Unit 3 Satellite Construction
(Space Segment)

Introduction :-

- A satellite communications system can be broadly divided into two segments - a ground segment & space segment. The space segment will obviously include the satellites, but it also includes the ground facilities needed to keep the satellites operational, these being referred to as the tracking, telemetry & command (TT & C) facilites.
- In many networks it is common practice to employ a ground station solely for the purpose of TT & C. The equipment carried aboard the satellite also can be classified according to the function. The payload refers to the equipment used to provide the service for which the satellite has been launched.
- The bus refers not only to the vehicle which carries the payload but also to the various sub-systems which provide the power, attitude control, orbital control, thermal control & command & the telemetry functions required to service the payload.
- In a communication satellite, the equipment which provides the connecting link betn the satellites transmit & receive antenna is referred to as the "transponder". The transponder forms one of main section of the payload.

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Q. Explain attitude and orbit control system.

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Attitude and orbit control system :-

Orbit control system :-

- The attitude and orbit of a satellite must be controlled so that the satellites antenna point toward the earth and so that the user knows where in the sky to look for the satellite.
- This is particularly important for GEO satellites since the earth station antennas that are used with GEO satellites are normally fixed & movement of the satellite away from its pointed position in the sky will cause a loss of signal.
- There are several forces acting on an orbiting satellite that tend to change its attitude & orbit.
- The most important are the gravitational field of the sun and moon irregularities in the earth's gravitational field, solar pressure from the sun & variations in earth's magnetic field.

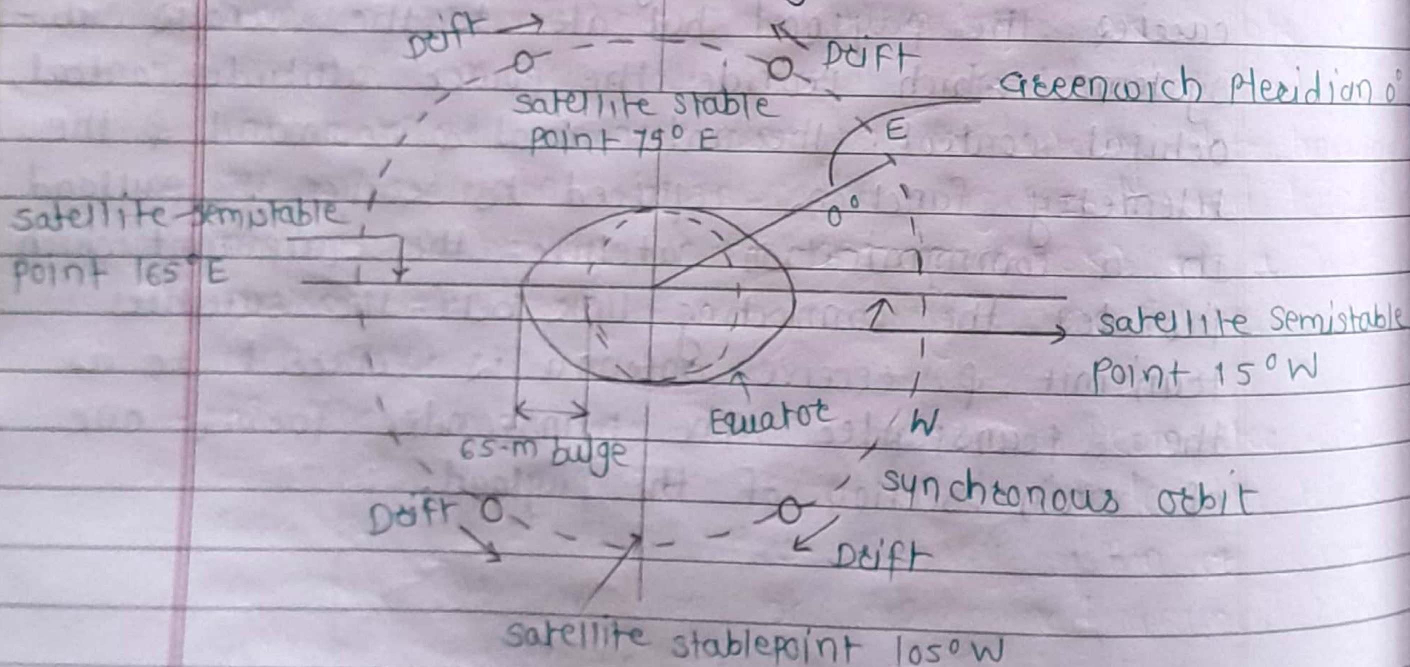

fig :- Forces on a synchronous satellite.

