The DSS Radio Science Subsystem — Data Handling of Very Long Baseline Interferometry (VLBI) Data

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The DSS Radio Science Subsystem, originally implemented to provide the data handling capabilities for the DSN Radio Science System, will be modified and augmented to provide similar capabilities for the newly created DSN Very Long Baseline Interferometry (VLBI) System. This article describes the key characteristics, functional requirements, and operation of the DSS Radio Science Subsystem (DRS) as they pertain to usage of the DRS by the DSN VLBI System.

I. Introduction

The DSN Very Long Baseline Interferometry System was recently instituted as a DSN data system, following a successful review of DSN VLBI System requirements on February 28, 1978. Very Long Baseline Interferometry is a method of measuring the difference in the time of arrival of a signal produced by a distant natural radio source at two or more mutually distant antennas via simultaneous signal reception and recording. Because of the difference in signal ray paths between the antennas, the signal will evidence small time delays in reception between any pair of antennas. By cross correlating the recorded signals, the time delay and its derivative may be established for each pair of antennas. Because the natural radio source is extragalactic, and hence can be considered a fixed object, the measured time delay and its derivative provide information on the earth's motion and the baseline vectors between the various antennas. The DSN intends to use VLBI to determine Universal Time one (UT1; the instantaneous rotational angle of the earth), polar motion, and the relative positions of the Deep Space Stations (DSS), as well as the time offsets and rates of change between the various DSS clocks.

The DSN VLBI System will be a phased implementation with the first two phases identified as "Block 1" and "Block 2." Block 1 VLBI will provide for clock synchronization between the DSS and is characterized by usage of strong radio sources and a relatively low data rate of 500 kbits/s. Block 2 VLBI will provide the radio source catalog for Block 1 operations, as well as the earth motion and baseline vector parameters required for the Block 1 data processing. Block 2 VLBI can operate with weak radio sources as well as strong sources, and is characterized by a relatively high data rate of 32 Mbits/s.

The DSS Radio Science Subsystem provides the data handling capabilities for the recently created DSN Radio Science System, and was described in detail in a previous article (Ref. 1). VLBI data is quite similar to radio science data in that both are generated via open loop receivers, and hence

the DSS Radio Science Subsystem will be modified and augmented to additionally provide the data handling capabilities for the DSN VLBI system. This article provides a description of the key characteristics, functional requirements, and operation of The DSS Radio Science Subsystem in specific regard to DRS usage by the DSN VLBI System.

II. Functional Description of the DSS Radio Science Subsystem

A. Definition

The DSS Radio Science Subsystem, an integral element of the DSN VLBI System, performs the following functions:

(1) Receives, digitizes and records narrowband open-loop receiver data, and transmits via wideband data line to the Network Operations Control Center (NOCC).

(2) Receives, digitizes and records wideband open-loop receiver data, and transmits via magnetic tape to the NOCC.

(3) Receives calibration and ancillary data and transmits in real-time via High-Speed Data Line (HSDL) to the NOCC.

DSS Radio Science Subsystem functions and interfaces are shown in Fig. 1, while Fig. 2 presents functions and data flow.

B. Key Characteristics

The key characteristics of the DSS Radio Science Subsystem are listed below for functions of the Occultation Data Assembly (ODA) and the Digital Recording Assembly (DRA).

(1) VLBI Block 1 (ODA) Key Characteristics

    (a) Hardware and software compatibility with the DSN Mark III configuration.

    (b) A to D conversion of narrowband open-loop receiver data with 1-bit quantization.

    (c) Total data rate of 500 kbits/s.

    (d) Merging of open-loop receiver data with calibration and ancillary data ("VLBI data") in real-time.

    (e) Reconstruction of analog signals for verification of calibration tones.

    (f) Temporary storage of VLBI data on magnetic tape at the DSS with subsequent transmission via Wideband Data Line (WBDL) to the NOCC.

    (g) Real-time transmission of VLBI calibration and status data to NOCC via High-Speed Data Line.

