Implementation of the Radio Science Subsystem in the DSN

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The DSN is implementing a new subsystem for support of radio science data acquisition requirements beginning in late 1978. The article describes the functional characteristics of this equipment and utilizes the factors that were of major importance in the design and implementation approach.

I. Introduction

The Radio Science Subsystem becomes operational in mid-1978 at the 64-m Deep Space Stations and at the DSN's Compatibility Test Area (CTA-21). This is a new subsystem at these locations, and it is intended to bring radio science data acquisition and processing functions into a more operational and automated environment. The initial application of this equipment will be to acquire and record open-loop receiver data during the Pioneer Venus probe entry in December 1978, and during the Pioneer Venus orbiter planetary occultations.

II. Functional Overview

A high-level block diagram of the Radio Science Subsystem equipment is shown in Fig. 1. At the 64-m DSS sites, the subsystem is composed of two functionally independent elements known as the Digital Recording Assembly (DRA) and the Occultation Data Assembly (ODA). At CTA-21 the subsystem consists of a DRA and a bandwidth reduction filter (BFR).

The DRA is a general-purpose wide-band digital recording system that can accommodate data recording rates from 150 kbits/s to 5×10^6 bits/s. The DRAs at the DSS sites will be used primarily for data recording, whereas the DRA at CTA-21 constitutes a centralized playback facility. The recording medium for the DRA is 1-in. wide instrumentation tape.

The ODA similarly performs a data acquisition and recording function, but operates in the data rate range of 2 kbits/s to 640 kbits/s. These rates permit recording of data on standard computer tape. The ODA contains a standard DSN minicomputer (Modcomp II/25) that acts as the control and buffering device for the data acquisition/recording process. A primary impetus for implementation of the ODA is to transfer the on-site recording function from analog recorders to digital recorders; analog recorders have been used for recording occultation data for Viking and previous flight projects. The machines that have been used are becoming obsolete and unmaintainable, and the data flow to the end product has been cumbersome. By placing the original data on computer-type magnetic tape, the ODA implementation will streamline the data processing and handling necessary to produce a deliverable to the radio science data users.

The bandwidth reduction filter (BRF) located at CTA-21 has been implemented specifically for the purpose of processing the Pioneer-Venus probe entry data. It operates in conjunction with bandwidth reduction software, which is to reside in the CTA 21 telemetry processor assembly. The bandwidth reduction hardware/software combination allow selected narrow "bands" of the wideband spectrum recorded on the DRA for extraction and recording on computer-compatible tape, which is the deliverable to the data user.

III. Key Functional Characteristics of the Radio Science Subsystem

A. DRA Functional Characteristics

The DRA has been designed as a general-purpose digital recording device (i.e., its capabilities are not tailored to the near-term radio science applications). A functional block diagram of the DRA is shown in Fig. 2, and a summary of functional performance characteristics of the equipment is as follows:

(1) Digital data can be recorded at any discrete rate between 150 kbits/s and 50×10^6 kbits. The average bit error rate of the overall recording/reproduction process is less than 1×10^{-6}.

(2) A dual-transport configuration (at the DSS sites) provides the capability for continuous (overlapped) recording. This configuration also permits tapes to be copied on site.

(3) Data is recorded on 1-in. wide instrumentation tape. A 28-track longitudinal recording format is used; 18 tracks are assigned to user data recording, two tracks are used to record redundant data time tags to a resolution of 1 μs, and one track is used for recording a servo reference tone. The remaining seven tracks are not presently used (electronics for these tracks have not been included in the equipment).

(4) Real-time visibility into the quality of the data recording is provided (i.e., data reproduction occurs in a read-after-write mode).

B. ODA Functional Characteristics

The ODA performs a set of functions which are more diversified and automated than those of the DRA. A functional block diagram of the ODA is shown in Fig. 3. The functions performed by the hardware/software combination of the ODA are summarized below:

(1) Narrowband analog output signals (up to 4) from the open-loop receiver can be digitized and recorded at a maximum aggregate sampling rate of 80K samples/s (e.g., 80K samples/s on 1 signal or 20K samples/s on 4 signals). Lower sampling rates at binary submultiples are also available. Samples are time-tagged and recorded on computer-compatible tape.

(2) The ODA exercises real-time control over the programmed local oscillator in the receiver subsystem; the local oscillator frequency is controlled such that the desired signals are translated into the baseband spectrum which the ODA has the capability of recording. The information necessary to perform this control function is received by the ODA via the high-speed data line (HSDL). These time-tagged predicts are transmitted from NOCC prior to the pass and stored on the ODA disc.

