of better computer timing, the current scan in progress can only be displayed by executing Q1 and Q2 since data pair running averages are now kept in core until the very end of a scan when the final result is recorded on tape and disk. Thus a scan should not be added to the scan table for COMBINE or AVERAGE operations until the end of the scan. Moreover, at the moment the definition of Q as it appears on page 170 is inoperative;

there is no way to see a frequency switched scan until the scan has ended.

Also in the SPECTRA program a total power observing scheme is now possible. The verb to execute this is TP (analogous to PS, FS, etc.). The TP command takes a series of ON observations (the number of observations equal to the value of RPT) each of which is SEC long and pointed at the source. A previous OFF from (say) a VANE calibrate is used to form ON-OFF pairs. Care must be taken to insure that the time duration of the OFF portion of the calibrate is the same as the SEC to be used in the TP observation. A warning message will print out if a TP is attempted with an ON-OFF time mis-match and the TP will abort. Moreover the TP observation will not focus the receiver but will indicate on the TV screen what the new focus should be under the present temperature and elevation conditions. This is instituted so that baseline problems due to standing waves are not incurred. However, the telescope will re-focus upon execution of a calibrate. It is only a matter of time before base-line problems will occur when using TP and one is forced to re-calibrate. There are a few limited situations where TP may be useful to an observer such as spectral line mapping and occultation work. TP observations should be employed cautiously where weak lines intensities are involved.

Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

February 10, 1978

To: Distribution List

From: Jan M. Hollis

Subject: #3 Change Memo for the 36-ft Telescope Computer System Manual (October 1976)

The SPECTRA program now automatically sets the synthesizer at the beginning of each scan or CALIBRATE. The verb REFRESH no longer computes a new synthesizer setting. You will notice that the TV screen has two synthesizer numbers now. The top one is Signal and the bottom is Comparison for frequency switching. For pure position switched scans the two numbers will be identical. A new parameter FSO (frequency switched offset) is also displayed in MHz. To set FSO to 16 MHz, one would type at the teletype:

1600 FSO !

For pure position switched scans, set FSO to zero; however, it will have no effect if it is set to a non-zero value for pure position switched scans.

The 2 GHz box will only accommodate settings in the range 1.850 to 1.950 GHz and the computer program will calculate a suitable setting.

If one wants to use the HP-65 calculator program to compute synthesizer settings by hand, use the existing program. If the answer does not fall within the range of 1.850 and 1.950 on the N^{th} or $N + 1^{th}$ harmonic, you can get the $N + 2^{th}$ harmonic by the following sequence:

RCL 4
ENTER
RCL 3
2
+
÷

The verb SYN-SET has been defined to set the synthesizer in lieu of doing a CALIBRATE or a scan. It may only be executed at the teletype and should not be executed while taking data.

Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

February 4, 1976

To: Distribution List

From: Jan M. Hollis and P.J. Rhodes

Subject: Documentation Memo #1: Spectral Line Calibrations

A. Motivation for this Memo:

Calibration of spectral line data for the 36' telescope can be accomplished by observing a chopping absorber (see section B) or a modulating noise tube (see section C). Much confusion exists on calibration procedures and what they mean. This fact prompts a (hopefully) simple explanation in this memo. Absolute calibration (using a chopping mechanical vane) of spectral lines is thoroughly described in Ulich and Haas (Ap. J. Suppl. March 1976). The Ulich and Haas paper is difficult to read for those unfamiliar with the physics and mathematics of their excellent treatment; section B of this memo we caution is an over-simplification of the Ulich and Haas paper. Proper calibration of spectral line data is the responsibility of the observer.

