Data reception system for IRS-1C

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Data transmitted by IRS-1C satellite is received at Earth Station at Shadnagar near Hyderabad. This sophisticated Data Reception Complex works in a multimission mode supporting data reception from several remote sensing satellites, viz. IRS series and also Landsat and ERS. This article describes the various elements in the data reception chain. The specifications of various sub-systems and necessity of having these in a data reception station is also discussed. Complete data flow from the time, RF signal is picked up at antenna and till it is recorded on high density digital tape is explained at sub-system level. Data archival and real time system is also explained giving details about level 'O' processing of data. Required test facilities and system margins desirable are also given apart from necessary infrastructure.

IRS-1C is the latest new generation satellite of India with added features of high resolution tiltable PAN camera, LISS-III and WiFS sensors. This is also the first remote sensing satellite with three X-band carriers, two for data and one beacon and one S-band telemetry carrier. All this has put more stringent requirements on the ground station.

Existing data reception facilities at Shadnagar, 55 km from Hyderabad, which were being used for data reception from several national and international remote sensing satellites, viz. IRS-1A/1B, P2, LANDSAT-5, ERS-1/2 and NOAA series of satellites, are augmented to provide a reliable data reception system for IRS-1C satellite. This is the only data reception station in the country presently. IRS-1C is a global mission, with on board tape recorder (OBTR) for taking pictures of places outside our visibility zone. IRS-1C mission has decided that OBTR data shall be dumped only over Shadnagar Earth Station and thus put further emphasis on the reliability and back-up requirements.

It was decided to upgrade the existing Earth Station by way of augmentation and addition of equipment for making the stations capable of receiving data from two carriers of IRS-1C, and also tracking on X band beacon and on S band telemetry carrier, along with telemetry data reception with adequate back-up to avoid single point failures in the receive chain.

Multimission requirement

Remote sensing satellite earth stations have to operate with low altitude polar orbiting satellites in sun-synchronous near-circular orbits. Due to high relative velocities between the satellite and the ground station, the earth station antenna has to move with high speeds in azimuth and elevation axes to keep the antenna pointed towards the satellite for the entire duration of satellite visibility.

At Shadnagar Earth Station, there are several remote sensing satellites from which data reception is carried out, and therefore causing added complications in operations as satellite visibilities will clash in time with other satellite visibilities. Scheduling of satellite reception between two stations has to be done in such a way that we lose minimum data, and also prioritize the user request from a particular sensor.

Two stations at NRSA earth station complex are upgraded for data reception in X and S band such that one station (Terminal-I) is dedicated for data reception from all IRS series of satellites and the other (Terminal-II) is capable of receiving data from all IRS series as well as from foreign satellites, viz. Landsat-5 and ERS-1 and ERS-2.

In case of clashes of visibility terminal-I shall be prioritized for IRS-1C reception while terminal-II shall support other user requested satellite data reception.

This paper describes various sub-systems used in the Earth Station, their functions and also operational requirements of data reception station for IRS-1C satellite.

Data reception system

The ground station consists of: Antenna and receive system, data archival and realtime system, test facilities, support facilities (electrical, communication).

Antenna and receive station

This system comprises of three main elements: Antenna system, servo control system, receive/tracking system and does the following basic works:

- Acquisition and recording of payload and telemetry data
- Tracking of satellite in both X and S bands apart from program tracking as back-up.
- Back-up support to mission from Terminal-II providing all the functions of main station.

