

Satellite Communication

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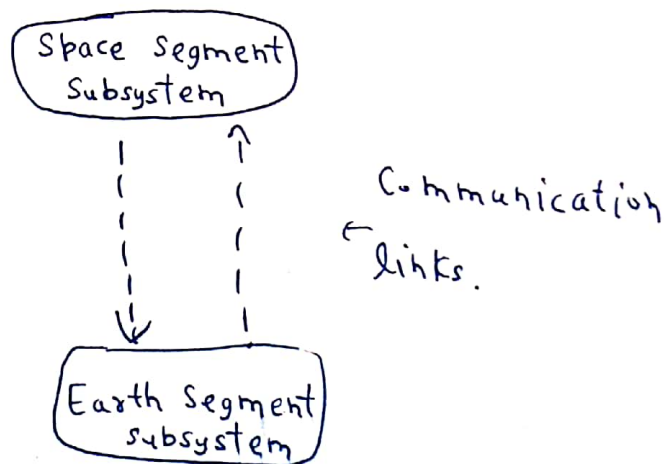
* In satellite communication system, various operations take place, among which the main operations are orbit controlling, altitude of satellite, monitoring and controlling of other subsystems.

* Earth Segment

- It is present in the ground segment which have the ability to access the satellite repeater in order to provide the communication between the users.
- It is also called as ground segment.

* Space Segment

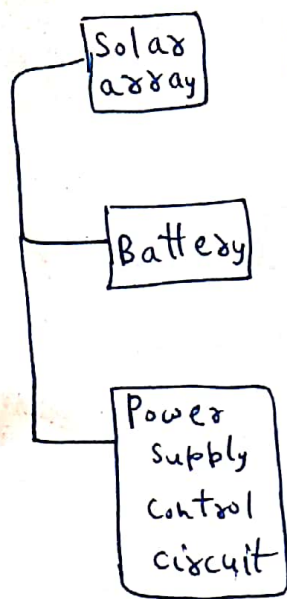
- It is present in space, major space segment subsystems are:
 - AOC Subsystem
 - TT&C Subsystem
 - Power & Antenna subsystem
 - Transponders



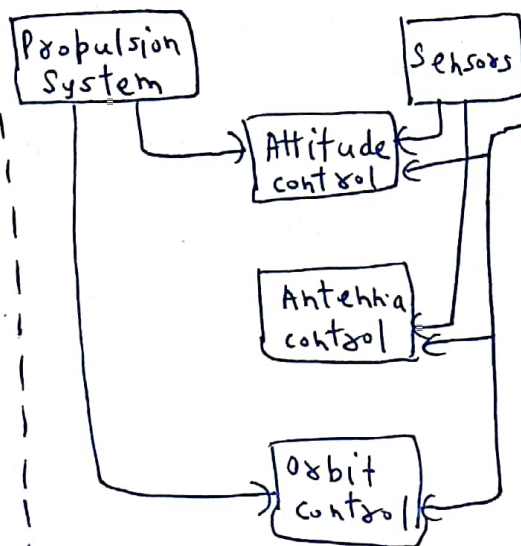
* A satellite communication consists of mainly two segments.

* Now, we'll understand about various subsystems in detail by making a diagram.

