PROJECT FINAL REPORT 2021

Study of Remote Sensing Ground Station at NRSC/ISRO

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Certificate

Date: 09-08-2021

This is to certify that the project entitled **"The *Study of Remote sensing Ground Station at NRSC/ISRO*"** is a bonafide work carried out by **Sadhvika Kadari** at National Remote Sensing Centre, Hyderabad during the period from 07 Jul 2021 to 09 Aug 2021 in virtual mode under my virtual guidance.

The student is pursuing B.Tech in Electronics & Electrical Communication at Indian Institute of Technology, Kharagpur.

Sadhvika, completed project work under my guidance, and results given in this project report are true.

Sadhvika is regular and learned about Ground Station parameters. The behavior and knowledge is very good. She has completed the assigned task successfully.

डॉ. सत्यनारायण 9/8/21

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Govt of India
Indian Space Research Organization

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Project Guide

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Contents

Abstract

The procedure for Satellite Data acquisition system of the Remote Sensing Satellite Ground Station and functioning of various systems required for data acquisition are explained in this report. The Antenna, RF, Servo Electronics, Data Ingest systems and boresight system is studied and focus is laid on the operation procedure. The technical specifications required for the procedure is mentioned. The daily operations of Real time data acquisition are explained.

1 Introduction

The National Remote Sensing Centre (NRSC) which is under Indian Space Research Organisation (ISRO), Department Of Space (DOS) is responsible for Remote Sensing Satellites data reception, processing and dissemination to the users. NRSC is the focal point for the distribution of remote sensing satellite data products in India and its neighbouring countries. NRSC earth station and associated facilities for data product generation are located at Shadnagar, which is about 55 km from the Hyderabad city, Telangana State. In order to improve the turnaround time from data acquisition to product delivery to the user, the entire chain of operations at the Shadnagar and Balanagar campuses were re-engineered to adopt an Integrated Multi-mission Ground segment for Earth Observation Satellites (IMGEOS), located at Shadnagar campus. IMGEOS is configured to provide faster processing and dissemination of data to users.

It is one of the most important components of the Indian Space Programme, dealing with the applications of Earth Observation or Remote Sensing at grassroots level. The Ground Station is responsible for Data Reception from all Indian Remote Sensing Satellites (IRS). Indeed, it is well said that the ground station is the “brain” of the entire satellite network.

Space science, technology and applications in India have come a long way from a modern start.Today, India ranks amongst the leading nations in the world in successfully tapping the immense potential of space applications. This has been achieved through a focused vision and years of painstaking research and development. With the obtained Earth observation data collected by the satellites a wide range of features and phenomena can be monitored which helps several sectors of the country like agriculture, disaster management, urban planning, rural development, water resources, mineral prospecting, etc. ISRO has a vision of harnessing space technology for the development of the country and pursuing space science research and planetary explorations.

This document launches you on a short journey, focusing on basic understanding of Remote Sensing, how it works, along with looking into the science that governs these.

2 Motivation

Planet Earth, with its basic elements such as Air, Water and Land is the only habitable place in the Universe. Its natural bounciness has sustained a variety of life for millions of years. However, the stress on the balance of nature has never been as profound as it is today.

The ever-increasing population, unplanned growth, pollution and indiscriminate destruction of forests have led to land degradation, poor crop yield, drinking water problem, health hazards and pressure on urban facilities. These problems prompt continuous caution and monitoring in order to evolve developmental plans for effective management of land and water resources.

Frequent natural calamities like floods, cyclones, earthquakes, landslides, etc.; leave behind a trail of destruction in their wake, setting all the development activities back by several paces. An effective disaster warning system is imperative to ensure minimum damage to life and property and plan remedial measures.

Since most of these problems operate in large space and time, they require observations from a position that gives an overview of the situation.

An 'eye in the sky' would be the most ideal platform. Man-made satellites provide a reliable platform for this purpose. We are now better equipped to manage our environment wisely and efficiently with the help of this ability of viewing Earth from Sky- called Remote Sensing.

- Remote Sensing ensures,
  - Large area coverage enabling local, regional, national and global surveys.
  - Continuous observation for disaster mapping and assessment. Periodic monitoring of environment and resources like land, water, agriculture, etc.
  - All weather viewing capability. Mapping inaccessible areas like flood-affected areas, mountains, swampy areas, thick forests, etc.
  - Fully computer-compatible data, ensuring fast and accurate results.
  - Cost effective assessment of environment and habitation.
    As man became more and more civilized, curiosity for the mysteries of space gave way to several novel inventions in order to obtain more information.

