Real-Time High-Rate Telemetry Support of Mariner 10 Operations

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Television pictures from the Mariner 10 spacecraft were received and displayed in real-time at JPL during important phases of the MVM'73 mission. In order for the DSN to support this activity, the telemetry data processing equipment at DSS 14 had to be modified and a special microwave super group channel established between the station and JPL to handle transmission of the high rate (117.6 kbps) data. How this capability was implemented and operated by the DSN is described in this article.

I. Introduction

The approved Mariner Venus/Mercury 1973 (MVM'73) mission profile established a requirement for real-time evaluation at JPL of spacecraft uncoded 117.6-kbps high-rate telemetry data (video pictures). Mission events which called for real-time transmission of the 117.6-kbps data were as follows:

Mission event	Date or period
Earth-Moon television system calibration	Mid-November 1973
TV scan calibrations	November through January 1974
Kohoutek comet pictures	January 1974
Venus encounter	February 1974
Mercury encounter	March 1974

To meet the requirement, the DSN established a 230.4-kbps data transmission capability between DSS 14 and JPL, with the Western Union (WU) leased portion of this capability being known as the 240-kHz super group microwave channel.

At DSS 14, a word formatter assembly was provided by the project to receive the 117.6-kbps data from the symbol synchronizer assembly (SSA) of the Telemetry and Command Data (TCD) Subsystem and arrange the data in a nonblocked, synchronous word-formatted mode for forwarding to the station's Ground Communications Facility (GCF) interface. The data were then transmitted via the GCF and the WU-leased super group microwave channel to the Mission Control and Computing Center (MCCC) at JPL for processing and display of the pictures on television monitors.

As an added feature, during the Mercury encounter the capability was provided to transmit the pictures from JPL

to NASA Headquarters and Goddard Space Flight Center (GSFC), where they were also displayed on television monitors in real-time.

II. Description of Capabilities

A. Basic Data Handling Configuration

The basic configuration of this real-time data handling capability is depicted in Fig. 1 and includes the DSS 14, MVM'73 Project, GCF and MCCC equipment and interfaces indicated below.

(1) DSS 14

(a) Symbol Synchronizer Assembly (SSA).

(b) SSA word formatter switch and word formatter (Project-supplied).

(c) 230.4-kbps Wideband Data Assembly (WBDA) which included wideband (WB) patch panels, General Electric Time Division Multiplex (GE TDM) 522 data set/modems, and bit error rate tester (BERT) 901.

(2) GCF switching center at Goldstone (GCF 10).

(a) Dual Area Microwave Assembly (AMWA) radio channels.

(b) 230.4-kbps WBDA (same as DSS 14).

(c) Western Union (WU) leased GE TDM 501 data sets.

(d) WU-leased GE TDM 520 modems.

(3) GCF 10 to GCF 20 intersite transmission (WU-leased 240-kHz super group microwave channel).

(4) GCF switching center at JPL (GCF 20).

(a) WU-leased GE TDM 501 data sets.

(b) WU-leased GE TDM 520 data sets.

(c) 230.4-kbps WBDA, which included WB patch panels, BERT 901, and line driver amplifiers.

(5) MCCC

(a) Mission Test Computer Facility (MTCF) communications interface patch panel.

(b) Word deformatter.

(c) MTCF 1230 computer.

(d) Project/Mission Control Computing Facility (MCCF) Television Assembly (TVSA).

B. Wideband Data Transmission Capability

The wideband portion of the capability depicted in Fig. 1 was engineered and installed by the Ground Communications System Engineering Group of the DSN Data Systems Development Section as the 230.4-kbps WBDA under Engineering Change Order (ECO) Number 72-224. It was used to support MVM'73 test and mission operations activities from July 1973 through April 1974. The main features of the 230.4-kbps WBDA are the following capabilities that it provided:

(1) A full duplex 230.4-kbps data transmission capability. The data were routed from DSS 14 to GCF 10, utilizing dual Area Microwave Assembly radio channels and a WU-leased 240-kHz super group microwave channel between GCF 10 and GCF 20.

