SETI Radio Spectrum Surveillance System

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The SETI Radio Spectrum Surveillance System (SRSSS) will provide a data base for assessing the RFI environment for SETI and minimizing RFI disruptions during the search. This article describes the system's hardware and software and discusses the sensitivity of the system.

I. Introduction

The Search for Extraterrestrial Intelligence (SETI) Radio Spectrum Surveillance System (SRSSS) was built to provide a data base to assess the RFI environment for SETI. Initially the system will be used to study the RFI environment at the Goldstone Complex. A survey will be conducted over the next year to cover the frequency range from 1 to 10 GHz. The SRSSS is sufficiently portable so that it can be moved easily to other radio astronomical sites (see Figs. 1 and 2). Later, the SRSSS will be used as a coincidence detector with the SETI search instrument.

The SRSSS was designed as a stand alone system capable of detecting and recording RFI signals in an unattended mode. Periodic system calibration is achieved using a noise diode to provide a known input power. Detected signals are stored on floppy diskettes and will be processed with the SETI/Radio Astronomy VAX 11/750 at the Jet Propulsion Laboratory (JPL).

The SRSSS data base will provide guidance to the SETI project on how to search the frequency, time and space dimensions. The objective is to minimize the probability of RFI disrupting the search.

This article gives an overall description of the system, including hardware and software, and a discussion of the system sensitivity.

II. Hardware

The SRSSS occupies one standard rack of equipment and has a one-meter antenna, antenna rotator and associated RF-module assembly mounted externally. The rack contains a Tektronix 494p Spectrum Analyzer under the control of a Tektronix 4052A controller. The controller also controls the antenna position, amplifier selection and data storage on a dual-floppy disk. A hard copy unit is available to record "interesting" spectra. The data from the floppy disk will be processed in a VAX computer at JPL. An overall block diagram is presented in Fig. 3.

A. RF Module

The signal from the antenna is amplified in one of seven GaAsFET amplifiers. The set of seven GaAsFET amplifiers is required to cover the spectrum from 1 to 10 GHz. Specifications of the GaAsFET amplifiers are given in Table 1.

Each GaAsFET amplifier is followed by a transistor amplifier with a minimum gain of 20 dB to eliminate subsequent cable loss from contributing to the system noise temperature. The measured gain and noise temperature for the RF assembly are shown in Figs. 4 and 5.

The selection of different sets of amplifiers for the specific frequency ranges is controlled by the 4052A Tektronix computer through HP actuators. A directional coupler is used at the input of the coaxial switch to inject noise into the system for the purpose of system calibration.

Calibration of the system is performed by turning the HP346B noise source on and off and calculating the system temperature from the y-factor measurement in the 4052 controller. This noise source has a 15.2 dB ±0.2 dB excess noise ratio (ENR) over a range of 10 MHz to 18 GHz. The low SWR of the noise source in both the on and off condition reduces a major source of measurement uncertainty. The ENR is related to the effective noise temperature of the source (Tne):

$$ENR = 10 \log \frac{(Tne-290)}{290}$$

B. Relay Actuators

The HP relay actuators provide the control of the microwave coaxial switch and the HP 346B noise source via control lines to the RF unit located in the antenna rotator pedestal.

C. Antenna Control

The antenna elevation is manually set at a fixed elevation angle (adjustable from 0 to 30 degrees). The azimuth position and rate of rotation are controlled by the RPM antenna controller through the Tektronix 4052A computer via an IEEE-488 Bus.

The azimuth position of the antenna may be controlled in local mode with the front panel control. The rate of rotation is displayed in RPM on the RPM LED indicator. The rotator angular position is simultaneously displayed on the azimuth DEGREES LED indicator. In a remote controlled operation, rate or position command signals from the IEEE-488 Bus may be used to control the rate of rotation of the rotator from −15.5 RPM to +15.5 RPM in 0.5 RPM increments, or to cause the rotator to point at any azimuth with a 0.1 degree resolution and 0.15 degree accuracy.

D. Spectrum Analyzer

The 494P Tektronix Programmable Spectrum Analyzer is controlled by the 4052A Tektronix Computer through the IEEE-488 Bus to select the desired frequency range, frequency span/division and resolution bandwidth.

This spectrum analyzer has a frequency range of 10 KHz to 21 GHz and a minimum resolution bandwidth of 30 Hz. The sensitivity is −121 dBm at 30 Hz resolution bandwidth.