B. CHOPPER or VANE CALIBRATIONS

1. GAINS and TC Explained

Section X of the 36 Telescope Computer System Manual gives the following formula for the GAINS array (C) which is created at calibration time:

$$C_i = \frac{R_{ci} - Z_i}{S_{ci} - R_{ci}} * TC \qquad (1)$$

The subscript c refers to data taken at calibration time and subscript i to one of the channels of the multiplexer where ($1 \leq i \leq 512$). Z refers to a zero check performed immediately before the calibration process starts. (Here the IF signal is disconnected from the filter bank and the DC offset voltages in each channel are recorded in the Z array). R refers to the reference signal during the calibration and is equal to the following:

$$R_{ci} = T_{(BLANK\ SKY)i} + T_{(RCVR)i} \qquad (2)$$

Here $T_{(BLANK\ SKY)i}$ is the antenna temperature recorded by the i^{th} channel caused by the telescope looking at blank sky; $T_{(RCVR)i}$ is the temperature recorded by the i^{th} channel caused by the noise generated internally in the receiver. S in equation 1 refers to the chopping vane during the calibration and is equal to the following:

$$S_{ci} = T_{(ABSORBER)i} + T_{(RCVR)i} \qquad (3)$$

Here $T_{(ABSORBER)i}$ is the antenna temperature recorded by the i^{th} channel caused by the telescope looking at the chopping vane. If we substitute equations 2 and 3 into equation 1, we arrive at a more physically meaningful expression for the i^{th} channel GAIN (C_i):

$$C_i = \frac{(T_{(BLANK\ SKY)i} + T_{(RCVR)i} - Z_i) * TC}{T_{(ABSORBER)i} - T_{(BLANK\ SKY)i}} \qquad (4)$$

However we are still left with no explanation of the parameter TC which does not depend on any channel. We define TC to be the following:

$$TC \equiv \frac{T_{(ABSORBER)} - T_{(BLANK\ SKY)}}{G\ \eta_\ell \exp(-\tau \sec(z))} \qquad (5)$$

G is the gain of the sideband which is defined as 1 when using the rejection filter (SSB ≡ single sideband system) and is ∿ 1/2 (see section B.3 for explanation) when observing without the rejection filter (DSB ≡ double sideband system). We point out that because G = 1 for the SSB configuration and G ≃ 1/2 for the DSB configuration, TC in the DSB configuration is approximately twice the value of TC in the SSB configuration. η_ℓ is described in section D; for the 36 foot telescope η_ℓ is ∿ 0.72 for prime focus work and ∿ 0.64 for Cassegrain work; $\exp(-\tau \sec(z))$ compensates for atmospheric loss of the signal where τ is the atmospheric optical depth measured at the zenith and z is the angular distance of the source from the zenith. Note that the numerator in equation 5 (i.e., $T_{(ABSORBER)} - T_{(BLANK\ SKY)}$) would not remain constant if one measured it at different elevation angles; this is so because the system sees more atmosphere (i.e., higher sky temperature) if the telescope is pointed at the horizon than at the zenith. Thus the numerator of equation 5 establishes the temperature scale for a given elevation angle for data taken later at that same elevation angle. The exponential term in the denominator compensates for atmospheric attenuation of data taken later at that same given elevation angle. If the numerator of equation 5 varies exponentially and cancels the exponential in the denominator, TC then turns out to be a constant. In general this is not true (e.g., CO observations) but sometimes it is a good approximation (e.g., HCO^+ or HCN observations). If every channel system responded the same and if we could ignore gain, antenna efficiency and atmospheric loss, we could equate equation 5 with the denominator of equation 4. Then equation 4 reduces to

$$C_i = T_{(BLANK\ SKY)i} + T_{(RCVR)i} - Z_i \tag{6}$$

Thus GAINS are (in an over-simplified way) measures of the sum of the temperatures of blank sky and internal receiver noise, which is the system temperature.

2. TS Explained

Section X of the 36' Telescope Computer System Manual gives the following formula for TS:

$$TS = \langle C_i \rangle = \sum_{i=1}^{\#CH} C_i / \#CH \tag{7}$$

#CH refers to the total number of channels used by the spectral line system. Thus TS is not system temperature but is an average over all channels (except for eliminated channels) of GAINS, which is the effective noise temperature of a hypothetical system consisting of a perfect (lossless) antenna located outside the earth's atmosphere.