(2) Redundant equipment to provide a backup to prime equipment.

(3) Full duplex end-to-end testing capability utilizing loopback techniques and special 230.4-kbps bit error rate testing equipment known as the BERT 901.

(4) Equipment necessary to provide a compatible interface with Project-supplied equipment and MCCC assemblies.

C. NASA Headquarters/GSFC Television Configuration

In March 1974, a requirement was established by the Office of Space Science Applications, NASA Headquarters, to provide some real-time Mercury encounter pictures to NASA Headquarters and GSFC. The configuration shown in Fig. 2 was used to meet this requirement. The system was active for a total of 10 h and 30 min, which included 2-½ h of testing and 8 h of prime Mercury encounter picture transmissions.

III. System Installation and Checkout

A. Schedules

The 230.4-kbps Wideband Data Assembly installation began approximately June 1, 1973. The GCF portion (WU-leased 240-kHz super group microwave channel and GCF MCCC/Project cable interface) was completed during the first week of July 1973. This wideband system, along with the DSS 14 GCF/Project word formatter and the JPL GCF/MCCC word deformatter interfaces, was tested during the last three weeks of July and declared operable on August 1, 1973.

B. Problem Areas

The GCF experienced almost no technical or installation problems in the establishment of the DSS 14-to-JPL 230.4-kbps capability. In fact, the hardware performance and test results exceeded all expectations. All GCF installation and checkout schedules were met; however, a minor problem was experienced with Western Union and General Electric in assuring that the July 1, 1973, committed date for completion of the GCF 10-to-JPL leased 240-kHz super group installation was met. A slip in the July 1, 1973, date was averted by the JPL Communications and Supply Section's direct coordination with the Vice Presidents of Western Union and General Electric, to effect a speedup of deliveries of the 230.4-kbps data set/modems from General Electric to Western Union.

C. Test Results

The GCF provided a full duplex end-to-end testing capability for the 240-kHz super group, with an additional microwave link test capability at GCF 10. BERT 901's were provided to DSS 14, GCF 10 and GCF 20. This test capability allowed the GCF to transmit a 2047-bit pseudo-random pattern in both directions for channel performance validation.

The GCF established an allowable bit error rate of 1×10^{-5} as the test criteria for circuit validation. To meet the bit error rate objective at a line transmission rate of 230.4 kbps, a 5-min bit error rate count end-to-end for both links could not exceed 700 bits in error. The following formula was used to calculate bit error rates:

$$\frac{\text{bit error count}}{\text{block count} \times \text{block size}} = \text{error rate}$$

(Note: block size equaled 99999 bits in each test.) Results of testing conducted on October 25, 1973, on the prime 230.4-kbps wideband circuit between DSS 14 and GCF 20 are tabulated in Table 1.

IV. Operational Performance

A. General

This mission-dependent high-rate telemetry data handling and transmission system performed exceptionally well. Of the approximately 9000 pictures obtained through the Mercury encounter, some 5000 were processed and displayed at JPL in real-time. Those pictures not received from DSS 14 via the 230.4-kbps Wideband System were received from the overseas 64-m stations (DSS 43 at Canberra, Australia, and DSS 63 at Madrid, Spain) via the 28.5-kbps wideband circuits, or were processed directly from the digital original data records that were shipped from the DSSs to JPL.

B. Data Quality

The quality of the pictures received during Venus encounter was excellent, averaging an approximate bit error rate of 1×10^{-5}, or one bit in error for every 100,000 bits received. For Mercury encounter, the bit error rate averaged approximately 2.5×10^{-2}. The 230.4-kbps Wideband System equaled or exceeded all established performance specification during both encounters. Had the system added significantly to the bit error rate, especially during periods of marginal spacecraft telecommunications performance at Mercury encounter, the Project would have had degraded data.