E. Digital Clock

The HP 59309A digital clock supplies the system time. This clock can be set under local control or by remote commands received from the IEEE-488 Bus.

F. Dual Disk Drives

The double density dual floppy diskette storage facilities can hold up to two megabytes of information which translates to 50,000 messages (assuming 40 characters per message). These messages typically will contain the following data: time, frequency, azimuth, threshold, number of hits above threshold, operating mode, etc. At low threshold setting, which may result in 1,000 messages per hour, the SRSSS can operate unattended for a full weekend. At a more conservative threshold, say 60 messages per hour, the SRSSS can operate unattended for a full month.

G. Hard Copy Unit

The 4631 Tektronix Hard Copy Unit provides hard copies of any spectra displayed on the 4052A CRT. A sample display is shown in Fig. 6.

III. Software

The software that runs on the SRSSS is written in Tektronix BASIC. The program allows a user to build and save a customized observation program on the cartridge tape. This schedule will later direct the system when and where to point the antenna, how to set the threshold, frequency range and resolution bandwidth by issuing detailed hardware commands.

There are five main modules in the SRSSS software. The EDITOR allows the operator to build and edit observation schedules. The RUN module runs observation according to the prerecorded schedule. The MAINTENANCE and UTILITIES modules aid in software development and hardware diagnostics. Figure 7 is the top level flow diagram of the SRSSS. The RUN module is further expanded in Figs. 8, 9, and 10. The EDIT module flow diagram is shown in Fig. 11.

An observation schedule is a set of tasks (up to 20). The tasks of a schedule are separated into 10 Sequential Time Events (STE) tasks and 10 Absolute Time Event (ATE) tasks.

The STE tasks are executed by the SRSSS system one after another. An ATE task starts and stops according to its predetermined absolute time schedule, and it interrupts any currently running STE task. An interrupted STE task resumes execution as soon as the interrupting ATE task is completed.

Any task, whether an STE task or ATE task, falls into one of three categories:

1. Data Only
2. Calibration Only
3. Data and Calibration

In a Data Only task, the SRSSS determines and records hits above some predetermined threshold. In a Calibration Only task, system calibration operations are performed. In a Data and Calibration task, the SRSSS interleaves calibration operations with hits collected. Figure 12 shows schematically the azimuth-frequency coverage for a DATA/CALIBRATION task.

The SRSSS was intended for unattended data collection, but its software provides some convenient functions for an observer to get information in real time. By request, the system can work in a stepped, frame-by-frame mode, reporting hits on the CRT, plotting current spectra on the screen and making hard copy.

The SRSSS software utilizes the fact that the spectrum analyzer contains an internal controller which allows some parallel processing. This allows the spectrum analyzer to collect the data, while the 4052 controller processes that data from the last spectrum.

IV. Future Plans

Currently, the JPL SETI team is working on building data base software on the VAX 11/750 for RFI signal storage and analysis. This data base will provide an estimate of how many RFI events may be expected for a given SETI run. Based on this information an optimal pattern of sky/frequency coverage in SETI SKY Survey will be developed. A year long survey is planned to assess the RFI environment at Goldstone. This RFI data base should be of general interest for all potential DSN users.

Table 1. Specifications of the GaAsFET amplifiers

Amplifier	Frequency Range, GHz	Minimum Gain, dB	Noise Figure, K
AR1	1.1 – 1.7	44.5	100
AR2	1.7 – 2.3	37	100
AR3	2.3 – 3.1	38	120
AR4	3.1 – 4.3	36	120
AR5	4.3 – 5.8	40	160
AR6	5.8 – 7.7	42	225
AR7	7.7 – 10.0	37	390