3 Remote Sensing Literature Review

The concept underlying the remote sensing technology can be understood with the following simple analogy. When we look at the world through our eyes, we don't actually come into contact with it. Our eyes record the shape, size and color of an object and pass on the information to the brain. Based on the knowledge already available with it, the brain then recognizes the object. Here what we are actually doing is 'sensing' things 'remotely' from a distance. Our eyes are 'sensors' that record information to pass it on to the brain. Similar is the technology of remote sensing of obtaining information about an object without actually coming into contact with it.

So we can think in this way that our body is a 'satellite' which moves and collects information through our eyes which are the 'sensors'. We cannot see any object in the dark. Just as our eyes need objects to be illuminated by light so that we can see them, sensors also need a source of 'light' to illuminate the Earth's surface. Different forms of light or electromagnetic energy are utilized for this purpose. Whenever light falls on an object, part of it is absorbed, part of it is allowed to pass through and the remaining is either reflected or scattered. The light that is reflected back to us gives us information about the object.

Similarly, a sensor on board a satellite collects information that is reflected from different objects on the Earth's surface. This information is conveyed back to Earth, so that we can get the required information about our object of interest.

3.1 Principles & Physics of Remote Sensing

- Various objects return different amounts of energy in different bands of electromagnetic spectrum. The amount of energy we receive from these objects depends on various properties ranging from material (structural, chemical & physical) of the object to the incident energy (angle of incidence, intensity & wavelength) of radiant energy.

- Due to the uniqueness of the reflected/emitted EM radiation from different objects, detection, monitoring and distinguishing of objects/surface features is done.

- Detection of the EM radiation from an object can be achieved through a device called as a "sensor" (Image sensor-cameras, scanners)
- A vehicle used to carry the sensors is called a "platform" (Aircraft, Satellites)

3.2 Stages of Remote Sensing

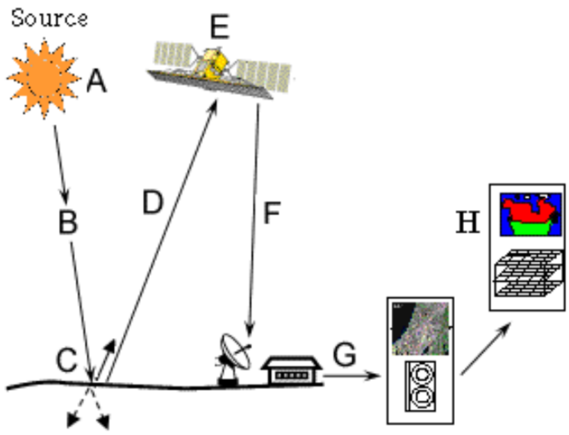

Figure 1: Important stages in remote sensing

Main stages in remote sensing are the following.

A. Illumination/Emission of electromagnetic radiation

- First requirement for remote sensing is the energy source which provides EMR to the target that is the Sun or an EMR source located on the platform

B. Transmission of energy from the source to the object

- Absorption and scattering of the EMR while transmission

C. Interaction of EMR with the object and subsequent reflection and emission

D. Transmission of energy from the object to the sensor E. Recording of energy by the sensor

- Photographic or non-photographic sensors

F. Transmission of the recorded information to the ground station (Reception)

G. Processing of the data into digital or hard copy image

H. Analysis of data (Application)

3.3 Types of Remote Sensing

3.3.1 Passive & Active Remote Sensing

Based on the source of electromagnetic energy, remote sensing can be classified as passive or active remote sensing.

