NATIONAL RADIO ASTRONOMY OBSERVATORY
COMPUTER DIVISION
INTERNAL REPORT

MULTI-CHANNEL RECEIVER ON-LINE PROGRAMS

BY

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I. INTRODUCTION

This report describes the on-line programs available for the multi-channel receivers used at the NRAO. The on-line programs herein described are used for observing at the telescopes using the DDP-116 computer.

II. ON-LINE COMPUTER PROGRAM

A. General

The on-line computer program accepts inputs from the telescope, multi-channel receiver, teletype, and operator's control panel. Several types of output are provided. A magnetic tape is recorded for further off-line processing and is described in Appendix II. Data for each channel are averaged for the integration period and stored in double precision. RA and DEC refer to the center of integration.

On-line outputs, which do not affect the data recorded on magnetic tape, include CRT displays, printed outputs, and plotted outputs.

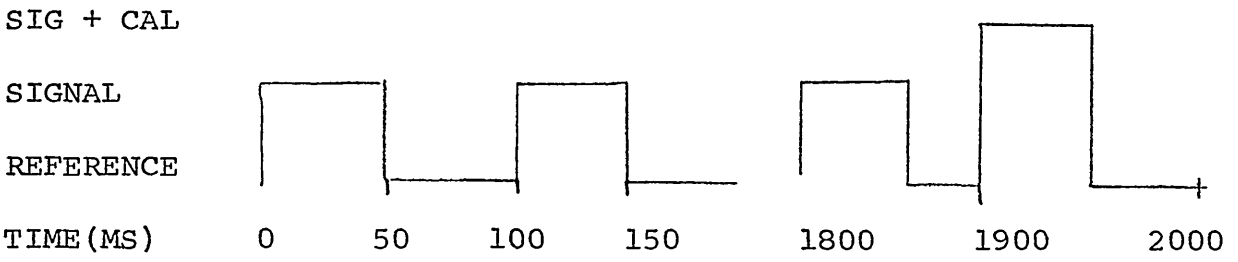
B. Integration

At the beginning of each observation, two seconds are spent in collecting zero corrections and stabilizing. Samples are collected and corrected in the computer for the time selected by the "Cal-Time". They are then normalized to the calibration. Normalized samples are averaged for the time selected by the "Integration Period". Normalized samples are then output to the tape, CRT display, and, optionally, to the printer and plotter.

There are four senses of integration in the hardware and computer.

1. INTEGRATORS - Each detector output (ref: Electronics Division Internal Report No. 70) is integrated in the analog buffer. Signals are output by the computer to control the length of the integration. It is fixed at 50 ms. A 5 ms. blanking time is used during which the computer switches the L.O. or front-end and reads, through the A/D converter, the integrator outputs for the previous 50 ms.

2. CALIBRATION PERIOD - A complete data cycle consists of a series of measurements of signal, reference, and calibration as follows: (cal time assumed 1.9)



A normalized (to the cal) data value is computed for each data cycle for each channel as described in Appendix I.

3. INTEGRATION PERIOD - The normalized data values are averaged for a variable period of time after which they are output to the tape, CRT, and, optionally, to the printer and plotter. The operator selects the Integration Period and Cal-Time by setting digi-switch registers.

4. SCAN INTEGRATION - The term scan is used to denote a complete observation. 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 averaged samples for each integration period within the scan are added into an accumulator array in the computer memory. This array is not recorded on tape but may be used to produce on-line outputs. The "cumulative" data is the average of all signals accumulated since the measurement was started. The "current" data is the signal collected during the previous integration period.

C. Data Taking Sequence

The telescope operator determines the sequence of data taking operations by setting various switches on the control panel. Two distinct segments are indicated:

1. OBSERVING - During this time samples are recorded on tape and displayed on the CRT for each integration period. Typically, the telescope tracks during this time at the 140'. Normalized samples for each channel are added into an accumulator array (which is initialized to zero at the start of the scan).

2. HOLDING - During this time, the accumulator array contains the integrated samples produced during the previous observation. The operator may obtain several types of output on the CRT, printer, and plotter.

After an observation, the cummulative signal may be stored in an off-array by pressing the button labeled "STORE-OFF". This array can then be used later to obtain a difference of signal on-source and that which was stored previously. Outputs of the difference can then be obtained on CRT, printer, and plotter, if desired, by selecting the ON-OFF selector switch for each device.

D. On-Line Outputs

1. CRT outputs are chosen by setting the CRT selector switch on the options panel (see figure 1). A CRT display is produced automatically at the end of each integration period (while observing). The display may be renewed at any time by pressing the CRT "renew" command button. The option selector switch may be set to the following:

a. CURRENT - The normalized samples for the previous integration period are displayed (while observing). While holding, the most recent integration period is displayed. This display has a scale of cal units/cm, as typed from the teletype.

b. CUM - The normalized samples for the period from the start of the scan are displayed. The scale is in cal units/cm.

