DSN VLBI System MK 1-80

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This article describes the DSN VLBI System MK 1-80 that is being implemented to provide navigation support to the Voyager Project. It describes the system requirements, description and the implementation plan.

I. Introduction

The DSN VLBI System MK 1-80 is being implemented to provide navigation support to the Voyager Project. The measurements made by Very Long Baseline Interferometry (VLBI) will provide precision time and time interval between the 64-m Deep Space Stations located at Goldstone, California, Canberra, Australia, and Madrid, Spain. In addition, measurements of interstation baseline, Earth rotation (Universal Time One) and polar motion will be made.

The Voyager project navigation requirements for Saturn encounter are < 10 μsec interstation time synchronization and < 3 parts in 10^{13} for intercomplex time interval measurements. In addition, it is desired to measure Universal Time One to < 1 millisecond and polar motion to < 0.7 meters.

A functional description, estimated accuracies and implementation phasing are discussed in this article.

II. System Description

A. Definition

The Deep Space Station (DSS) VLBI System is the assemblage of various subsystems at a specific DSS which form an instrument for receiving and obtaining necessary VLBI data in conjunction with other similar DSSs and, together with elements involved with the monitoring and control and data processing functions, comprise the DSN VLBI System.

Elements external to the DSSs receive the data via the Ground Communication Facility (GCF) and through further data processing provide information in a form for user application. These elements are located at JPL, as portions of the Network Operational Control Center.

The DSS system, when used for VLBI application, is defined as the mode when observation of only extragalactic radio source (EGRS) is being performed by two DSSs. From the measurements of difference in time of arrival of the EGRS signal between stations, the position of the radio sources can be determined, together with several other parameters of the problem solution. These other parameters include Universal Time One (UTI), Earth polar motion, the relative position of the observing stations, as well as the time offset and rate of change between station clocks.

B. Description

Functionally the VLBI system (Fig. 1) is comprised of the DSSs, which individually receive the RF signal and down-convert segment bandwidths of the RF spectrum to video-band frequencies which are then digitized and formatted by digital equipment. The digital data is then transmitted via the GCF to the NOCC and to the VLBI processing area for signal processing with data from other observing stations.

The DSS Antenna Subsystem is pointed to the appropriate signal source at the proper time by the Antenna Pointing Subsystem, which obtains pointing information (predicts) from the Network Data Processing Area (NOPA) of the NOCC via the GCF and DSS Tracking Subsystem (DTS).

The Antenna Microwave Subsystem (UWV) receives the signal flux gathered by the antenna. After amplification by the Traveling Wave Maser (TWM) the signal is sent to the Receiver-Exciter Subsystem, which heterodynes this signal to an intermediate frequency (IF). The IF signal is down-converted to video-band frequencies which are then digitized and formatted by the DSS Radio Science Subsystem (DRS).

The Frequency and Timing Subsystem (FTS) provides the station local clock, using a very stable hydrogen maser as the primary standard. Reference frequencies and timing signals are derived from the clock for distribution to other subsystems. Similarly, a reference signal from the coherent reference generator (CRG), which distributes the reference signals, will drive coherent comb generators located within the Microwave Subsystem via a coaxial-cable, phase-stabilization assembly which effectively translates the station's clock frequency stability to the comb generators. The comb generator provides comblike, phase-stable, line spectra S- and X-band microwave frequencies, which are injected into the respective Microwave Subsystems prior to the input circuitry of the TWMs.

These phase-stable reference signals are amplified by the receiver and are down-converted simultaneously with the received signals. These reference signals will be used to calibrate out phase variations (which occur within the receiver, down converter, and digital subsystems) later during the cross-correlation and data processing procedure. Since the comb signal encounters the received signal for the first time at the injection point, this point is established as the instrument's RF reference point for the DSS VLBI System. This is the point at which the cross-correlation and postcorrelation estimation calculations refer the resultant Earth parameters, station location and clock offset and rate information relative to the other instruments.

The reference is used to relate other station references such as the station's location reference point (intersection of antenna axes or equivalent) and the Epoch reference point at the FTS CRG output located within the control room. The cable stabilizer effectively translates these points with a known time delay for interstation clock synchronization purposes. The clock Epoch reference point in turn will function as the reference for all subsystems and assemblies within the respective stations.