(2) VLBI Block 2 (DRA) Key Characteristics

    (a) Hardware compatibility with the DSN Mark III configuration.

    (b) Provision for recording eight wideband open-loop receiver channels of 4 Mbit/s data rate each.

    (c) Provision for time tagging of recorded data to one microsecond or better resolution.

    (d) Reconstruction of analog signal for verification of calibration tones.

    (e) Automated control of the DRA by the ODA.

C. Functional Operation

1. VLBI Block 1 Phase 1. Natural radio source signals are received by the Block IV closed-loop receivers and processed by the Advanced System Equipment (ASE). Multiplexed signals from the ASE are received by the VLBI Converter Subassembly and digitized. The ODA Modcomp Computer receives the data from the VLBI Converter Subassembly and records it on magnetic tape. Concurrently, the ODA receives calibration and ancillary data from the DSS Tracking Subsystem (DTK). In real-time the ODA formats the calibration and ancillary data for HSDL transmission to the NC Radio Science Subsystem (NRS) via the Communications Monitor and Formatter (CMF). Post pass, the ODA formats the digitized receiver data, calibration data, and ancillary data for Wideband Data line transmission to the GCF Data Records Subsystem. During VLBI operations, a reconstructed analog signal is passed to the Spectrum Signal Indicator (SSI) for verification of the calibration tones in the recorded receiver data. The DSS Radio Science Subsystem is configured and controlled by the DSS Monitor and Control Subsystem (DMC), while the DRS status is routed to both the DMC and NRS. Figure 3 presents a functional block diagram of the ODA while performing VLBI Block 1 Phase 1 operations.

2. VLBI Block 1 Phase 2. Natural Radio source signals are received by the Wideband Multi-mission Receiver (MMR) and pass through VLBI Intermediate Frequency (IF) Converters. The ODA configures both the VLBI IF Converters (Bandwidth selection) and the Wideband MMR synthesizer (fixed frequency information). From the VLBI IF converters, the signals are received by the VLBI Converter Subassembly, where they are multiplexed and digitized. The Occultation Data Assembly Modcomp computer receives the data from the VLBI Converter Subassembly and records it on magnetic tape. Concurrently, the ODA receives calibration and ancillary data from the DSS Tracking Subsystem (DTK). In real-time the ODA formats the calibration and ancillary data for High-Speed Data transmission to the NC Radio Science Subsystem via the Communications Monitor and Formatter. Post pass, the ODA

formats the digitized receiver data, calibration data, and ancillary data for Wideband Data line transmission to the GCF Data Records Subsystem. During VLBI operations, a reconstructed analog signal is passed to the SSI for verification of the calibration tones in the recorded receiver data. The DSS Radio Science Subsystem is configured and controlled by the DSS Monitor and Control Subsystem, while DRS status is routed to both the DMC and NRS. Figure 3 presents a functional block diagram of the ODA while performing VLBI Block 1 Phase 2 operations.

3. VLBI Block 2. Natural radio source signals are received by the Wideband Multi-mission Receiver and pass through VLBI Intermediate Frequency Converters. The ODA configures both the VLBI IF Converters (Bandwidth selection) and the Wideband MMR synthesizer (fixed frequency information). From the VLBI IF converters, the signals are received by the VLBI Converter Subassembly, where they are multiplexed and digitized. The Digital Recording Assembly receives the data from the VLBI Converter Subassembly and records it on magnetic tape. The DRA is controlled by the ODA; for example, recording is halted during slew between radio sources. Concurrently, the ODA receives and records calibration and ancillary data from the DMC. These data are formatted for HSDL transmission to the NRS via the CMF. During VLBI operations, a reconstructed analog signal is passed to the SSI for verification of the calibration tones in the recorded receiver data. The DRS is configured and controlled by the DMC, while DRS status is routed to both the DMC and NRS. Post pass, the DRA and ODA recorded tapes are shipped via Network Information Control (NIC) to the Network (NWK) VLBI Processor Subsystem. Figure 4 presents a functional block diagram of the DRA while performing VLBI Block 2 operations.

