Voyager Support

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This is a continuation of the Deep Space Network report on tracking and data acquisition for Project Voyager. This report covers the Jupiter encounter period for Voyager 1, from 1 January through March 1979.

I. Voyager Operation – Status

Voyager 1 made its closest approach to Jupiter and its largest satellites on the morning of March 5, 1979, 18 months to the day after its launch. This event was preceded by the Observatory Phase, which started on 4 January 1979, and was followed by the Movie and Far Encounter Phases. The closest Encounter Phase was followed by the Post Encounter Phase that continued through March 1979. The entire period went well with the spacecraft performing in an excellent manner and the Deep Space Network (DSN) acquiring and processing the data without undue incidents.

II. DSN Operations

As the Encounter time approached, a modified configuration control/freeze was imposed on the supporting facilities to ensure that the encounter activities were supported with known hardware and software capabilities. This required that any known or newly discovered anomalies had acceptable work around procedures to ensure continued support. The control essentially was within three categories.

A. SFOF Physical Plant and Data Systems

Soft freeze from 0000Z 4 December 1978 through 2400Z 28 August 1979, except for the following hard freeze periods (0000Z first day through 2400Z last day):

12/12/78 through 12/14/78	Voyager 1 NET
1/29/79 through 3/14/79	Voyager 1 TCM 3, Movie, FE1, FE2, TCM 4, NE and PE1

B. DSN Facilities

Modified configuration control is in effect from 4 December 1978 through 30 September 1979. The Voyager NOPE defined, prior to 1 December 1978, modified configuration control to encompass level of support for encounter (OB through PE2), spacecraft maneuvers and tracking cycles, the Movie Phase, Far Encounter 2, Near Encounter, and Post-encounter 1 Phase, the Near Encounter Test, and the major scan platform calibration preceding each encounter. The definition of a normal DSN freeze was modified to accommodate regular alternating tracking between Voyager and Pioneer Venus.

C. Encounter Configuration

The Jupiter encounter phase for Voyager 1 began on 4 January 1979 and will continue through 9 April 1979. Supplemental procedures and configurations were required by the DSN to support the Jupiter encounter activity. Generally, only the telemetry configuration changed significantly while other subsystem configurations remained essentially the same as they were for the Cruise Phase.

Figure 1 shows the standard 64-m telemetry configuration which is 7.2 kb/s to 115.2 kb/s convolutionally encoded TLM on the X-band carrier with simultaneous 40 b/s uncoded TLM on the S-band carrier.

There were times when the Project configured the spacecraft for the same high rate encoded telemetry transmission via both RF carriers (360 kHz and 22.5 kHz). This was normally done when the Project wished to ensure full recovery of critical data. Figure 2 shows the S/X-band configuration that was used when the Project exercised its option to put the same telemetry rate on both carriers (S/X-band carriers). This configuration was also used when Voyager Project had important TLM data on the S-band carrier and the X-band carrier was not in use, or vice versa.

In order for the Project to optimize the telemetry return and to ensure that each experiment objective was met, there were frequent bit rate changes during the encounter period. To support this operation, the DSN was required to be cognizant of the changes and the supporting equipment configuration. To obtain maximum data it was necessary to determine whether the first bit of the new rate or the last bit of the old rate would result in maximum return. When a determination was made, the following procedure was used to support the decision.

Obtaining the First Bit of Data

(1) The station initialized for the new bit rate per the time in the SOE when the subcarrier frequency and modulation index remain the same as for the previous rate. The Subcarrier Demodulator Assembly (SDA) had to be in lock prior to stream initialization.

(2) When the SDA subcarrier or modulation index was changed simultaneously with data rate, it was impossible to get the first bit of data since there was a delay in acquiring SDA lock.

(3) Whenever the first bit of data was important, the station did not wait for TLM stream lock to put TLM data to line; instead, they put data to line at the same time that the TLM stream was first initialized.

Obtaining the Last Bit of Data

(1) The station did not initialize for the new bit rate until the telemetry stream dropped lock, or was requested to acquire the new bit rate by Network Operations Control (NOC).