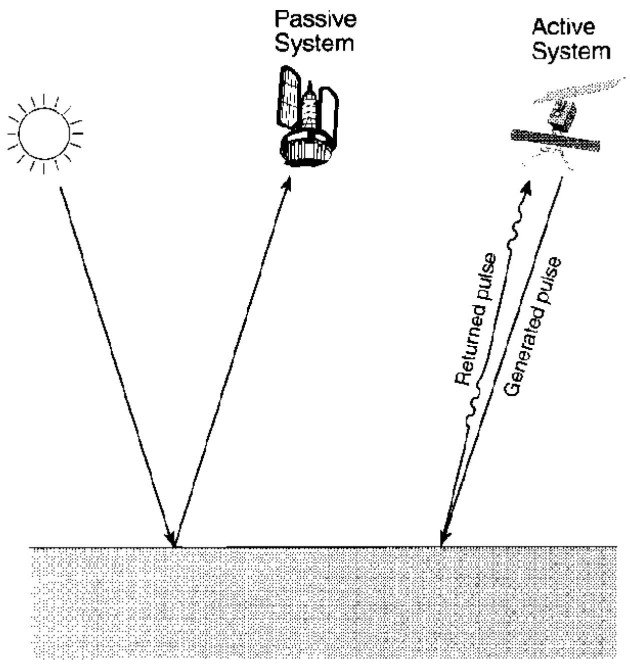

Figure 2: Schematic representation of passive and active remote sensing

In the case of passive remote sensing, naturally available sources such as the Sun acts as the energy source. Most of the remote sensing systems work in passive mode using solar energy as the source of EMR. Solar energy reflected by the targets at specific wavelength bands are recorded using sensors on-board air-borne or space borne observation platforms. In order to ensure ample signal strength received at the sensor, wavelength energy bands capable of traversing through the atmosphere (long distances), without significant loss through atmospheric interactions, are generally used in remote sensing.

Any object which is at a temperature above 0° K emits some radiation, which is approximately proportional to the fourth power of the temperature of the object. Thus the Earth also emits some radiation since its ambient temperature is about 300° K. Passive sensors can also be used to measure the Earth's radiance but they are not very popular as the energy content is very low.

In the case of active remote sensing, energy is generated and sent from the remote sensing platform towards the targets. The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform. Most of the microwave remote sensing is done through active remote sensing. As a simple analogy, passive remote sensing is similar to taking a picture with an ordinary camera whereas active remote sensing is analogous to taking a picture with camera having built-in flash. Most of the microwave remote sensing is done through active remote sensing. Examples of active sensors: LiDAR, Radar (InSAR, PSInSAR, SAR, SqueeSAR.)

3.4 Remote Sensing Platforms

Essentially three different types of platforms are used to mount the remote sensors, from which they collect data on the earth's surface and transmit this information to the ground station for further analysis and processing. Based on the elevation from the earth surface can be classified as follows,

1. Ground Observation Platform

2. Air-borne Observation Platform
3. Space-borne Observation Platform

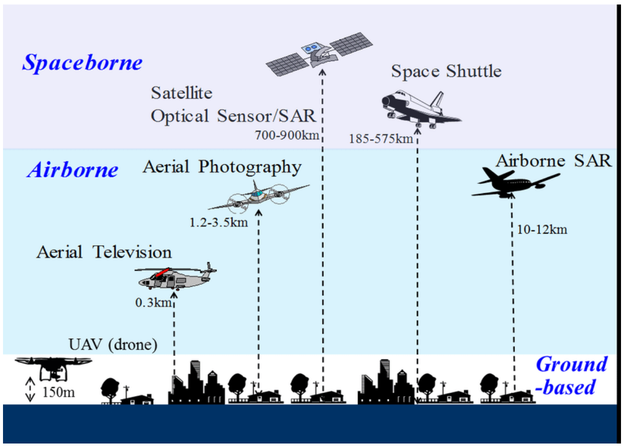

Figure 3: Diagram of multi-level sensor platforms for remote sensing data acquisition

3.4.1 Ground Level Remote Sensing

To develop and calibrate sensors for different features on earth's surface a wide variety of ground-based platforms are used in remote sensing. Both at laboratory and field levels, ground observation platforms are necessary to gain a good scientific understanding on signal-object and signal-sensor interactions. This platform consists of hand-held devices, like photographic cameras, tripods, cranes and towers each having their own advantage of use.

3.4.2 Aerial Remote Sensing

To test the stability performance, airborne observation platforms are important. This platforms includes-

- Balloons: For aerial photography and nature conservation studies.
- Drones: This miniature like looking aircraft has its payload consisting of equipment of radar observation, photography, infrared detection and TV surveillance.
- Aircrafts: Acquires Multispectral scanners, black and white, infrared color photographs.
- High Altitude Sounding Rockets: Useful in assessing the reliability of the remote sensing techniques.

LiDAR, thermal imagery, videography, analog aerial and digital photography are commonly used in this remote sensing. Airborne remote sensing missions are mainly one-time operations. Also this type of sensing has less coverage area and high cost per unit area of ground coverage.

3.4.3 Space-borne Remote Sensing

Significantly space-borne remote sensing are satellite platforms. Here sensors are mounted on space shuttles or satellites orbiting the Earth. The main advantages of this type of sensing are large area coverage, less cost per unit area of coverage, continuous monitoring, automatic/semi-automatic computerized processing and analysis. Landsat satellites, IRS satellites, SPOT satellites, INSAT satellite series are a few examples. NRSC mainly deals with Indian remote sensing

(IRS) Satellites. Several remote sensing satellites provide imagery for research and operational applications about which we would know in detail in the next section.