- Solar pressure acting on a satellites solar sails & antennas, & the earth magnetic field generating eddy currents in the satellite magnetic field tend to cause rotation of satellite body.
- careful design of the structure can minimize these effects but the orbital period of the satellite makes many of the effects cyclic, which can cause nutation of the satellite.
- The attitude control system must dampout nutation & counter any rotational torque or movement.

Attitude Control System :-

- There are two ways to make a satellite stable in orbit when it is weightless. The body of the satellite can be rotated typically at a rate betn 30 & 100 rpm, to create a gyroscopic force that Provides stability of the spin axis & keep it Pointing in the same direction, such satellites are known as spinner design. Alternatively the satellite can be stabilized by one or more momentum wheels. This is called as three axis stabilize by one or more momentum wheels.
- The momentum wheel is usually a solid metal disk driven by an electric motor. Either there must be one momentum wheel for each of the three axes of the satellite or a single momentum wheel can be mounted on gimbals & rotated to provide a rotatational force about any three axes.
- Increasing the speed of the momentum wheel ~~axes~~ causes the satellite to process in the opposite direction.

- **Attitude & orbit control system :-**
- It is cabable of placing the satellite into the right orbit.
- It is helpful to control the satellite orbit, maintaining stabilization.
- This subsystem consists of four major components
- sensor :
- orbit control system :
- propulsion system :
- Attitude control system :

- **Sensors :-**
- For attitude control, two sensor are commonly use
  1. Earth sensor :- passive Infrared device :- 14-16 wavel
  2. sun sensor :- It has fan shape field of view. It accept to photo cell for detecting the solar rad?

- **Orbit control system :-**
- sensors are used in satellite to measure linear acceleration; changes in velocity, sensed by the velocity sensors are transmitted to the earth's controlling stations.

- **Propulsion system :-**
- Propulsion system is a reaction control system
- usually a propulsion system consists of three units.
- Low thrust actuators.
- High thrust motors
- with space shuttle launch vehicles :-

Attitude and orbit control system :-

Attitude :- Attitude means position or location of the satellite. Rocket motors, move's the satellite in correct orbit.
- Orientation of satellite in space.

Purpose of Attitude control :-
- To keep the directional antennas pointed at the correct earth location.
- To keep the solar array pointed towards the sun.

factor affecting the attitute :-
- Disturbance torques are the forces which can alter the attitude.

External forces :-
1. Gravitational forces of Earth as the sun.
2. Solar radiation.
3. Meteorite impact.

Internal forces :-
- Motor bearing friction.

- There are two way make a satellite to stable in orbit.
1. Spinner satellite
2. Three axis stabilised satellite