(2) Even though the TLM stream was not initialized for the new TLM rate, there was always the danger that the Symbol Synchronizer Assembly (SSA) and Maximum Likelihood Convolutional Decoder (MCD) would false lock to the new rate. Therefore, the station and the Network Operations Control Team (NOCT) guarded against false locks in this mode of operation, although neither the NOCT Real-Time Monitor (RTM) or Test and Telemetry System (TTS) were able to obtain synchronization on the data if the station was false locked. The best solution found was to initialize for the correct bit rate immediately after losing lock on the present bit rate within the guidelines of the SOE.

1. Critical Periods. During the encounter phase, there were specific time periods when data collection was critical. These critical mission periods are defined in Table 1. However, the Project could and did declare as critical periods other than those listed below.

Analog recordings and redundant Telemetry Processor Assembly (TPA) DODRs were required during critical period support at the 64-m DSS's. The Project accepted the additional risks when a 34-m DSS (DSS 12) was used to support critical mission periods. When TLM data rates were above 44.8 kb/s, DSS 43 was not required to record redundant TPA DODRs, but analog recordings were required. During this time DSS 43 utilized the backup TPA for data replay as described below.

2. Data Replay Strategy. The primary concern during the encounter period was the timely receipt of the high rate telemetry and imaging data at JPL. Wide-band data lines were provided from all three of the 64-m stations. However, only the 230 kb/s capability from DSS 14 and the 168 kb/s capability from DSS 63 allowed transfer of the data rates above 44.8 kb/s in real-time. The 56 kb/s capability from DSS 43 required special consideration and strategy to provide the data in as near real-time as possible. To accomplish this requirement a special return procedure was instituted as follows:

3. Methods of Data Return from DSS 43. Two methods of telemetry return were employed: real-time and near real-time.

a. Real-Time Data Return. DSS 43 processed and returned in real-time (on the 56 kb/s WBDL) all high rate data with rates of 44.8 kb/s or lower.

b. Near Real-Time Data. For data rates above 44.8 kb/s, DSS 43 recorded real-time data on a DODR using one telemetry string and replayed the DODRs, using the second telemetry string, as soon as they were available. The data replays were done at the maximum line rate of the 56 kb/s wide-band data circuit. With the replays occurring at less than the real-time record rate a TLM return backlog existed until all DODRs had been replayed. Negotiations with other station users ensued to utilize their S/C track. All low rate data, 40 kb/s, were returned via the HSDL in real-time.

For DSS 43 passes containing data rates above 44.8 kb/s, but with no Optical Navigation (OPNAV) data, the replay strategy was:

(1) DSS 43 logged all HR data on DODR.

(2) As soon as the first DODR tape was completed, the station immediately started a replay of that tape over the 56 kb/s WBDL.

(3) When the first DODR tape replay was completed, the second tape was replayed and so forth until all data had been played in.

(4) DODR tapes were normally replayed in the same sequence as they were recorded.

(5) Some passes contained periods of HR data 44.8 kb/s or less between periods of higher rate data. During these periods, the station suspended replay, returned the high rate data in real-time and resumed replays when the WBDL was again available.

During some of the DSS 43 passes short periods of OPNAV data were contained in the high rate. It was a requirement of the Project Navigation Team that each period of this data be returned within a time not to exceed 4 hours after it was recorded on the spacecraft. To accommodate this requirement, the following replay strategy was used:

(1) Replay of the OPNAV data periods were specifically requested by the user. The requests were designated by data start and stop Earth received times.

(2) Due to the DODR replay backlog, the OPNAV replay requests in some cases required that DODRs be loaded for out of sequence replay. This was necessary to meet the OPNAV data return time requirement.

(3) In such cases the station completed the DODR tape replay already in process, mounted the tape containing the requested period, made the short replay and then resumed the normal replay sequence where it left off.

(4) During OPNAV replays, the data was processed by *Mission and Test Imaging System (MTIS) only.* TTS and Network Data Processing Terminal (NDPT) turned off the WB processors to prevent processing of non-sequential data.