3. Unbalanced Sideband Response for DSB Observations

The gain of the image sideband, G_i, and the gain of the signal sideband, G_s, may or may not be the same. If $G_s > G_i$, then lines in the signal sideband will appear larger relative to line in the image sideband. On the other hand if $G_i > G_s$, then lines in the image sideband will appear larger relative to lines in the signal sideband. This unbalanced sideband response is dependent upon what frequency the receiver is tuned to along with how far the sidebands are separated in frequency. For example, Figure 1 (a) shows that for a given tuning of the cooled Cassegrain receiver with a sideband separation of 9496 MHz, SO_2 in the lower sideband (LSB) has the same intensity as CN in the upper sideband (USB). However, re-tuning at a slightly different frequency produces Figure 1 (b) where the LSB SO_2 line intensity has decreased with respect to the USB CN intensity.

We feel that SSB observations (using the rejection filter) are to be preferred over DSB observations since there is no easy way to compensate for unbalanced sideband response. This is especially true if one wants well calibrated data and not just detections of new molecular species.

4. Empirical and Theoretical Determinations of TC

The observer may generate his own empirical TC values if he desires. Periodically measure a source of known intensity from zenith to horizon while changing TC to maintain a constant peak intensity for the line. This method presupposes that the observer knows what the absolute line intensity of the source is outside the earth's atmosphere. It should only be done during clear weather. Empirical determinations are encouraged at the least to spot check theoretical calculations of TC. As mentioned in section B.1, TC values for HCO^+ and HCN are approximately constant for all elevation angles. The following TC values for HCO^+ are from empirical determinations:

Cassegrain Receiver		Prime Focus Receiver
DSB	SSB	DSB
700 K	400 K	600 K

From the Cassegrain values above we deduce the relationship:

$$TC(SSB) \quad = \quad TC(DSB) \; * \; 0.57 \qquad (HCO^+ \text{ or HCN Cassegrain}) \qquad (8)$$

The observer may generate his own theoretical TC values by application of equations in the Ulich and Haas paper. Table 1 is theoretical determinations of TC values for ^{12}CO and ^{13}CO as a function of elevation angle for ideal DSB and SSB Cassegrain observations. Table 2 is similar TC values for HCO^+. An HP-65 program exists at the 36' telescope for generating TC values such as those in Tables 1 and 2. The HP-65 program solves the following equation:

$$\begin{aligned} TC \simeq\ & (1 + r)\, R \left[J(T_m) - J(T_{bg})\right] + (1 + r)\, R \exp(\tau_s A) \left[J(T_{sbr}) - J(T_m)\right] \\ \cdots\cdots\ & + r\, R \left(\exp\left[(\tau_s - \tau_i) A\right] - 1\right) \left[J(T_m) - J(T_{bg})\right] \\ \cdots\cdots\ & + (1 + r) \exp(\tau_s A) \left[J(T_{amb}) - J(T_{sbr})\right] / \eta_{source} \end{aligned} \tag{9}$$

where (1) $J(T) = \dfrac{h\nu/k}{\exp(h\nu/kT) - 1}$

(2) $r = G_i / G_s$

(3) $R = \eta_{sky} / \eta_{source}$

(4) G_i and G_s are the gains of the image and signal sidebands.

(5) τ_i and τ_s are the earth's atmospheric optical depths of the image and signal sidebands.

(6) $A = 1.0 / \sin(EL) = \sec(z)$

(7) η_{sky} is the antenna coupling efficiency to the sky.

(8) η_{source} is the antenna coupling efficiency to the source.

(9) T_{amb} is the ambient temperature.

(10) T_{bg} is the cosmic background temperature.

(11) T_m is the mean atmospheric temperature.

(12) T_{sbr} is the temperature due to spillover, blockage and ohmic loss.

