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UNIT-II
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SEMESTER-VII

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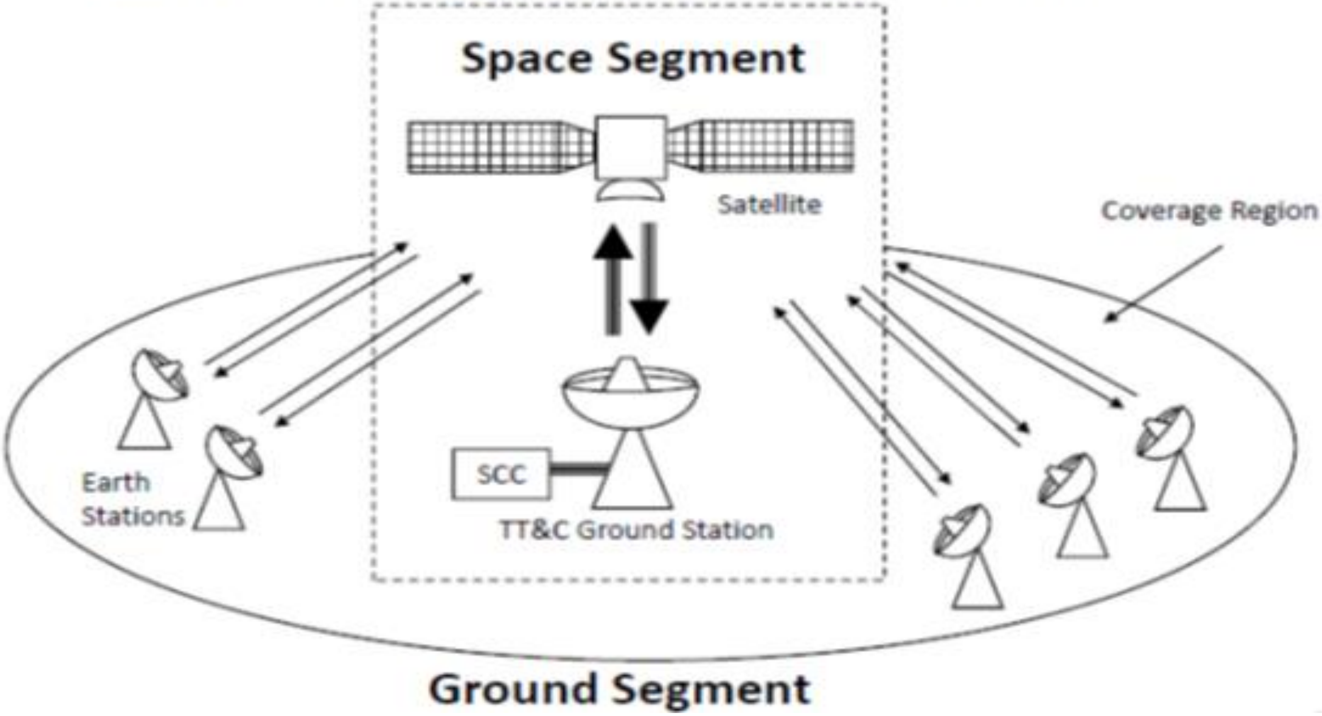
Satellite Communication

Space Segment and Earth Segment

Satellite System Elements



- A satellite communication system is broadly classified into two segment:
  - Ground Segment
  - Space Segment

- The space segment consists of satellites, but also includes ground facilities needed to keep the satellite operational, these is referred as telemetry, tracking and command (TT & C) facilities.

- In many case, the ground station solely consists of TT & C purpose.

- To accomplish this task, satellites carry many subsystems. These subsystems may be placed in two groups – payload and support subsystems. Payload comprises of transponders and antenna, which form the essential parts of communication. These are the revenue earning subsystems as signals from the users are carried and processed through these subsystems. However, payload alone cannot exist independently in space. It requires the help of other subsystems. The major subsystems of a communication satellite in the geo orbit are listed below.
- Transponder system
- Antenna system
- Power system
- Telemetry tracking and command system (TT&C)
- Attitude and orbit control system (AOC)
- Thermal system

Payload & Bus

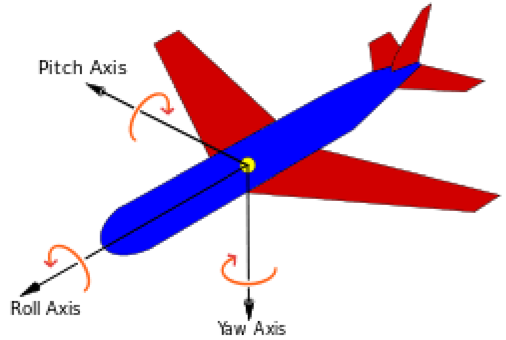
- The equipment carried by the satellite is also classified as per the function.
- The **payload** refers to the equipment used to provide service for the satellite being launched.
- The **bus** refers to a vehicle which carries the payload along with various subsystems which provides power, attitude control, orbital control, thermal control and command and telemetry functions.
- **Transponder** is a device which provides link between the satellite's transmit antennas and receive antennas

Power supply

- The primary electrical power for operating the electronic equipment is obtained from solar cells.
- Individual solar cells generates very less power and hence an array of solar cells is required in series-parallel connection.
- At beginning of life, the panel produces 940 W dc power (for HS-376 satellite) which drops down to 760 W at the end of 10 years.
- During eclipse, power will be provided by nickel-cadmium long life battery which is capable of delivering 830 W of power.

Attitude control

- **Attitude** is something different from altitude. It refers to the orientation and position of **satellite**. The way it's antenna are pointed on to earth , the way they spin in all the three axes. All **satellites** have **attitude** control devices to control their pitch ,roll and yaw.
- An aircraft in flight is free to rotate in three dimensions: **yaw**, nose left or right about an axis running up and down; **pitch**, nose up or down about an axis running from wing to wing; and **roll**, rotation about an axis running from nose to tail.



Attitude Control

- The attitude of a satellite refers to its orientation in space. Much of the equipment carried a satellite is there for the purpose.
- Attitude control is a necessary task to ensure that directional antennas point to the proper directions.
- A number of forces, referred to as disturbances torques can alter the attitudes, some of the example being the gravitational fields of the earth and the moon, solar radiation and meteorite impacts.

Station keeping

- In addition to satellite control, it is important that a geo-stationary satellite be kept in its correct orbital slot
- Satellite kept in geo-stationary usually drift in velocity due to gravitational pull of sun and moon
- These forces cause the inclination to change at a rate of 0.84 degrees/year
- If left uncorrected, the drift would result in the change of inclination going to 0 to 14.67 degrees in 26.6 years.
- To compensate for these drift, an oppositely directed velocity component is imparted to the satellite

Thermal control

- Satellites are subject to thermal gradients, receiving the sun's radiation on one side while the other side faces into space
- Equipment in the satellite also generates heat which is required to be removed
- The most important requirement is that satellite's equipment should be kept at nearly stable environment
- Thermal blankets and shields are used to provide insulation.
- Heaters can be used to maintain constant temperatures

Thermal Control

- Satellites are subject to large thermal gradients, receiving the sun’s radiation on one side while the other side faces into space.

- Equipment in the satellite also generates heat which has to be removed. The most important consideration is that the satellite’s equipment should operate as nearly as possible in a stable temperature environment.

- Various steps are taken to achieve this. Thermal blankets and shields may be used to provide insulation. Radiation mirrors are often used to remove heat from the communications payload.