Subsequent paragraphs shall describe each of the main

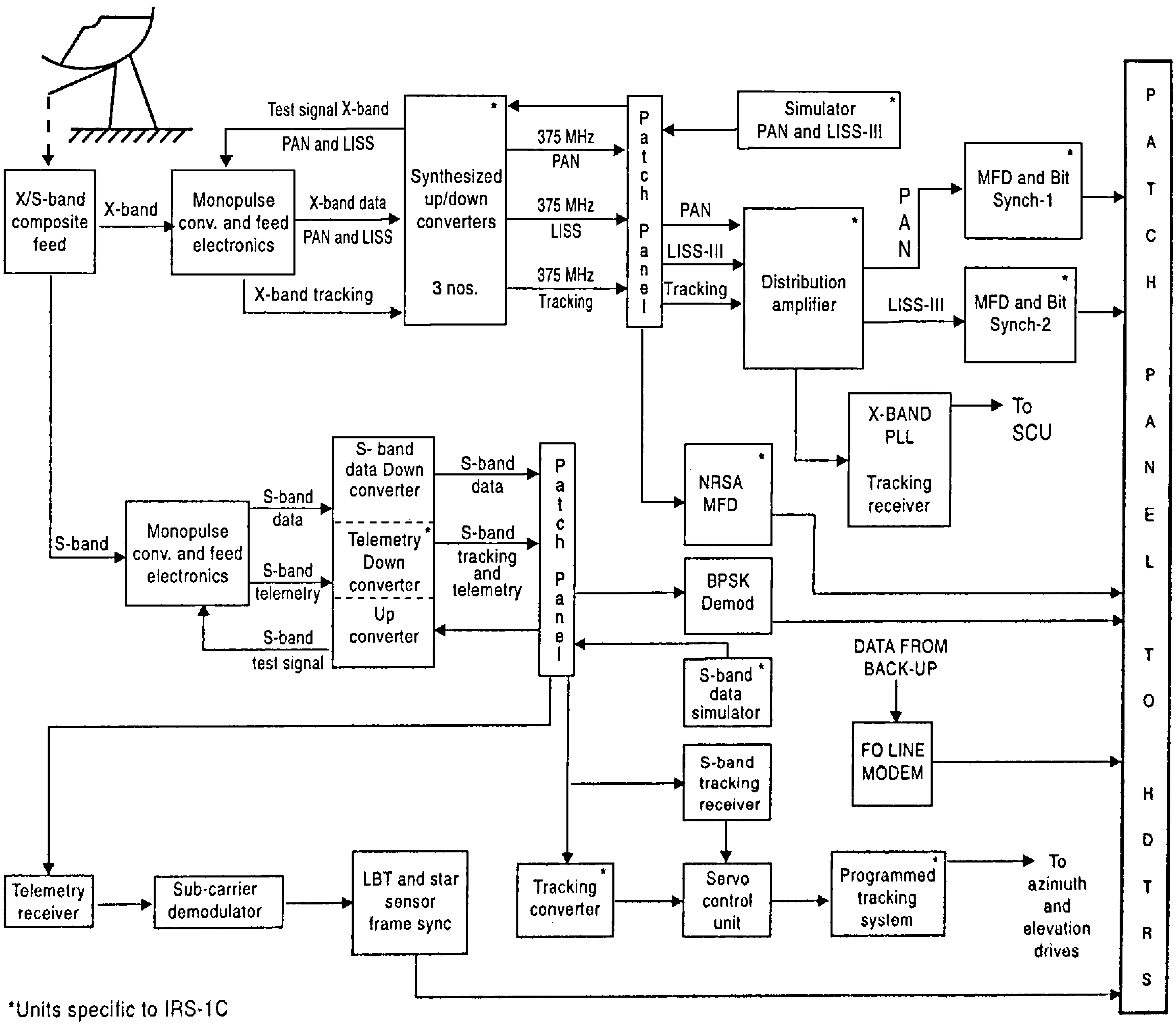
:lements of earth station. Figure 1 describes the basic ›lock diagram of antenna and receiving system.

\ntenna system

:he antenna system consists of a parabolic reflector and nultihorn composite feed (X and S band) in cassegranian .rrangement. The feed is a dual frequency monopulse racking type, designed to receive X and S band signal requencies, simultaneously. The detailed description of ach subsystem is given below.

?eflector

'he reflector is a 10 m dia parabolic dish. The reflector consists of a machined, reinforced circular hub which supports 24 radial truss ribs. The 24 trusses support 24 solid reflector surface panels. The entire reflector is assembled by bolting all these components together. Each panel is supported by machined tabs on the radial trusses which lock the overall shape and antenna surface tolerance. There are red aircraft warning lights and lightning rods mounted on the reflector. The reflector assembly is mounted on a EL over AZ tracking pedestal which drives the antenna. The reflector weighs 1.6 tonnes and the tracking pedestal weighs 5.5 tons. The tracking pedestal also houses drive trains, gear boxes, synchros, limit switch, etc. and contributes to the overall low inertia of the pedestal structure due to its compact size.



*Units specific to IRS-1C

Figure 1. IRS-1C data reception station.

Sub reflector

The sub-reflector is a part of cassegranian feed assembly. Its diameter is 1.52 m machined by hyperboloidal surface with an eccentricity of 1.55 and is supported by four aluminium spars with ogival cross section. The sub-reflector has been chosen to take care of the large offsets caused by the S band feed horns.

Antenna system characteristics

Main reflector	10.06 m dia parabolic
Sub reflector	1.5 m dia hyperbolic
Focal length over diameter (F/D)	0.39
Surface accuracy	0.8 mm RMS static 1.25 mm RMS at 96 kmph wind
Weight	1.6 tonnes
Tracking pedestal type	Elevation over azimuth
Delivered torque	60,000 ft lb
Orthogonality tolerance	0.02°
Gear type	Precision spur gear
Gear ratio	Azimuth 1026 : 1 Elevation 1700 : 1
Elevation travel limits	Primary electrical, secondary mechanical
Azimuth travel limits	Primary and secondary electrical limits
Elevation travel	0–180°
Azimuth travel	± 360°

Feed

The feed is a dual band monopulse tracking type, which consists of two sets of four diagonal waveguide horns. The feed assembly consists of a waveguide monopulse comparator and a phase commutation unit for generating the single channel monopulse tracking signal. The feed front is covered with a radome which offers an acceptable axial ratio at both the signal frequencies.

