Antenna Microwave Subsystem Controller

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The development of a new microwave subsystem controller is discussed, and results of installing the equipment at the DSS 13 R&D station are reported. This controller is serving as the prototype for a new generation of microwave controllers for the DSN.

I. Introduction

The Antenna Microwave Subsystem Controller (Fig. 1) has been developed utilizing a microprocessor-based digital system to monitor and control microwave switch type equipment. This report details the results of the development and the implementation of the prototype equipment which controls the microwave equipment in the second-generation common aperture X- and S-band uplink feedcone (XSU, Ref. 1) at the DSS 13 Venus station, Goldstone, California.

The hardware consists of two major assemblies, the Microwave Switch Control Interface (USCI) and the Microwave Switch Controller (USC). The USCI is a control room rack-mounted assembly which accepts high level inputs and initiates corresponding subsystem changes and/or responses. The USC accepts direction from the USCI and translates the software commands into hardware switch commands which configure the microwave system, then reports the results.

The software consists of individual modules which have distinct and separate functions. The modular structure of the software lends itself well to timely delivery and clarity as the software evolves in the development process.

The operator controls the microwave equipment by entering commands to the USCI from a local terminal. The system responds with acknowledgments and results of his inputs. The interface with the host computer has been planned, but due to schedule constraints the interface was not fully developed and implemented initially.

Additional refinements and developments to the monitor and control equipment are needed to improve this prototype and implement all the functions that are required of a fully automated and integrated subsystem controller. These refinements and developments would resolve interface, timing, executive control, interrupt, power failure and equipment failure problems that have not been fully solved. Future application of this control system to the Deep Space Network (DSN) presents additional challenges when the more complicated 64-m UWV subsystem is considered. The ability to communicate with up to 5 USC's will present some additional difficulties.

II. Hardware

The UWV subsystem controller functional block diagram is shown in Fig. 1. The USCI is the central focal point for all messages to and from the control room and interfaces with the local CRT terminal, the Host or station controller, the floppy disk memory and the USC.

The local CRT terminal provides the means for the operator to input commands or directives into the system, and receive response messages from the system. The physical interface between the local terminal and the USCI is a standard RS232C operating at 9600 baud. The station controller or HOST computer will also be able to input command to the USCI through the HOST interface. This physical input is the star switch standard interface also operating at 9600 baud.

The floppy disk memory provides permanent program storage for the USCI. During development the use of this disk drive was not intended to be a long-term solution to software storage but was an expedient short-term solution for the needed memory in light of schedule constraints. The drive will be replaced, as will be discussed later. The interface between the USCI and the floppy disk drive unit uses the disk control board and a standard 50-pin connector.

Transparent to the system but nevertheless important is the modem/fiber optic communications link between the USCI and USC. The Canoga Data Systems modems convert standard RS232C data and control signals to a stream of optical pulses for transmission over the optical cables. The data and handshaking signals are directly combined into a serial data stream. A light emitting diode driven by the data stream produces optical pulses which are carried over one of two channels in the optical cable extending from the control room up the antenna to the feedcone. At the feedcone the optical pulses are converted back to the standard RS232C data and control signals.

Internal to the USCI, a standard Intel rack mountable chassis, commercially available boards are used. A list of the boards is presented in Table 1. The intent of this design was to develop a system which used all standard components and avoided the use of special purpose boards, thus simplifying maintenance, sparing, and repairs.

The USC is the central focal point for the incoming commands, outgoing responses and the hardware command and indicate signals. The USC is mounted in the feedcone near the microwave equipment to be controlled. The interfaces to the USC are the USCI by way of the fiber optic link, the local CRT terminal (optional), two transmitter interlocks and inhibits, eight safety interlocks and 16 switch command and indicators.