C. DSN Support

DSN support of the Mariner 10 real-time 117.6-kbps high-rate telemetry data retrieval effort was based on a "best efforts" commitment and low cost implementation. Nevertheless, during DSN/Ground Data System (GDS)/MCCC prelaunch testing, the only problems experienced were minor ones encountered at DSS 14 with the word formatter. Furthermore, throughout the mission and especially during the critical Venus and Mercury encounter sequences, the system functioned reliably and with a minimum amount of downtime.

The real-time 117.6-kbps high-rate telemetry data retrieval capability was de-implemented following Mercury encounter. Subsequently, however, the decision was made to provide the same support for the second Mercury encounter, the closest approach of which occurs on September 21, 1974. All equipment modifications and installations were completed at DSS 14 and DSC 10 by mid-August, and arrangements made for lease of the DSC 10 to the JPL 230.4-kbps super group microwave channel for the month of September 1974. DSN/GDS/MCCC testing is scheduled to be completed by September 15, 1974.

D. Operational Constraints

Despite the success indicated above, certain features of this capability were undesirable from an operations support standpoint. For example, at the station and throughout the GCF interfaces, little or no capability existed for on-line real-time monitoring of the system status; system design was such that standard DSN data and circuit

monitoring techniques could not be employed because of the nonstandard word formatted data transmission mode that was used.

These constraints required stopping the data flow and conducting off-line testing in order to troubleshoot the system when problems occurred. In addition, use of the mission-dependent word formatter assembly necessitated modifications at DSS 14 to interface this equipment with the SSAs and the 230.4-kbps WBDA. These nonstandard interfaces created an awkward operational situation at DSS 14 which was too troublesome to be acceptable on a long-term basis.

V. Conclusions

The MVM'73 high-rate telemetry data transmission system met its objectives in an impressive manner. Limitations and constraints imposed on the DSN by the system design were overcome and the system was operated successfully. If a similar system is to be used for future missions, then design and engineering effort should be expended in order to provide the DSN with a standard capability that is free of any constraints that could hamper successful DSN support of critical mission operations.

Table 1. 230.4-kbps wideband circuit test results

Test	Terminal	Duration, h	Bit error rate	Data, % throughout
Part 1	GCF 20	3	2.3×10^{-8}	99.999
Part 2	GCF 20	8	5.2×10^{-8}	99.998
Part 1	DSS 14	3	6.1×10^{-7}	99.975
Part 2	DSS 14	8	4.2×10^{-7}	99.983