TT & C

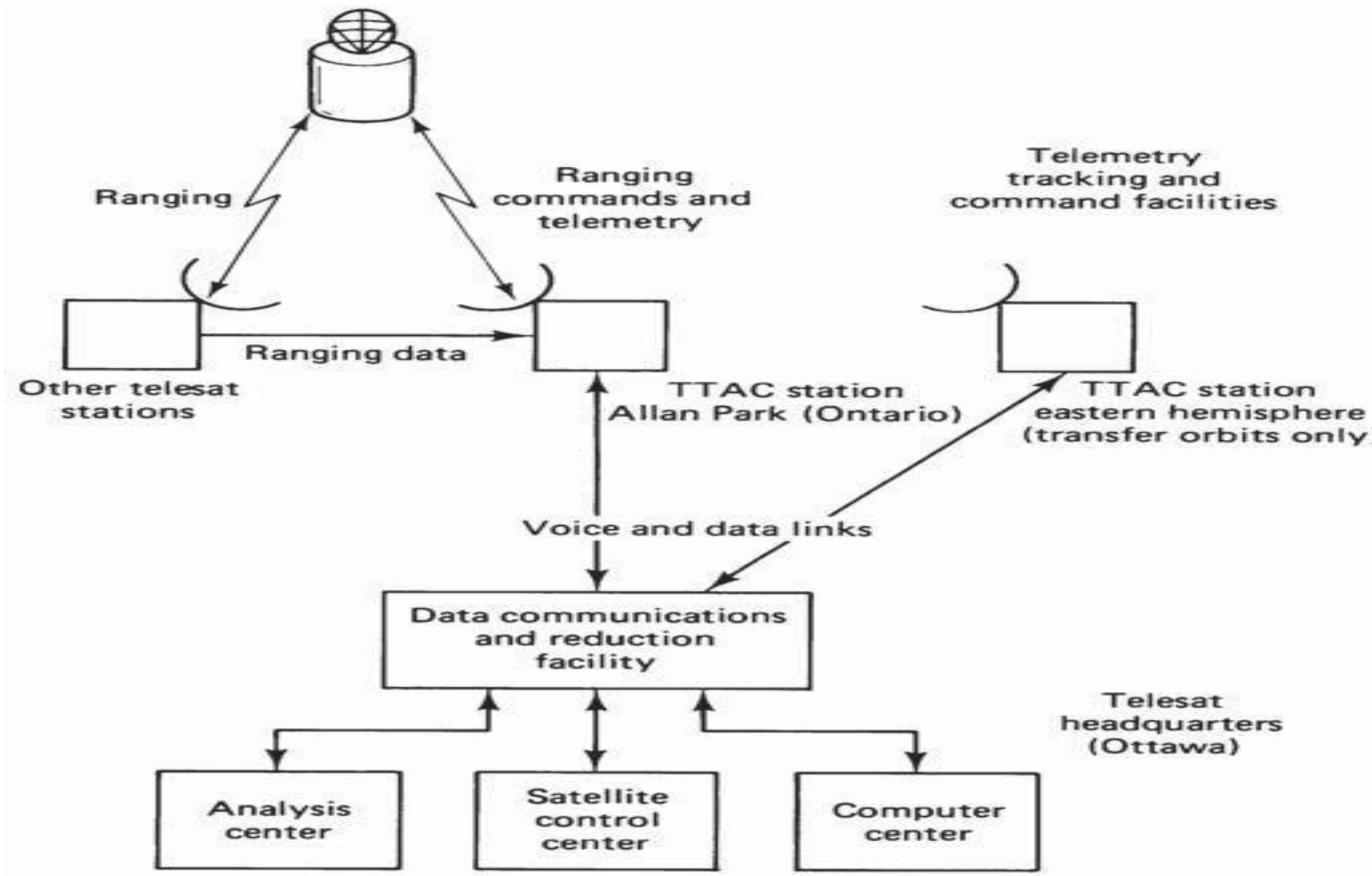
- Telemetry, tracking and command subsystem performs several functions abroad the spacecraft.

- The telemetry is used for measurement of distance.

- Telemetry information include attitude information from sun and from earth, environment information such as magnetic field intensity and direction and frequency of meteorite impact(A **meteor** is a smaller body in space that collides with the Earth or another planet) and space craft information such as temperatures and power supply and fuel pressure.

TT & C

- Telemetry and Command systems are complementary to one another. The telemetry transmits information from satellite to earth station.
- While command system is thought of as feedback to the telemetry. Transmits information from earth station to satellite.
- Tracking of the satellite is an important task to keep satellite at the right orbital place.
- Tracking is done by having satellite transmit beacon signals (A beacon is a small Bluetooth radio transmitter. It's kind of like a lighthouse: it repeatedly transmits a single signal that other devices can see)which are received by TT & C earth stations.