(3) Following the recording of the data, the tapes can be played back via the HSDL to NOCC, where they are incorporated into the network data log. Alternatively, tapes can be copied on site and mailed to NOCC for incorporation into the data records system.

IV. Design Considerations Related to Operability/Maintainability

The design of the radio science hardware and software has been influenced strongly by operability and maintainability considerations. Special attention was given to the man-machine interface in the design review process. Being that both the DRA and ODA involve extensive use of the magnetic tape recorders, the operational impact of such an implementation has been a legitimate concern to operations organization personnel. Given that the use of tape recorders is a "necessary evil" in the effort to implement the subsystem functional requirements, the design goal has been to minimize the amount of time required by operations personnel for control, monitoring, and maintenance of the equipment.

A. Equipment Control/Monitoring/Checkout Approaches

An important design objective for all new equipment being implemented in the DSN is to allow remote operation of the equipment from a single centralized location at the station; the long-term objective is to have a single operator capable of controlling all station functions. In the case of equipment where tape recorders are used, such as the DRA and ODA, this goal cannot be fully achieved in that an operator is required to periodically change tapes. A second design objective is to provide automated checkout capability in all new equipment. Both of these objectives have been partially achieved in the initial configuration of the radio science subsystem.

The ODA can be fully controlled and monitored from the DSS data system terminal (DST). Tape changing is the only operator action required at the ODA itself. There are no operational controls or indicators built into the ODA special-purpose hardware. For pre-pass equipment checkout, the ODA operational software program is capable of performing an automated checkout sequence which verifies that all hardware is functioning properly.

The capability for remote control and monitoring of the DRA was included in the original equipment design, but the implementation was postponed due to (1) budgetary constraints and (2) the fact that the initial operational use of the DRA (for the Pioneer Venus probe entry) will be infrequent and of short duration. Implementation of a remote control/monitor capability, along with an automated checkout capability, is now planned to start in October 1978 and be operational by December 1980. The DRA presently contains the necessary front panel controls and indicators which allow the operator to easily set up and monitor the assembly performance.

B. Conformance to Operational Software Standards

During the design phase of the ODA software, a separate effort was initiated to establish a standardized set of operator input/output interfaces for all minicomputer-based assemblies at the DSS. These standards, which deal primarily with Operator Control Instructions (OCIs) and the format of status displays, were defined in time to allow their incorporation into the initial ODA software release.

C. Utilization of DSN Standard Hardware Devices and Components

The radio science subsystem hardware has incorporated standard DSN hardware devices and components wherever applicable. In the case of the ODA, the hardware consists of a standard DSN minicomputer (Modcomp II/25), standard DSN peripherals (disks, mag-tape units, keyboard-printer, and input/output hardware), and a single special-purpose hardware subassembly known as the occultation converter. This subassembly uses standard DSN packaging hardware, and approximately 95% of the components of the subassembly are standard DSN Hi-Rel parts.

A large portion of the DRA equipment consists of commercially procured hardware. Although it was not considered appropriate or feasible to impose the utilization of DSN standard hardware for this equipment, it was specified that certain critical elements be fabricated with commercially available Hi-Rel electronic components (screened to MIL-STD-883, Level B). Those portions of the DRA which were designed and developed at JPL use standard DSN packaging and components, except in certain areas where very high-speed logic operation was required.

V. Key Aspects of Implementation Approach

The hardware and software implementation activities for the radio science subsystem have generally proceeded smoothly and on schedule. The implementation has involved major contracts with system integration contractors. The implementation schedule and contractor performance have received a high degree of management attention throughout the implementation phase.

A. DRA Hardware Implementation

The DRA is a composite of commercial and noncommercial hardware elements. An outline of the significant aspects of the implementation approach is summarized below:

(1) A decision was made early in the implementation phase that the basic digital record/reproduce equipment should be procured commercially from a *single* systems contractor.

(2) A set of prototype DRA equipment was built and tested. Martin-Marietta Corp. (Denver Division) was selected to build the prototype set of the digital record/reproduce equipment. Martin selected the Honeywell Model 96 tape transport for use in the system. At the completion of the prototype evaluation phase, several functional design changes were specified to enhance the flexibility, operability, and maintainability of the equipment.

