Configuration Summary of HAMSAT

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SSS Programme Management Office
ISRO Satellite Centre
Indian Space Research Organisation
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Contents

1. MISSION

Mission Objective

To develop, launch and operationalise a microsatellite to support amateur radio transponder payloads with minimum support from ground station.

Orbit Specifications

Since HAMSAT is an auxiliary satellite and shares the launch with IRS-P5, the orbit is the same as IRS-P5.

Altitude	:	622 km
Semi major axis	:	7000.175 km
Inclination	:	97.89 deg.
Period	:	97.13 minutes

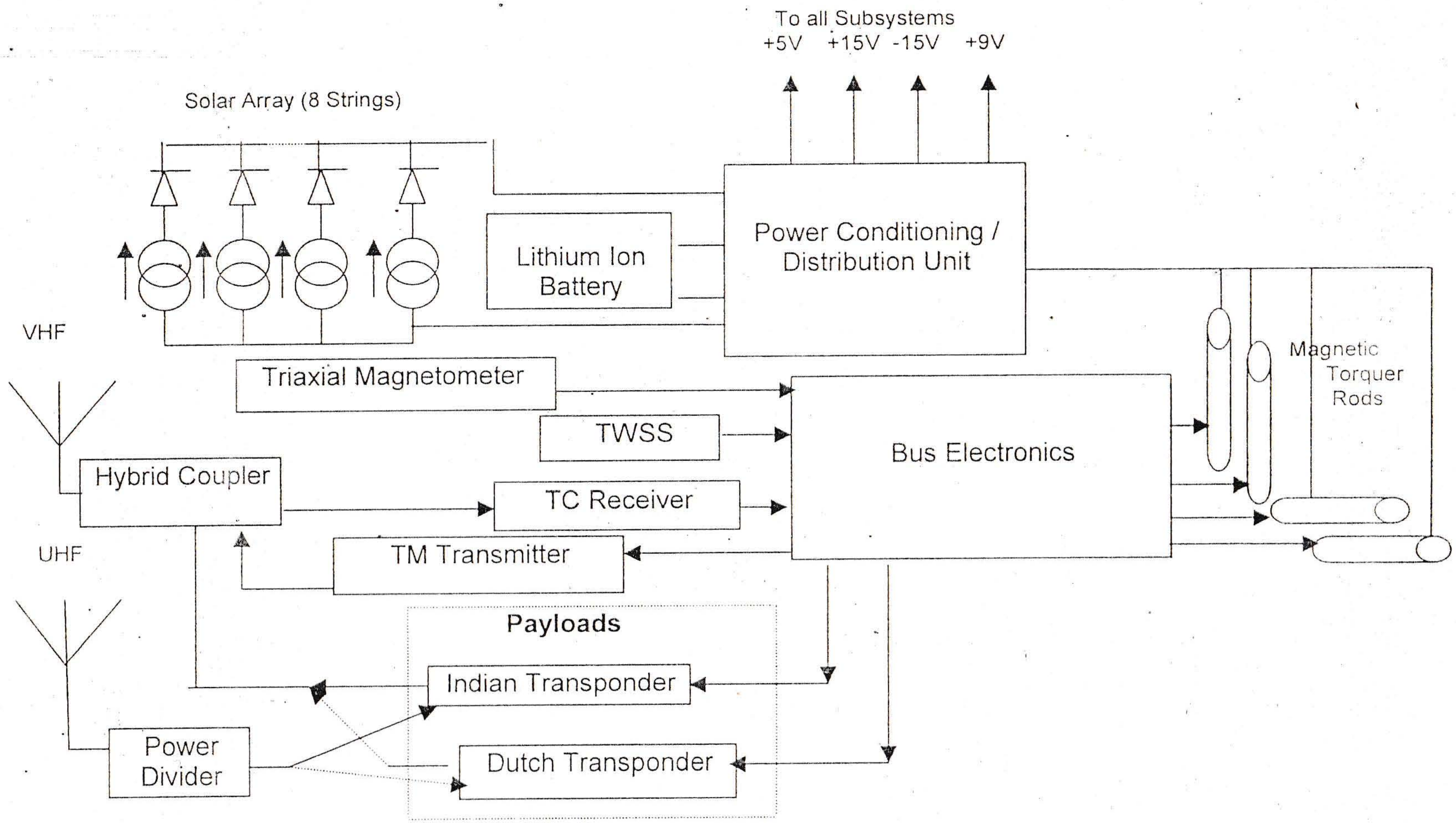
Mission Elements

HAMSAT mission has the following elements

- The payloads are bent pipe transponders, which are used by HAMs (amateur radio operators) to communicate among themselves within the area of coverage.
- A spacecraft to support the payloads in terms of structure, thermal, attitude control, power supply, telemetry, telecommand and communications functions for an operational life of two years.
- The TTC ground station at Bangalore will the prime ground station. Lucknow ground station is planned as standby. The Spacecraft Control Centre is at Bangalore. Spacecraft health monitoring and required commanding for control of the spacecraft and payload operations will be supported by this network.

