S-X 34-Meter Conversion Receiver and Microwave Performance

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The S-X 34-meter conversion provides for upgrading a subnet of three stations to a 34-meter antenna aperture and adding X-band receive capability. This subnet will consist of DSSs 12, 42, and 61. Implementation of DSS 12 was completed in October 1978. A description of the conversion as applied to the antenna microwave and receiver subsystems is given. Performance requirements and test results are included.

I. Introduction

The conversion of the first 26-meter station, DSS 12, to a 34-meter aperture with X-band receive capability added to the existing S-band uplink and downlink has now been completed. The additional antenna gain afforded by the enlarged aperture increases the usefulness of the station to the Voyager mission and other outer planet missions and enhances the capability of the 34-meter station to offload the 64-meter subnet during cruise modes. The X-band receive capability is needed to provide adequate data returns from the outer planets and improve immunity from the increasing incidences of radio frequency interferences that have been occurring at S-band. Two additional 26-meter stations, DSS 42 (Australia) and DSS 61 (Spain), will be completed in May 1980.

II. Description

The principal modifications involved in the S-X conversion project are in the antenna mechanical, the antenna microwave, and receiver-exciter subsystems. The microwave and receiver-exciter subsystems are the subject of this report. An overall description of the program is given by Ref. 1. A block diagram of the RF subsystems is shown in Fig. 1.

The antenna microwave subsystem (UWV) modifications subdivide into three prime areas:

(1) The microwave S/X-band feed assembly.

(2) The X-band maser and associated instrumentation.

(3) A new microwave switch configuration assembly.

During the initial phase of the S-X 34-meter conversion program, a significant effort was expended in studying the optimum feed system configuration, the RF optics design, and the predicted gain and noise temperature performance of the 34-meter antenna. The outcome of this study was the choice of a previously developed and demonstrated dual-band feed system employing separately located feeds combined in a reflex-dichroic reflector arrangement. A particularly compact design was chosen, minimizing aperture blockage for optimum performance. The details of the design study are given in Ref. 2.

At the conclusion of the design study, the detail arrangement of the dual-frequency feed cone (SXD) was initiated. Two detailed progress reports have been previously given for the SXD cone assembly in Refs. 3 and 4. The latter report includes a description of the high-powered diplexing tests conducted at the microwave test facility at Goldstone, and the test results measured there. The performance requirements for the microwave portion of the S-X 34-meter conversion are given in Table 1.

A new X-band maser and supporting instrumentation have been added as a part of the S-X 34-meter conversion. The amplifying portion of the X-band maser is identical to the operational maser which has been reported previously in Ref. 5. The maser includes a super conducting magnet for improved gain and phase stability. The closed cycle cryogenic system is identical to that used previously. The maser amplifier assembly has been repackaged, however, to afford a more compact and flexible packaging arrangement. Several new instrumentation features have been incorporated, which include a serial communication link for ground-to-antenna controls and monitoring signals, a new type of X-band monitor receiver, and a built-in X-band test signal source for adjustment and calibration of the maser amplifier. A more detailed progress report will be issued on the S-X 34-meter conversion maser system at an early date. The performance requirements for the X-band maser are given in Table 2.

The UWV switch control group for the 34-meter S-X conversion has been completely redesigned to be compatible with centralized station control and monitoring. This group of equipment establishes the RF signal routing within the antenna microwave subsystem. Waveguide and coaxial switches are commanded to the desired configuration, while interlock switches associated with equipment and personnel protection prevent the application of beam voltage to the transmitters until all safety conditions are established. Once beam voltage is applied, further movement of critical microwave switches is automatically prevented.

The control and monitoring of the microwave switches and transmitter interlocks are accomplished from either the DSS Data System Terminal assembly (DST) or a local control keyboard within the switch control equipment. A local graphics display is also provided for the local operator. A number of permanent standard configurations are available from the switch control equipment. Each configuration is identified by a standard alphameric name. The graphics display presents a detailed block diagram associated with the selected configuration. The configuration name and various monitor functions are also displayed. Figure 2 shows a typical configuration display entitled "M1TRK."

Manual pushbuttons have been provided in the antenna electronics room for local control of each individual microwave switch. This provision is useful for servicing, maintenance and other manual switch operations. Reference 6 provides more details of the microwave switch control equipment. A progress report on this portion of the system is planned for the near future.