During other specified periods requirement for near real-time DODR replay was for the latest data recorded. The station replayed the first completed DODR tape followed by the latest DODR tape to be completed, regardless of the order in which it was recorded. As each tape replay was finished, the next tape to be replayed was the most recent tape recorded. This out of order DODR replay continued until the end of the track at which time the skipped over tapes were replayed. The Project exercised the option of requesting the replay of any completed DODR tape during these periods of "Out of Order" replay. Such requests were made by the user through ACE to Operations Chief. The DSN honored these requests at the completion of the tape replay already in process and then resumed replay of the latest completed DODR.

c. DSS 43 Telemetry Back-up. During certain real-time data periods determined by the Project to require "hot back-up" TLM system with redundant DODR, the station configured both TLM strings for real-time data and suspended any data replays until the second TLM string was again available. For a data rate of 44.8 kb/s or less, the station was outputting data from the prime telemetry string, while at the same time recording a DODR on the back-up telemetry string. When the data rate was above 44.8 kb/s, the station recorded DODR on both TLM strings for subsequent replay.

When high rate data (real-time or replay) was not required from DSS 43 during the DSS 43/14 or DSS 43/63 overlaps the station was requested to halt the WB data output and record on DODR only.

d. Configuration – DSS 43. The telemetry configuration used by DSS 43 was dependent on two conditions of the downlink high rate data:

(1) HR TLM 44.8 kb/s or lower
For data rates of 44.8 kb/s or less, DSS 43 used the standard 64-m TLM configuration shown in Fig. 2.

(2) HR TLM above 44.8 kb/s
For data rates above 44.8 kb/s, DSS 43 used the record and replay configuration shown in Fig. 3.

III. Data Products

The Intermediate Data Record (IDR) is the primary data product provided to the Project by the DSN. Although telemetry data is provided in real-time or near real-time to the

Mission Control and Computing Center (MCCC) for the Project's use, the IDR is still required to provide the permanent record and gap filling of the data. In the case of radiometric data and tracking calibration data, the IDR is the only source of data to the Project. Monitor data is provided to the MCCC telemetry system (via the NOCC real-time monitor 5-8 data block) for inclusion with the telemetry data record. Command IDRs or fill tapes could be required by the Project to complete their system data record as required.

Stringent requirements are placed on all IDRs provided by the DSN. In the case of telemetry during cruise, the requirement is for 97.5% of the in-lock data blocks and during critical periods it is at least 99% of the in-lock data blocks. For radiometric data and tracking calibration data, the requirement is for the IDR to contain, at least 95% of the data required to be transmitted in real-time, by a DSS. As an indication of the impact of IDR production during this period, 367 telemetry IDRs were produced in January and 820 telemetry IDRs (with an additional 74 supplementary IDRs) in February. Even this later number increased in March during critical encounter activities. These IDRs were in addition to the optical navigation and radiometric data IDRs likewise produced.

IV. Occultation Data (Radio Science)

One Jupiter/Earth occultation was observed during the DSS 63 pass on 5 March 1979. To record this event, both closed loop and open loop receiver data and radiometric data were provided as the complete radio science package. New operational procedures were developed for the open loop receiver operation since the closed loop and radiometric data were already provided.

DSS 63 was provided with the radio science occultation subsystem during the later part of 1978. Testing and training were accomplished during January and February. Final preparation was completed just prior to the Jupiter encounter closest approach.

Figure 4 shows the Voyager occultation recording configuration. Figure 5 shows the Voyager open loop receiver configuration.

Prior to the Voyager mission, occultations were supported using an open-loop receiver with a fixed first local oscillator passing a bandwidth sufficient to encompass the event of interest, plus uncertainties, onto an analog recording. The analog recordings were shipped to JPL and digitized at CTA 21 and the resulting computer compatible tapes (CCT) were delivered to the experimenters. For Voyager, the total shift in frequency due to the Jupiter atmosphere was large and the existing system could not be used. A new subsystem was implemented; this new subsystem was called the DSS Radio Science Subsystem (DRS). This subsystem involved a computer-controlled programmable first local oscillator in the open-loop receiver that followed (using a series of linear ramps) the time-related frequency excursion of the expected signal of interest, thereby enabling the real-time bandwidth to be reduced to the point where real-time analog-to-digital conversion and production of a CCT recording was possible. This is the new system that was implemented at DSS 63, for the first Jupiter encounter.