- The microsatellite is planned to be launched as auxiliary satellite, onboard PSLV along with IRS P5

Configuration Summary of HAMSAT



Block Diagram of HAMSAT

2. STRUCTURE

The structure of HAMSAT is designed to meet the stiffness and strength requirements of the payload and bus systems, with overall volume to meet the envelope specified by the launch vehicle for auxiliary satellite.

The spacecraft structure consists of a cuboid of 630 mm x 630 mm x 550 mm with the antennae projecting about 500 mm from the top deck. The top deck, bottom deck and intermediate deck accommodate the packages. The solar panels are body mounted and they project by 35 mm below the bottom deck and 50 mm above the top deck. The intermediate deck is supported by shear webs. TWSS is mounted on a bracket below the bottom deck. The spacecraft interface with launch vehicle is through IBL-298 interface ring. The ball-lock separation mechanism is operated by pyro. The fore-end ring of the separation system remains with the spacecraft after injection from the launch vehicle.

Major Specifications of Structure

Spacecraft stiffness requirements

Fundamental frequency in longitudinal mode	:	> 90 Hz
Fundamental frequency in lateral mode	:	> 45 Hz

Launcher Interface

IBL 298 interface ring

Quasi Static loads at Spacecraft Interface.

- Quasi static loads in longitudinal direction (static+dynamic) is +7 g/ -2.5g
- Quasi static loads in lateral direction(static+dynamic) is ± 6 g
- Load factor : 1.25
- Lateral loads are considered acting simultaneously with longitudinal levels

Sine Vibration Test Levels

	Frequency Range (Hz)	Qualification level	Acceptance level
Longitudinal Axis	5 - 10 10 - 100	10 mm (0 to peak) 2.5 g	8 mm (0 to peak) 2 g
Lateral Axis	5 - 8 8 - 100	10 mm (0 to peak) 1.25 g	8 mm (0 to peak) 1 g
Sweep rate		2 Oct/min	4 Oct/min

Random Vibration Test Levels

Frequency Range (Hz)	**Qualification PSD (g^2/Hz)**	**Acceptance PSD (g^2/Hz)**
20	0.002	0.001
110	0.002	0.001
250	0.034	0.015
1000	0.034	0.015
2000	0.009	0.004
g_{RMS}	6.7	4.47
Duration	2 min/axis	1 min/axis

Shock Test levels

The shock specification(qualification levels) for the spacecraft are given below:

Frequency	Acceleration (g)
100	20
1000	1000
5000	1000

All three axes

Handling and Transportation

It is assumed that loads from the handling at various stages of the Spacecraft assembly and transportation are far less critical than during the launch phase. Accordingly care is taken while designing the transportation equipment to satisfy the above assumptions.

Heritage and Model Philosophy

Only flight model is made. Flight model of HAMSAT was subjected to proto flight sine and random vibration test levels.

Longitudinal frequency	:	147.95 Hz
Lateral frequency, Y	:	56.95 Hz
Lateral frequency, X	:	61.75 Hz

3. THERMAL CONTROL SYSTEM

Temperature specification of subsystems

Package	Operating temp
All electronics boxes	0 to 40
Battery	10 to 30
Solar cells	-70 to 50
TWSS	-10 to 50

A thermal model of the spacecraft was developed using IDEAS-TMG. The model consists of 864 elements with 965 conduction and 5390 radiation exchange factors respectively.

Thermal control system of HAMSAT spacecraft is achieved by passive means. The design employs Multilayer Insulation Blankets, thermal control tapes and paints

The thermal control scheme followed in HAMSAT is given below:

- Inside surfaces of the solar panels (belly band) are given low emittance finish.
- Bottom deck inside, intermediate deck inside and outside, all vertical webs are given high emittance finish