The DRS records the VLBI data for a real-time record and, in near-real-time, sends the data to the NOCC and the VLBI processing area. This subsystem controls the various DSS subsystems for proper configuration during the operational sequence. It also receives ancillary data from the DSS subsystems which is forwarded to NOCC for monitoring information and to the processing area as processing information.

The DSS Monitor and Control Subsystem (DMC) sends control and configuration information to the DRS from data received from NOCC via the GCF. It also collects various calibration and configuration data which is provided to the DRS for logging and transmission, via the GCF, with the VLBI data or separately for monitoring purposes.

At NOCC (Fig. 2), the Network Data Processing Terminal (NDPT) uses the data for monitoring-display functions in the Network Operations Control Area (NOCA). The NOCA also provides the control information to the DSSs, via the GCF, to the DMC. The NDPA uses the data for real-time monitor functions.

The VLBI Processor Subsystem performs the cross-correlation of the data from the observing stations and, with further postcorrelation and estimation processing, VLBI information is made available to the user in the proper form.

III. Implementation

A. General Description

Implementation of the DSN VLBI System MK 1-80 will be in four phases as described below.

Phases 1, 2, and 3 configurations (Fig. 3) at the DSS remain essentially unchanged, with the changes occurring in the NOCC and VLBI processing area. The Phase 4 configuration change occurs largely within the DSS portion where the Receiver-Exciter and Radio Science Subsystems are involved. The DSN VLBI System MK 1-80 configuration will exist at the 64-m DSSs with the VLBI processor in NOCC.

B. Phase 1 Configuration

The Phase I configuration (Fig. 3) will utilize the existing DSS BLK IV receivers for a simultaneous S- and X-band reception capability. The wide-band capability is achieved by providing a separate wide-band output from the antenna mounted assemblies and a separate coaxial cable to the control room equipment.

The receiver outputs are input to the Advanced Equipment Subsystem (AES), which can select any receiver IF signal. The receiver IF signal is input to the IF to video down-converter for bandwidth synthesis (BWS) function. The outputs of the down converter channels are sent to the DRS, via an interface assembly, where the VLBI Converter Assembly and Occultation Data Assembly (ODA) digitizes and formats the data for transmission to NOCC. The ODA also provides a Real Time Record of the data and control to the AES via the interface assembly.

Station weather data, which is obtained by the Meteorological Monitoring Assembly (MMA) of the Technical Facility Subsystem (FAC), is sent to the DSS Tracking Subsystem (DTS). This information, together with the antenna angles sent from the Antenna Mechanical Subsystem (ANT), is also sent to the ODA and is included with the VLBI data which is forwarded to the station wideband data assembly of the GCF.

The antenna pointing predicts are generated by the Predict Program within the Network Control Support Subsystem (NCSS) of the NOCC, from the Radio Source Catalog, and are received by the DTS via the GCF HSDL and CMF. These predicts are then used to direct the Antenna Pointing Subsystem (APS) from a drive tape prepared via the DSS Monitor and Control Subsystem (DMC).

The DMC obtains various monitor input information which is sent to the DRS as control and configuration data for transmission to NOCC. Sequence-of-Events (SOE) and status information is also sent between the DMC and NOCC via the HSDL. The NOCC NDPT displays the configuration and status information at the Network Display Subsystem, with display to and control from the Network Operations Area (NOA).

The VLBI data from the ODA is received by the Network Log Processor Assembly (Fig. 4) of the GCF, which generates a network data log. This data is used to generate an Intermediate Data Record (IDR), which is then sent to the NOCC NDPA as a precorrelation record, with similar records from the other observing stations for cross-correlation within the VLBI Processor Subsystem. A postcorrelation record is obtained from the correlation program of the proccessor and, with the postcorrelation program and estimation program, the information related to station clock synchronization, UTI and Earth polar motion is made available to the user.

C. Phase 2 Configuration

The DSS portion of this phase remains the same as Phase I. The main change occurs in the VLBI data transmission and the VLBI Processor Subsystem (Fig. 5). The VLBI data from the DRS is sent via the GCF over wide-band data lines (WBDL) to the VLBI Processor Subsystem, located in the VLBI Processor Subsystem, which cross-correlates the similar precorrelation record from the other observing station.

The postcorrelation record is obtained from the VLBI Processor Subsystem and, in addition, the VLBI correlator status information is sent from this processor to the DMC via the GCF HSDL. The postcorrelation record is then used by the postcorrelation and estimation program of the interim VLBI Post Correlation Processor (360/75), which is remotely located from the VLBI Processing Room. The resulting computed information on clock synchronization, UTI and polar motion is obtained from the processor for user application.