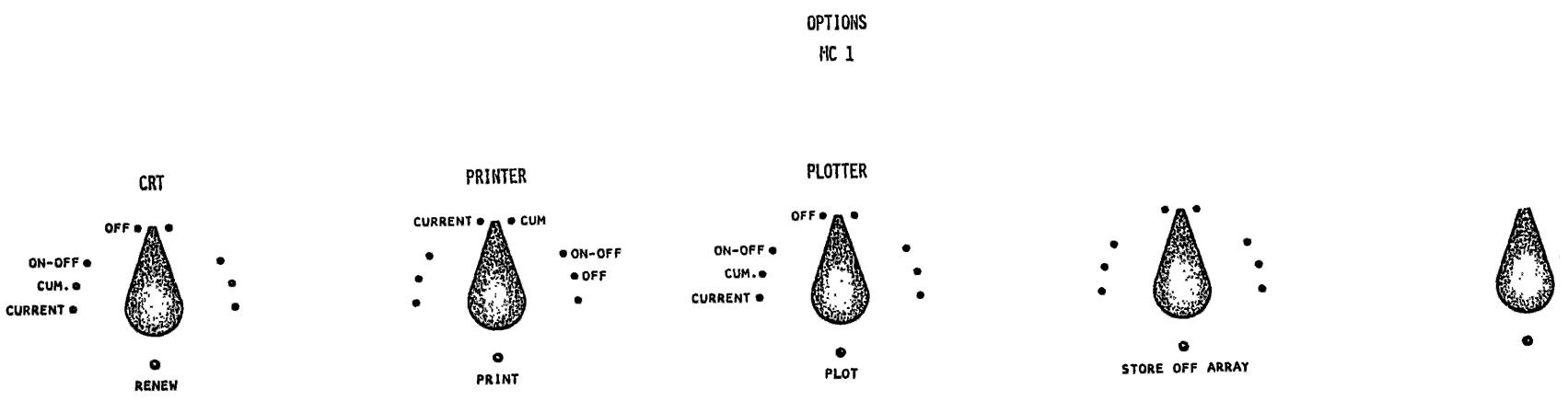
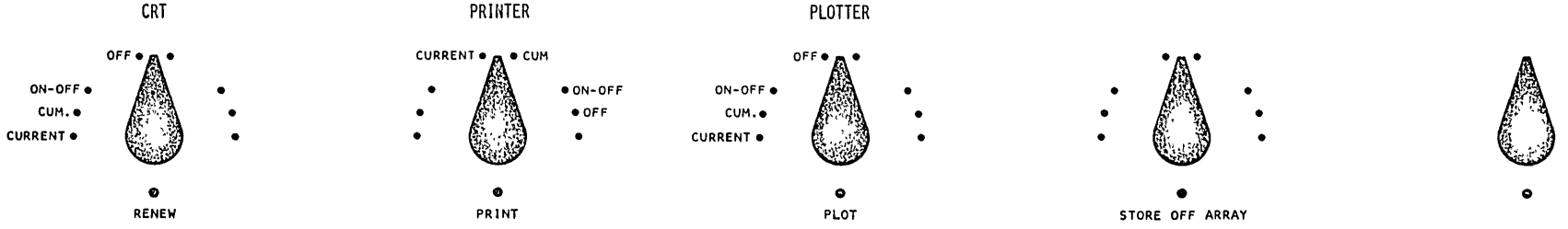


FIGURE 1

OPTIONS PANEL

OPTIONS

MC 1


CRT
OFF
ON-OFF
CUM.
CURRENT
RENEW
PRINTER
CURRENT
CUM
ON-OFF
OFF
PRINT
PLOTTER
OFF
ON-OFF
CUM.
CURRENT
PLOT
STORE OFF ARRAY

c. ON-OFF - This option allows the most recent cumulative array minus the stored OFF array to be displayed.

d. OFF - This provides for the displaying of the last measurement taken off source and stored as such to be displayed.

2. The printer options selector switch has the same features and selections as the CRT options selector switch.

A header is printed on each printer output. A code word is used to identify which output option was selected. The following shows the format of the header:

XX	MMDDYY	HHMMSS
**(code word)	(Date)	(E. S. T.)
XXXX	XXXXX	
(Scan No.)	(Total Integration Time in Seconds)	
HHMMSS	± DDMMSS	
(RA)	(DEC)	

**Code words are defined as:

05 - Printout of one integration period
(Current selected)

06 - Printout of accumulated integrations
(Cum selected)

07 - Printout of ON-OFF measurement
(ON-OFF selected)

08 - Printout of accumulated integrations stored as last OFF measurement
(OFF selected)

3. The plotter options selector switch has the same features and selections for output as the CRT and Printer.

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

F. Operating Considerations

The program is loaded from tape or cards according to the usual bootstrap procedures. The program may be restarted as noted in the operator instructions. 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. Descriptions of these points are contained in the operator instruction book at the telescope.