The USC interface to the USCI is the same as was described for the USCI. The local CRT terminal is optional; that is, it is not needed for normal operations. Its main purpose is to provide local control if the feedcone were involved in ground test or if the USCI communication had failed and a direct control is needed for maintenance or other special tests. The USC was designed to interface with the two on-site transmitters. Through this interface, the transmitter indicates if the beam is on in order to inhibit the movement of critical switches in the transmit path. The interface also provides "safe to transmit" indication which means all critical switches and interlocks are in the correct configuration to radiate RF energy from either transmitter. The eight safety interlocks, which are part of the "safe to transmit" signal, monitor such items as feedcone doors, main dish hatch, nitrogen pressure, water flow, and three spares for expansion. The interface with the microwave equipment, such as waveguide switches, polarizer controllers, test oscillators and others, consists of 16 connectors, one connector for each component to be controlled.

The same philosophy of using standard commercially available boards was adopted for the USC. The USC assembly is a Hoffman enclosure. 24 × 36 × 10 inches. One of the key components within the USC is a bank of solid state relays. Half of the bank is devoted to switch command function; the other half is devoted to the indicated functions. Through these relays the software programs command and sense the switch functions. The boards used in the USC are listed in Table 2 along with their descriptions and functions.

III. Software

The software for the USC and USCI was planned and developed in a modular form. The design approach expedited timely delivery and enhanced the clarity of the final software. For each module, a sufficiently detailed description was first generated so that coding could subsequently take place entirely from the description. Each description discussed six categories:

(1) The functional description addressed what the module was to accomplish.

(2) The entry requirements addressed the inputs to the module and the assumptions made of the outside world.

(3) The results provided were the output from the module and the assumptions made of the outside world.

(4) The exceptions enumerated the error conditions detected in the module and indicated any errors encountered.

(5) The external effects addressed the observable effects such as reading a file, displaying something on a CRT, and interacting with the physical environment.

(6) The processing addressed and expanded on the algorithm, explanatory remarks and the sequence of the steps of the algorithm used in the routine.

The flow charts in Figs. 2, 3, 4, and 5 illustrate the modular nature designed into the software structure. Figure 2 shows the flow for the initialization, self-test and executive routine of the USCI. Figure 3 expands the USCI executive routine into its major functions. Figure 4 shows the initialization, self-test, and executive routine for the USC. Figure 5 expands the executive routine into its major functions. A description of the software modules, along with the major subroutines, their location and brief functional narrative is given in Table 3.

IV. Venus Site Application

The prototype X- and S-band uplink controller was installed into the second-generation common aperture feedcone XSU at DSS 13 during November 1981. The functional block diagram of the microwave subsystem is presented in Fig. 6.

This feed incorporated a geometrically symmetrical common aperture feedhorn and combiner which operates at both X- and S-band. Its capabilities include S-band transmit from 2110 to 2120 MHz and receive from 2200 to 2300 MHz and X-band transmit from 7145 to 7235 MHz and receive from 8200 to 8600 MHz with fully independent diplex functions.

The S-band labyrinth and combiner provide the "hard wired" right circular polarization while the X-band motorized polarizer can select either right or left circular polarization.

A combination of waveguide and coax switches as well as the motor driven polarizer is controlled by the microwave subsystem controller to configure the system. The useful system configurations were defined and mode names were assigned to allow a desired mode to be selected by simply specifying a mode name at the CRT terminal. Such modes could direct the RF energy from the transmitter into the water load or toward the feedhorn. Calibration signals can be routed from the signal sources to the TWMs. System noise calibrations are achieved by switching the TWM input between the feedhorn and the calibrated ambient load. Most useful configurations are accommodated by operator input of the desired mode. For those configurations not planned, the control system will accept changes to the hardware as specified by the MODIFY command.

The feed system will accommodate 20 kW of Rf radiated power at both S- and X-band. Safety interlocks and waveguide switch positions are monitored by the USC. From this information, "safe to transmit" or "inhibit" signals were designed to be sent to the transmitter through the transmitter interface and status reports to the operator, but due to the lack of field experience with software interlocks, a system of relay logic was implemented as a proven, reliable method of ensuring RF safety of personnel and equipment.