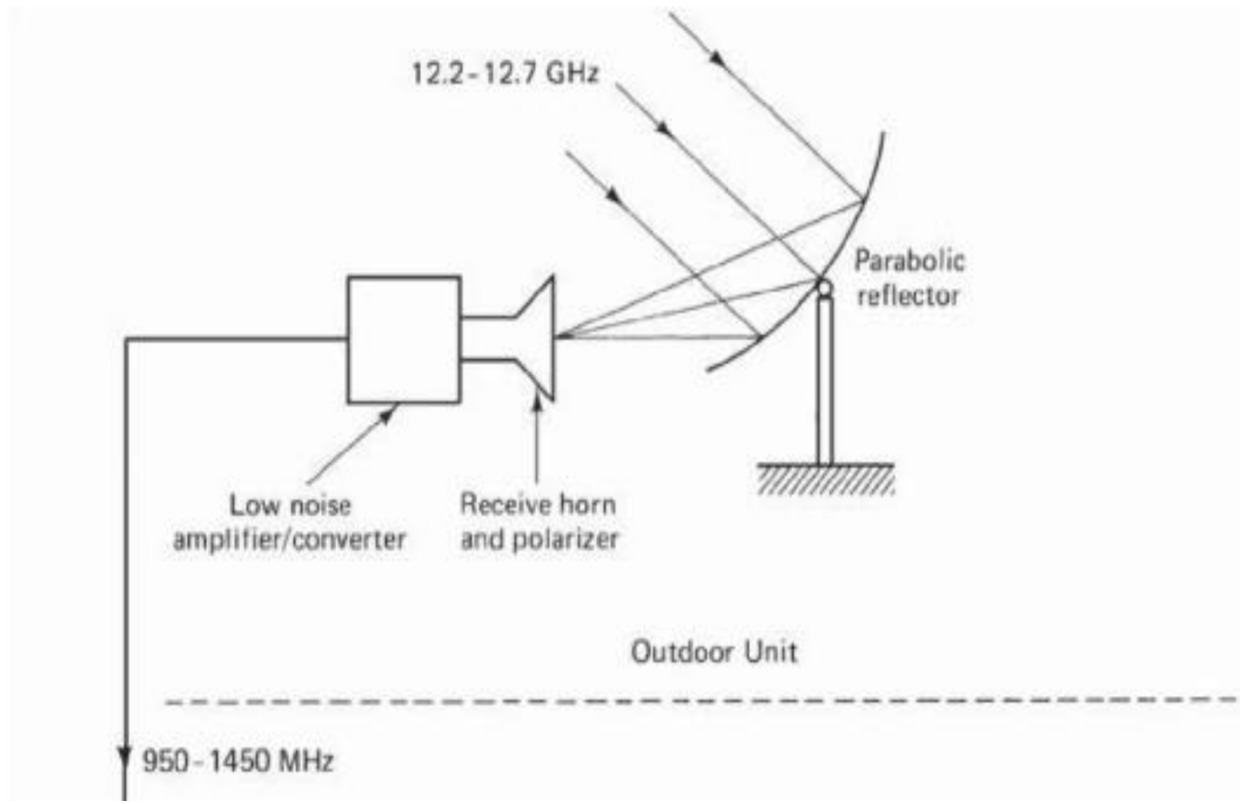
Satellite Control System

Earth Station

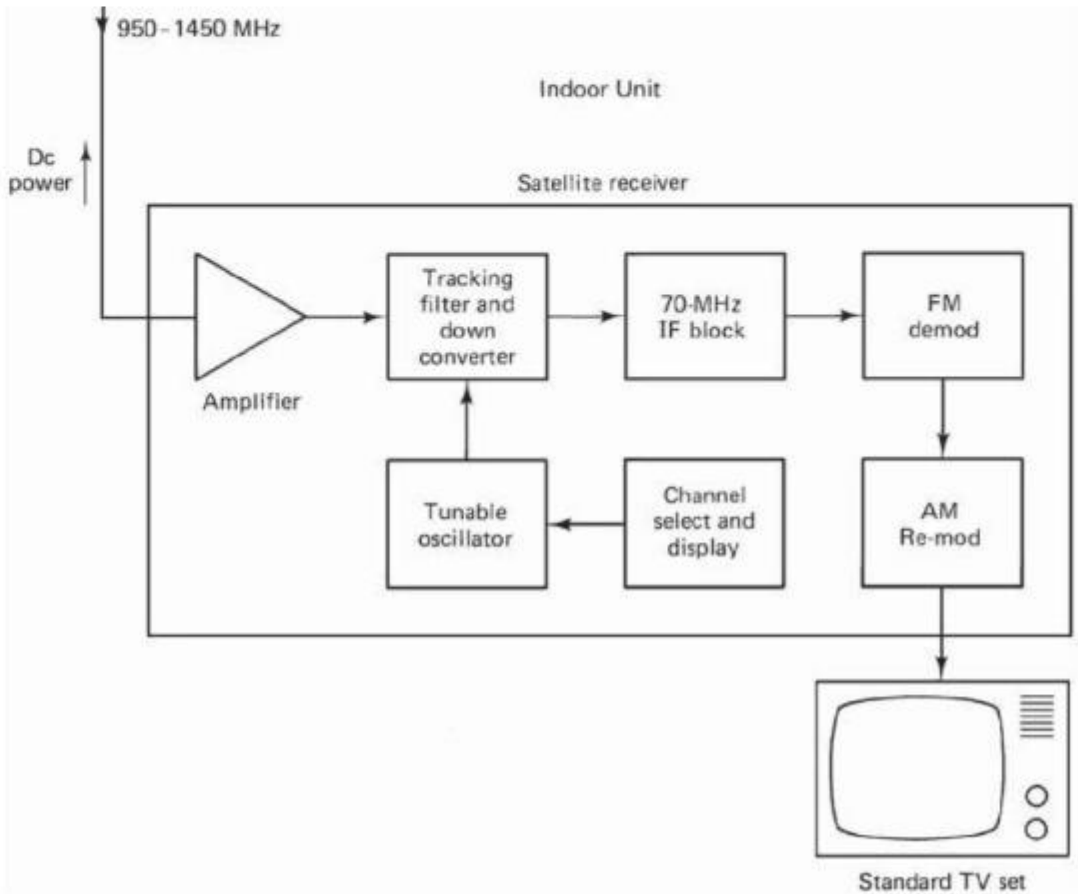
- Types of earth stations
- Classification based on performance
- Fixed and mobile earth stations
- Major subsystems
- Antenna , feed systems and tracking systems
- RF Communication equipment
- IF systems
- Baseband equipment
- Parameters and measurements

The earth segment of a satellite communications system consists of the transmit and receive earth stations. The simplest of these are the home TV receive-only (TVRO) systems, and the most complex are the terminal stations used for international communications networks. Also included in the earth segment are those stations which are on ships at sea, and commercial and military land and aeronautical mobile stations

Earth station is a vital element in any satellite communication network. The function of an earth station is to receive information from or transmit information to, the satellite network in the most cost-effective and reliable manner while retaining the desired signal quality. The design of earth station configuration depends upon many factors and its location. But it is fundamentally governed by its



TVRO System block diagrams (Outdoor Unit)



TVRO System block diagrams (Indoor Unit)

Location which are listed below

- In land
- On a ship at sea
- Onboard aircraft

The factors are

- Type of services
- Frequency bands used
- Function of the transmitter
- Function of the receiver
- Antenna characteristics

Any earth station consists of four major subsystems

- Transmitter
- Receiver
- Antenna
- Tracking equipment

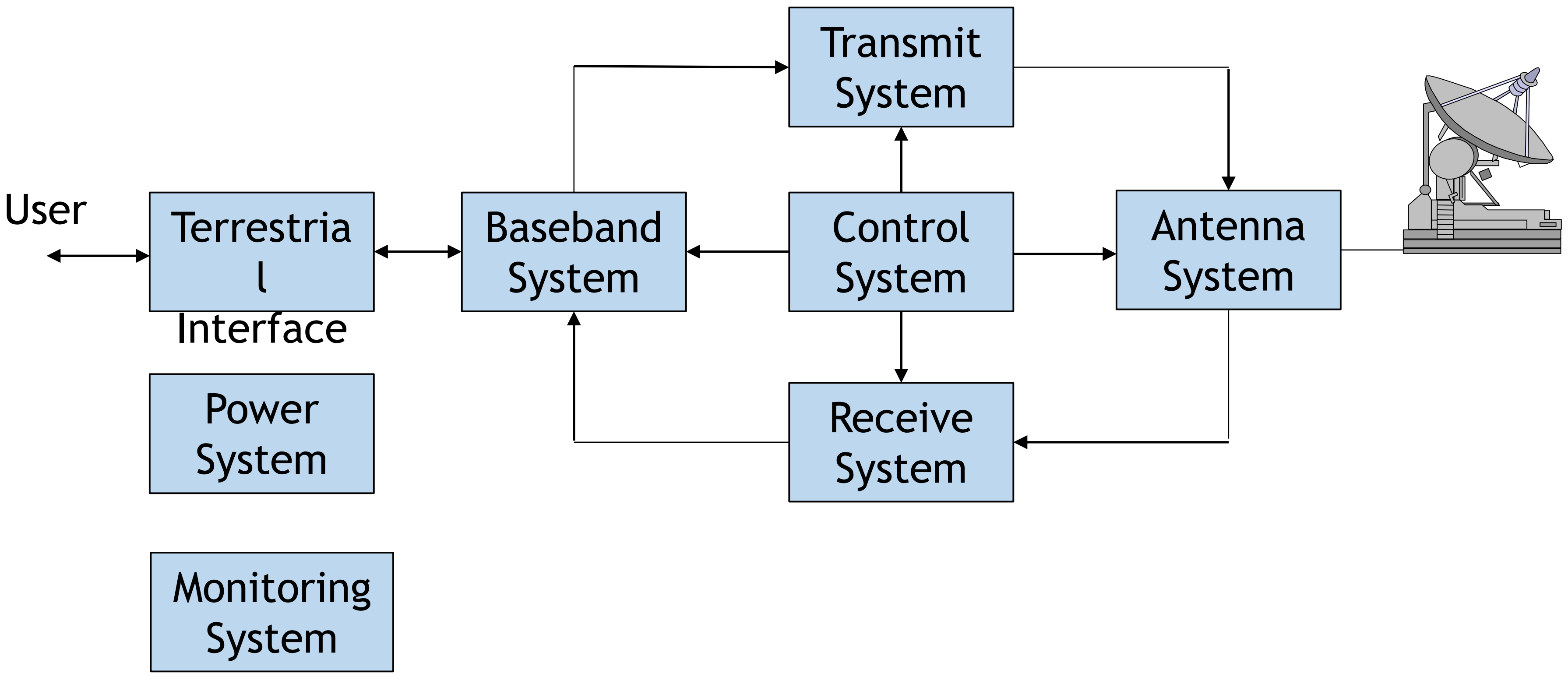
Two other important subsystems are

- Terrestrial interface equipment
- Power supply

The earth station depends on the following parameters

- Transmitter power
- Choice of frequency
- Gain of antenna
- Antenna efficiency
- Antenna pointing accuracy