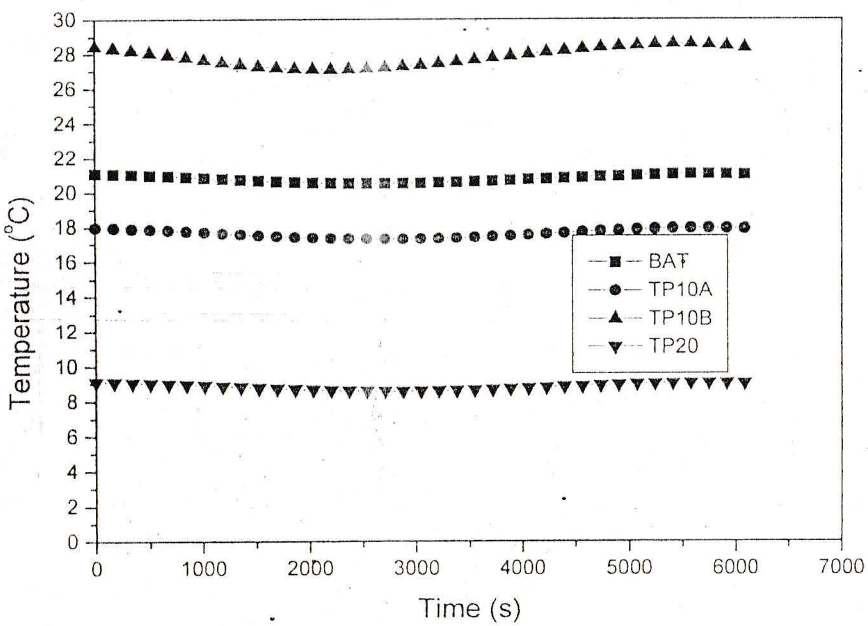
Configuration Summary of HAMSAT

- Top deck external face is covered with 15 layers MLI.
- Top deck inside portion is given low emittance finish.
- Bottom deck external face is used to radiate heat out of the spacecraft. The radiator window size is 0.28m x 0.28m. The radiator window is placed in the centre of the deck. White paint is used to provide the required low absorptance and high emittance finish for the radiator. The remaining portion of bottom deck is covered with 15 layers MLI.
- Bottom deck packages are given high emittance finish.
- Packages on bottom side of intermediate deck are given high emittance finish
- Packages on top side of the intermediate deck are given low emittance finish except MM10 and TX10, which are given high emittance finish.
- Packages on inside of top deck are given low emittance finish
- Two magnetic torquers mounted on vertical web are given high emittance finish while the other two on top deck inside is given low emittance finish
- All packages are having bare metal to metal contact with the decks.
- The backside of the ring portion of solar panels (anti sun side) is given low emittance finish
- The backside of the ring portion of solar panels (on sun side) is covered by kapton tape.
- All external antennae are anodized and no additional thermal treatment is carried out.
- The anodized TWSS is covered with 15 layers MLI. The bracket used to mount the TWSS is anodized and covered with MLI
- Interface ring is left anodized without any further thermal treatment
- No heater is used for thermal control purpose.

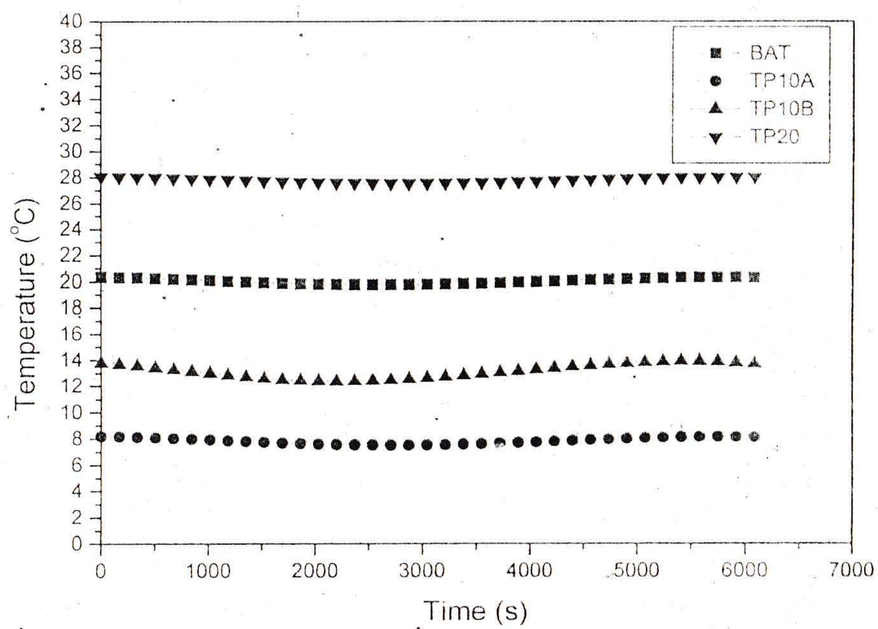
The spinning belly band solar panels are maintained -50 to +45^0 C. By providing the low emittance finish on the back side of the panels the packages of the spacecraft are radiatively isolated and protected from the large temperature swing of the solar panel. The bottom deck of the spacecraft forms the anti sun view panel.

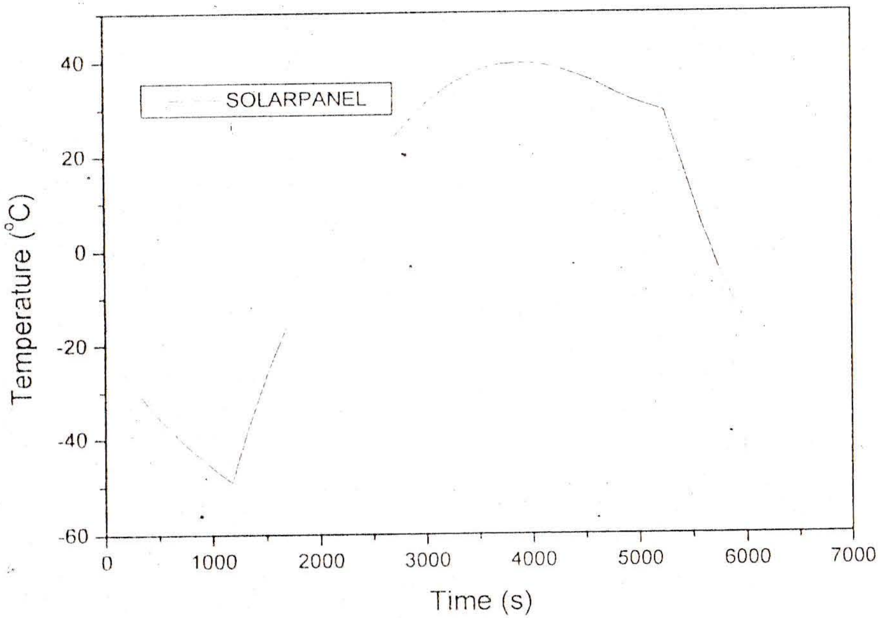
Orbital temperature characteristics of transponders and battery