In general terms, preparations for support of the occultation experiment began approximately two months prior to the event. The project experimenters supplied the DSN with the information necessary for the configuration and setup of the Occultation Data Assembly (ODA). The DSN then produced ODA predicts for the station supporting the pass. NAT Track transmitted the predict file to the DSS in advance of the pass to be supported and other occultation data information was datafaxed to the DSS prior to the encounter pass. The station supported the experiment, supplied pertinent information to the net controller, played back a portion of the recorded ODA CCT, duplicated the CCT and then shipped the tape to JPL. In addition to taking data using the Multimission Receiver (MMR)/ODA, the station used an Open Loop Receiver (OLR) (300 kHz output) and the Digital Recording Assembly (DRA) to record wide bandwidth data for backup purpose only. Upon special request these DRA recordings were shipped to CTA-21 where the bandwidth reduction equipment was used to produce a narrow bandwidth digital recording. The ODA CCTs shipped to JPL were delivered directly to the Project. The high speed portion of the recorded ODA data was processed by NDPT and an IDR provided to the Project, within 72 hours, for quick-look verification by spectrum analysis.

Operational and initialization instructions for the radio science subsystem were in the ODA Software Operations Manual (SOM) DMO-5123-OP and the operation procedures were documented in the Voyager Network Operations Plan 618-700, Rev. B. Special real-time messages were used to augment the operational and initialization instructions that were Voyager Project dependent. The open loop receiver Programmed Oscillator Control Assembly (POCA) predicts were generated at JPL and transmitted to the ODA, where the predicts were stored on disks. During Jupiter occultation, the predicts were used to drive the S/X-band open loop receiver POCA.

For the open loop recording, the DODR recording began prior to the start of Jupiter occultation. It was necessary to collect baseline data prior to and after occultation. The Project

Sequence of Events was the controlling document for the ODA recording on and off times. Open loop (S-band) backup recording was provided by the wide-band (300 kHz) OLR, and its DRA.

Voyager did not make use of the High Speed Data Line (HSDL) to get open loop ODA data to JPL, except for preliminary quick-look data, because the number of station hours required to replay data via HSDL was prohibitive. The prime method of getting data to JPL was to ship the open loop DODRs.

DODR recording for Voyager used six DODR tapes per hour, five DODRs per hour for the narrow-band MMR/ODA subsystem, and approximately one DODR per hour for the wide-band OLR/DRA subsystem. The DSS collecting the open loop data was required to ensure that adequate personnel were on board to handle the open loop recording task. Technical assistance was sent from JPL to DSS 63 to support the occultation period.

New or once used digital tape, at least 2300 feet in length for ODA and 12,500 feet in length for DRA, were required to be used for recording open loop data, to ensure optimum data return. DSS 63 required about 30 good digital tapes (24 for narrow-band recording, and 6 for wide-band recording) to meet this requirement.

Station personnel used the Spectral Signal Indicator (SSI) to verify that occultation data was actually being recorded onto the DODR. The SSI provided recording status for both the narrow-band and the wide-band recording subsystems. The narrow-band was used for the prime data and required more monitoring by the DSS operator than the wide-band subsystems. The Voyager Project planned to use the narrow-band data only, but in the event that the narrow-band data was not available, then CTA-21 would be requested to provide wide-band IDRs. The DSS was required to report signal status to the NOC at least every 15 minutes and more often when the signal disappeared or was marginal.

Table 1. Critical mission periods

Critical period	Duration	Remarks
1. Trajectory correction maneuvers	M-10h to M+3h	
2. Science calibrations (every 1/2 AU for each spacecraft)	24 hours	
3. Imaging movie	4 days each S/C for each planet	
4. Planetary closest approach	E-10d to E+1d	E-2d to E+2d for analog ODR retention requirement
5. Spacecraft emergencies	When declared for as long as declared	
6. Targets of opportunity (specified at least one month in advance)	No longer than 4 days	

