DSN Telemetry System, Mark III-77

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This article provides a description of the DSN Telemetry System, Mark III-77, which is now being used to support multiple deep space missions. Telemetry functions performed by the Deep Space Stations, Ground Communications Facility, and the Network Operations Control Center are defined. Recent improvements to the system and planned upgrades are described.

I. Introduction

The Deep Space Network Telemetry System is implemented by means of incremental additions and modifications to provide multiple-mission support to a variety of planetary and interplanetary flight projects. The current system, designated Mark III-77, provides support for:

(1) Pioneers 6 through 9.

(2) Pioneers 10 and 11.

(3) Helios A and B.

(4) Viking.

(5) Voyager 1 and 2.

(6) Pioneer Venus.

This Mark III-77 configuration is derived from the Mark III-75 configuration (Ref. 1), which supported Viking, Helios, and Pioneer projects.

II. System Definition

The DSN Telemetry System provides the capability to acquire, process, decode, and distribute deep space probe telemetry data. Telemetry data are defined as consisting of science and engineering information modulated on radio signals transmitted from the spacecraft.

The DSN Telemetry System, Mark III-77, performs three main functions:

(1) Telemetry data acquisition.

(2) Telemetry data conditioning and transmission.

(3) Telemetry System validation.

Telemetry data acquisition consists of those functions necessary to extract the telemetry information modulated on the downlink carrier(s) of the spacecraft. Telemetry data conditioning and transmission consist of those functions necessary to decode, format, record, and transmit the data to users. Telemetry System validation consists of those functions necessary to validate the performance of the Network in the acquisition, conditioning, and transmission of telemetry data. Verification of correct system performance is made and corrective action is taken when such performance does not meet specifications.

III. Key Characteristics

The key characteristics of the DSN Telemetry System, Mark III-77, consist of:

(1) High rate X-band telemetry capability at both a 34-m and a 64-m subnet.

(2) Maximum likelihood decoding of short-constraint-length convolutional codes at all Deep Space Stations.

(3) Replacement of the Telemetry and Command Processor with a dedicated processor for telemetry, the Telemetry Processor Assembly (TPA).

(4) Centralized monitoring and control of the DSN Telemetry System by the Network Operations Control Center (NOCC).

(5) Real-time reporting of DSN Telemetry System status through the DSN Monitor and Control System.

(6) Low-loss on-site recording at selected DSS of predetection analog records with non-real-time playback.

(7) Production of a digital telemetry Original Data Record (ODR) at each DSS with playback via local manual control or in automatic response to recall requests.

(8) Simultaneous reception and recording of five carriers at selected DSS.

(9) Replacement of the Data Decoder Assembly (DDA) and incorporation of its functions into the TPA.

(10) Increased high-speed data (HSD) line rate to 7200 bps, and wideband capability up to 230 kbps (selected DSS).

(11) Stand-alone fault detection and self-test capability.

(12) Generation of a telemetry Intermediate Data Record (IDR), a time-merged record of all received data.

IV. Functional Description

A simplified block diagram of the system is shown in Fig. 1.

Standards and limits messages (predicts) are initially generated at the NOCC for high-speed data line (HSDL) transmission to the DSS for the purpose of selecting the proper data modes and configurations. Such messages consist of predicted signal levels, tolerances, data mode, and system configuration information.

At the Deep Space Station, the received spacecraft signal is amplified by the Antenna Microwave Subsystem (UWV). The RF carrier is tracked by the Receiver-Exciter Subsystem (RCV) and the sidebands are routed to the Subcarrier Demodulator Assembly (SDA). The subcarrier is regenerated by the SDA and the data are demodulated. The resulting data stream is passed to the Symbol Synchronizer Assembly (SSA). Coded data are decoded, either in special decoder assemblies or by software in the Telemetry Processor Assembly (TPA), depending on code type and data rate. All data are formatted for high-speed or wideband data line transmission by the TPA.

An Original Data Record (ODR) of the decoded data is then written by either the TPA for high rate data, or the Communications Monitor and Formatter Assembly (CMF) for low rate data. The data are passed to the high-speed or wideband buffer, depending upon the data rate.