3.5 Remote Sensing Satellites

A space-borne remote sensing platform is placed and stabilized in an orbit in which it moves. The plane in which a satellite always moves is called the *orbital plane*, which passes through the centre of the earth. Depending on the eccentricity and geometrical characteristics point of view, the orbit can be circular or elliptical. In either case, various orbits are possible depending on the plane of orbital inclination with that of the Earth's equatorial plane.

If the orbital inclination is 0° / 180°, then the orbital plane lies in the equatorial plane which is called the *equatorial orbit*.

If the orbital inclination is 90°, the satellite moves over the poles, that is the centre of the earth, the north and the south pole lie in the orbital plane. Such an orbit is called a *polar orbit*.

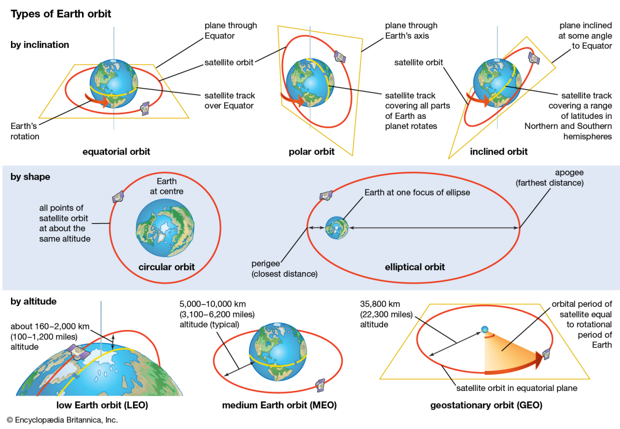

Figure 4: Types Of Orbits

We will now briefly discuss some important orbits which are used for remote sensing. From the point of view of periodicity of satellite movement, orbits can be classified as:

1. GeoSynchronous and Geostationary Orbits
2. Polar/Sun Synchronous Orbits

3.5.1 Geosynchronous Orbits

The orbital period is synchronized with the rotational period of the earth. It is an important case of the circular orbit class which is achieved by placing the satellite at an altitude of about 36000 km height, equating to an orbital speed of 3.07 kilometres per second such that it revolves at an angular velocity equal to the earth's rotation rate. A Geostationary orbit is a special case of geosynchronous orbit, where it maintains the satellite over a narrow longitude band over the equator. Here geostationary orbit has 0° inclination to the equatorial plane. The satellite will appear stationary with respect to the earth. This is the quintessential orbit used for satellite communications. Various communication services satellites can provide include Broadcasting, Telecommunication, Cellular Technology. Examples: INSAT, GISAT. The antenna on the earth is pointed to the satellite without having the need to track the satellite. For the same reason our Dish of the TV need not have movement, it is fixed static as it is relative to the movements of the earth. This is the beauty of science!

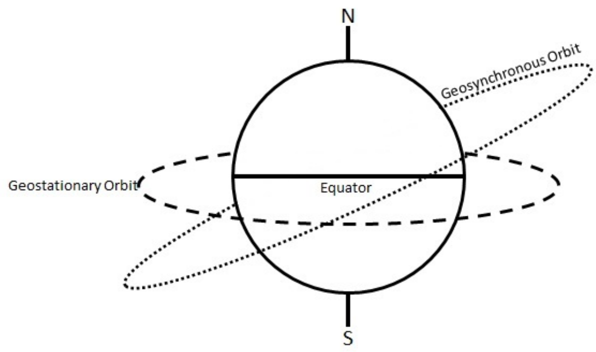

Figure 5: Geosynchronous Orbits

3.5.2 Sun Synchronous Orbits

The angle between the sun-earth line and the orbital plane keeps on changing as the earth moves around the sun. Ultimately, this act leads to varying sun illumination over an area when the satellite revisits the area leading to hindrance in our area of study. To avoid this phenomena, orbit precession exactly compensates for the earth's revolution around the sun. That is the reason it is called 'Sun-Synchronous'. Not just the above reason but also satellites run on rechargeable batteries, where the batteries get recharged by receiving from the solar energy of the sun. When the satellite is not in the illuminated area in the space it works on this battery power and the cycle continues. It is an important case of elliptical orbit class in which the orbital plane is near the polar and the advantageous point is the altitude which is such that the satellite passes over all the places on the earth having the same latitude twice daily revolving in the same mode at the same local sun time. To complete one orbit rotation satellite takes 100 minutes. The low altitude here helps in more precise image capturing with good resolution for our analysis.

