SYNTHETIC APERTURE RADAR PAYLOAD OF
RADAR IMAGING SATELLITE (RISAT) OF ISRO

Tapan Misra[(I)], S S Rana, Dr. KN Shankara

Space Applications Centre
Indian Space Research Organisation (ISRO)
Ahmedabad-380015, India
[(I)]**Email :misratapan@sac.isro.gov.in**

ABSTRACT

Multimode SAR system of *Radar Imaging Satellite* (RISAT) is planned to provide complementary imaging capability along with optical images from the well established IRS class of satellites. RISAT, based on active antenna technology, supports variety of resolution and swath requirements in C-band. Both conventional stripmap and scanSAR modes are supported with dual polarization operation. Additionally a quad polarization stripmap mode is provided for availing additional resource classification. In all these modes resolutions from 3m-50 m can be achieved with swath ranging 30 km –240 km. On experimental basis, a sliding spotlight mode is also available. The system is capable of imaging on either side of flight track depending upon prior programming of the satellite. The satellite will be placed in sun-synchronous orbit with 6am-6pm local time condition. This orbit configuration is chosen to maximize solar power availability. The satellite has on-board solid state recorder for supporting beyond ground station visibility of operation. The satellite is planned to be launched in 2007 and is expected to fulfill the requirements of remote sensing with all weather and day night operation capability.

INTRODUCTION

Radar Imaging Satellite (RISAT), a new class of remote sensing satellite, distinct from the established IRS class, is being developed in Indian Space Research Organisation (ISRO). RISAT carries a multi-mode Synthetic Aperture Radar (SAR) as the sole payload. The principal motivation behind this development is to provide imaging radar data which will complement and supplement application capability provided by the existing and follow on optical payloads of IRS (Indian Remote Sensing) class of satellites. The basic focus of the RISAT is agriculture. In fact, the orbit is selected such that it provides requisite temporal sampling capability necessary for monitoring of Khariff crop, produced during monsoon season. The choice of C-band frequency of operation and the RISAT SAR capability of simultaneous imaging in both co and cross polarisation will ensure wide applicability in the thrust areas like Vegetation, Agriculture, Forestry, Soil Moisture, Geology, Sea Ice, Coastal Processes, Man-made object identification and flood mapping.

OPERATING MODES AND IMAGING PARAMETERS

The RISAT-SAR is designed for operation from a sun-synchronous orbit of 608 km altitude. The operating frequency is selected in C-band (5.35 GHz). The SAR system is designed to provide constant swath for all elevation pointing and almost near constant minimum radar cross section performance. The proposed SAR will operate in following basic modes (Fig-1):

- **Fine Resolution Stripmap Mode-1 (FRS-1):** 3 m resolution, 30 km swath, co and/or cross polarisation
- **Fine Resolution Stripmap Mode-2 (FRS-2):** 12 m resolution, 30 km swath, Quad polarisation.
- **Medium Resolution ScanSAR   Mode (MRS):** 25 m resolution, 120 km swath, co and/or cross polarisation.
- **Coarse Resolution ScanSAR   Mode (CRS):** 50 m resolution, 240 km swath, co and/or cross polarisation.
- **High Resolution Spotlight Mode (HRS):** better than 2 m resolution, spot of 10 km (Azimuth) and 10 km (ground range), co and/or cross polarization

HRS mode will have an experimental capability to increase the azimuth extent upto 100 km. Further all the images are available in single look only except in CRS mode where possibility of 2 range looks are provided.

The SAR can image either side of the track by roll tilting of the antenna. However, in one orbit, only one side of the orbit can be imaged. On either side, imaging area is restricted over 400 km distance starting at stand-off distance of 200 km. Possibility of additional imaging area of 100 km on either side of qualified imaging area of 400km exists on experimental basis.