TP 10 ON



TP 20 ON





Solar panel temperature characteristic

Configuration Summary of HAMSAT

The thermal control system of HAMSAT spacecraft maintains the spacecraft and its subsystems within the operating temperature limits without the use of heaters. Both the nominal and sun perpendicular to the belly band solar panel cases are supported. A very nominal rise in temperature is expected at EOL.

Heritage

All the elements used to achieve the desired temperature control have the heritage of earlier IRS / INSAT Missions.

CONFIGURATION Highlights

Temperature Sensors : The health and thermal behaviour of the spacecraft is monitored by measuring temperature at identified locations. Indigenous 10 kΩ thermistors (12 nos.) are used for temperature measurement onboard.

MLI : All MLI blankets for HAMSAT flight are of 15-layer configuration similar to IRS satellites.

4. POWER SYSTEM

The Power System generates, stores, regulates, controls and distributes the required power to various subsystems through raw buses, for a 2-year lifetime of HAMSAT.

Specifications

Solar Panel

Panel type	:	Body mounted, aluminium honeycomb substrate with Al face sheets.
Solar array power	:	50 W average, EOL
Array area	:	1.35 m^2
No. of panels	:	four
Panel dimensions	:	630 mm x 550 mm- 2 panels, 600 mm x 550 mm- 2 panels
Solar panel	:	Aluminium honeycomb substrate with Al face sheets on both sides
Panel thickness	:	15 mm
Insulator	:	Fibreglass sheet, 180 micron thick
Cells in series	:	40
No. of strings	:	8 per panel
Solar cell type	:	GaAs/Ge single junction

Battery

Type	:	Lithium-ion
Name plate capacity	:	6 Ahr
No. of cells	:	7 series x 3 parallel
Dimension	:	164.5 mm x 99 mm x 80 mm
Maximum depth of discharge	:	12 %
Design operating temperature	:	-10°C to 40 °C

BUS

Bus voltage : 22 to 30 V

Configuration highlights:

- Single battery tied bus.
- DC/DC converters for Bus Electronics and Indian payload are located inside the respective packages. The other DC/DC converters are located in the power Electronics package.
- Solar array is designed to generate a required power of 50W at the end of life (EOL) at a bus voltage of 28V for two years life in approximately 622 km low earth orbit.
- Lithium ion battery of 5.1 Ahr(BOL) capacity
- Battery emergency logic disconnects the battery from the bus if the battery voltage goes below 21 V.

5. Bus Electronics

The Bus Electronics does the functions of attitude control, telemetry, telecommand and data acquisition. Attitude control includes functions like killing of injection rates during tumbling mode, initial spin up, spin rate control (SRC) and spin axis orientation control (SAOC). Towards meeting these specifications, the spacecraft is configured as spin stabilized with magnetic bias control logic, magnetometer and Twin Slit Sun Sensor (TWSS) as sensors and two magnetic torquers, one along Z-axis and one along Y-axis.

The telemetry provided by BE for HAMSAT accepts the performance data from other systems of spacecraft. It multiplexes the analog channels, digitizes the data and formats the data along with digital channels. The formatted data is modulated on a sub-carrier, of frequency 25.6KHz and fed to the transmitter. To achieve this, a low bit rate TM with PCM/PSK/PM scheme is used.

Telemetry Specification

Bit rate	:	256 bps
Word length	:	8 bits
Frame length	:	128 words
Master Frame length	:	8 frames
Frame rate	:	4s
Frame sync. Code	:	24 bits (ACCA1F(Hex))
Spacecraft ID	:	C0 (Hex)
Frame ID	:	3 bits
Modulation	:	PCM/PSK
Sub carrier frequency	:	25.6 KHz
Input signal level	:	$\pm$ 5V for analog words, 0/5V for digital words
Output level	:	1.2V P-P

Telemetry requirements

Subsystem	No. of digital telemetry channels	No. of analog telemetry channels
Power	-	7
Thermal	-	12
Payload	1	-
RF TTC	-	2
TM, TC, Control and sensors	67	8
Spare	18	2

Telecommand system

The telecommand system for HAMSAT provides the up link for transmitting command information and data in binary form for operation of various subsystems onboard the spacecraft. The telecommand processing system is realised using FPGAs and HMCs. The received PCM/FSK data undergoes demodulation, BCH decoding and command decoding. It also provides all required status monitoring through telemetry. The TC link requires very low probability of wrong execution and command rejection. As command information is transmitted in burst, block codes such as BCH (56, 32, 9) is used.