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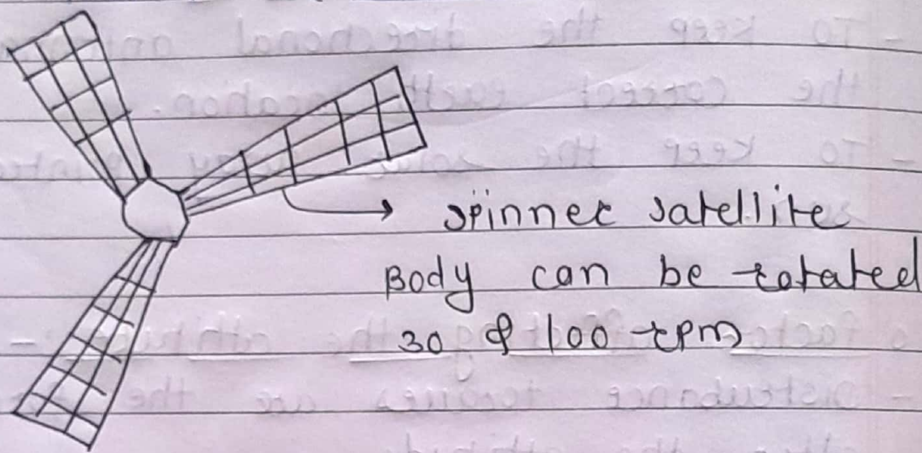
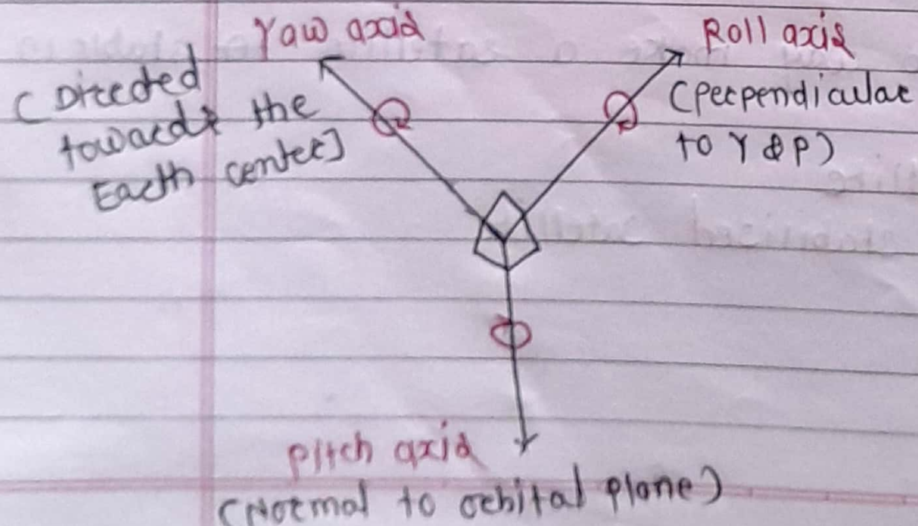
① spinner satellite :-

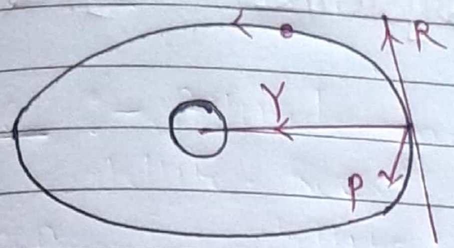
- The body of the satellite can be rotated at rate betn 30 to 100 rpm that provides stability of the spin axis and keeps it pointing in the same direction such as satellites known as "spinners"



② Three axis stabilization :-
[RPY axes - Roll, pitch & Yaw)

- satellite attitude is defined by three axes RPY.
- These 3 axes pass through the center of gravity of the satellite.





- RPY axis for the geostationary orbit.
- Roll axis is tangential to the orbit & lies along the satellite velocity.

- for an equatorial orbit :-
- Movement about roll axes moves the antenna footprint north & south.
- Movement about the pitch axis moves the foot-print East & West.
- Movement about the yaw axis rotates the antenna.

Attitude control methods :-

- How are we going to control the orientation in satellite.
- There are two types :-

① Passive Attitude control	Active Attitude control
- It uses the attitude stabilization mechanisms without using power supply.	- corrective forces are applied in response to the disturbing torques. - No overall stabilizing torque.
Ex:- spin stabilization, Gravity gradient stabiⁿ	Ex:- Movement wheel mtd, EM coil method, Mass expulsion devices.

Q. Explain typical tracking, telemetry, command and monitoring system.

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○ Telemetry Tracking and Command :-

The TTC & M system is essential to the successful operation of a communication satellite. It is a part of the satellite management task which also involves an earth stations, usually dedicated to that task & a group of personnel.