III. Functional Requirements of the DSS Radio Science Subsystem

A. Functional Requirements for Block 1 VLBI (ODA)

Block 1 VLBI system requirements on the ODA are as follows:

(1) 250 kHz bandwidth

(2) 1 bit/sample

(3) 500 kbit/s data rate

(4) 10^9 bits data volume

(5) 1×10^{-6} bit error rate

(6) 2-nanosecond maximum sampling jitter of any bit with respect to station reference

(7) 10-microsecond time tag accuracy

B. Functional Requirements for Block 2 VLBI (DRA)

Block 2 VLBI system requirements on the DRA are as follows:

(1) 8 parallel channels

(2) 2 MHz bandwidth/channel

(3) 1 bit/sample

(4) 32 Mbit/s data rate

(5) 5×10^{12} bits data volume

(6) 1×10^{-6} bit error rate

(7) 2-nanosecond maximum sampling jitter of any bit with respect to station reference

(8) 5-microsecond time tag accuracy

(9) Control of the DRA by the ODA

IV. DRS Planned Implementation Schedule

The planned implementation dates for the various DRS capabilities are presented below:

VLBI Block 1 Phase 1

(Includes VLBI Converter Subassembly, modification of ODA hardware and software, DTK interface, wideband interface.)

DSS 14 .... July 1, 1979
DSS 43 .... July 1, 1979
DSS 63 .... July 1, 1979

VLBI Block 1 Phase 2

(Includes MMR interface and ODA software modifications.)

DSS 14 .... July 1, 1980
DSS 43 .... July 1, 1980
DSS 63 .... July 1, 1980

VLBI Block 2

(Includes modification of DRA, ODA, VLBI Converter Subassembly, and DMC interface.)

DSS 14 .... April 1, 1981
DSS 43 .... April 1, 1981
DSS 63 .... April 1, 1981

Reference

1. Berman, A. L., "The DSS Radio Science Subsystem — Real-Time Bandwidth Reduction and Wideband Recording of Radio Science Data," in *The Deep Space Network Progress Report 42-44*, Jet Propulsion Laboratory, Pasadena, California, April 15, 1978.
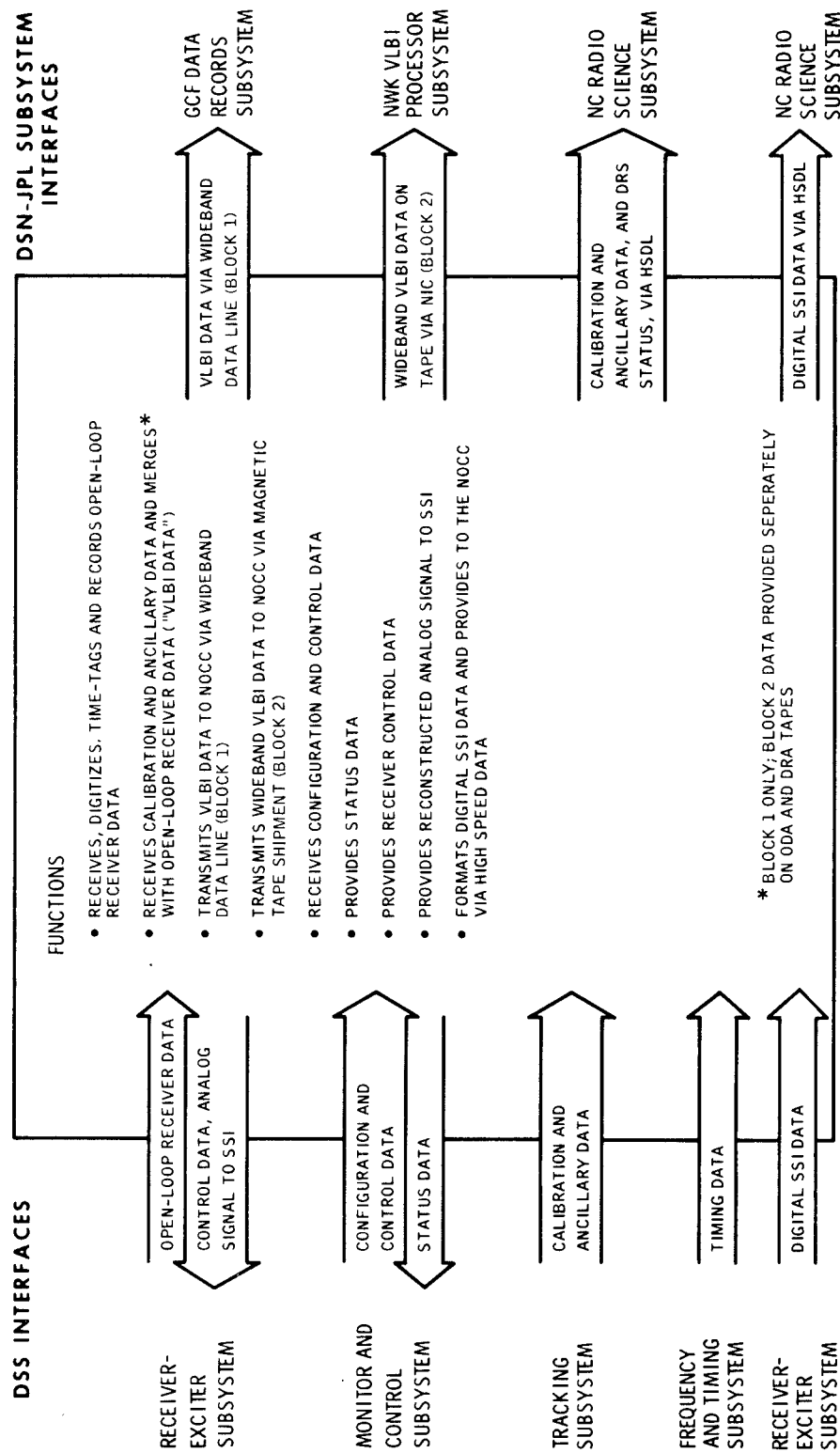
DSS INTERFACES