(3) A contract was let in January 1977 to Martin-Marietta for delivery of the production version of the digital recording equipment. The first system was delivered in August 1977, which was very close to the originally planned schedule.

(4) Those portions of the DRA equipment which are peripheral to the basic recording function were designed at JPL; an integration contract was established with Sperry-Rand Corporation (Univac Defense Systems Division) for documentation, fabrication, test, and integration of this equipment with the Martin-Marietta equipment. The fully assembled DRA's were tested and transferred to the DSN operations organization at the contractor's facility.

(5) As of April 1978, all DRA equipment was installed and operating at the respective DSS sites.

B. ODA Hardware Implementation

The ODA hardware implementation was much more straightforward than that of the DRA. Key aspects of the implementation activities are summarized below:

(1) All hardware elements except the occultation converter subassembly were standard DSN devices and were commercially procured.

(2) The occultation converter subassembly was designed at JPL, but no prototype was built. The documentation, fabrication, and test of the subassembly was accomplished under the same integration contract as the DRA equipment; all cables for the ODA were also supplied under this contract.

(3) Final integration of the complete ODA's took place at JPL, where the equipment was transferred to the DSN operations organization.

C. ODA Software Implementation

The ODA software implementation effort has also proceeded smoothly and on schedule. Key aspects of the implementation approach have been:

(1) The software was designed and implemented in accordance with DSN software methodology standards.

(2) A high-level program language (Fortran) was used wherever possible.

(3) Existing software elements from other DSS subsystems were incorporated as much as possible; specifically, much of the input/output software was transferred from the Metric Data Assembly with very little modification.

(4) The implementation effort was organized into a work breakdown structure, which was used to monitor progress toward completion.

(5) Software verification testing was performed in a hardware environment which matched that of the final DSS configuration as closely as possible.

The software is scheduled to become operational in June 1978. It is planned to reverify performance in the station environment at that time.

VI. Future Plans for Augmenting Subsystem Capability

Several efforts to enhance and expand the initial capabilities of the radio science subsystem are also well underway. A partial list of these plans is presented below:

(1) It is planned to increase DRA data rate capability by 33% by December 1980. This increase is necessary for support of VLBI recording functions, which require a 32M b/s recording rate at a tape speed of 60 in./s.

(2) The DRA will also be upgraded by December 1980 to provide remote control/monitor capability and automated checkout capability. This upgrade will involve a connection to the ODA computer for control/monitor data flow.

(3) The ODA will be upgraded (by October 1978) to provide the capability to monitor the actual frequency output of the programmed local oscillator in the receiver subsystem.

(4) Special-purpose hardware will be added to the subsystem by April 1979 which will accommodate the digitization and recording of medium-band occultation data from the Voyager Saturn ring encounter.

(5) Special-purpose hardware will be added to subsystem for acquisition and recording of VLBI data. This addition is also scheduled for April 1979.

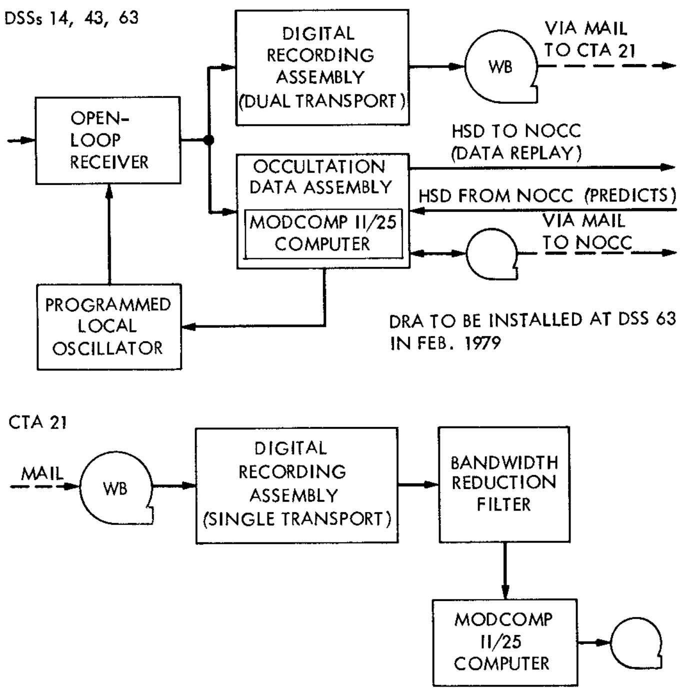

Fig. 1. Radio science subsystem equipment configuration (bold outlines)