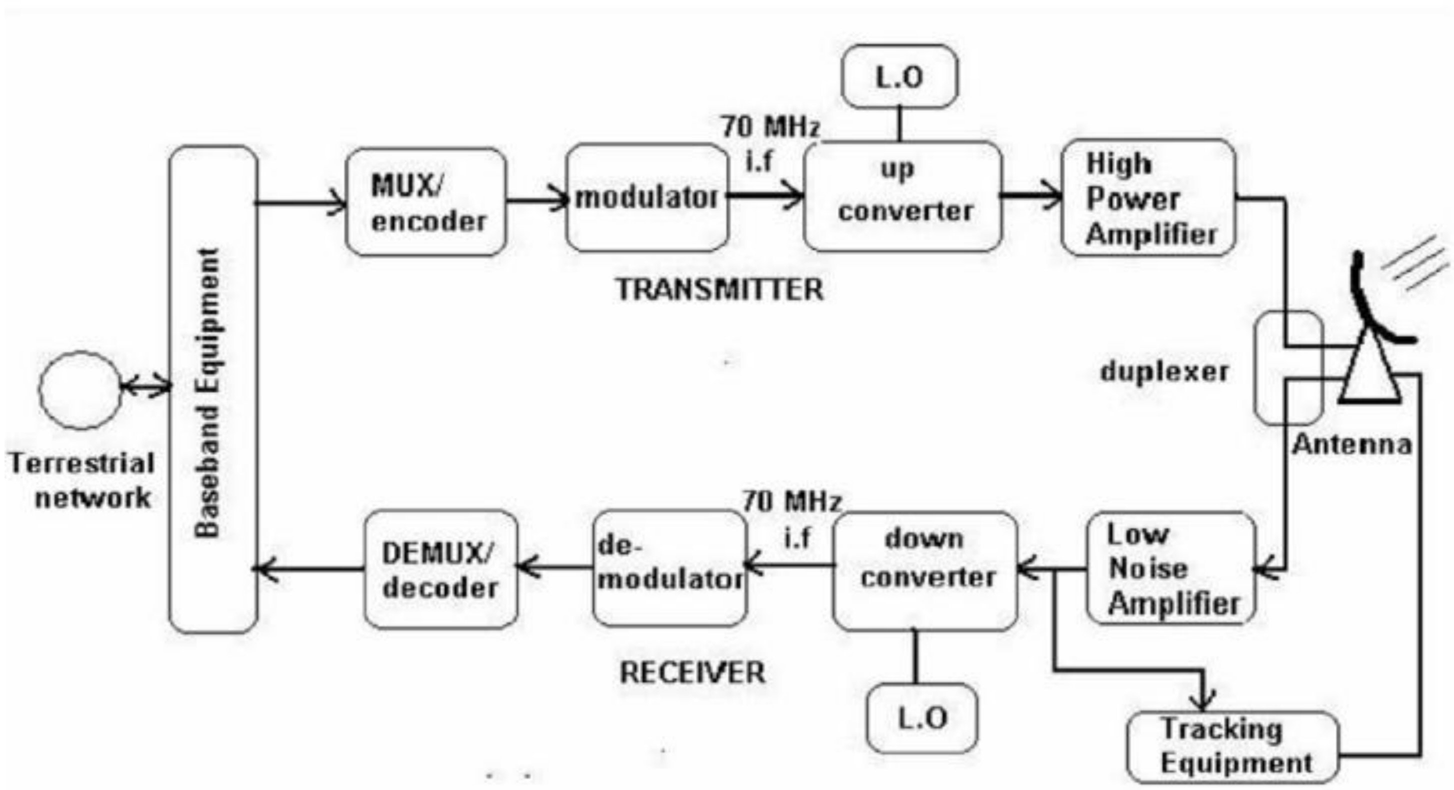
Typical Earth Station



Information is transmitted and received fro a satellite using earth stations which act as gateways. The information to earth station is received from terrestrial systems such as telephone exchanges, TV and radio stations, computer centers etc. The data received from these systems over cables, wires etc. need to formatted for transmission over satellite channels.

For example, analog voice or video signals may be converted to digital signals for transmission in digital format on satellite channels. Also, signals received from many terrestrial systems may be multiplexed (combined) on a single stream. The 'terrestrial interface' circuits do all such tasks, both on transmit side and receive side of the earth stations.

Functional elements of a basic digital earth station



- Digital information in the form of binary digits from terrestrial networks enters earth station and is then processed (filtered, multiplexed, formatted etc.) by the base band equipment

- The encoder performs error correction coding to reduce the error rate, by introducing extra digits into digital stream generated by the base band equipment. The extra digits carry information

- In satellite communication, I.F carrier frequency is chosen at 70 MHz for communication using a 36 MHz transponder bandwidth and at 140 MHz for a transponder bandwidth of 54 or 72 MHz.

- On the receive side, the earth station antenna receives the low-level modulated R.F carrier in the downlink frequency spectrum

- The low noise amplifier (LNA) is used to amplify the weak received signals and improve the signal to Noise ratio (SNR). The error rate requirements can be met more easily.

- R.F is to be reconverted to I.F at 70 or 140 MHz because it is easier design a demodulation to work at these frequencies than 4 or 12 GHz.

- The demodulator estimate which of the possible symbols was transmitted based on observation of the received if carrier

- The decoder performs a function opposite that of the encoder. Because the sequence of symbols recovered by the demodulator may contain errors, the decoder must use the uniqueness of the redundant digits introduced by the encoder to correct the errors and recover information-bearing digits.

- The information stream is fed to the base-band equipment for processing for delivery to the terrestrial network.
- The tracking equipment's track the satellite and align the beam towards it to facilitate communication

Earth Station Tracking System :

Tracking is essential when the satellite drift, as seen by an earth station antenna is a significant fraction of an earth station's antenna beam width.