Telecommand specifications

Modulation	:	PCM/FSK
Command bit rate	:	100 bps
Command bit duration	:	5 ms
FSK sub-carrier frequency-ones	:	5.55 KHz
FSK sub-carrier frequency-zeroes	:	3.125 KHz
Command word length	:	32 bits
Command frame length	:	56 bits
Command message length	:	2/4 frames with 10 bit gap between frames
Command types	:	a) On/Off b) Data

Command Requirements

Subsystem	No. of commands required
Power	10 CMOS pulse
Payload	2 raw bus pulse
Bus Electronics	11 CMOS pulse
Spare	1
Total	24 pulse commands

No external data command.

Internal data commands	:	60
Total no. of commands	:	84

Configuration Highlights

- Bus Electronics is based on MAR-31750.
- The software is developed in Ada
- All the logics are implemented using FPGAs and HMCs. Actel RT 1280 devices are used
- Newly developed devices are ASIC relay driver (BE03RD), Input Buffer (143IB), Output Buffer (144OB), Solid State Switch (112SSS).
- Fault tolerant features: FDI logic, remote programming, EDAC

BE On Board timer

BE provides a hardware based on board timer. The timer is implemented using a counter, which is read by processor major cycle. The time is computed by multiplying the resolution factor (1 millisecond). The OBT overflows on 49 days.

BE onboard software

All the functionalities such as data acquisition, command processing, telemetry, control logics etc are provided through software. Following gives a brief description of the software modules.

Data Acquisition and Processing modules

The data acquisition and processing modules carry out the data acquisition for the Digital and analog sensors. The acquired data is stored in memory to be used by various modules and telemetry purpose. All other subsystem data acquired by BE is for only telemetry purpose.

Telecommand Processing module

This module carries out TC processing. Command processing hardware is part of BE. All commands are routed through command processing card. BE software reads all commands for telemetry purpose. The internal data commands are decoded for operations such as Spin Rate Control, Spin Axis Orientation Control etc.

Telemetry module

The main functionality of this module to format the information to be telemetered, add Frame Sync., Spacecraft Id and frame Id and send to the telemetry downstream. Software generates frame sync. (AC CA 1F), space craft ID (C0) and Frame ID (0-7) and all words in different frame and output to TM hardware once in 4 seconds.

Cycle completion check modules, NMI

To repeat the BE functions once in a major cycle, a hardware flag is polled. On detection of this signal, the processor repeats the major cycle execution. The software resets the watch dog timer every cycle, which indicates proper execution.

Actuator Processing Modules

In HAMSAT magnetic torquers are used as actuators. Torquer current polarity selection is carried out in these modules.

On-board software - Resource usage

- 32 K Words of PROM
- 16 K Words of RAM

Statistics of Hamsat on-board software

Sl. No.	Characteristics	Values
1	Packages	32
2	Procedures	105
3	Functions	6
4	ELOC	3658
5	Code Size (K words)	11.2
6	Constants (K words)	0.481
7	Tm Data Base (K words)	1.052
8	Address Pages used	1
9	Execution time (ms)	2.74

6. ATTITUDE CONTROL SYSTEM

The attitude control system is configured to meet the following mission specifications:

The spin axis orientation should be maintained within ± 3.0 deg.

The spin rate should be maintained at 4.0 ± 0.5 rpm

HAMSAT is a spin stabilized satellite with spin axis along orbit normal with maximum moment of inertia value. Attitude Control System (ACS) consists of detumbling & initial spin up mode to kill the transverse rates on the spacecraft on injection by launch vehicle & simultaneously spin up along maximum moment of inertia axis, spin rate control (SRC) and spin axis orientation control (SAOC) mode. Towards meeting these specifications, ACS is configured with onboard computer, magnetometer and TWSS as sensors and magnetic torquers as actuators. OBC is used to realize logics like killing of injection rates & initial spin up, SRC & SAOC. It interfaces with telemetry, telecommand, power, sensors and actuators for execution of control logic.

Configuration highlights

- Negative Bdot law is used for control functions.
- Modes of ACS function on the operation of the satellite are
  - Detumbling mode
  - SRC- auto, manual
  - SAOC- auto, manual
  - Magnetic bias control

Sensors

Introduction

HAMSAT has two sensors- magnetometer and Twin Slit Sun Sensor (TWSS).

Miniature magnetometer is an integrated triaxial magnetometer. This unit measures the components of geomagnetic field along the three axes of the spacecraft. Magnetometer measurements are used as sensor inputs for ACS control functions for using negative bdot law.

TWSS provides sun transit pulse and sun aspect pulse. The time interval between two sun transit pulses is used for computation of spin rate onboard. The time interval between sun transit pulse and sun aspect pulse is used on ground for computation of sun aspect angle.