The X band horns of the feed are square wave guide apertures that flare down slightly to 1.12 inch square wave guide. A capacitive slot fitted with di-electric surrounds the X band horns to isolate them from the effects of the S band horns. The four S band horns are arranged in a diamond array outside X band horns. The feed is designed to receive a right circular polarization which is converted into a linearly polarized signal by a polarizer with iris design. The polarizer is followed by a square waveguide, supporting a linearly polarized wave, adapted to a rectangular waveguide with an impedance matching section.

The feed collects the offset signal amplitudes in AZ and EL axes to produce tracking error signals and feeds it to the monopulse comparator. The comparator compares each pair of beams to produce the tracking error signals. When the signal source is on boresight, each beam has equal amplitude and the comparison results in zero signal in different channel. The data signal or sum signal is formed in the monopulse comparator by adding all four beams together.

When the signal source is not on boresight, the offset beams create signal amplitudes in AZ and EL axes and the comparator outputs these signals to the phase commutation unit. Both the monopulse comparator and the phase commutation unit in X band chain are waveguide type while those in S band chain are of strip line design.

Servo control system

A servo system drives the EL over AZ mount to point the antenna axis in the required direction. It has one narrow band width (NB II) of 0.5 Hz and a wide band width (WB) of 0.9 Hz and performs auto tracking function and uses two permanent magnet d.c servo motors per axis. These motors can deliver up to 15 hp power for short durations.

During tracking, feed supplies the error signals modulated over the sum signal and also the synchronizing signals to detect these errors in tracking receiver. The demodulated d.c errors form the input to the servo system. The heart of servo control system is a microprocessor-controlled unit which contains almost all the operator selectable functions for the system. Various modes of operations are as follows:

Ready. In this mode, system is ready to accept auto acquisition commands.
Manual position. Antenna positioning is possible using synchro position handwheel.
Command angle. In this mode, the antenna can be positioned to any desired position by selecting the required angle on the command angle display.
Manual rate. Antenna can be moved at constant rates in both axes.
Program track. In this mode, the antenna movement is controlled by the computer which is connected to the system.
Auto backup modes. If the target is lost then these modes come into play and put system ready for reacquisition.

Control circuit for servo system is designed using logic chips and solid state devices specially designed for fully automatic functions and operators ease. The servo control unit feeds the compensated/integrated d.c error signals, to torque bias circuitry, which is responsible for torque-biasing the two drives of each axis such that backlash of the gears is effectively removed. The torque bias, in turn, feeds signals to power the amplifier and to servo motors. Drive motors are coupled to load (antenna) through torque coupling. Power amplifiers also incorporate current feedback and limiting circuits.

Instantaneous angular positions of antenna are displayed by the digital display unit with a resolution of 0.01°. Dual speed synchro transmitters coupled to each pedestal axis provide input to this unit.

Zenith pass is tracked in programme tracking mode, thus keeping loss of data to minimum in passes having elevation angles higher than 89° due to the AZ-EL mount constraint.

The integrated servo control system is a user-friendly system built around a PC AT 486. This also does:

- Scheduling of passes for the station and configuring the station for the particular mission.
- Moves antenna to desired angles (to expected direction before a pass)
- Monitors all critical parameters during realtime and automatic feedback to programme tracking in case of auto track failure.
- This system generates its own pre-pass planner report giving look angles of antenna for the satellite trajectory, making it a stand alone system.

Characteristics of servo system

Motor	7.5 HP, 5,000 rpm, short time rating up to 15 HP
Pointing accuracy	±0.1°
Synchro/readout accuracy	0.01°
Maximum velocity	Azimuth 22°/s Elevation 5°/s
Maximum acceleration (in auto mode)	Azimuth 10°/s^2 Elevation 1°/s^2
Locked rotor frequency	4.2 Hz
Power amplifier	Using single phase, fully reversible, SCR power amplifier peak current 70 amp

Receive system

Low noise amplifiers (LNA)

The front end amplifier of X band and S band systems is GaAs FET LNA. The noise temperatures of these units have been so selected that the station provides a G/T of 31 dB/K in X band and 19.6 dB/K in S band. (Low noise amplifiers of appropriate noise figure and gain have been used in the difference channel also to amplify the error signal after the phase communication unit.) The gains of the LNA are so selected that, the error amplitudes are comparable to the sum signal amplitudes to create the amplitude modulation index of the tracking signal within a limit of 30% in X band and 15% in S band.

X band tracking unit

The amplitude-modulated tracking signal is generated separately in the tracking unit. The sum signal from the data LNA is divided into two channels. One channel goes independently as a data channel not interfered by the tracking information. The other channel is fed to a 6 dB directional coupler. The difference channel signal from the corresponding LNA is passed through a variable phase shifter and fed to the 6 dB directional coupler to which the sum channel signal is also fed. The error channel thus amplitude modulates the sum channel in the coupler to create an amplitude modulated tracking signal.