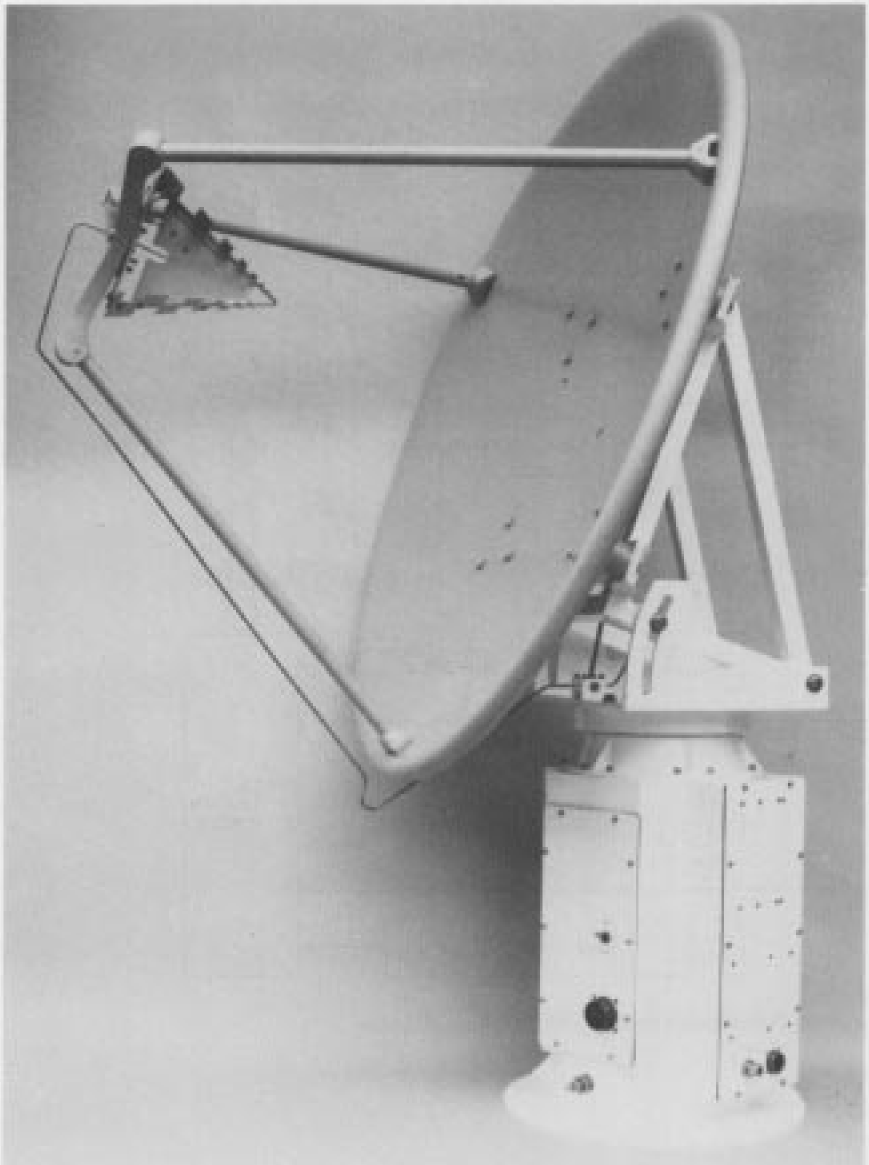

Fig. 1. SRSSS antenna assembly

Fig. 2. SRSSS electronics assembly

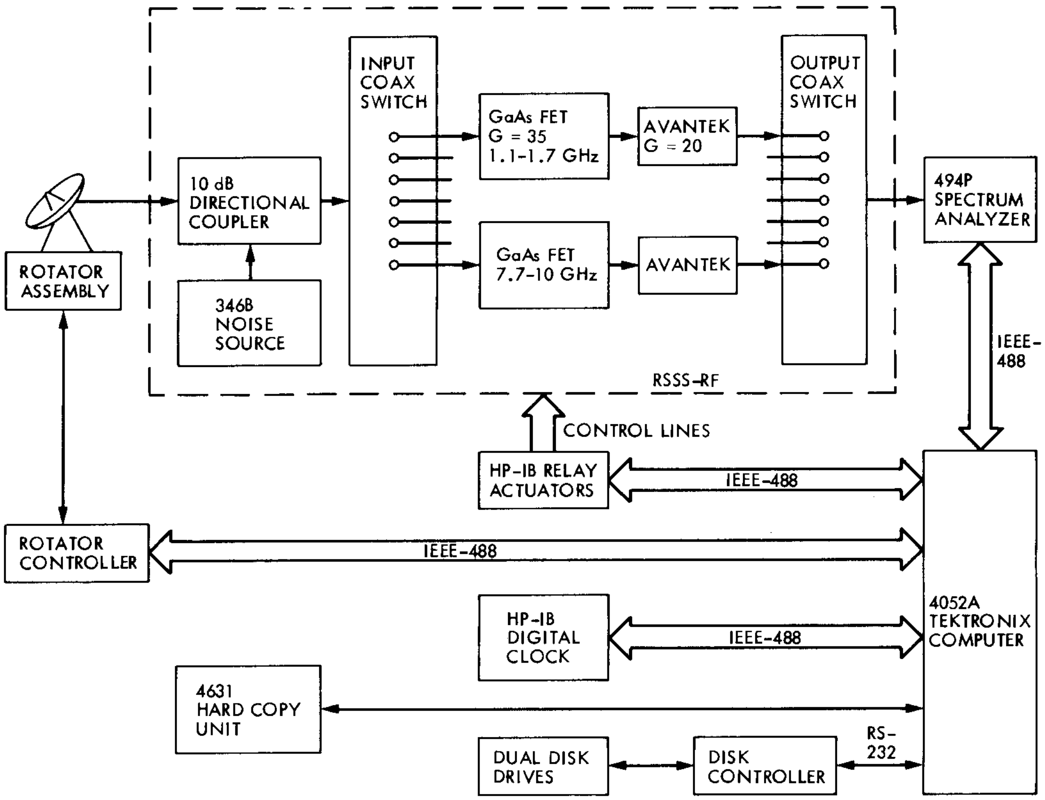