The addition of an X-band receive capability at the 34-meter antenna stations requires the addition of another microwave element, a fourth harmonic filter. This element is actually a part of the transmitter subsystem. The purpose of this filter is to highly attenuate the fourth harmonic output from the S-band klystron amplifier. This harmonic signal is near the amplifying frequency range of the X-band maser and must be suppressed to prevent interference with the normal X-band reception performance.

The most cost-effective method of providing X-band receive capability was determined to be the addition of an X- to S-band down converter inserted in front of the existing Block III receiver. The coherent reference for the down converter is obtained through appropriate frequency multipliers and dividers which are driven from the exciter synthesizer. As can be seen from Fig. 1, each Block III receiver may select either an S-band signal from the S-band maser or an X-band signal which has been down converted to S-band.

In addition to the X- to S-band down converter, the S-X 34-meter conversion also included the addition of an X/S-band translator to provide either S-band or X-band coherent test signals and the addition of the doppler extractors, as shown in Fig. 1. The performance requirements, specifications, and test data associated with the S-band receiver are given in Table 3. A more detailed discussion of the receiver conversion is presented in Ref. 7.

III. Installation

The S-X 34-meter conversion at DSS 12 was completed in October 1978. Post-installation test results are indicated in Tables 1, 2, and 3. With the exception of the X-band gain performance, all RF test results demonstrate that the design requirements have been successfully met. The X-band antenna gain performance is still being investigated with the primary emphasis on the condition of surface panels of the main reflector. This investigation is being pursued as station scheduling time permits.

References

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Table 1. SXD cone assembly performance requirements and test data

Parameter	S-band Transmit	S-band Receive	X-band Receive	Notes
Frequency, MHz	2110 ± 10	2285 ± 15	8420 ± 20	
Gain, dBi				
Required	55.3 ± 0.7	$56.1\ ^{+0.3}_{-0.9}$	$66.9\ ^{+0.3}_{-0.9}$	
Test	Note 1	56.2	65.7	See Note 2
Diplexed system noise temperature, K				
Required		27.5 ± 2.5	25.0 ± 3.0	
Test		Note 3	24.0	See Note 4
Listen only system noise temperature, K				
Required		21.5 ± 2.5	–	
Test		21.6	–	
System noise increment 30° elevation to zenith, K				
Required		–	5.0	
Test		–	4.0	See Note 5

Notes:

1. Transmit antenna gain has not been verified by test.
2. X-band receive gain is still under investigation. The reflector surface panels are to be reset in the near future.
3. Adequate test data are not yet available.
4. It is expected that further refinement of the X-band system temperature to 23 K may result as more test data become available.
5. Measured increment of 4 K is based upon limited amount of test data.

Table 2. X-band maser performance requirements and test data

Parameter	Requirements	Test
Frequency, MHz	8420 ± 20	8420 ± 20
–1 dB bandwidth, MHz	40	53
Gain stability, dB peak-to-peak		
Short term, 10 seconds	0.06	0.04
Long term, 12 hours	1.0	<1.0
Moving, 0.2 deg/s max	1.0	0.6
Equivalent noise temperature, K	8 ± 2	7.7 at 8400 7.7 at 8420 9.9 at 8440

Table 3. Receiver performance requirements, specifications, and test data

Parameter	Requirements	Specifications	Test
Frequency range	8.4-8.44 GHz	8.4-8.44 GHz	8.4-8.43 GHz[a]
Noise figure	<10 dB	<10 dB	8.0 dB
Doppler phase error noise	<12 deg	<12 deg	8 deg
Doppler shift during mission lifetime	80 km/s	80 km/s (X = 4.51 MHz) (S = 1.267 MHz)	X>4.6 MHz S>4.6 MHz
Doppler shift during single pass	1.0 km/s	1.0 km/s (X = 56.3 kHz) (S = 15.4 kHz)	150 kHz
Doppler rate near Earth	100 m/s^2	100 m/s^2 (X = 5630 Hz/s) (S = 1540 Hz/s)	5630 Hz/s with 32-deg phase error
Doppler rate planetary encounter or orbit	0.1 m/s^2 (<10° error when 10 dB above receiver 12-Hz threshold)	0.1 m/s^2 (X = 5.63 Hz/s) (S = 1.54 Hz/s)	<10-deg phase
Doppler stability 5×10^4 second averaging	0.4 m	0.4 m X = 8100 deg	625 deg[b]
Group delay	1.4 m	1.4 m (9.3 ns)	0.5 ns[b]
X-band translator output	–50 dBm min	–50 dBm min	–34 dBm

[a]8.43 – 8.44 GHz noncoherent mode.
[b]Added instability due to S-X conversion over $\Delta\tau$ of 5°C.