V. Operator Interfaces

The operator may input commands to the microwave controller from either the local CRT terminal or from the station control terminal through the star switch interface. In November 1981 the star switch and station controller interface were not operational, so the local CRT terminal was the only viable means with which to interface with the USCI.

To communicate with the microwave subsystem controller, the operator has seven basic commands at his disposal for either the USC or the USCI. From these basic commands he can configure and modify the signal flow, change the polarization and inject test signal and noise signals for calibration. He may also request assistance to better understand the commands and modes at his disposal. He may inquire as to the health and status of the equipment or completely initialize the system.

Operator input of long command names could be a source of errors and delays in configuring any computer-controlled equipment, so a command name recognition scheme was developed. The command names can be abbreviated down to as few characters as needed to uniquely identify them. For example, CON is sufficient to uniquely identify CONFIGURE, since no other command begins with that letter sequence. The alternate command name text, CFG, is included for that particular command in order to handle entry of this commonly used abbreviation. Multiple word command designators can be similarly shortened. For example, ST COM successfully selects STATUS COMPRESSED. All characters typed in are verified against the referenced command, and misspelled command names, in whole or in part, are not accepted.

VI. Additional Developments

The antenna microwave subsystem controller has been in operation at the Venus site for almost a year with no major problem. Operator acceptance of the commands and responses has been good and no operational difficulties have been encountered.

The implementation of this prototype has demonstrated that some areas need additional development. Some modifications are needed to this prototype to meet all the desired functions required to provide full control to the station controller and to provide the flexibility to accommodate changes to the microwave system.

The communication package used between the USC/USCI should operate under interrupt control. Preliminary software has been written to implement this interrupt control package and simulation tests have proven successful. As time permits, this package will be integrated into the prototype at the Venus site and fully tested.

The area of software interlocks with the transmitter and station operator needs some improvements. The total software control of interlocks and inhibits may not be advisable but some software monitoring and automatic reporting as a back-up function should be considered. To accomplish these changes in a real-time executive program would result in timing questions to be resolved, because such a fail safe system requires periodic servicing within some time limits.

Most DSN systems change or evolve as the requirements change. To accommodate such changes the system-dependent data such as switch functions, channel assignments and configuration should be designed into table form. These tables should be readily adaptable to additions and changes. To implement a change, the data tables should be confined or isolated to a limited set of memory hardware. This gives the implementer the opportunity of changing the data table in the particular set of ROMs without disturbing any software routines. The field changes to the configuration control equipment will consist of replacing a relatively few number of ROMs containing configuration data tables without replacing the entire software programs. The operating programs should not be hardware dependent. After a given modification the man-machine interface should be no different except for the additions of the new equipment.

A maintenance routine is needed to cycle failed equipment for possible recovery. This routine would be called automatically if a switch failed to arrive in the commanded position. The switch would be commanded to reverse its direction, then return to the commanded position. After such an exercise, if the switch again failed, then the operator would be advised.

The USCI operating programs need to be transferred to PROMs and installed within the USCI chassis. The system has performed well using the floppy disk drive but a more permanent long-term solution is required.

Acknowledgment

The author would like to acknowledge the work of Dave Nixon and Prentiss Knowlton, who devoted their time and effort to produce this first-generation Microwave Subsystem Controller.

References

1. Withington, J. R., "Second-Generation X/S Feedcone: Capabilities, Layout and Components, *TDA Progress Report 42-63,* pp. 97-103, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1981.