The main functions of satellite management are to control the orbit and attitude of the satellite, monitor the status of all sensors & subsystem on the satellite & switch on or off section of the communication system.

○ Telemetry :-

- The sensor the status of each subsystem, and the positions of switches in the communication system are reporte back to the earth by telemetry system.
- The sighting devices used to maintain attitude are also monitored via the telemetry link : this is essential in the case of one should fail and caus the satellite to the point in the wrong direction.
- Telemetry data are usually digitized and trans-mitted as phase shift keying (PSK) of a low-power telemetry carrier using time division techniques.
- At the controlling earth station a computer can be used to monitor, store and decode the telemetry data so that the status of any system or sensor on the satellite can be determined immediately by the controller on the earth.

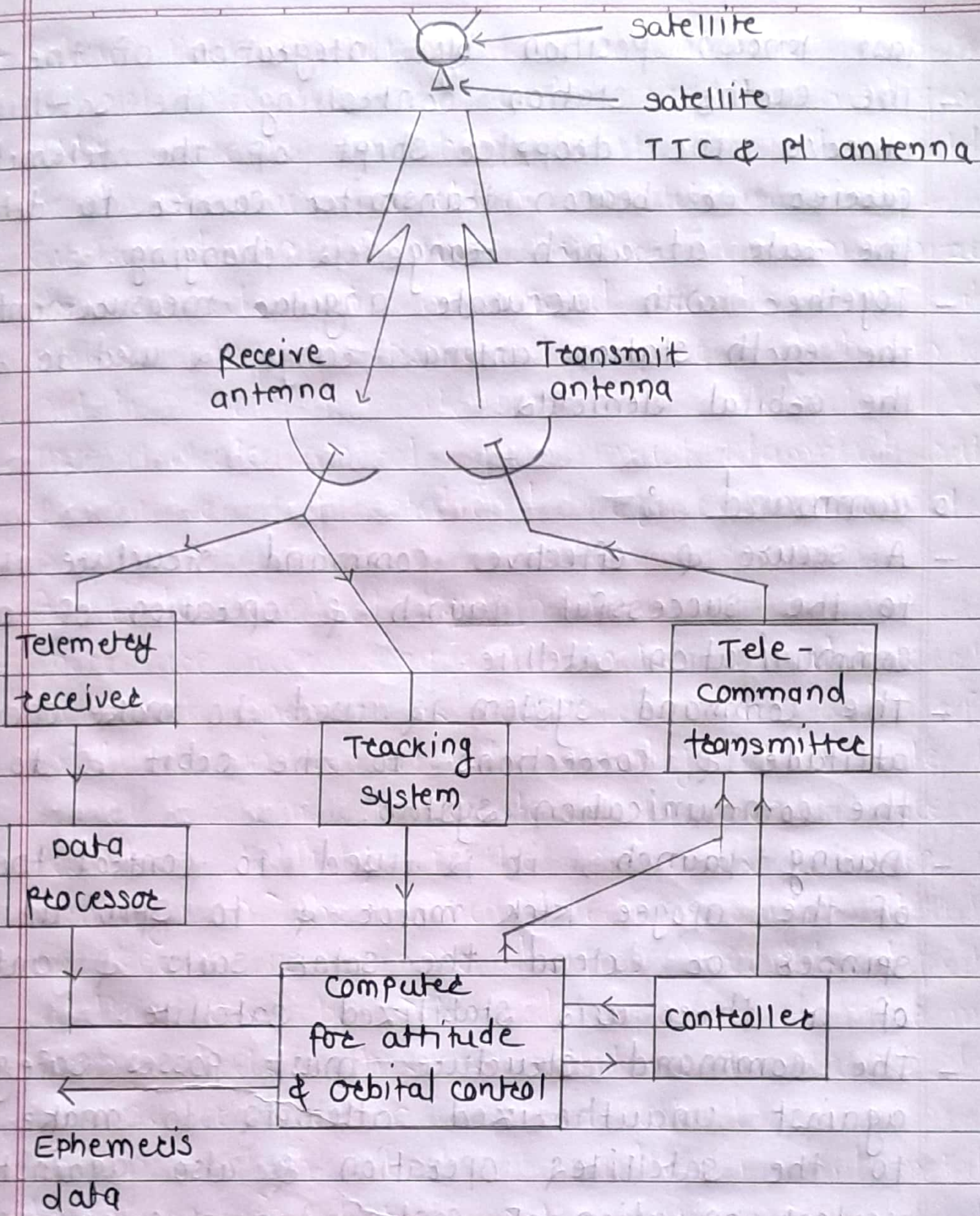

fig :- Typical tracking, telemetry, command & monitoring :-

o Tracking :-

- A number of techniques can be used to determine the current orbit of a satellite. Velocity & acceleration sensors on the satellite can be used to establish the change in the orbit from the

last known position by integration of the data.
- The earth's station controlling the satellite can observe the doppler shift of the telemetry carrier or beacon transmitter carrier to determine the rate at which range is changing.
- Together with accurate angular measurements from the earth station antena, range is used to determine the orbital elements.

○ Command :-
- A secure & effective command structure is vital to the successful launch & operation of any communication satellite.
- The command system is used to make changes in attitude & corrections to the orbit & to control the communication system.
- During launch, it is used to control the firing of the apogee kick motor & to spin up a spinner or extend the solar sails & antenna of a three axis stabilized satellite.
- The command structure must posses safeguard against unauthorized attempts to make changes to the satellites operation & also against inadvertent operation of control due to error received in command.

○ Monitoring :-
- The monitoring systems collects data from many sensors within the satellite & sends these data to the controlling earth station.

Q. Write short note on power subsystem.

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- There may be several hundred sensors located on the satellite to monitor pressure in the fuel tank, voltage & current in the power conditioning unit, current drain by each subsystem & critical voltage & current in communication electronics.

Power systems :-