The data are then transmitted to the Mission Control and Computing Center (MCCC) or Remote Mission Operations Centers (RMOC), and in parallel to the NOCC. At the NOCC, a limited amount of decommutation of telemetry data is performed to analyze system performance and to obtain certain spacecraft parameters useful in controlling the Network. The NOCC also receives and displays DSN Telemetry System parameters.

A log tape containing all data received at the NOCC, either in real-time or by recall, is generated by the Network Log Processor (NLP). This log is the Network Data Log (NDL). The Data Records Assembly provides for the recall of data from the station ODRs and for merging the recalled data with data on the NDL. It also provides for the generation of the IDR.

A special configuration at DSS 14 and DSS 43 for the Pioneer Venus 78 entry mission allows simultaneous reception of five carriers and processing of four carriers in real-time. For backup purposes, four open-loop receivers are used with band-pass filters and an analog recorder. This combination allows for recording a wideband spectrum around the anticipated carrier frequencies of the four atmospheric probes. In non-real-time, these data can be played back and converted up to

S-band for reception and processing by conventional receiver-SDA-SSA-TPA telemetry equipment.

DSN Telemetry System performance is validated by the NOCC Telemetry Subsystem Real Time Monitor (RTM) processor in response to the controls and standards and limits applied from DSN Operations personnel in the Network Operations Control Area (NOCA). Telemetry System alarms, status, and data are transmitted from the NOCC Telemetry RTM to the NOCC Display Subsystem. DSN Telemetry System alarms and status are also transmitted to the DSN Monitor and Control System and are included in the Network Performance Record (NPR). A DSN Telemetry System Performance Record (SPR), containing status and alarms, is maintained for non-real-time analysis. The SPR also contains a list of all telemetry data gaps. This list is used by the Data Records Assembly to compose recall requests from the station ODRs.

The DSN Test and Training System is used to provide simulated DSN Telemetry System data for the checkout of the system and for the training of DSN personnel.

V. System Configurations

The current configurations of equipment comprising the DSN Telemetry System are shown in Fig. 2.

A. DSS Functions and Modifications

1. RF carrier reception and power measurement. Receiver and low-noise maser amplifiers are provided at each DSS, with full backup capability. At the 64-meter DSSs, both S- and X-band capability is provided. Starting in 1978, it is planned to augment one 26-meter subnetwork (DSS 12, 42, and 61) to 34-meter diameter and to add X-band receiving capability.

The receivers are calibrated with test transmitters, and the Automatic Gain Control (AGC) is monitored to provide a measure of received signal level. Starting in 1978, precision signal power measurement equipment will be added to each DSS to provide continuous output of received carrier signal power and also system noise temperature.

2. Subcarrier demodulation. At 64-meter DSSs, demodulators are provided for two subcarriers per carrier. Only a single subcarrier is envisioned at the 26-meter DSSs, although a second can be accommodated by using the backup equipment.

3. Symbol synchronization. Symbol synchronizers are available for each telemetry stream, operating from 8 to 250,000 symbols per second. The symbol synchronizers are operated automatically under software control from the Telemetry Processing Assembly (TPA).

4. Decoding. Channel decoding is provided for biorthogonal block codes and for convolutional codes of either long or short constraint length:

(1) *Block Codes*: 32, 6 biorthogonal codes are handled by the Block Decoding Assembly (BDA) equipment at 64-meter DSS at data rates up to 16,000 bits per second. At other DSS the block decoding is performed by TPA software, limited to a maximum output rate of 2000 bps.

(2) *Convolutional Codes – Long Constraint*: These codes are sequentially decoded by the Faro algorithm, using TPA software (Ref. 2). Output rates up to 4000 bps can be handled.

(3) *Convolutional Codes – Short Constraint*: These codes are decoded by maximum-likelihood convolutional decoding equipment (MCD) at each DSS (Ref. 3). Output rates up to 250,000 bps can be handled by this equipment.

5. Data handling and formatting. Two new processors combine to perform these functions, the Telemetry Processing Assembly (TPA) and Communications Monitor and Formatter Assembly (CMF). As indicated in Fig. 2., these assemblies are provided with backups. The functions performed by these assemblies for all received telemetry data are as follows:

(1) Format the data into standard communications data blocks.

(2) Interlace partial status data into the data blocks. Partial status includes lock indicators, configuration codes, signal level, and signal-to-noise ratios.

(3) Generation of Original Data Records (ODR).

