NATIONAL RADIO ASTRONOMY OBSERVATORY
COMPUTER DIVISION
INTERNAL REPORT

INTEGRATION SYSTEM OF COMPUTER PROGRAMS

FOR THE 413-CHANNEL AUTOCORRELATION RECEIVER

BY

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To: All 400 Channel Users January 30, 1969

From: S. Farris, J. Greenhalgh, D. Vitiello

Subject: Errors in Integration System

This memo describes all known errors in the integration system. Some data may require reprocessing. All these problems have been corrected and do not apply to future observations.

1. Receiver C outputs prior to December 3, 1968 were incorrect due to an error in the on-line program. There are errors in spectral shapes and frequency scale which depend on the shape of the spectra. All such outputs can be corrected by re-running the AC4141 output tape through a special version of AC4142 (which is called CCC4142A and which will not be put in the library).

2. In version 44/3 of AC4141 and possibly in version 44/2 of AC4141, there was an error in the power counter plot for receiver C for the series configuration of the auto-correlator. The power counter plot for receiver C displayed receiver B's output. This means that values and plots given for reference power, difference power, and gain for receiver C are meaningless.

   The 9-track output tape of AC4141 was not affected by the error. The error has now been corrected; the corrected version is called NRAO 44/4. It has been in use since January 2, 1969.

3. The temperature calibration in AC4142A was sometimes incorrect, depending on how the receiver was used. The error affects channels 193-384 of the serial operation of receiver A. The error was corrected on December 10, 1968 and the new version is called NRAO 49/A2.

   Many observations done in the serial mode of operation do not require reprocessing. This occurs if the IF cables were connected to both the A and B filter banks. (This has usually been the case). It can be easily seen if this is the case from a comparison of the outputs of AC4141 and AC4142.

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INTEGRATION SYSTEM OF COMPUTER PROGRAMS FOR THE 413-CHANNEL AUTOCORRELATION RECEIVER

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I. Introduction

This report describes the integration system of programs available for use with the 413-channel autocorrelation receiver. These programs are intended primarily for observations carried out at the 140-foot telescope during which the telescope beam tracks a source.

The on-line program (AC3) runs on the DDP-116 computer at the telescope. Data from the autocorrelator is integrated and a Fourier transform is taken on-line. The spectra thus calculated may be stored on tape, printed, displayed on a CRT, and plotted. Section II of this report describes the on-line program.

Program I (AC4141) runs on the IBM-360 computer and processes the tape produced by the on-line program. This program produces as its output a FORTRAN readable tape and a printout of selected useful information. It is described in Section III of this report.

Program II (AC4142A or AC4142B), which is described in Section IV, also runs on the IBM-360 computer. It processes the tape output of Program I, together with a deck of cards which contain editing information. Temperature calibrations and velocity calculations are carried out at this stage. An output tape is produced for further processing and generally contains one 413 point spectrum for each complete observation.

Program III (AC4143A or AC4143B), which is described in Section V, processes the output tape produced by Program II. It is used to average several observations together and to subtract off measurements from on measurements.

Section VI contains discussions of several unrelated topics not covered elsewhere which are important in the use of the receiver and computer.

Figure 1 is a system flowchart showing the various programs, their inputs and outputs.

II. On-Line Computer Program

A. General

The on-line computer program accepts inputs from the telescope, autocorrelation receiver, teletype and operator control panel. Several types of output are provided. A magnetic tape is recorded for further off-line processing and contains spectra for each integration period. On-line outputs, which do not affect the data recorded on magnetic tape, include CRT displays, printed outputs and plotted outputs. In addition, a log of various messages is maintained on a teletype output.

B. Integration

The autocorrelation receiver integrates for 10 seconds before transferring data to the computer. The computer provides two additional forms of integration:

1. Integration period - A series of 10 second outputs are integrated in the computer. The operator selects the integration

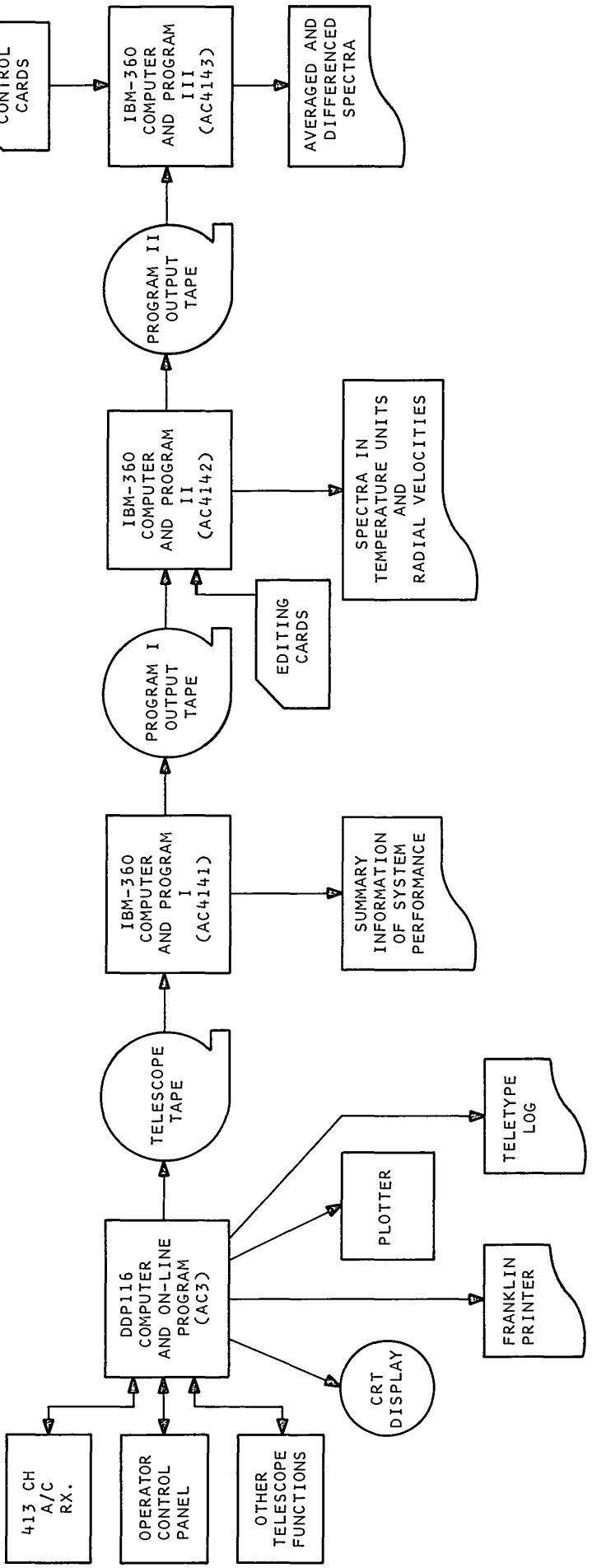


Figure 1

Computer System Flowchart

period by setting a four digit digi-switch register. Values for the integration period may range from 40 seconds to 15 minutes. A value of 1 minute is recommended for two reasons. First, the editing of individual records during off-line processing can recover useful output if only a few output records are suspect (e.g., interference, brief equipment malfunction, etc.). Second, at the 10 Mc bandwidth, under usual conditions, the receiver noise is equal to the low order bit of the signal power counters recorded on tape after approximately one minute. After each integration period the spectra may be recorded on tape and displayed on the CRT. Computer integration for the integration period consists of adding data from the autocorrelator.

2. Scan integration - The inappropriate term "scan" is used to denote a complete observation (i.e., a series of integration periods on the same source). The start and stop of a scan are controlled by the operator through the control panel. The "scan number" is used to identify all records made for that observation. The spectra for each integration period within the scan are added into a set of accumulator arrays in the computer memory. These arrays are not recorded on tape but may be used to produce various on-line outputs.

C. Data taking sequence

The telescope operator determines the sequence of data taking operations by setting various switches on the control panel. The sequencing is indicated in Figure 2. Three distinct segments of time are indicated:

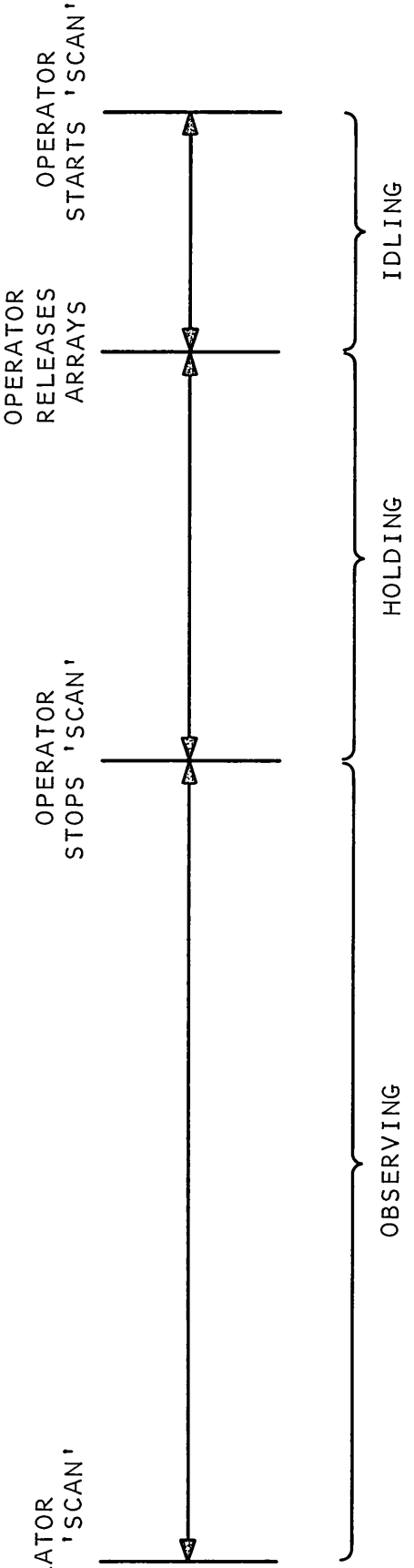


Figure 2

Data Taking Sequence

1. Observing - During this time spectra are recorded on tape and displayed on the CRT for each integration period. Typically the telescope tracks a source during this time. Each spectrum is added into an accumulator array (which is initialized to zero at the start of the scan).

2. Holding - During this time the accumulator arrays contain the integrated spectra produced during the previous observation. The operator may obtain several types of output on the CRT, printer, and plotter.

3. Idling - During this time spectra for alternate 10 second outputs of the autocorrelator are produced. They can be displayed on the CRT and various printed outputs can be obtained. Such spectra can be used to set up equipment for the next observation. Alternate 10 second outputs are bypassed to aid in equipment debugging procedures.

D. Spectral Calculations

The calculation of spectra has been described in another report (NRAO Electronics Division Internal Report, no. 75). To summarize, the following steps are used for each spectrum:

1. normalization
2. clipping correction
3. Fourier transform

Spectra which are inverted in the IF system are re-inverted in the computer. The inversion is done in a way which keeps the

center frequency for the band in the same channel for different bandwidths (97, 193, or halfway between 15 and 16, depending on the receiver configuration).*

E. On-Line Outputs

1. Two types of spectral output are provided: Fourier transforms (for signal and reference) and quotients (see NRAO Electronics Division Internal Report No. 75). The Fourier transforms are normalized so that the average spectral value equals 1. Thus the units generally range from 0 to 1.5. The Fourier transform for signal gives the receiver bandpass plus any spectral features in the signal band. The Fourier transform for reference usually gives the receiver bandpass.

2. Tape output is given at the end of each integration period while observing. The output tape format is listed in Appendix J. Both signal and reference spectra are recorded in double precision (30 bits). Identification information is output with the spectra. Sidereal time, indicated right ascension and indicated declination are referred to the center of the integration period. Three power counter values are recorded for each receiver: the average signal power counter with the noise tube on, the average signal power counter with the noise tube off, and the average

*Channel numbers are assumed to start with 1. Prior to September 1, 1968 a different convention was used. This was described in a memo.

reference power counter. Receiver controls and local oscillator settings are also entered in the record. Since only one local oscillator has output lines to the computer, the identification of observing frequency for all possible receiver configurations is ambiguous. Special card inputs are required for later processing.

3. CRT outputs are chosen by setting the CRT selector switch on the options panel (see Figure 3). A CRT display is produced automatically at the end of each integration period (while observing) and at the end of each 20 second data cycle (while idling). The display may be renewed or a different option chosen and displayed at any time by pressing the CRT "renew" command button. The option selector switch may be set to the following:

a. REF - The Fourier transforms for reference spectra are displayed. The transforms are the result of the integration for the previous integration period (while observing) or of a 10-second autocorrelator output (while idling). While holding, the most recent integration period is displayed. This display is on a fixed scale of .2 units/cm.

b. SIG - The Fourier transforms of the signal spectra are displayed. The integration times and scale are the same as for REF.

c. QUOT - Quotients of (SIG-REF)/REF are displayed. The integration times are the same as for REF. The scale for the display is chosen through the teletype.

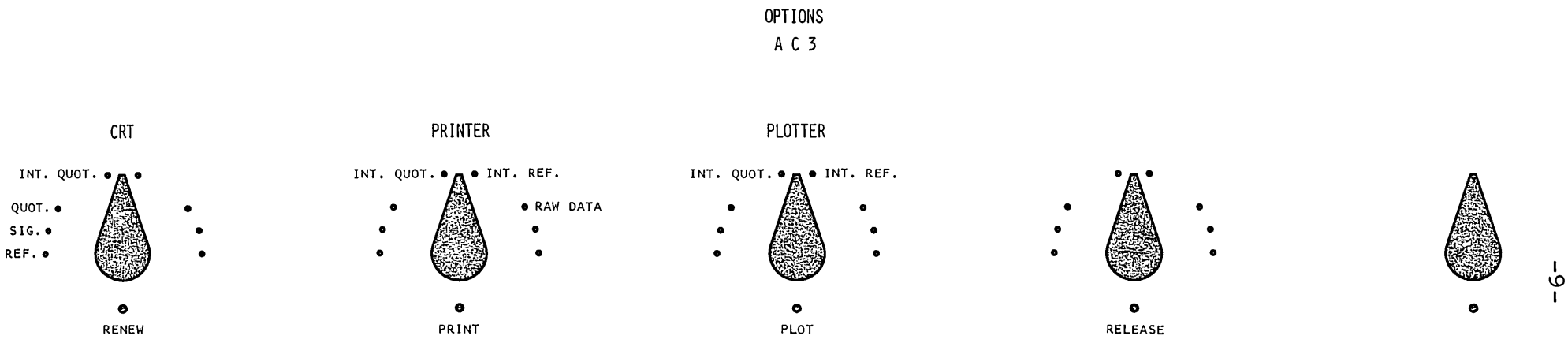


Figure 3

Options Panel

d. INT QUOT - The integrated signal and reference spectra are used to calculate quotients. While observing the most recent integrated spectra are used (e.g., if a 1 minute integration period is in use, the output 1 minute after the scan starts is for the first minute. The output 2 minutes after the scan starts is for the first two minutes, etc.). The scale for the display is chosen through the teletype. While holding, the integrated reference and signal spectra for the entire scan are used.

4. Printer outputs are chosen by setting the print selector switch on the options panel. A printout is started by pressing the "print" command button. The option selector switch may be set to the following:

a. INT REF - The Fourier transforms for the accumulated* reference spectra are printed. They are printed in tables with channel numbers ranging 1-29, 1-192, or 1-384.

b. INT QUOT - Quotients of the accumulated* signal and reference spectra are printed.

c. RAW DATA - This option is intended as an equipment debugging aid. The printout consists of all counter data from the autocorrelator printed in decimal. Control words are printed in binary. When used while idling, this option can be used to cause the printout of the data from the autocorrelator which

*accumulated since the start of the scan

caused a given spectrum on the CRT display. The print command button should be pressed within 5 seconds after the display is complete. Initiation of printing causes the normal sequencing to be interrupted and the hold sequence is entered. Thus additional displays and printouts can be obtained for the same set of data.

Examples and descriptions of printed output are contained in Appendix E.

5. Plotter outputs are chosen by setting the plotter selector switch on the options panel. A plot is started by pressing the "plot" command button. Plotting should be done while holding. The option selector switch may be set as follows:

a. INT QUOT - Quotients of the accumulated* signal and reference spectra are plotted. The scale is chosen on the teletype. The output is a permanent record of the equivalent display on the CRT.

b. INT REF - The accumulated* reference spectra are plotted. The scale is fixed and the output provides a permanent record of the bandpass spectra.

F. Setting the scale for the CRT and plotter

Typing "G" on the teletype at any time causes the computer to interrogate the operator and allow entry of a scale for CRT displays and plots of quotients. The operator types in a scale

*accumulated during the previous scan

in units/cm as desired for the CRT display. The plotted outputs are on an equivalent scale in units/inch.

G. Data validity checks

As data is transferred between the autocorrelator and computer, checks are made to insure the validity of the transfers. An error message is typed on the teletype if any problem is detected and, if observing, the scan is discontinued.

The data cycle is checked to insure proper modulation of the signal spectrum by the noise tube. The series/parallel control and bandwidths are checked from one 10 second period to the next to insure no change occurs. Errors of this type while observing cause a message to be typed out and the observation is terminated.

Various receiver controls are checked for appropriate settings:

1. switch rate and duty cycle - must be in one of the 50/50 positions
2. dump time - must be 10 seconds
3. clipper test signal - all 3 switches must be in normal
4. front end switch - must be locked signal or modulated normal
5. noise tube mode - must be interrupted modulation normal
6. noise tube duty cycle - must be 50/50

Appropriate error messages are typed for each of the above error conditions. These will be described in the future.

H. Operating considerations

The program is loaded from tape or cards according to the usual bootstrap procedures. The program may be restarted in the usual way. Tapes should be initialized and terminated by typing the control characters E, C, and L as usual. Observer identification should be entered by typing S and alphanumeric comments should be typed to identify the source (this documents later program outputs). Descriptions of these points are contained in the operator instruction book at the telescope.

Releasing arrays to enter the idling mode is accomplished by pressing the "release" command button on the options panel. The arrays do not have to be released between scans unless the idling mode is to be used.

Printed outputs at the end of a scan for integrated reference and quotients must be initiated after all calculations are complete. This does not occur for approximately 7 seconds after the scan is finished. When the CRT display for the last integration begins, the calculations are complete.

The CRT and plotter share some hardware so that these outputs are mutually exclusive. At the end of a scan, plotted outputs should be obtained only after the CRT display for the last integration period is complete. Plotted output is similar to equivalent CRT displays. Only the size of the plots is changed. Thus the CRT may be used to set up for a plot.

III. Program I

General

AC4141[1] (NRAO 44/2 in the NRAO library) gives a standard header, power counters plot, tape and data error messages, average quotients telescope tape index, and a labeled 9-track FORTRAN readable output tape.

Scan Heading[2]

The scan heading is printed at the start of every scan. Some of the quantities are explained by their labels and others are explained in J. P. Greenhalgh's memo dated March 5, 1968 and in A. M. Shalloway's memo dated May 3, 1968. A copy of these memos is included in appendices J and M respectively.

PARALLEL OPERATION indicates the parallel configuration of the autocorrelator with receivers A and B having 192 channels each and receiver C having 29 channels. SERIES OPERATION indicates the series configuration of the autocorrelator with receiver A having 384 channels and receiver C having 29 channels.

TYPE OF OBSERVATION with code number 12 indicates that the data on the telescope tape is data for the integration system. It is important to note that this program will not process data that has a code number different from 12. This means that if any other

[1]Meaning of the name: AC4 = 413 channel A/C receiver, 14 = 140' telescope, 1 = Program I.

[2]The term 'scan' as defined in Section II, B2 of this report.

data is on the same tape with integration system data, it will not be processed or written on the output tape.

The following table shows units used for various items:

L O FREQ	...MHZ	...MHZ	...MHZ
BANDWIDTH	...KHZ	...KHZ	...KHZ
ATTENUATOR	...DB	...DB	...DB
NOISE TUBE	...K	...K	...K
GAIN MOD	...	...	
CLIPPER	...	...	...

The first number in the L O FREQ line is the local oscillator frequency which is used in AC4142 (section VI, A) for the radial velocity calculation. The other two numbers are printed here for documentation. If there is a local oscillator frequency where one or more of the decimal numbers on the telescope tape cannot be translated into a binary number, the program will print out the message *****UNTRANSLATABLE L O FREQUENCIES***** and then list the record numbers of the incorrect L O frequencies. When this occurs, it is important that the user supply correction cards to the next program for the incorrect L. O. frequencies.

BANDWIDTH and ATTENUATOR values are the bandwidth and attenuator values of receivers A, B, and C. For series operations receiver B will have the same value as receiver A.

NOISE TUBE is the noise tube values in degrees Kelvin for receivers A, B, and C as read into the program from a control card.

These values are fixed for the entire run. This means that if the noise tube value should change during the creation of a telescope tape, it will be necessary to supply change cards to the next program to alter the noise tube value in the appropriate scan or scans.

GAIN MOD and CLIPPER values are code numbers for receivers A, B and word A, B, C that are defined in Shalloway's memo in appendix M. Other code numbers that are defined in Shalloway's memo have the following labels:

SENSE SWITCH ..
FRONT END SWITCH ..
DIGITAL TEST SIGNAL .. ..
NOISE TUBE MODE ..
SWITCH RATE AND DUTY CYCLE ..
GAIN MOD AND SYN DETECTOR PHASE ..
NOISE TUBE AND DUTY CYCLE O/F IND .. ..

The DUMP TIME and BLANK TIME are defined as the integration time in the autocorrelator and time needed to allow transient effects in the autocorrelator to die out.

SAMPLE RATE is the integration period (see section II, B1). An integration period is at least 40 seconds but not longer than 15 minutes.

Power Counter Plot

The Power Counter Plot displays information about each record on the telescope tape. For a usual record, it prints record number,

indicated right ascension, indicated declination, from one to six power counter values, and a graphical display of these values. For an unusual record, it might print:

1) ***** PARITY ERROR DELETED THIS RECORD *****
2) **** 360 OPERATOR INTERVENTION DELETED THIS TAPE *****
3) **** LENGTH ERROR DELETED THIS RECORD *****
4) **** END OF FILE *****

Parity and length errors are telescope tape errors and when they occur the data in that record is skipped and the job keeps processing.

360 operator intervention means something abnormal happened while the tape was being processed at the 360. When this happens, the job is terminated.

END OF FILE - end of data on the telescope tape.

The type of plots (reference power, difference power, gain), number of plots (≤ 6), and scaling of each plot for both series and parallel operations can be specified by inputing a control card or by allowing the program to plot a standard number of plots (6) with a standard scaling (0.03). If the autocorrelator is in series operation, the standard plot displayed is reference power, difference power and gain for receivers A and C, and if the autocorrelator is in parallel operation the standard type of plot displayed is reference power and gain for receivers A, B, and C.

The values of reference power, difference power, and gain as computed in the program are defined as follows:

1. Reference Power - value as given on telescope tape (CR).
2. Difference Power - signal with noise tube off minus reference power (CSF - CR).
3. Gain - signal with noise tube on minus signal with noise tube off (CSN - CSF).

The origin and width of each plot is determined by the number of plots to be displayed and the width of the total plot. The expression used to determine the width of the total plot is:

M = 132 - ((6*N)+26)

where N is the number of plots desired. The position and type of character plotted is determined by the expression

P(L) =(RECORD(k) - RECORD(1))*SCALE(L) + 0.5 + ORIGIN(L)

where L=1,...,N, K=1,...,k,...,R; R is the total number of records in a scan. RECORD(k) is the value of either reference power or difference power or gain on a particular record. The integer portion of P(L) is used to determine the position and type of character for each plot. The following chart shows how the computed value determines the position and type of character used:

	L=1	L=2	L=3	L=4	L=5	L=6
P(L)<-(L-1)	+	+	+	+	+	+
-L<P(L)<1	1	4	7	A	D	G
0<P(L)<(L+1)	2	5	8	B	E	H
L<P(L)<(2L+1)	3	6	9	C	F	I
2L<P(L)	-	-	-	-	-	-

As an example assume that N=6, SCALE (1)=0.3, RECORD(2)=10072, RECORD(1)=10090 and ORIGIN(1)=10, then M=70, P(1)=9. The character plotted would be 2 and its position would be one character to the left of the origin.

The standard deviation of the power counter with noise tube on (CSN), the power counter with noise tube off (CSF), and the difference of the power counter with the noise tube on and off (CSN - CSF) of each receiver is displayed under the respective headings ABC SIGMA CSN, ABC SIGMA CSF, and ABC SIGMA DIF. The expressions used in computing these quantities are:

$$\text{RMSCSM}(J) = \left(\frac{1}{M} \sum_{I=1}^{M} \text{CSN}(J,I)^2 - \overline{\text{CSN}}(J)^2 \right)^{\frac{1}{2}}$$

where $\overline{\text{CSN}}(J) = \frac{1}{M} \sum_{I=1}^{M} \text{CSN}(J,I)$ is the average, I=1,...,M M is the total number of records in a scan, and J=1,2,3 indicates receivers A, B, C respectively. Similar expressions hold for RMSCSF(J) and RMSDIF(J), with CSF(J,I) and DIF(J,I) being the arguments.

The label FACTOR is the system temperature in the signal band in each receiver and it is computed by using the following expression:

$$\text{FACTOR}(J) = \frac{\text{NT}(J)}{2} \cdot \frac{\overline{\text{CSN}}(J) + \overline{\text{CSF}}(J)}{\overline{\text{CSN}}(J) - \overline{\text{CSF}}(J)}$$

where NT is the noise tube temperature in the 3 receivers.

An estimate to the power spectrum (P) in temperature units over a scan can be had by multiplying FACTOR by the average quotient: $\overline{P}=\overline{Q}$ * FACTOR.

If NT(J)/FACTOR(J)<0.01, this indicates that there could be something wrong with the firing of the noise tube. When this occurs, a message is printed NOISE TUBE TEMP/SIGNAL TEMP = ... ON RECEIVER X COULD HAVE AN ERROR IN NOISE TUBE TEMP.

The AVERAGE QUOTIENT plot displays quotients plotted against channel number. The expression used in computing the quotient is

$$AVQ(K) = \frac{1}{M}\sum_{I=1}^{M} Q(K,I)$$

where

$$Q(K,I) = \frac{S(K,I) - R(K,I)}{R(K,I)}$$

M again is the number of records in the scan, and K=1,2...,413 is the channel number. The description of the symbols used in the plot are described in Section IV, subsection "Plot".

The STANDARD DEVIATION TABLE gives the standard deviation for each channel over a scan. The expression used in computing the standard deviation is

$$RMS(K) = \left(\frac{1}{M}\sum_{I=1}^{M} Q^2(K,I) - AVQ(K)^2\right)^{\frac{1}{2}}$$

where Q, $\overline{Q}$ is the quotient and average quotient respectively with K=1,...413.

The TELESCOPE TAPE INDEX prints out summary information about the telescope tape. A copy of this index is kept in Charlottesville. Additional copies of the index are printed for each observer and each type of observation on the telescope tape. These additional copies are sent to Green Bank with the output data of AC4141 so the observer can have a personal record of the contents of the telescope tape.

IV. Program II

General

Program AC4142,[1] using the FORTRAN readable tape produced by AC4141, accomplishes three main functions. First, it allows the user to edit the input tape in a very general fashion through input cards; second, it averages the power spectrum over a group of records; and third, it performs a velocity calculation and a velocity correction. In the description of the on-line program and AC4141 a complete observation is referred to as a scan and it is associated with a scan number. Program AC4142 multiplies this scan number by 10 to obtain a new number, henceforth called the observation number. Program AC4142 averages records with the same observation number. The user can change the observation number on a group of records, however; and in this way break up a scan or extend the averaging process over more than one scan. Thus a scan, consisting of 30 records, of scan number 4326 can be broken up into three groups of 10 records each with observation numbers 43261, 43262, and 43263. The input cards are described in Appendix B and the velocity calculation in section VI, A. A FORTRAN readable tape is produced containing the averaged power spectrum, the velocity

[1]There are two versions of Program II, AC4142A for non-polarization switching (NRAO library number NRAO 49/A1) and AC4142B for polarization switching (NRAO library number NRAO 49/B1). When no distinction needs to be made between the two, the name AC4142 will be used to apply to both versions of the program. Meaning of the name: AC4=413 channel A/C Receiver, 14=140' Telescope, 2=Program II.

information, and various identifying information. The tape format is described in Appendix L.

Printed Output

The first page of printed output lists the data cards submitted to AC4142. The cards are listed, single spaced, following the heading "123...", which gives the number of the card column.

Any error messages encountered during the program will be printed after the first page. A dictionary of error messages is provided in Appendix B.

The second page of output lists the observations which have been processed and the records written on the output tape. The page is printed after the input tape is processed and during the time when the output tape is being written. The observation number, the number of records within the scan of which the output record is the average, the total integration time in minutes, and the identifying remarks included by the observer at the 140 foot telescope at the time of observation are listed. Also listed is the output tape record number. At the end of the list of scans, information about the output tape is printed. The output tape record number is the relative record number of the output record on the output tape. The output data will be put on the same tape as the previous day's data and this practice will be continued until the entire tape is filled. (The printed material about each group

of averaged records begins on the the third page). The heading contains the observation number and identifying remarks included by the observer outlined so as to be readily observed. Also included in the heading are the number of records, the total integration time in minutes, the output tape record number and the output tape volume - serial number.

The next section contains data from the first record in the observation and from the last record in the observation. The quantities included are listed in Figure 4. Immediately following this data the corrected and uncorrected velocities of the center of the bands are given in km/sec. The velocity is corrected by subtracting the average of the velocity correction at the beginning and end of the observation. Following these quantities is the velocity change per channel for the three receivers.

The above data is followed by a plot of the average power spectra in temperature units.

AC4142B

Program AC4142B must have information about which scans are calibration scans. This is done by input cards. The printed output is similar to AC4142A. The word "calibration" or "polarization switching" is printed to the right of the identifying comments to distinguish the observations. For a calibration observation, the average power spectra (corresponding to signal minus reference/reference is plotted.

Figure 4

Quantity	Units
Date	Year, Month, Day
Operation	Series, Parallel
Local Sidereal Time	Hours, Minutes, Seconds
Eastern Standard Time	Hours, Minutes, Seconds
Indicated Right Ascension	Hours, Minutes, Seconds
Indicated Declination	Degrees
Polarization Angle	Degrees
Local Oscillator Frequency for A and C	KHz
Local Oscillator Frequency for B	KHz
Noise Tube Temperatures for A/B/C	°K
Attenuators for A/B/C	db
Bandwidths for A/B/C	KHz
Julian Date	
Velocity Correction	km/sec

For a polarization switching observation two quantities are plotted; first, the average power spectrum for signal 1 (that is, signal 1 minus reference divided by reference) and second, the difference between the power spectrum for signal 1 and the power spectrum for signal 2 (that is signal 1 minus signal 2 divided by reference).

Plot

The quantity plotted in AC4142 is temperature (across the page) as a function of channel number (down the page). The graph is meant to be viewed by rotating the computer page 90° counter-clockwise. Viewed in this manner one sees that the method of plotting employs the symmetry between the symbols "6" and "9". Two points are printed in one line by printing a "9" to represent the first point and a "6" to represent the second. If the two points fall in the same print position, an "8" is printed. The values of the points in temperature units are printed to the left of the graph, the first point in the line in the column labeled "1" and the second point in the line in the column labeled "2". The resultant graph should be viewed by following the closed circles; that is, one should ignore the "tails" on the "6" and "9". By printing the graph at 8 lines per inch the accuracy of the points is improved. The distance between the center of the circles in a "9" and a "6" in the same line is only slightly less than the corresponding distance in a "6" and a "9" in adjacent lines.