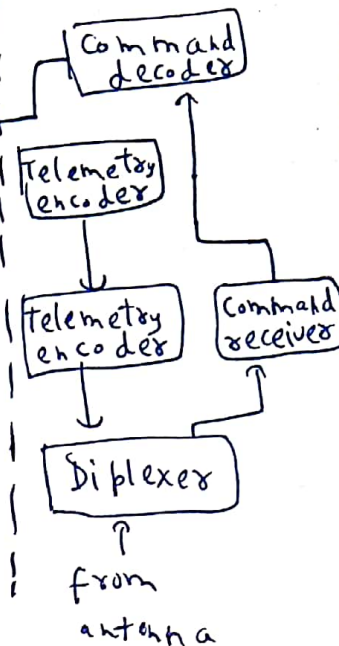
Power Supply Subsystems



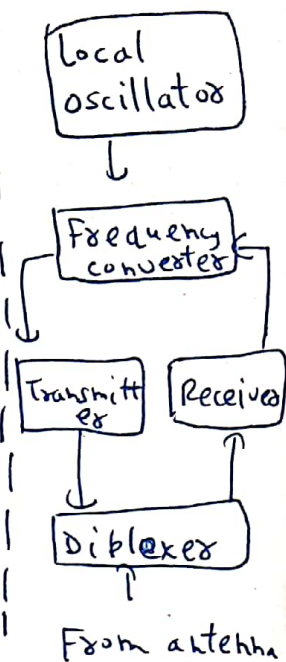
Altitude and Orbit control



Telemetry, Tracking & Command



Communication Subsystem



Power Supply Subsystems

- * Solar cells are photovoltaic cells. They convert solar radiation into electricity.
- * A typical satellite solar cell has conversion efficiency of 12-15% and it generates 1-2 kW of Power.
- * Thousands of minute solar cells are placed on the surface of satellite. If the surface area is not adequate there, then separate projections can be installed there called solar panel.
- * When solar power is not present like during night, adverse weather condition, then battery is used.
- * Power supply control circuit controls various units.

Altitude and Orbit Control

- * There are various orbital perturbations which may affect the satellite orbit. So, there is a requirement of Altitude and Orbit Control system

- * In case of Altitude control, two types of sensors are used.
 - 1) Earth sensor
 - 2) Sun sensor

* Propulsion System is a reaction control system which is carried by the satellite in the geostationary orbit and usually there are three kinds of units for the propulsion system. The units are low thrust actuators, high thrust motors and with space shuttle.

* Four operations are required to check for satellite stability and altitude etc., these are

1) detection of altitude

— sensors on satellite help to send the data to the ground station

2) compare with reference

3) ~~requirement of correction~~ (evaluate corrective torque)

4) requirement of correction.

Two types of control

Active Altitude
control

Passive Altitude
control

Telemetry, Tracking and Command

* Function of telemetry is to receive the data. Telemetry system collects the data from many sensors and sends it to controlling earth station. The data may be in the form of pressure and fuel tank, temperature, voltage in power conditioning unit.

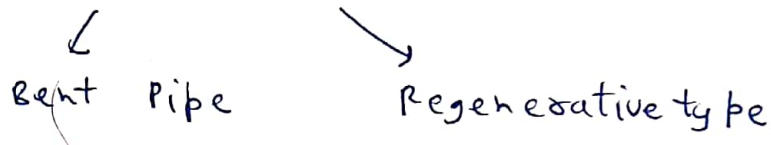
* Tracking determines the slant range for accurate determination of satellite orbit. (range, elevation, azimuth angle etc.) so that if there is any change in the orbital elements then correction can be made.

* Command means, if there is a requirement to convey certain commands and there is a requirement to convey

certain information according to which some action needs to be taken out, then the particular system works. (4)

Communication Subsystems

- * one of the major component of the satellite.
- * Transmitters and receivers are used to amplify & retransmit the incoming signals.
- * combination of transmitters and receivers is known as transponder.
- * In satellite comm., two types of transponders are used.



- * At uplink frequency, signal is being transferred towards the satellite while for downlink, signal is transmitted from the satellite to the earth station.
- * There are various satellite antennas which are commonly used, :- reflector antenna, horn antenna, wire antenna, cassegrain antenna.
- * Antenna is an integral part of satellite subsystem.

Altitude and Orbit Control System (AOCS)

- * Altitude and Orbit Control Subsystem (AOC) is capable of placing the satellite into the right orbit.
- * It is helpful to control the satellite orbit, maintaining stabilization etc.

This subsystem consists of four major components:

- Sensors
- Orbit Control System
- Propulsion system
- Altitude control system.

Sensors

(5)

For altitude control, two sensors are commonly used:-

* Earth sensor

* Sun sensor.

— Earth sensor is a passive infrared device which operates in 14-16 μm wavelength. It senses the infrared waves which are coming from around the horizon.

There is a sharp temperature difference between space and earth horizons because the space is cool and earth is warm.

So, the phase difference pulses are sent to the earth station and they need to be measured which is a term known as earth aspect angle.

— Sun sensor has a fan shaped field of view and it operates in the visible spectrum and it actually uses a photocell for detecting the solar radiations. So there are two sensors: one is parallel to the spin axis and the other is centered at 35° and the pulses ~~are~~ from the sun sensors which are sent to earth station are used to determine solar angle.

Orbit control System

— Sensors are used in the satellite to measure linear acceleration; changes in velocity sensed by the velocity sensors are transmitted to the earth's controlling station.

When the ground station receives the information and if there is any change that is to be analyzed and appropriate command signals are generated and that will be sent to the satellite for correction.