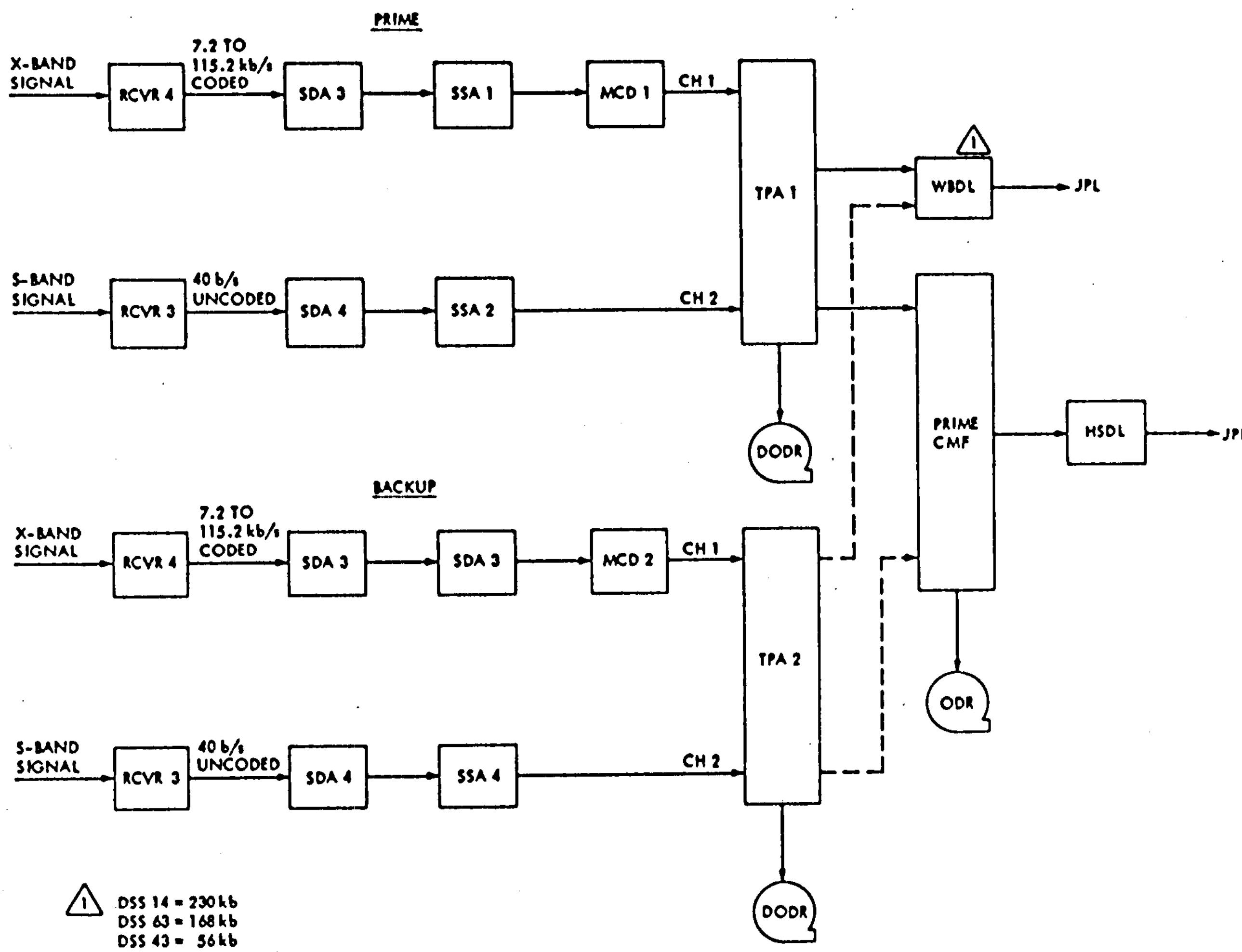

Fig. 1. 64-m standard telemetry configuration

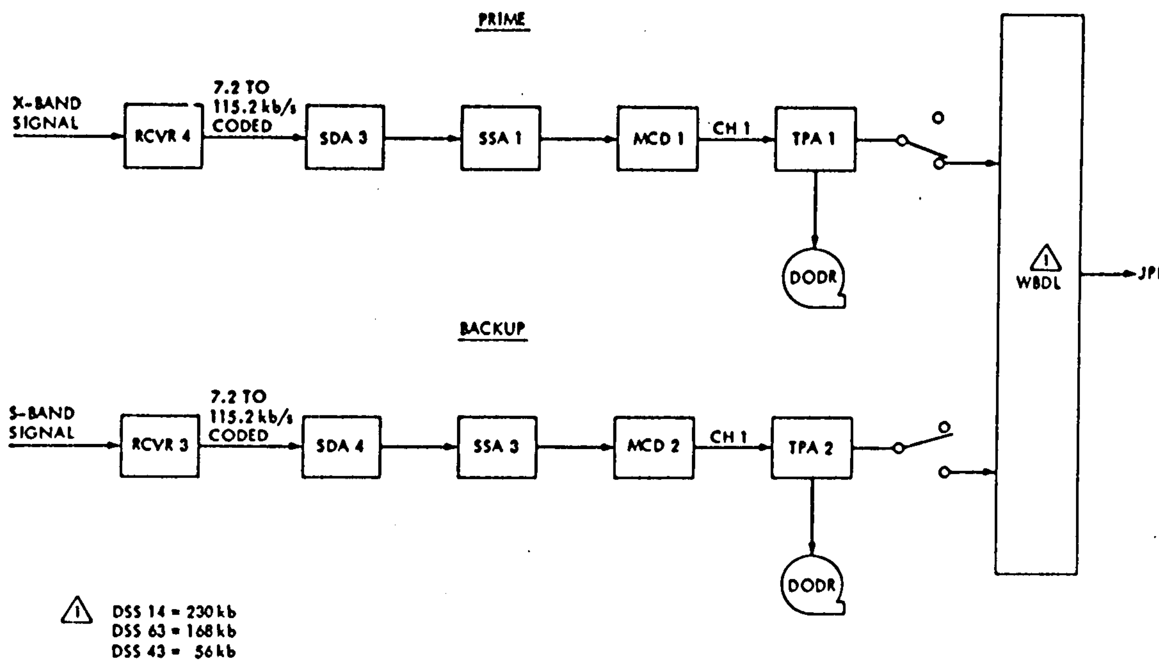

Fig. 2. 64-m S/X-band configuration (7.2 kb/s to 115.2 kb/s)