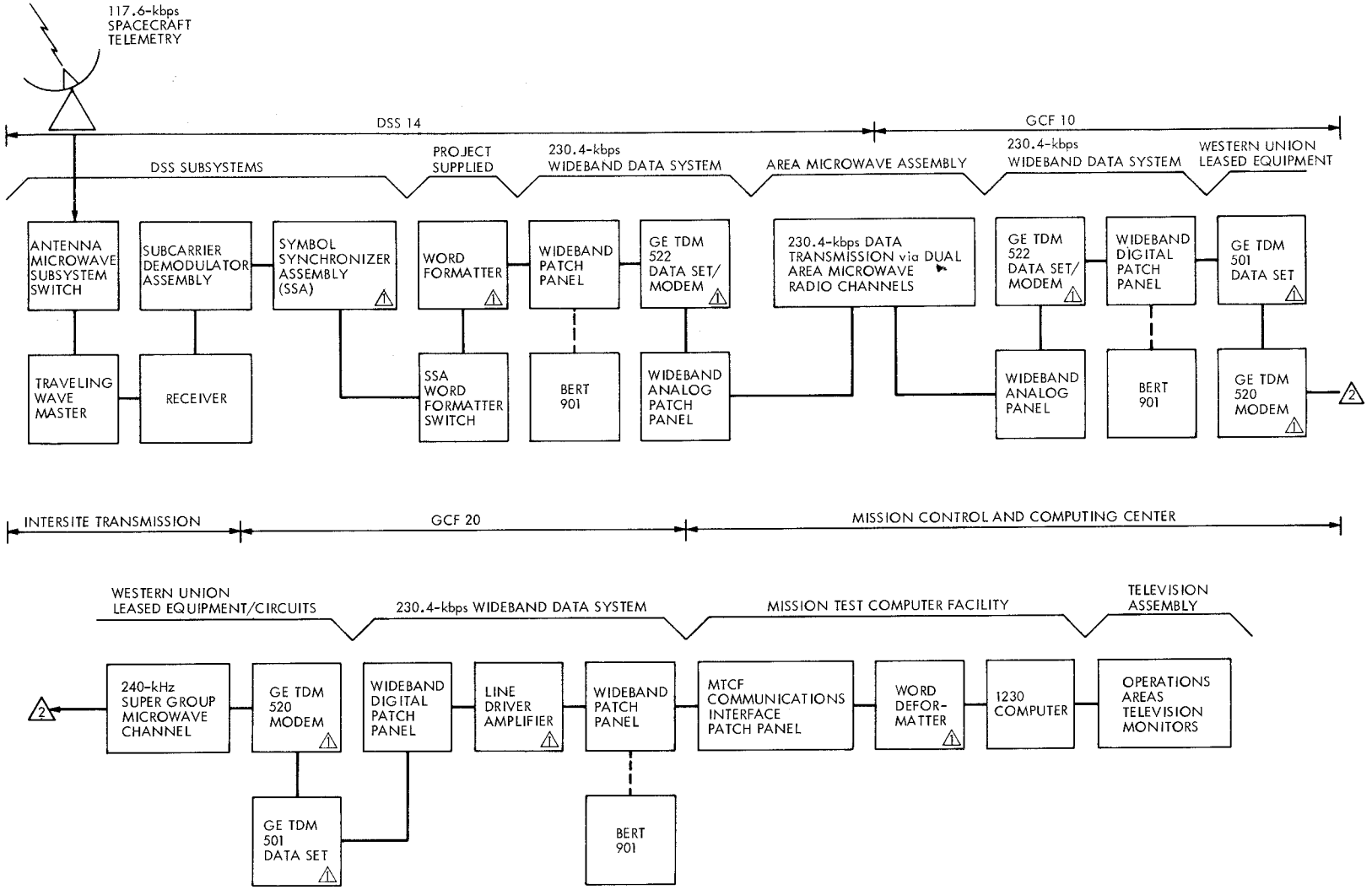

Fig. 1. DSS 14 to JPL high-rate telemetry configuration

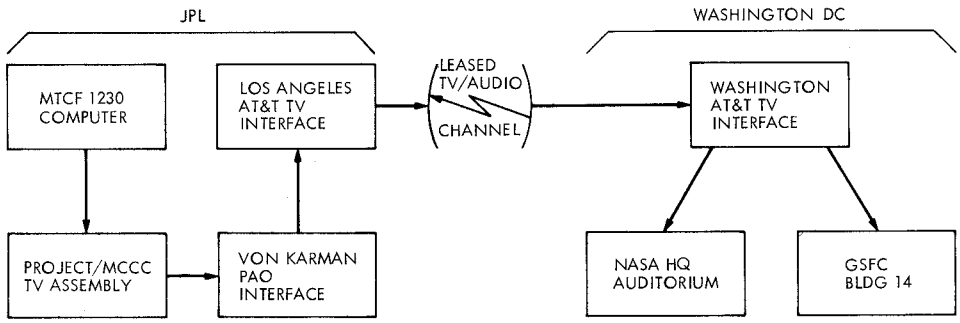

Fig.2. JPL-NASA Headquarters/GSFC real-time system configuration