Propulsion System

Usually a Propulsion System consists of three units:

→ low thrust Actuators

→ high thrust motors

→ with space shuttle launch vehicles

- Propulsion system is a reaction control system carried by (6) satellite in geostationary orbit so as to generate forces when required.
- Low thrust Actuators are devoted for altitude and orbit ~~control~~ corrections.
- High thrust Motor provides the velocity increment required for the geostationary orbit injection at the transfer orbit apogee.
- Space shuttle launch vehicle provides the velocity increment required to inject the satellite into the transfer orbit.
- Low thrust actuators keep providing annual increment of 50 m/s. Low thrust actuators can be chemical one or mechanical one, depending upon requirement.

Altitude Control System

- It is required so that the antenna ~~which~~ is pointed correctly at the earth-gravitational forces may impact the orbit.

Two types of ACS

Active

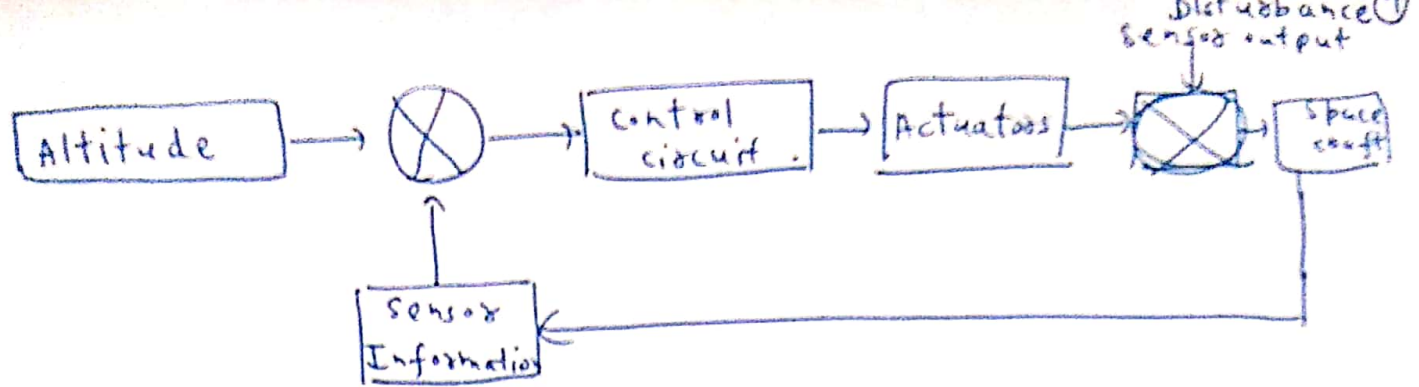
— it maintains altitude by the use of active devices in the control loop.

Passive

— maintains the attitude by orbiting equilibrium at the desired orientation and there is no use of the active altitude devices

For Active Attitude Control, Four operations are required:

- Detection of Satellite Attitude
- Comparison with the reference axis
- Determination of corrective torques
- Correction of Attitude by actuators mounted on the satellite.

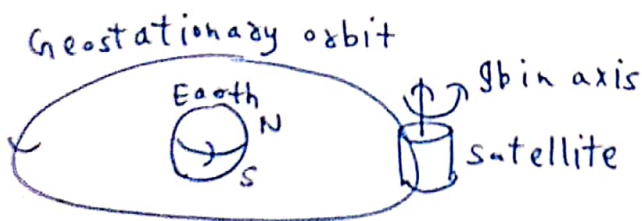


* Altitude Control Subsystem takes care of the orientation of satellite in its respective orbit and therefore the satellites has to be properly oriented using momentum wheels and thruster motors.

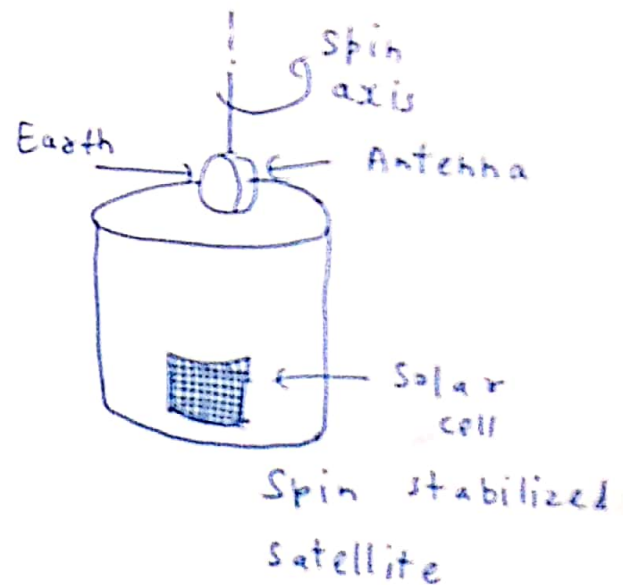
Two methods are:

- spin stabilization
- Three axis body stabilization.