Table 1. Single board computer cards for the USCI

Part number	Card description	Function
BLC-80/204	CPU	Program control
BLC-8064	RAM, 64K	Read/write memory for USCI
iSBC-534	Serial I/O 4 channels	USCI-USC communication, local maintenance, terminal interfaces
BLC/8201	Disk control	Floppy disk program, memory control

Table 2. Single board computer cards for the USC

Part number	Card description	Function
BLC-80/204	CPU	Program control
BLC-8064	RAM, 64K	Read/write memory
BLC-8432	ROM, 32K	Read only memory
iSBC-534	Serial I/O 4 channels	USCI-USC communication, local maintenance, terminal interfaces
SBC-519	Parallel I/O	Switch commands and indicates

Table 3. Software Module Descriptions

Routine name	Incorporated in	Description
BAD COMMAND		
BAD & CMD	USC/USCI	Reports unrecognizable commands to operator
CONFIGURE		
USCCFG	USC	Processes the USC configure command, verifies that it has been correctly specified, and that the functions can be performed before exeucting the command
DEBUG		
DEBUG	USC/USCI	Provides software debugging as a tool for program development
DIRECTORY		
USI DIR	USCI	Processes the USCI Directory command, verifies that it has been correctly specified, and displays detailed information to the USCI operator
EXEUCTIVE COMMAND		
USI	USCI	Main executive program for the USCI which handles operator interaction through the maintenance terminal as well as the machine interaction through the Host, in order to process the high level requests for microwave switch control and to translate to the low level requests for processing by the USC. Status information is translated to high level responses.
USC	USC	Main executive program for the USC which handles operator interaction through the maintenance terminal as well as the machine interaction through the USCI, in order to process requests for microwave switch control for up to 16 four-position switches
HELP		
USIHLP	USCI	Displays helpful information on USCI operation to the operator
USCHLP	USC	Displays helpful information on USC operation to the operator
INITIALIZE		
USIINI/USCINI	USC/USCI	Performs initialization after a power up, or as a result of processing the initialize command
MODIFY		
USIMOD	USCI	Processes the USCI MODIFY command, verifies that it has been correctly specified, and passes a detailed modification specification to the USC via the MODIFY command
SELF TEST		
MTEST	USC/USCI	Provides memory test and report errors to operator
STATUS		
USISTS	USCI	Generates a USCI switch status report for the operator
USISTI	USCI	Generates a USCI interlock status report for the operator
USISTC	USCI	Generates a USCI compressed status report (typically for use by a higher level processor)
USCSTC	USC	Generates a USC compressed status report (typically for use by the USCI)
USCSTA	USC	Generates a USC status report for the operator (typically at the maintenance terminal)
TRANSFER		
USITRA	USCI	Processes the USCI transfer command, verifies that it has been correctly specified, and passes a detailed configuration via the configure command down to the USC.