Points which fall outside the range of the graph are treated in the following manner, presupposing that one is viewing the graph by rotating the computer page 90^{0} counterclockwise. In general, a vertical bar indicates the point is off scale. If the first point in the line is off scale a "T" is printed; if the second is off scale an "L" is printed. If both points in the line are off scale in the same direction, an "=" sign is printed. If a point in a line falls in the first or last print position and the other point in the line is off scale, then in order to be consistent one should print both a circle and a vertical line in the same print position. This problem is solved by printing a "5" if the first point is off scale or a "2" if the second point is off scale.

The plotting, treated in the above manner, retains the basic properties of a visual display of data while at the same time making efficient use of both the computer and printer.

When the receiver is operated in the parallel mode receivers A, B, and C are displayed on separate coordinates. When in the serial mode, receivers A and C are displayed on the same coordinates, broken at the midpoint.

V. Program III

Program AC4143[1] uses the output tape of program AC4142 for further processing. It can be used to combine the averaged power spectra in a variety of ways which can be controlled by the user. Program AC4143 can perform the following functions: 1) average the power spectra weighted by the total integration time for each spectra, 2) average the power spectra weighted by the total integration time for each spectra and then average receivers A and B, disregarding receiver C, 3) average a first group of scans weighted by the integration time; then average a second group of scans weighted by the integration time and subtract the second group from the first group.

The program initially writes the records from the input tape onto a direct access storage device, thus enabling the program to retrieve the records in any order specified by the user. However, due to the limitations on the disk pack only 1000 records can be stored on the disk pack at any one time for AC4143A and only 500 for AC4143B. This means that at any given time the user can only stack scans within a range of 1000 records for AC4143A and 500

[1]There are two versions of Program III, AC4143A (NRAO library number NRAO 40/A1) and AC4143B (NRAO library number NRAO 50/B1), corresponding to the two versions of Program II and tape formats A and B. When no distinction needs to be made between the two, the name AC4143 will be used to apply to both versions of the program. Meaning of the name: AC4=413 channel A/C Receiver, 14=140' Telescope, 3=Program III.

records for AC4143B. However, by writing an output tape this problem can be overcome. If an output tape is desired, it is supplied by the user and retained by the user and can be written in either format A of AC4142A or format B of AC4142B. The input cards and various options involved in processing a tape are explained in detail in Appendix N.

The printed output of AC4143 consists of summary information about each scan stacked and a plot of the resultant power spectrum. Included in the summary information are scan number, integration time in minutes, date, local sidereal time in hours, indicated right ascension in hours, indicated declination in degrees, bandwidth codes for receivers A, B, and C, velocities of the center of bands A, B, C and identifying remarks by observers. The plot is temperature (101 positions across the page) as a function of channel number (down the page), one point per line.

VI. Additional Information

A. Velocity Calculation

The frequency measured by the observer, ν, in terms of the rest frequency of a source of radiation ν_o, the velocity of the source of radiation relative to the observer $\vec{V}$, and the direction of the light in the system of the observer $\vec{n}$, where $\vec{n}$ is a unit vector, is

$$\nu = \nu_o \frac{1 - \vec{V} \cdot \vec{n}/c}{\sqrt{1 - V^2/c^2}} \qquad (1)$$

(The Theory of Relativity, C. Moller, Oxford, 1952, p. 62). Given the rest frequency and measured frequency of the light, the velocity of the source of radiation in the direction of the light, that is, the radial velocity, assuming that the transverse velocity is small compared to the speed of light, is

$$\beta = \frac{\nu_o^2 - \nu^2}{\nu_o^2 + \nu^2} \qquad (2)$$

where $\beta = V/c$ and V is the radial velocity.

For a receiver of N+1 channels and bandwidth W, the frequency of channel M is

$$\nu = \nu_c + (M/N - \tfrac{1}{2})W \qquad (3)$$

where ν_c is the frequency of the center of the band and where the

channels are numbered beginning with zero. Then the velocity corresponding to channel M is

$$\beta_m = \frac{\nu_o^2 - \left[\nu_c + (M/N - \tfrac{1}{2})W\right]^2}{\nu_o^2 + \left[\nu_c + (M/N - \tfrac{1}{2})W\right]^2} \tag{4}$$

Expanding this expression in terms of the order of W/ν_o gives

$$\beta_m = \beta_c - (1 + \beta_c)\frac{2\,(M/N - \tfrac{1}{2})\,\nu_c W}{\nu_o^2 + \nu_c^2}$$

$$- (1 + \beta_c)\frac{(M/N - \tfrac{1}{2})^2\,W^2}{\nu_o^2 + \nu_c^2} + (1 + \beta_c)\frac{4\,(M/N - \tfrac{1}{2})^2\,\nu_c^2\,W^2}{(\nu_o^2 + \nu_c^2)^2}$$

$$+ 0\,(W^3/\nu_o^3) \tag{5}$$

$$\beta_{m+1} - \beta_m = (1 + \beta_c)\,1/N\,\frac{2\,\nu_c\,W}{\nu_o^2 + \nu_c^2} + 0\,(W^2/\nu_o^2) \tag{6}$$

The 413 channel autocorrelation receiver has bandwidths from 10 MHZ to 0.039 MHZ. The frequency of the 21 cm H line is 1420 MHZ. Therefore, to an approximation better than 1%, we can neglect the higher order terms, giving for the velocity change per channel,

$$\beta_{m+1} - \beta_m \simeq (1 + \beta_c)\,1/N\,\frac{2\,\nu_c\,W}{\nu_o^2 + \nu_c^2} \tag{7}$$

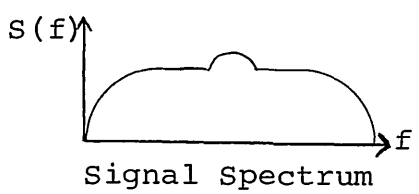
Program AC4142 uses equation 2 to calculate the uncorrected velocity of the center of the band and equation 7 to calculate the velocity change per channel.

A correction of the observed radial velocity to the local standard of rest is also computed in program AC4142. First program DSIT (NRAO 2/1S) is used to compute the Julian date and then program LSR (NRAO 43/1S) is used to compute the correction of the radial velocity to the local standard of rest.

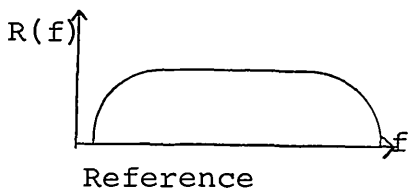
B. Polarization Switching

Special versions of Program II and Program III (AC4142B and AC4143B) are used for polarization switching and similar measurements. Such measurements differ from the usual in that the "reference" spectra contain spectral features. Special observations are necessary in this case to calibrate the receiver bandpass. The sequence of observations below is an example of such a series of measurements for a single receiver.

Observation I

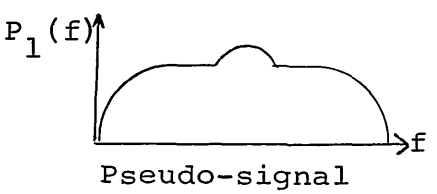


Signal Spectrum

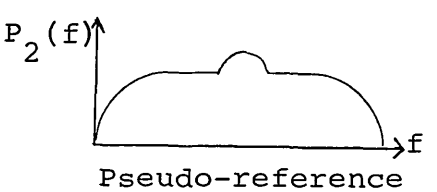


Reference Spectrum

Observation II



Pseudo-signal Spectrum



Pseudo-reference Spectrum

Observation type I is used to calibrate the bandpass and can also be used to measure the spectral line in the normal way (frequency switching, load switching, etc.). The temperature calculations in Programs II and III are carried out as usual using a quotient:

$$Q_I(f) = (S(f) - R(f))/R(f)$$

Observation type II is made with a spectral line in both spectra. A difference spectrum is calculated and corrected for receiver bandpass:

$$Q_{II}(f) = (P_1(f)-P_2(f))/R(f)$$

The correction for receiver bandpass (denominator) comes from observation I and does not contain the spectral line. Temperature calibrations are carried out in the usual way.

Each telescope tape must start with a type I observation. Each type II observation must be preceeded by a type I observation for the same bandwidths. Additional type II observations may continue until a new bandpass is used (change of bandwidth or L. O.).

Type I observations usually need not be as accurate as type II. If $(P_1(f)-P_2(f)) \ll R(f)$, the relative error in Q_{II} is equal to the relative error in $(P_1(f)-P_2(f))$. Therefore, far less accuracy is necessary in determining R(f).

C. Temperature Calibration

A temperature calibration is applied to the measured spectra. The following quantities are used in the temperature calculations for each receiver:

CSN - a counter value which is proportional to the total power in the signal spectrum with the noise tube on.

CSF - same as CSN except with noise tube off.

R(f) - the normalized power spectrum of the reference band. This is recorded for discrete values of f, the frequency normalized to the bandwidth.

S(f) - the normalized power spectrum of the signal band.

The power spectra S(f) and R(f) can be expressed in terms of receiver parameters as follows:

$$R(f) = \frac{R'(f)}{\int_0^1 R'(f)\,df} \qquad S(f) = \frac{S'(f)}{\int_0^1 S'(f)\,df}$$

where:

$$R'(f) = \alpha(f)\beta_R(T_R + T_C)$$

$$S'(f) = \alpha(f)\beta_S(T_R + T_C + T_{NT}/2 + T_L(f))$$

$\alpha(f)$ = frequency varying response of system

β_R, β_S = attenuation in reference and signal

T_R, T_C, T_{NT}, T_L = temperature of receiver, continuum, noise tube and line

The preceeding expressions for S(f) and S'(f) do not follow the actual sequence of calculations carried out by the on-line program. The autocorrelation functions for signal and for signal plus noise tube are added before the Fourier transform S(f) is computed. As a result the expression for S'(f) is an approximation. The approximation causes an overestimate of spectral line values by

$$\left(\frac{T_{NT}/2}{T_S + T_C}\right)^2 .$$

For usual receiver set-ups this causes a very small error, less than .001.

If χ is the response of the power counters to a given input:

$$\frac{CSN + CSF}{2} = \chi \int_o^1 \alpha(f)\beta_S(T_S + T_C + T_{NT}/2 + T_L(f))df$$

$$CSN - CSF = \chi \int_o^1 \alpha(f)\beta_S T_{NT} df$$

Combining the above gives the equation used for calibration:

$$\frac{S(f) - R(f)}{R(f)} \cdot \frac{CSN + CSF}{2} \cdot \frac{T_{NT}}{CSN - CSF} = T_L(f) + \text{constant}$$

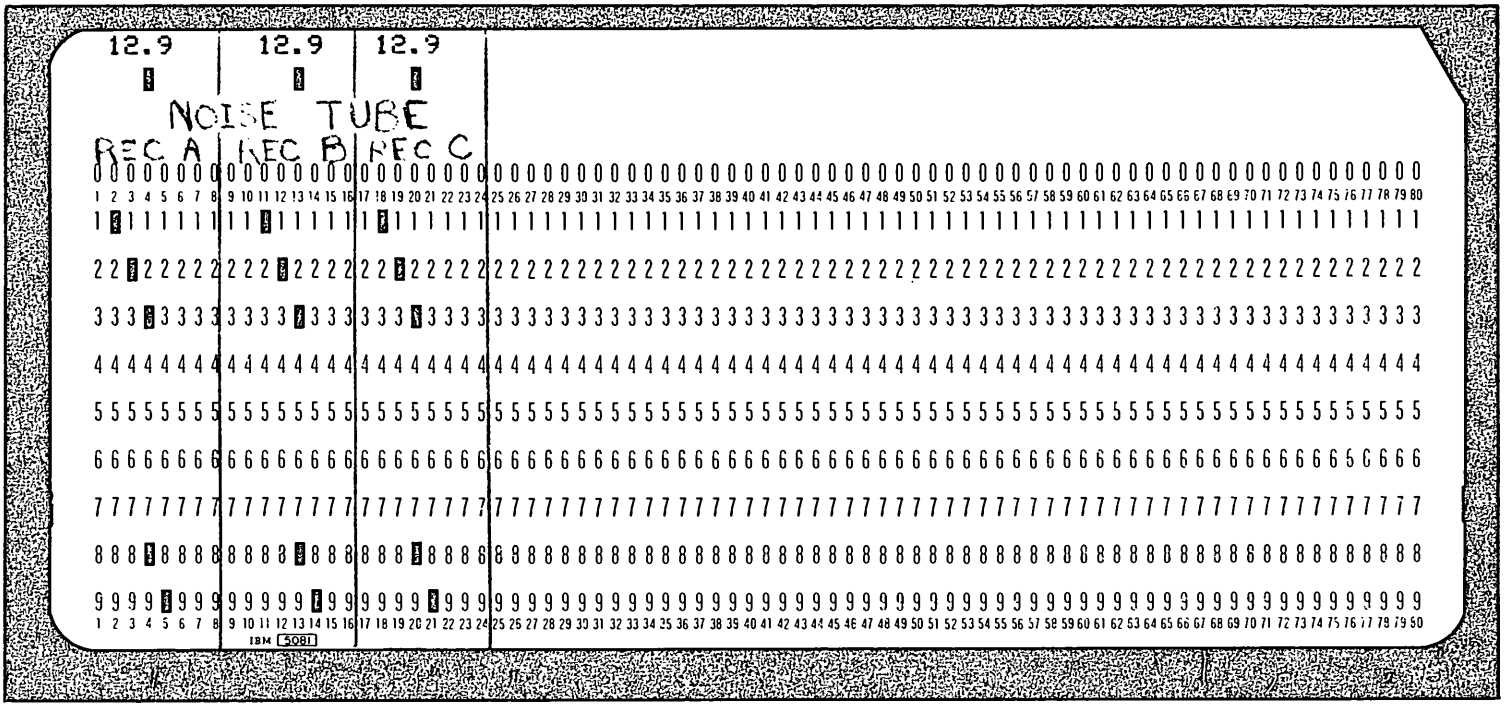
The constant term on the right does not depend on frequency and is, in general, difficult to calibrate because of uncertainties in attenuation factors.

APPENDIX A

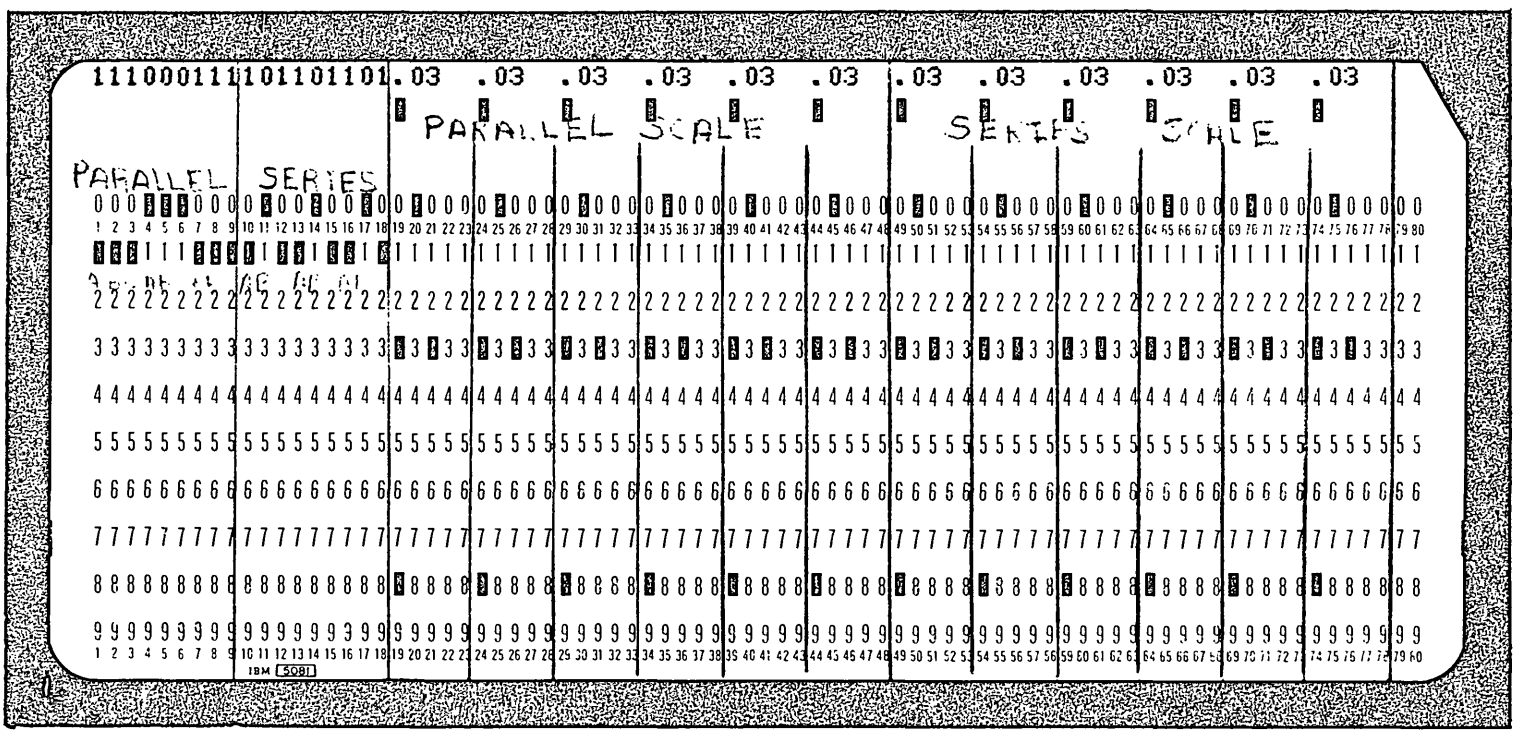
Input Program I

Control Cards

The first control card inputs the noise value for receivers A, B, and C. The decimal point is assumed in columns 8, 16, and 24. If the user wishes, he can punch the decimal points anywhere in the fields for A, B, and C and change the assumed positions of the decimal points.



The second control card allows the user to input control information to the power counter plot. By punching from one to six ones in the first field the user can select the specific power counts he wishes to see. Columns 1, 2, 3 and 10, 11, 12 indicate reference power for receivers A, B, and C for parallel and series operations. Columns 4, 5, 6 and 13, 14, 15 indicate difference power, and 7, 8, 9 and 16, 17, 18 indicate gain for receiver A, B, and C. The scales for the selected power counter plots are inputed to the program in field 3 and 4. The decimal point assumed is right justified in the sub-fields of fields 3 and 4.



APPENDIX B

Input Program II

Since the purpose of breaking this autocorrelation reduction program into a Program I and II is to give the observer a measure of control over the data before the final stages of data reduction are entered, program AC4142 has been written to implement this purpose. The mechanism by which records can be changed is such that the observer has full control over them, i.e., he can, in principle, change everything on the record or on a series of records. The description of input cards which follows holds for both AC4142A and AC4142B. The major difference between the two is that cards designating the calibration observations for AC4142B must precede all other data cards.

The first data card designates whether the local oscillator frequencies are to be read in from cards or tape. If the local oscillator frequencies recorded on the input tape are to be used and the frequency of receiver B is not different from A, then the word "SKIP" should be punched in columns 1-4. If the local oscillator frequencies for receiver B are to be read from cards, then the word "READ" should be punched in columns 1-4. In addition if the local oscillator frequencies for receiver A are to be read from cards, the word "READ" should also be punched in columns 11-14.

Examples of the three possible data cards are given in Figure 1.

If the first data card designates that local oscillator frequencies are to be read from cards, those cards must immediately follow the first card. They are punched in the following manner. The 5 digit observation number is punched in columns 1-5, the local oscillator frequency for receiver B is punched with the decimal point in column 16, and the local oscillator frequency for receiver A (if it is to be read from a card) is punched with the decimal point in column 36. The two possible kinds of cards are shown in Figure 2. If the local oscillator frequencies are to be read from cards, there must be one card for each group of averaged records. For example, if a scan is broken into two parts there must be two frequency cards; or if a scan or group of scans are skipped, there must be no cards for these. The observation number on the card must be the same as the observation number of the averaged records. If it is not, the values recorded on the input tape are used in the velocity calculation.

If the local oscillator frequencies are not to be read from cards, the user is only required to punch "SKIP" in the first data card as described previously. Nothing further is required.

All succeeding data cards employ the namelist facility in FORTRAN IV (IBM 360 FORTRAN IV Language, No. C28-6515-6, pp. 47-49) and are of three basic types: update cards, delete cards, and

change cards. The update cards are used to specify values for certain variables. These variables retain the specified values throughout the run of the program unless they are changed by the user. The delete cards are used to delete records and the change cards are used to change the values of variables within records. A variable, "CODE", which must be equal to "U", "D", or "C", distinguishes the three cards.

All namelist cards begin by having "&V" punched[1] in columns 2 and 3. Columns 1 and 4 are blank. The variables follow as illustrated in Figure 4, in the sequence, "VARIABLE NAME = VALUE OF VARIABLE". They may be punched in any order and in a free field format (i.e., they do not have to be punched in any particular column). In addition they can be continued on as many cards as desired; however, column 1 must be blank on all namelist cards. The end of the data set is denoted by ",&END".

Update Cards

Normally an update card will be the first of the namelist cards. The variables which it is possible to include on an update card are shown in Figure 3. All these variables are initialized to zero and remain so unless changed by the user. Examples of update cards are given in Figure 4. An explanation of the variables follows.

[1]"&" is an "and" sign - punch code 12.

SCAN - the observation number of the observation at which the update is to take effect. If the update card is the first namelist card and is intended to take effect at the beginning of the run, SCAN does not need to be included (see Figure 4, A).

CØDE - must be equal to "U" and means that this card is an update card.

FQMLTA, FQMLTB, OFFSTA, OFFSTB - the frequency multiplier and I. F. offset for receivers A and B used to calculate the observed frequency. The formula used to calculate the observed frequency in Hertz is

$$(\text{FQMLTA} * \text{L.O. Frequency} + \text{OFFSTA}) * 10^6.$$

RESTA, RESTB - rest frequency indicators for receivers A and B. These codes are given in Figure 5. If the desired frequencies are not supplied, the user may specify 9 or 10 for the rest frequency indicators and insert the desired frequencies in REST (9) and REST (10).

REST (10) - An array of 10 words, the first eight of which contain the frequencies given in Figure 5 and the ninth and tenth of which may be used by the user to supply additional frequencies.

NSTART - the observation number of the observation at which the user wishes to begin processing the tape. If the user wishes to begin with the first record on the tape NSTART should not be specified. NSTART may also be used to skip many scans in the middle of a tape. E.g., if a user wanted to skip observations 22460-22600 following observation 22450 and continue processing the tape with

observation 22610, his update card would be as shown in Figure 4, C.

NSTOP - the observation number of the observation following the last observation the user wishes to process. If the user wants the processing to end with the last record on the tape, NSTOP should be omitted.

YMAX, YMIN - the maximum and minimum on the plot of the average power spectrum in temperature units. The user should be aware that the plot is 43 positions wide. If YMAX is not specified or changed to 0.0, the program determines the scale on the plot. For AC4142B the namelist names YMAXD and YMIND are also included and these may be used to specify the maximum and minimum of the plot of the difference between the average power spectrum for signal 1 and the average power spectrum for signal 2.

BASSOL (4) - an array of 4 words used to specify the constants of solar motion if other than the standard ones are used. The standard values for the basic solar motion are: velocity = 20 km/sec, right ascension (apex) = $18^h\ 1^m\ 55^s.062$, declination (apex) = 30° D' 4".16 (1950). If these are to be used BASSOL should not be specified or BASSOL (1) should be zero. If they are not to be used, BASSOL (1) should be non-zero, BASSOL (2) should contain the velocity in km/sec, BASSOL (3) and BASSOL (4) the right ascension (apex) and declination (apex) respectively in radians precessed to 1950.

NOISE (3) - an array of 3 words used to specify the temperature of the noise tube for receivers A, B, and C respectively. If NOISE is not specified or if NOISE (1) is zero, the values recorded on the input tape are used.

Delete Cards

Delete cards may contain four variables.

SCAN - the observation number of the scan of which records are to be deleted.

CODE - should be equal to "D" meaning delete.

BREC (type I*4) - beginning record number (this number may be found in the output of AC4141) to be deleted.

EREC (type I*4) - ending record number to be deleted.

Three options may be chosen as follows:

1) delete an entire scan - SCAN and CODE are specified; BREC and EREC are not,

2) delete one record in a scan - SCAN, CØDE, and BREC are specified; EREC is not,

3) delete a group of records in a scan - all four variables are specified; records numbered BREC through EREC are deleted.

Figure 6 illustrates the three kinds of delete cards.

Change Cards

The change cards give the user the ability to change any variable in the input record. The variable names to be specified

are given in Figure 7. If a variable is not specified, it is not changed. The variables SCAN and CODE must always be specified and these, together with BREC and EREC, have a meaning analogous to that of the delete cards with the difference being that the records are changed, not deleted. Examples of change cards are given in Figures 8-10.

Warnings

A record cannot be both changed and deleted; that is the range of the delete cards and change cards cannot overlap. It is very important that the editing cards be punched correctly. Two errors occur easily. First, the user must be certain that there actually is a scan on the input tape which corresponds to the observation number on the editing card. This can be determined from the output of program AC4141. Second, the order of the editing cards must correspond to the order in which they appear on the input tape. Failure to observe these rules will lead to erroneous results.

AC4142B

The observation numbers of the calibration observations must be punched on the first data cards submitted to AC4142B. These cards must all have "CAL" punched in columns 1-3. The five digit observation numbers are then punched with one space between each number as shown in Figure 11. The numbers may be continued on more than one card if there are more than 12 numbers. The cards are punched with 12 numbers per card extending to a maximum of 8 cards. The observation numbers must be in the same order as they appear on the input tape.

The remaining data cards are the same as AC4142A and have been described.

Error Messages

Most error messages will be of the form

"***...*ERROR NUMBER 1"

The meaning of the errors and the action taken by the program follow:

ERROR NUMBER 1 - The entire tape was read but the program did not find the proper starting position. The job was terminated. Check your variable NSTART.

ERROR NUMBER 2 - The variable CØDE was not equal to "U", "D", or "C". The job was terminated.

ERROR NUMBER 3 - same meaning as error number 1 but occurring at a later stage in the program. The job was terminated.

ERROR NUMBER 4 - The first data card (for AC4142B the first data card following "CAL" cards) does not contain either "SKIP" or "READ". The job was terminated.

ERROR NUMBER 6 - The observation number on the L. O. frequency card was not equal to the observation number of the output record. The values found on the input tape were used. Also printed are the number recorded on the input card and the observation number of the output record.

ERROR NUMBER 7 - The frequency multiplier, I. F. offset, or rest frequency for receiver A were not specified. The velocity calculation for receiver A will not be performed.

ERROR NUMBER 8 - L. O. frequencies for receiver B were specified but the frequency multiplier, I. F. offset, or rest frequency for receiver B were not. The velocity calculation for receiver B will not be performed.

Parity errors on the input tape cause the following message to be printed:

"***...*READ ERROR ON TAPE"

Also printed are the observation number and record number of the previous record. The program skips records for which parity errors are encountered.

Figure 1

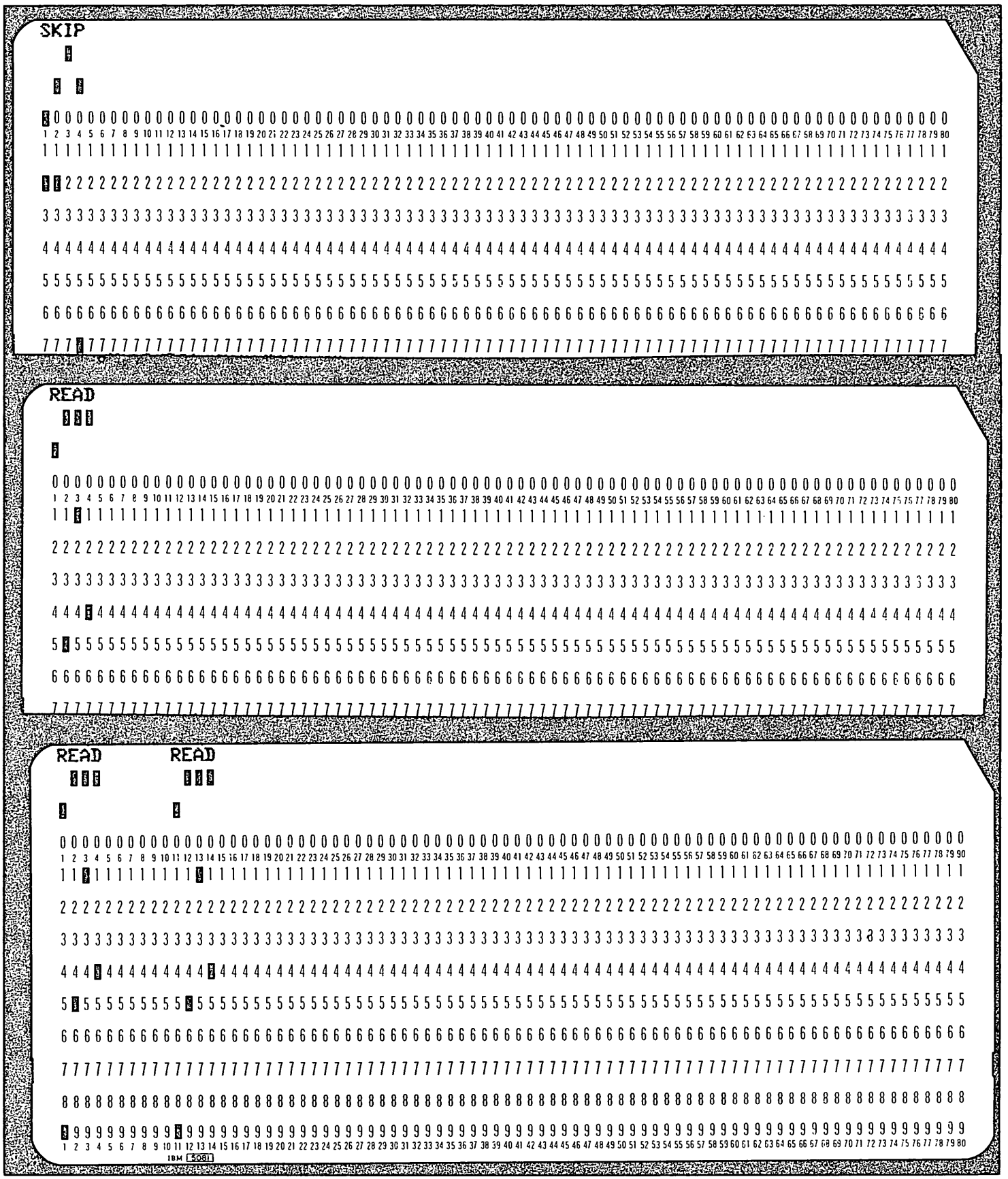


Figure 2

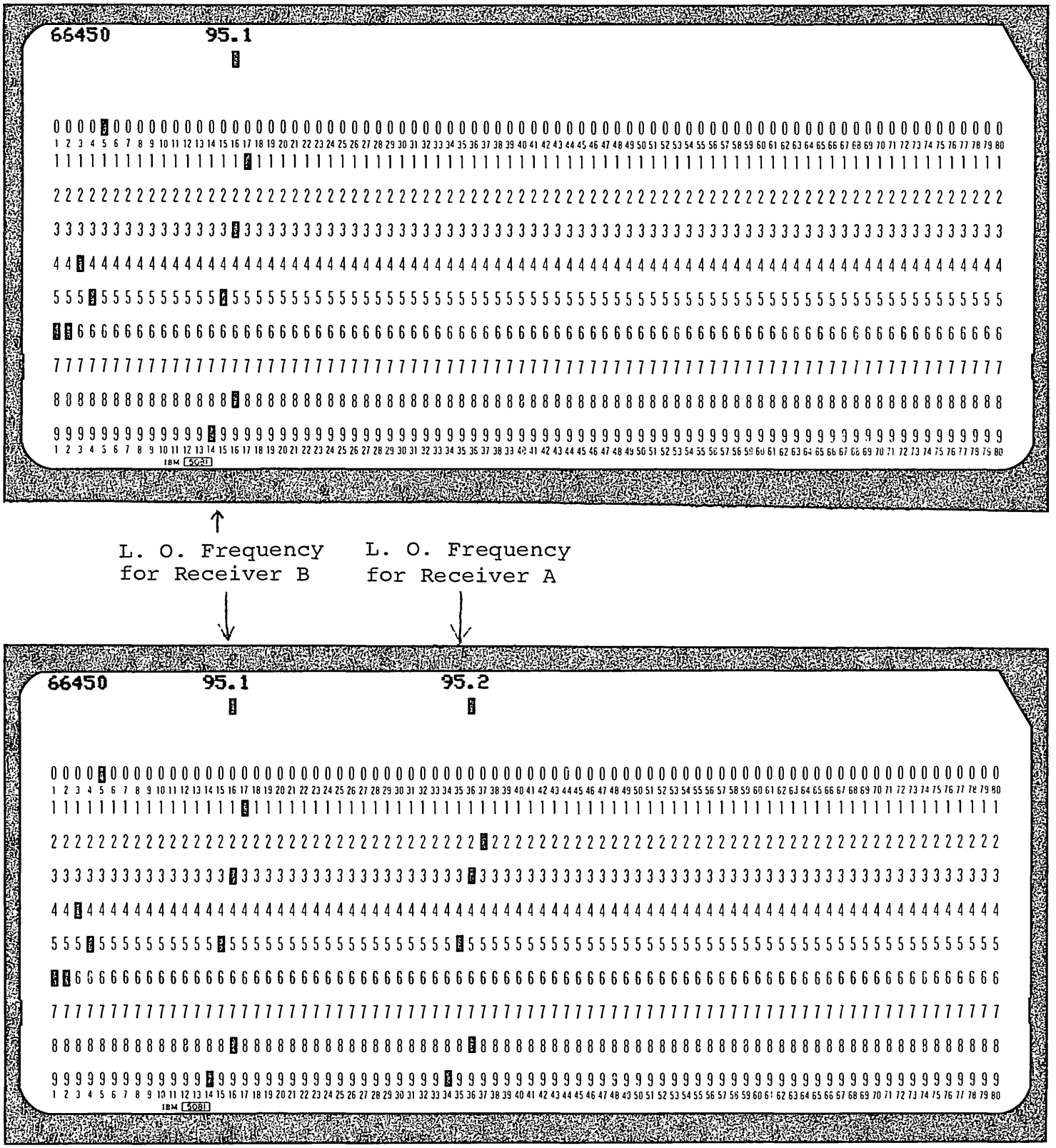

66450
95.1
IBM 5081
L. O. Frequency for Receiver B
L. O. Frequency for Receiver A
66450
95.1
95.2
IBM 5081