Spin Stabilization



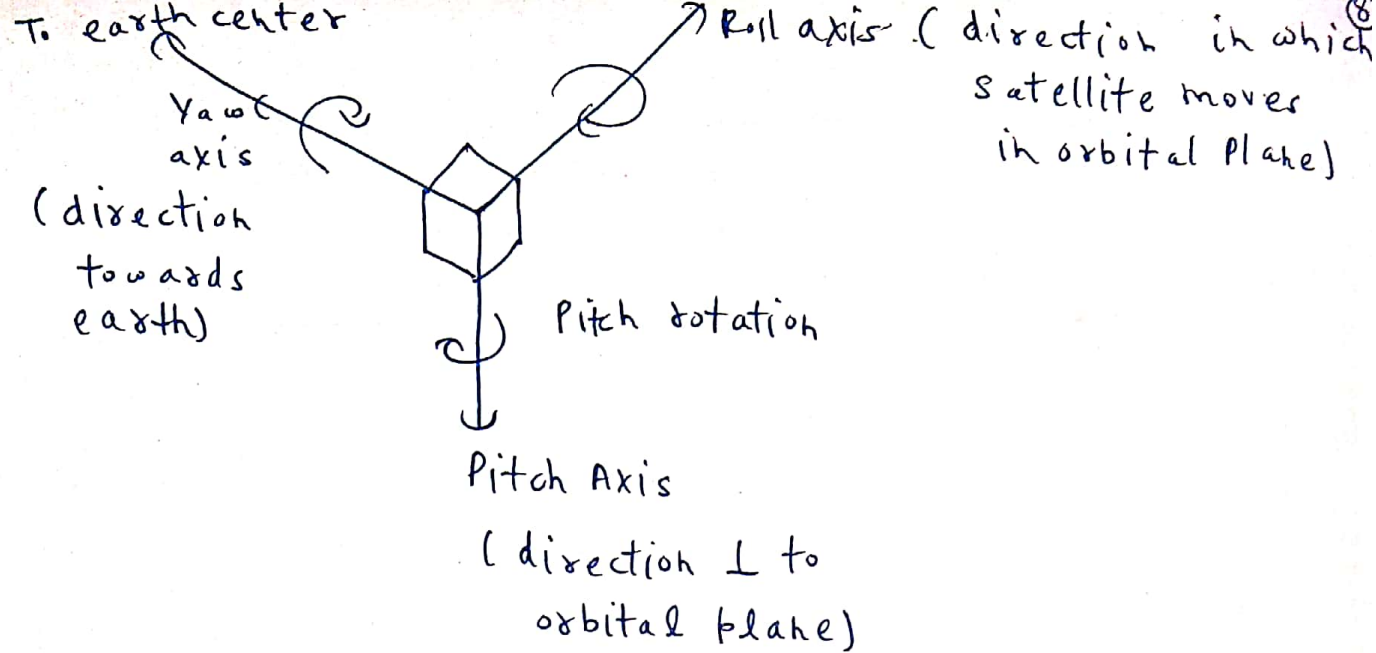
Spin stabilization in Geostationary orbit



— entire spacecraft is rotated at 3-100 rotations/min because of which gyroscopic action will be there which help to maintain the satellite direction

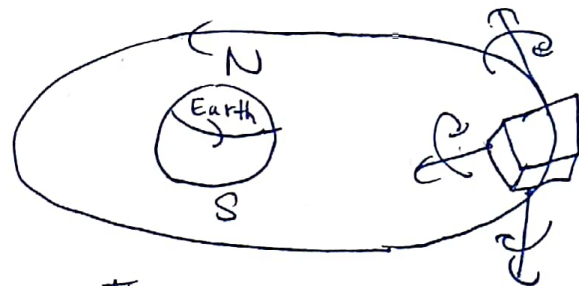
Three-axis Body Stabilization

— satellite is rotated among the three axis. called Roll, Yaw & Pitch Axis.