- All communications satellites obtain their electrical power from solar cells, which convert incident sunlight into electrical energy.
- Sun is powerful source of energy. In the total vaccum of outer space at attitude, the radiation falling on satellite has an intensity of 1.39 kW/m^2
- Solar cells do not convert all this incident energy into electrical power, their efficiency is typically 20 to 25% at beginning of life (BOL) but falls with time because of aging of the cells and etching of the surface by micrometer impacts.
- Since, sufficient power must be available at the end of the life (EOL) of the satellite to supply all the systems on board, about 15% extra area of solar cells.
- During eclipse the satellite can not in the sun energy for its operation so at that time it has its own batteries of overall operation of satellite. This batteries are the high depth of discharging.

Q. Write a short note on communication subsystem.

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Communication subsystems :-

The communication subsystem is the major component of communication satellite, and the remainder of the satellite is there solely to support it frequently the communication equipment is only a small part of the weight & volume of the whole satellite.

It is usually composed of one or more antennas which receive & transmit over wide BW at microwave frequency & a set of receivers & transmitters that amplify & retransmit the incoming signals.

The receiver transmitter units are known as transponders. There are two types of transponders in use on satellites. The linear or bent pipe transpondor that amplifies the received signal & retransmits it at a different usually lower frequency and the baseband processing transponder which is used only with digital signals, that converts the received signal to baseband process it & then retransmits a digital signal.

For the system to perform satisfactority the signal power must exceed the power of the noise generated in the receiver by betn 5 & 25 dB, depending on the BW of the transmitted signal & the modulation scheme used.

With low power transmitter, narrow receiver BW have to be used to maintain the required signal-to-noise ratios.

Q. Write a short note on antenna subsystem.

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Early communication satellite were fitted with transponders of 250 or 500 MHz BW but bad low gain antennas & transmitters of 1 or 2 W o/p power.

The earth station receiver could not achieve an adequate signal-to-noise ratio when the full BW was used with the result that the system was power limited.

Antenna Subsystem :-

- The antenna subsystem is one of the most critical components of the spacecraft design because of several well founded reasons.

1) The antenna or antennas on board the spacecraft cannot be prohibitively large as large antennas are difficult to mount.