Figure 3

Variables which may be included on an Update Card:

Variable Name	Type	Meaning
SCAN	I*4	see text
CØDE	I*4	must always be "U" for update cards
FQMLTA	R*4	frequency multiplier for receiver A
FQMLTB	R*4	frequency multiplier for receiver B
ØFFSTA	R*4	I. F. offset for receiver A
ØFFSTB	R*4	I. F. offset for receiver B
RESTA	I*4	rest frequency indicator for receiver A
RESTB	I*4	rest frequency indicator for receiver B
REST(10)	R*8	rest frequencies
NSTART	I*4	starting observation number
NSTØP	I*4	ending
YMAX	R*4	maximum of scale
YMIN	R*4	minimum of scale
BASSØL(4)	R*4	constants of basic solar motion
NØISE(3)	R*4	noise tube for receivers A, B, C

Figure 4

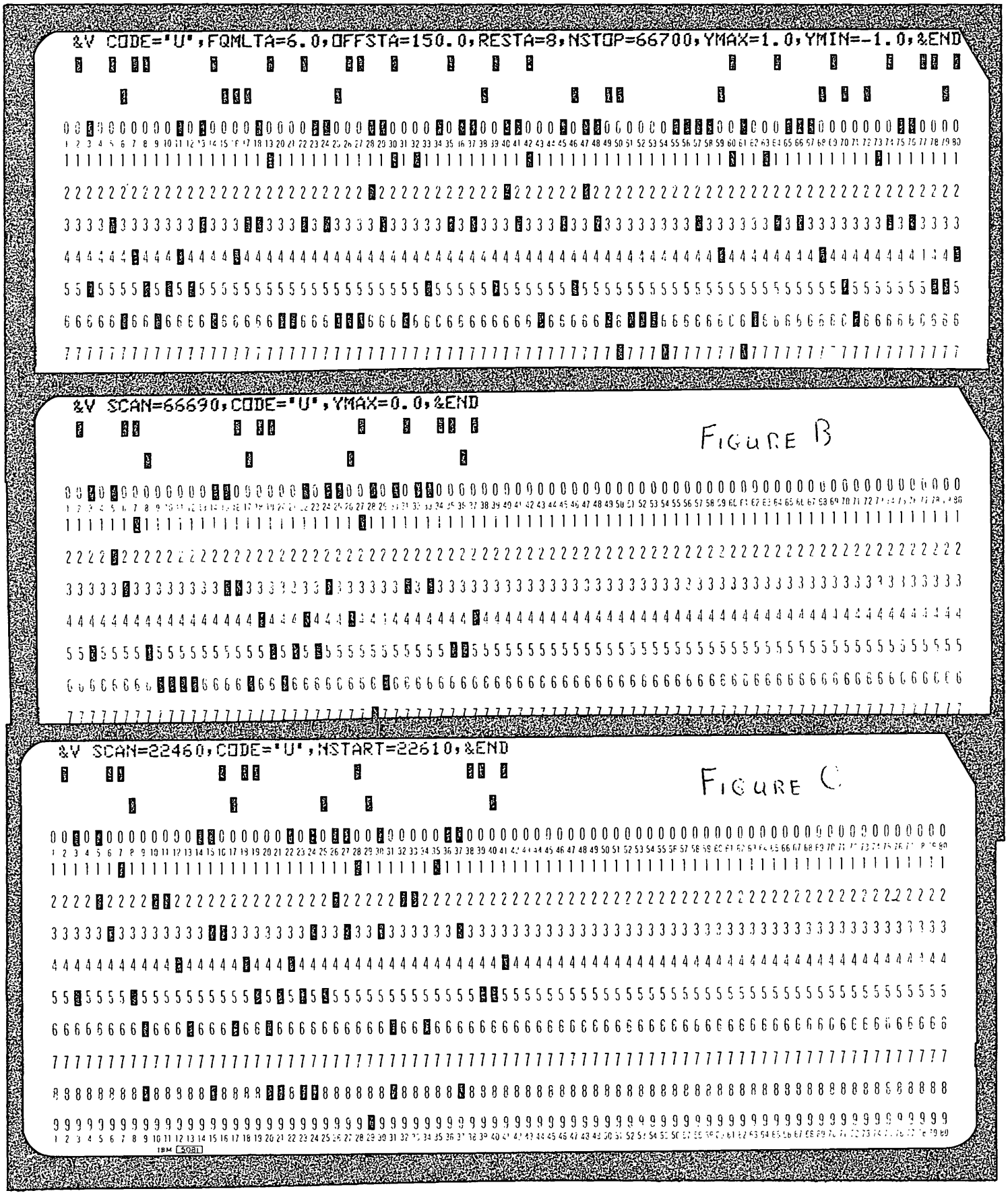

&V CODE="U",FQMLTA=6.0,OFFSTA=150.0,RESTA=8,NSTOP=66700,YMAX=1.0,YMIN=-1.0,&END
&V SCAN=66690,CODE="U",YMAX=0.0,&END
FIGURE B
&V SCAN=22460,CODE="U",NSTART=22610,&END
FIGURE C
IBM 5081

Figure 5

Rest frequency indicator codes:

Code	Frequency (Hertz)
1	1420405700
2	1477338100
3	1612231000
4	1637460000
5	1639460000
6	1665401000
7	1667358000
8	1720527000

Figure 6

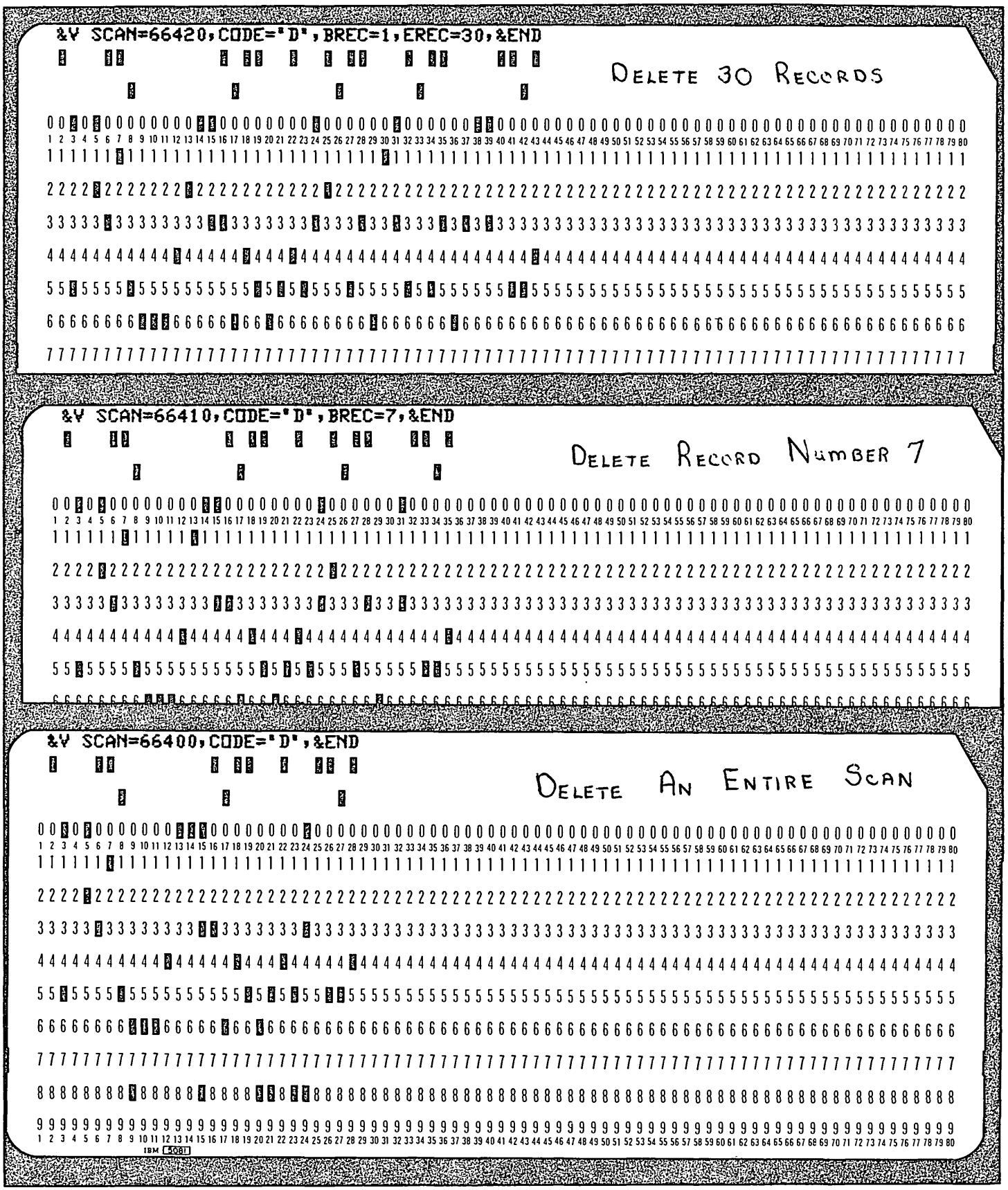

&V SCAN=66420,CODE="D",BREC=1,EREC=30,&END
DELETE 30 RECORDS
&V SCAN=66410,CODE="D",BREC=7,&END
DELETE RECORD NUMBER 7
&V SCAN=66400,CODE="D",&END
DELETE AN ENTIRE SCAN
IBM 3081

Figure 7

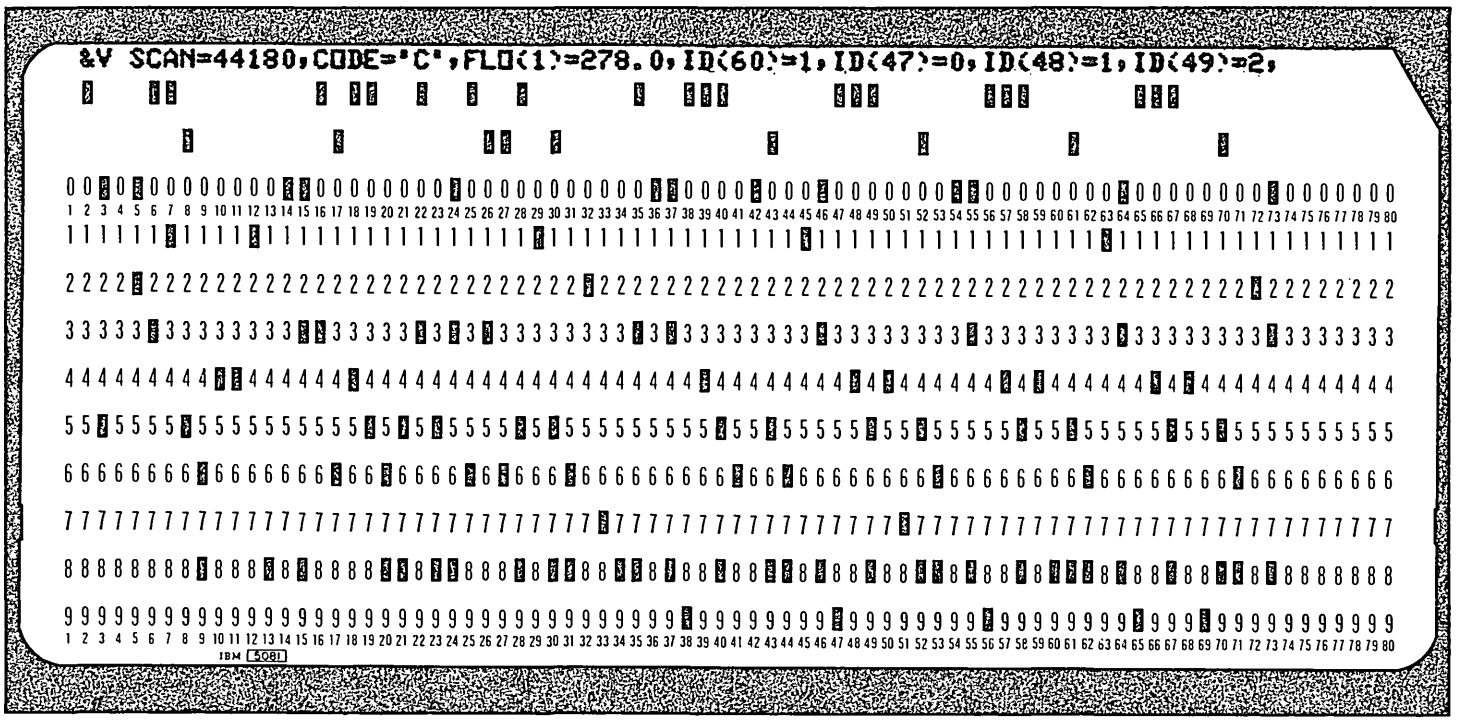
Namelist Name	Type	Meaning
SCAN	I*4	observation number of the scan of which records are to be changed
CODE	I*4	should be equal to "C" meaning change
BREC	I*4	beginning record number to be changed
EREC	I*4	ending record number to be changed
NSCAN	I*4	variable to be used if the observation number is to be changed
SIG(1)-SIG(413)	I*4	413 channels signal transform
REF(1)-REF(413)	I*4	413 channels reference transform
CSR(1)	I*4	power counter average of signal with noise tube on for receiver A
(2)	I*4	power counter average of signal with noise tube off for receiver A
(3)	I*4	power counter average of reference for receiver A
(4)	I*4	same as C(1) for receiver B
(5)	I*4	same as C(2) for receiver B
(6)	I*4	same as C(3) for receiver B
(7)	I*4	same as C(1) for receiver C
(8)	I*4	same as C(2) for receiver C
(9)	I*4	same as C(3) for receiver C
NTUBE(1)	R*4	temperature of noise tube for receiver A
(2)	R*4	temperature of noise tube for receiver B
(3)	R*4	temperature of noise tube for receiver C
ATEN(1)	R*4	attenuator for receiver A
(2)	R*4	attenuator for receiver B
(3)	R*4	attenuator for receiver C
PØL	R*8	polarization angle
ST	R*8	sidereal time of middle of dump (rad)
EST	R*8	eastern standard time of middle of dump (rad)
RA	R*8	indicated right ascension of middle of dump (rad)
DEC	R*8	indicated declination of middle of dump (rad)
FLØ(1)	R*8	L. O. frequency F_0
(2)	R*8	L. O. frequency F_1
(3)	R*8	L. O. frequency F_2
ID(1)	I*2	subscan number from program AC4141
(2)	I*2	telescope scan number
(3)	I*2	not used

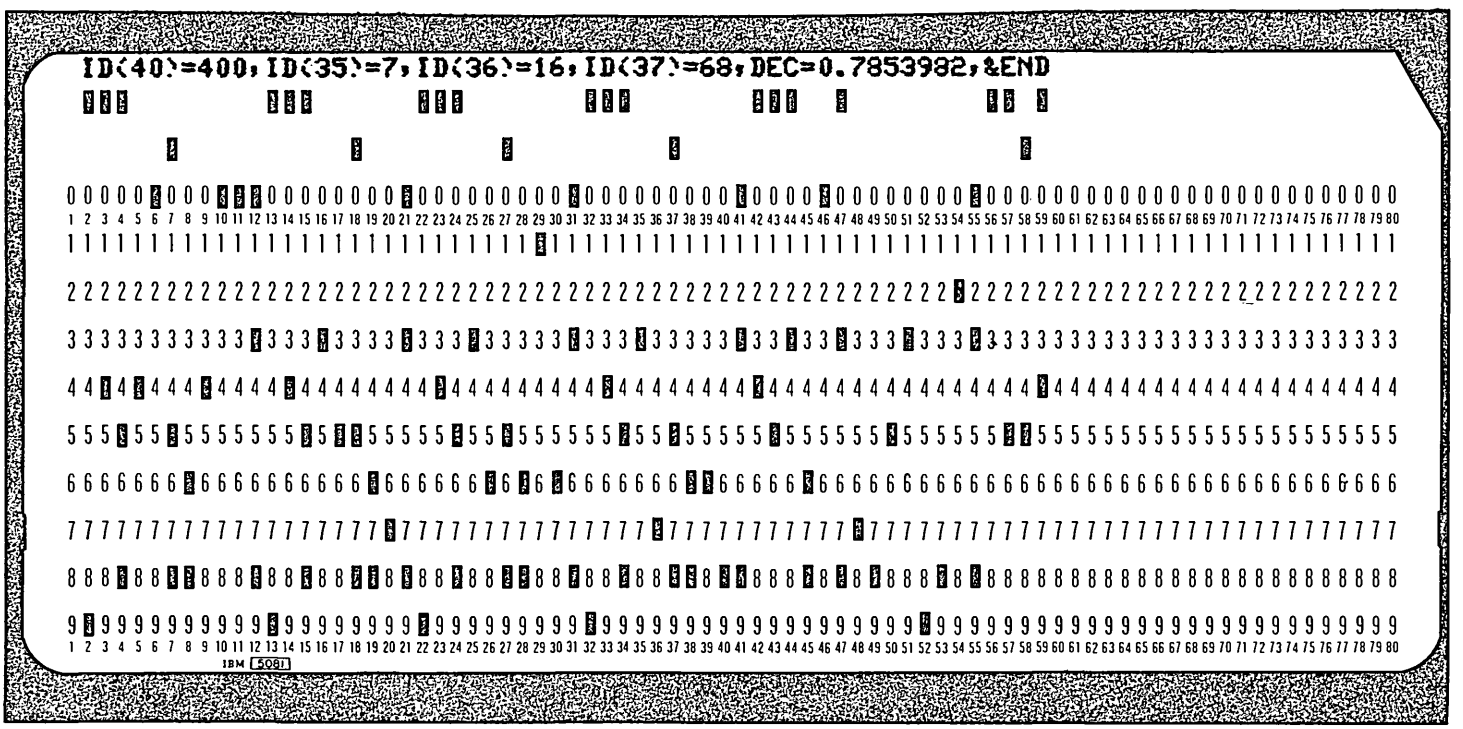
Namelist Name	Type	Meaning
ID(4)-ID(13)	I*2	Observer name
ID(14)-ID(33)	I*2	Observer comments
ID(34)	I*2	not used
(35)	I*2	date - month
(36)	I*2	date - day
(37)	I*2	date - year
(38)	I*2	type of observing
(39)	I*2	observer number
(40)	I*2	sample rate in 0.1 sec.
(41)	I*2	not used
(42)	I*2	site (1 = Green Bank)
ID(43)-ID(45)	I*2	comments by Joe Greenhalgh
ID(46)-ID(73)	I*2	autocorrelator words 1-28

The most important autocorrelator words are given below:

ID(47)	I*2	bandwidth indicator for receiver A
(48)	I*2	bandwidth indicator for receiver B
(49)	I*2	bandwidth indicator for receiver C
(60)	I*2	series-parallel operation
(62)	I*2	dump time
(63)	I*2	blanking time

Figure 8


&V SCAN=44180,CODE='C',FLO(1)=278.0,ID(60)=1,ID(47)=0,ID(48)=1,ID(49)=2,
IBM 5081


ID(40)=400,ID(35)=7,ID(36)=16,ID(37)=68,DEC=0.7853982,&END
IBM 5081

Explanation of Figure 8

Figure 5 shows how changes are made in the following quantities for the entire scan number 44180:

	Quantity	Changed To
1)	L. O. Frequency	278.0
2)	Operation	parallel
3)	Bandwidth of receiver A	10 MHz
4)	Bandwidth of receiver B	5 MHz
5)	Bandwidth of receiver C	2.5 MHz
6)	Integration time	40 sec
7)	Month	July
8)	Day	16
9)	Year	1968
10)	Declination	$\pi/4$ degrees

Figure 9

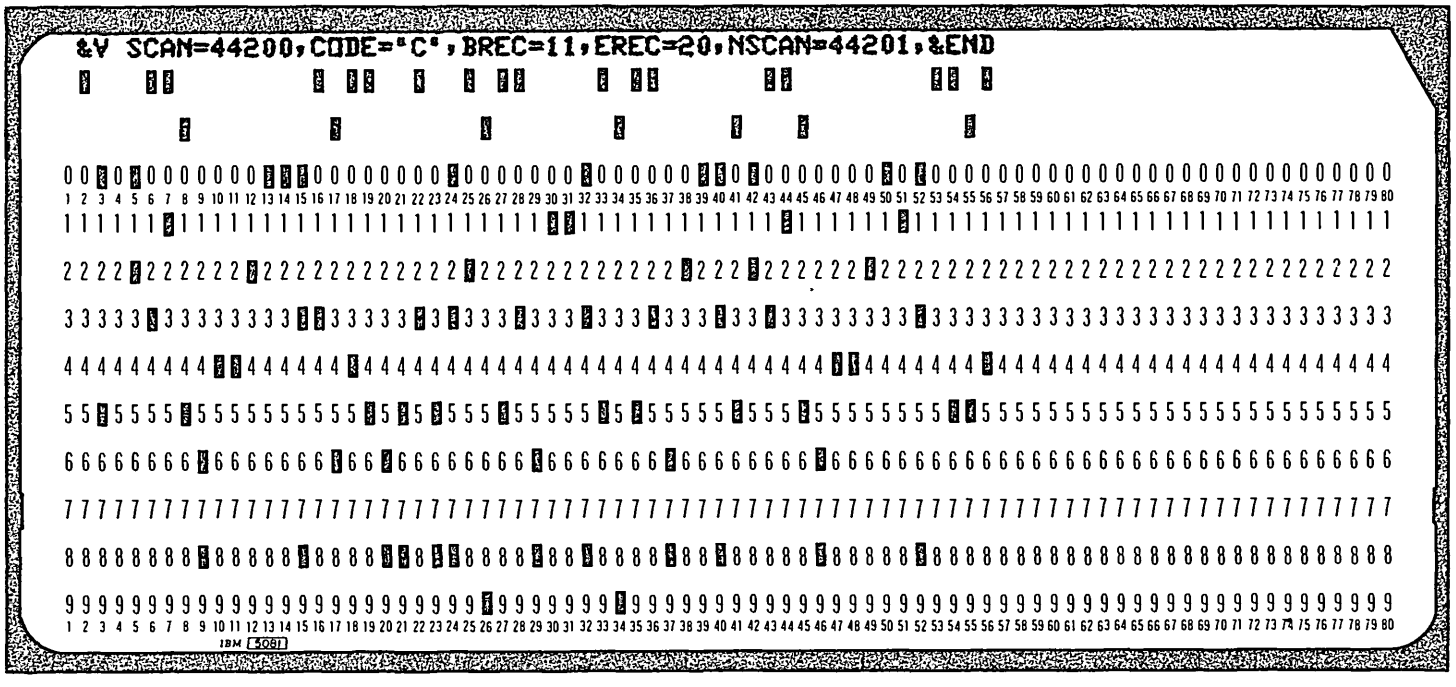
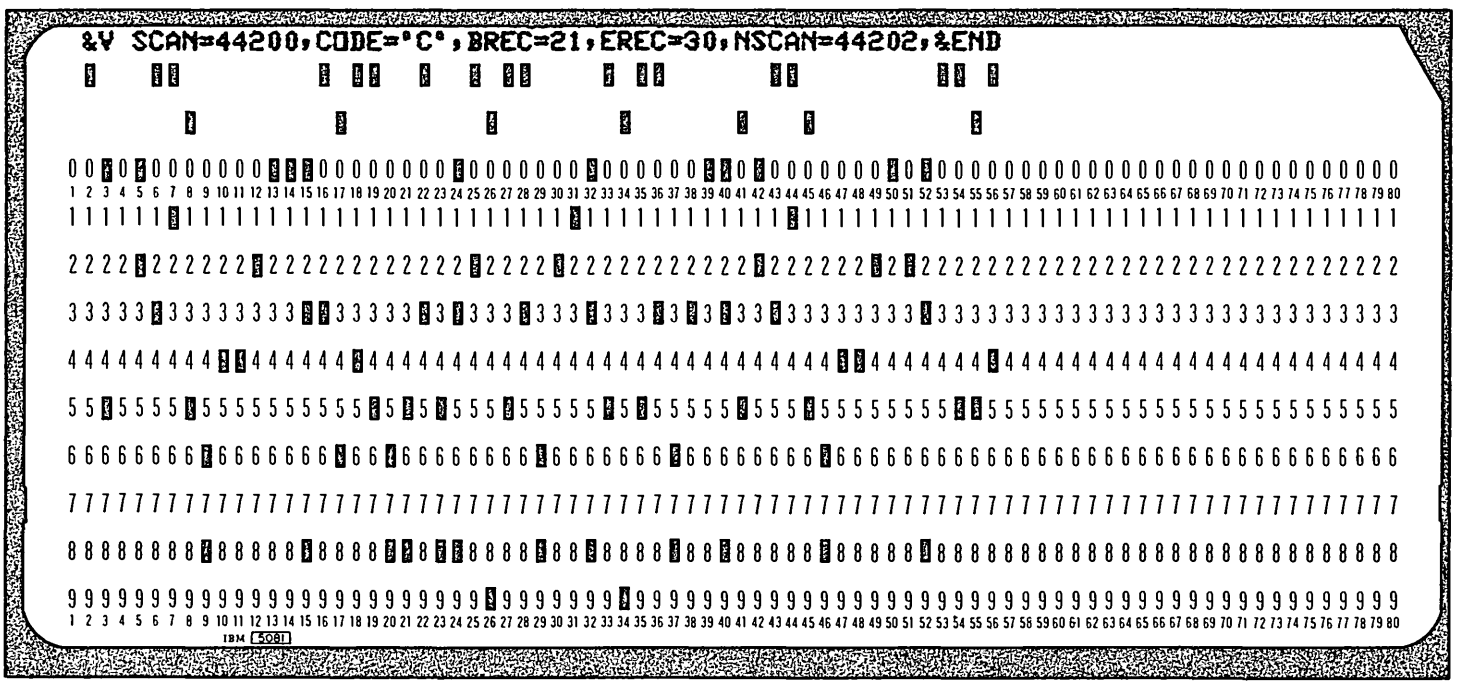

&V SCAN=44200,CODE='C',BREC=11,EREC=20,NSCAN=44201,&END
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
IBM [5081]

Figure 10

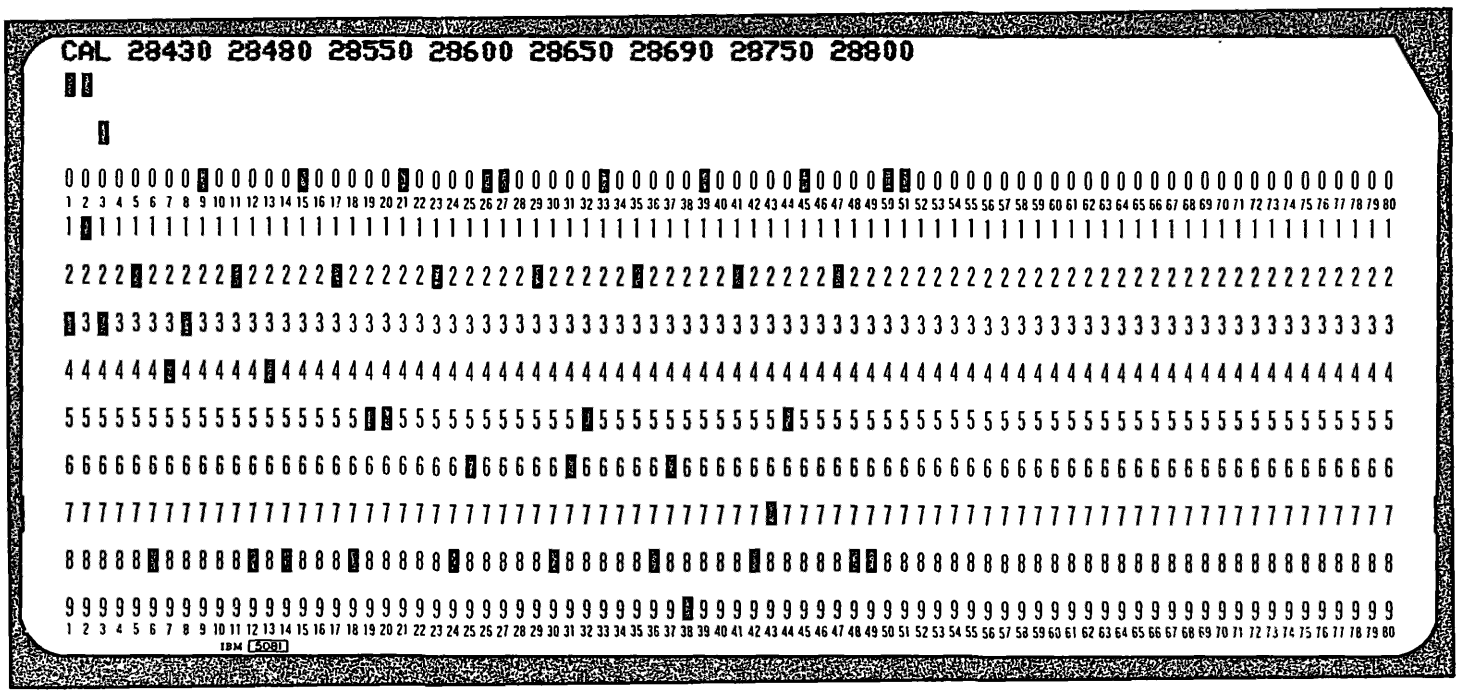

&V SCAN=44200,CODE='C',BREC=21,EREC=30,NSCAN=44202,&END
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
IBM 5081

Explanation of Figures 9 and 10

Figures six and seven show how to break up a scan into two or more parts. Suppose observation number 44200 consists of 30 records and the user wishes to break it up into 3 observations of 10 records each. The user must change the observation number of those records he wishes to separate from the scan. The example breaks observation number 44200 consisting of 30 records into 3 observations - 44200, 44201, 44202 - of 10 records each. The main program averages records until the observation number of the present record differs from the previous record. Then it writes the average on tape, prints information and reinitializes variables and continues.