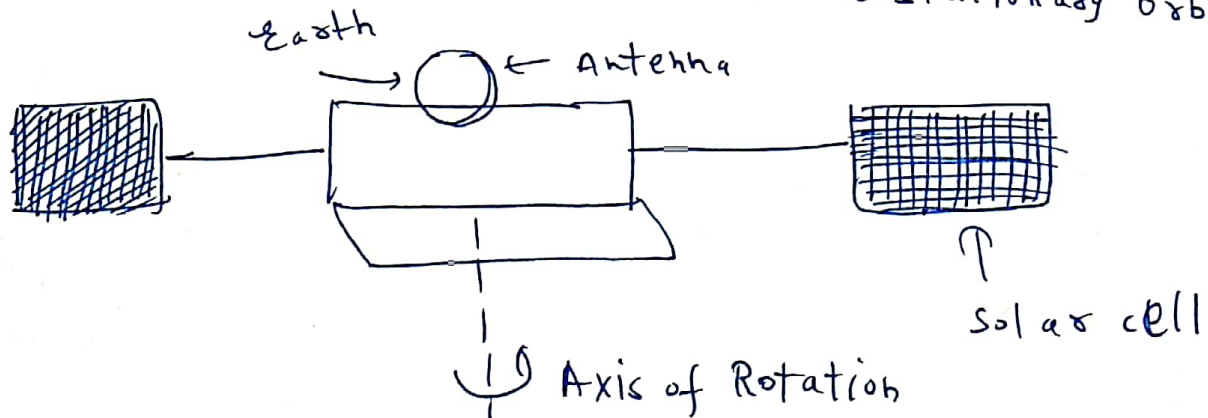


— When the satellite is stabilized about all the three axis, then it is known as three axis body stabilization.

Geostationary orbit



Three axis stabilization in geostationary orbit



Three axis stabilized satellite.

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* Telemetry, Tracking and Command (TT&C) Systems of a spacecraft provides the most dynamic telecommunication link between a satellite and a ground station.

* The link is provided using a ground station and onboard tele command and tracking data receiving systems, onboard ~~decoder~~ decoder and telemetry transmitter.

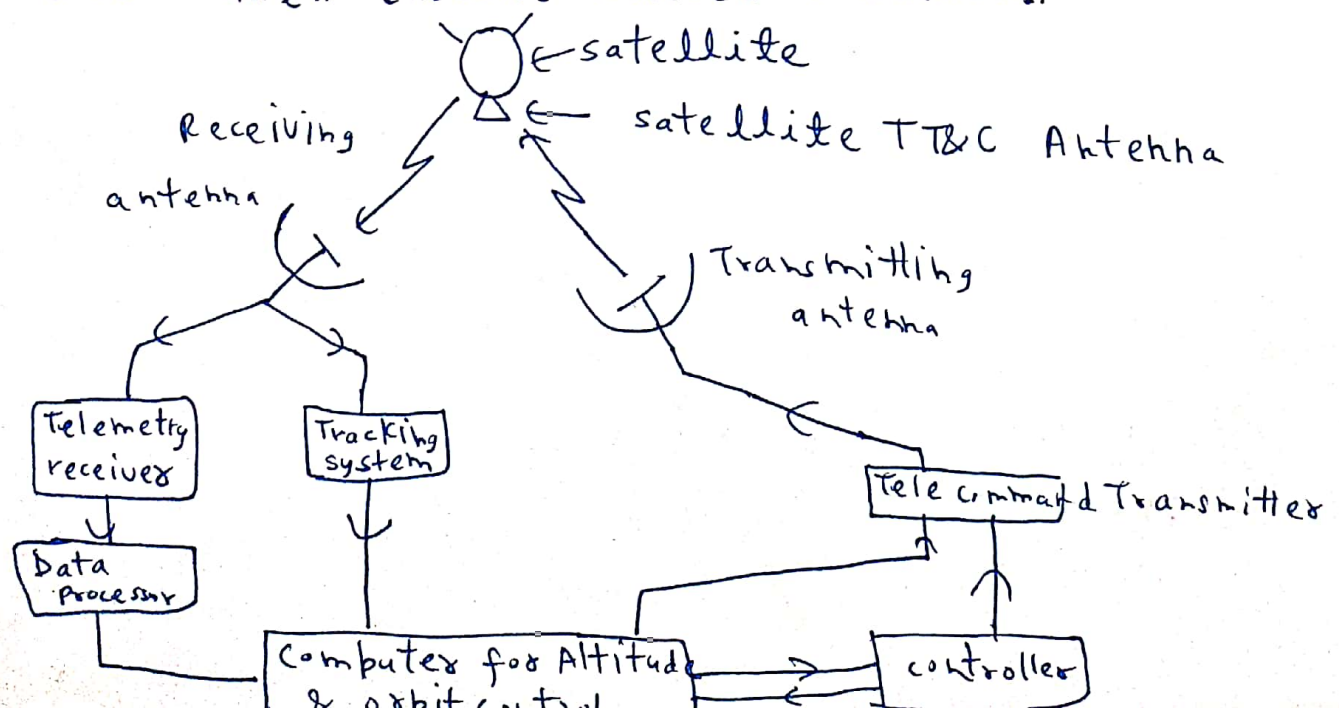
TT&C System has 3 units:

- Telemetry Subsystem
- Tracking Subsystem
- Command Subsystem

* The function of a telemetry subsystem is to monitor various satellite parameters and to transmit the measured values to the satellite control center.

* Function of tracking subsystem is to monitor the movement and correction signals are sent to the satellite.

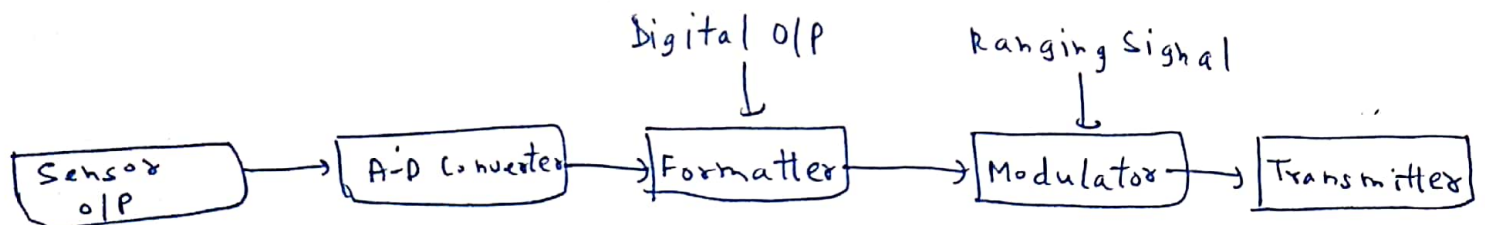
* The Command subsystem receives commands from the satellite control center, verifies this reception and then executes received commands.



The diagram on the previous page is titled:
"General Block Diagram of Telemetry, Tracking & Command system"

Telemetry System

- The telemetry data is analyzed at the control center & it is used for routine operation and failure diagnostic process.
- The most commonly monitored parameters by sensors are:
 - Voltage, current & temp. of all major systems
 - Switch status of communications transponders
 - Pressure of Propulsion tanks
 - Output from altitude sensors
 - Reaction wheel speed
 - Current draw
 - Environmental info like magnetic field & direction etc.



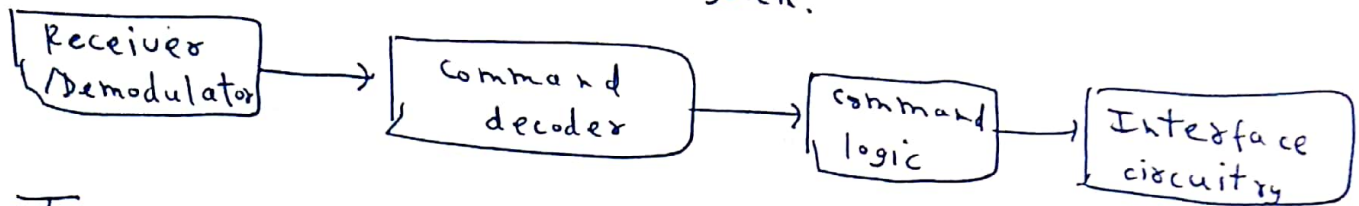
Tracking System

- located at earth station & it provides the info on elevation & azimuth angles of satellite
- important during the transfer and drift orbital phases of satellite launch
- The position of a geostationary satellite tends to be shifted because of the various disturbing forces.
∴ It is required to track the satellite's movement and send correction signals ^{as} and when required.

