DSN Frequency and Timing System, Mark IV-85

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As part of the DSN Mark IVA Implementation Program, the DSN Frequency and Timing System is currently undergoing changes. With the implementation of Signal Processing Centers (SPC) at each Deep Space Communications Complex (DSCC), major changes to the frequency and timing distribution equipment were necessary. This article provides a functional description of the Mark IVA Frequency and Timing System (FTS) as it exists today and planned capabilities through 1988.

I. System Definition

A. Background

The necessity to upgrade the Mark III-77 FTS was driven by two factors. First, the consolidation of the DSN stations at a central complex required an increased distribution capability for time and reference frequencies. It also required centralized control and monitor of the frequency and timing equipment. Since a complex would be supporting concurrent operational activities, a need for the generation and distribution of simulated time was necessary. The second factor was the growing need to replace aging equipment that had been in service for twenty years.

B. Functional Definition

The DSN Frequency and Timing System provides precision frequency and timing data required at the Deep Space Stations throughout the DSN.

The DSN Frequency and Timing System performs two main functions, providing frequency and timing data and validation. Frequency and timing data consists of sinusoidal reference frequencies, timing pulses, and epoch time codes. Frequency and timing validation assures that the primary frequency standards throughout the entire DSN are maintained within prescribed tolerances relative to the National Standard–United States Naval Observatory/National Bureau of Standards (USNO/NBS).

C. Functional Description

The Frequency and Timing System functions are conceptualized as follows:

(1) Generation of precision frequency signals to provide references for the generators of sinusoidal signals, timing pulses, and time codes within DSCC's.

(2) Generation and distribution of sinusoidal reference frequency signals, timing pulses, time codes, and provision for time displays within DSCC's.

(3) Control and monitoring of configuration status and operating mode of the FTS at DSCC's.

(4) Network-wide synchronization of all Frequency and Timing System signals to NBS, validation of frequency

standard calibration, and traceability of time to Universal Time, Coordinated (UTC).

Figure 1 depicts the Mark IVA Frequency and Timing System configuration.

D. Key Characteristics

The key characteristics of the Frequency and Timing System are:

- Knowledge of time synchronization (to ± 10 μs) and frequency offset (± 3 parts in 10^{-13}) between DSCC's
- Knowledge of time synchronization (to ± 5 μs) between the DSN and the National Standard (USNO/NBS)
- Knowledge of time synchronization (to ± 10 μs) and frequency offset (to ± 1 part in 10^{-11}) within each DSCC
- Performance validation of frequency and timing functions for each Front End Area (FEA) and SPC at a DSCC
- Maintenance of a permanent record of frequency and time parameters including configuration and synchronization
- Simulation time selectable from the DSCC Monitor and Control Subsystem (DMC).

II. System Elements

A. Functional Elements

The major elements of the Frequency and Timing System consist of a Frequency and Timing Subsystem located at each DSCC and a Network FTS Data Base subsystem located at DSN Network Operations Control Center. The Frequency and Timing Subsystem consists of six major subsets of equipment. (The relationships between the subsets are depicted in Fig. 2.)

- Frequency reference standards
- Frequency synthesis and distribution
- Reference frequency cable stabilization
- Time and timing generation and distribution
- Time synchronization
- Monitor and control.

B. DSS Frequency and Timing Subsystem

The master frequency standard consists of two Hydrogen Masers backed by two Cesium Beam Frequency Standards. These standards, which are located in an environmentally controlled area, are provided with an uninterruptible power source for emergencies. Any of the four standards can be selected by the complex operator as the prime standard. However, if the prime standard fails, another standard is automatically selected.

The frequency synthesis and distribution subset consists of a Coherent Reference Generator (CRG), which includes discrete synthesis, distribution amplifiers, and an interface panel. The CRG receives 0.1 MHz, 1 MHz, 5 MHz, and 100 MHz from the on-time frequency standard. It generates 10.1 MHz, 45 MHz, 50 MHz, and 55 MHz and provides distribution ports for user subsystems.

Sinusoidal reference signals are also distributed to users at the antenna areas. This is accomplished by the use of active stabilized cables that compensate for small phase changes in the distribution path. These actively stabilized cables are used for VLBI to provide the same stability as that of the Hydrogen Maser reference frequency standard. The stability requirements for the standard reference frequency are defined in Table 1.

The time and timing subset consists of a triple redundant master clock, simulation time generator, time insertion and distribution, and time code translators. The master clock equipment provides the following new capabilities for the DSN:

- Year End–Automatic reset
- Leap Year–Automatic extra day addition
- Leap Second–Automatic subtraction or addition of leap second
- Resetability–Simple clock adjustments

Time codes and timing pulses are provided to each user via a time code translator. Two types of translators are provided for user application, and the time code is available in binary milliseconds or binary-coded decimal (BCD) seconds. Time codes are also distributed to users at the antenna areas via fiber optic cables.