2) Large antennas also cause structural problems as they need to be folded inside the launch vehicle during launch and orbital injection phase and are deployed only subsequent to satellite reaching the desired orbit.

3) The need for having a large antenna arises from the relationship betn antenna size & its gain.

4) All satellites need to have a variety of antennas. these include omnidirectional antenna, which is an isotropic radiator, a global or Earth coverage antenna, zone coverage antenna.

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- The omnidirectional antenna is used for TT&C operations during the phase when the satellite has been injected into its parking orbit until it reaches its final position.

- The global or Earth coverage antenna has a beam width of 17.34°, which is the angle subtended by the Earth at geostationary satellite.

- The zone antenna offers a coverage that is smaller than that of an Earth coverage antenna.

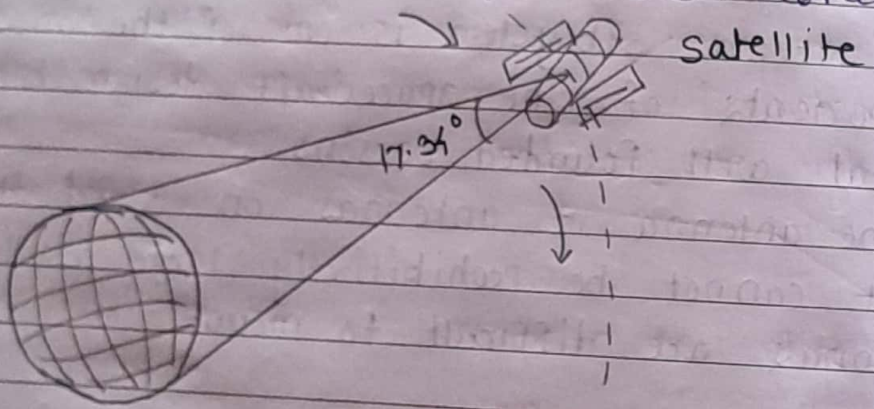

fig :- Beam width of a global antenna.

Antenna parameters :-

The under-mentioned performance parameters are :-

1. Gain
2. Effective isotropic radiated power (EIRP)
3. Beam width
4. Bandwidth
5. Polarization
6. Aperture

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1. Gain :- The gain of an antenna is nothing but its ability to concentrate the radiated energy in a given direction.

2. EIRP (Effective isotropic radiated power) :-
EIRP is of fundamental importance to the designers and operators of satellite communication systems as magnitude and distribution of satellites EIRP over its coverage area.

3. Beam width :- The beamwidth gives the angular characteristics of the radiation pattern of the antenna.

4. Bandwidth :- The antenna bandwidth in general is the operating frequency range over which the antenna gives a certain specified performance.

5. Polarization :- Polarization is the direction of the electric field vector with respect to ground in the radiated electromagnetic wave.

$$\text{Polarization loss} = 20 \log \left(\frac{1}{\cos \phi}\right)$$

$\because$ ϕ - angle betn pto poln.

6. Aperture :- The antena aperture is the physical area of the antenna projected on a plane perpendicular to the dirn of the main lobe.
For given antenna aperture A, the directive gain is

$$\text{Gain} = \frac{4\pi A_e}{\lambda^2}$$

where $A_e = \eta \times A$, A_e - Effective Aperture, η - Aperture efficiency.

Q. What are the different types of antennas? Explain

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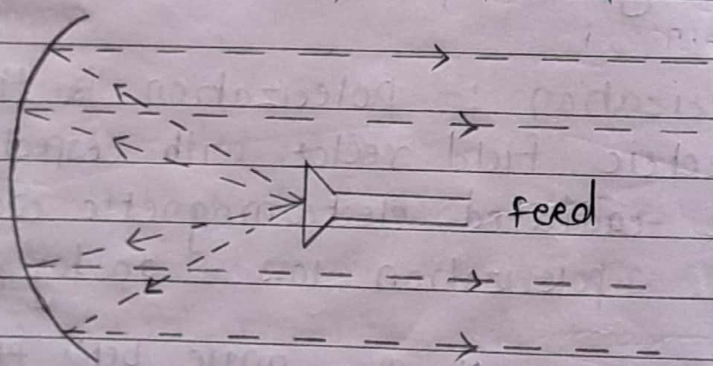
Types of Antennas :-