5. Temperature Ordinate at the Tektronix

The temperature scale for spectral line observing (using CHOPPER or VANE calibrations) is T_A^* which is related to the true antenna temperature, T_A, by

$$T_A^* = \frac{T_A}{\eta_\ell \exp(-\tau \sec(z))} \tag{10}$$

Thus T_A^* is the source antenna temperature one would measure outside the earth's atmosphere with a lossless antenna and a single sideband receiver. If one knows that the source fills the beam, T_A^* is then the source brightness temperature. If the source does not fill the beam, one can convert equation 10 to brightness temperature by dividing by the beam dilution factor.

C. NOISE TUBE CALIBRATIONS

1. GAINS and TC Explained

Section X of the 36' Telescope Computer System Manual gives the following formula for the GAINS array (C) which is created at calibration time:

$$C_i = \frac{R_{ci} - Z_i}{S_{ci} - R_{ci}} * TC \qquad (11)$$

The subscript c refers to data taken at calibration time and subscript i to one of the channels of the multiplexer where ($1 \leq i \leq 512$). Z refers to a zero check performed immediately before the calibration process starts. (Here the IF signal is disconnected from the filter banks and the DC offset voltages in each channel are recorded in the Z array). R refers to the reference signal during the calibration and is equal to the following:

$$R_{ci} = T_{(BLANK\ SKY)i} + T_{(RCVR)i} \qquad (12)$$

Here $T_{(BLANK\ SKY)i}$ is the antenna temperature recorded by the i^{th} channel caused by the telescope looking at blank sky; $T_{(RCVR)i}$ is the temperature recorded by the i^{th} channel caused by the noise generated internally in the receiver. S in equation 11 refers to the noise tube signal during the calibration and is equal to the following:

$$S_{ci} = T_{(\text{NOISE TUBE})i} + T_{(\text{BLANK SKY})i} + T_{(\text{RCVR})i} \tag{13}$$

If we substitute equations 12 and 13 into equation 11, we arrive at a more physically meaningful expression for the i^{th} channel GAINS (C_i):

$$C_i = \frac{(T_{(\text{BLANK SKY})i} + T_{(\text{RCVR})i} - Z_i)}{T_{(\text{NOISE TUBE})i}} * TC \tag{14}$$

TC is the temperature of the noise tube defined by hot and cold load measurements and does not depend on any channel:

$$TC \equiv \frac{T_{(\text{NOISE TUBE})}}{G} \tag{15}$$

G is the gain of the sideband which is defined as 1 when using the rejection filter for SSB observations and is $\sim 1/2$ (see section B.3 for explanation) when observing with no rejection filter for DSB observations. We point out that because $G = 1$ for the SSB configuration and $G \simeq 1/2$ for the DSB configuration, TC in the DSB configuration is approximately twice the value of TC in the SSB configuration. If every channel in the 512 channel system responded the same, and if we could ignore gain, we could equate equation 15 with the denominator of equation 14. Then equation 14 reduces to:

$$C_i = T_{(\text{BLANK SKY})i} + T_{(\text{RCVR})i} - Z_i \tag{16}$$

Thus GAINS are measures of the sum of the temperatures of blank sky and internal receiver noise which is the system temperature (for exception see C.4).

2. TS Explained

Section X of the 36' Telescope Computer System Manual gives the following formula for TS:

$$TS = \langle C_i \rangle = \sum_{i=1}^{\#CH} C_i \, / \, \#CH \tag{17}$$

#CH refers to the total number of channels used by the spectral line system. Thus TS is a measure of system temperature and is an average over all channels (except for eliminated channels) of GAINS (for exception see C.4).

3. The Need to Correct Data for Atmospheric Absorption

Data taken with NOISE TUBE calibrations need to be corrected for attenuation by the earth's atmosphere. To do this tipping scans must be performed periodically to monitor the atmosphere. Setting the parameter ATTN in the computer program, based on the results of the tipping scan, will apply a multiplicative scale factor to the data at data taking time. The scale factor is $\exp(\tau \sec(z))$.