(4) Output data blocks on high-speed and wideband circuits as appropriate. The CMF handles high-speed interface; the TPA handles the wideband. A temporary ODR (TODR) is maintained on disc to insure that the transfer of data between TPA and CMF is accomplished without loss of data.

(5) ODR replay.

B. GCF Functions and Modifications

1. Data Transmission. GCF high-speed circuits have been upgraded to 7200-bps rate. Wideband circuits run at several rates depending on the DSS involved (Ref. 4). Error detection is provided on all data blocks.

2. Data Records. All telemetry data blocks transmitted to flight projects are also logged on tape in the Central Communications Terminal at JPL. Provision is made also to recall missing data from the station ODRs and to merge the recalled data blocks with those extracted from the central log. This merged record can be supplied to flight projects and is called the Intermediate Data Record (IDR). The details of Telemetry Data Records are described in Ref. 5.

C. NOCC Functions and Modifications

The function of the NOCC for Telemetry is to validate the performance of the DSN. Specifically, the following functions are performed for every active Deep Space Station and telemetry stream:

(1) Monitor the Telemetry System configuration and generate alarms when the configuration departs from that planned.

(2) Detect status and anomalies and generate displays and alarms.

  (a) Time tag errors.

  (b) Frame sync status.

  (c) DSS lock indicators, signal-to-noise ratios, and signal level.

  (d) Missing or defective data.

  (e) Channel decoder performance.

(3) Decommutate each telemetry stream, at least to the major frame level. Analysts in the Network Operations Control Area have the capability to select for display up to four measurements or data fields from each stream.

(4) Generate a gap list for each stream. This is used in recalling data from the DSS (Ref. 5).

D. Planned Improvements

This article describes the current configuration of the DSN Telemetry System as of October 1977. Improvements to this system are already being designed, including:

(1) Augmenting of one subnet of 26-meter DSSs (one each at Spain, Australia, and Goldstone, California), to 34-meter diameter and to include X-band operation.

(2) Capability to combine the receiver baseband outputs from two or more DSSs at one location to provide an effective increase in signal-to-noise ratio by "arraying" the antennas. This capability will be used to enhance the Voyager project Saturn encounter.

(3) Precision signal power and system noise temperature measurement capability.

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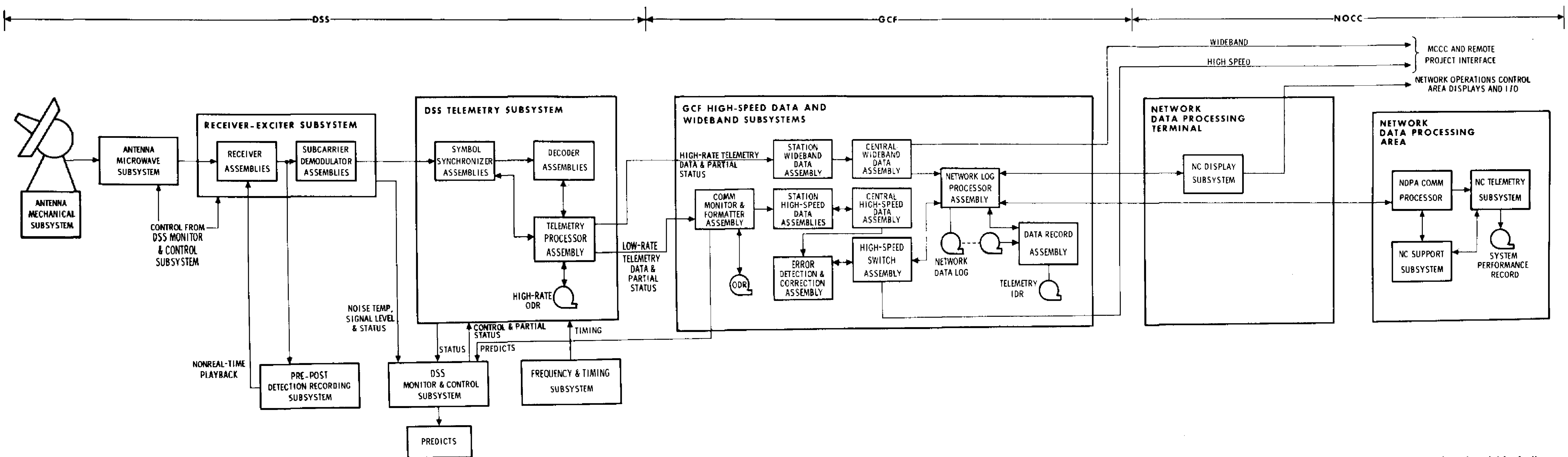