Command System

- receives command signals from earth station
- it is important to prevent unauthorized commands from being received & decoded ∴ command signals are often encrypted.

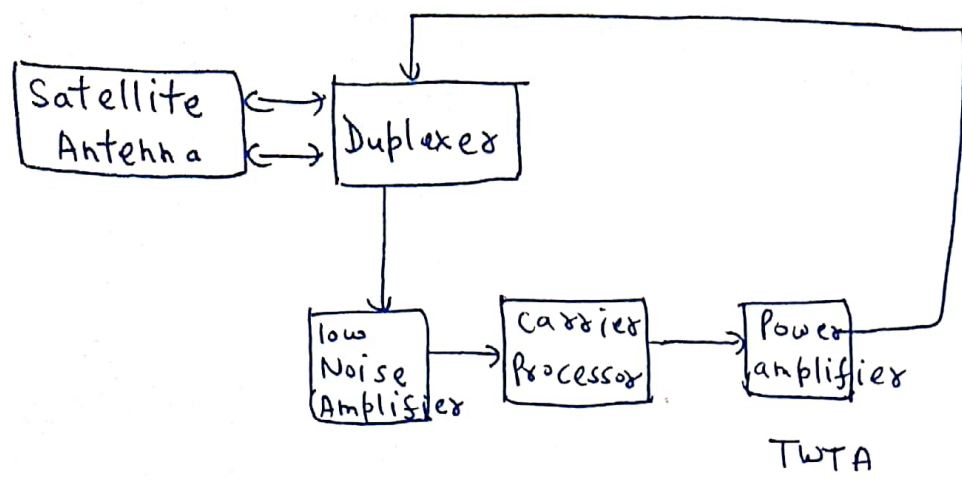
e.g Transponder switching, Antenna Pointing Protocol, Battery reconditioning, Beacon switching, Thrusters firing, switching heaters of various subsystems.



TRANSPONDERS

- Transponder is the component of the subsystem that receives the signal and shifts its frequency for transmission
- This subsystem provides the connecting link between transmitting and receiving antennas of a satellite.
- It is one of the most important subsystems of a space segment subsystems.
- Transponder performs the functions of both transmitter and receiver (responder) in a satellite.
- Transmitter (Trans) + Responder (ponder) = Transponder

Block Diagram of Transponder



Four kinds of frequency translation are

- * RF-RF translation
- * RF-IF "
- * IF Remodulation
- * demodulation - remodulation

Duplexer: It is a two way microwave gate which receives uplink signal from the satellite antenna and transmits downlink signal to the satellite antenna.

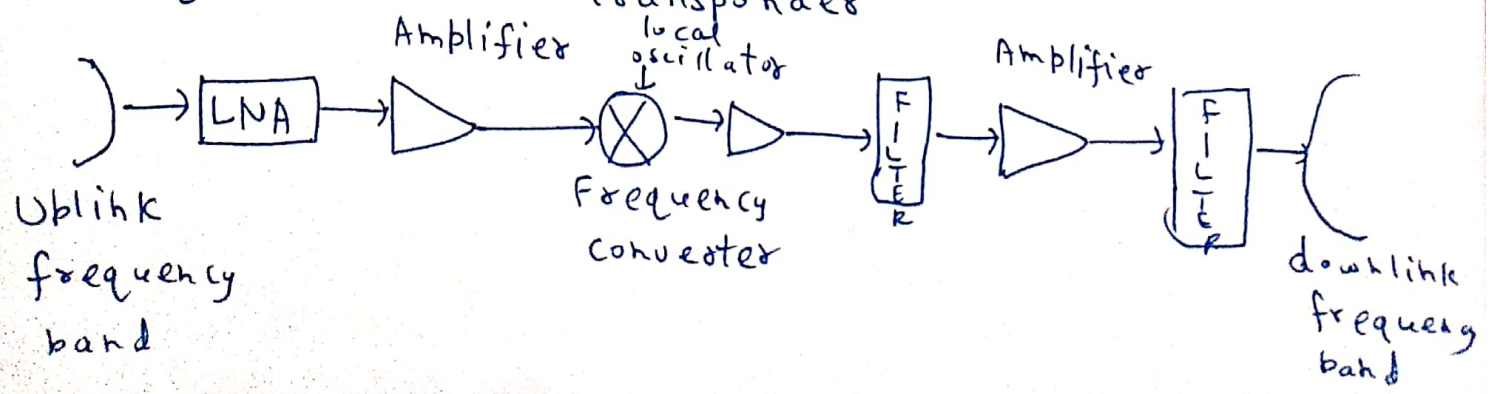
low noise amplifier (LNA): It amplifies weak received signal.