Fig. 3. Radio Spectrum Surveillance System (RSSS) block diagram

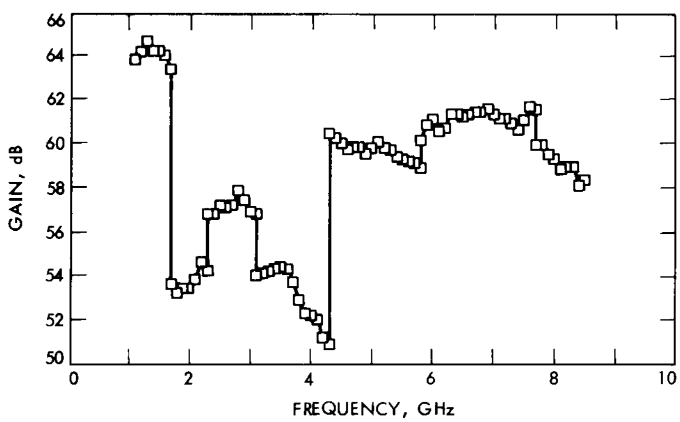

Fig. 4. Gain vs frequency for the SRS3 amplifier

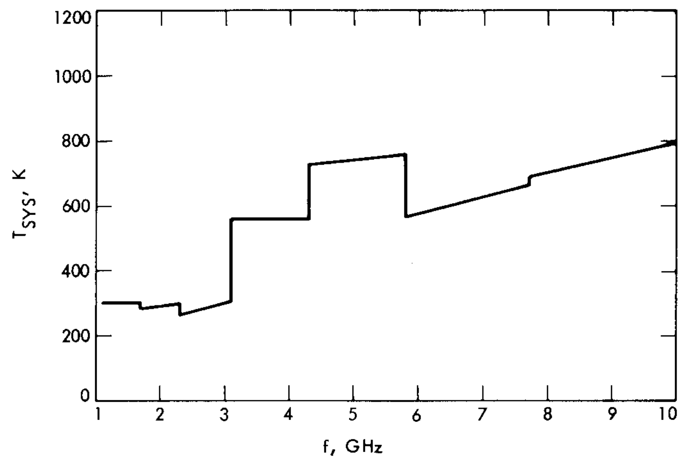