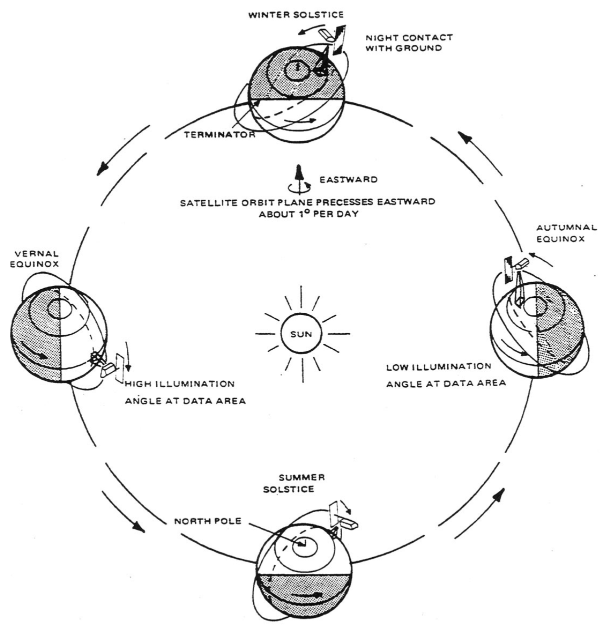

Figure 6: Sun-synchronous Orbits

3.6 Satellites

In NRSC we track and receive the data from the following satellites:

- IRS-P6 (Resource Sat-1)
- Resource sat-2
- IRS-P5 (Cartosat-1)
- Cartosat-3
- Oceansat-2
- RISAT
- TERRA (foreign satellite)
- AQUA (foreign satellite)

4 Overview of Ground Station Units

Basic Prerequisite Contents of Remote Sensing Ground Station / The Data Acquisition System comprises of the following major blocks:

- Antennas & Tracking Pedestal
- LNA & RF Electronics
- Frequency Down Converters & Demodulators
- Servo, Error Generation Logic & Tracking receiver

5 Satellite Acquisition

The satellite acquisition procedure is divided into

- Satellite Pre-Pass Planner (PPP) Generation
- System configuration
- Real time operations

6 Satellite Pre-Pass Planner Generation (PPP)

To compute the antenna, look angles for the passes which are within the visibility range of the Earth Station, the pre pass planner data has to be generated during the early hours of the day.

It requires state vectors of the previous day as inputs. State vectors for any satellite indicate the position of satellite at epoch time on a particular day.

These predicted values would be provided by mission control Bangalore for supported missions. With state vectors of one day, the PPP's of the next day can be generated and this is done only through computer using given software. After PPP Generation, printouts of the day's pass PPP can be taken and kept ready for satellite acquisition.

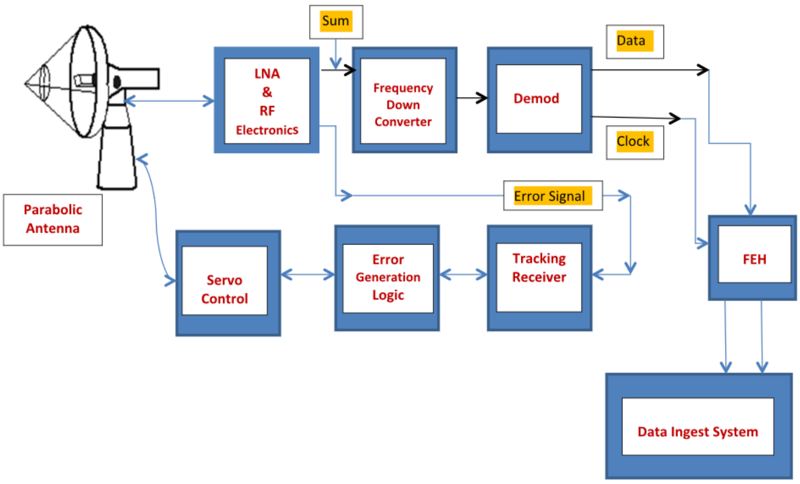

Figure 7: Ground Station Basic Block Diagram

6.1 Data Reception System Configuration of Ground Station

As per the PPP, position antenna in the appropriate sector in AZ and EL axis and enable auto track mode and wait for the satellite. All these activities are completed before 3 minutes of any satellite pass. Three spectrum analyzers in the equipment racks are provided for real-time monitoring of X and S-band IF Signals. These spectrum analyzers must be configured for respective IF signals.