D. Phase 3 Configuration

The primary change of this phase occurs in the VLBI Processor Subsystem. This subsystem replaces the interim postcorrelation (360/75) function (Fig. 2) and performs all the normal functions of cross-correlation and postcorrelation and estimation within the VLBI Processor Subsystem.

E. Phase 4 Configuration

This phase has the major change within the DSS, particularly within the Receiver-Exciter and Radio Science Subsystems (Fig. 1). The receivers operating at both S- and X-band replace the DSS Block IV receivers previously used. These new receivers are phase stable and possess a wide instantaneous bandwidth (span bandwidth of approximately 400 MHz centered at 300 MHz).

The IF signals terminate in their individual IF to video converter assembly, which replaces the BWS channels of the AES. The video converters each provide two down-converted video band spectrum signals, in quadrature phase, which are sent to the DRS for further operation. The local oscillator which down-converts the wide-band IF spectrum into individual channels is comprised of 8 (for X-band) separate frequency-set digital controlled oscillators (DCO), which are sequentially selected to provide the narrow segment bandwidth channels. This scheme permits the independent frequency setting and continuous operations of the individual channel oscillators to maintain the phase continuity as they are sequentially selected.

The DRS receives the two quadrature signals from the converters and, after digitization and further processing, rejects the image noise "foldover" of the video spectrum and then low-pass filters this spectrum to reduce the harmonics by using digital techniques. The signal is then formatted and transmitted to the VLBI Processor Subsystem via the GCF WBDL. The DRS also provides the control signals to the receiver subsystem for DCO frequency control and channel selection.

The S-band receiver IF video converter contains only four channels instead of the eight channels.

IV. Summary

The DSN VLBI System MK 1-80 Phases 1 and 2 will be operational to support Voyager Project navigation and will meet or exceed the accuracy requirements. It is expected that the Galileo project will have the same accuracy requirements. The design of the DSN VLBI System MK 1-80 anticipated a future requirement of ΔVLBI (angular measurement of a spacecraft relative to a known radio source). The DSN VLBI System MK 1-80 can support ΔVLBI, with some software additions to the VLBI Processor Subsystem.