Triaxial Magnetometer

Specifications

Range	:	± 60,000 gamma
Output voltage	:	± 5 volt
Accuracy of sensor	:	± 100 gamma
Accuracy of sensor measurements	:	± 500 gamma

Configuration Highlights

- Magnetometer package has built-in electronics.
- The magnetometer outputs are given to bus electronics package, which uses it for control functions.

Twin Slit Sun Sensor(TWSS)

TWSS is used to measure spin rate of spacecraft and sun aspect angle with respect to spin axis.

The slit parallel to spin axis is called straight slit. The straight slit detector is used to generate sun transit pulse and the curved slit detector generates the sun aspect pulse. Sun transit pulse is used for spin period measurement. Sun aspect angle is derived from the time difference between the STP and SAP pulses from the detectors.

Specifications:

Field of view	:	± 80 deg
Angular resolution	:	± 1° upto ± 60 °
		± 2° between ± 60 ° to ± 80°

Configuration Highlights

- Processing electronics is located in bus electronics package.

Actuator- **Magnetic Torquers**

Specifications

Capacity	: 4.5 A m^2
Operating voltage	: 24 V - 30 V
Wire used in coil	: 38 SWG, Polyimide coated copper wire
Coil resistance	: 860 Ω
Material of core	: Permendur-49
Length of core	: 165 mm

Configuration Highlights

HAMSAT has two magnetic torquers on spin axis and two magnetic torquers on transverse axis (Y-axis). The two torquers on each axis are connected in parallel. The magnetic field generated by the magnetic torquers interacts with the geomagnetic field to produce control torques. Each torquer is of 4.5 Am^2.

Flight packages have undergone acceptance level vibration tests and thermal cycling. One qualification model torquer was subjected to qualification level vibration and thermal cycling.

7. TTC (RF)

The TTC (RF) systems for HAMSAT consists of the following:

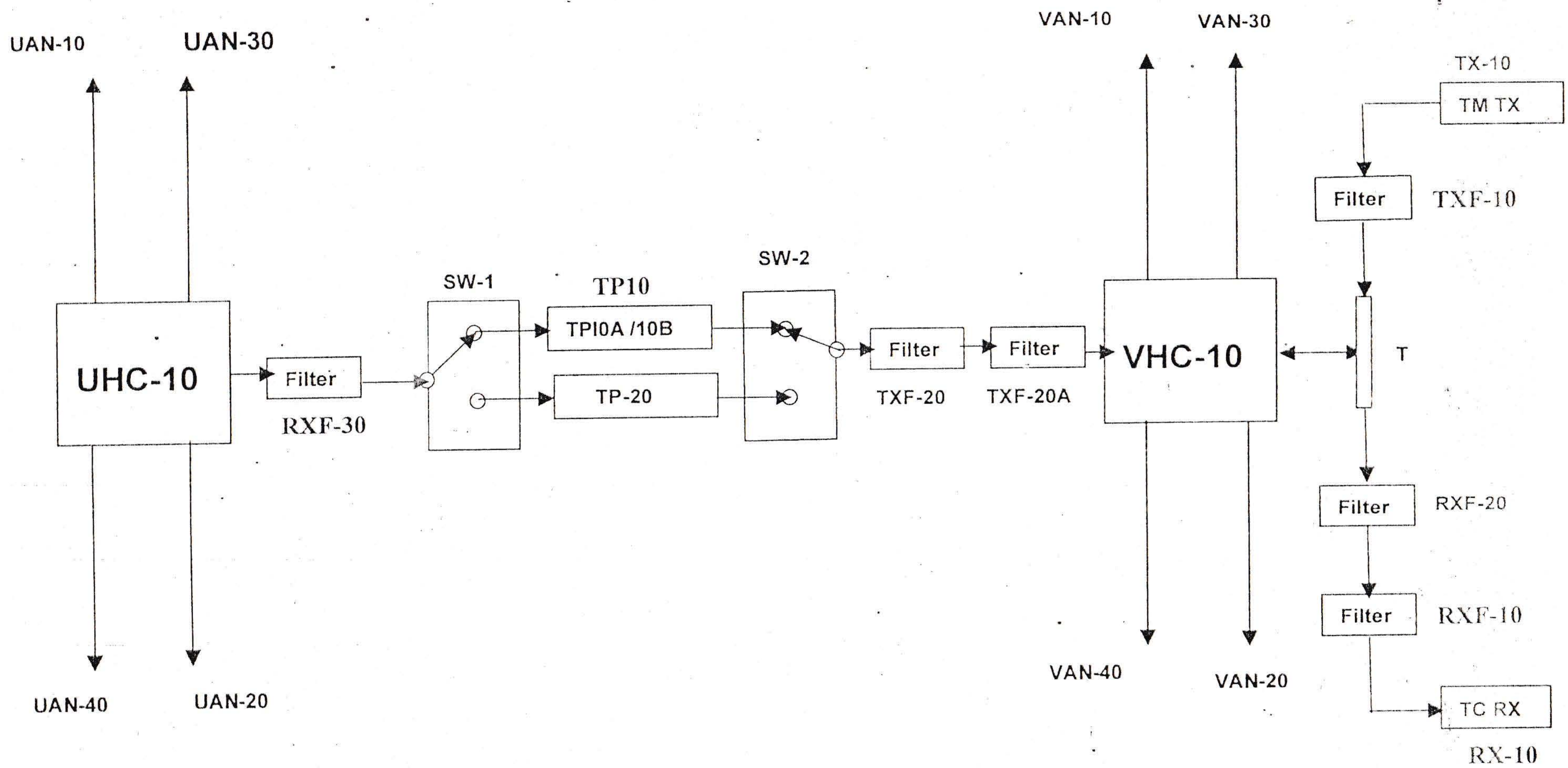
a) A telecommand receiver at 149.522 MHz.