An earth station's tracking system is required to perform some of the functions such as

- Satellite acquisition
- Automatic tracking
- Manual tracking
- Program tracking

Antenna Systems :

The antenna system consist of

- Feed System
- Antenna Reflector
- Mount
- Antenna tracking System

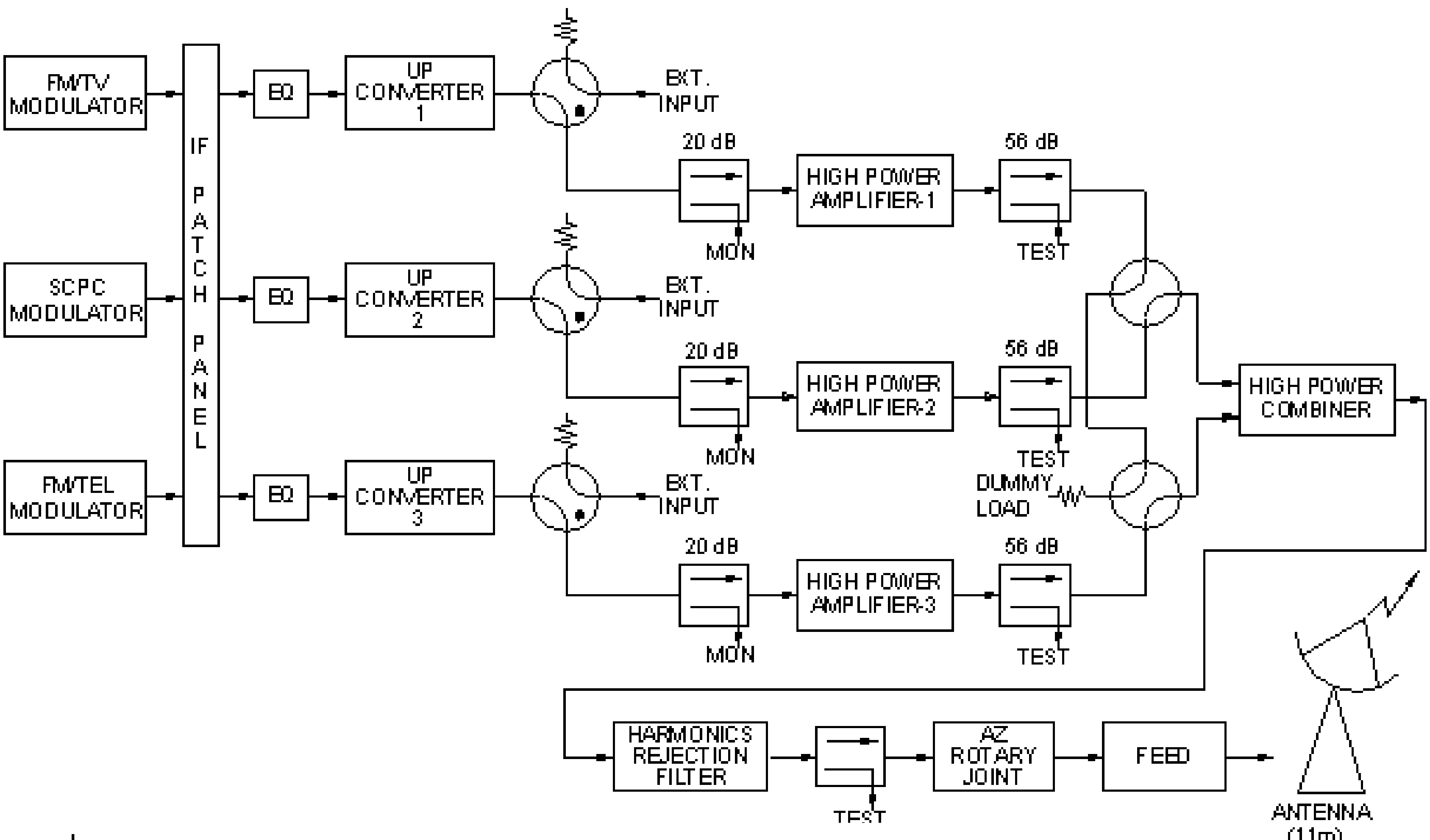
Types of Earth Stations

Parameters	**Large**	**Medium**	**Small**
Antenna	Fully steerable	Limited steerability	Fixed
Feed	Horn, sub reflector	Sum mode	Prime focal
HPA	Klystron	TWTA	SSPA(**Solid State Power Amplifiers**)
Power	3 kW	100-400 W	1-10 W
LNA Noise Temp	30^oK	45^oK	65^oK
Redundancy	Full	HPA, LNA	No
Power system	No break	Standby redundancy	Battery , Solar

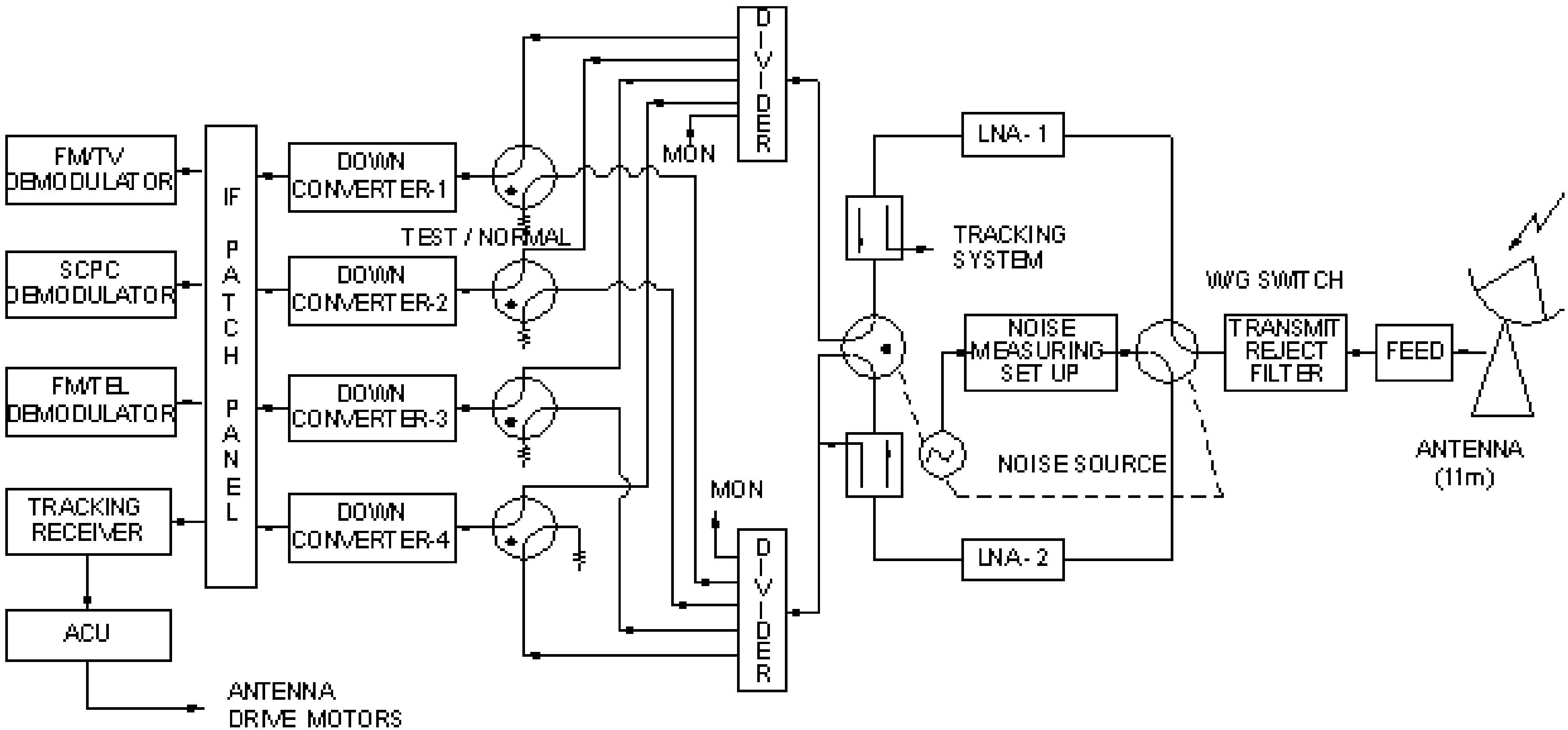
Types of Earth Stations

- Large Earth Stations
  - Fixed structures, carry large telephone traffic, video
- Transportable Earth Stations
  - Truck mounted- fixed
  - Ad-hoc networks
- Portable Earth Stations
  - Jeep mounted, air lifted
  - News gathering, disaster area communication
- Small Earth Stations
  - VSAT(Very Small Aperture Terminal) is a satellite communications system that serves home and business users. A VSAT end user needs a box that interfaces between the user's computer and an outside antenna with a transceiver.
- Receive only Earth Stations
  - DTH, TVRO, DBS receivers