Figure 11

Calibration Observations for AC4142B



NRAO 140 FOOT TELESCOPE / 413 CHANNEL AUTOCORRELATION RECEIVER / NRAO 44/2 M (D) AC4141

/SCAN NUMBER 2843 / DATE OF COMPUTER RUN 09/24/68 DATE OF OBSERVATION 5/ 2/68 / PARALLEL OPERATION /

TELESCOPE TAPE 534 EASTERN STANDARD TIME 15 15 37 SIDERAL TIME 05 40 27 360 OUTPUT TAPE 923

START SCAN ON OUTPUT TAPE 2843 COMMENTS TAURUS TYPE OF OBSERVATION 12

OBSERVER NUMBER 63 VERSCHUR

L O FREQ	278.05025000	MHZ	278.20025000	MHZ	277.90025000	MHZ	DUMP TIME	10 SEC	NOISE TUBE MODE		3
BANDWIDTH	312.5000	KHZ	625.0000	KHZ	2500.0000	KHZ	BLANK TIME	20 MS	SWITCH RATE & DUTY CYCLE		0
ATTENUATOR	28.1	DB	28.1	DB	4.0	DB	SAMPLE RATE	10 SEC	GAIN MOD & SYN DETECTOR PHASE		0
NOISE TUBE	12.5000	K	12.5000	K	12.5000	K	SENSE SWITCH	63	NOISE TUBE & DUTY CYCLE O/F IND		0 1
GAIN MOD	1		1				FRONT END SWITCH	1			
CLIPPER	0		0		0		DIGITAL TEST SIG	0 0			

/ POWER COUNTER PLOTS /

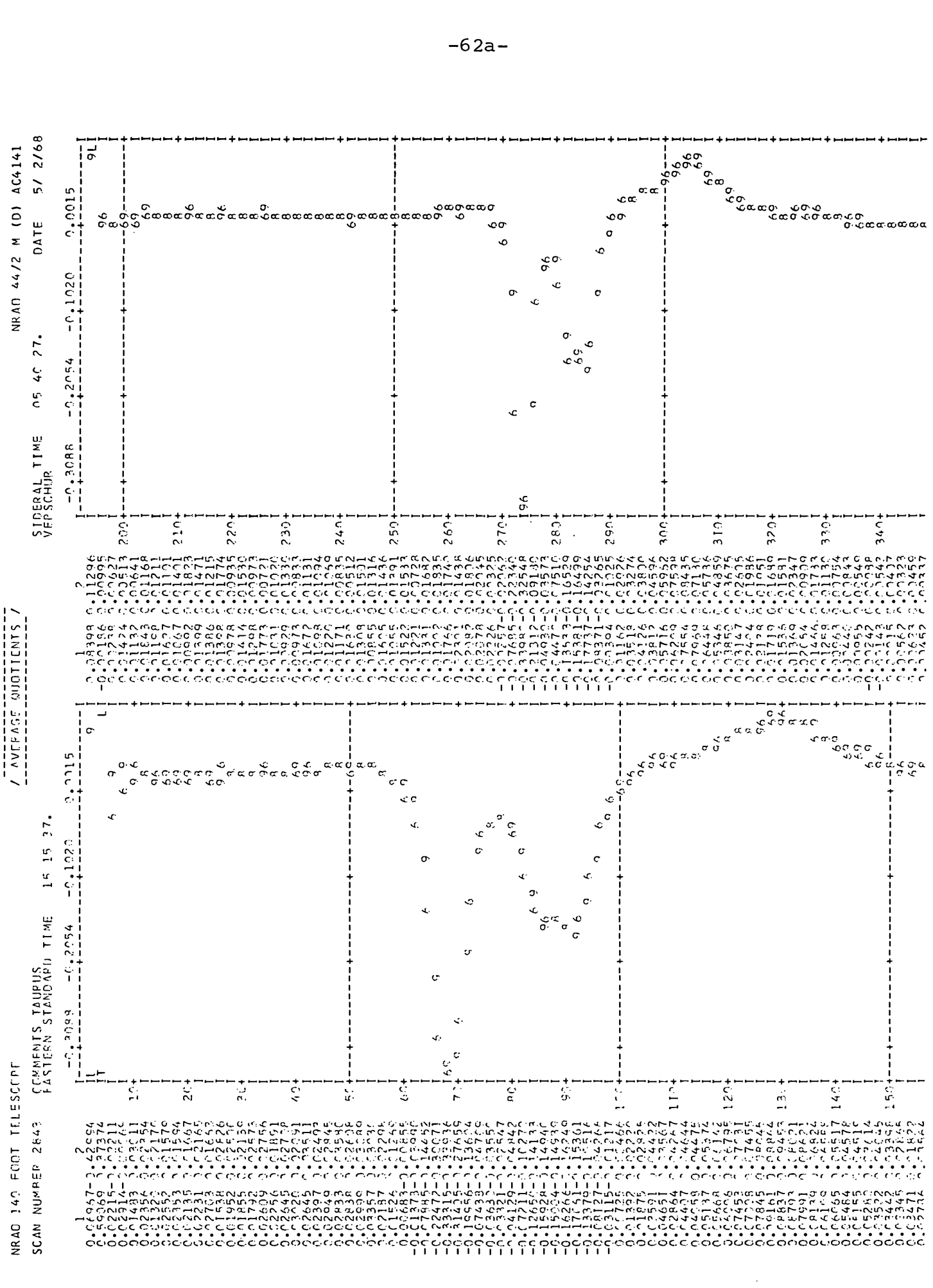
REFERENCE POWER A B C - DIFFERENCE POWER A B C - GAIN A B C SCALE OF PLOTS 0.0300 0.0300 0.0300 0.0300 0.0300 0.0300

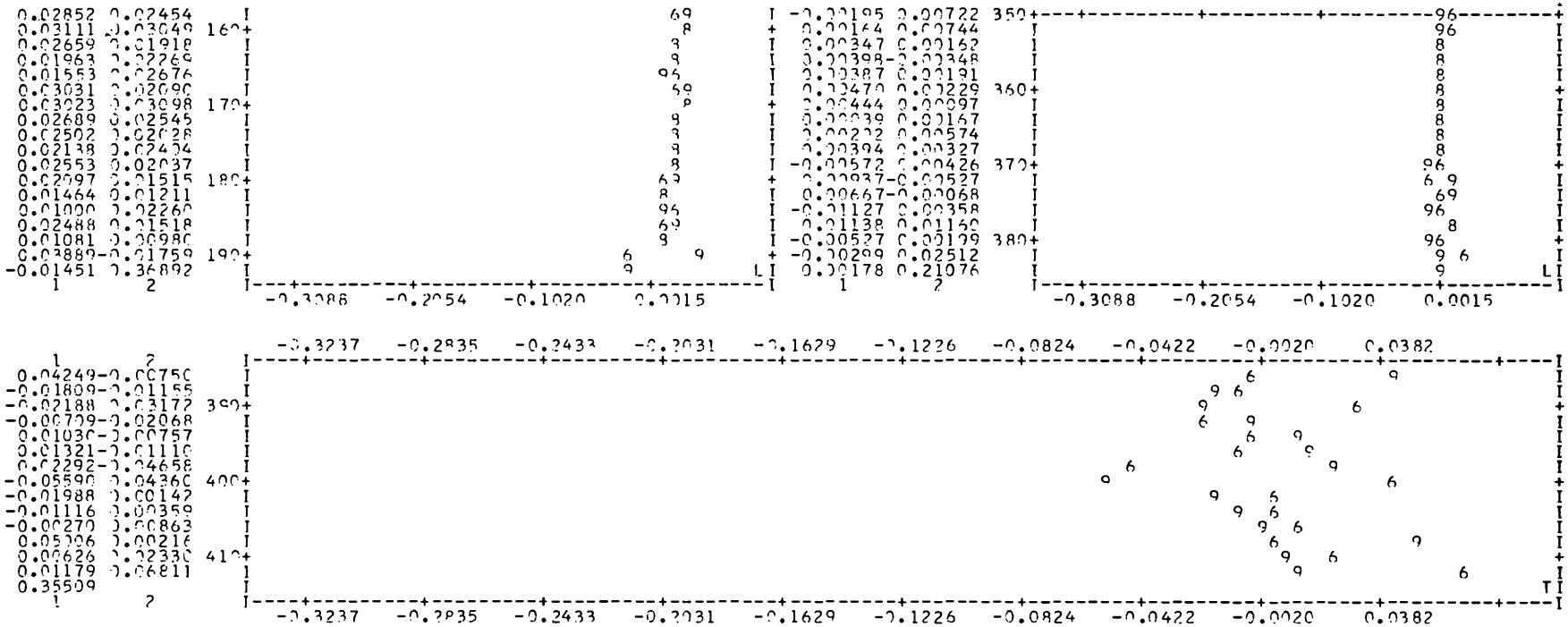
RECORD	RT. ASC.	DEC.	REFER A	REFER B	REFER C	GAIN A	GAIN B	GAIN C						
1	05 32 40	022 01 07	10090	9433	9622	301	288	296	2	5	8	B	E	HHH
2	05 32 40	022 01 07	10072	9421	9615	298	282	287	2	5	8	B	E	HHH
3	05 32 40	022 01 07	10076	9429	9621	299	273	292	2	5	8	B	E	HHH
4	05 32 40	022 01 06	10085	9434	9626	320	298	303	2	5	8	B	E	HHH
5	05 32 40	022 01 06	10088	9436	9631	308	285	289	2	5	8	B	E	HHH
6	05 32 40	022 01 06	10086	9433	9624	311	284	293	2	5	8	B	E	HHH
7	05 32 40	022 01 05	10103	9449	9637	308	291	301	2	5	8	B	E	HH

ABC SIGMA CSN			ABC SIGMA CSF			ABC SIGMA DIF			FACTOR	
9.706	6.797	6.958	6.250	5.151	4.655	7.228	7.200	5.500	408.884	413.246	413.498

APPENDIX C

Output Program I


NRAO 140 FOOT TELESCOPE
SCAN NUMBER 2643
COMMENTS TAURUS
EASTERN STANDARD TIME 15 15 27.
/ AVERAGE QUOTIENTS /
SIDERAL TIME 05 40 27.
VERSCHUR
DATE 5/ 2/68
NRAO 44/2 M (D) AC4141



/ STANDARD DEVIATION TABLE /

1	0.10551	41	0.00987	81	0.01337	121	0.01123	161	0.01028	201	0.00850	241	0.00804	281	0.00804	321	0.00526	361	0.00365	401	0.00115
2	7.81299	42	0.01292	82	0.01008	122	0.00826	162	0.01310	202	0.01066	242	0.00607	282	0.00525	322	0.00770	362	0.01346	402	0.00163
3	0.66381	43	0.00835	83	0.01077	123	0.00822	163	0.01244	203	0.01434	243	0.01138	283	0.00441	323	0.00482	363	0.00773	403	0.00177
4	0.33261	44	0.01703	84	0.00937	124	0.00953	164	0.00776	204	0.00832	244	0.01002	284	0.00787	324	0.00270	364	0.01559	404	0.00130
5	0.51464	45	0.00605	85	0.00911	125	0.00818	165	0.00563	205	0.01179	245	0.01075	285	0.00526	325	0.00683	365	0.01063	405	0.00151
6	0.16991	46	0.01231	86	0.01053	126	0.00869	166	0.00682	206	0.00625	246	0.00790	286	0.01048	326	0.01051	366	0.00538	406	0.00111
7	0.05099	47	0.00962	87	0.00923	127	0.00954	167	0.01143	207	0.00747	247	0.00958	287	0.00570	327	0.00575	367	0.01290	407	0.00171
8	0.06506	48	0.01125	88	0.00802	128	0.01087	168	0.00997	208	0.01029	248	0.00893	288	0.01178	328	0.01293	368	0.00787	408	0.00127
9	0.02393	49	0.00690	89	0.01045	129	0.01625	169	0.01370	209	0.00363	249	0.00651	289	0.00745	329	0.00945	369	0.01119	409	0.00239
10	0.02379	50	0.01197	90	0.00549	130	0.01078	170	0.00796	210	0.01028	250	0.00696	290	0.00588	330	0.01449	370	0.00978	410	0.00140
11	0.02020	51	0.01551	91	0.00513	131	0.00800	171	0.01158	211	0.01084	251	0.00818	291	0.00723	331	0.00679	371	0.00747	411	0.00162
12	0.00861	52	0.01293	92	0.00676	132	0.00981	172	0.01596	212	0.01424	252	0.00346	292	0.00581	332	0.00632	372	0.01003	412	0.00677
13	0.01443	53	0.01148	93	0.01563	133	0.00865	173	0.01295	213	0.00463	253	0.00449	293	0.00520	333	0.00903	373	0.01228	413	0.04509
14	0.01044	54	0.01285	94	0.00598	134	0.00752	174	0.01386	214	0.00328	254	0.00675	294	0.00758	334	0.00776	374	0.01102		
15	0.01417	55	0.00825	95	0.00922	135	0.01085	175	0.00862	215	0.00986	255	0.00916	295	0.00929	335	0.00900	375	0.01108		
16	0.01258	56	0.00478	96	0.00979	136	0.01186	176	0.00819	216	0.01015	256	0.00964	296	0.00666	336	0.00612	376	0.00857		
17	0.01643	57	0.01255	97	0.00510	137	0.01130	177	0.00594	217	0.00761	257	0.00647	297	0.00876	337	0.00587	377	0.01339		
18	0.01619	58	0.00982	98	0.01662	138	0.01693	178	0.01967	218	0.01012	258	0.00995	298	0.00753	338	0.00894	378	0.01166		
19	0.00960	59	0.00860	99	0.00871	139	0.01107	179	0.01050	219	0.00519	259	0.01239	299	0.00977	339	0.00653	379	0.01522		
20	0.01327	60	0.00875	100	0.00638	140	0.01681	180	0.00810	220	0.00940	260	0.01164	300	0.00985	340	0.00836	380	0.01816		
21	0.00552	61	0.01041	101	0.01038	141	0.01076	181	0.00978	221	0.00463	261	0.00660	301	0.00760	341	0.01113	381	0.05583		
22	0.01260	62	0.00869	102	0.01172	142	0.01032	182	0.01897	222	0.00738	262	0.01096	302	0.00572	342	0.00448	382	0.04902		
23	0.01143	63	0.00799	103	0.01093	143	0.00875	183	0.01846	223	0.00924	263	0.00379	303	0.00586	343	0.00912	383	0.08942		
24	0.00687	64	0.00697	104	0.01253	144	0.00947	184	0.01031	224	0.00586	264	0.00599	304	0.00821	344	0.00905	384	0.21261		
25	0.00693	65	0.00459	105	0.00946	145	0.01592	185	0.01628	225	0.00589	265	0.00796	305	0.00635	345	0.00485	385	0.43346		
26	0.00710	66	0.00925	106	0.00733	146	0.00895	186	0.00579	226	0.01001	266	0.00851	306	0.01021	346	0.00666	386	0.00251		
27	0.01622	67	0.00226	107	0.00813	147	0.00567	187	0.01659	227	0.00425	267	0.00520	307	0.00684	347	0.00820	387	0.00120		
28	0.00777	68	0.00636	108	0.01420	148	0.01190	188	0.01457	228	0.00441	268	0.00964	308	0.00640	348	0.00794	388	0.00231		
29	0.01011	69	0.01039	109	0.01036	149	0.01204	189	0.02270	229	0.00505	269	0.00448	309	0.00796	349	0.00683	389	0.00214		
30	0.01693	70	0.00951	110	0.00860	150	0.02197	190	0.26074	230	0.00635	270	0.00648	310	0.01269	350	0.00626	390	0.00151		
31	0.00909	71	0.00971	111	0.00873	151	0.01059	191	0.07726	231	0.00723	271	0.00680	311	0.00577	351	0.00788	391	0.00176		
32	0.01206	72	0.00932	112	0.01378	152	0.00693	192	0.15262	232	0.00555	272	0.00446	312	0.00548	352	0.00896	392	0.00101		
33	0.00819	73	0.01154	113	0.01277	153	0.01227	193	0.14920	233	0.00480	273	0.00229	313	0.00940	353	0.00518	393	0.00145		
34	0.01632	74	0.01403	114	0.01293	154	0.00616	194	0.09401	234	0.00600	274	0.00427	314	0.00613	354	0.01021	394	0.00126		
35	0.01548	75	0.00616	115	0.02034	155	0.01051	195	0.06832	235	0.00680	275	0.00411	315	0.01373	355	0.00616	395	0.00167		
36	0.01069	76	0.01278	116	0.01018	156	0.01054	196	0.03817	236	0.01037	276	0.01058	316	0.00752	356	0.01047	396	0.00186		
37	0.01415	77	0.01114	117	0.00830	157	0.01371	197	0.01860	237	0.01100	277	0.00827	317	0.00468	357	0.00736	397	0.00176		
38	0.00984	78	0.01309	118	0.00990	158	0.00871	198	0.01930	238	0.00805	278	0.00986	318	0.00940	358	0.00420	398	0.00110		
39	0.00925	79	0.01028	119	0.00704	159	0.01068	199	0.01239	239	0.00586	279	0.01129	319	0.00765	359	0.00350	399	0.00136		
40	0.01255	80	0.01223	120	0.00944	160	0.01303	200	0.00837	240	0.00931	280	0.00822	320	0.00774	360	0.00950	400	0.00095		

```
NRAO 140 FOOT TELESCOPE          DATE -- 09/25/68     TIME -- 23/ 8/37     PAGE --    1          NRAO 49/A1 M (D)  AC4142A

  DATA CARDS SUBMITTED TO THIS PROGRAM
12345678901234567890123456789012345678901234567890123456789012345678901234567890
SKIP
 &V CODE='U',FQMLTA=5.0,CFFSTA=30.0,RESTA=1,NSTOP=28480,&END
```


APPENDIX D

Output Program II

Version AC4142A

TAPE REC. NO.	OBS. NO.	NO. OF RECORDS	TOTAL INTEGRATION TIME	IDENTIFICATION	
1	28430	7	1.17	VERSCHUR	TAURUS
2	28440	49	8.17	VERSCHUR	TAURUS
3	28450	39	6.50	VERSCHUR	TAURUS
4	28460	44	7.33	VERSCHUR	TAURUS
5	28470	40	6.67	VERSCHUR	TAURUS

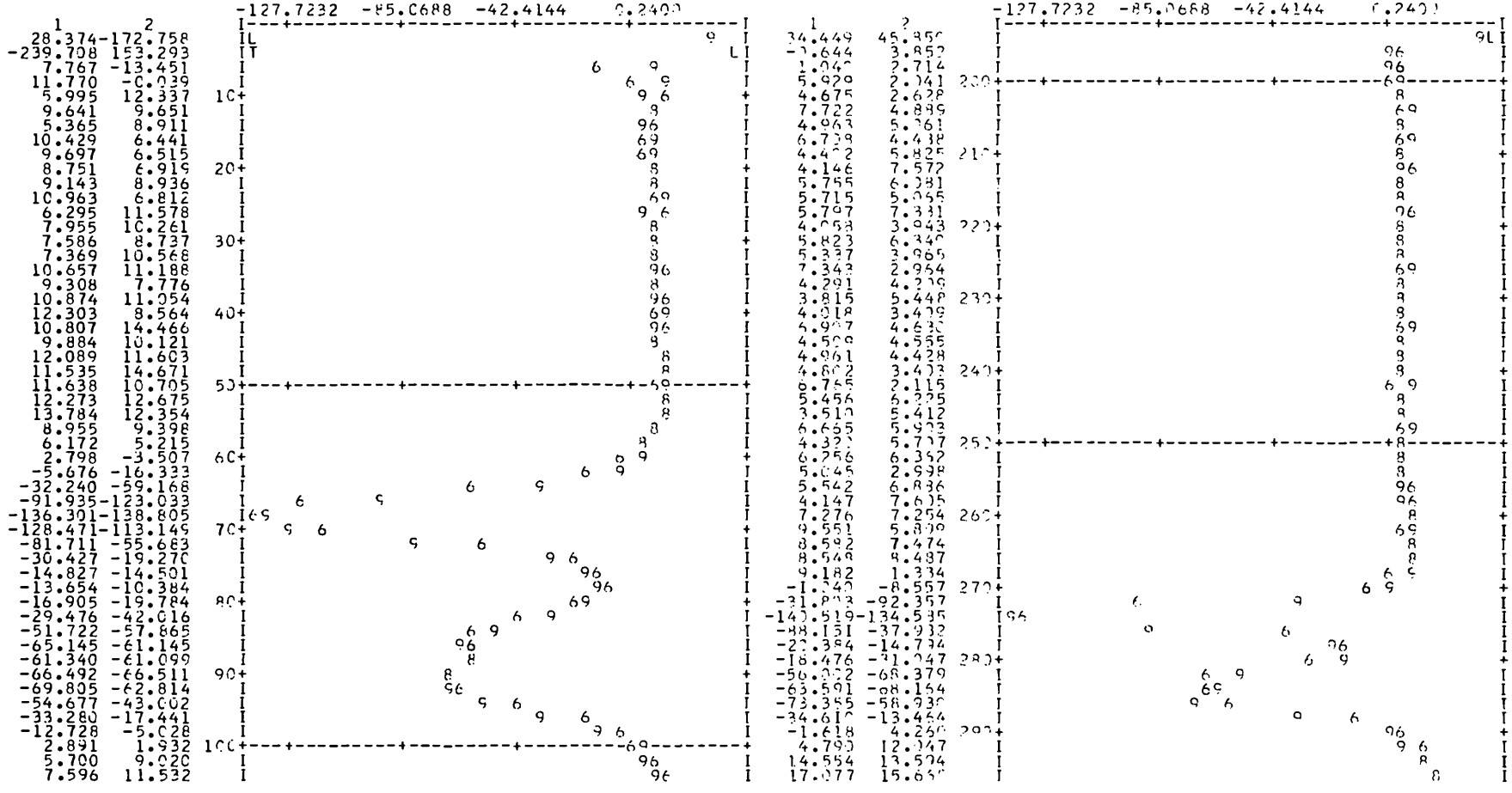
FT08F001 DSNAME=SPECTRA
UNIT=281 VOLUME=SER=1203 DISP=NEW
RECFM=V LRECL= 3620 BLKSIZE= 3624

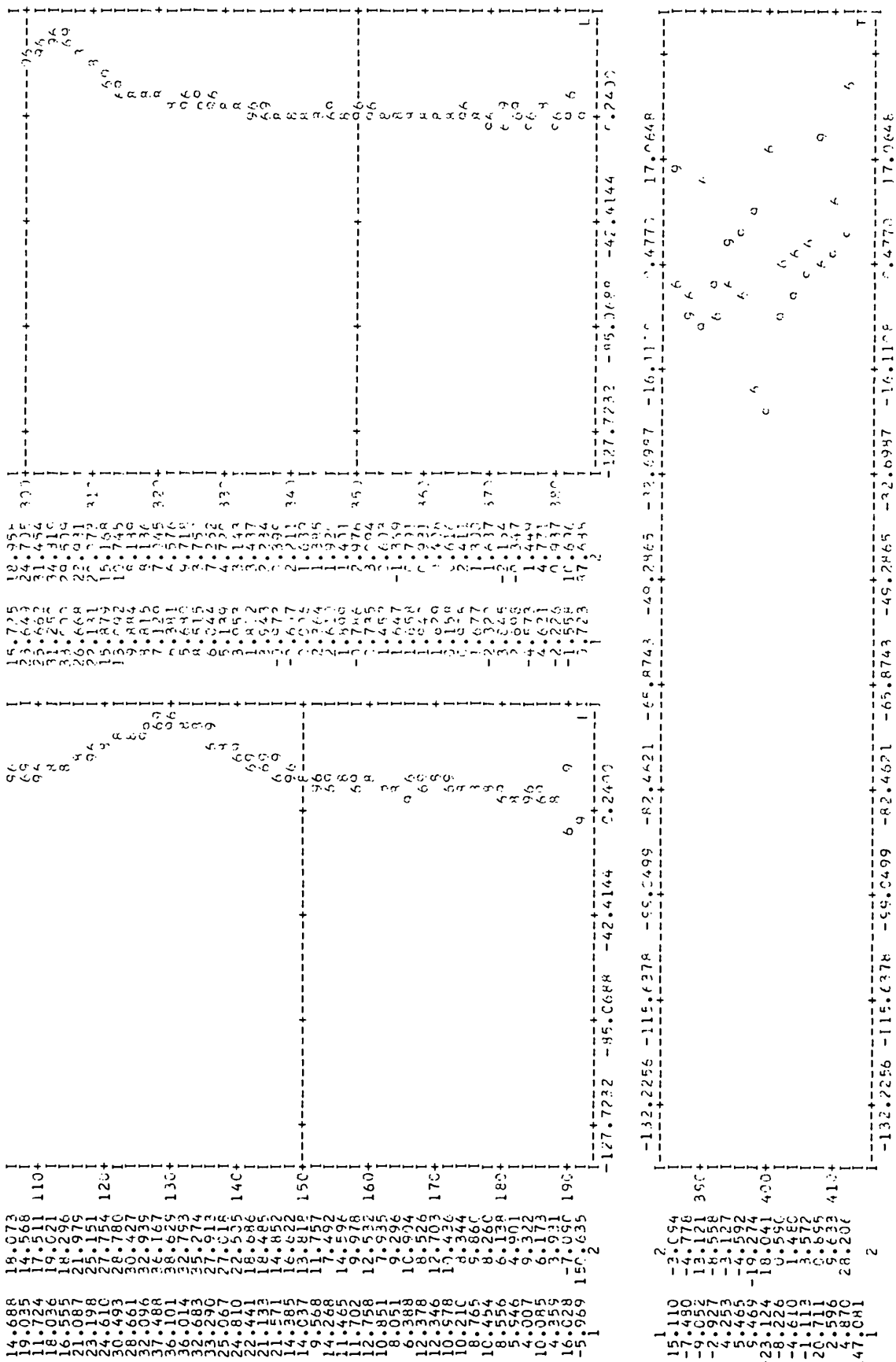
OUTPUT TAPE RECORD NUMBER 1 / OBSERVATION 28430 / AVERAGE OF 7 RECORDS TOTAL INTEGRATION TIME 1.17 MINUTES
OUTPUT TAPE NUMBER 1203

/ VERSCHUR TAURUS /

	DATA OF RECORD NUMBER 1	DATA OF RECORD NUMBER 7
DATE	68/ 5/ 2	68/ 5/ 2
OPERATION	PARALLEL	PARALLEL
LOCAL SIDEREAL TIME	05 40 27.4	05 44 27.4
EASTERN STANDARD TIME	15 15 37.4	15 19 36.7
RIGHT ASCENSION	05 32 40.3	05 32 40.1
DECLINATION	022 01 36.6	022 01 24.8
POLARIZATION ANGLE	000 00 00.0	000 00 00.0
L. C. FREQ A+C C/1/2	278.25025000 / 278.20005000 / 277.90005000	278.25025000 / 278.20005000 / 277.90005000
L. C. FREQ B C/1/2	278.25025000 / 278.20005000 / 277.90005000	278.25025000 / 278.20005000 / 277.90005000
NOISE TUBES A/B/C	12.50000000 / 12.50000000 / 12.50000000	12.50000000 / 12.50000000 / 12.50000000
ATTENUATORS A/B/C	28.09999084 / 28.09999084 / 4.00000000	28.09999084 / 28.09999084 / 4.00000000
BANDWIDTHS A/B/C	312.5000 / 625.0000 / 2500.0000	312.5000 / 625.0000 / 2500.0000
JULIAN DATE	2439979.3441825	2439979.3469527
VELOCITY CORRECTION	31.9557343	31.9604645
VELOCITY OF CENTER OF BANDS CORRECTED A/B/C	0.64027405 / 0.64027405 / 0.64027405	
VELOCITY OF CENTER OF BANDS UNCORRECTED A/B/C	32.59837341 / 32.59837341 / 32.59837341	
VELOCITY CHANGE PER CHANNEL A/B/C	0.34354258 / 0.68708509 / 18.15589233	

TEMPERATURE -- (SIGNAL - REFERENCE)/REFERENCE





```
NRAO 140 FOOT TELESCOPE              DATE -- 09/25/68     TIME -- 17/15/38     PAGE --     1              NRAO 49/81 M (D)  AC4142B

  DATA CARDS SUBMITTED TO THIS PROGRAM
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CAL 28430
SKIP
 &V CODE='U',FQMLTA=5.0,OFFSTA=30.0,RFSTA=1,NSTOP=28480,$END
```


APPENDIX D

Output Program II

Version AC4142B

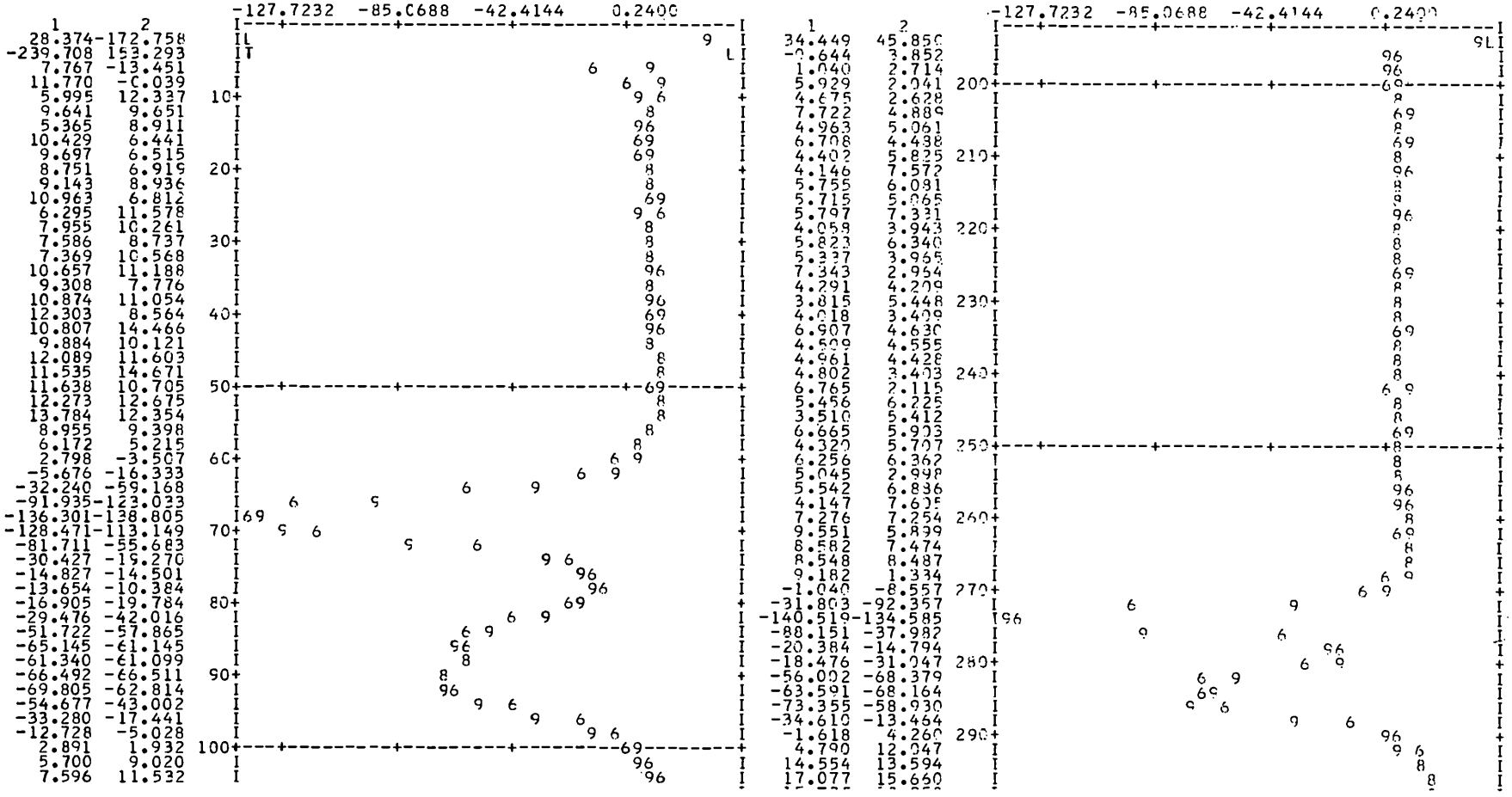
TAPE REC. NO.	OBS. NO.	NO. OF RECORDS	TOTAL INTEGRATION TIME	IDENTIFICATION	
1	28438	7	1.17	VERSCHUR	TAURUS
2	28440	49	8.17	VERSCHUR	TAURUS
3	2845C	39	6.50	VERSCHUR	TAURUS
4	28460	44	7.33	VERSCHUR	TAURUS
5	2847C	4C	6.67	VERSCHUR	TAURUS