Fig. 5. The SRSSS system temperature vs frequency, April 1985

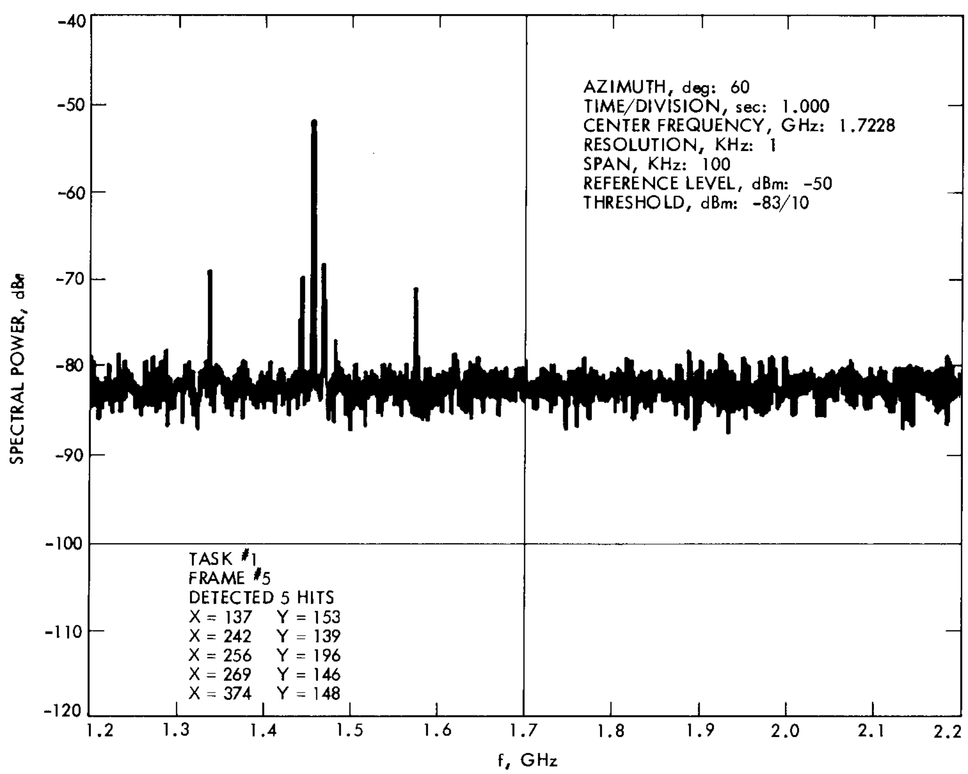

Fig. 6. The SETI Radio Spectrum Surveillance System