Carrier processor: It performs frequency down conversion of received signal. (uplink).

Power amplifier: It amplifies the power of frequency down converted signal (downlink) to the required level.

There are two types of Transponders:-

1) Single Conversion Transponder



→ used for 6/4 GHz band or C-band

→ local oscillator is at 2225-MHz.

→ Also known as Bent Pipe transponder, which receives microwave frequency signal.

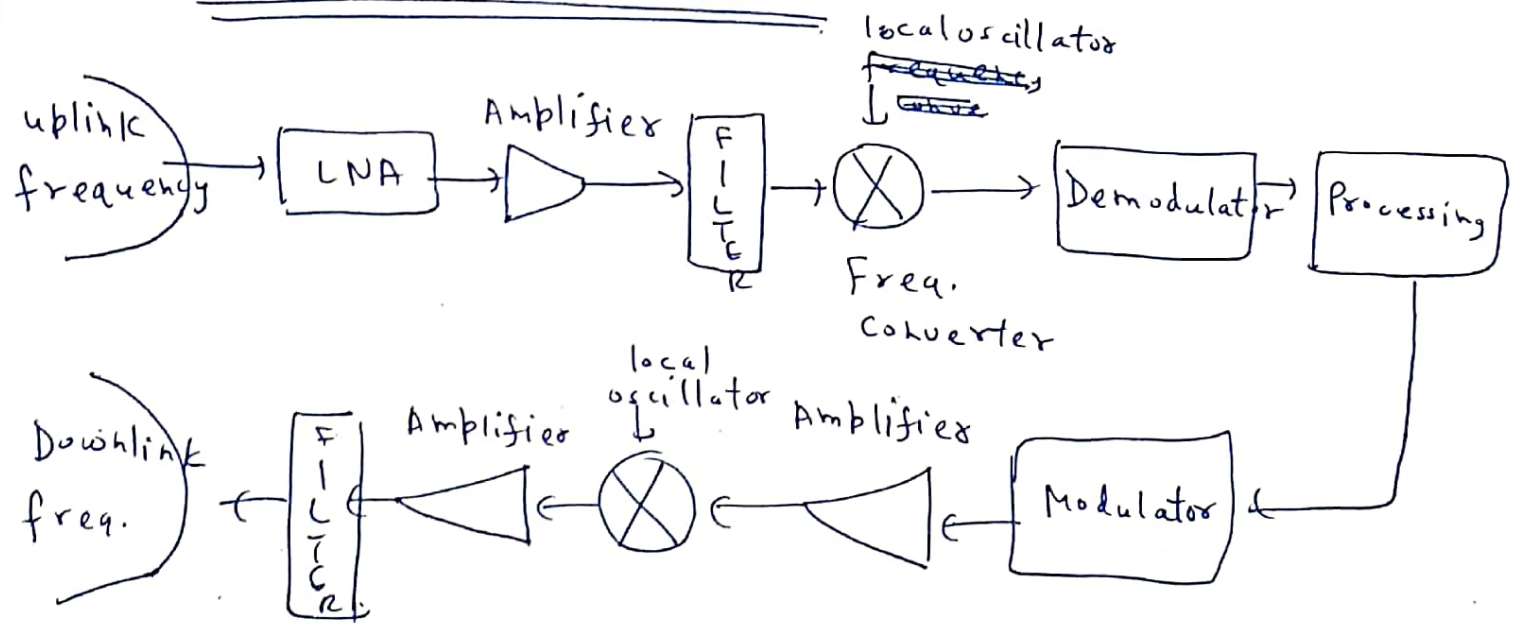
→ converts frequency of input signal to RF frequency and then amplifies it.

→ also known as repeater and conventional transponder

→ suitable for both analog & digital signals.

→ frequency conversion happens at a single place \therefore known as single conversion transponder.

Regenerative Transponder



→ performs the functions of Bent pipe transponder along with demodulation of RF carrier to baseband, regeneration of signals & modulation.

→ ~~is~~ also known as processing transponder

→ suitable only for digital signals.

Adv.

→ improvement in SNR.

→ flexible in implementation

Disadv.

→ suitable only for digital signals

→ more complex structure