DSN-JPL SUBSYSTEM INTERFACES

FUNCTIONS

- RECEIVES, DIGITIZES, TIME-TAGS AND RECORDS OPEN-LOOP RECEIVER DATA
- RECEIVES CALIBRATION AND ANCILLARY DATA AND MERGES* WITH OPEN-LOOP RECEIVER DATA ("VLBI DATA")
- TRANSMITS VLBI DATA TO NOCC VIA WIDEBAND DATA LINE (BLOCK 1)
- TRANSMITS WIDEBAND VLBI DATA TO NOCC VIA MAGNETIC TAPE SHIPMENT (BLOCK 2)
- RECEIVES CONFIGURATION AND CONTROL DATA
- PROVIDES STATUS DATA
- PROVIDES RECEIVER CONTROL DATA
- PROVIDES RECONSTRUCTED ANALOG SIGNAL TO SSI
- FORMATS DIGITAL SSI DATA AND PROVIDES TO THE NOCC VIA HIGH SPEED DATA

*BLOCK 1 ONLY; BLOCK 2 DATA PROVIDED SEPERATELY ON ODA AND DRA TAPES

DSS INTERFACES (left):

RECEIVER-EXCITER SUBSYSTEM
- OPEN-LOOP RECEIVER DATA
- CONTROL DATA, ANALOG SIGNAL TO SSI

MONITOR AND CONTROL SUBSYSTEM
- CONFIGURATION AND CONTROL DATA
- STATUS DATA

TRACKING SUBSYSTEM
- CALIBRATION AND ANCILLARY DATA

FREQUENCY AND TIMING SUBSYSTEM
- TIMING DATA

RECEIVER-EXCITER SUBSYSTEM
- DIGITAL SSI DATA

DSN-JPL SUBSYSTEM INTERFACES (right):

GCF DATA RECORDS SUBSYSTEM
- VLBI DATA VIA WIDEBAND DATA LINE (BLOCK 1)