RISAT-SAR SYSTEM CONFIGURATION AND SPECIFICATIONS

RISAT-SAR system is configured on dual receiver concept providing identical resolution in both simultaneous co- and cross-polarisation operation. Basic hardware specifications of the RISAT-SAR are presented in Table-1. The SAR consists of two broad segments namely (1) Deployable Active Antenna and (2) RF and Baseband Systems housed on the satellite deck.

Deployable Active Antenna

The earth facing side of the active antenna is a broadband dual polarized microstrip radiating aperture. Antenna consists of three deployable panels, each of 2mx2m size. Each of the panels is subdivided into four tiles of size 1mx1m, each consisting of 24x24 radiating elements. In each tile, all the 24x24 radiating elements are grouped into 24 groups, each group consisting of 24 elements spread along azimuth directions which are fed by two stripline distribution networks feeding for V and H polarisation. Each of these groups of 24 radiating elements are catered to by a functionally two separate TR modules feeding two separate distribution networks for V and H operation with the same radiating patches. The peak RF power, fed by each TR module, is 10 W at a duty cycle of ~7%. These two functionally separate TR-modules are housed in the same physical enclosure, sharing same power supply and TR control electronics. This sort of grouping also enables phase steering in elevation direction. All the 24 TR modules on the tile are controlled by one Tile Control Unit (TCU). The TR modules and TCU are housed on the backside of the antenna.
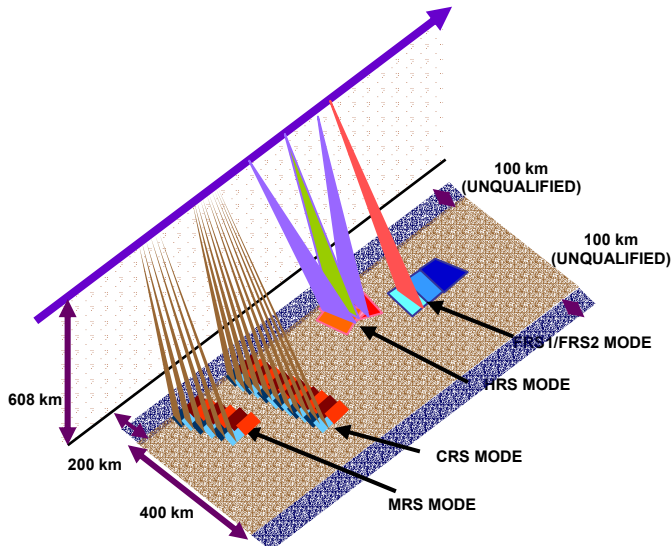

Fig.-1 Illustration of Modes of Operation of RISAT-SAR

The mechanical organization of the complete antenna, grouped into three panels/twelve tiles and a detailed view of the basic Tile structure are depicted in Fig.-2.

An extensive on-board calibration facility is provided with the help of a set of CAL switches and dedicated distribution networks for calibrating transmit and receive paths of each of the TR modules separately.
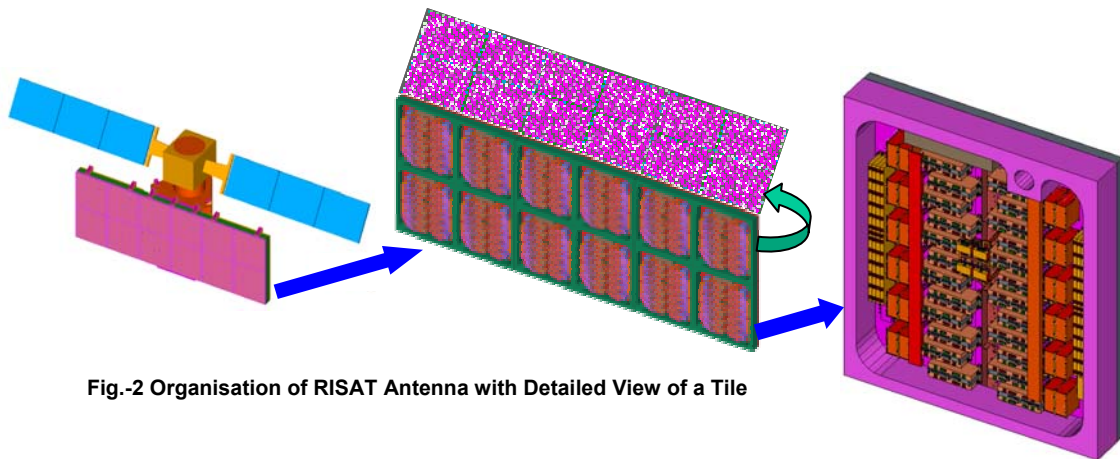
Table-1
Hardware Specification of RISAT-SAR