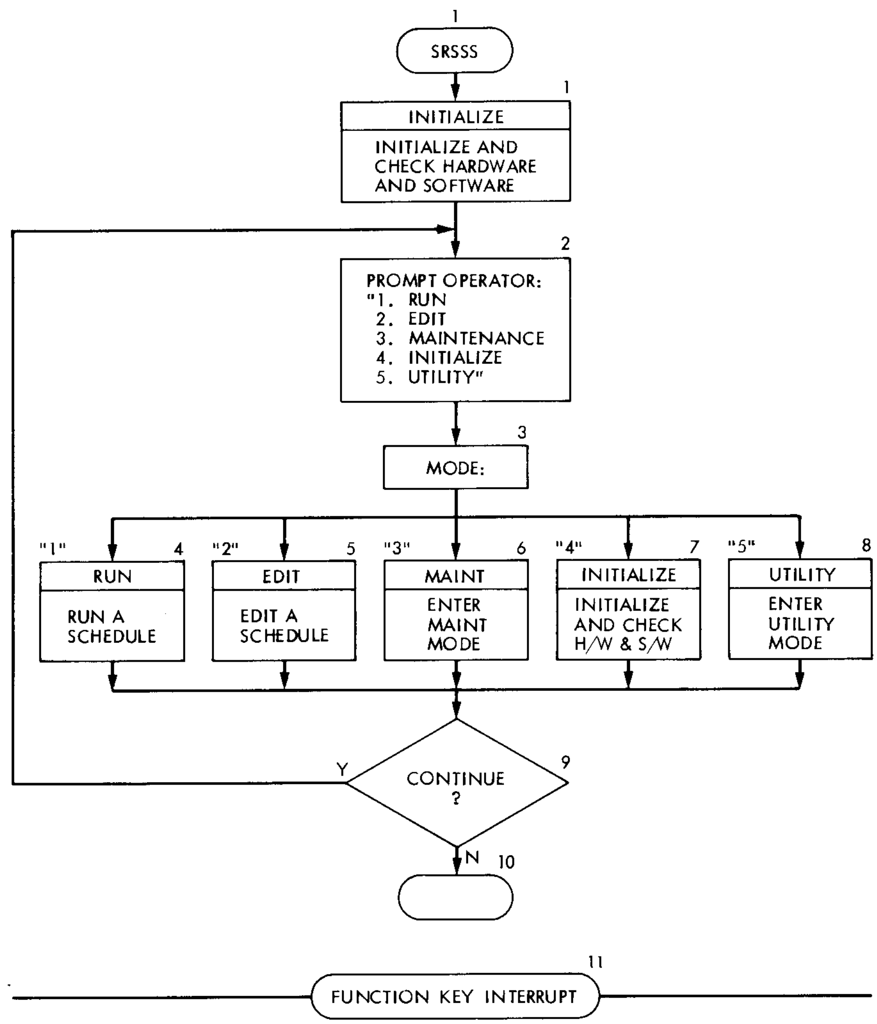

Fig. 7. The main program of SRSSS

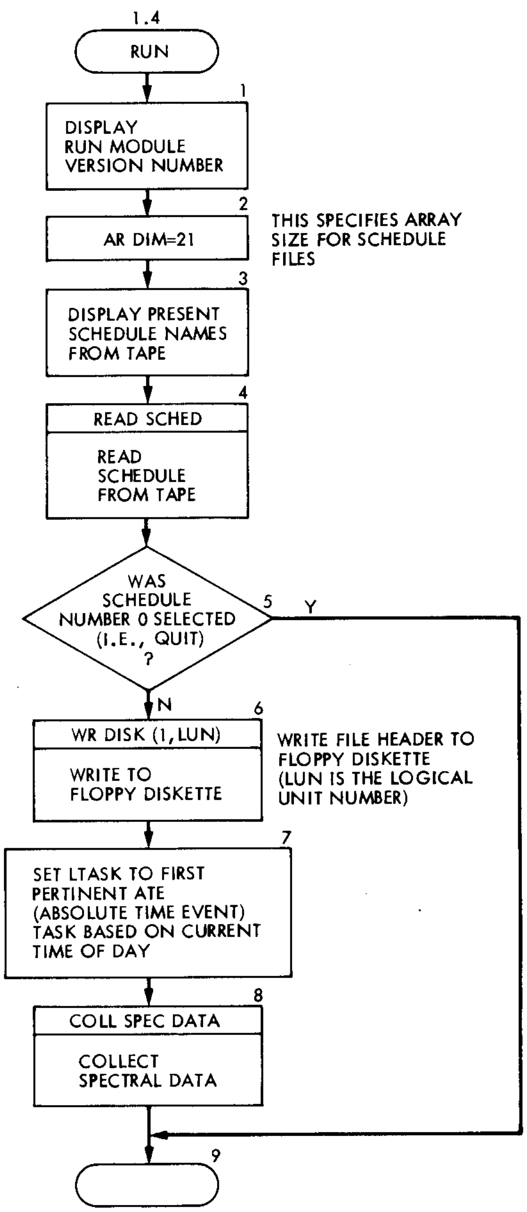

Fig. 8. RUN mode flowchart