Earth Station Transmit system



Earth Station Receive system

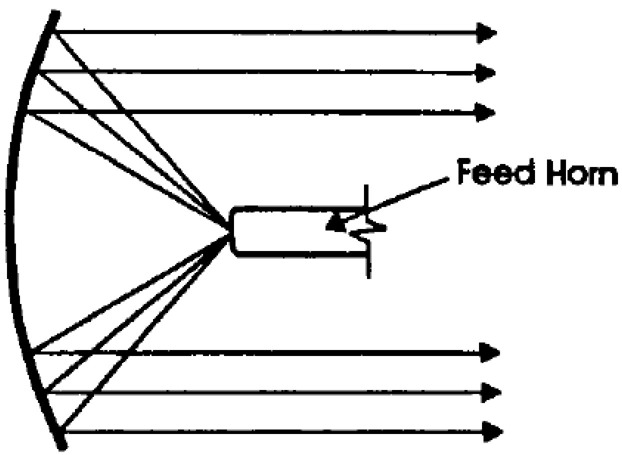


Antenna system

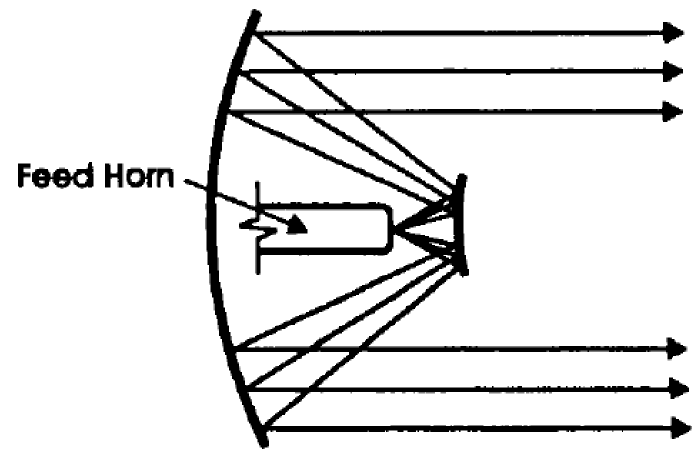
- Antenna structure
  - Reflector
  - Feed
  - Waveguide

- Tracking System
  - Manual tracking
  - Program controlled tracking
  - Auto tracking