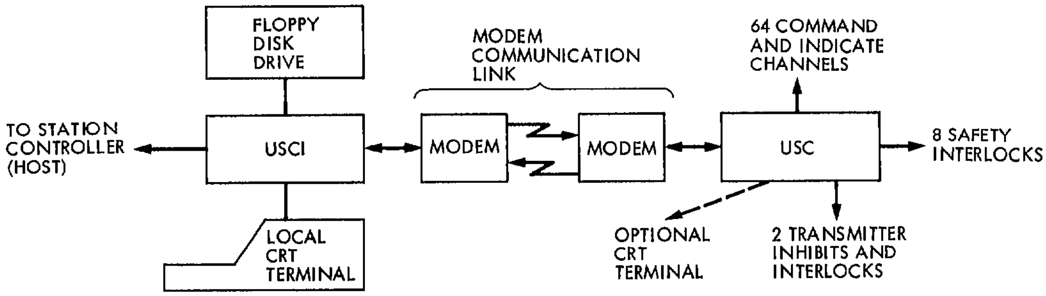

Fig. 1. Antenna Microwave Subsystem Controller functional block diagram

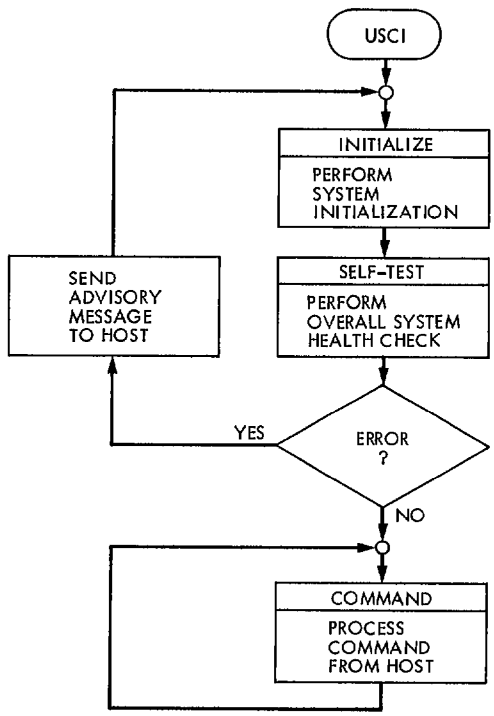

Fig. 2. USCI software flow diagram: Initialize USCI and process USCI command sequence