Time synchronization of the three complexes to the National Bureau of Standards is accomplished via the Global Positioning Satellite (GPS) System by utilizing a GPS receiver at each complex. Also, other sources for time synchronization include: WWV, LORAN C, TV line 10, and traveling clocks. Time-sync data are also available from the VLBI system.

The functional capabilities of the Frequency and Timing Subsystem can be controlled locally at the equipment level or remotely from the complex operator position. The complex operator is provided with various displays that contain both status and performance parameters. Such parameters will be forwarded to NOCC for application in the Network FTS Data Base.

C. NOCC Subsystem

The Network FTS Data-Base Subsystem, to be implemented in 1988 at NOCC, will receive configuration data, status data, and performance data from the FTS subsystem at each DSCC. Also it will receive GPS time-sync data from the Tracking System and VLBI time-sync data from the VLBI System. The data will be analyzed as to time and frequency offsets between complexes, clock behavior, and Hydrogen Maser performance. The results will be available to complexes and to Network Operations.

Presently, the analysis function is being performed by the Network Operations and Analysis Section (NOA) as a DSN supporting element. NOA is responsible for generating reports, monitoring the FTS system, and coordinating changes to complex time and frequency standards, as well as generating monthly reports containing both time and frequency measurement data.

III. FTS System Schedule

The following additional implementations will complete the Mark IVA FTS:

In support of the X-band uplink implementation, stabilized cables and distribution equipment are required for distributing 100-MHz reference signals on the antennas at DSS 45, 65, and 15.

Time analyzer assemblies and frequency standard monitor equipment will be implemented as part of the FTS monitor and control in FY 86.

FTS Data-Base Subsystem at Network Operations Control Center will be implemented in FY 88.

Table 1. Reference Frequency Stability

T	Allen Variance (τ)	
	Signal Processing Center	VLBI Antenna-Mounted Equipment
1 sec	1×10^{-12}	1×10^{-12}
10^4 sec	1×10^{-14}	1×10^{-14}
12 hours	1×10^{-14}	1×10^{-14}
10 days	1×10^{-13}	1×10^{-13}