① Reflector Antennas
② Horn Antennas
③ Helical Antennas
④ Lens Antennas
⑤ Phased Array Antennas

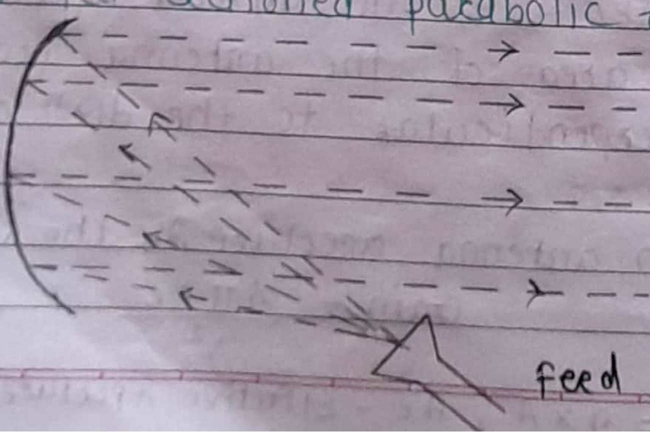
① Reflector Antennas :-

- A reflector antenna made in different types, shapes & configurations depending upon the shape of the reflector and type of feed mechanism - is by far the most commonly used antenna type in all those application that require high gain and directivity.

ⓐ focal point fed parabolic reflector :-



ⓑ offset fed sectioned parabolic reflector :-



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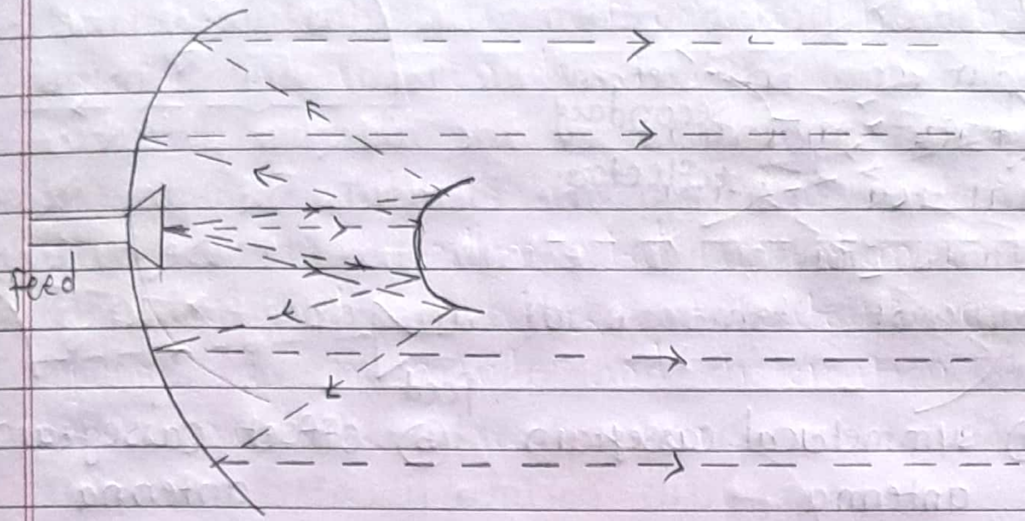
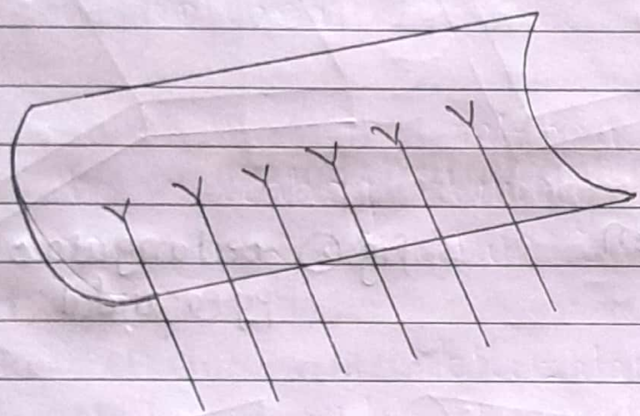
(c) Casegrain fed reflector :-