4. Dividing TC by Antenna Efficiency η_ℓ

η_ℓ is described in section D. For the 36 foot telescope η_ℓ is $\sim$0.72 for prime focus work and $\sim$0.64 for Cassegrain work. If one divides the NOISE TUBE temperature by η_ℓ and sets this into TC, data taken subsequently will account for η_ℓ. (Note that if this is done, equation 15 will be modified accordingly and so will the explanation for equations 16 and 17.)

5. Temperature Ordinate at the Tektronix

Only if 3 and 4 above are performed will the temperature scale for spectral line observing (using NOISE TUBE calibrations) be T_A^* which is related to true antenna temperature, T_A, by equation 10.

EFFICIENCIES, T_A^* AND FLUX DENSITY S

1. Various Efficiencies

η_ℓ is the efficiency of the telescope taking into account blockage, spill over and ohmic losses. η_t accounts for random surface errors and taper efficiency (non-uniformly illuminated antenna). η_A is the aperture efficiency and is equal to the product of η_ℓ and η_t.

2. T_A^* in Terms of Planck Function J(T) For All Sources

$$T_A^* = \beta\,(1 - e^{-\tau})\left[J(T_e) - J(T_{bg})\right] \tag{18}$$

where (1) β is the beam dilution factor.

(2) τ is the cloud optical depth.

(3) T_e is the excitation temperature.

(4) T_{bg} is the cosmic background temperature.

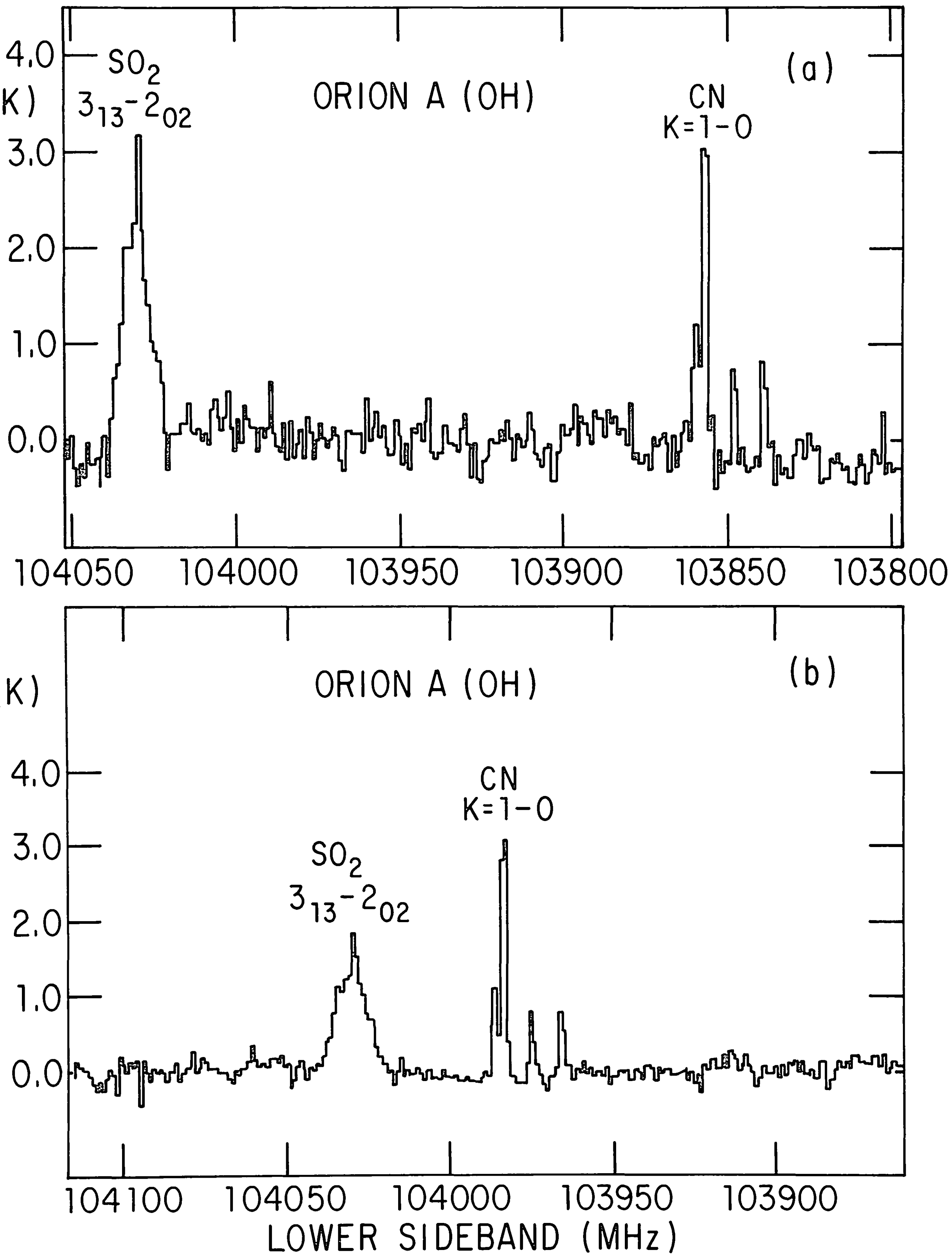
(5) $J(T) = \dfrac{h\nu/k}{\exp(h\nu/kT) - 1}$