Frequency	5.350 GHz
Antenna Type	Printed Antenna
Antenna Size	6m (Along Flight Dirn) x 2m (Cross Flight Dirn)
Side Lobe Level	-15 dB (Az.), -18 dB (El.)
No. of TR modules	288, each with 10 W peak power
Pulse width	20 µsec
Average Output Power (TR-SSPA)	200 W
Average DC Input Power	3.1 kW

	HRS	FRS-1	FRS-2	MRS/CRS
Chirp Bandwidth	225 MHz	75 MHz	37.5 MHz	18.75 MHz
Sampling Rate	250 MHz	83.3 MHz	41.67 MHz	20.83 MHz
PRF	3500 Hz ± 200 Hz	3000 Hz ± 200 Hz	3000 Hz ± 200 Hz	3000 Hz ± 200 Hz
Quantisation	2/3 BAQ	2/3/4/5/6 bit BAQ		
MAX. Data Rate @ 3 bit BAQ for HRS @ 6 bit BAQ for rest of the modes	739 Mbits/sec (Single Pol.) 1478 Mbits/sec (Dual Pol.)	556 Mbits/sec (Single Pol.) 1112 Mbits/sec (Dual Pol.)	564 Mbits/sec	142 Mbits/sec (Single Pol.) 284 Mbits/sec (Dual Pol.)

RF and Baseband Subsystems

Two separate chains of receiver and Data acquisition and compression system cater to simultaneous operation in two polarisation. However, Feeder SSPA, Frequency generator and Digital Chirp Generator will be common to both the polarisation chains. All the subsystems will be configured with 100% redundancy. Feeder SSPA transmits a chirped pulse of 20µsec to active antenna during transmit duration. Flexible Digital Chirp Generator provides expanded pulses of four different bandwidths of 225, 75, 37.5 and 18.75 MHz for operation in various imaging modes. The combined

Fig.-2 Organisation of RISAT Antenna with Detailed View of a Tile

signal from active antenna is down converted to IF which is subsequently I-Q detected prior to digitisation. No provision of on-board range compression is kept and range compression needs to be carried out on ground. The base band I-Q detected received signal is suitably band limited to maximize SNR by a set of four selectable I-Q filters. The first stage of data acquisition unit is 8 bit digitiser. RISAT provides the unique option of user choice of seamless BAQ option from 2-6 bits depending upon the application requirements. Each of the I and Q channels are separately digitized, BAQed and formatted with identical repetition of common auxiliary parameters and data is taken out from each I-Q channel as 16bit parallel stream at constant rate of 31.25 MHz. The choice of antenna dimension put a constraint in selection of PRF within a range of 2800-3700 Hz from both Doppler sampling requirement and range ambiguity consideration. .

Payload Control and Management

RISAT-SAR Payload is controlled by an array of controllers organized in three tier hierarchy as depicted in Fig.-3. At the top level of hierarchy, complete payload is controlled by a central computer called Payload Controller (PLC), which interfaces with all the RF and baseband subsystems namely Digital Chirp Generator (DCG), V and H Receivers, Frequency Generator (FG), Feeder SSPA, Calibration Switch Matrix and Four Data acquisition and Compression units (DACS). PLC is an autonomous controller with only spacecraft interface being DC Power and 1553 interface with Bus Management Unit (BMU) of the spacecraft. The bit parallell data at the DACS output is directly interfaced with spacecraft's Baseband Data Handling Unit (BDH) for further formatting, recording, encryption and transmission.