The phase shifter in the difference channel provides a fine phase matching between sum and difference channels. The tracking unit is mounted inside the antenna hub nearer to sum LNA to avoid cable losses at RF frequency.

X band synthesized up/down converter

The X band synthesized down converter unit inside the hub receives the data and tracking channel RF signals. There are three downconverter channels, two for data and one for tracking.

The signals are passed through the input band pass filters and get mixed in a double balanced mixer with the local oscillators, i.e. synthesized oscillators, to get converted to IF signals of 375 MHz frequency. The down converter is designed to cover the entire allotted frequency band of 8025–8400 MHz. The same synthesized oscillators feed down converters and the upconverters for test loop through power dividers.

A test signal of 375 MHz of PAN and LISS-III from the simulators coming from control room are upconverted in synthesized upconverter and these combined RF signals are fed to test coupler in front of LNA for local loop data quality checking of system.

Data demodulators and bit synchronizers

The X band data and tracking signals driven down from the antenna hub to the control room are amplitude-equalized and amplified.

The data signal is fed to the respective multifunction DEMOD/BSSCs to extract the PAN and LISS-III payload data in I and Q channels and the clock signal.

One set of DEMOD/BSSC is available as stand-by for either PAN or LISS-III data in main terminal for recording in case of backup terminal non-availability due to clash of passes of other missions.

The ECL signals from the demodulators/BSSCs are buffered and fed to the corresponding high density tape recorders for on line recording.

The LISS-III X band tracking IF signal is fed to a PLL type tracking receiver to extract the AM video. Both tracking signal IF of S band and AM video of X band tracking chain are fed to tracking receiver through coaxial switch for selecting the tracking chain. The tracking receiver can select and demodulate either the AM video of X band or 70 MHz IF of S band tracking signal. The tracking receiver output of AZ and EL dc errors are fed to servo system.

A stand-by to tracking receiver for S and X band tracking is also provided as a tracking controller unit as this is one critical unit and can cause loss of data in case of tracking failures.

Back up terminal

Terminal-II is an identical terminal as the main station of IRS-1C and provides backup support. The data and clock of PAN and LISS-III are driven through fiber optical link to IRS control room for recording on stand-by recorders.

Telemetry reception

The telemetry (TM) signal, which can also be used as tracking signal, is fed through a power divider (in front of the tracking receiver) to the telemetry receiver to demodulate the PSK modulated sub-carrier.

The PSK sub-carrier is fed to a PSK demod/bit-synchronizer to extract low bit rate real time and play back TM data for recording. Low bit rate data are sent to SCC on data lines.

Receive system specifications

Parameter	S band	X band
Frequency band (MHz)	2200–2300	8025–8400
Feed configuration	Composite single channel	Monopulse Cassegrain
Antenna gain (dB)	43.0	54.0
Beam width (deg)	0.93	0.25
G/T (dB/K)	19.6	31.0
Polarization	RHC	RHC

IRS-1C frequency/payload parameters

	Payload	
Parameter	PAN	LISS-III
X band		
Data rate (Mbps)	84.903	42.4515
Type of modulation	QPSK	QPSK
Carrier frequency (MHz)	8150	8350
Beacon frequency (MHz)	8255 (CW)	
S band		
Telemetry	HK data and star sensor data	
Telemetry carrier (MHz)	2203.2	
Sub carrier frequency for HK (kHz)	25.6	
Data rate (bps)	512	
Sub carrier frequency (kHz)	128	
Star sensor (kbps)	6.4	
Modulation type	PCM/PSK/PM	

Link estimate

	Sensor		
Parameter	PAN	LISS-III	Beacon
Frequency (MHz)	8150	8350	8255
Modulation	QPSK	QPSK	—
Data rate (Mbps)	84.903 (79.3 dB)	42.4515 (76.3 dB)	—
Orbit height (km)	817	817	817
Transmitter power	16 dBw	16 dBw	+20 dBm
Onboard losses	2	2.2	2
Onboard antenna gain (dBi)	+7	+7	+7
EIRP	21 dBw	20.8 dBw	25 dBm
Elevation (deg)	5	5	5
Free space path loss (range 28–20 km)	179.7	179.9	180.5
Miscellaneous loss	2	2	2
G/T of NRSA station	30.2	30.2	30.2
Receive CNDR (dB)	98.1	97.7	71.3
Eb/No available (dB Hz)	18.8	21.4	—
Eb/No required for BER of 1×10^{-6} (CNDR for beacon)	12.5	12.5	68.0
Margin available (dB)	6.3	8.9	3.3

For X band total system noise temperature is taken as 240 K for calculation of G/T.

Test facilities

For qualifying the entire data reception station for quality data reception, adequate test facilities are required which must be able to quantitatively certify entire receive chain prior to satellite visibility. For this, the following facilities are established.