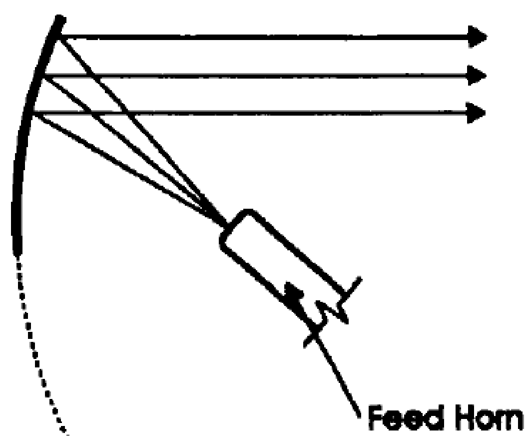
Antenna feeds



Prime-focus feed

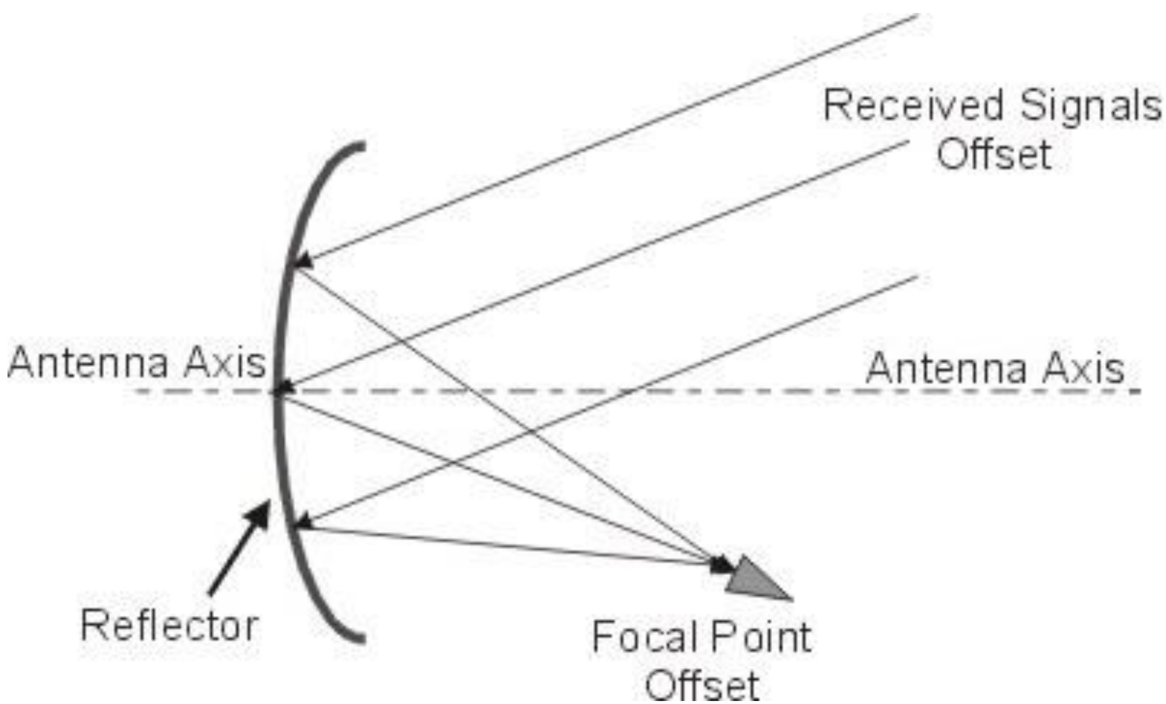


Dual-reflector

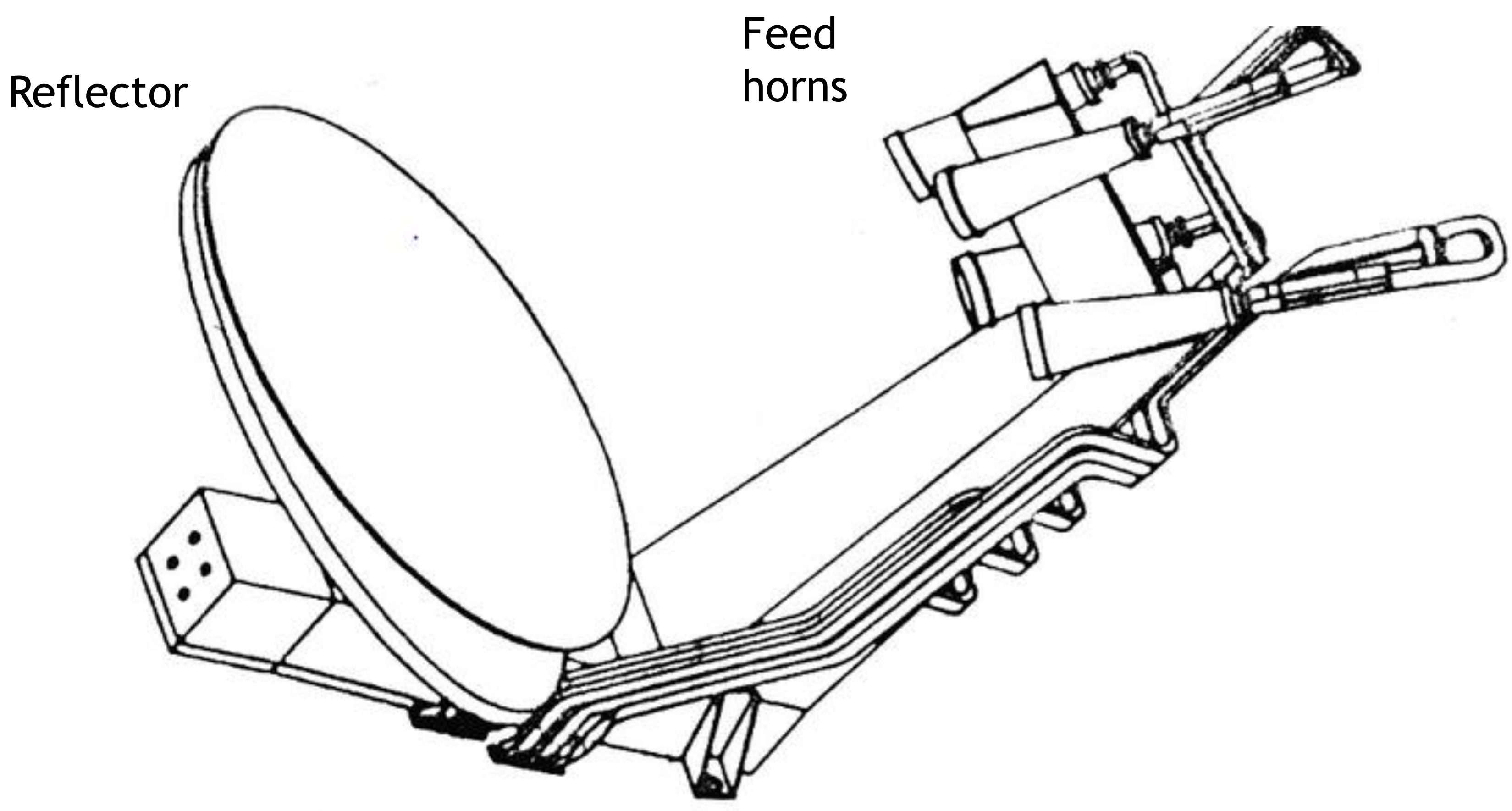


Off-set feed

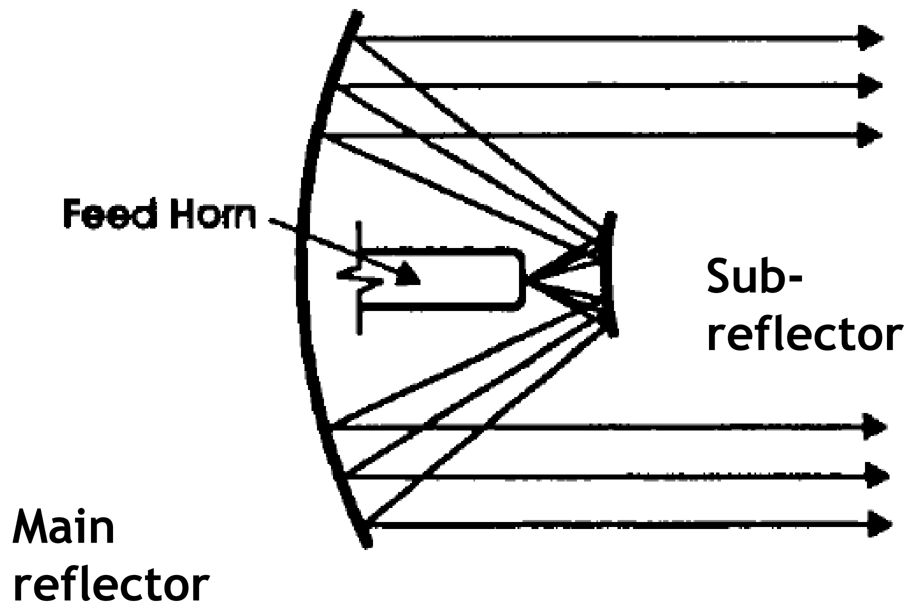
Offset feed antenna



Offset reflector antenna with multiple feed horns



Antenna feed with Dual-reflector



Cassegrain antenna: sub reflector is convex towards main reflector
Gregorian antenna: sub reflector is concave towards main reflector