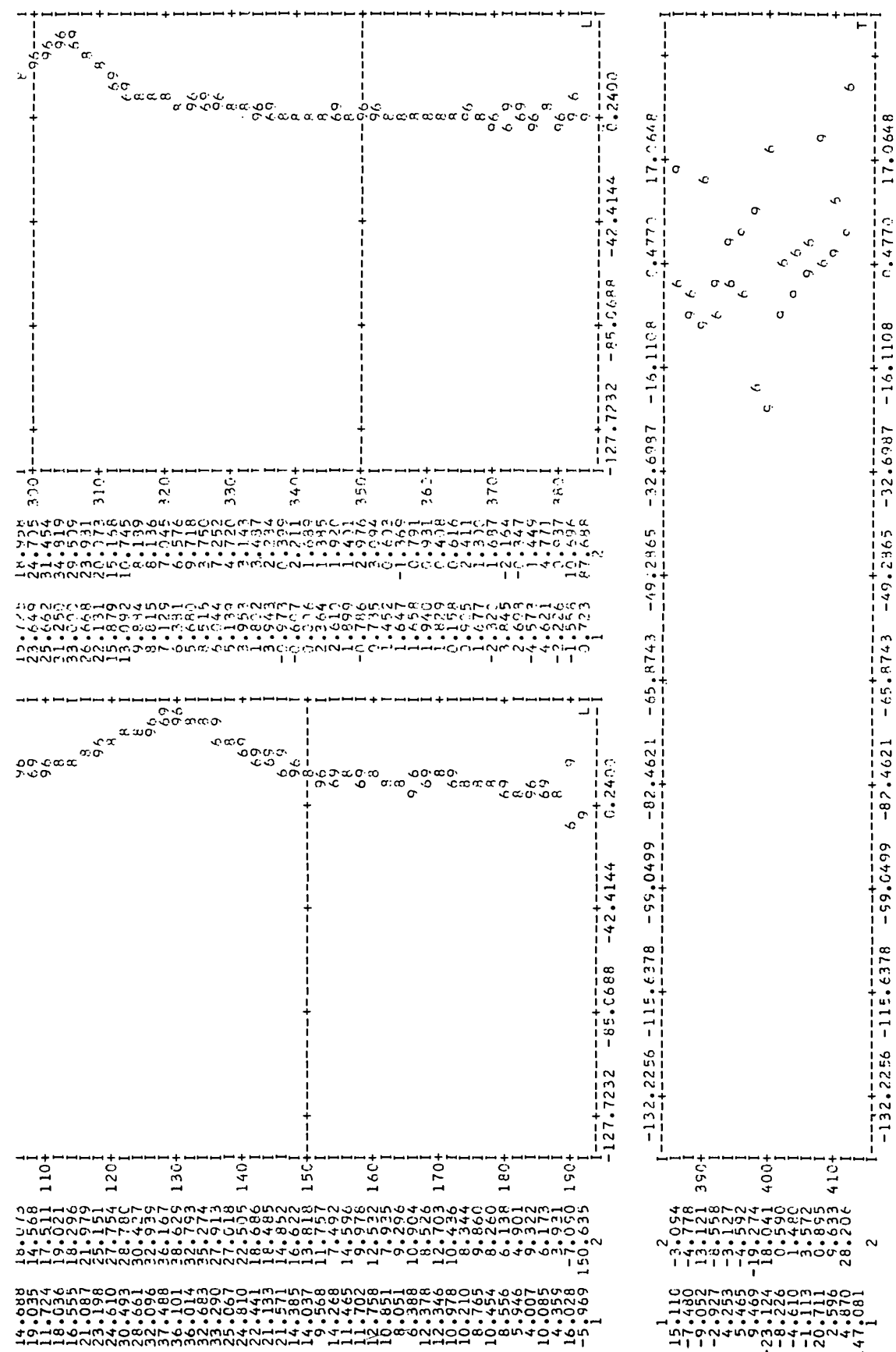
FTC8FC01 DSNAME=SPECTRA
UNIT=281 VOLUME=SER=12C3 DISP=NEW
RECFM=V LRECL= 7140 BLKSIZE= 7144

OUTPUT TAPE RECORD NUMBER 1 / OBSERVATION 28430 / AVERAGE OF 7 RECORDS TOTAL INTEGRATION TIME 1.17 MINUTES
OUTPUT TAPE NUMBER 1203 / VERSCHUR TAURUS / CALIBRATION /

	DATA OF RECORD NUMBER 1			DATA OF RECORD NUMBER 7		
DATE	68/ 5/ 2			68/ 5/ 2		
OPERATION	PARALLEL			PARALLEL		
LOCAL SIDEREAL TIME	05 40 27.4			05 44 27.4		
EASTERN STANDARD TIME	15 15 37.4			15 19 36.7		
RIGHT ASCENSION	05 32 40.3			05 32 40.1		
DECLINATION	022 01 06.6			022 01 04.8		
POLARIZATION ANGLE	000 00 00.0			000 00 00.0		
L. O. FREQ A+C 0/1/2	278.05025000 /	278.20005000 /	277.90005000	278.05025000 /	278.20005000 /	277.90005000
L. O. FREQ B 0/1/2	278.05025000 /	278.20005000 /	277.90005000	278.05025000 /	278.20005000 /	277.90005000
NOISE TUBES A/B/C	12.50000000 /	12.50000000 /	12.50000000	12.50000000 /	12.50000000 /	12.50000000
ATTENUATORS A/B/C	28.09999084 /	28.09999084 /	4.00000000	28.09999084 /	28.09999084 /	4.00000000
BANDWIDTHS A/B/C	312.5000 /	625.0000 /	2500.0000	312.5000 /	625.0000 /	2500.0000
JULIAN DATE	2439979.3441825			2439979.3469527		
VELOCITY CORRECTION	31.9557343			31.9604645		
VELOCITY OF CENTER OF BANDS CORRECTED A/B/C	0.64027405 /	0.64027405 /	0.64027405			
VELOCITY OF CENTER OF BANDS UNCORRECTED A/B/C	32.59837341 /	32.59837341 /	32.59837341			
VELOCITY CHANGE PER CHANNEL A/B/C	0.34354258 /	0.68708509 /	18.19589233			

CALIBRATION OBSERVATION TEMPERATURE -- (SIGNAL - REFERENCE)/REFERENCE





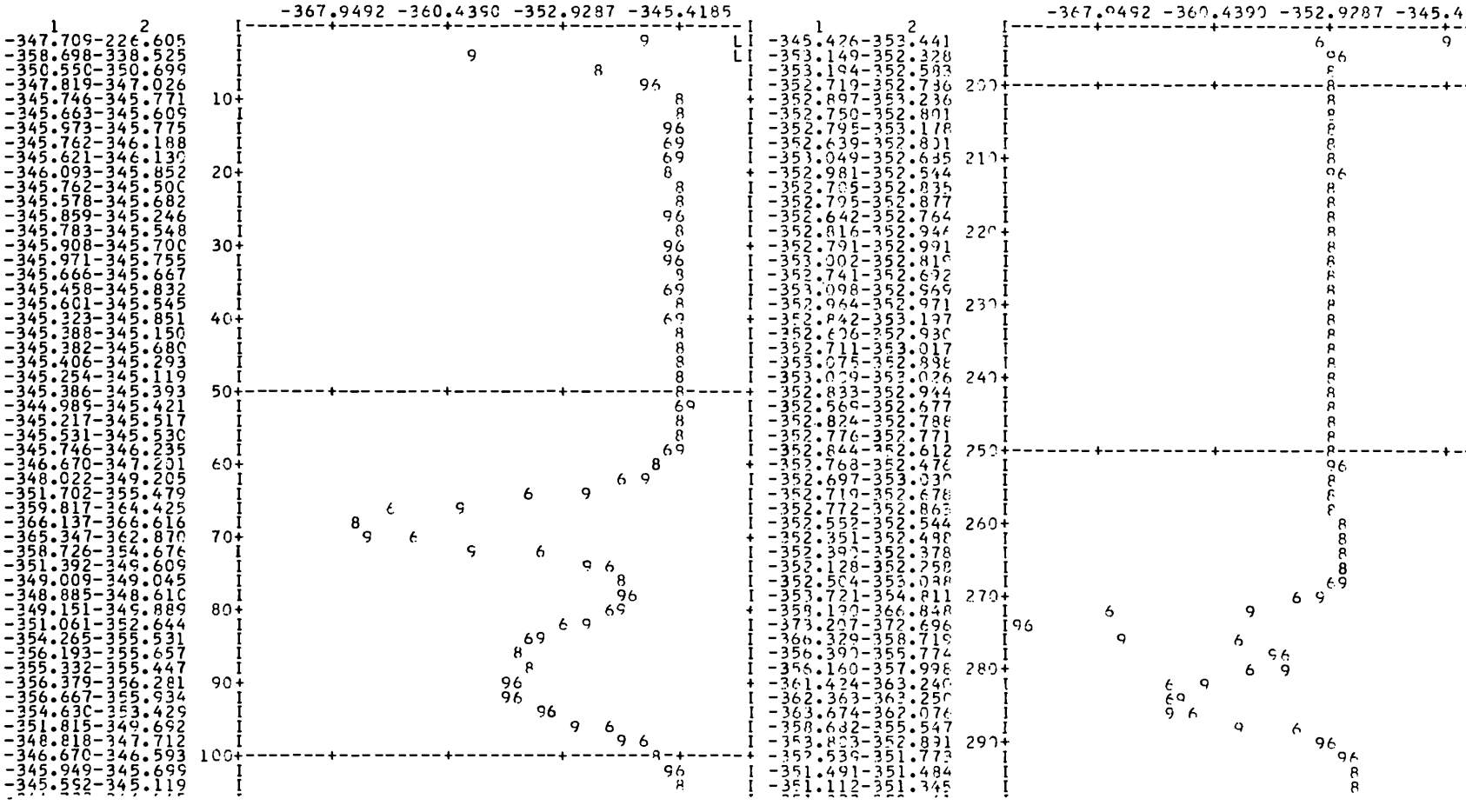
OUTPUT TAPE RECORD NUMBER 2 / OBSERVATION 28440 / AVERAGE OF 49 RECORDS TOTAL INTEGRATION TIME 8.17 MINUTES
OUTPUT TAPE NUMBER 1203

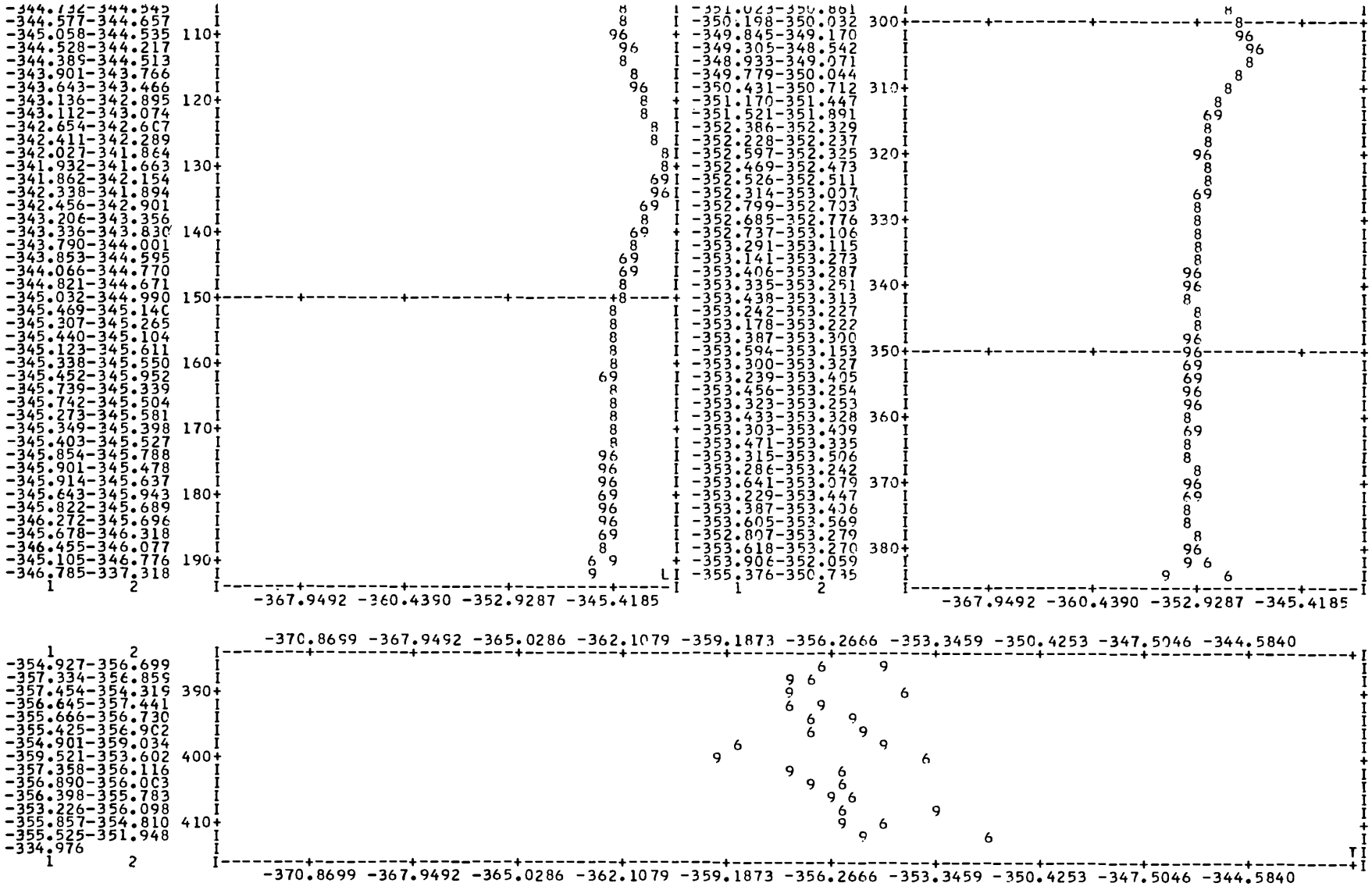
/ VERSCHUR TAURUS / / POL. SWITCHING /

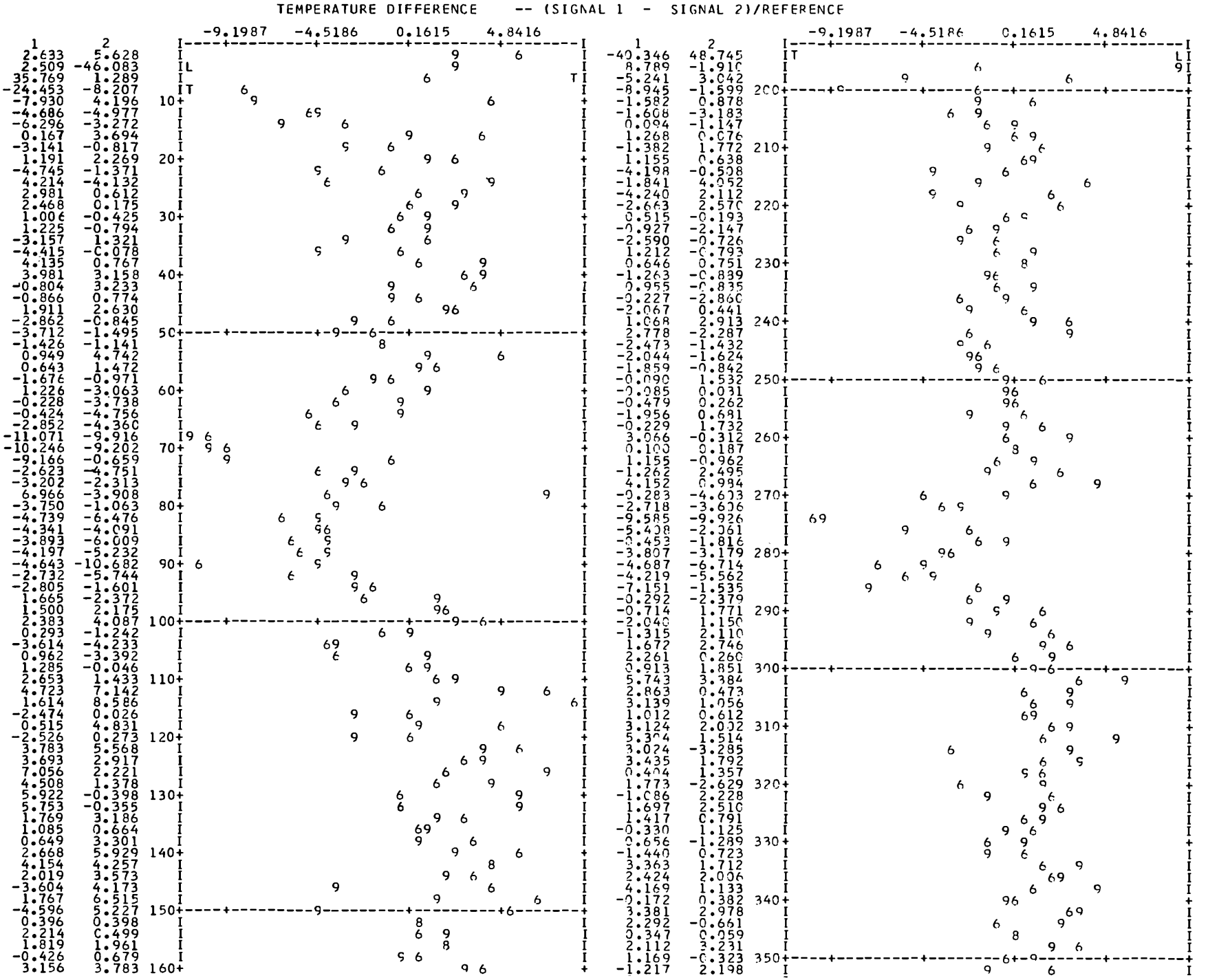
	DATA OF RECORD NUMBER 1			DATA OF RECORD NUMBER 49		
DATE	68/ 5/ 2			68/ 5/ 2		
OPERATION	PARALLEL			PARALLEL		
LOCAL SIDEREAL TIME	05 47 17.4			06 19 17.4		
EASTERN STANDARD TIME	15 22 26.2			15 54 21.0		
RIGHT ASCENSION	05 32 40.1			05 32 39.7		
DECLINATION	022 01 00.6			022 00 55.8		
POLARIZATION ANGLE	000 00 00.0			000 00 00.0		
L. O. FREQ A+C 0/1/2	278.05022000	278.20002000	277.90002000	278.05022000	278.20002000	277.90002000
L. O. FREQ B 0/1/2	278.05022000	278.20002000	277.90002000	278.05022000	278.20002000	277.90002000
NOISE TUBES A/B/C	12.50000000	12.50000000	12.50000000	12.50000000	12.50000000	12.50000000
ATTENUATORS A/B/C	28.39999390	28.19999695	4.00000000	28.39999390	28.19999695	4.00000000
BANDWIDTHS A/B/C	312.5000	625.0000	2500.0000	312.5000	625.0000	2500.0000
JULIAN DATE	2439979.3489149			2439979.3710764		
VELOCITY CORRECTION	31.9639740			32.0019531		

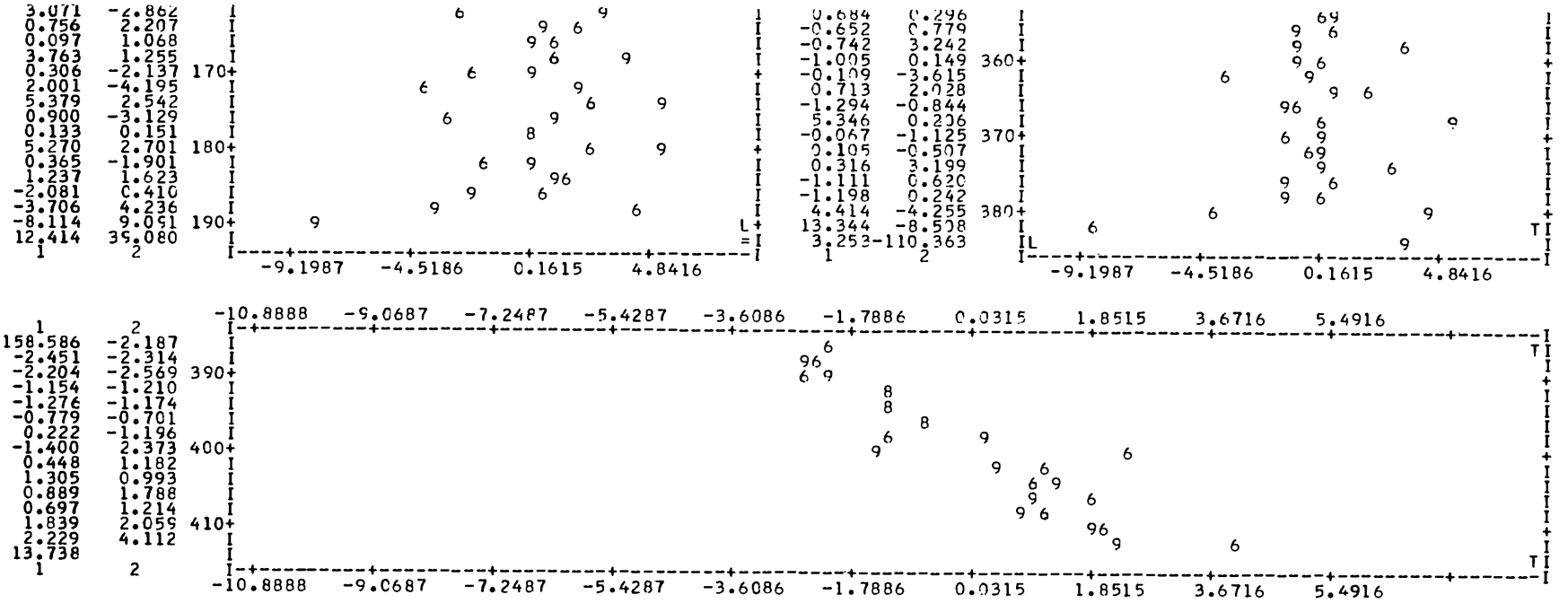
VELOCITY OF CENTER OF BANDS	CORRECTED	A/B/C	0.64707947 / 0.64707947 / 0.64707947	
VELOCITY OF CENTER OF BANDS	UNCORRECTED	A/B/C	32.63003540 / 32.63003540 / 32.63003540	
VELOCITY CHANGE PER CHANNEL	A/B/C		0.34354264 / 0.68708521 / 18.19590759	

TEMPERATURE -- (SIGNAL 1 - REFERENCE)/REFERENCE




-367.9492 -360.4390 -352.9287 -345.4185
-370.8699 -367.9492 -365.0286 -362.1079 -359.1873 -356.2666 -353.3459 -350.4253 -347.5046 -344.5840


TEMPERATURE DIFFERENCE -- (SIGNAL 1 - SIGNAL 2)/REFERENCE
-9.1987 -4.5186 0.1615 4.8416
1 2
2.633 5.628
2.509 -46.083
35.769 1.289
-24.453 -8.207
-7.930 4.196
-4.686 -4.977
-6.296 -3.272
0.167 3.694
-3.141 -0.817
1.191 2.269
-4.745 -1.371
4.214 -4.132
2.981 0.612
2.468 0.175
1.006 -0.425
1.225 -0.794
-3.157 1.321
-4.415 -0.078
4.135 0.767
3.981 3.158
-0.804 0.233
-0.866 0.774
1.911 2.630
-2.862 -0.845
-3.712 -1.495
-1.426 -1.141
0.949 4.742
0.643 1.472
-1.676 -0.971
1.226 -3.063
-0.228 -3.738
-0.424 -4.756
-2.852 -4.360
-11.071 -9.916
-10.246 -9.202
-9.166 -0.659
-2.623 -4.751
-3.202 -2.313
6.966 -3.908
-3.750 -1.063
-4.739 -6.476
-4.341 -4.091
-3.893 -6.009
-4.197 -5.232
-4.643 -10.682
-2.732 -5.744
-2.805 -1.601
1.665 -2.372
1.500 2.175
2.383 4.087
0.293 -1.242
-3.614 -4.233
0.962 -3.392
1.285 -0.046
2.653 1.433
4.723 7.142
1.614 8.586
-2.474 0.026
0.515 4.831
-2.526 0.273
3.783 5.568
3.693 2.917
7.056 2.221
4.508 1.378
5.922 -0.398
5.753 -0.355
1.769 3.186
1.085 0.664
0.649 3.301
2.668 5.929
4.154 4.257
2.019 3.573
-3.604 4.173
1.767 6.515
-4.596 5.227
0.396 0.398
2.214 0.499
1.819 1.961
-0.426 0.679
3.156 3.783
-9.1987 -4.5186 0.1615 4.8416
1 2
-40.346 48.745
8.789 -1.910
-5.241 3.042
-8.945 -1.599
-1.582 0.878
-1.608 -3.183
0.094 -1.147
1.268 0.076
-1.382 1.772
1.155 0.638
-4.198 -0.508
-1.841 4.052
-4.240 2.112
-2.663 2.570
0.515 -0.193
-0.927 -2.147
-2.590 -0.726
1.212 -0.793
0.646 0.751
-1.263 -0.839
0.955 -0.835
-0.227 -2.860
-2.067 0.441
1.068 2.913
2.778 -2.287
-2.473 -1.432
-2.044 -1.624
-1.859 -0.842
-0.090 1.532
-0.085 0.031
-0.479 0.262
-1.956 0.681
-0.229 1.732
3.066 -0.312
0.100 0.187
1.155 -0.962
-1.262 2.495
4.152 0.984
-0.283 -4.603
-2.718 -3.606
-9.585 -9.926
-5.408 -2.061
-0.453 -1.816
-3.807 -3.179
-4.687 -6.714
-4.219 -5.562
-7.151 -1.535
-0.292 -2.379
-0.714 1.771
-2.040 1.150
-1.315 2.110
1.672 2.746
2.261 0.260
0.913 1.851
5.743 3.384
2.863 0.473
3.139 1.056
1.012 0.612
3.124 2.002
5.364 1.514
3.024 -3.285
3.435 1.792
0.404 1.357
1.773 -2.629
-1.086 2.228
1.697 2.510
1.417 0.791
-0.330 1.125
0.656 -1.289
-1.440 0.723
3.363 1.712
2.424 2.006
4.169 1.133
-0.172 0.382
3.381 2.978
2.292 -0.661
0.347 0.059
2.112 3.231
1.169 -0.323
-1.217 2.198


-9.1987 -4.5186 0.1615 4.8416
-10.8888 -9.0687 -7.2487 -5.4287 -3.6086 -1.7886 0.0315 1.8515 3.6716 5.4916

APPENDIX E

On-Line Printed Output

Below is an example of a printed output for quotients. The top portion of an output for receiver C is given. To the right each of the quantities in the header is explained.