b) A telemetry downlink transmitter at 137.2 MHz.

c) VHF antenna system and its associated feed networks.

The TTC system onboard HAMSAT consists of a Telecommand receiver and a Telemetry transmitter along with their associated filters. The Telecommand (TC) receiver receives uplink command signals from main ground station in VHF frequency band. The demodulated command signal is passed on to the onboard TC decoder for command execution. The Telemetry (TM) transmitter transmits the satellite house keeping and other relevant telemetry data from the spacecraft to the main ground station in VHF frequency band. The Telecommand uplink, Telemetry downlink and Payload Transponder signals are all connected to a single VHF antenna system through a feed network.

Configuration Summary of HAMSAT



HAMSAT RF System Configuration

8. Payloads

Introduction

Payloads are HAM transponders. There are two payloads - One Indian (TP10) and one Dutch (TP20). The payloads are HAM transponders operated in UV mode by amateur radio operators. Only one payload will be ON at any time. The TP10 or TP20 can be selected by ground command. The transponders input and outputs are selected by two onboard RF switches. Both switches are coupled ie, if one is selected for position-1 then other would also select position-1. The transponders carry a low power beacon. The payload operation is slated above 15^0 elevation. One of the transponders is designed and realised by a Dutch student. The uplinking for the payloads is done in UHF (435 MHz) and downlinking is in VHF (145 MHz). The payload transponders inputs are connected to an UHF antenna system and its associated feed networks. The payload transponders outputs are connected to a VHF antenna system and its associated feed networks.

The Payload systems for HAMSAT consists of the following:

1. An Indian payload transponder (TP-10) in UV mode (uplink in 435.22-435.28 MHz and a downlink in 145.87-145.93 MHz bands) with a CW beacon at 145.936 MHz.
2. A Dutch payload transponder (TP-20) in UV mode (uplink at 435.8 MHz and a downlink at 145.9 MHz) with a Morse coded CW beacon at 145.860 MHz.
3. VHF/UHF antenna systems along with their associated feed networks.