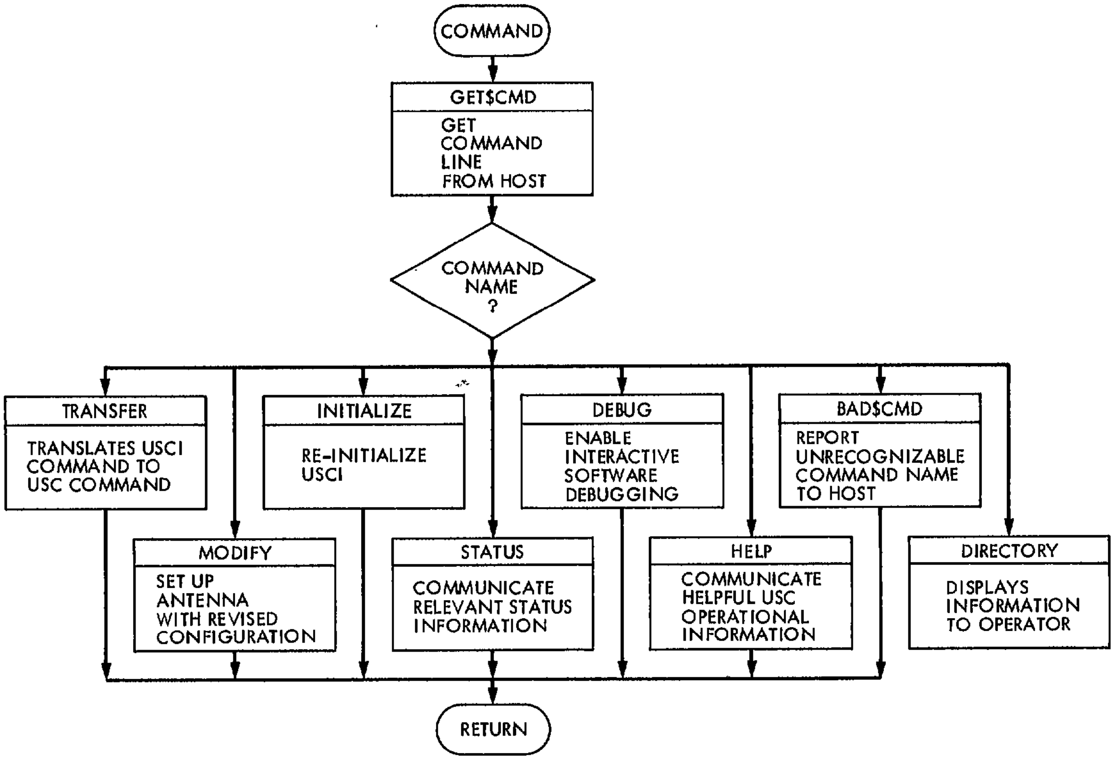

Fig. 3. USCI software flow diagram: Process command from Host

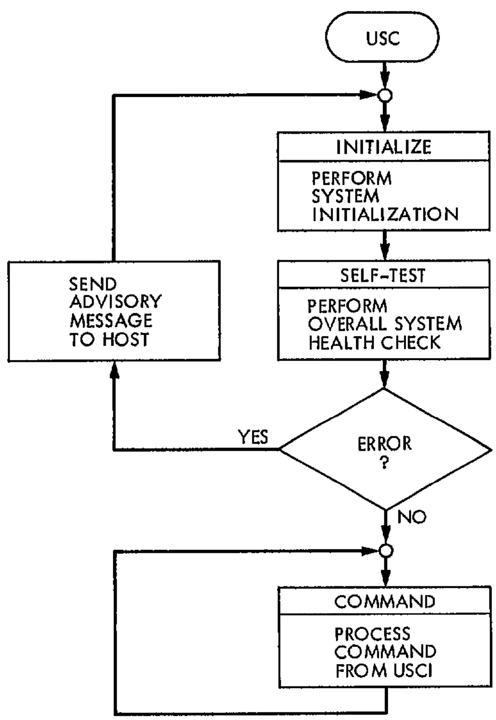

Fig. 4. USC software flow diagram: Initialize USC and process USC command sequence