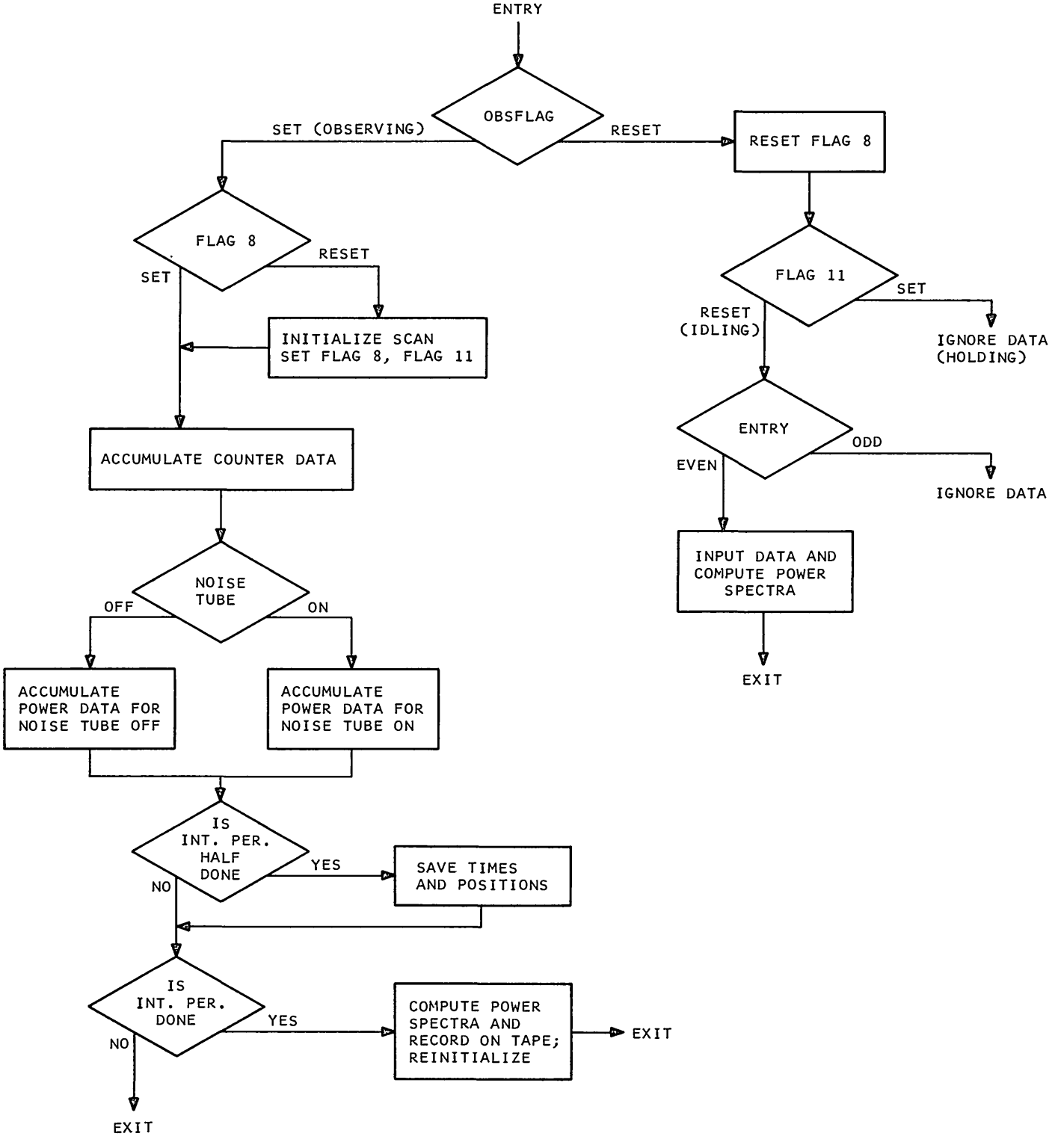
```
 13  091068  150123        Format     Date     Est

  1339  000900             Scan no.     Total integration time
  192158  143135           ind. R. A.    ind. DEC.

001  0.0195                quotient channel 1
002  0.0135                quotient channel 2
003  0.0129                quotient channel 3
004  0.0122                quotient channel 4
005  0.0101                quotient channel 5
006  0.0100                quotient channel 6
007  0.0104                quotient channel 7
008  0.000
009                                .
                                   .
                                   .
```

Header information for all printed spectral outputs is the same. The positions which are printed are saved during the last integration period of a scan. The format number is used to identify the receiver configuration and type of output as follows:

Format	Description
11	integrated quotient receiver A (parallel)
12	integrated quotient receiver B (parallel)
13	integrated quotient receiver C

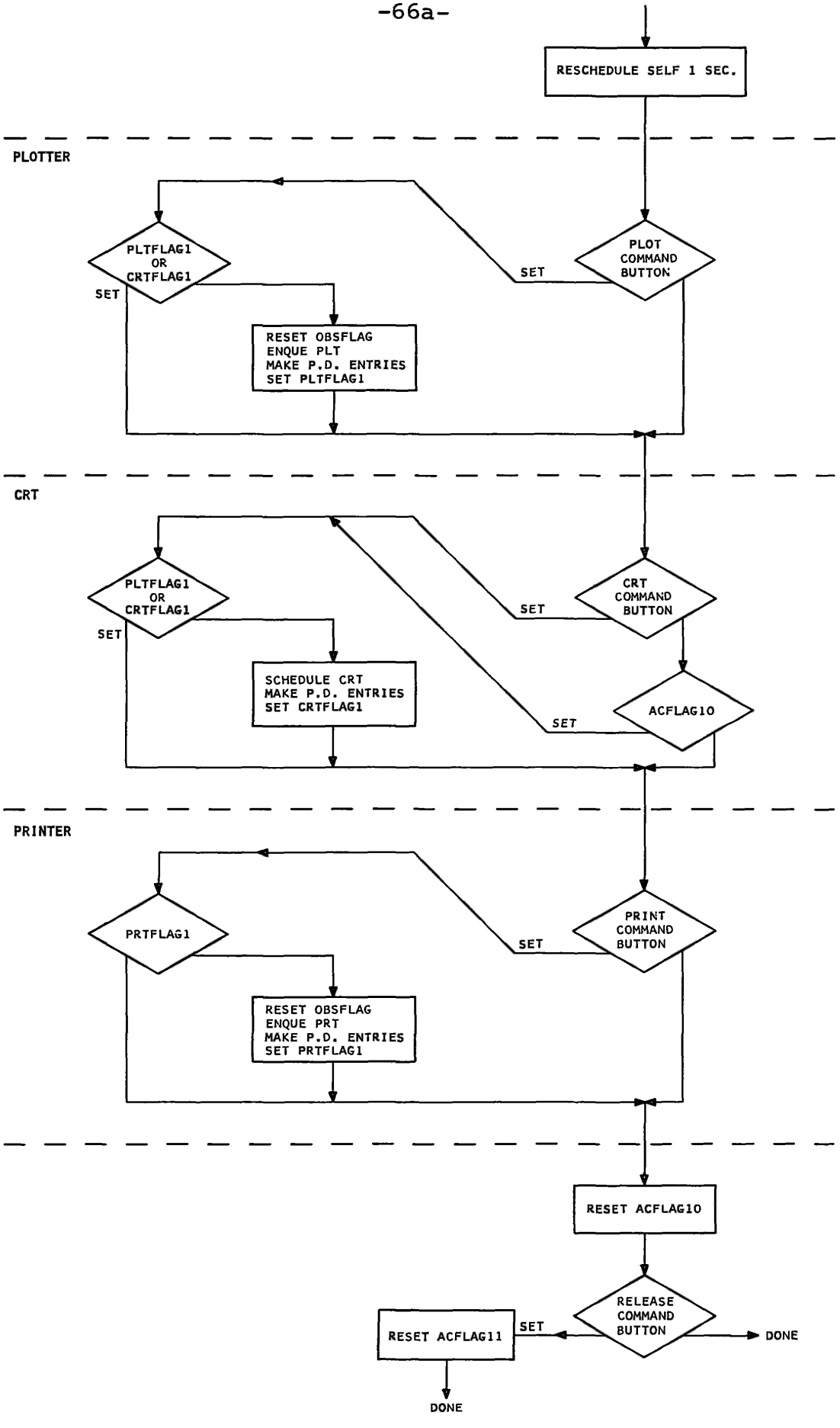
Format	Description
14	integrated quotient receiver A (series)
16	integrated reference receiver A (parallel)
17	integrated reference receiver B (parallel)
18	integrated reference receiver C
19	integrated reference receiver A (series)
21	raw data - counters
22	raw data - control words

THE FOLLOWING ROUTINE IS ENTERED WHEN AN INTERRUPT FROM THE AUTOCORRELATOR OCCURS:

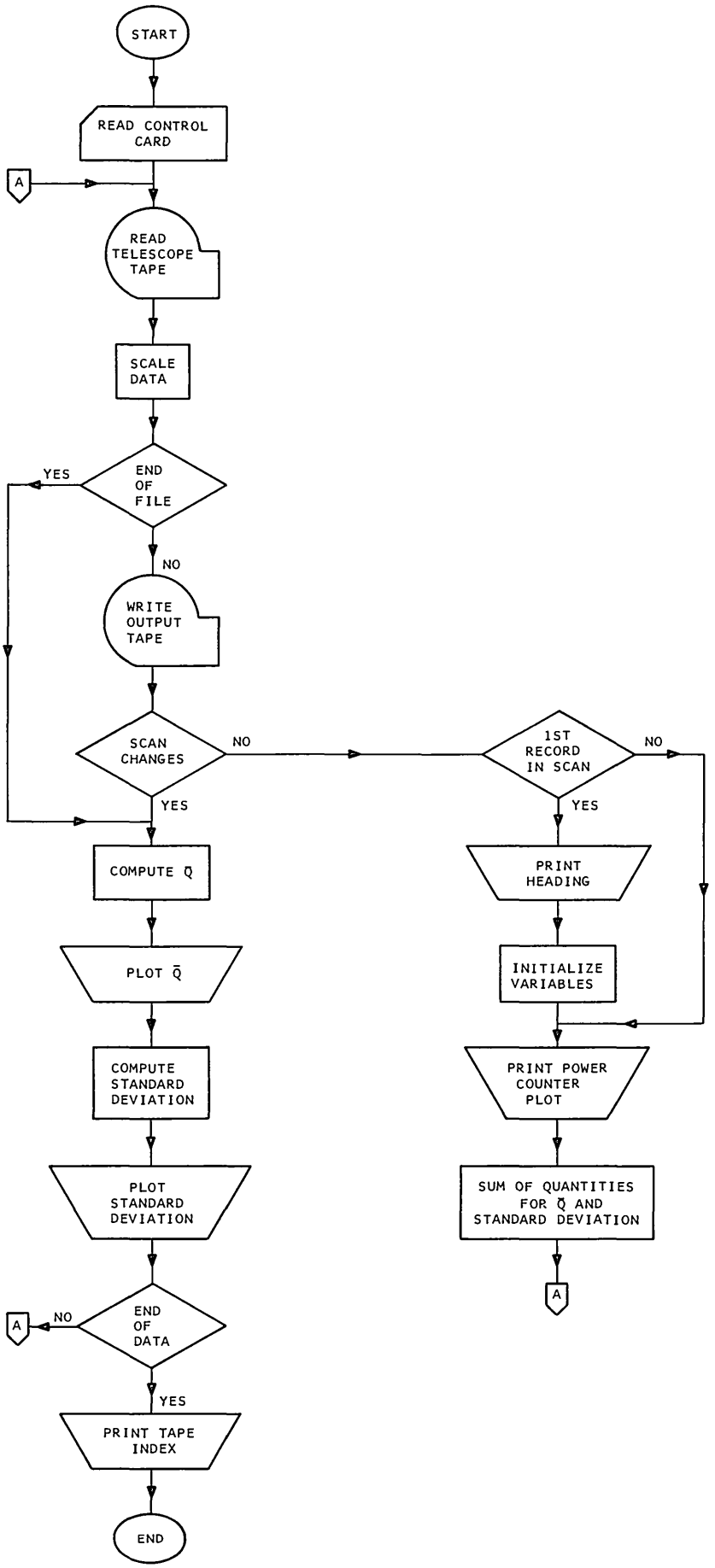


APPENDIX F

On-Line Program Flowchart

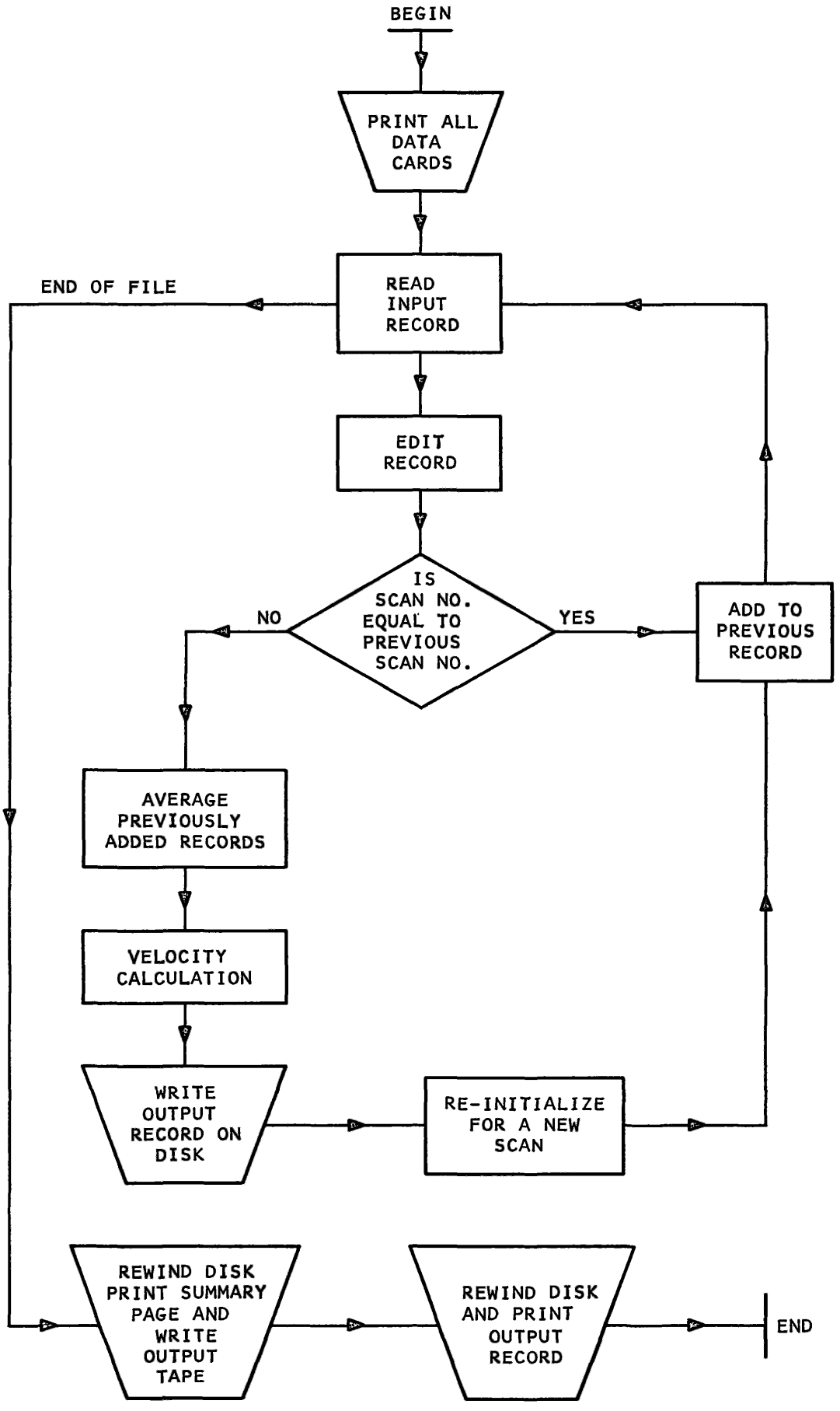


Output Controller



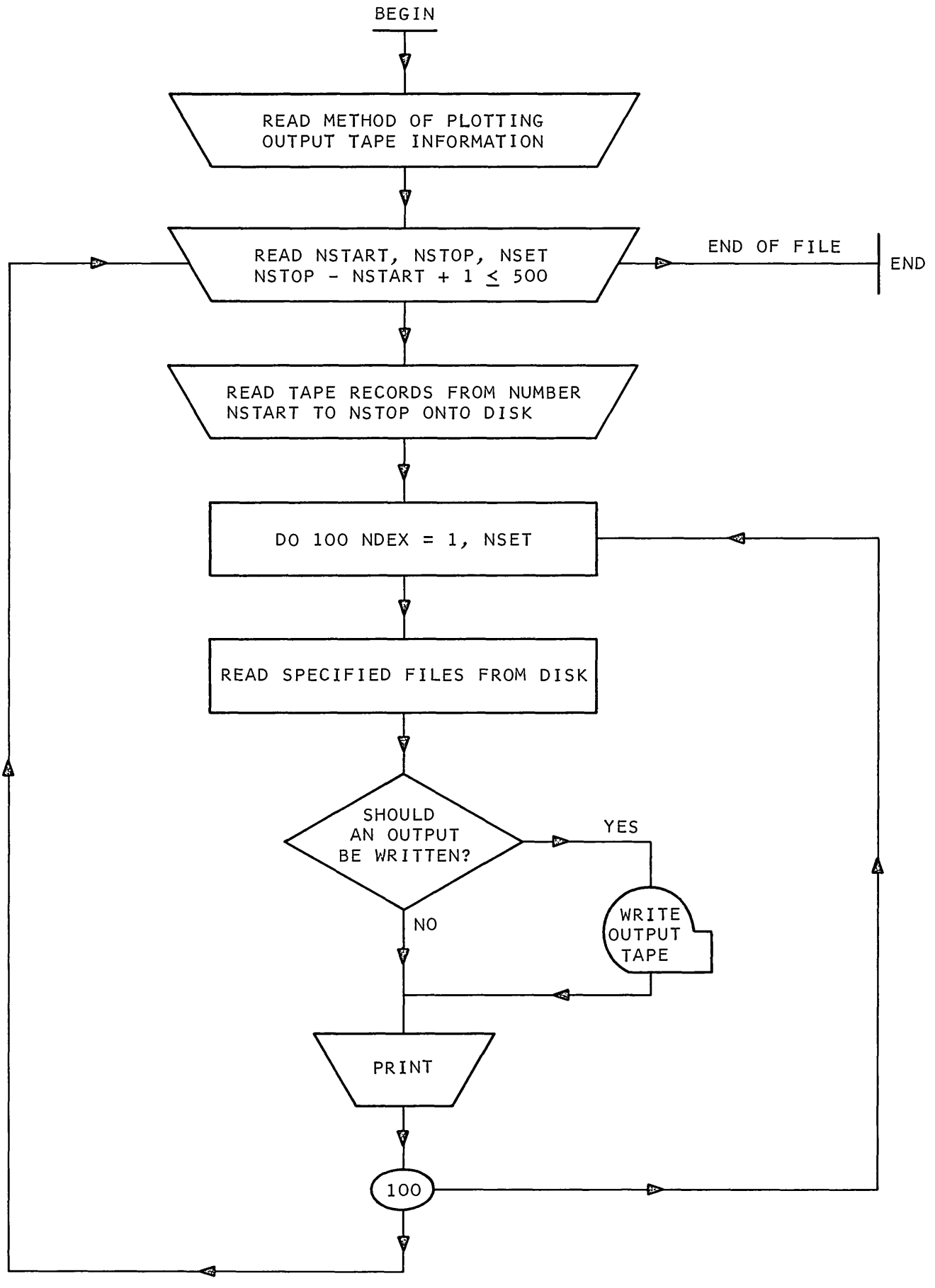
APPENDIX G

Program I Flowchart



APPENDIX H

Program II Flowchart



APPENDIX I

Program III Flowchart

APPENDIX J

Telescope Tape Format

Tape format for output of on-line programs. All records the same format in binary 3 ch/wd.

$Word_{10}$	Format	Contents
1	2	Scan number
2	2	Subscan number - N. A.
3-12	1	Observer name
13-32	1	Comments
33	2	Number of channels - N. A.
34-35	4	Polarization angle - N. A.
36-37	4	LST of middle dump from Autocorrelator
38-39	4	EST of middle dump from Autocorrelator
40	2	Date - month
41	2	Date - day
42	2	Date - year
43	2	Type of observing (12)
44	2	Observer number
45	2	Sample rate in 0.1 sec.
46	2	Focus - N. A.
47	2	
.		
.		
.		
51-52	4	Right ascension of middle dump
53-54	4	Declination of middle dump
55-880	5	413 channels signal transform
881-1706	5	413 channels reference transform
1707-1708	5(B30)	CSN1**
1709-1710	5(B30)	CSF1**
1711-1712	5(B30)	CR1**
1713-1714	5(B30)	CSN2**
1715-1716	5(B30)	CSF2**
1717-1718	5(B30)	CR2**
1719-1720	5(B30)	CSN3**
1721-1722	5(B30)	CSF3**
1723-1724	5(B30)	CR3**

$Word_{10}$	Format	Contents
1725-1744	‡	Autocorrelator words 1664-1683
1745-1750	‡	L. O. Frequencies

*Format 1 - ASCII
2 - Single precision binary integer
4 - Double precision fraction of circle
5 - Double precision binary scaled as indicated

‡ Raw Data

**CNX indicates a power counter average
X = SN - signal with noise tube on
SF - signal with noise tube off
R - reference
N = 1 - receiver A
2 - receiver B (if used)
3 - receiver C

APPENDIX K

LABELED 9-TRACK FORTRAN READABLE OUTPUT TAPE OF AC4141

$Word_{10}$	Format	Contents
1	I*2	Record count
2	I*2	Scan number
3	I*2	Subscan number N. A.
4-13	I*2	Observer name
14-33	I*2	Comments
34	I*2	Number of channel N. A.
35	I*2	Date - month
36	I*2	Date - day
37	I*2	Date - year
38	I*2	Type of observation 12
39	I*2	Observer number
40	I*2	Sample rate
41	I*2	Focus N. A.
42	I*2	Spare Word
43	I*2	Spare Word
44	I*2	Spare Word
45	I*2	Spare Word
46-73	I*2	28 autocorrelator code words (see following page)
74-486	I*4	413 channels signal transform
487-899	I*4	413 channels reference transform
900	I*4	Power counter with noise tube on rec. A
901	I*4	Power counter with noise tube off rec. A
902	I*4	Power counter reference rec. A
903	I*r	Power counter with noise tube on rec. B
904	I*4	Power counter with noise tube off rec. B
905	I*4	Power counter reference rec. B
906	I*4	Power counter with noise tube on rec. C
907	I*4	Power counter with noise tube off rec. C
908	I*4	Power counter reference rec. C
909	R*4	Noise tube rec. A
910	R*4	Noise tube rec. B
911	R*4	Noise tube rec. C
912	R*4	Attenuator rec. A
913	R*4	Attenuator rec. B
914	R*4	Attenuator rec. C
915	R*8	Polarization angle
916	R*8	Sidereal time
917	R*8	Eastern standard time
918	R*8	Indicated right ascension
919	R*8	Indicated declination
920-922	R*8	F0, F1, F2 L. O. Frequencies

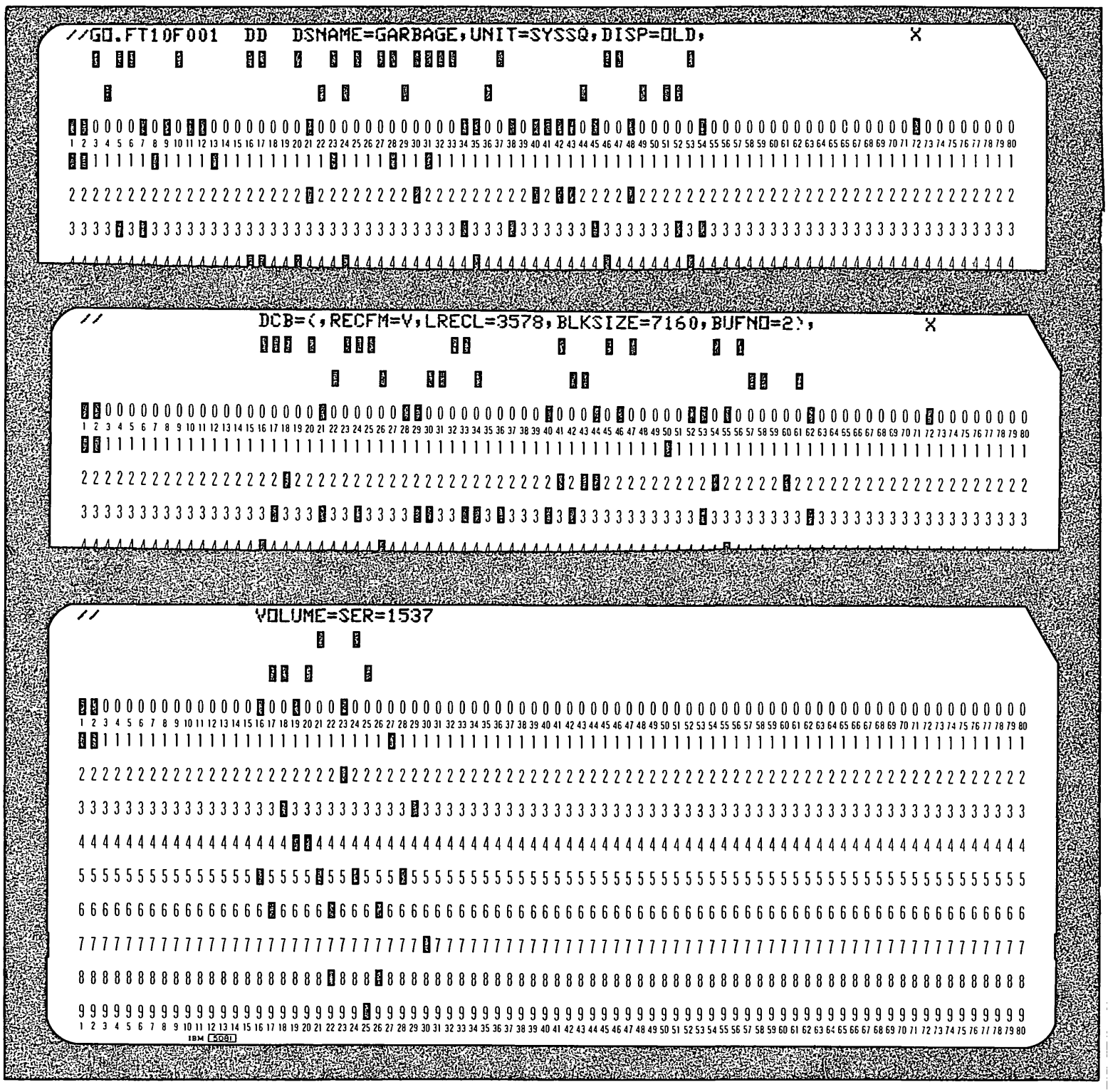
Autocorrelator Words On 9-Track Tape

Word	Format	Content
46	I*2	Spare Word
47	I*2	Receiver A bandwidth
48	I*2	Receiver B bandwidth
49	I*2	Receiver C bandwidth
50	I*2	Receiver A attenuator word C
51	I*2	Receiver A attenuator word B
52	I*2	Receiver A attenuator word A
53	I*2	Receiver A gain modulator
54	I*2	Receiver B attenuator word C
55	I*2	Receiver B attenuator word B
56	I*2	Receiver B attenuator word A
57	I*2	Receiver B gain modulator
58	I*2	Receiver C attenuator
59	I*2	Gain modulator synchronous detector phase
60	I*2	Series - parallel operations
61	I*2	Switch rate and duty cycle
62*	I*2	Dump time*
63*	I*2	Blank time*
64	I*2	Digital test signal word A
65	I*2	Digital test signal word B
66	I*2	Clipper test signal A
67	I*2	Clipper test signal B
68	I*2	Clipper test signal C
69	I*2	Front end switch
70	I*2	Noise tube mode
71	I*2	External sense switches
72	I*2	Noise tube duty cycle on off indicator word A
73	I*2	Noise tube duty cycle on off indicator word B

*contain proper magnitude instead of the code number in Shalloway's memo.

Control Cards Needed to Read 9-Track Tape

The control cards needed to read 9-track binary output tape of AC4141. In the third control card after VOLUME=SER=, the 9-track tape number is punched.



APPENDIX L

Labeled, Binary 9-Track FORTRAN Readable Output Tape of AC4142A

Word	Format	Contents
1	I*4	Output tape record number
2	I*4	Observation number
3	I*2	Number of records averaged
4-7	R*8	Words 916-919 of first input record* in observation
8	R*4	Velocity correction of first input record in observation
9-81	I*2	Words 1-73 of last input record in observation
82-87	R*4	Words 909-914 of last input record in observation
88	R*4	Velocity correction of last input record in observation
89	R*8	Julian date of last input record in observation
90-97	R*8	Words 915-922 of last input record in observation
98-100	R*4	Uncorrected velocity of center of band for receivers A, B, C
101-103	R*4	Velocity change per channel for receivers A, B, C
104-516	R*8	413 channels average power spectrum

Total length of record: 3620 bytes

*See Appendix K

Labeled, Binary 9-Track FORTRAN Readable Output

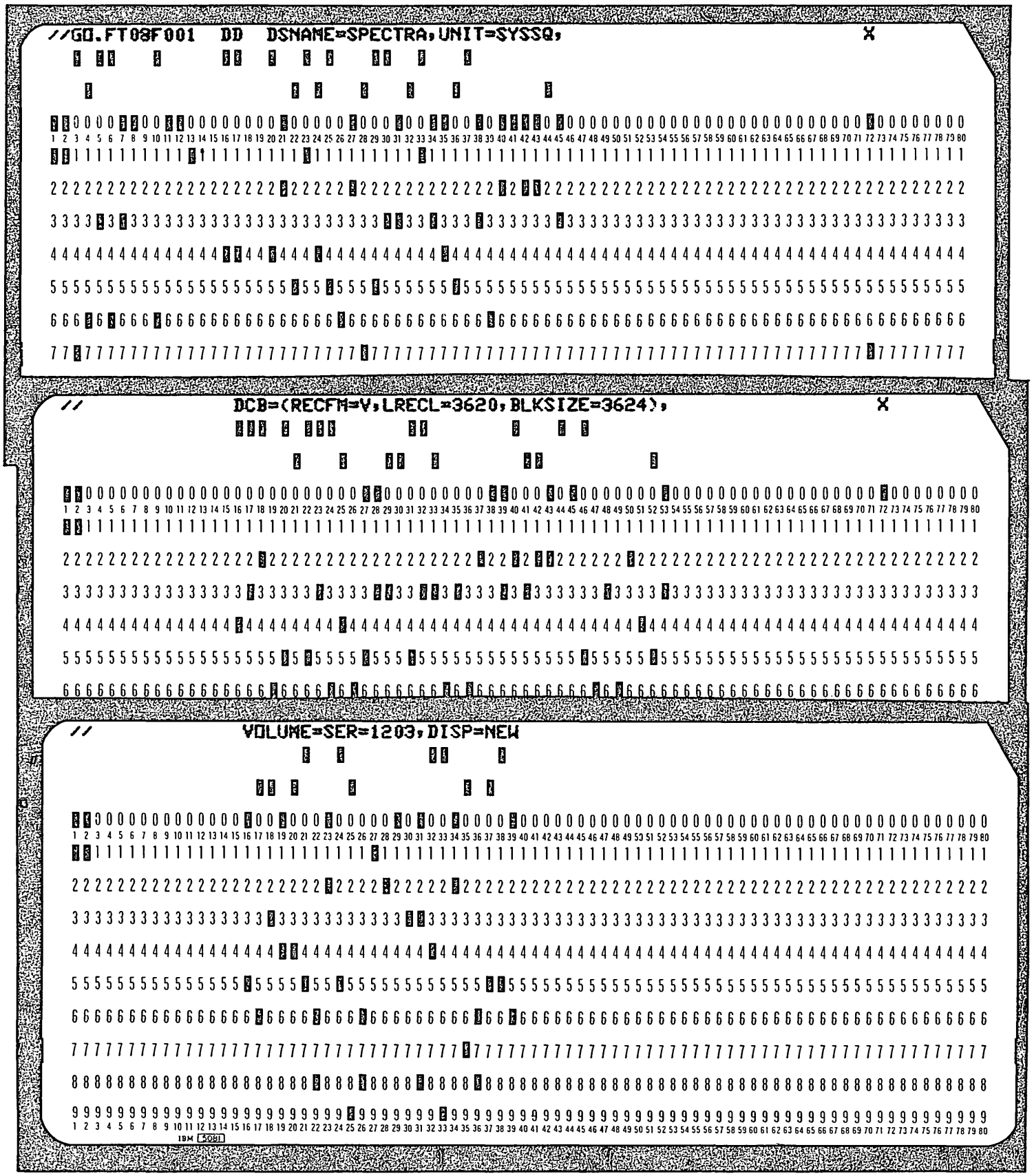
Tape of AC4142B

Word	Format	Contents
1	I*4	Output tape record number
2	I*4	Observation number
3	I*4	Number of records averaged
4	L*4	TRUE indicates calibration observation FALSE indicates polarization switching observation
5-81	I*2	Words 1-73 of first input record* of observation
82-87	R*4	Words 909-914 of first input record of observation
88	R*4	Velocity correction of first input record of observation
89	R*8	Julian date of first input record of observation
90-97	R*8	Words 915-922 of first input record of observation
98-170	I*2	Words 1-73 of last input record of observation
171-176	R*4	Words 909-914 of last input record of observation
177	R*4	Velocity correction of last input record of observation
178	R*8	Julian date of last input record of observation
179-186	R*8	Words 915-922 of last input record of observation
187-189	R*4	Velocity of center of band for receivers A, B, C (uncorrected velocity)
190-192	R*4	Velocity change per channel for receivers A, B, C
193-605	R*8	413 channels average power spectrum for signal 1
606-1018	R*8	The difference between the power spectrum for signal 1 and the power spectrum for signal 2, 413 channels (for a calibration observation these words contain 413 channels average reference transform)