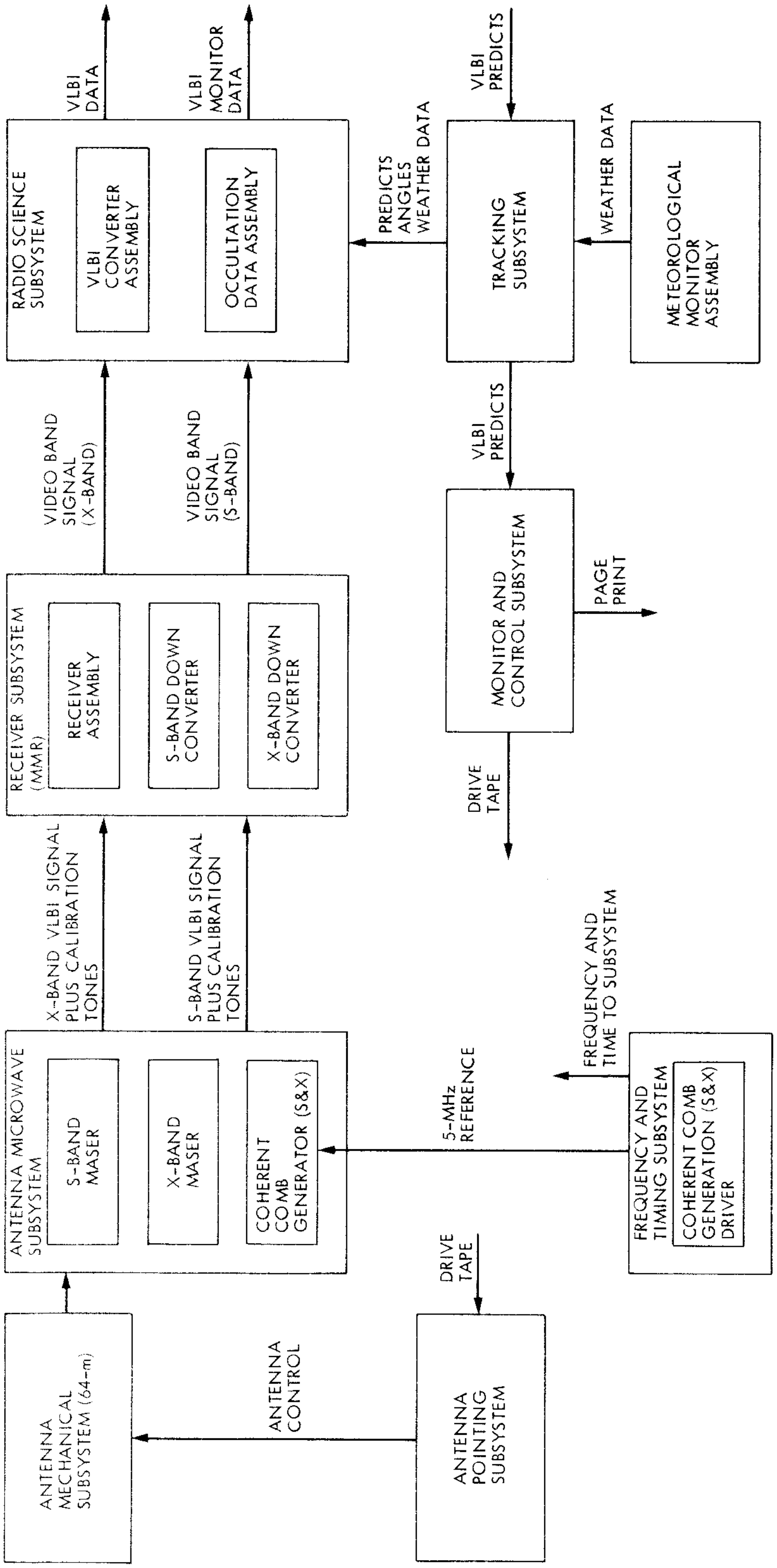

Fig. 1. DSS VLBI functional block diagram

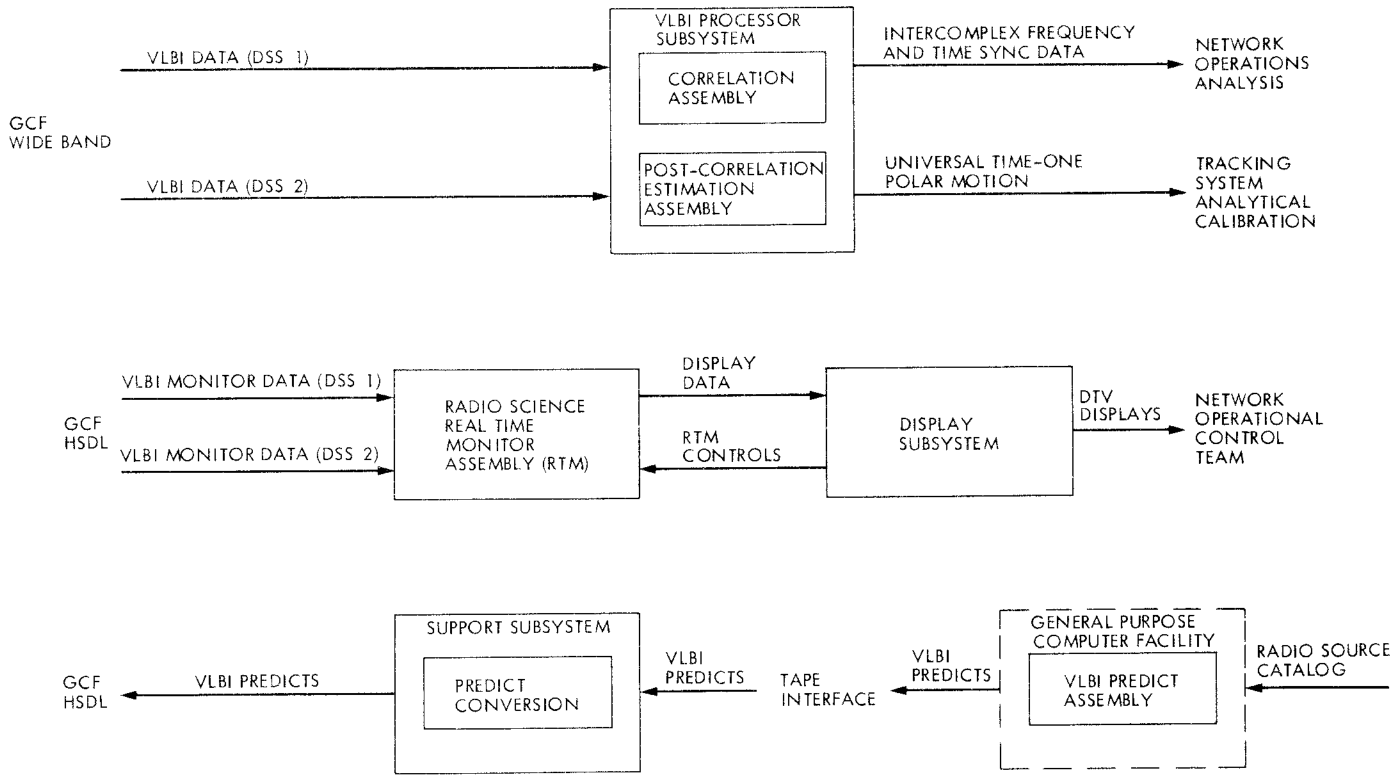