Local and RF loop checks. Modulated test signals are fed from a baseband simulator to the test coupler via a modulator and upconverter to simulate the realtime data streams of satellite and check the BER performance of the entire receive chain.

Boresight test facility. A boresight has been installed about 750 m away from the Earth Station antennae providing a near field boresight. One antenna each of 1.2 m dia and with multiband focal feed are mounted on top of a 30 m tall steel tower. These antennae point to the main earth station antennae of Terminal-I and Terminal-II.

For testing, a simulated signal from spacecraft suitcase model is transmitted from boresight and received by earth station antenna.

Boresight transmission is used for checking the BER performance of receive system and also auto track performance of the antenna and servo control system.

Electrical sub-system

Since the antenna has to continuously track the satellite for its entire visibility, it is essential that reliable electrical power system should be available. At NRSA earth station a captive power generation system apart from State Electricity Board feeder is available as follows:

	Capacity	Quantity
Diesel generating sets (kVa)	100	1
	200	2
	180	2
Uninterrupted power supply systems (kVa)	55	2

During satellite pass systems use only DG set power and all essential system (viz. computers, HDTRs, receive chain) uses only UPS power.

Communication link

Dedicated communication links are established between ISTRAC Bangalore, Earth Station Shadnagar and NRSA Balanagar and are used for VOD circuits, speech circuits and TP circuits for receiving and transmission of data.

VOD link/FAX

Presently two data circuits, six voice circuits and two TP circuits are operational between NRSA Balanagar and Earth Station Shadnagar. One more data circuit is being established between SAC Ahmedabad and NRSA Balanagar.

Similarly, three VOD circuits and two TP circuits are operational between Earth Station, Shadnagar and ISTRAC, Bangalore. Out of three VOD circuits, two are used as data circuits and one is used as speech circuit. One FAX CCT is also operational through hot line between Balanagar, Shadnagar and ISTRAC.

This communications link network is used for sending data to/from Spacecraft Control Centre and Earth Station. Information such as state vectors, pass scheduling and ancillary CCT, etc. are transferred on these links for reliability and saving on time.

Data archival and real-time systems

Data archival and real-time systems carry out the function of real-time data recording of both the sensors LISS-III and PAN on HDTRs from IRS-1C satellite, extraction of ancillary information in real-time from both the sensors, recording of LBT along with payload on HDTR and transfer of the same to the system along with auxiliary data and real-time telemetry data transfer to Spacecraft Control Centre (SCC), Bangalore.

The system also process the ephemeris data, attitude of the satellite from the real-time auxiliary information and then generates the ancillary information for data processing including data quality. Similar functions are carried out for night OBTR data also. In addition to the above, the system records the calibration data in real-time during night calibration passes and carries out the calibration analysis, which forms one of the basic input for data quality evaluation. The system is tightly scheduled for 24 h operations.

Description

The systems are broadly classified into: Data recording systems, timing support systems, and real-time computer systems.

Data recording systems

Primarily, Metrum make 28-track high density digital tape recorders are used for data recording. Along with the data on digital tracks, the analogue tracks are used for telemetry and UTC (time) for both payloads (LISS-III/PAN), including OBTR and CAL.

The data rates are 84.953 Mbps for PAN, 42.45 Mbps for LISS-III and 42.45 Mbps for OBTR passes. The recording speeds are 127 IPS for PAN and 63.5 IPS for LISS-III. OBTR data can be PAN-I or Q or LISS-III.

OBTR data are played in reverse mode from OBTR for recording forward on HDTR. After the real-time pass the reverse data are played and copied forward on to another HDTR to create forward OBTR data tape.

Timing and support systems

These systems include timing systems, data path controller, multi-function front-end processing hardware (MFPH), LBT frame synchronizer, fibre optic links, bit error test systems, etc.

Timing systems comprise of time code generators to maintain the synchronized station time with respect to GPS, time code translators to read time from HDTR's, time buffers to distribute the serial and parallel time to various units in the system. Time is maintained with an accuracy of better than 1 microsecond.

Clock, data and time goes through a number of distribution channels through patching. This has been achieved through a data path controller developed in-house. The necessary controls are generated by a micro controller. Thus all the patchings are done electronically. Fiber optic links were also developed in-house to drive the backup terminal data to the recording systems.

Multi-function front-end processing hardware is a frame synchronizer for each sensor of LISS-III and PAN. It also provides a display for each sensor separately for a selected band of data after decommutation. WiFS being a part of LISS-III stream, the MFPH used for LISS-III separates WiFS data and provides the display. MFPH units are developed for real-time data rates. Hence in real-time using the read-after-write mode of HDTRs, the data are fed to MFPH units which transfers the auxiliary data to computer system while providing the real-time single band display after de-commutation. Thus, during real-time data can be seen on quick-look displays for PAN, LISS-III and WiFS either in frame mode with annotation or in the scroll mode without annotation. All the systems were developed in-house.