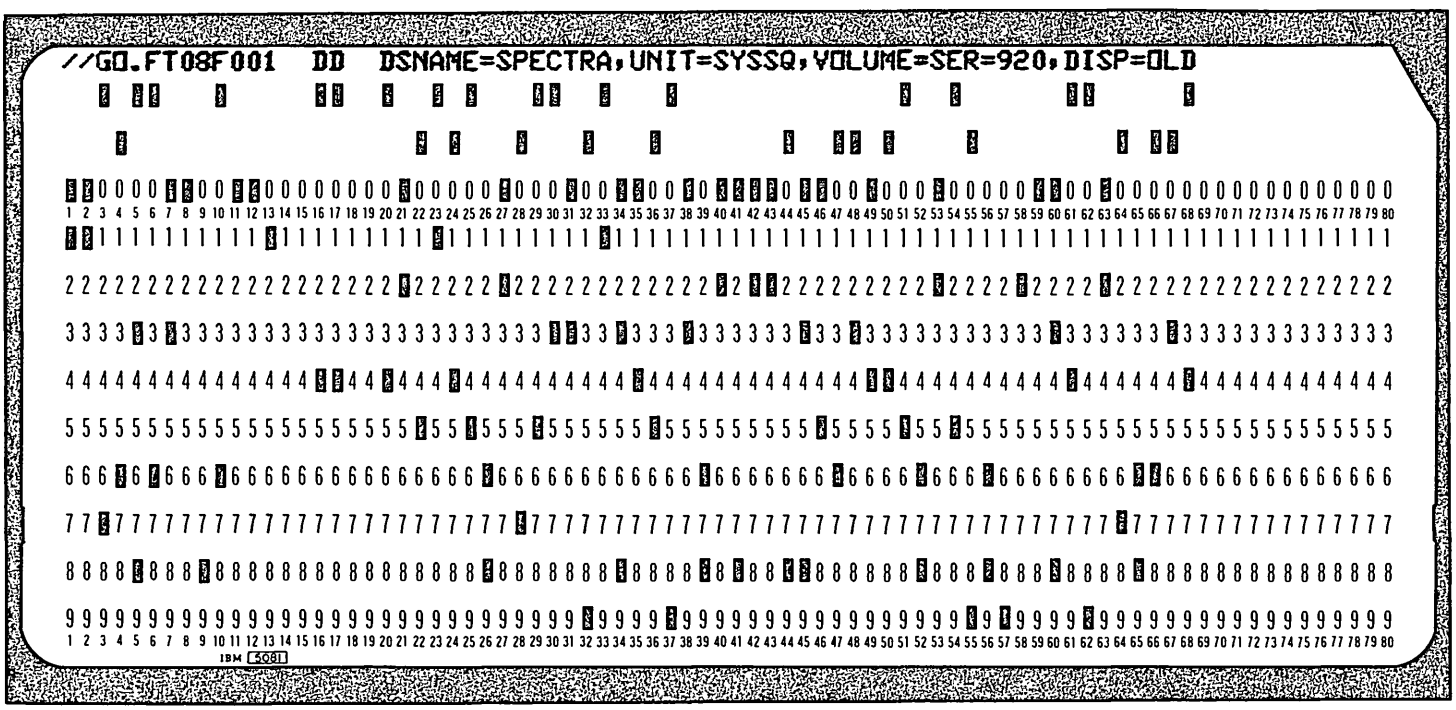
Total length of record: 7140 bytes

*See Appendix K

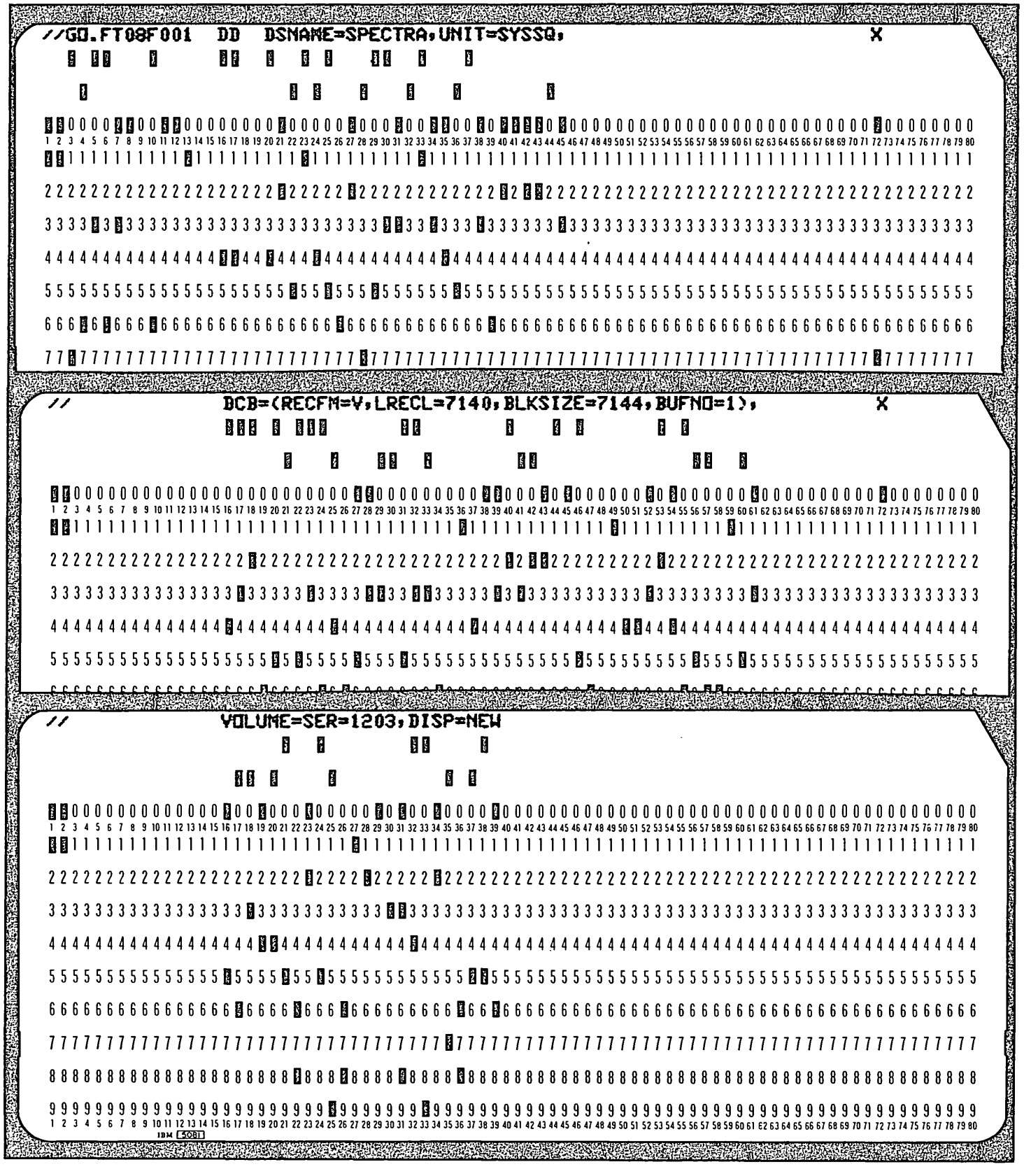
Data Definition Statement Used to Write Output Tape of AC4142A



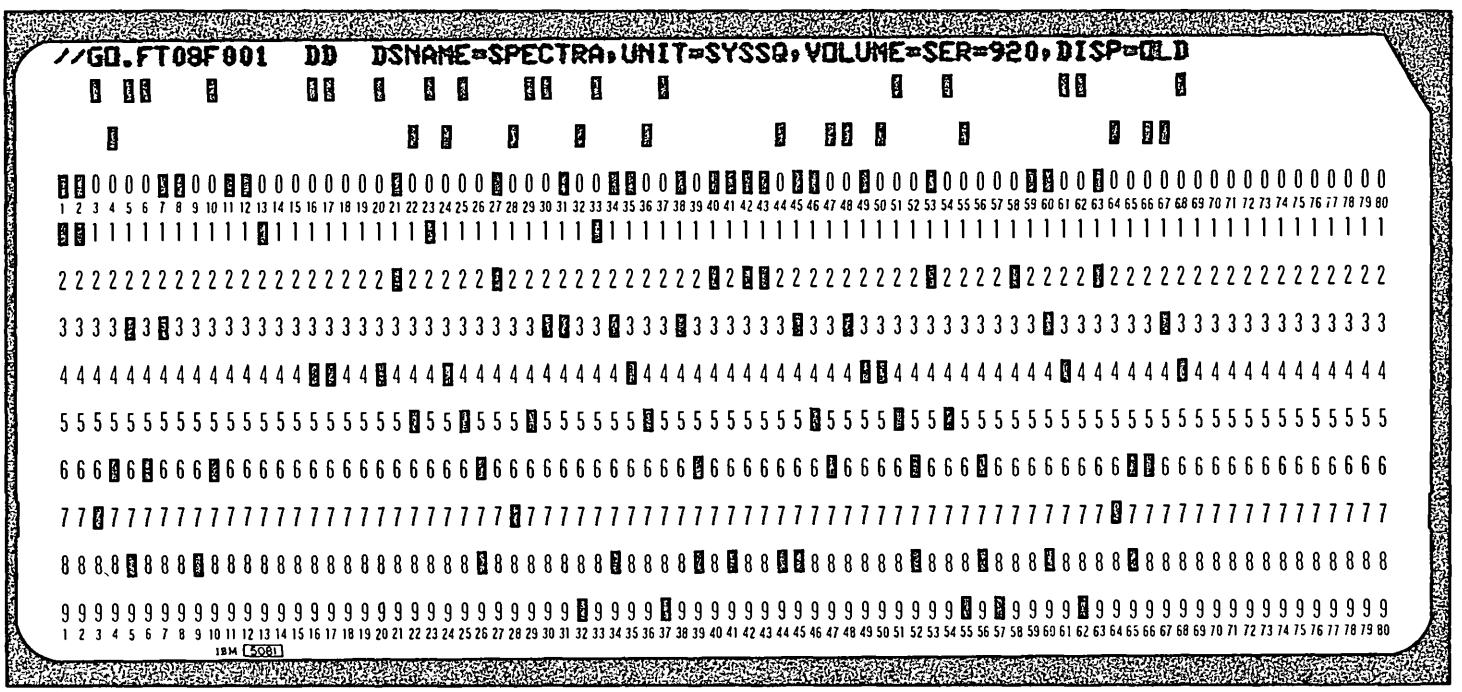
Data Definition Statement Used to Read Output Tape of AC4142A



Data Definition Statement Used to Write Output Tape of AC4142B



Data Definition Statement Used to Read Output Tape of AC4142B



APPENDIX M

Memorandum of May 3, 1968

Arthur M. Shalloway

Subject: Revised Functional Description of NRAO Correlation Receiver Model II (See Original Description September 11, 1967)

The following information is being made available for those planning to use the receiver or program computers to process its output data.

SPECIFICATIONS OF NRAO CORRELATION RECEIVER MODEL II:

Number of Channels:

Total - 416

Correlation Channels - 413

Receiver Power Channels - 3

Configurations:

1. Receiver A - 192 Channels Autocorrelation - 1 Channel Power
   Receiver B - 192 Channels Autocorrelation - 1 Channel Power
   Receiver C - 29 Channels Autocorrelation - 1 Channel Power
2. Receiver A - 384 Channels Autocorrelation - 1 Channel Power
   Receiver C - 29 Channels Autocorrelation - 1 Channel Power

Bandwidths:

1.	10MHz	Available on Receivers A, B, &C
2.	5 MHz	
3.	2.5 MHz	
4.	1.25 MHz	
5.	625 KHz	
6.	312.5 KHz	Available on Receivers A & B
7.	156.25 KHz	
8.	78.125 KHz	
9.	39.0625KHz	

Dump Times (Integration Time Available in Correlation Receiver Prior to Dumping Data into Computer):

1 sec. and 10 sec.

Switching Rates:

1 Hz - 50%/50% (Signal/Reference) Duty Cycle
5 Hz - 50%/50% (Signal/Reference) Duty Cycle
10 Hz - 50%/50% (Signal/Reference) Duty Cycle
1 Hz - 90%/10% (Signal/Reference) Duty Cycle
5 Hz - 75%/25% (Signal/Reference) Duty Cycle

Blanking Times:
4 to 26 ms. in steps of 2 ms.

Switching Modes:
1. Load Switching
2. Frequency Switching

} With continuous or separate calibration, gain modulator switching, and synchronous detector switching for analog continuum recording

Autocorrelation Data:
Signal and reference output data are provided as two independent groups of numbers. Thus, a continuous bandpass correction can be provided in the computer.

Display:
Any channel - signal or reference - plus the six power counters can be displayed in decimal.

Test Signals:
Square waves from 39.0625KHz to 10MHz can be fed into clipper inputs. Special internal tests available in digital system. Internally generated noise source can be fed into IF input.

Reference should be made to Memo: Input Interface - 300' and 140' On Line Computers by A. M. Shalloway dated October 18, 1966 for detailed information on transfer of data from the receiver to the computer. The following tabulation lists all of the output data available from the receiver and its format.

APPENDIX I

DETAILED DESCRIPTION OF DATA TRANSFERRED FROM CORRELATOR TO COMPUTER

Computer Words	Description	Format — DDP-116 Word Bits Note: All even numbered words have a "1" in word bit 1. All odd words have a "0" in word bit 1.															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0 thru 825 — 413 Channels of Signal Correlation	Each channel is represented by a 20-bit word which is taken into the computer as two words.	1st word 1	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
		2nd word 0	0	0	0	0	0	0	0	0	0	0	2^{19}	2^{18}	2^{17}	2^{16}	2^{15}
826 Receiver A - Signal Power Counter 827 " " " " 828 Receiver B - Signal Power Counter 829 " " " " 830 Receiver C - Signal Power Counter 831 " " " "	Each counter is represented by a 20-bit word which is taken into the computer as two words.	Same as words 0 - 825.															
832 thru 1657 — 413 Channels of Reference Correlation	Each channel is represented by a 20-bit word which is taken into the computer as two words.	Same as words 0 - 825.															
1658 Receiver A - Reference Power Counter 1659 " " " " 1660 Receiver B - Reference Power Counter 1661 " " " " 1662 Receiver C - Reference Power Counter 1663 " " " "	Each counter is represented by a 20-bit word which is taken into the computer as two words.	Same as words 826 - 831.															
1664 — Spare Word	For future requirements.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1665 — Receiver A - Bandwidth	4-bit word: 0 = 10 MHz 1 = 5 MHz 2 = 2.5 MHz 3 = 1.25 MHz 4 = 625 kHz 5 = 312.5 kHz 6 = 156.25 kHz 7 = 78.125 kHz 8 = 39.0625 kHz	0	0	0	0	0	0	0	0	0	0	0	0	2^{3}	2^{2}	2^{1}	2^{0}
1666 — Receiver B - Bandwidth	Same as word 1665.	Same as word 1665.															
1667 — Receiver C - Bandwidth	3-bit word: 0 = 10 MHz 1 = 5 MHz 2 = 2.5 MHz 3 = 1.25 MHz 4 = 625 kHz	0	0	0	0	0	0	0	0	0	0	0	0	0	2^{2}	2^{1}	2^{0}

Appendix I (continued) --

Computer Words	Description	Format — DDP-116 Word Bits															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1668 Receiver A - Attenuator	2 ea. 4-bit words, 1 ea. 3-bit words: 1 ea. 4-bit BCD word 0 = 0 dB 1 = 0.1 dB 2 = 0.2 dB 3 = 0.3 dB 4 = 0.4 dB 5 = 0.5 dB 6 = 0.6 dB 7 = 0.7 dB 8 = 0.8 dB 9 = 0.9 dB Word A 1 ea. 4-bit BCD word 0 = 0 dB 1 = 1 dB 2 = 2 dB 3 = 3 dB 4 = 4 dB 5 = 5 dB 6 = 6 dB 7 = 7 dB 8 = 8 dB 9 = 9 dB Word B 1 ea. 3-bit BCD word 0 = 0 dB 1 = 10 dB 2 = 20 dB 3 = 30 dB 4 = 40 dB 5 = 50 dB Word C	1	0	0	0	0	2^3	2^2	2^1	2^0 (A)	2^3	2^2	2^1	2^0 (B)	2^2	2^1	2^0 (C)
1669 Receiver A - Gain Modulator	1-bit word: 0 = on 1 = off	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^0
1670 Receiver B - Attenuator	Same as word 1668.	Same as word 1668.															
1671 Receiver B - Gain Modulator	Same as word 1669.	Same as word 1669.															
1672 Receiver C - Attenuator	4-bit word - same as section B of word 1668.	1	0	0	0	0	0	0	0	0	0	0	0	2^3	2^2	2^1	2^0

Appendix I (continued) --

Computer Words	Description	Format — DDP-116 Word Bits															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1673 Gain Modulator and Synchronous Detector Phase	1-bit word: 0 = normal 1 = inverted	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^0
1674 Series-Parallel Operation	1-bit word: 0 = series 1 = parallel	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^0
1675 Switch Rate and Duty Cycle	3-bit word: 0 = 1 Hz, 1 = 5 Hz, 2 = 10 Hz } 50%-50% Duty Cycle 3 = 1 Hz — 90%-10% (Sig. Ref.) Duty Cycle 4 = 1 Hz — 75%-25% (Sig. Ref.) Duty Cycle	0	0	0	0	0	0	0	0	0	0	0	0	0	2^2	2^1	2^0
1676 Dump Time	1-bit word: 0 = 1 sec. 1 = 10 sec.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^0
1677 Blanking Time	4-bit word: 0 = 4 ms, 6 = 16 ms 1 = 6 ms, 7 = 18 ms 2 = 8 ms, 8 = 20 ms 3 = 10 ms, 9 = 22 ms 4 = 12 ms, 10 = 24 ms 5 = 14 ms, 11 = 26 ms	0	0	0	0	0	0	0	0	0	0	0	0	2^3	2^2	2^1	2^0
1678 Digital Test Signals	These words apply only when word 1679 is not all zeros. 1 ea. 4-bit word, 1 ea. 1-bit word: Word A - 4 bits: 0 = 10 MHz, 1 = 5 MHz, 2 = 2.5 MHz, 3 = 1.25 MHz, 4 = 625 kHz, 5 = 312.5 kHz, 6 = 156.25 kHz, 7 = 78.125 kHz, 8 = 39.0625 kHz } To Clipper (continued) --	1	0	0	0	0	0	0	0	0	0	0	2^0 (B)	2^3	2^2	2^1	2^0 (A)

Appendix I (continued) --

Computer Words		Description	Format — DDP-116 Word Bits																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1678	Digital Test Signals (continued) --	9 = Logic - 0 - to Sampler Output Flip Flop 10 = Logic - 1 - to Sampler Output Flip Flop 11 = Shift Register Memory Test Signal Word B - 1 bit: Applies only when Word A is 11. 0 = Special Test Signal into Shift Register Memory for servicing purposes only. 1 = Standard Test Signal into Shift Register Memory																	
1679	Clipper Test Signal	3 ea. 1-bit words: Word A: 0 = normal 1 = test } Receiver A - Clipper Word B: 0 = normal 1 = test } Receiver B - Clipper Word C: 0 = normal 1 = test } Receiver C - Clipper	0	0	0	0	0	0	0	0	0	0	0	0	0	2^0 (C)	2^0 (B)	2^0 (A)
1680	Front-End Switch	2-bit word: 0 = Modulated-Inverted 1 = Signal 2 = Reference 3 = Modulated-Normal	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2^1	2^0
1681	Noise Tube Mode	3-bit word: 1 = Continuous Modulation-Normal 2 = Continuous Modulation-Inverted 3 = Interrupted Modulation-Normal 4 = Interrupted Modulation-Inverted 5 = On 6 = Off	0	0	0	0	0	0	0	0	0	0	0	0	0	2^2	2^1	2^0
1682	External Sense Switches	6 ea. 1-bit words: Each bit can be a one or zero to indicate the condition of a switch external to the correlator. For example, a noise tube level switch indicating 10^0 or 100^0.	1	0	0	0	0	0	0	0	0	0	2 (F)	2^0 (E)	2^0 (D) Word	2^0 (C)	2^0 (B)	2^0 (A)

Appendix I (continued) --

Computer Words	Description	Format — DDP-116 Word Bits															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1683 Noise Tube Duty Cycle and On-Off Indicator	2 ea. 1-bit words: 0 = 50%-50% 1 = 90%-10% (Sig. Ref.) } Word A 0 = Noise Tube Off 1 = Noise Tube On } Word B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^0 B	2^0 A

APPENDIX N

Input to Program III

The first input card to AC4143 selects the method of plotting and whether or not an output tape is to be written. At present columns 1-8 must contain the characters "360 PLØT" designating a printed plot on the IBM 360 computer. At a later date a Calcomp plot may be selected. If an output tape is to be written, columns 11-18 must contain "ØUT TAPE"; otherwise these columns should be blank. If an output tape is to be written, one of two formats may be selected - format A of AC4142A or format B of AC4142B. Columns 21-28 designate which format is to be used; they must contain "FØRMAT A" or "FØRMAT B". The three possible cards are shown in Figure 1.

The remaining data cards consist of groups of cards which actually control the combining of records. Within each group the first card controls the range of input records read into the program and the number of sets of records to be combined. The remaining cards within the group designate the records to be combined and the method to be used. These later cards employ the Namelist facility in FORTRAN IV described previously in the input to AC4142 (Appendix B). Figure 2 is an example of the first card and Figure 3 gives

three examples of the second type of card. The first type of card contains three fields: columns 1-5, the record number of the beginning record to be read from the input tape to the disk, columns 11-15, the record number of the ending record to be read from the input tape to the disk, columns 21-25, the number of sets of records to be combined, i.e., the number of cards following which begin with " &STACK ". The range of the first two numbers must not exceed 1000 for AC4143A and 500 for AC4143B. All namelist cards must begin with "&STACK" punched in columns 2-7 with column 1 blank. The end of the data set is denoted by ",&END". The namelist variable names and their meaning follow.

KEY - I*4 - designates the manner in which the observations are to be combined. "KEY=1" means that the observations are averaged, weighted by the integration time of each observation. "KEY=2" means that the observations are averaged, weighted by the integration time, and then receivers A and B are averaged, disregarding C. "KEY=3" means that two groups of observations are averaged, weighted by the integration time and the second group subtracted from the first group.

SCAN - I*4 - designates the observations to be combined. This number is the relative record number of the input record on the input tape and is found in the heading of the output of program

AC4142 as well as on the summary page. For "KEY=3" the numbers of the first group of observations are followed by "-99" and then the second group of observations follow. In Figure 3, C the average of numbers 3, 4 and 6 is subtracted from numbers 1, 2 and 5.

REMARK (20) - I*4 - used to enter any string of characters. These are printed immediately preceeding the plot. The characters must be enclosed in quote marks and may not be continued onto a second card. An example follows:

REMARK="THIS IS A REMARK"

YMAX, YMIN (also YMAXD and YMIND for AC4143B) - R*4 - These set the maximum and minimum values on the plot. It should be noted that the plot is 101 print positions wide. For AC4143B YMAXD and YMIND set the scale for the plot of the difference between the spectra for signals 1 and 2. These values are initialized to zero and retain their values until changed by the user. "YMAX=0.0" means that the scale is determined by the program.

As previously stated, the cards are in groups, the first card of which designates the range of input records. The number of the last input record of a previous group must always be less than the number of the first input record of a succeeding group. An example is given in Figure 4.

By writing an output tape the user may stack observations in any range. The records written on the output tape are numbered

consecutively and this output tape may be used in a subsequent run of AC4143. Thus a user with a first group of cards could combine observations in the range 1-1000 and with a second group of cards in the range 1001-2000. He could then run the program again with the produced output tape as input and combine the resultant records as previously described.

Error Messages

Error messages are of the form

"****...*ERROR NUMBER 1".

The meaning of the error messages follow:

ERROR NUMBER 1 - The method of plotting was not specified. The job was terminated.

ERROR NUMBER 2 - A parity error was encountered while reading the input tape. Also printed are the tape record number and the observation number of the record. The record was skipped, i.e., it was not written on the disk.

ERROR NUMBER 3 - The number of records to be written on the disk exceeds 1000 (500 for AC4142B). The excess records were not read.

ERROR NUMBER 4 - The variable KEY was not in the proper range.