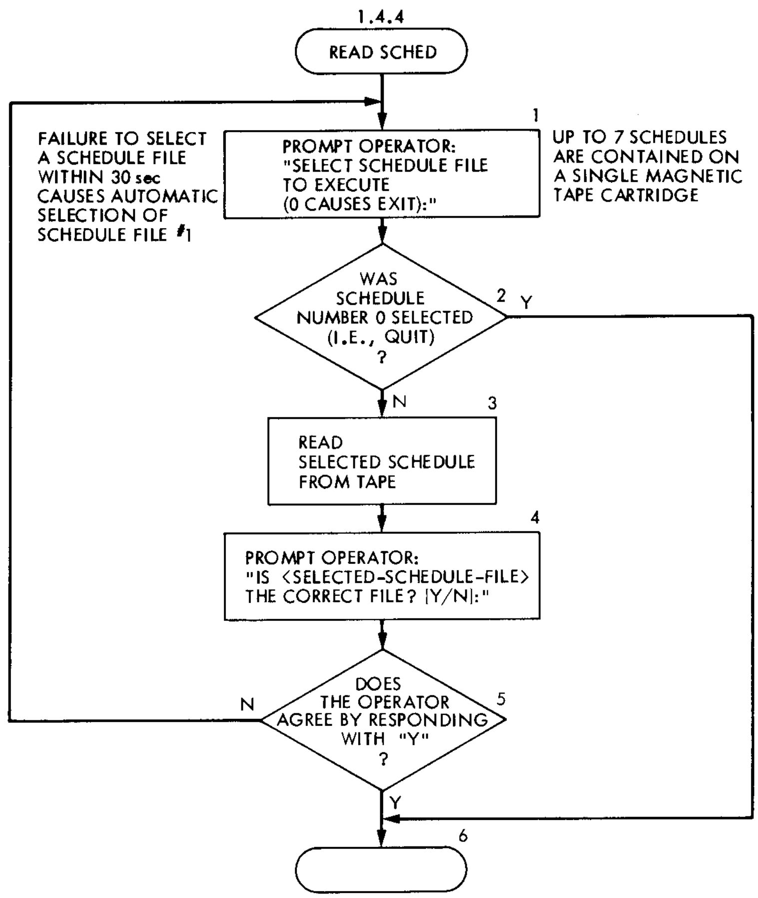

Fig. 9. READ schedule flowchart

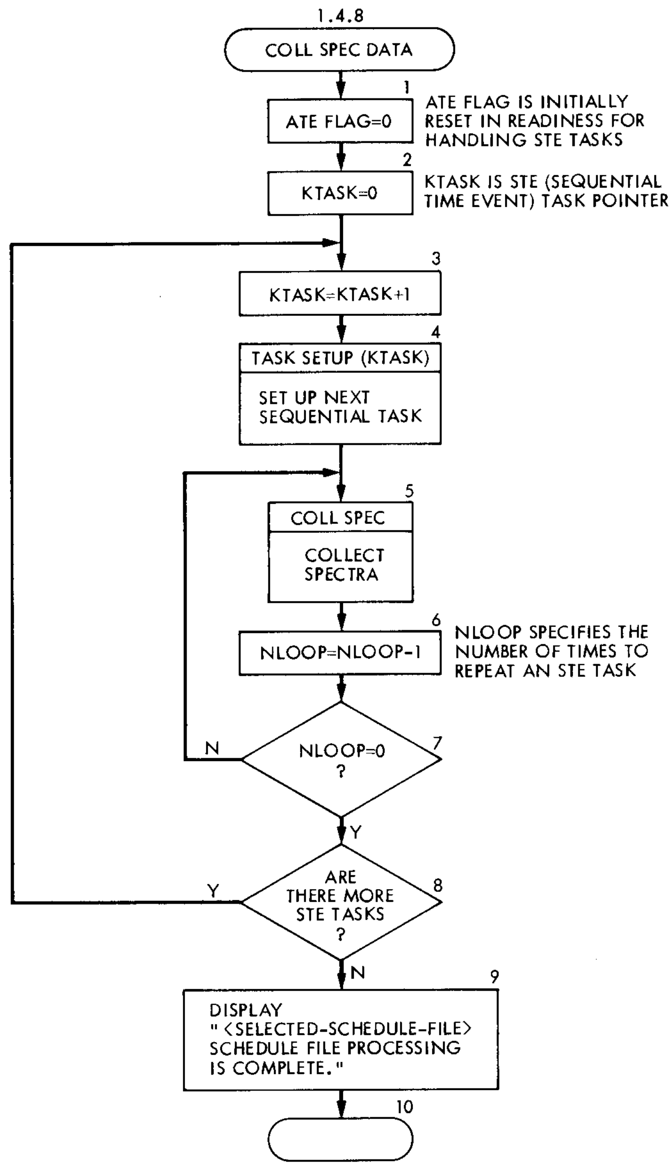

Fig. 10. Collect spectral data flowchart