The LBT data, after frame synchronization in telemetry interface unit (TIU), gets logged in the system in DMA mode to act as secondary source for auxiliary data and will be used for ancillary data generation in case, the auxiliary data from video is not available or usable.

Figure 2 gives the details of recording systems and Figure 3 gives the details of timing systems.

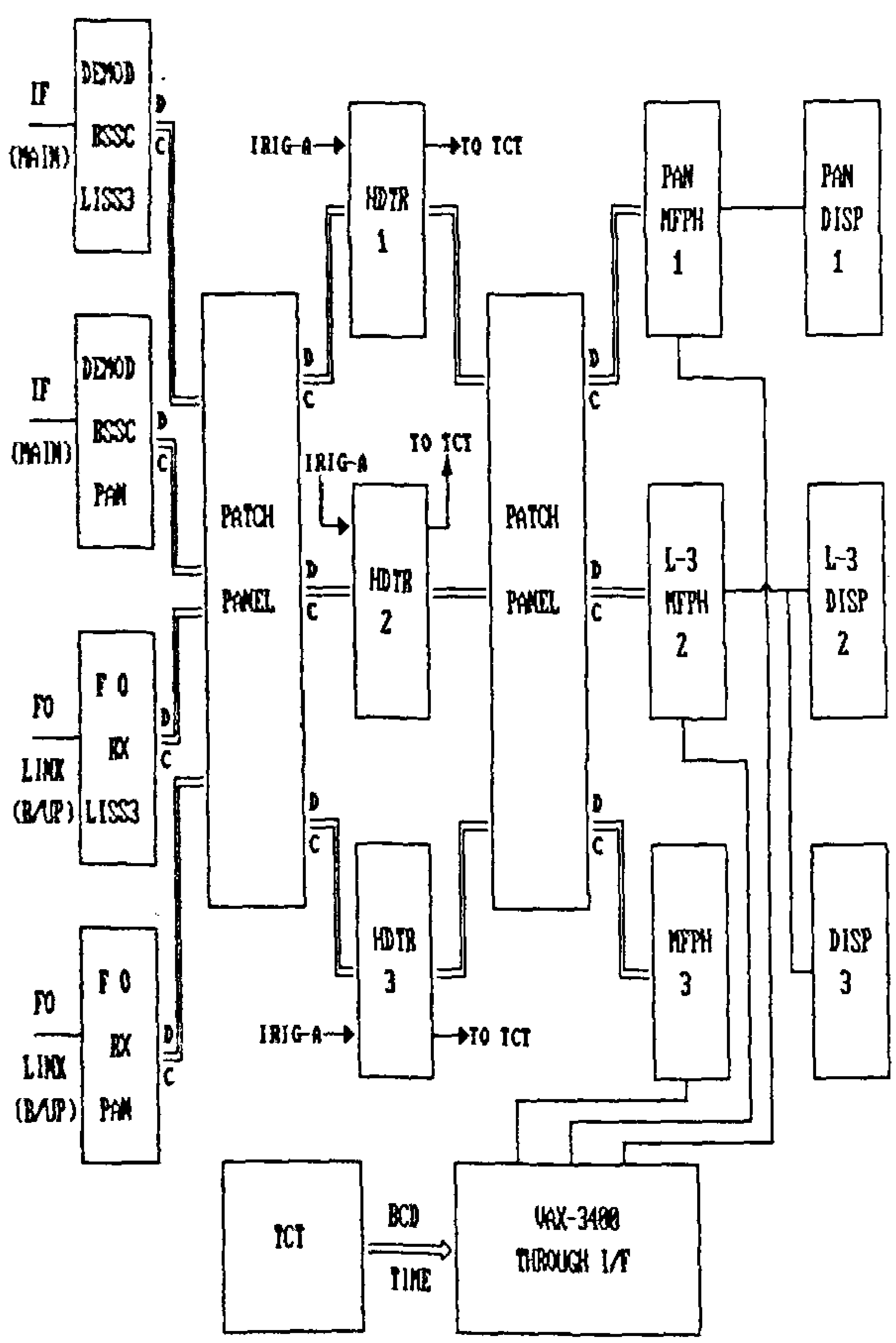


Figure 2. IRS-1C data recording systems.