3. Flux Density S for Point Sources

$$S = \frac{2\,k\,\eta_\ell\,T_A^*}{\eta_A\,A_g} \tag{19}$$

where k is the Boltzmann constant and A_g is the geometrical area of the antenna.

Figure 1



(a)
ORION A (OH)
T_A^*(K)
4.0
3.0
2.0
1.0
0.0
SO_2
$3_{13}-2_{02}$
CN
K=1-0
104050
104000
103950
103900
103850
103800
(b)
ORION A (OH)
T_A^*(K)
4.0
3.0
2.0
1.0
0.0
SO_2
$3_{13}-2_{02}$
CN
K=1-0
104100
104050
104000
103950
103900
LOWER SIDEBAND (MHz)

TABLE 1

^{12}CO (τ_s = 0.35, τ_i = 0.085)

EL	TC(DSB)	TC(SSB)
10	2338.8	493.0
20	1278.2	419.2
30	1077.1	407.2
40	997.1	402.7
50	956.2	400.4
60	932.9	399.2
70	919.3	398.4
80	912.1	398.1
90	909.9	397.9

^{13}CO (τ_s = 0.12, τ_i = 0.075)

EL	TC(DSB)	TC(SSB)
10	925.3	407.0
20	849.0	398.1
30	826.8	395.7
40	816.6	394.7
50	811.0	394.1
60	807.7	393.8
70	805.7	393.6
80	804.6	393.5
90	804.3	393.5

VALUES ABOVE COMPUTED FOR CASSEGRAIN OBSERVATIONS WITH:

T_m = 280 K

T_{bg} = 2.7 K

T_{sbr} = 280 K

T_{amb} = 290 K

η_{sky} = 0.87

η_{source} = 0.64

TABLE 2

HCO^{+} ($\tau_s = \tau_i = 0.08$)

EL	TC(DSB)	TC(SSB)
10	802.0	401.0
20	791.9	396.0
30	789.1	394.6
40	787.8	393.9
50	787.1	393.6
60	786.7	393.4
70	786.5	393.2
80	786.3	393.2
90	786.3	393.1

VALUES ABOVE COMPUTED FOR CASSEGRAIN OBSERVATIONS WITH:

T_m = 280 K

T_{bg} = 2.7 K

T_{sbr} = 280 K

T_{amb} = 290 K

η_{sky} = 0.87

η_{source} = 0.64