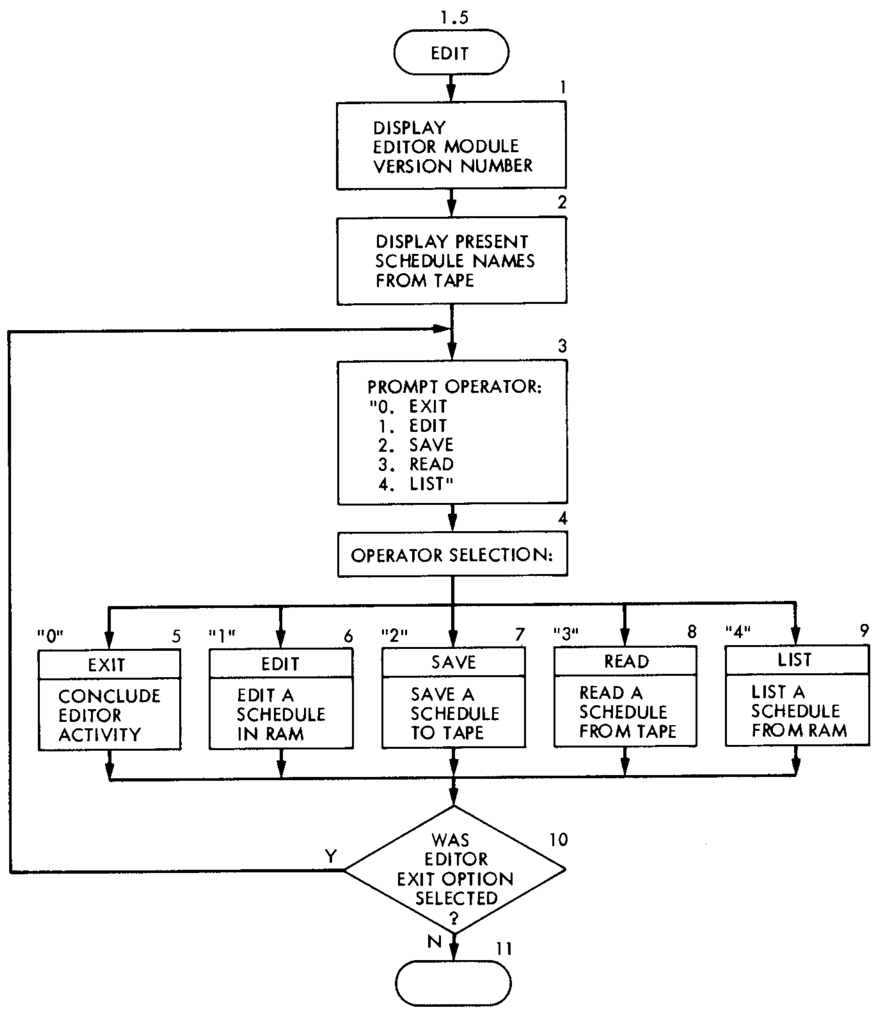

Fig. 11. EDITOR mode flowchart

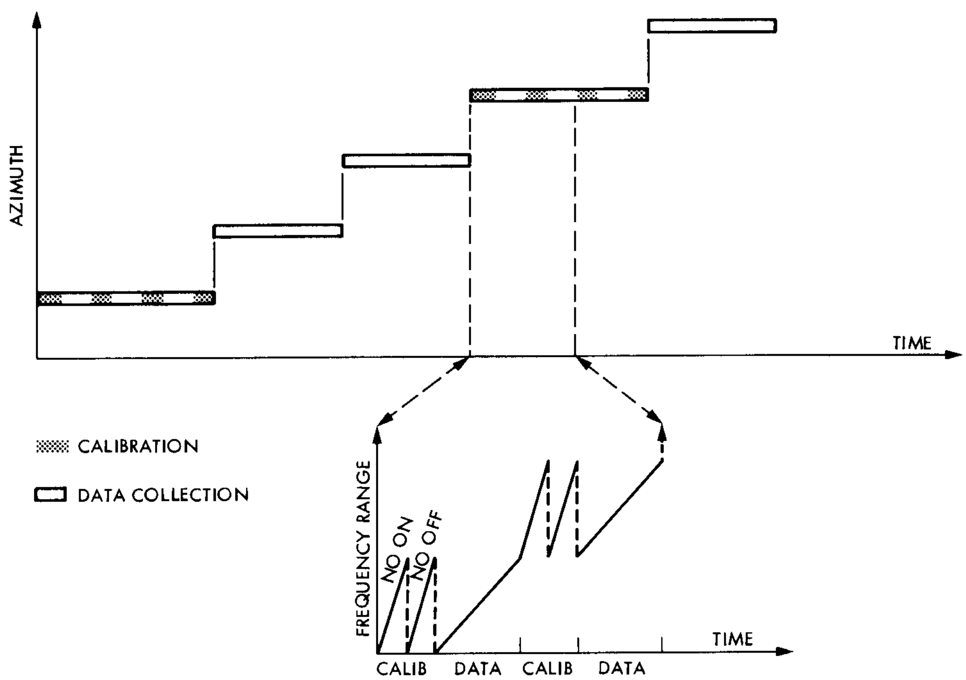

Fig. 12. Time history of system calibration as a function of azimuth