Fig. 2. NOCC VLBI functional block diagram, Block I, VLBI Phases 3 and 4

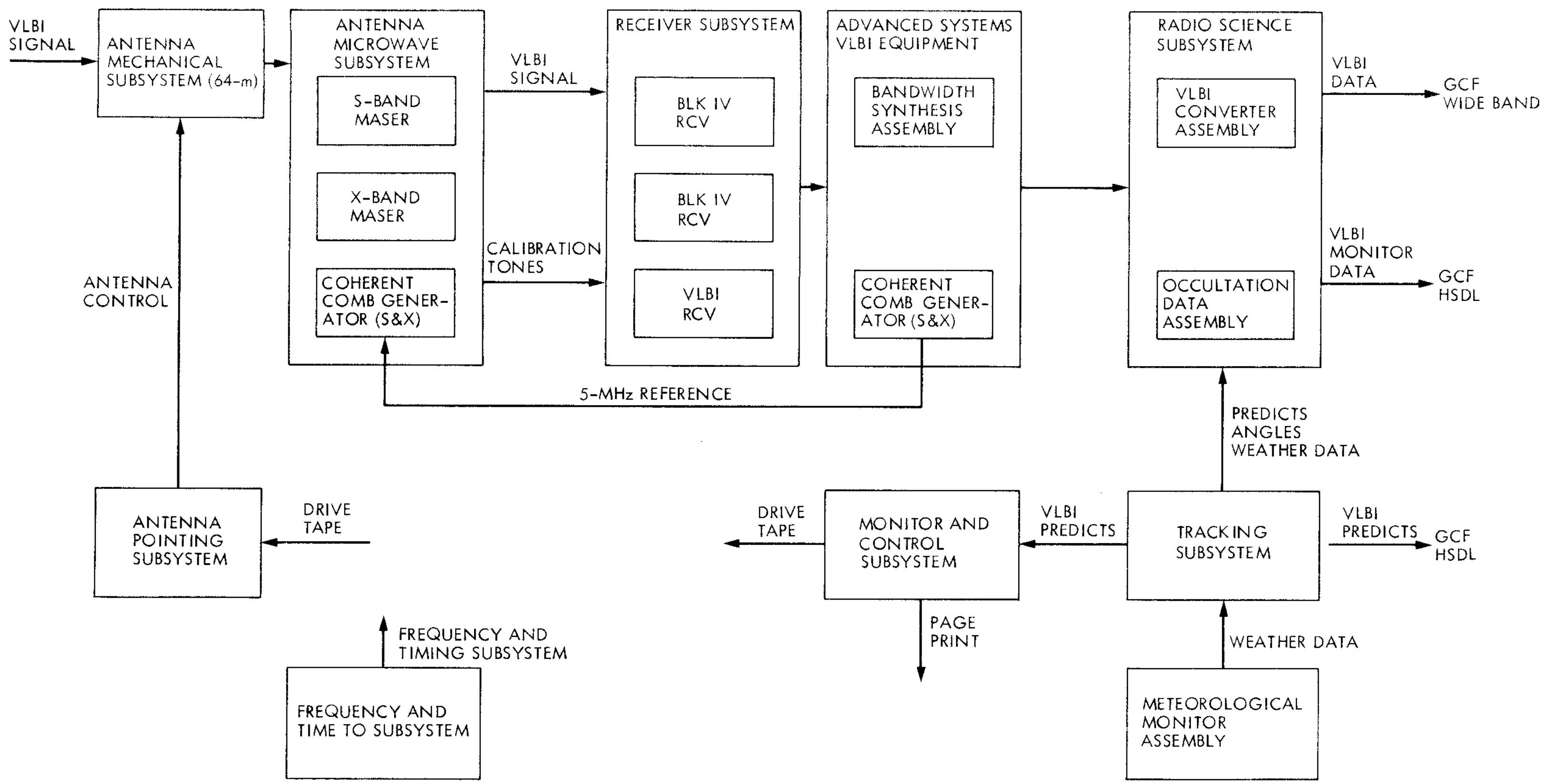

Fig. 3. DSS VLBI functional