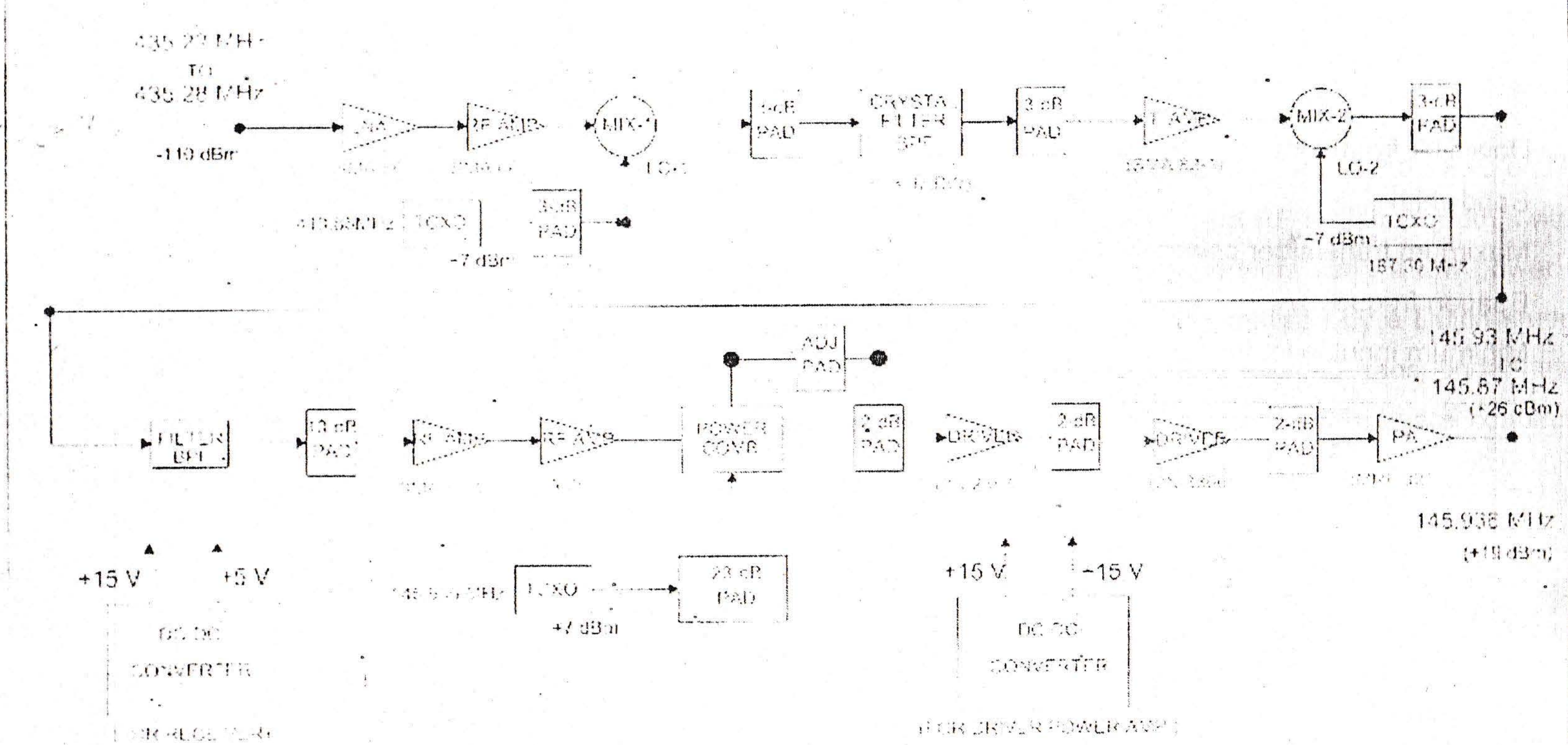
Configuration Summary of HAMSAT

Specification

Transponder type	:	Linear, inverting, frequency translation type
Uplink frequency	:	435.22 MHz to 435.28 MHz
Downlink frequency	:	145.87 MHz to 435.93 MHz
Bandwidth	:	60 kHz
Maximum transmitter power	:	1W
Beacon frequency	:	145.936 MHz for Indian and 145.86 MHz for Dutch

Minimum input level required to give an output of 30 dBm : -110 dBm.

HAMSAT PAYLOAD



9. OVERALL POWER REQUIREMENTS

Subsystem	Package	Regulated power, W	Power on bus, W	Remarks
Sensors	Magnetometer	1.2	**1.6**	
RF system	TM Tx	1.5		
	TC Rx	0.72		
	Total RF System	2.22	**2.96**	
Payload	TP – 10	6.75	9	
	TP – 20	2.76	8.16	Raw bus power: 4.48W
	Total Payload		**9**	
PW		2.7	**3.6**	
MT10, 20			**3.2**	
BE		4.125	**5.5**	

DC/DC converter efficiency of 75 % is assumed.

Total power requirement on bus during detumbling mode = 16.8 W max. from calc.(16.18 W from load measurements)

Total power requirement on bus when Payload 1 is ON = 24.14 W max.(24.08W)

Total power requirement on bus when Payload 2 is ON = 23.3 W max. (21.84W)

Spacecraft Power Summary

Item	Power (W)
Spacecraft Bus & payload	24.1
Battery charging requirement	16.2
Spacecraft design Power, Orbit Avg.	50
System Margin	9.7
Spacecraft orbit	622 km
Sunlit time	62 min
Eclipse time	35 min

10. MASS SUMMARY OF HAMSAT

Sl. No	Package	Package code	Mass (Kg)
1	**Structure -** Decks, Vertical webs, handling webs, inserts, L-angles etc., TWSS bracket, TWSS interface plate		7.88
	Interface ring	IBL 298	1.22
2	**Solar Panels**		5.628
3	**Battery**	BLI-01	1.24
4	**Power electronics**	PW-10	3.1
5	**Bus Electronics**	BE-10	4.35
6	**Sensors**		
	Magnetometers	MM-10	0.594
	TWSS	TWSS-10	0.149
7	**Actuators**	MT-10A, MT-10B, MT-20A, MT-20B	0.93
8	**RF TTC systems**		
	TM Tx	TX-10	0.692
	TX Filter and pl op filter	TXF-10 & TXF-20	0.822
	TC Rx	RX-10	1.228
	Filter	RXF-10	0.35

	Notch filter	RXF-20	0.281
9	**Antennae and feednetwork**		
	VHF antennae, feed network		0.989
	UHF antennae, feed network		0.752
10	**Payload transponders**		
	Indian transponder - Tx	TP-10B	0.564
	Indian transponder - Rx	TP-10A	1.375
	Dutch transponder	TP-20	1.1
	Input Filter (UHF)	RXF-30	0.249
	Filter	TXF-20A	0.337
	RF switch – 1	RFS-10	0.11
	RF switch - 2	RFS-20	0.11
	Interface plate for RXF30 and TXF20		0.235
11	**Thermal**- MLI		0.4
12	**AIT**		
	Cable harness		2.65
	Balance mass *		3.507
	Brackets, fasteners etc.		0.845
	Misc		0.549
	* To be confirmed -		
	Total mass of HAMSAT		**42.135**