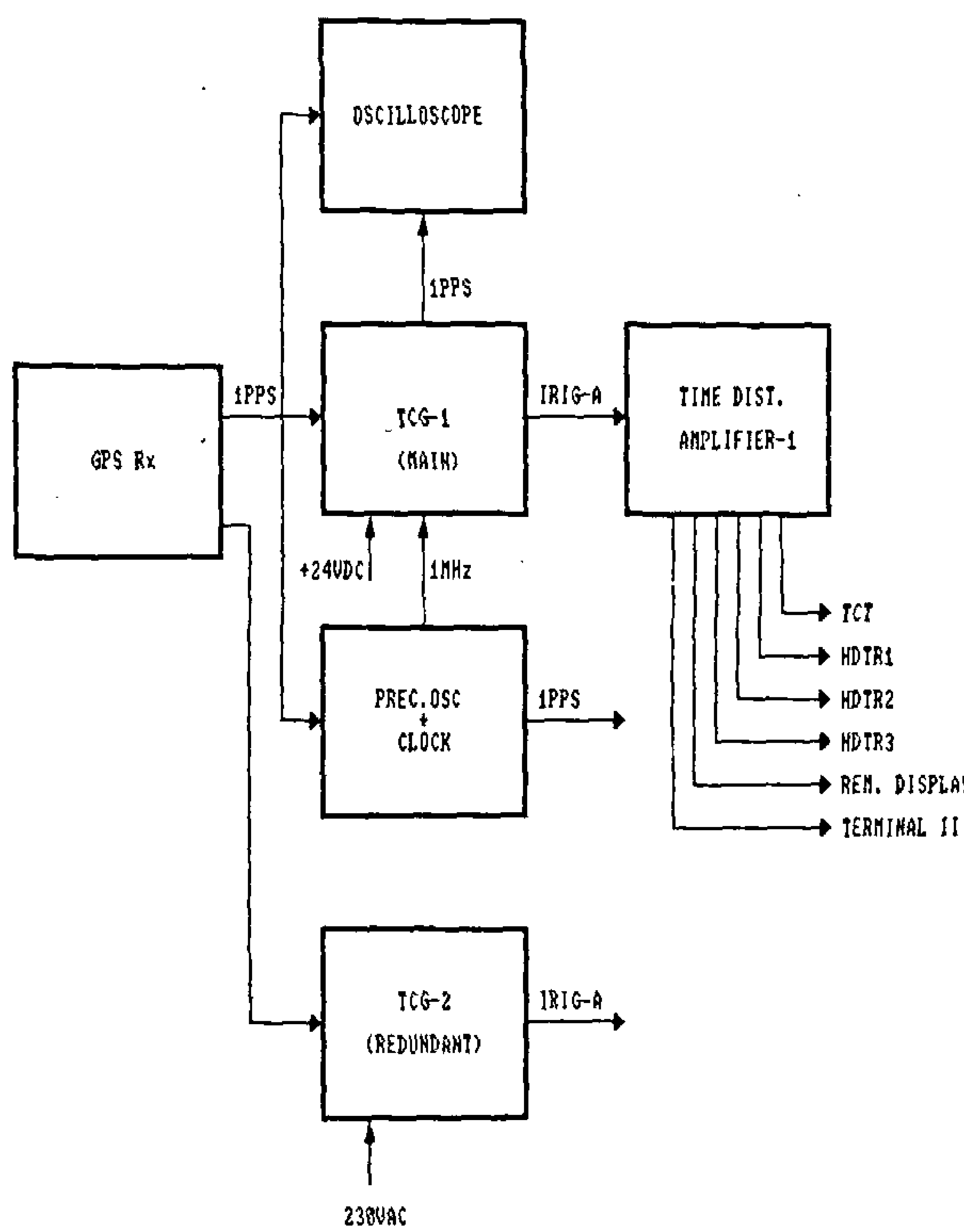


Figure 3. Timing systems.