NWK VLBI PROCESSOR SUBSYSTEM
- WIDEBAND VLBI DATA ON TAPE VIA NIC (BLOCK 2)

NC RADIO SCIENCE SUBSYSTEM
- CALIBRATION AND ANCILLARY DATA, AND DRS STATUS, VIA HSDL

NC RADIO SCIENCE SUBSYSTEM
- DIGITAL SSI DATA VIA HSDL

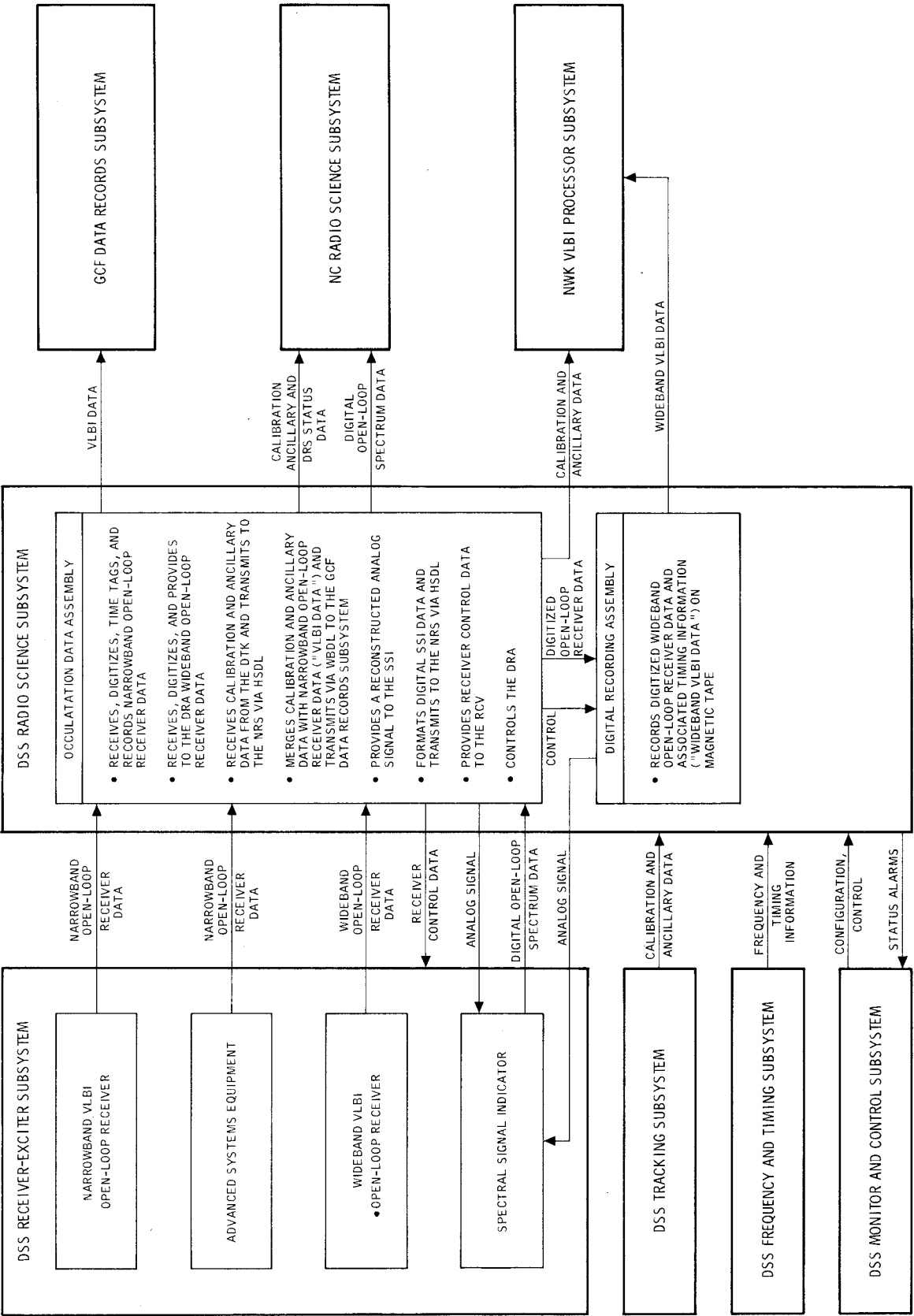Fig. 1. DSS Radio Science Subsystem functions and interfaces