block diagram, Block I, VLBI Phases 1, 2, and 3

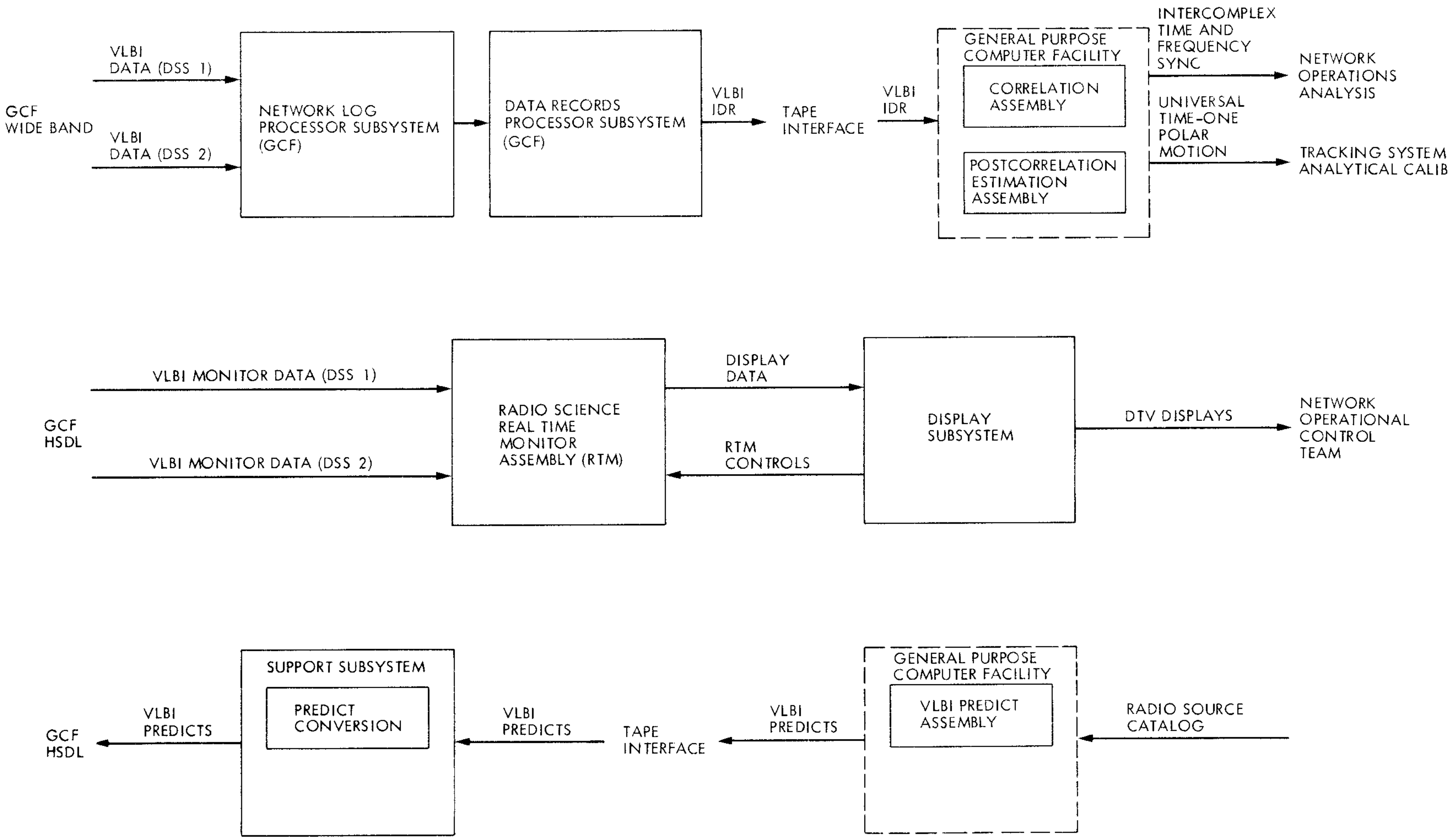

Fig. 4. NOCC VLBI functional block