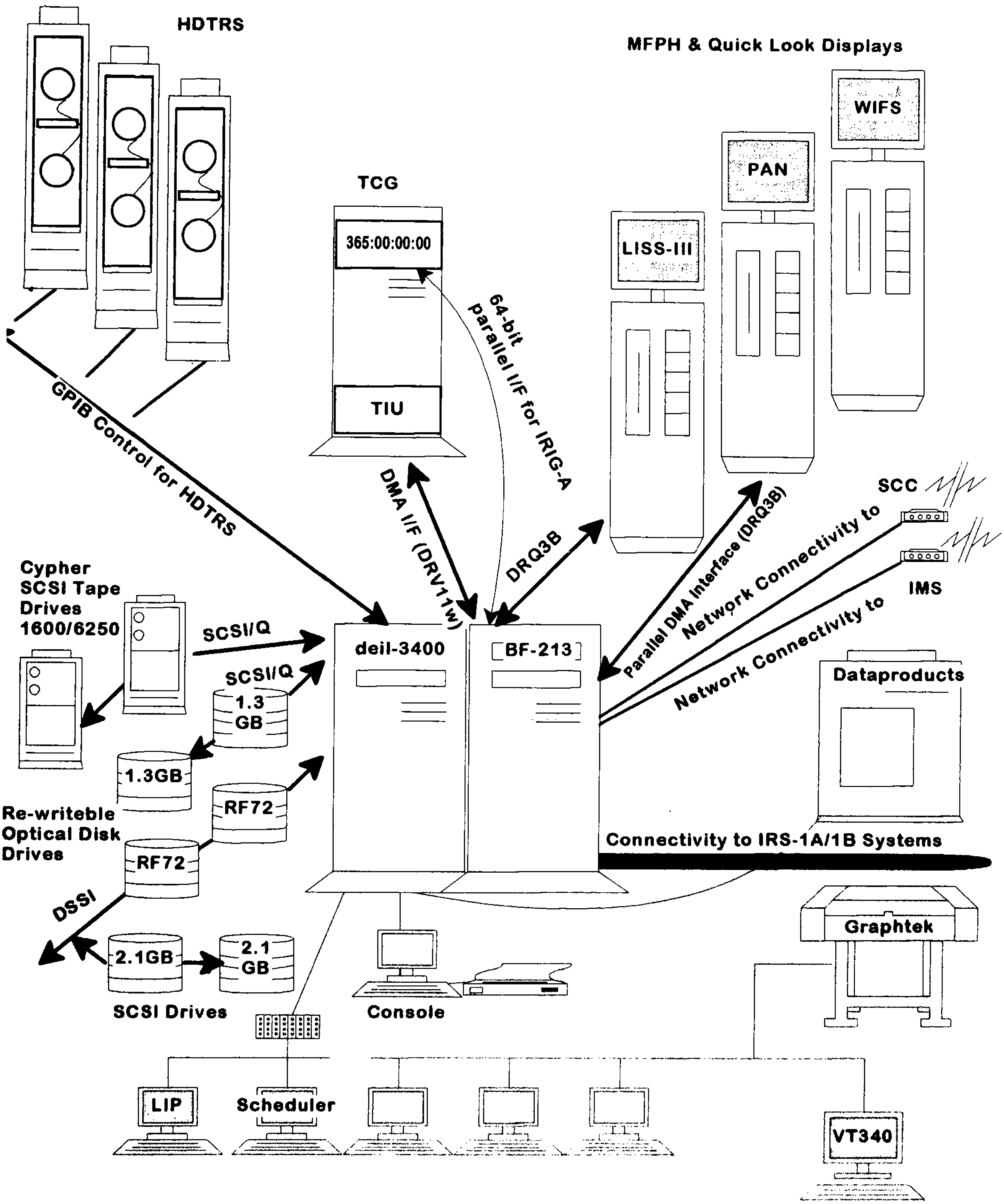


Figure 4. IRS-1C real-time computer systems.

All the systems are validated for bit error performance using the bit error test system. These test systems were also developed in-house. The BER value of better than 1 in 10^{-8} is maintained throughout. Test data are recorded on every HDDT before the pass for the validation of HDDT, HDTR and the same will help in validating the reproduction systems. All the systems are validated before every pass using BER test systems.

Real-time computer system

Real-time computer system is configured around VAX-3400 with all the peripherals as given in Figure 4. The system works under the open VMS environment. All the activities of the system are controlled by schedulers for supporting day payload operations, night OBTR operations and CAL operations. The system functions are basically divided into pre-pass activities, real-time activities and post-pass activities. The pre-pass activities refer to the system validation, for all its hardware and software function from HDTRs to end product. Real-time activities refer to the pass activities and post-pass activities refer to product generation. All the software has been developed in-house and is in regular operations. The functions of the systems in brief are as follows:

- Invoking schedulers for scheduling the real-time passes
- Generation of antenna look-angles based on state vectors for both day and night passes.
- Recording of data including LBT and GRT, extraction of auxiliary data, display of data (PAN, LISS-III and WiFS) along with annotation in real-time and creation of auxiliary data files.
- WiFS raw video data are also logged into the system along with LISS-III auxiliary data.
- Logging of low bit rate telemetry (LBT) and raw star sensor (RST) data into computer system.
- Real-time telemetry support to SCC.
- Real-time display of satellite health parameters on the monitor.
- After the real-time passes scheduling software will validate the quality of auxiliary data logged-in and generates the validated telemetry master frame from the same.
- Play back and repetition of all the above operations in case of data quality of auxiliary data logged is bad.
- Satellite ephemeris generation for the day and night passes.
- Attitude determination for payload and OBTR passes.
- Generation of ADIF and transfer on network to information management systems at Balanagar for the payload and OBTR passes.
- Generation of WiFS optical disk for payload and OBTR from the WiFS disk data file.
- Dispatch of HDDTs, WiFS optical disk to Data Processing Systems at Balanagar for all payload and OBTR passes.

Real-time systems are networked to Information Management Systems at Balanagar and Computers Systems at SCC, Bangalore. Hence the information transfer will be on the network. They include state vectors, attitude bias, raw star sensor data for the last pass of the day from Mauritius, ADIF transfer to IMS, pass schedulers, daily operation reports, payload programming requests and confirmation between NRSA Data Centre and SCC. All the network data transfers take place under DECnet, TCP/IP environment.