7 Functional Description

7.1 Antennas

Perhaps, the most obvious similarity between the ear and a microwave system is that the outer ear is essentially an acoustic antenna. In remote sensing the wavelengths commonly used for range are almost six orders of magnitude larger than those wavelengths employed for visibility. The data reception facility currently comprises four 7.5 diameter parabolic antennas of a focal length to diameter ratio (F/D) of 0.41 and with dual polarisation S/X band signal reception and tracking capability. Aviation warning lights and lightning arrestor are mounted on the reflector. Here the antenna is parabolic in nature because it has high gain. Implies, as the reflective property of parabolic states, 'any ray parallel to the axis of the parabola will bounce off the parabola and pass through the focus.' This is the advantage as more RF energy can be captured by the antenna.

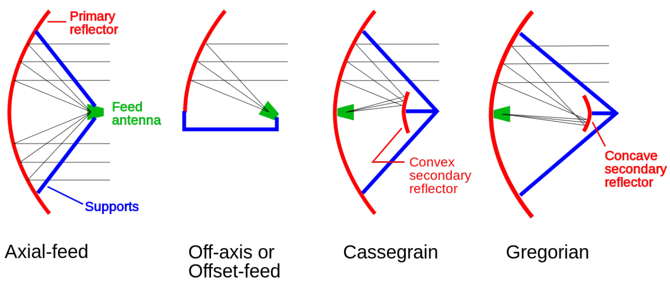

Figure 8: Different arrangements of Antenna

The above figure illustrates the principle of some reflecting antennas. At NRSC all the antennas are of Cassegrain arrangement which has a convex shaped reflector, which acts as a hyperboloid placed opposite to the feed of the antenna. It is also known as a secondary hyperboloid reflector or sub-reflector. It is placed such that its one of the foci coincides with the focus of the paraboloid. Thus, the wave gets reflected twice. Sub reflector is hyperboloid supported by four aluminum quadripods.

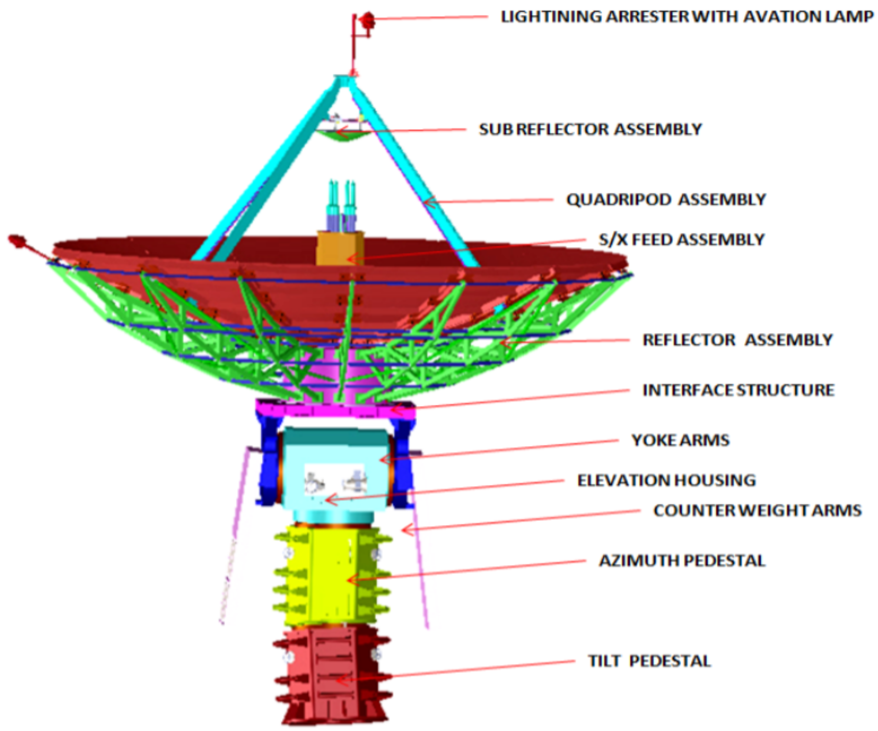

Figure 9: Structure of Antenna

The reflector and sub reflector focus the signals from the satellite into the antenna feed. The antenna has a highly directive pattern with half-power beam width. The monopulse Comparator compares each pair of beams to produce the tracking error signals, when the antenna points to Satellite. The sum channel is formed in the monopulse comparator by adding all four beams together. The AZ and EL error signals coming out of the monopulse comparator are given to the phase commutation unit.

7.2 Servo Control System

The servo system provides automatic acquisition and tracking of satellites in S and X bands. The servo system is a torque biased dual system consisting of the following sub units.

1. Servo Loop Electronics Unit
2. Drive units
3. Antenna Control Computer
4. Brushless DC servo motors
5. Real Time monitoring system

It controls 7.5 meter diameter Antenna system in ‘local’ and ‘remote’ in dual axis i.e. Azimuth & Elevation.