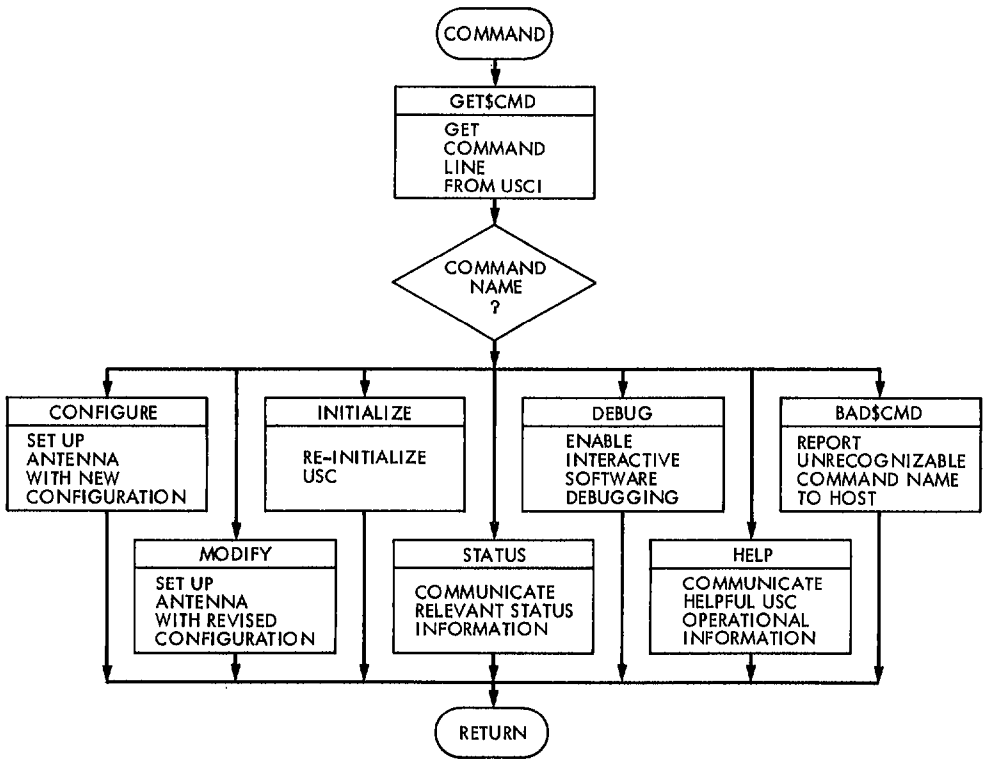

Fig. 5. USC software flow diagram: Process command from USCI

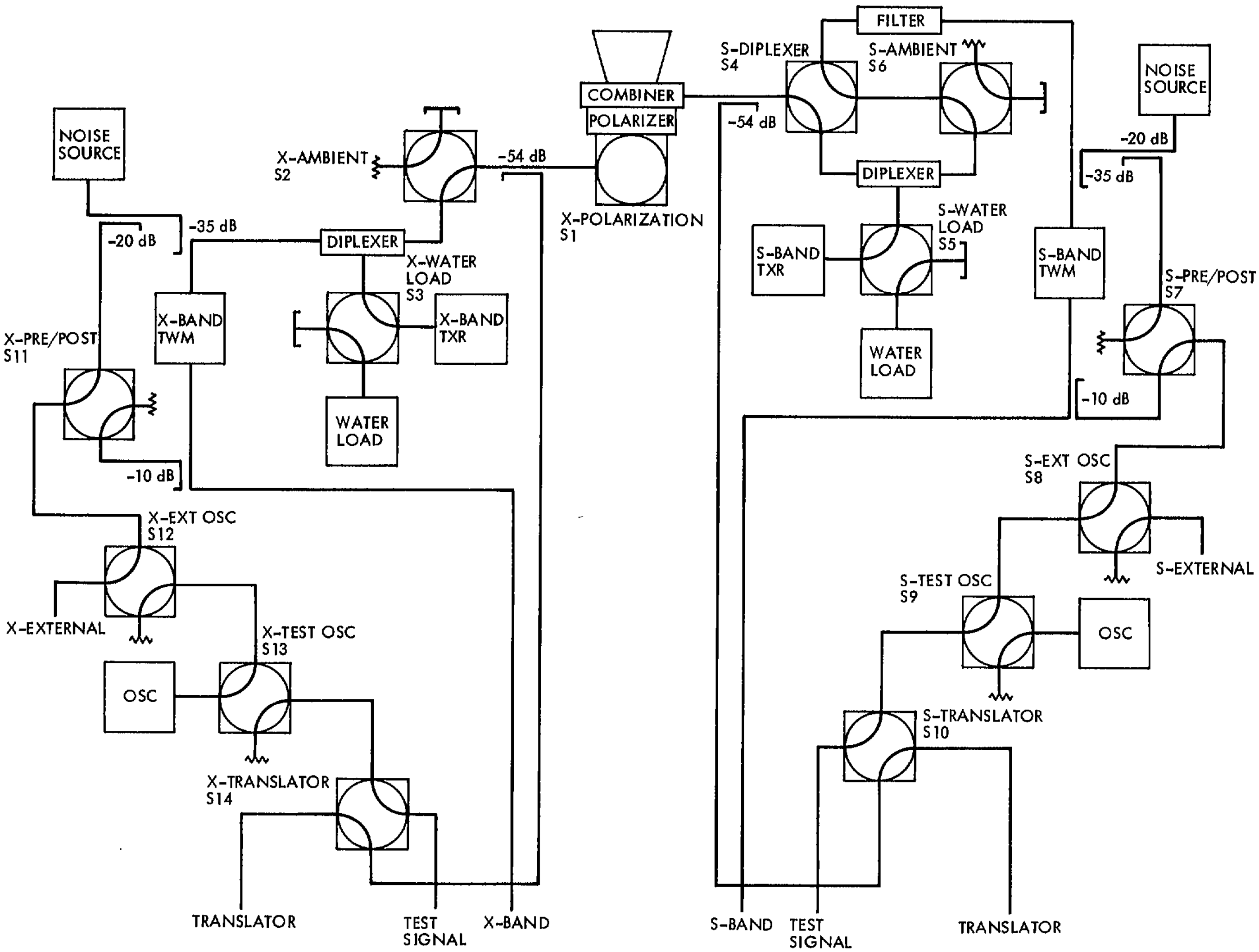

Fig. 6. Antenna Microwave Subsystem functional block diagram for the feedcone