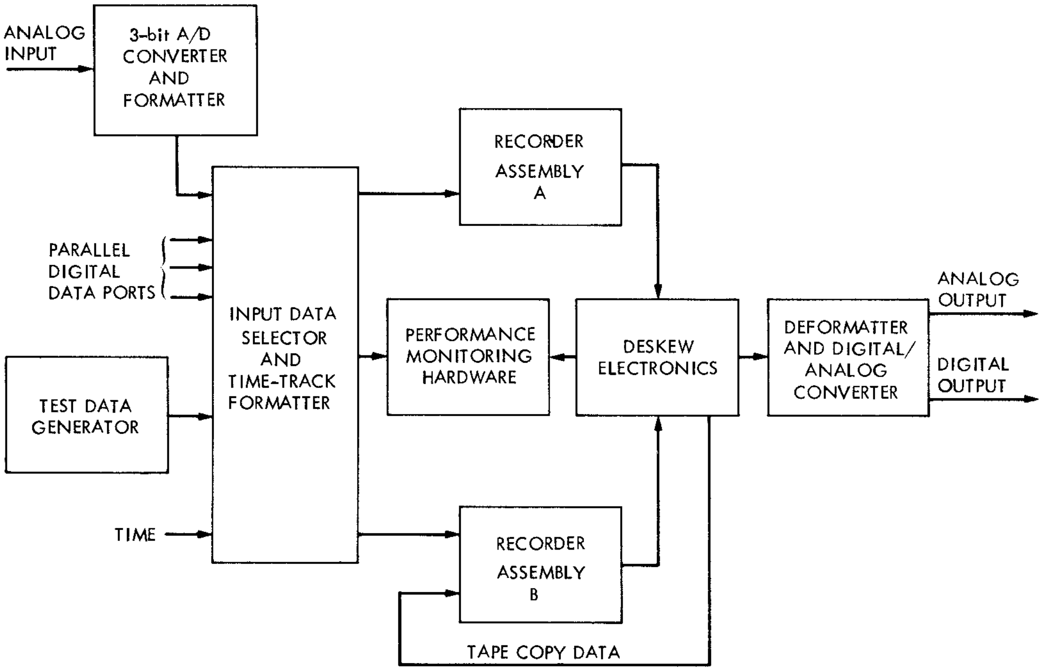

Fig. 2. Digital recording assembly functional block diagram

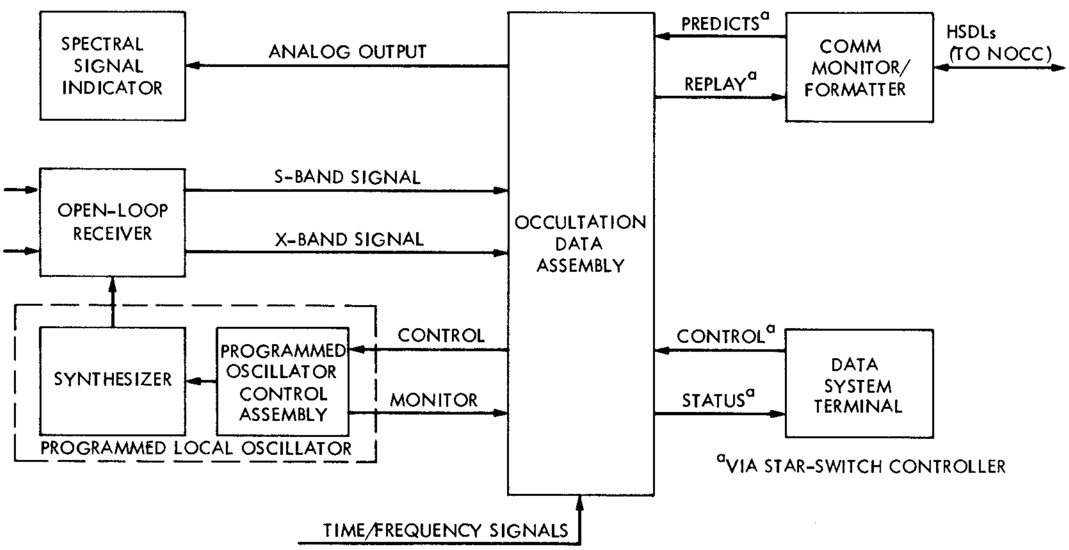

Fig. 3. Occultation data assembly functional interface