7.3 LNA & RF Electronics System

RF Systems consist of Antenna & LNA, feed electronics, down converters, data and tracking receivers. The received signals in X-Band are filtered to eliminate out of band interference and given to low noise amplifiers. The amplified outputs are down-converted to IF of 720MHz (X-Band).

The IF signals are transferred to control room through long cables. The received signals in control room are filtered & amplified and divided into three parts for interfacing with Main & Back-up chains and monitoring on Spectrum Analyzer.

7.3.1 X-band Down Converter

The up/down conversion of X-Band signals is based on dual conversion technique.The received X-Band signal in the frequency range 8000-8500 MHZ is converted into first IF signal in the range 2345-2845 MHz during first conversion, by mixing with a fixed local oscillator signal at 5655 MHz. In the second conversion, the first IF signal beats with a local oscillator signal derived from frequency synthesizer. The frequency of built-in synthesizer is programmable over the range 1560-2185 MHz in order to derive the desired Intermediate Frequency of 720 MHz and facilitate multi mission data reception. The frequency synthesizer is controlled and monitored through TCP/IP remote interface. The second IF output of tracking at 720 MHz is fed to Integrated tracking system for extraction of AZ and EL DC error signals and drive the digital servo system. The second data down converter unit is co-located with demodulators in control room.

7.3.2 S-band Down Convertor

The S-Band Down converter is based on single conversion. The down converter consists of two identical channels to support data and tracking. The received S-Band data and tracking IF signals in the range of 2.2 to 2.3 GHz are down converted to a 70 MHZ IF. The L.O. Signal for down conversion is derived using a programmable frequency synthesizer module.

7.3.3 Demodulation

Demodulator unit takes the input as the QPSK modulated signal and gives the output as synchronized clock and conditioned data. This unit also provides the continuous clock in the absence of real time data.

Demodulator unit provides Parallel / Serial data & clock outputs. Parallel outputs are used to connect to FEH (Front-End Hardware) for data processing archiving.

8 Tracking Control Unit

This unit takes signals from respective tracking receiver and gives out tracking dc error. Input AGC voltages from tracking receivers are utilized for auto acquisition and auto diversity. This unit generates additionally scan code pulses used for converting the error signals multiplexing in MSC in feed, into single channel and also used for synchronous error demodulation within the unit. This unit gives out AZ & EL dc error outputs to be given to servo system. This TCU can be employed for multi-mission tracking activities.

9 Brief overview of working of the Ground Station

A typical Remote sensing satellite Ground station is shown in figure 2. An Earth Station receives signals from satellite; it consists of tracking chain and Data chain.

The tracking chain is used to track the Satellite and align the Antenna in the direction of the satellite correspondingly to its antenna moments. The data chain is used for the reception of the data. The Ground station makes use of microwave frequencies and especially of X- band (8.2 to 8.4 GHz) and S- band (2.2 to 2.3 GHz) for the data acquisition. The ground station system configuration is explained with reference to the block diagram in Figure.7. The system consists of a diametric parabolic reflector antenna with cassegrain Feed. The Low Noise Amplifier (LNA) and RF Electronics gives out a SUM and Error Signal. The sum is fed to Down Converter its output is given to Demodulator, its outputs are Data and Clock. This is fed to Front End Hardware logic, which converts Serial to Parallel and its output is fed to Data Ingest System.

The Error Signal from RF electronics fed to tracking receiver, it is fed to Error generation logic system, and depending on error Antenna movement will be done.

9.1 Hands-on experience on Satellite Tracking System

The operation of this system involves activating the feed power supply. During routine operation, the only turn on action required is to switch on the main controls i.e. circuit breaker in the control room.

This will power ON the RF power panel which in turn extends the control to pedestal RF equipment's power by switching on the power supplies kept in the concrete pedestal.

This would provide the power, to all active components of the RF system in the pedestal, for both s and X - band together. A warming of 30 minutes is a must for all RF/IF systems. All RF system equipment's are extended with UPS supply.

Following steps are necessary for the system to acquire and track the satellite pass.

1. Setting of frequencies on frequency synthesizer.
2. Ensure programming of demod chains.
3. Spectrum analyzer settings.
4. Ensure proper patching of the chains on IF and base band patch panels.
5. Boresight radiation check for evaluation of auto tracking.
6. Confirm multi-function simulator OFF before pass.

IMPORTANT PRECAUTION:

- Person should stay near console during pass time (10 minutes before AOS to 5 minutes after LOS).

- Please ensure bore sight tracking and local loop checks were normal before going for satellite tracking.