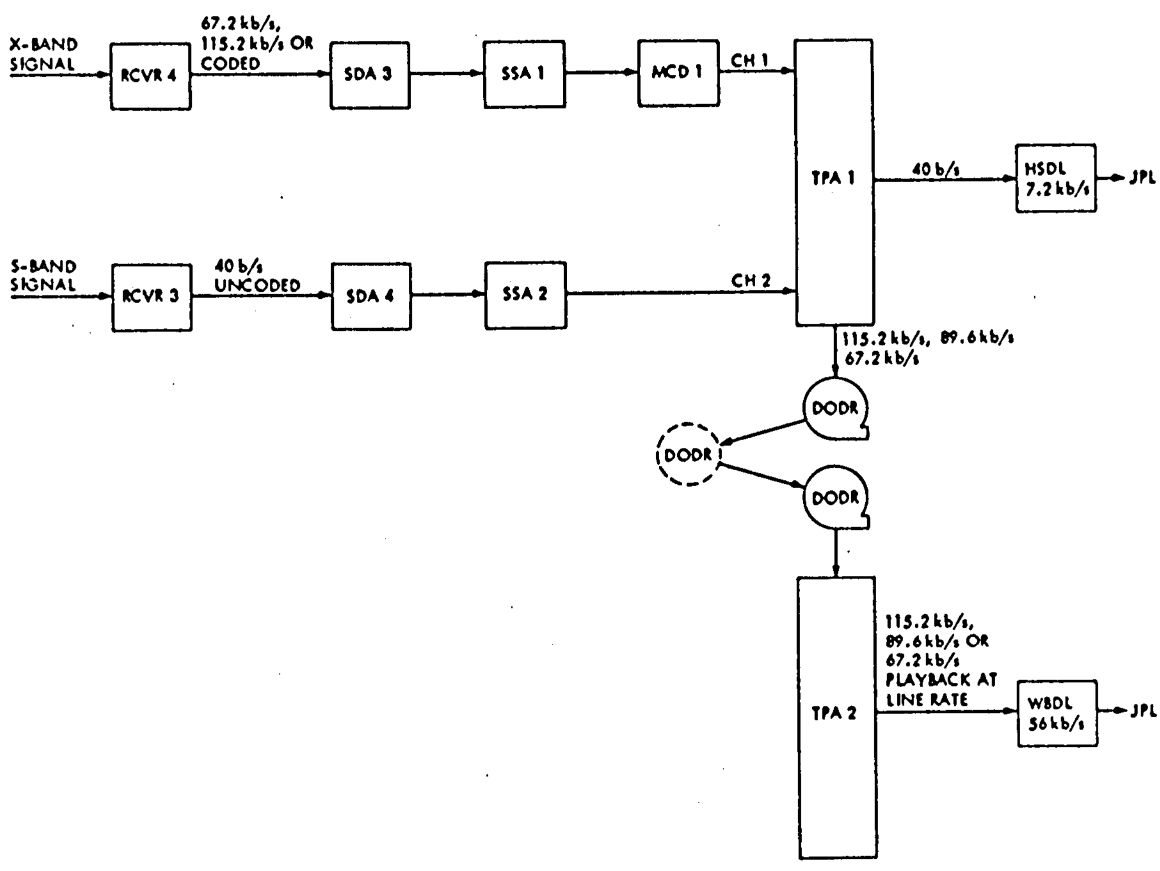

Fig. 3. 64-m recording and replay configuration (115.2 kb/s, 89.6 kb/s, or 67.2 kb/s)