Certain channels can be omitted in the computation of the calibration by typing "O" before the scan starts and typing in the channel numbers to be omitted. This is very useful when a channel filter is suspicious. If "O" is not typed, the program assumes none are to be omitted in the computation. Entering the channels to be omitted is only necessary once unless the program is reloaded or restarted.

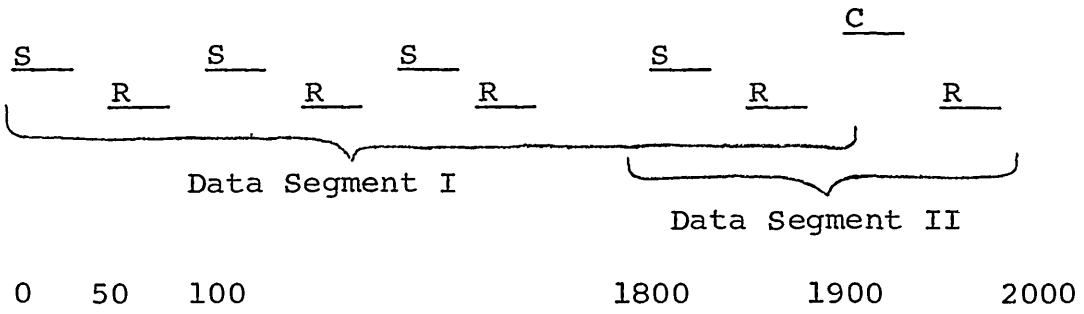
Printed outputs at the end of a scan for cumulative data must be initiated after all calculations are complete. The CRT and Plotter share some hardware so that these outputs are mutually exclusive. At the end of a scan, plotted outputs and CRT displays should be obtained separately.

Plotted output is similar to CRT displays. Only the size of the plots is changed. Thus, the CRT may be used to set up for a plot.

APPENDIX I

NORMALIZED DATA COMPUTATION

A calibration cycle consists of the following sequence of measurements (a calibration time of 1.9 seconds is assumed here):



A. General

The data taken between time 0 ms. and 1900 ms. (Data Segment I) is analyzed to derive line temperatures normalized to the system temperature for each channel. The data taken between 1800 and 2000 ms. (Data Segment II) is analyzed to derive the noise tube temperature normalized to the system temperature for each channel. The normalized calibrations are averaged across channels to improve signal-to-noise. Data Segment I is then normalized to the average cal from Data Segment II to derive line temperatures normalized to the noise tube.

B. Data Segment I

For each channel a series of measurements of signal (S_1, S_2.....S_{19}) and reference (R_1, R_s.....R_{19}) are made and each is the result of a 50 ms. integration. The following model of the receiver system is assumed:

$$S_i = G(T_S + T_L) + Z$$

$$R_i = G(T_S) + Z$$

where:

G = gain for the channel including all amplification and attenuation.

T_S = system temperature including receiver noise temperature and continuum temperature.

T_L = line temperature for the channel.

Z = detector zero offset.

A gain correction for each .1 seconds is made by normalizing the line temperature to the system temperature. The normalized values are then averaged for the length of the data segment as follows:

$$\frac{T_L}{T_S} = \left(\frac{S_1 - R_1}{R_1 - Z} + \frac{S_2 - R_2}{R_2 - Z} + \text{---} \frac{S_{19} - R_{19}}{R_{19} - Z} \right) \Big/ 19$$

C. Data Segment II

The calibration signal is fired at the end of each calibration cycle and the following model is assumed:

$$C = G(T_S + T_L + T_{REF}) + Z$$

where:

T_{REF} = noise tube temperature

For each channel a value for noise tube temperature normalized to system temperature is computed as:

$$\frac{T_{REF}}{T_S} = \frac{C - S_{19}}{R_{19} - Z}$$

These normalized noise tube temperatures are then averaged across channels to improve signal to noise. This gives:

$$\overline{\left(\frac{T_{REF}}{T_S} \right)}$$

For each channel the average obtained in data segment I is then normalized to give:

$$N_J = \left(\frac{T_L}{T_S}\right)_J \Big/ \overline{\left(\frac{T_{REF}}{T_S}\right)} \qquad J = \text{channel number}$$

which is the temperature of the line normalized to the noise tube temperature.

APPENDIX II

FORMAT 2

All records are identical, written in binary 3 ch./wrd.

Word	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
36-37	4	*LST
38-39	4	*EST
40	2	*Date - Month
41	2	*Date - Day
42	2	*Date - Year
43	2	Type of Observing (2)
44	2	Observer Number
45	2	Sample Rate in .1 sec (100)
46-50	-	Reserved for Future Use
51-52	4	*α indicated
53-54	4	*δ indicated
55-156	4(B15)	51 channels of normalized data
157-162	$\pm$	L.O. Frequency

* At center of integration.
$\pm$ Raw Data.