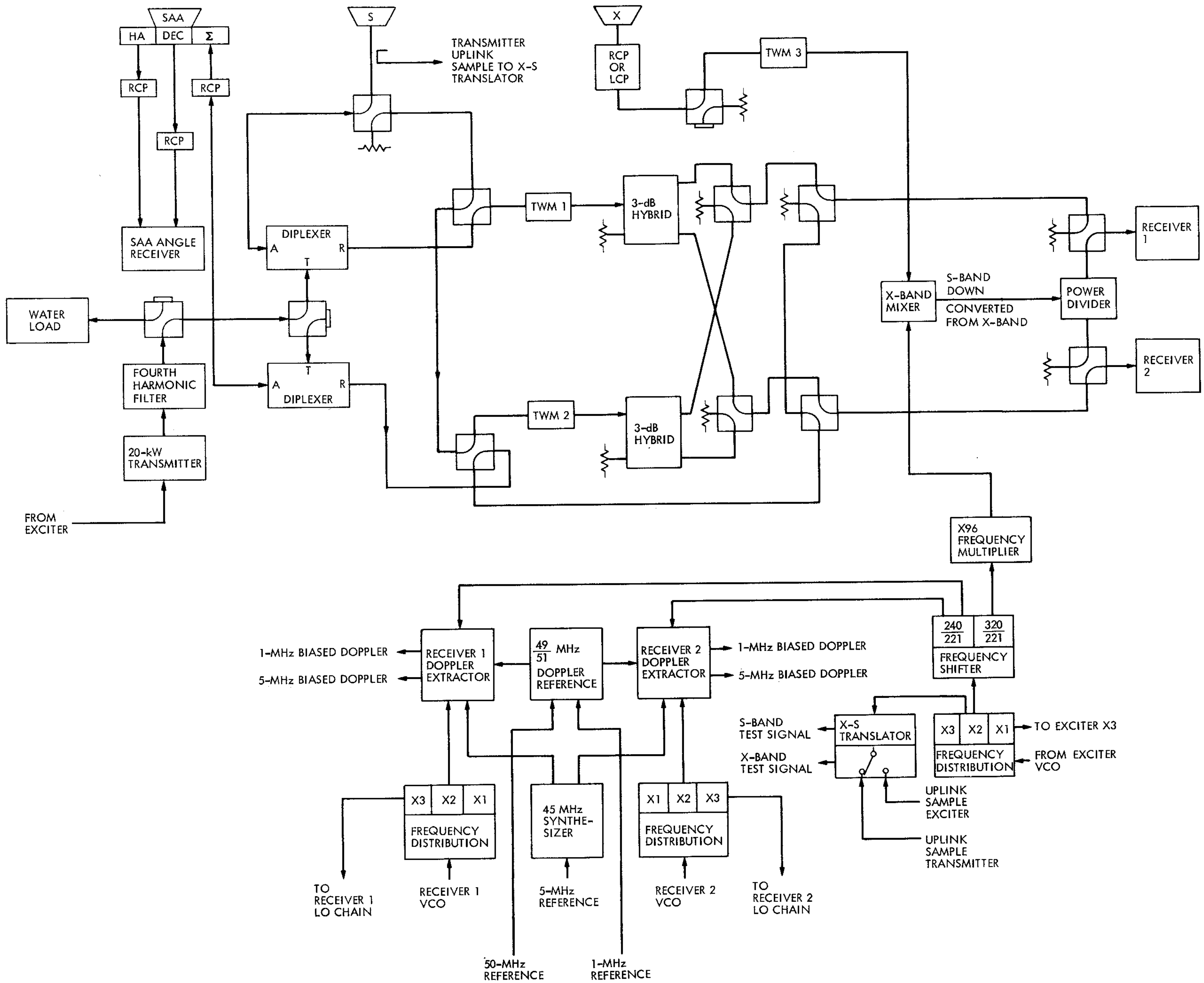

Fig. 1. RF subsystems simplified block diagram