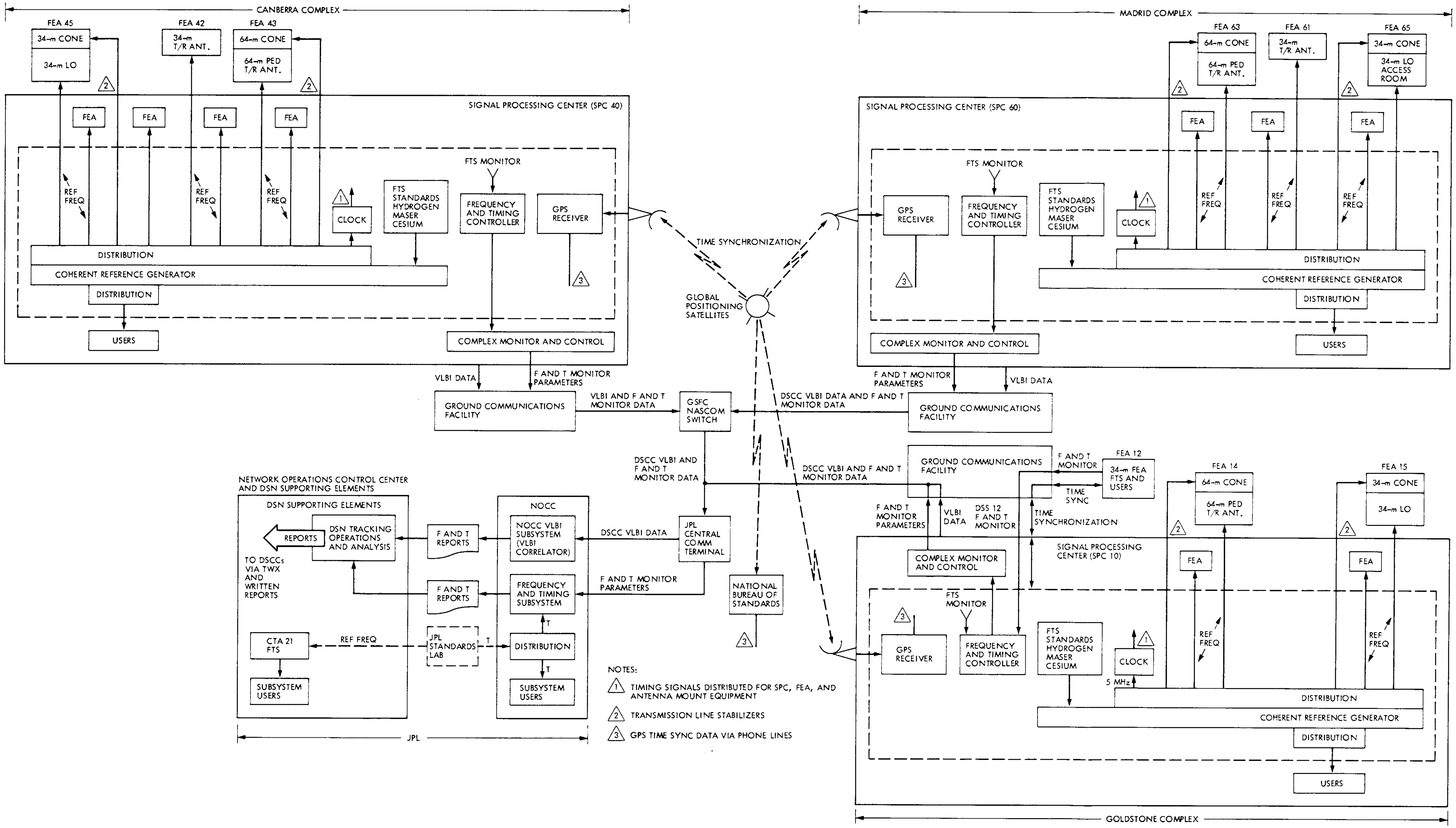

Fig. 1. Mark IVA DSN Frequency and Timing System functional design block diagram

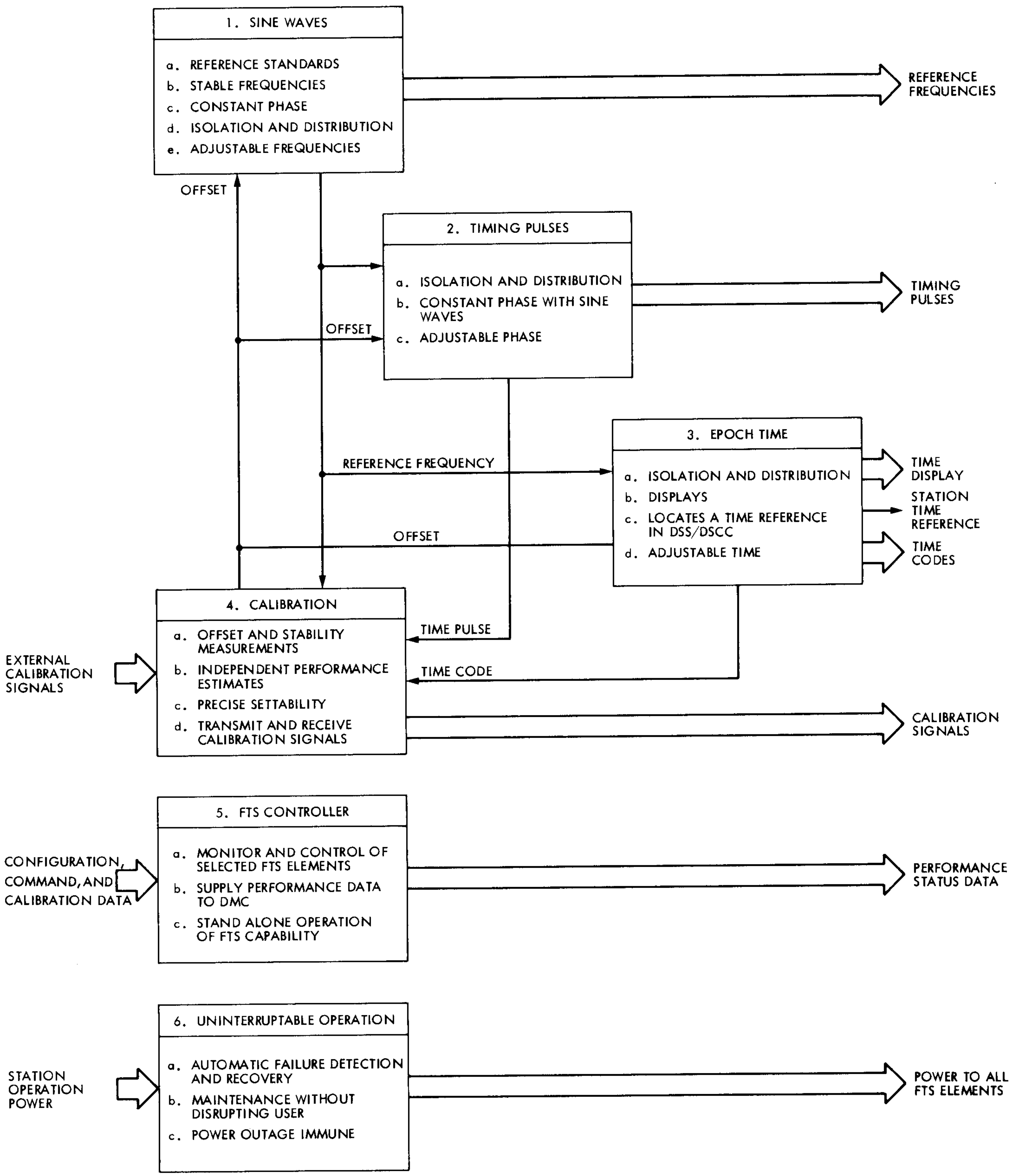

Fig. 2. FTS functional elements and relationships