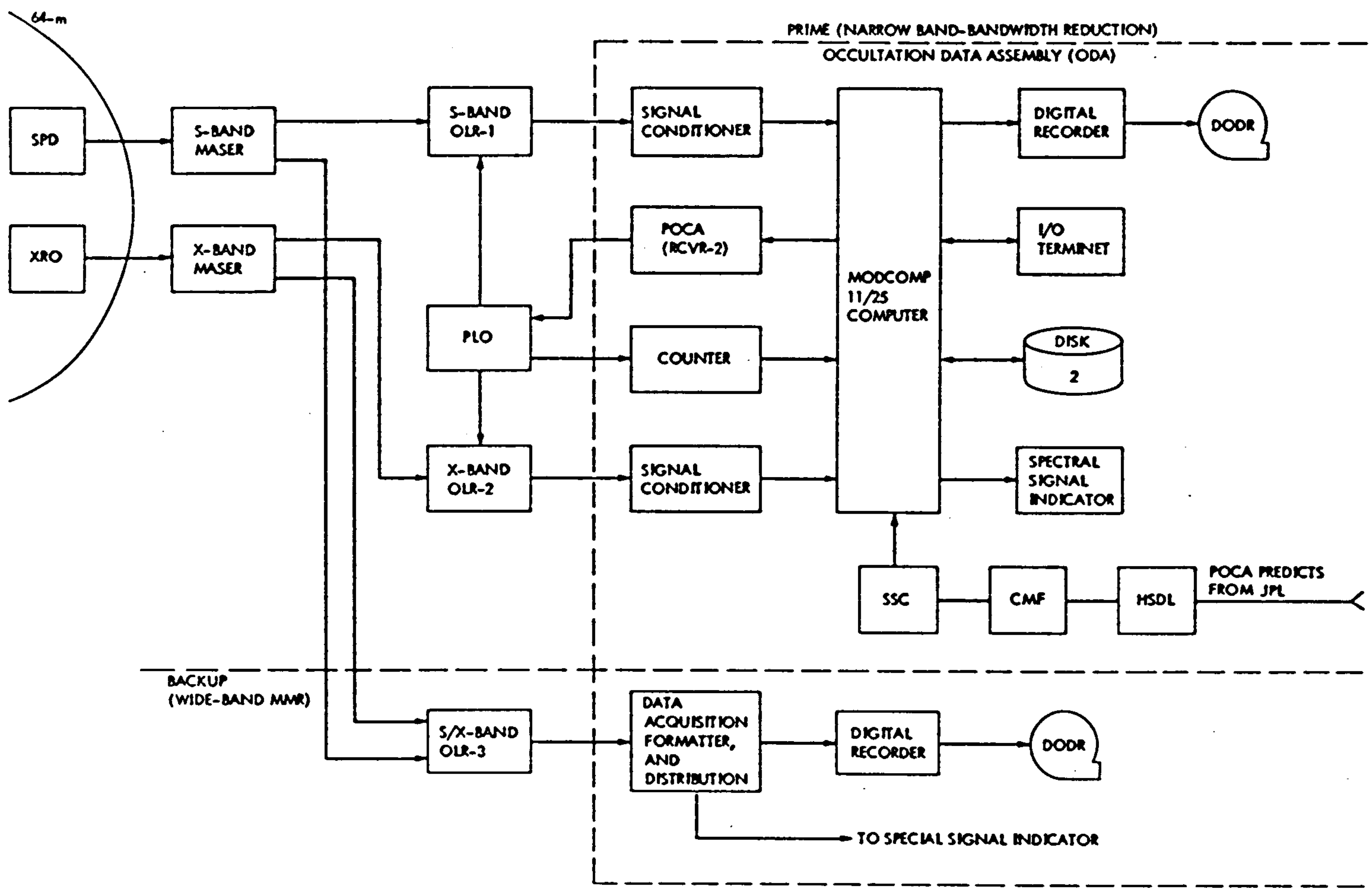

Fig. 4. 64-m open loop recording configuration