Figure 1

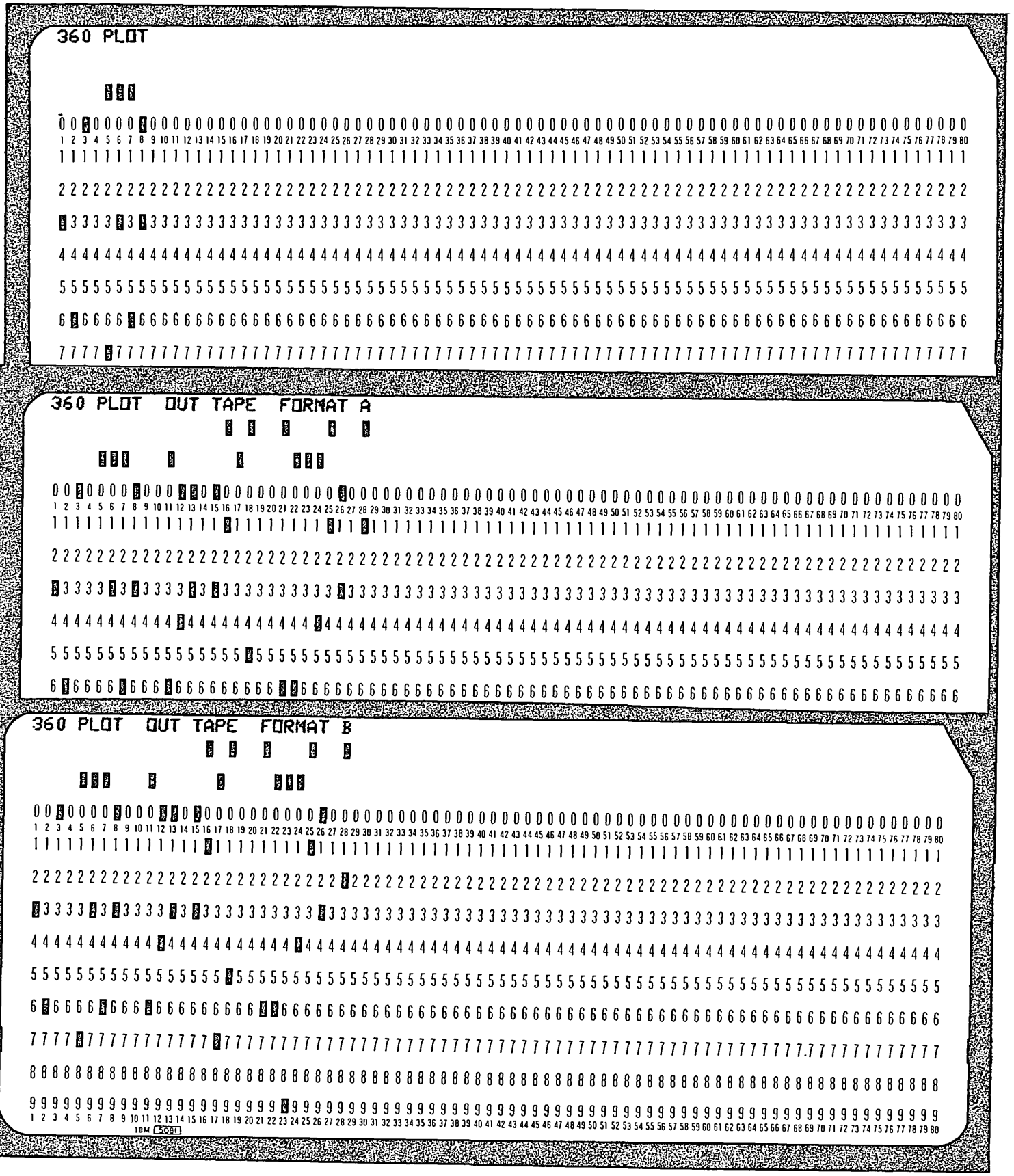

360 PLOT
360 PLOT OUT TAPE FORMAT A
360 PLOT OUT TAPE FORMAT B
IBM SORT

Figure 2

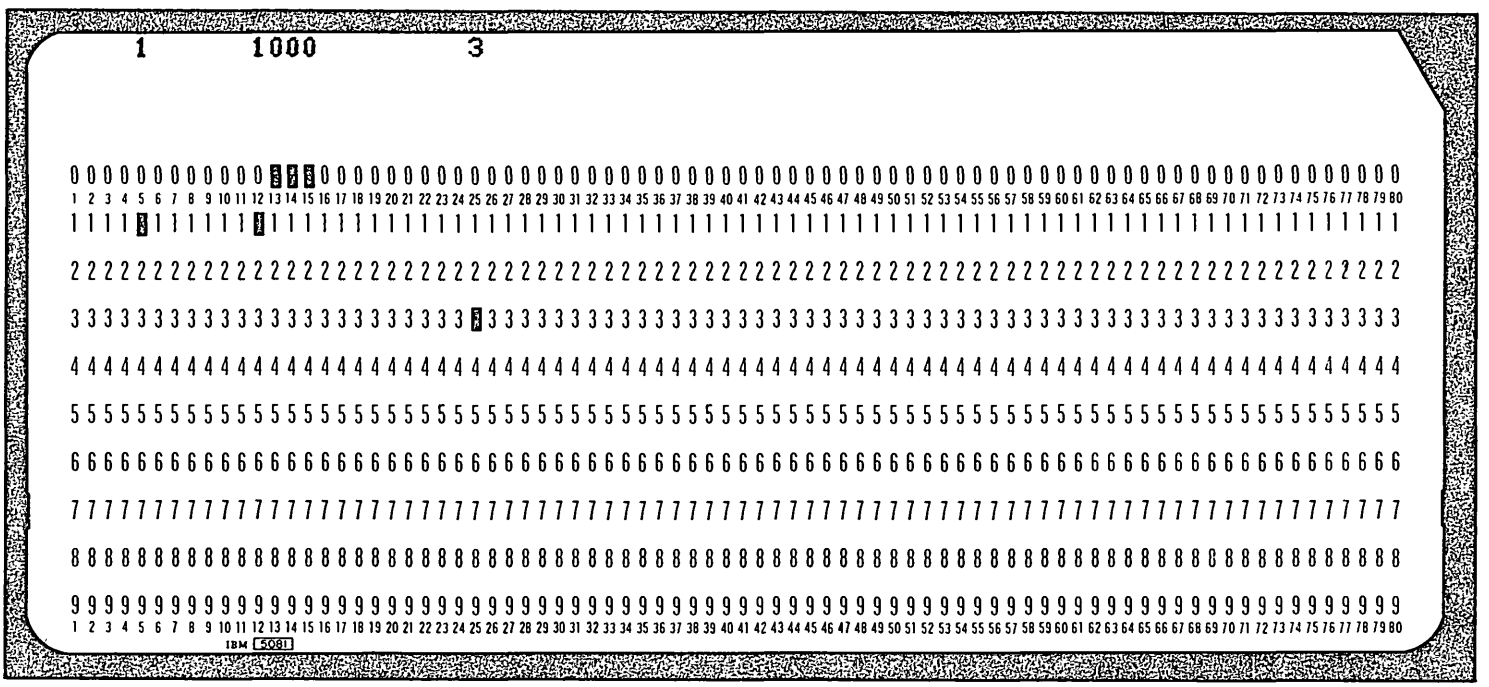

1 1000 3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
IBM 5081

Figure 3

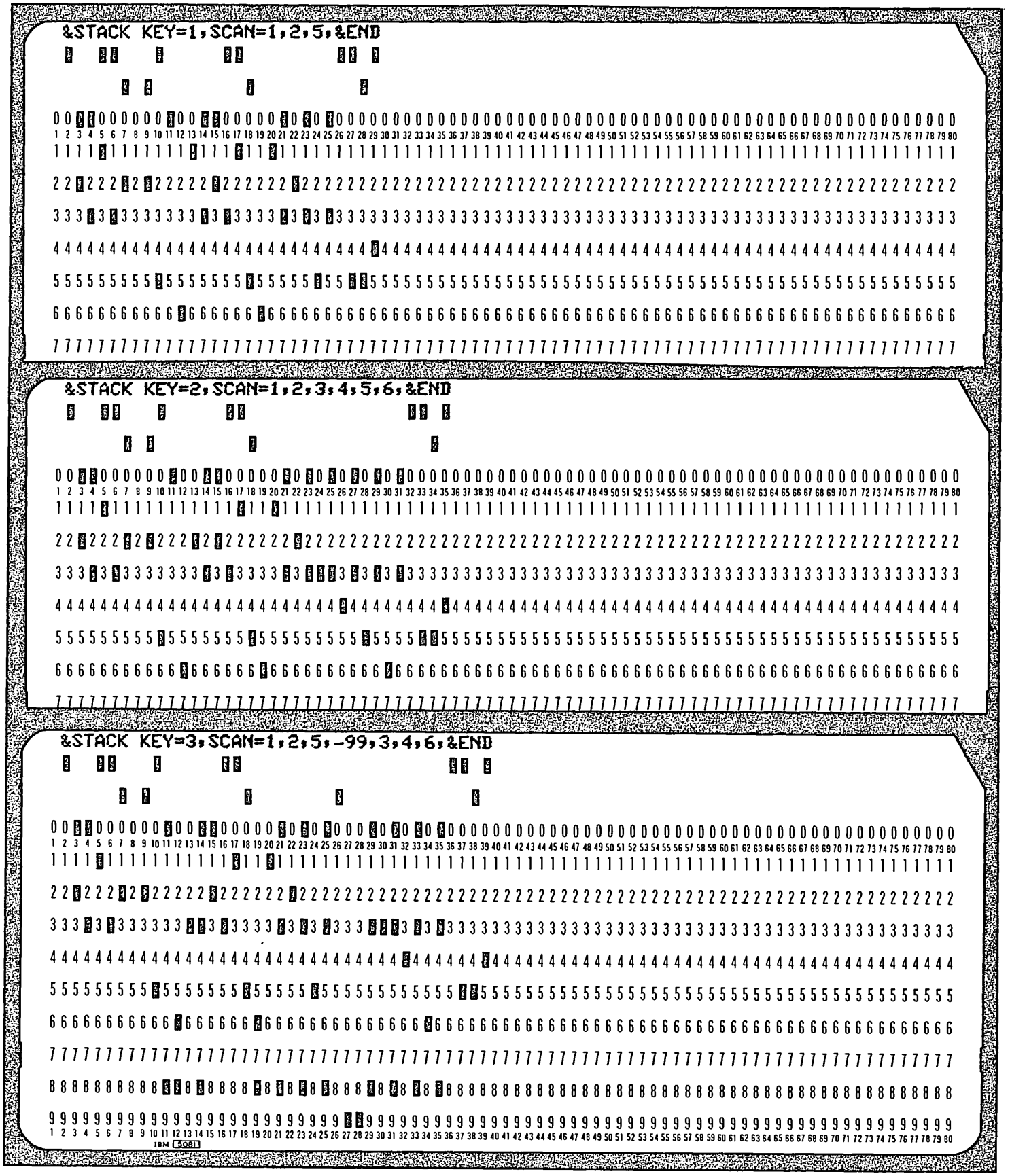
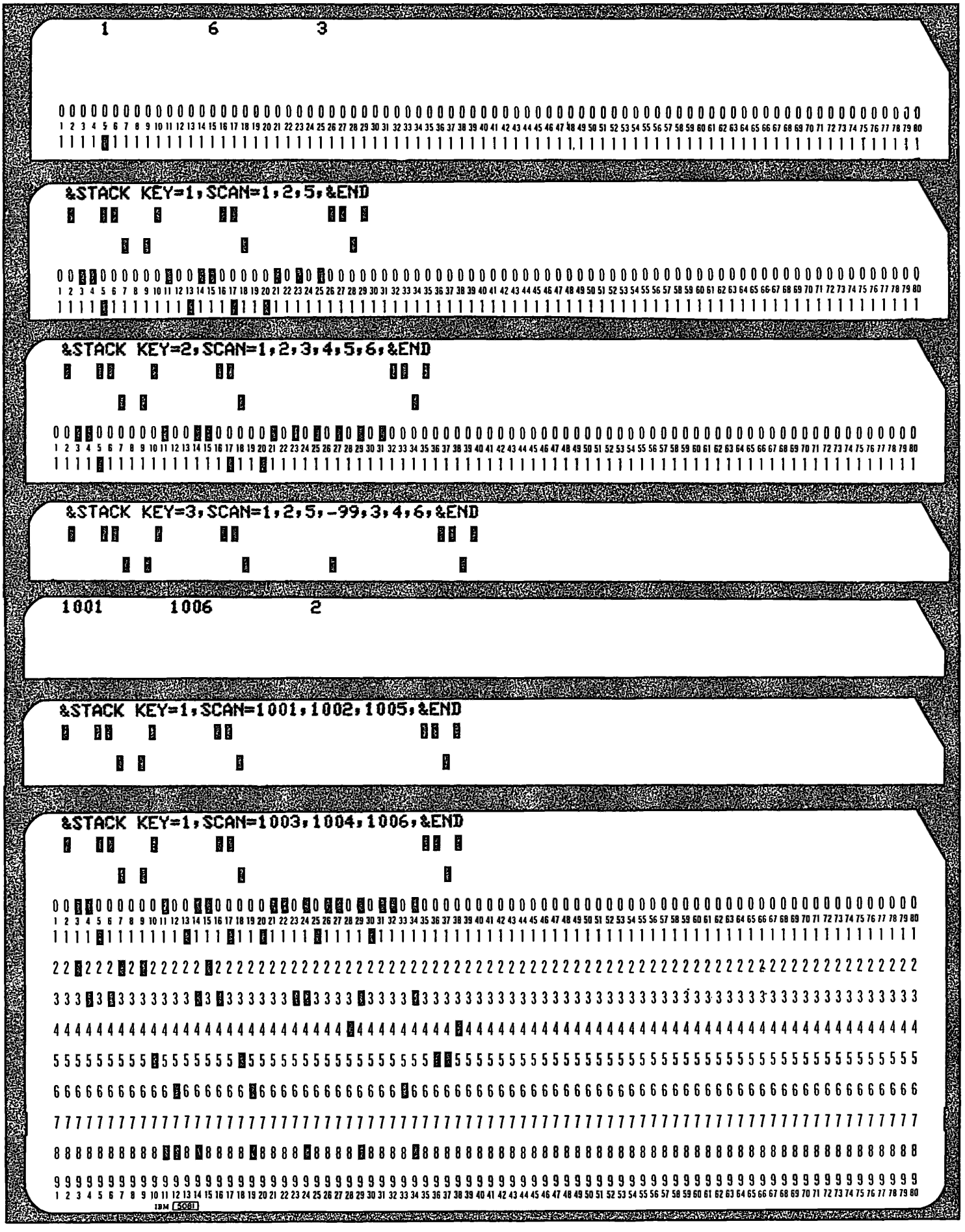

&STACK KEY=1,SCAN=1,2,5,&END
&STACK KEY=2,SCAN=1,2,3,4,5,6,&END
&STACK KEY=3,SCAN=1,2,5,-99,3,4,6,&END
IBM 3081

FIGURE 4


1 6 3
&STACK KEY=1,SCAN=1,2,5,&END
&STACK KEY=2,SCAN=1,2,3,4,5,6,&END
&STACK KEY=3,SCAN=1,2,5,-99,3,4,6,&END
1001 1006 2
&STACK KEY=1,SCAN=1001,1002,1005,&END
&STACK KEY=1,SCAN=1003,1004,1006,&END
IBM 5081

```
NRAO 140 FOOT TELESCOPE              DATE -- 09/25/68     TIME -- 23/15/54     PAGE --    1            NRAO 50/A1 M (D)  AC4143A

  DATA CARDS SUBMITTED TO THIS PROGRAM
12345678901234567890123456789012345678901234567890123456789012345678901234567890
360 PLOT
    1          5          1
 &STACK KEY=1,SCAN=2,3,4,5,
 REMARK='THIS IS A TEST CASE GENERATED FOR THE DESCRIPTION OF THE PROGRAM',&END
```


APPENDIX O

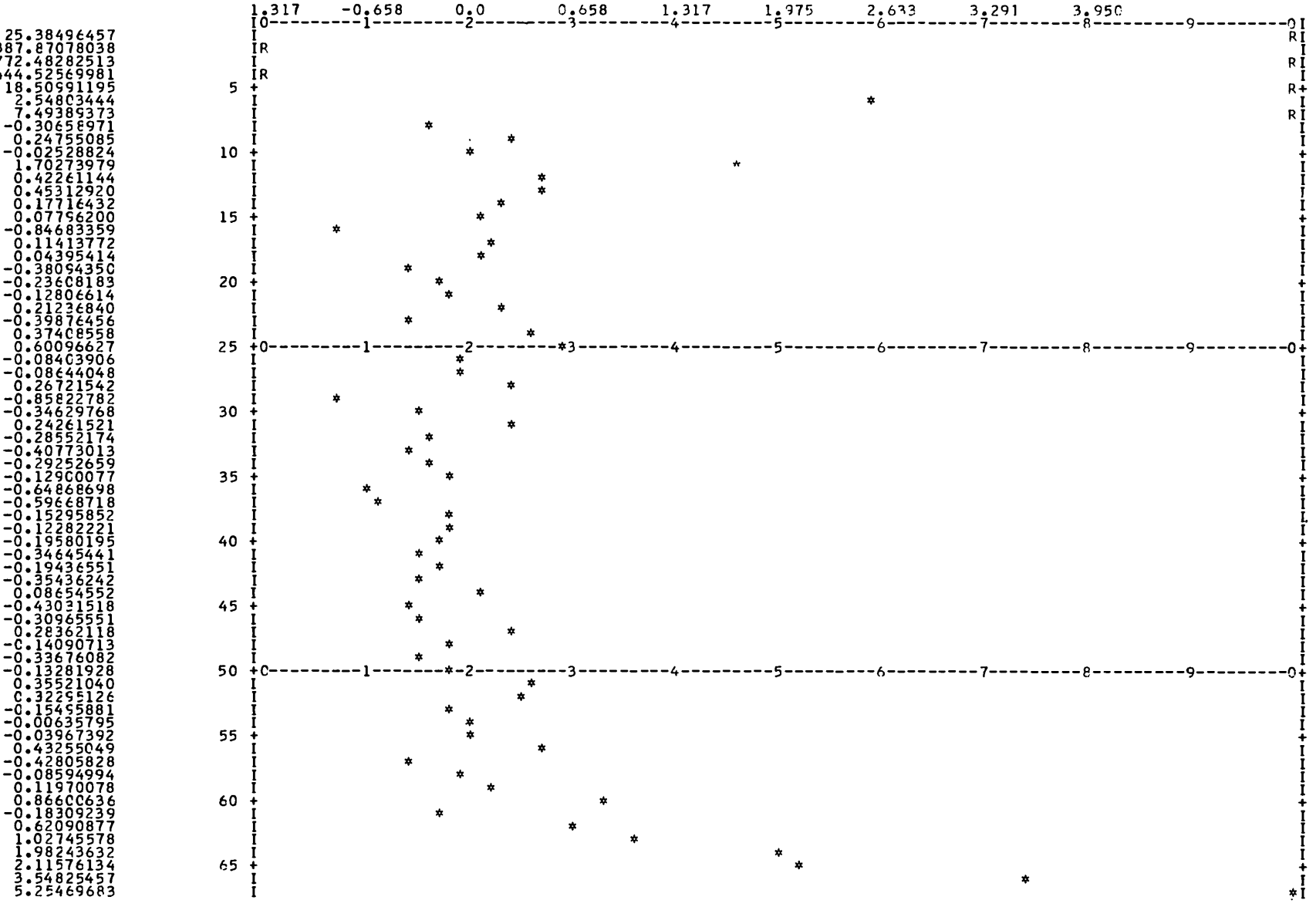
Output Program III

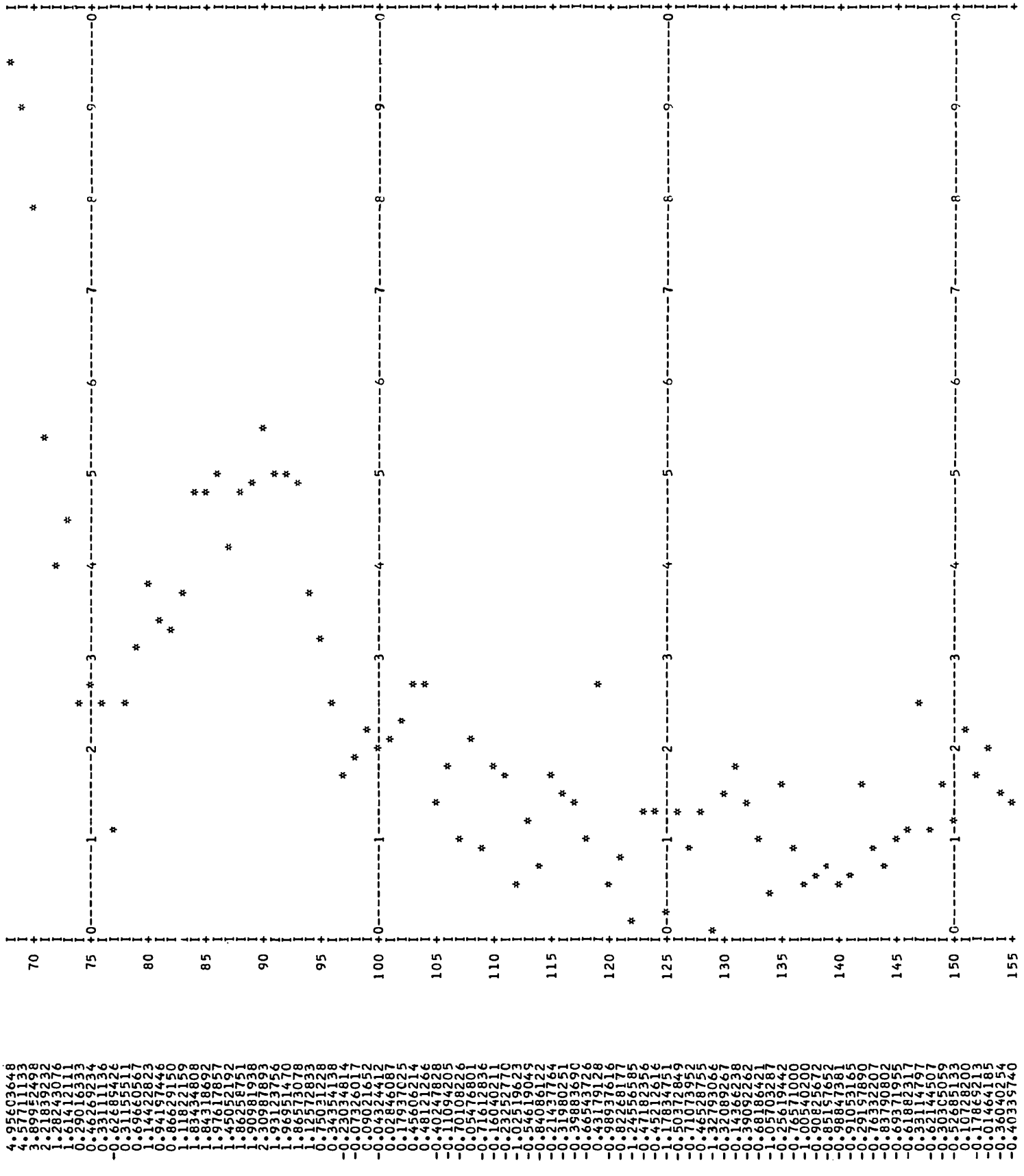
(Version AC4143A only)

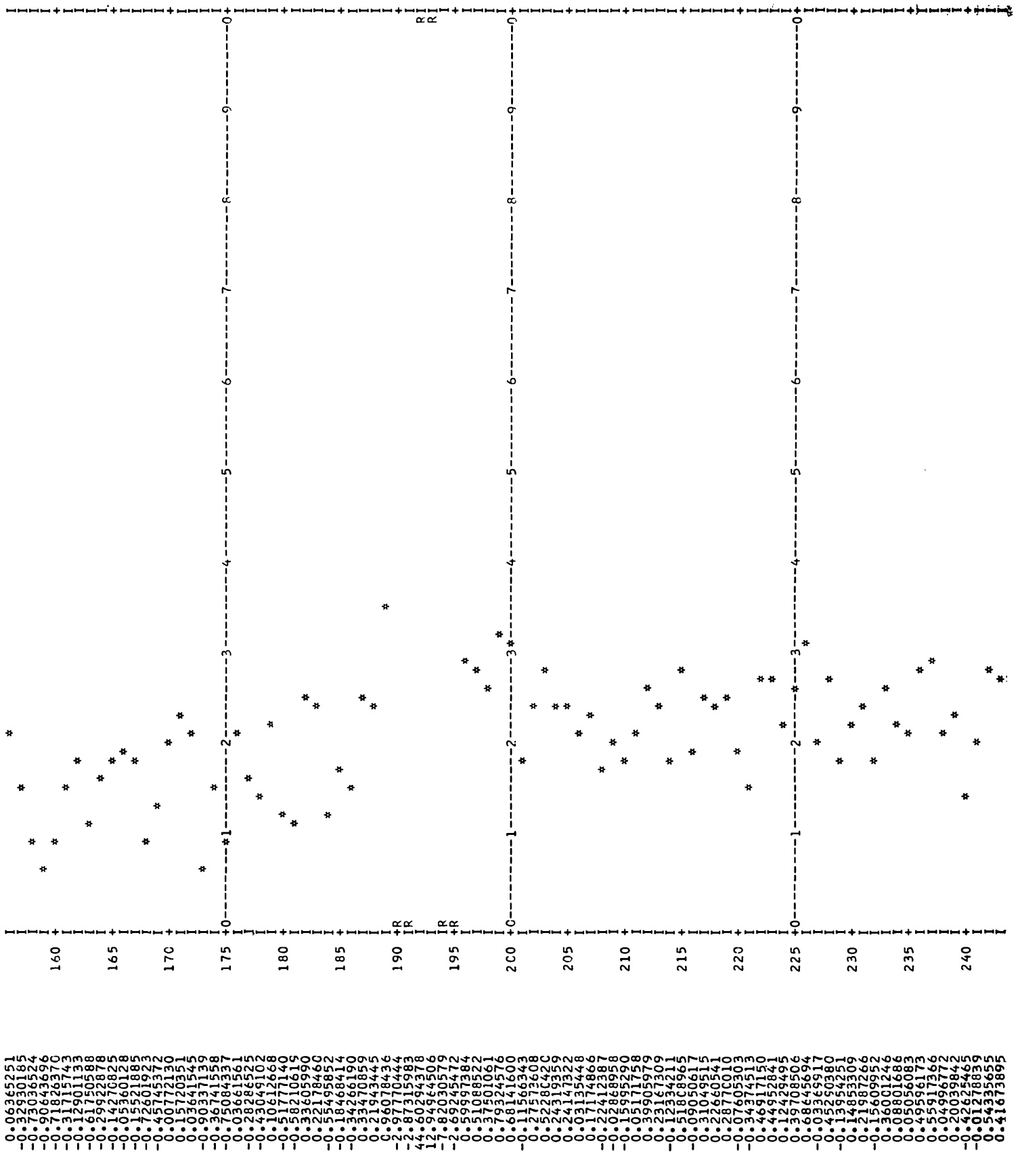
AVERAGE OF OBSERVATIONS WEIGHTED BY INTEGRATION PERIOD -- 413 CHANNELS -- KEY = 1

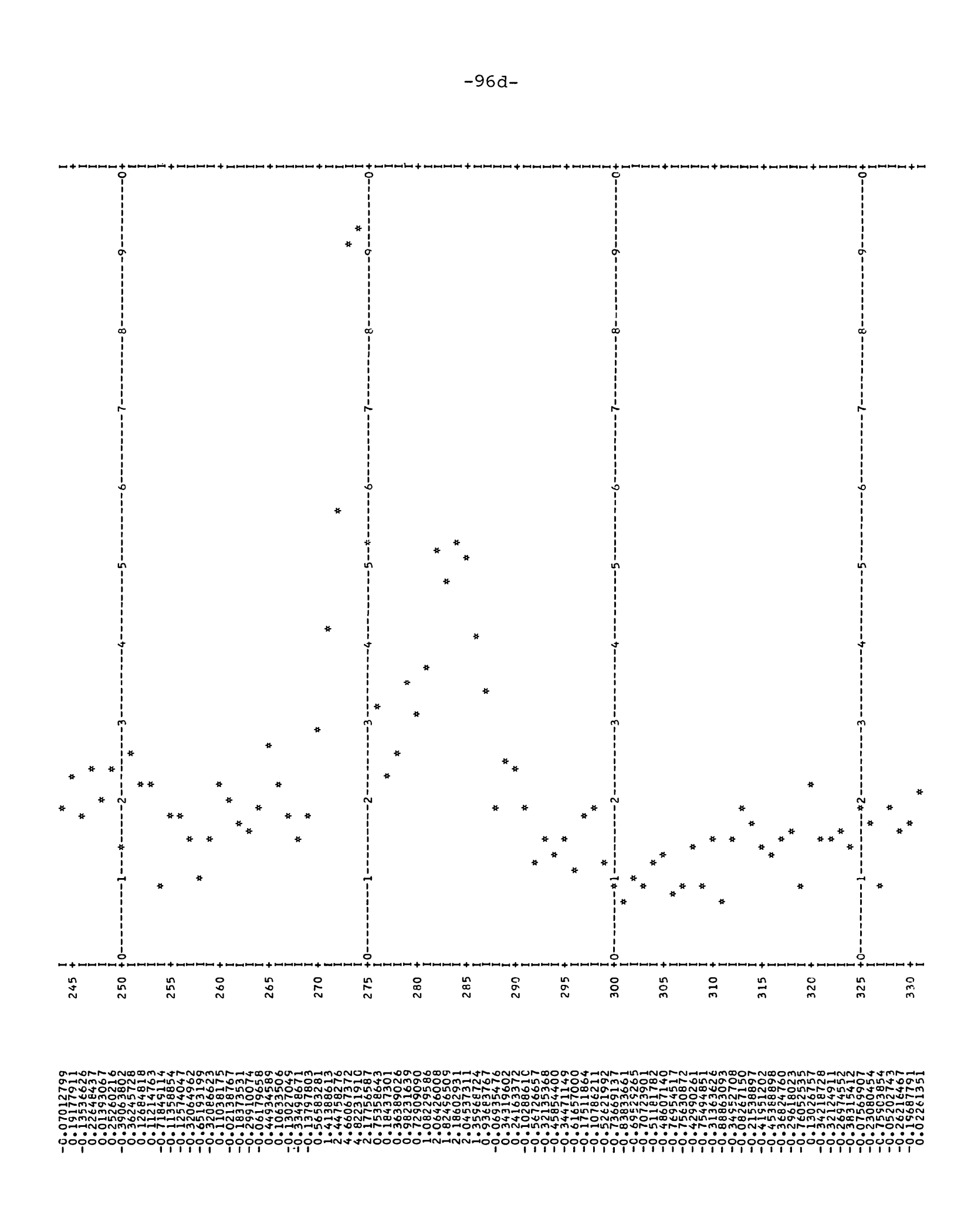
SCAN	INTEGRATE	DATE	LST	RA	DEC	BANDWIDTH	VELOCITY			IDENTIFICATION
28440	8.17	68/ 5/ 2	06 19 17.4	05 32 39.7	022 00 55.8	5/4/2	32.630/	32.630/	32.630	VERSCHUR TAURUS
28450	6.50	68/ 5/ 2	06 49 07.4	05 32 39.3	022 00 57.6	5/4/2	32.662/	32.662/	32.662	VERSCHUR TAURUS
28460	7.33	68/ 5/ 2	07 19 27.4	05 32 40.5	022 00 57.1	5/4/2	32.693/	32.693/	32.693	VERSCHUR TAURUS
28470	6.67	68/ 5/ 2	07 49 17.4	05 32 42.4	022 01 20.2	5/4/2	32.725/	32.725/	32.725	VERSCHUR TAURUS

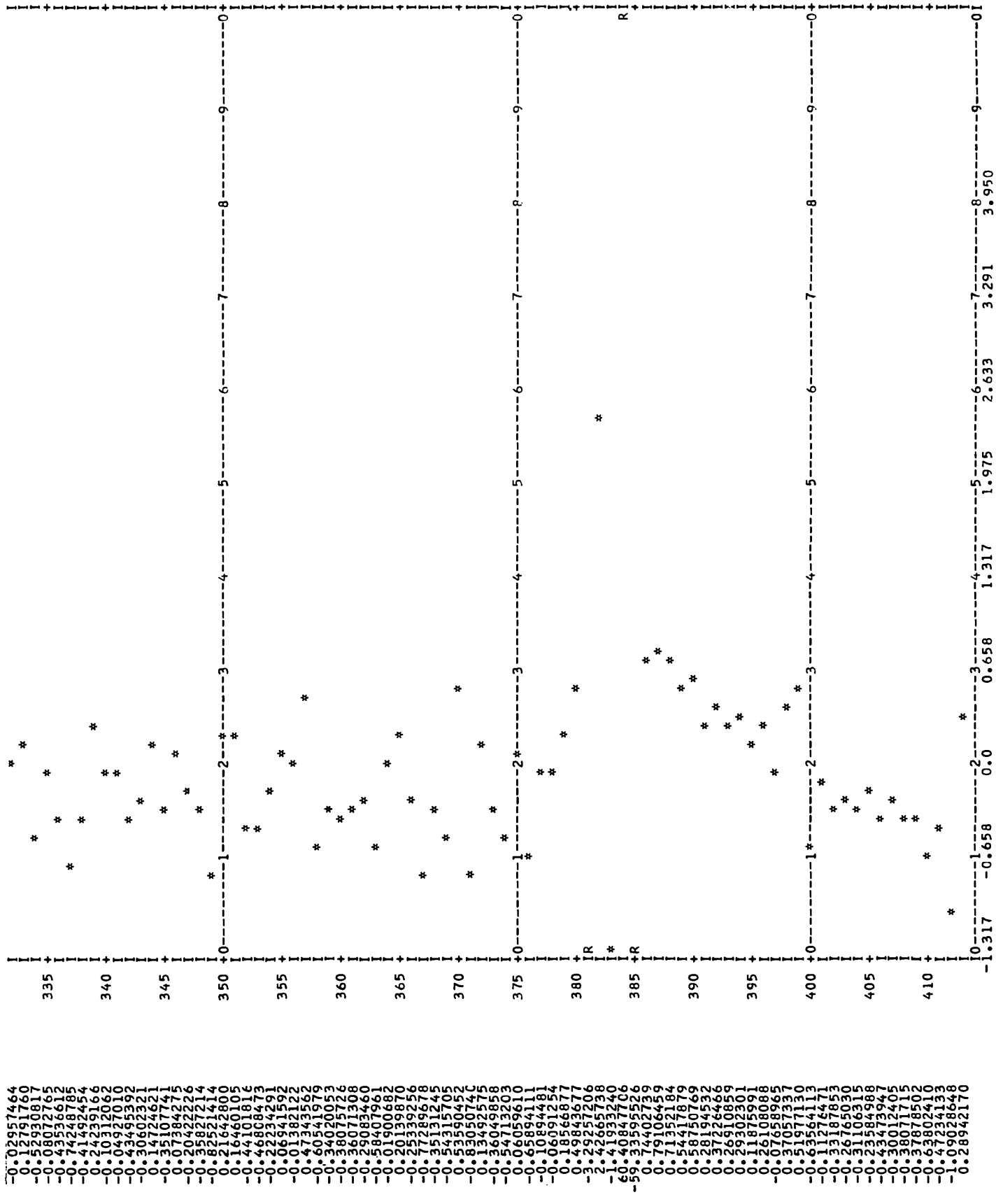
TOTAL INTEGRATION TIME 28.67 MINUTES THIS IS A TEST CASE GENERATED FOR THE DESCRIPTION OF THE PROGRAM










-0.29574464
-0.12791760
-0.52930817
-0.08072765
-0.43536612
-0.74248785
-0.41492454
-0.24239166
-0.10312062
-0.04927010
-0.43495392
-0.30602321
-0.14724621
-0.35107741
-0.07384275
-0.20422226
-0.35827214
-0.82521414
-0.21642805
-0.44101815
-0.46884873
-0.22234291
-0.06941592
-0.01382122
-0.47343562
-0.60541979
-0.34020053
-0.38075726
-0.36071308
-0.29083460
-0.58407961
-0.01900682
-0.20139256
-0.25339678
-0.77289645
-0.35131245
-0.54315705
-0.53590452
-0.83050745
-0.13492575
-0.36049858
-0.54713203
-0.06059610
-0.65894111
-0.10894481
-0.06091254
-0.18566877
-0.49843677
-3.29257206
-2.42665738
-1.41933240
-60.40847706
-59.33595526
-0.74402739
-0.79106459
-0.71352184
-0.54417879
-0.58750769
-0.28194532
-0.37226466
-0.26910859
-0.29302301
-0.11875991
-0.26108088
-0.07658965
-0.37057337
-0.51977130
-0.63564113
-0.11276471
-0.33187853
-0.26765030
-0.31106315
-0.23584988
-0.43473947
-0.30012405
-0.38071715
-0.37878502
-0.63802410
-0.47234133
-1.09028648
-0.28942170
335
340
345
350
355
360
365
370
375
380
385
390
395
400
405
410
-1.317
-0.658
0.0
0.658
1.317
1.975
2.633
3.291
3.950

Interoffice

National Radio Astronomy Observatory

Green Bank, West Virginia

To: Addressee 30 August 74

From: Bob Vance, Computer Division Programmer

Subject: Addendum to Computer Division Report No. 5, dated Sept. 1968, 413-Channel Autocorrelator Receiver, Section II, titled ON-LINE COMPUTER PROGRAM.

The On-Line data taking programs have some inherent time delays necessary for the Observer to calculate when setting up the Start and Stop times for the scan (either from cards or manually by the Operator).

The Model II Correlator dumps data to the computer on 10 second (Sidereal) intervals. (i.e., 10, 20, 30, . . . 00, . .)

The On-Line program has a built-in feature that ignores the data of the first dump from the correlator after Start of scan and then accumulates for the Integration period desired. This is necessary in order to zero certain arrays in core used for accumulating.

The Fourier-Transform on line requires approximately seven seconds to complete and then it writes the spectra on magnetic tape. Adding 1 second to the last dump time to complete the last integration period will allow the last integration period to use the Fourier Transform and write the spectra on tape. Ending exactly on the last dump time of the last integration may or may not cause the last integration to be written on the tape (depending on the timing cycles at program initialization).

CONSIDER THE FOLLOWING MODEL INTEGRATION PERIOD = 40 Secs.

Start Time	1st Dump Skipped	End INT. Time	Last INT. Tape Write	Stop Time
01 00 00	01 00 10	01 02 10	Yes	01 02 11
01 00 01	01 00 10	01 00 50	No	01 00 50
01 02 59	01 03 00	01 03 40	Yes	01 03 41
00 02 00	00 02 10	00 04 10	No	00 04 10
00 02 00	00 02 10	00 04 10	Yes	00 04 11

A 'Rule of Thumb' in order to get the last integration on tape is:

(NO. of Integrations desired) BY (Integration period) PLUS 11 seconds added to the Start time and entered as Stop time.

STORING AN OFF-SCAN

Using the Model II Correlator Receiver in the TOTAL-POWER mode requires the Observer to allow one 10 second dump period to occur after end of last scan so that the last scan may be marked as an 'OFF-SCAN' if so desired.

POSITIONING THE 140' TELESCOPE

Allow adequate time for the telescope to move to the next position in the sky before starting the next scan. Rough estimate of the time required to move the telescope can be derived by considering that for large distances the telescope accelerates for 8 secs. and moves at the top speed of 20^{o} / min. and after reaching within 1^{o} of the position, it decelerates at the same rate as at the beginning and zeroes in in about 10 seconds. The error is computed and updated every 100 msec. For moving 0.25^{o}, the telescope uses 3.5 sec; for 1^{o}, about 8 sec; for 10^{o}, around 40 sec; etc.

The telescope starts moving for the next position immediately at Stop time if in AUTO-UPDATE or CARD control on the control panel. However, if the last integration period has finished and started transform, the spectra are written on tape while the move is being accomplished.