The payload controller in turn controls the active antenna via the tile control units residing in each tile called Tile Control Unit (TCU). PLC essentially transmits beam definition command and switching sequence definitions to active antenna. TCU controls beam pointing and beam setting in a tile via TR controller. It also sequences TRM power on/off
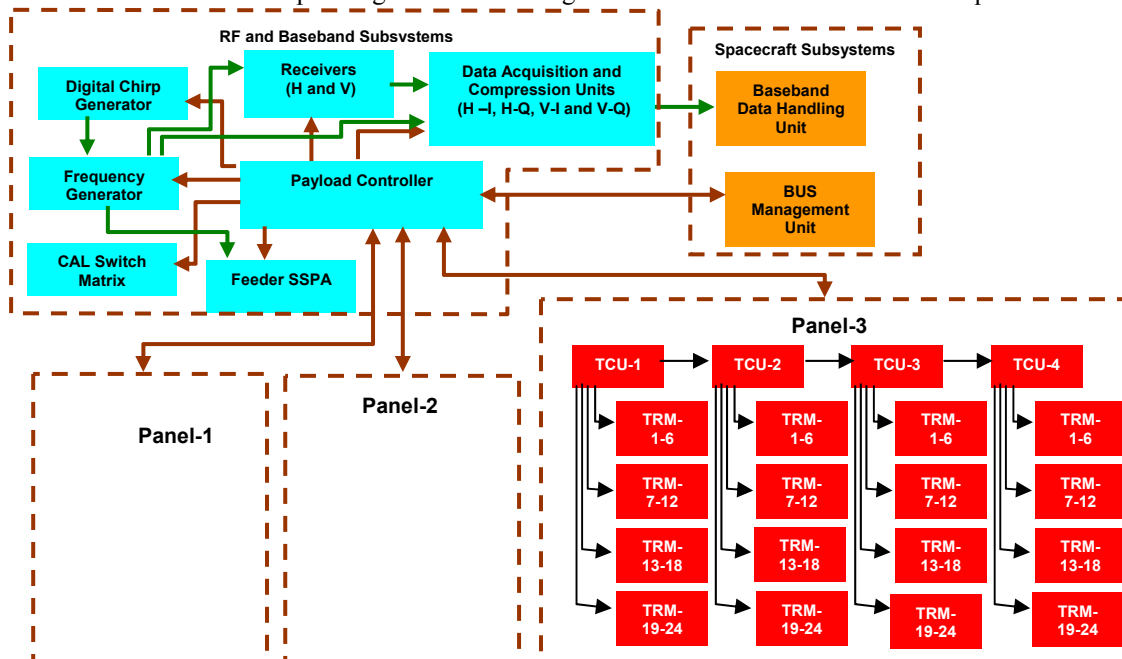

Fig.-3 Three Tier Control of RISAT

command. TCU transmits TR module specific bean shifting, beam weighting and residual corporate feed mismatch compensation related phase and amplitude coefficients to specific TR modules. Each of the TR Module is controlled by corresponding TR Controller (TRC). Each TRC controls two independent TR modules each dedicated for each polarization and one EPC (called Power Conditioning and Processing Unit or PCPU) powering the TRC and two TRmodules. TRC has in its memory all the temperature related phase and amplitude calibration data for each TR modules and imparts the corresponding corrections from instantaneous measurement of ambient temperature.
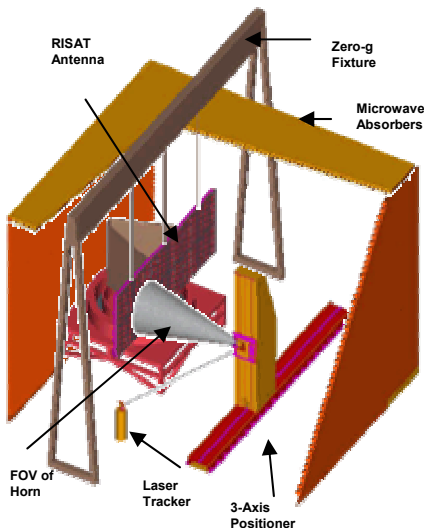
INTEGRATED TESTING OF RISAT ACTIVE ANTENNA