During satellite pass, the data spectrum of LISS-IV & LISS III, S-band signal and various lock status of demodulators, bit synchronizers, Front- end hardware (FEH) units are to be monitored and status to be noted. After the satellite pass, reposition the antenna at 90 deg. AZ and put the system in standby position.

After the completion of the passes, antenna is stowed and system can be switched OFF by switching OFF the main circuit breaker at the back of the data acquisition rack.

10 Station Control Computer Software Description

The SCC software is a GUI application with automated control routines. The application GUI display's current station schedule, real-time antenna tracking & receive chain sub-systems status, state vector reception transfer status, antenna schedules status and pass statistics. The application GUI is shown in below figure. The SCC software is assisted by another software module SccAgent which runs on all the antenna systems. The main functions of the software are as follows

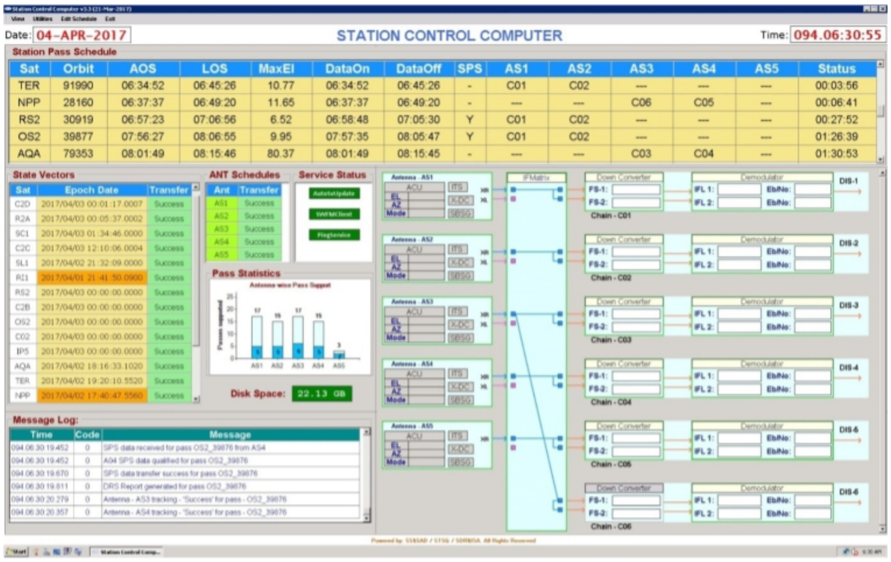

Figure 10: Station Control Computer Software GUI

11 Daily operations of RF and IF systems

I got the opportunity to get the hands-on training to witness the daily operations of the Satellite Tracking in the control room of NRSC. Real time observations of satellite acquisiton helped me to gain more insights. I got to know that about 60 orbits are tracked per day at the ground station. While tracking satellite *Spectrum Analyzer* is used to see the waveform. Signal received by the antenna system will synchronized S-band signal only. Once from the satellite X-band signal received, tracking system will be synchronized with X-band and the antenna will move with X-band signal.
I jotted down the tracking of few satellites where the data is received from different antenna stations in the below tables.

August 04, 2021

Table 1

SAT ID	LS8
Orbit No	54081
AOS	06:23:52
LOS	06:33:41
Data ON	06:24:30
Data OFF	06:32:15
Max. EL	08:52

Table 2

SAT ID	NPP
Orbit No	50619
AOS	06:56:07
LOS	07:09:34
Data ON	06:57:07
Data OFF	07:08:38
Max. EL	19:90

August 06, 2021

Table 3

SAT ID	TER
Orbit No	15071
AOS	05:35:12
LOS	05:48:59
Data ON	05:35:12
Data OFF	05:48:59
Max. EL	52.79

Table 4

SAT ID	OS2
Orbit No	62858
AOS	05:35:48
LOS	05:46:54
Data ON	05:45:55
Data OFF	05:55:24
Max. EL	11.63

12 Conclusion

The study of data acquisition system for satellite in X & S band frequency at NRSC has truly been an excellent learning experience for me. The working of various system like Antenna, RF Electronics, servo Electronics, Front End Hardware and data Ingest Systems is worthwhile. The data transfer and the role played by different components have been of great interest and served as a knowledge trove to me.

The field of remote sensing is moving extremely quickly, with ever evolving processes and increasing resolutions. There is a dramatic increase in data dimensionality. The esteemed organization is dealing with very large and varied data sets and it is exciting to see the response in technology and research.

I would like to thank my guide for helping me throughout the learning. I am also grateful to all the experts who have provided a much-needed assistance which has helped me to successfully complete my project.