diagram, Block I, VLBI Phase 1

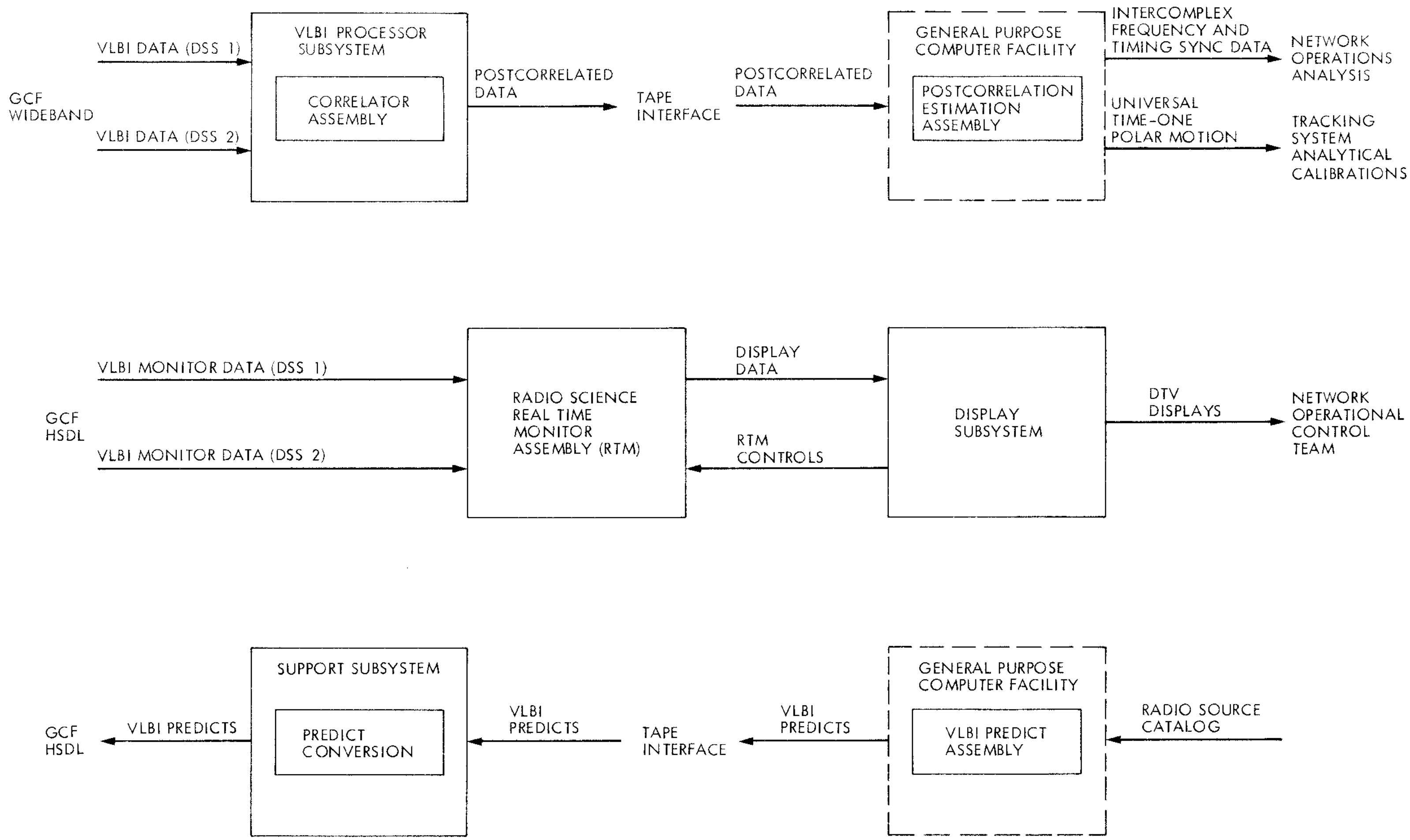

Fig. 5. NOCC VLBI functional block diagram, Block 1, VLBI Phase 2