Fig. -4 Mechanical configuration of the Planar Near Field Measurement setup

Active antenna is the major constituent of the RISAT supporting total 126 beams. The accuracy of pointing and knowledge of the pattern has a bearing on radiometry performance of RISAT and overall mapping requirement. So it is planned to carry out antenna pattern measurement in the integrated condition. It is planned to carry out the antenna measurement in the integration laboratory itself both at payload and space craft integration level. The measurement concept is based on Planar Near Field (PNF) concept (Fig.-4). It will have facility to measure both transmit and receive pattern measurement in both polarization using the SAR pulse.

The measurement will be carried out under zero G condition. The proposed measurement scheme will ensure the mechanical references are kept same for four different pattern (Tx-V,Tx-H, Rx-V and Rx-H) measurements. The scanner is basically capable of scanning a probe in X-Y plane of the clean scan area of 8mx4 m. However, it has a limited z axis scan capability of 20 cm. In realistic cases, the scan plane has to be made parallel to actual antenna plane. A laser tracking instrument will provide the plane information of the antenna plane. With limited z axis scanning this objective will be achieved.

RISAT SPACECRAFT CONFIGURATION

RISAT satellite in fully deployed configuration is shown in Fig.-2. The prism shape of the satellite allows stowing of the active antenna in three folds around the prism structure. The prism structure is built around a central cylinder. Most of the spacecraft subsystems and the complete payload are integrated in the prism structure and the central cylinder. The solar panel and rest of the spacecraft subsystems are mounted on the cuboid portion of the RISAT satellite. In-orbit mass of the satellite will be around 1750 kg of which SAR payload will contribute around 950 kg. Two solar panels with high efficiency multijunction solar cell charges two sets of Ni-H2 batteries each with 40 AHr capacity. The satellite has a capability of storing 240 Gbits of data. The on-board data transmitter can transmit with maximum data rate of 640 Mbits/sec in X-band on two polarizations (RHC and LHC) on the same X-band carrier.

In the non-operating condition, the active antenna looks at nadir. Prior to operation, the spacecraft will be roll tilted by $\pm34^o$ to enable viewing either right or left side of the flight track. Additionally the satellite has a capability of pitch steering upto $\pm13^o$ for operation in HRS mode. The satellite will also have yaw steering capability to minimize earth rotation effects. RISAT will operate in sun-synchronous orbit with altitude of 608.9 km with revisit period of 13 days for CRS mode. Equator crossing time is kept at 6 am-6 pm in order to minimize eclipse period to the extent of maximum 20 minutes during summer only and to ensure maximization of battery charging period.

CONCLUSION

Like all the programmes of ISRO, RISAT specifications have been drawn with the national requirements in mind. The choice of frequency and polarization diversity will ensure its wide utilisation in crucial applications, specially in the field of agriculture, forestry and vegetation. The choice of C-band will additionally ensure continuation of user expertise already built with experiences developed with ERS and RADARSAT series of satellites. Simultaneous co and cross polarization capability will provide additional edge over existing SAR satellites. Presently Development model of RISAT, consisting of complete radar with one tile, is being integrated. Preliminary hurdle of indigenous development of TR module, miniaturized PCPU and dual polarized printed antenna has been overcome and they are now in FM production stage. RISAT is expected to be launched in 2007 time frame and it is being designed for operation over next five years.