Fig. 2. DSS Radio Science Subsystem functions and data flow

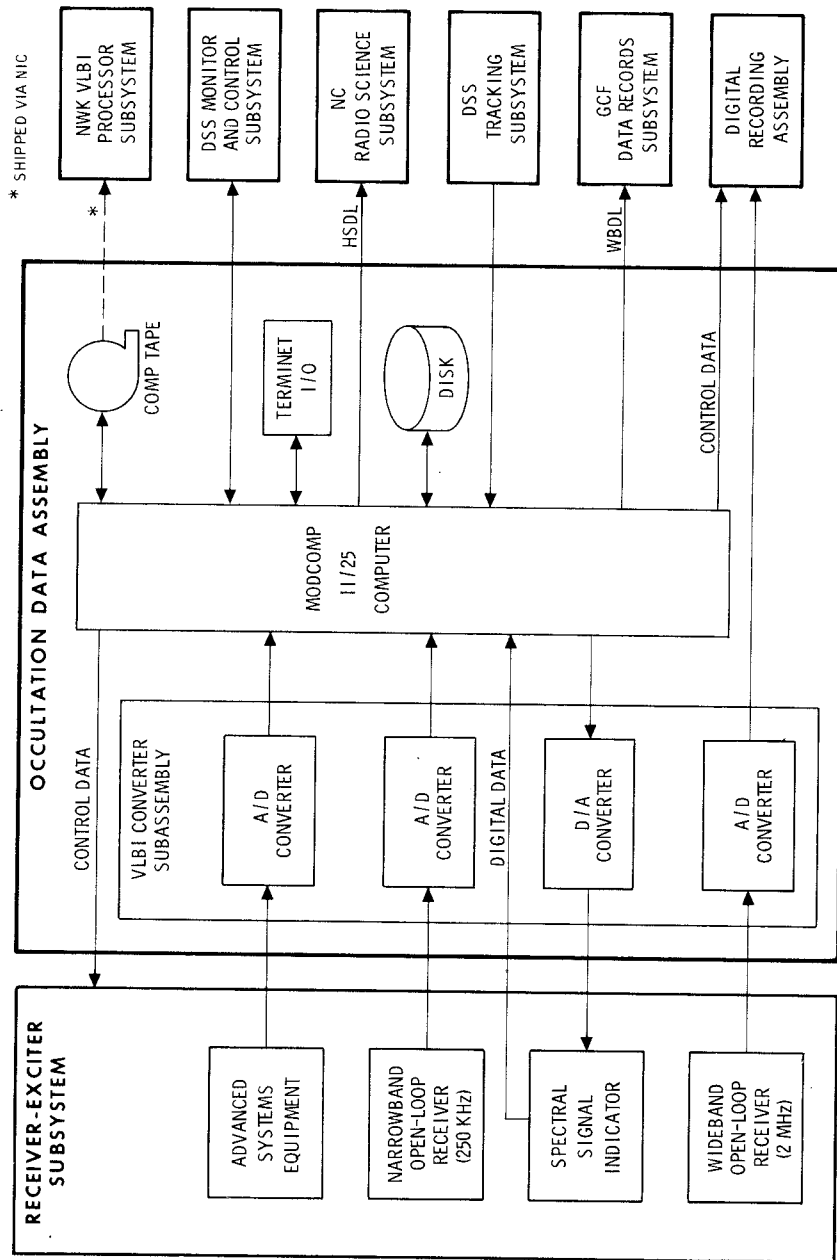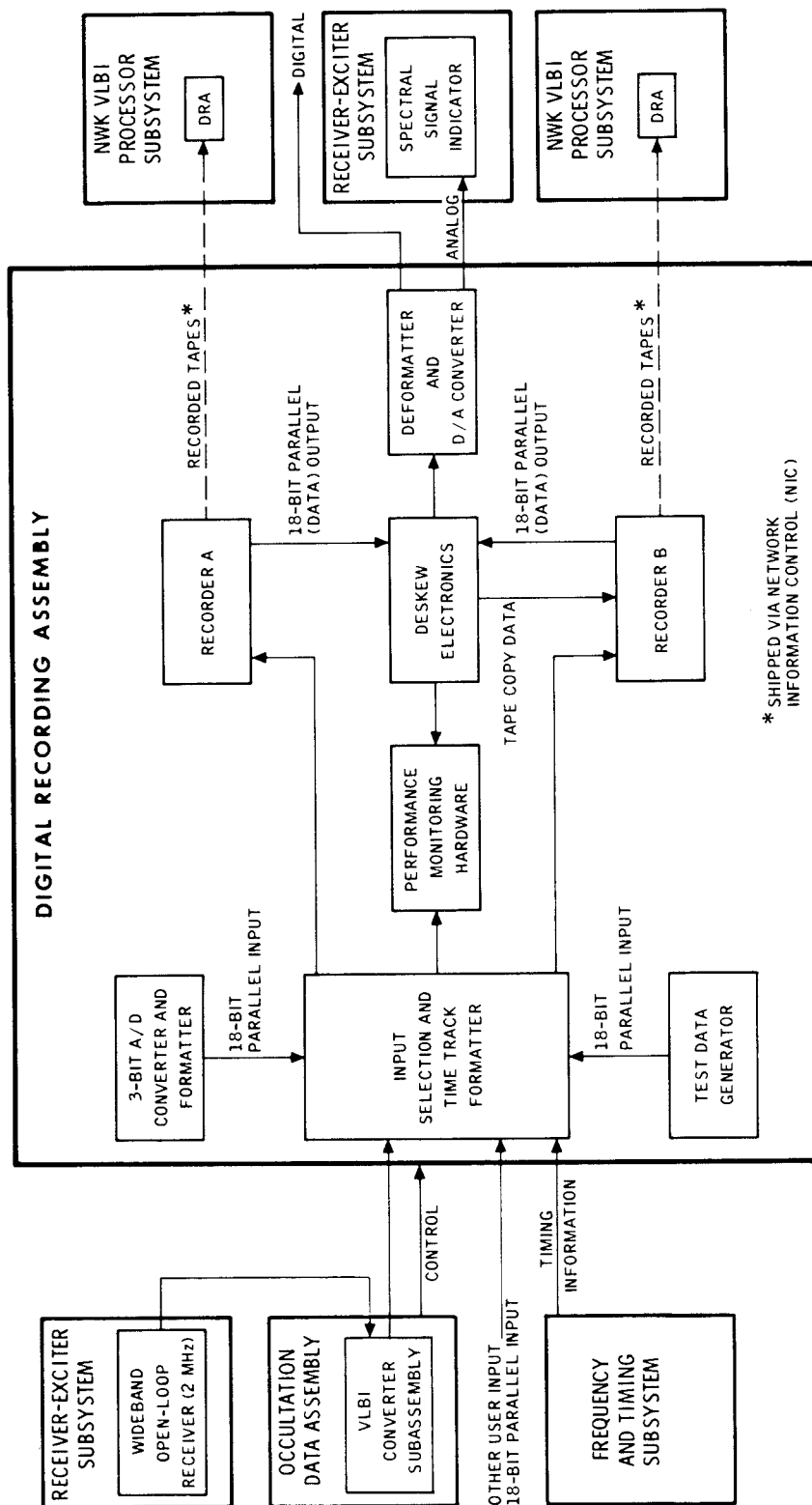Fig. 3. Occultation Data Assembly functional block diagram

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Fig. 4. Digital Recording Assembly functional block diagram