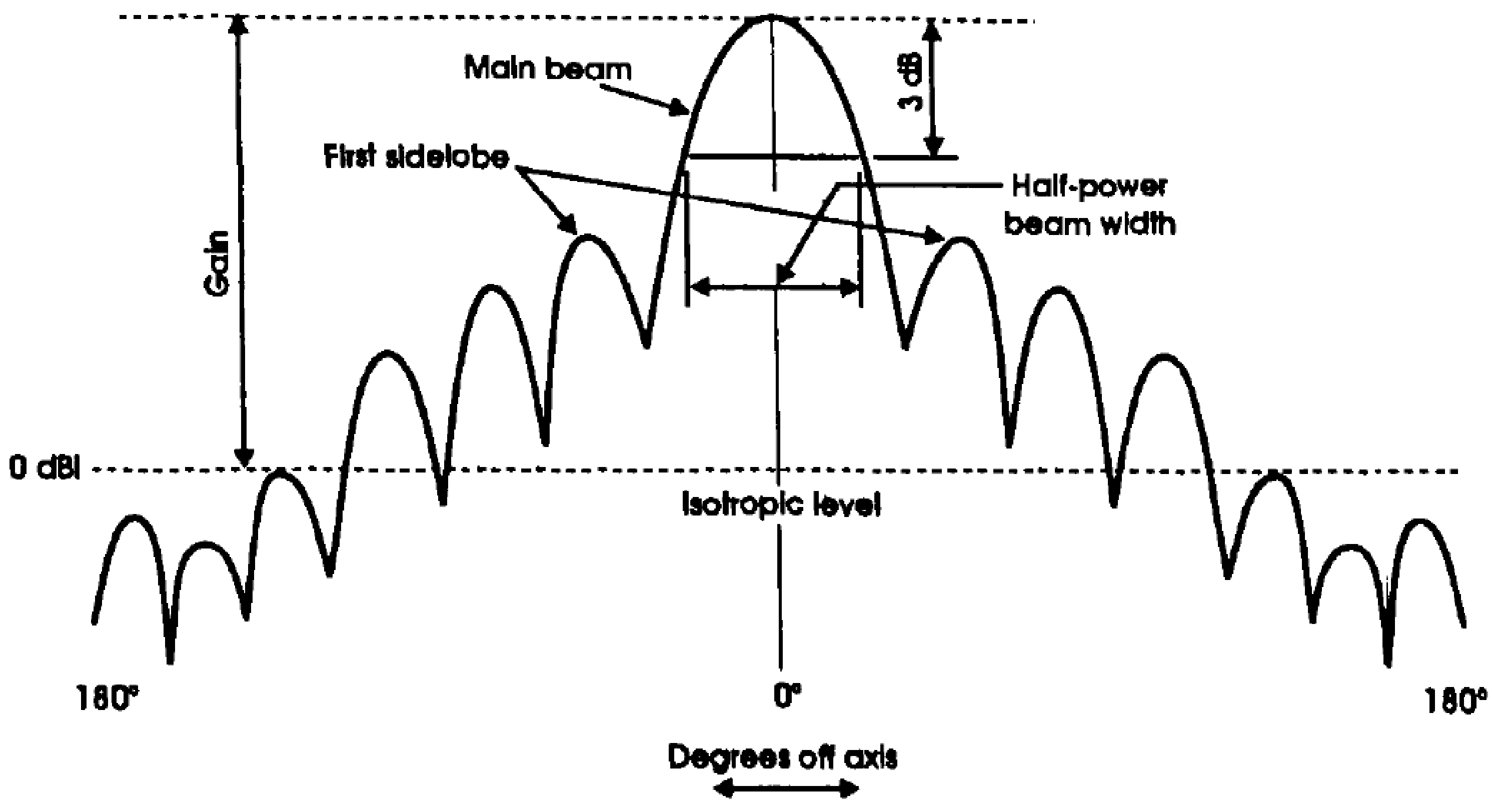
Cassegrain antenna

- Comprises of three elements:
  - **Main parabolic reflector**
  - **Hyperboloid convex sub reflector**
  - **Feed horn**
- The focal point of the main reflector and the virtual focal point of the sub reflector coincide
- Advantages:
  - **Low noise temperature-Spill over from feed is towards the sky**
  - **Pointing accuracy**
  - **Flexibility in feed design**
  - **Greater mechanical stability due to feed location at vertex of main reflector, resulting in better pointing accuracy**

Antenna Performance

- **Antenna directivity**
  - Discrimination against signals from adjacent satellites on the receive side
  - Avoids interference to adjacent satellites on the transmit side
  - Determines the gain
- **Gain of the antenna**
  - Decrease in HPBW increases the gain
  - Affected by the efficiency –fraction of the power emitted by the feed horn in the main beam
- **Polarization isolation**
  - High degree of isolation avoids mutual interference between cross polarized channels
  - Typically 30 dB isolation needed
- **Mechanical stability**
  - Pointing accuracy
  - Survival against wind

Antenna Radiation Pattern



Trade-off between beam width and side lobes

Multiple beam antennas

- Used in receive earth stations to receive signals from many satellites (For cable TV channels, for example)
- Economic and occupy less space compared to multiple antennas

Antenna control

- Antenna control is required to improve the pointing accuracy or reduce pointing error
- Pointing accuracy required depends on the beam width
- Tracking is essential for keeping contact with low orbit satellites which are in view for limited time
- Tracking may not be required for geostationary satellites if the beam width is more than $\pm$ 3 degrees which is the window of Geo satellite movement
- Tracking is necessary for narrow beam antennas

Antenna tracking methods

- Manual tracking
- Program controlled tracking (open loop tracking)
- Auto tracking (closed loop tracking)
  - All auto tracking systems depend on the continuous beacon signal transmitted from the satellite
  - Pointing error information is derived from the received beacon and control signal is generated to drive the servo mechanism

Manual and Program tracking

- Manual tracking
  - Operator controls the movement of antenna to receive maximum signal

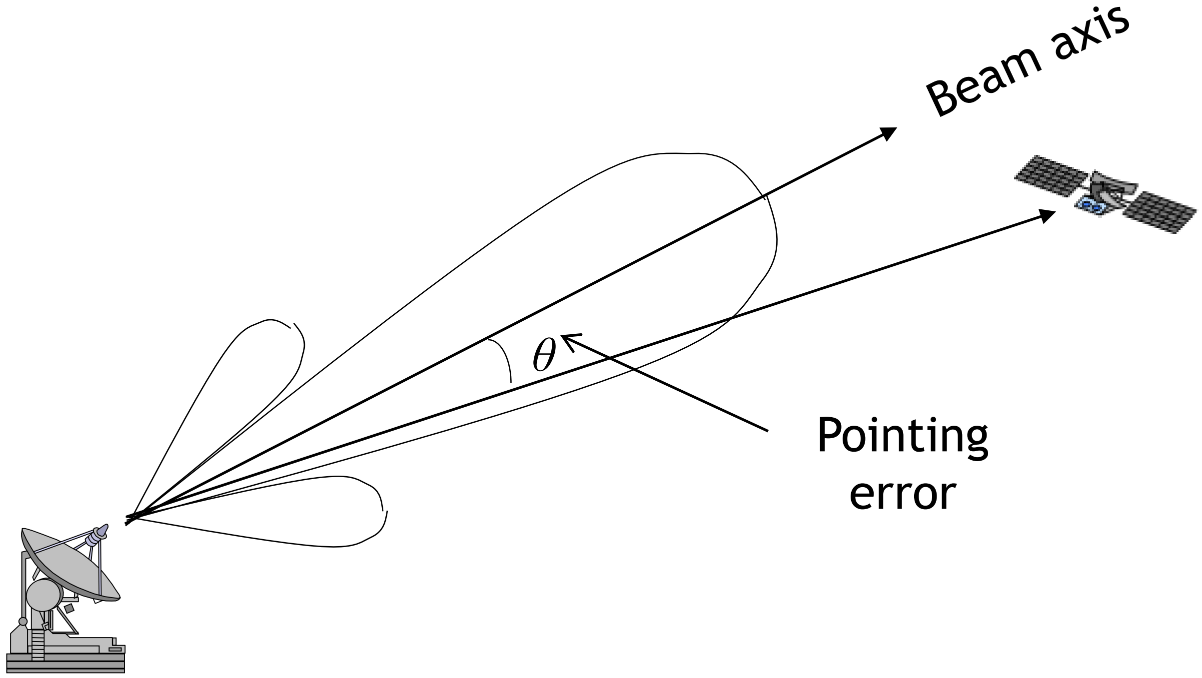
- Program tracking
  - Data describing the satellite path as observed from the earth station and stored and used to steer the antenna

- Tracking accuracy is poor

Auto tracking

- Closed loop system
- Higher accuracy
- Minimizes the pointing error (angular difference between the line joining the satellite and earth station and the bore sight of the antenna
- The satellite transmits a beacon signal
- Earth station has two or more feeds with antenna patterns symmetric about the bore sight of the main feed but not coincident with the main pattern
- Pointing error is derived from the difference in the received signal with these patterns in orthogonal planes

Antenna Pointing Error



Power Amplifier

- Separate HPA per transponder
- 40 to 80 MHz bandwidth
- For large earth station saturated power output≈ 3 kw
- Typical back-off for multi-carrier operation is 12-14 dB
- Linear power output is 300-500 W
- What is the problem with saturated operation in multi-carrier and single carrier operations?

Earth Station Performance

- Transmit EIRP
  - Transmit Power
  - Transmit Antenna Gain
- Receive G/T
  - Receive Antenna Gain
  - Receiver Noise Temperature