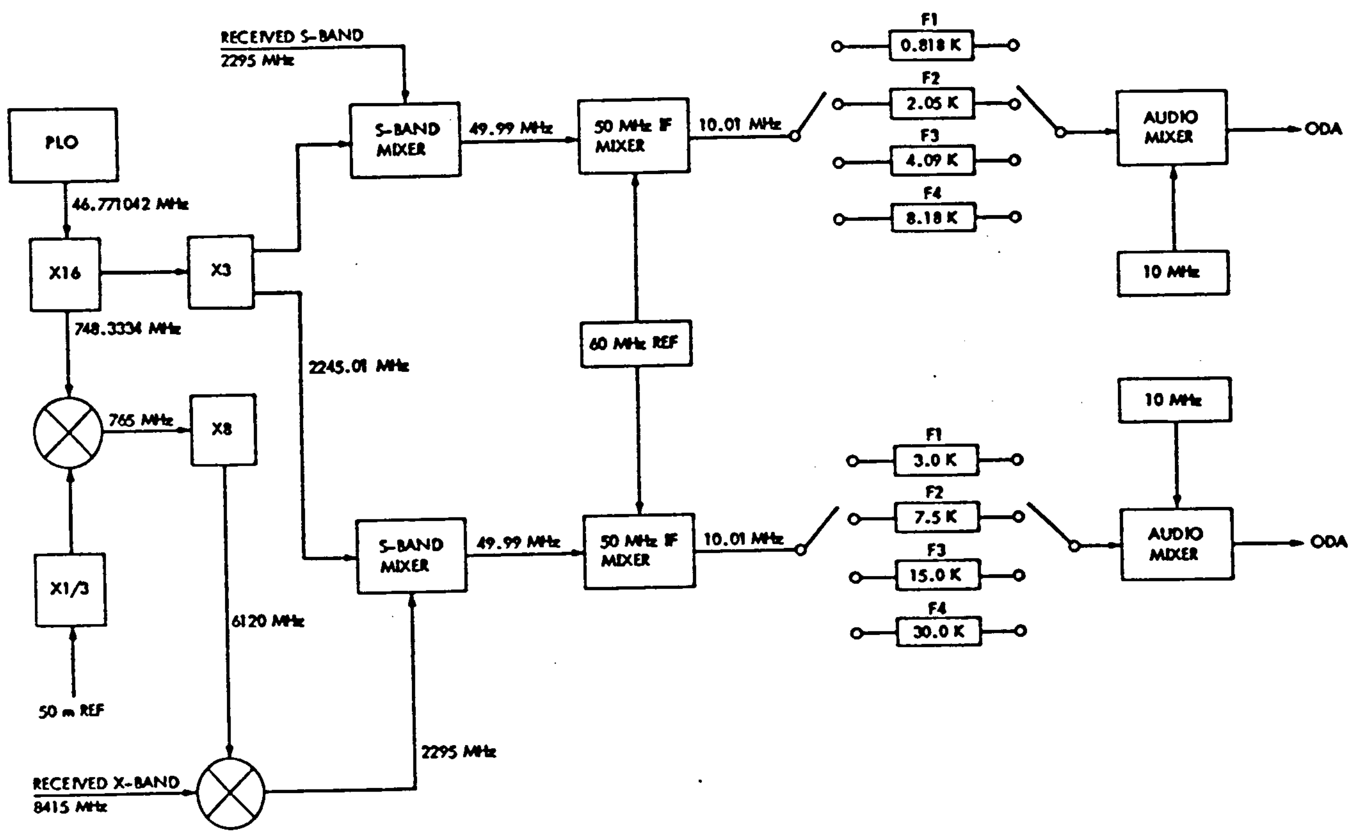

Fig. 5. 64-m open loop receiver configuration