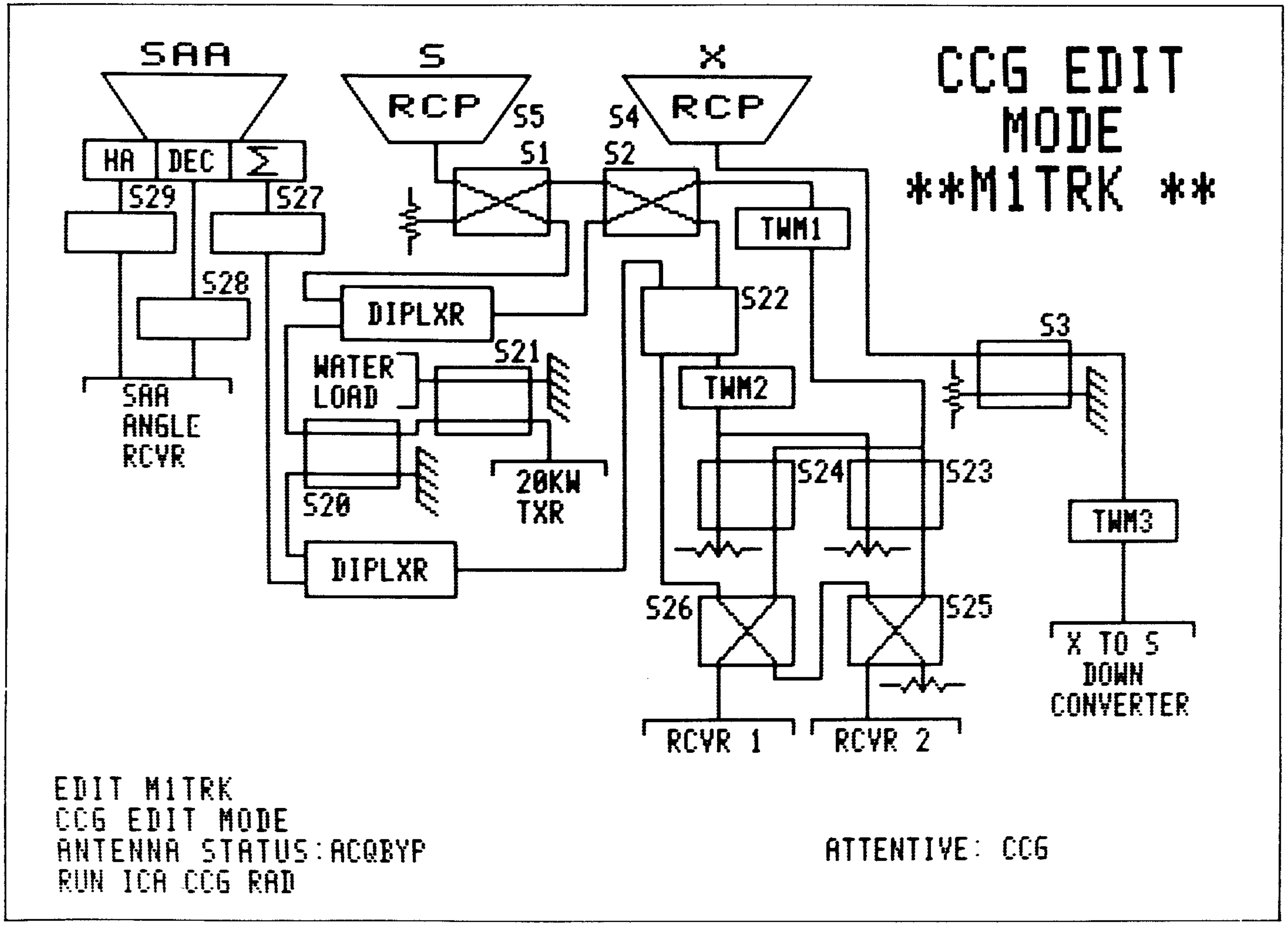

Fig. 2. Switch control standard configuration mode CRT display