Fig. 1. DSN Telemetry System, Mark III-77, functional block diagram

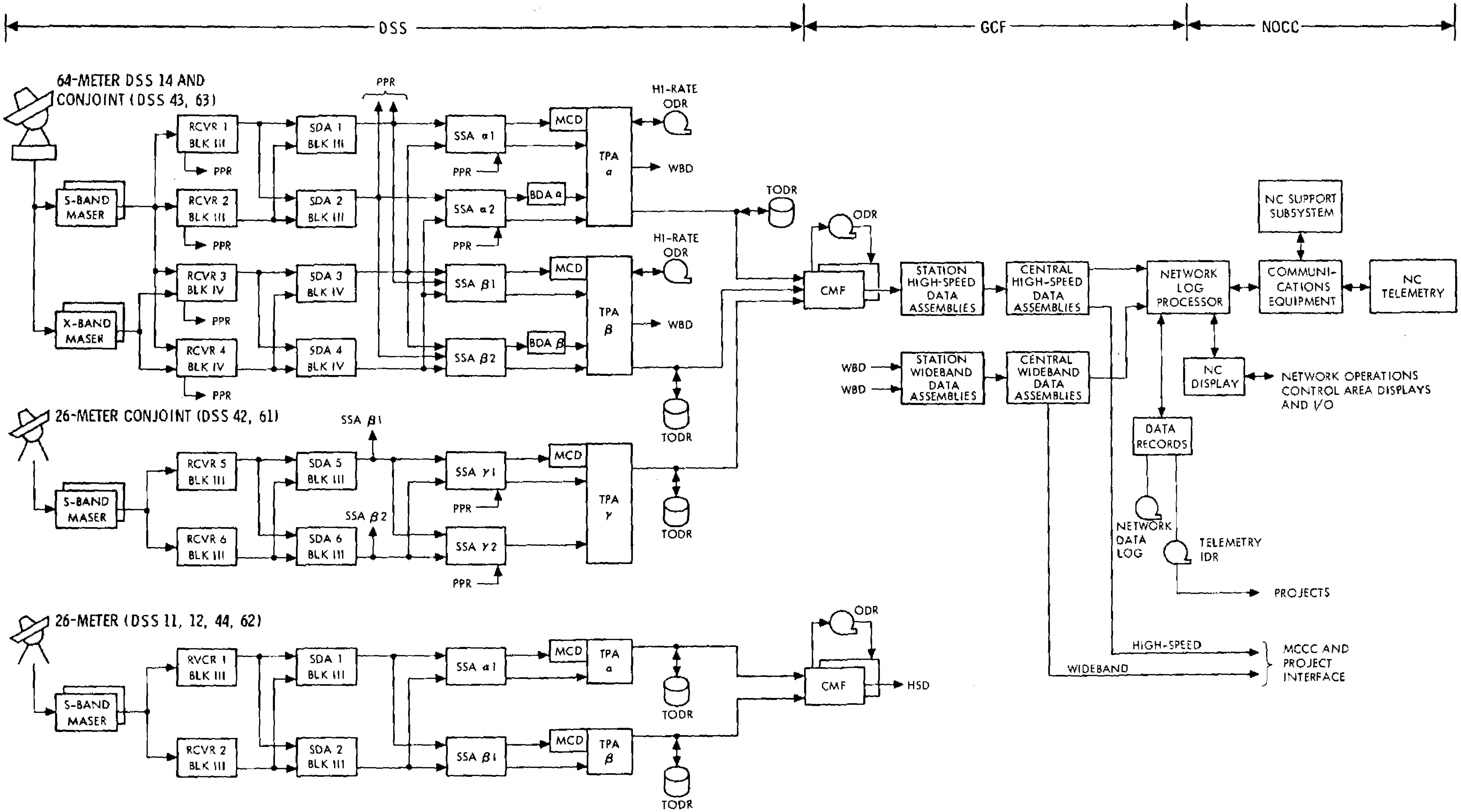

Fig. 2. DSN Telemetry System, Mark III-77 configuration