(d) Array fed cylindrical reflector :-



(2) Horn Antennas :-

- In the case of a transmission line with an open circuit load end, not all the electromagnetic energy is reflected and some of it does escape to surrounding atmosphere, the same is true for waveguides too. This radiation of electromagnetic energy is inefficient due to combination of factors, the most Prominent being the impedence mis-match betn the transmission line and the atmo-sphere.

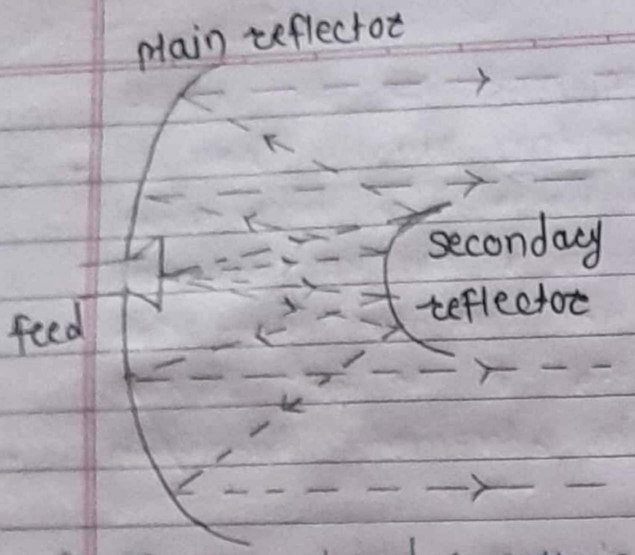
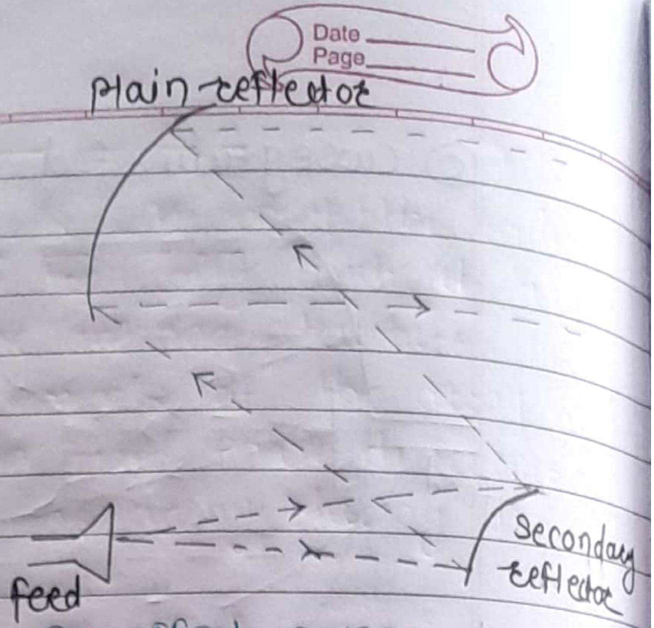


fig (a) symmetrical cassegrain antenna



(b) offset cassegrain antenna

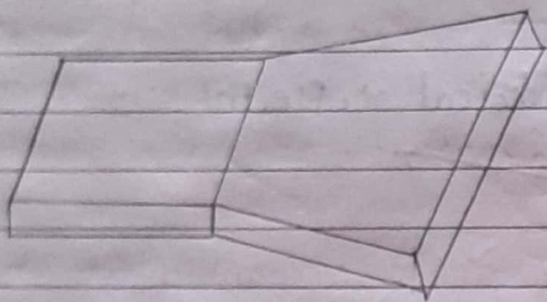


fig (1) sectoral horn antenna

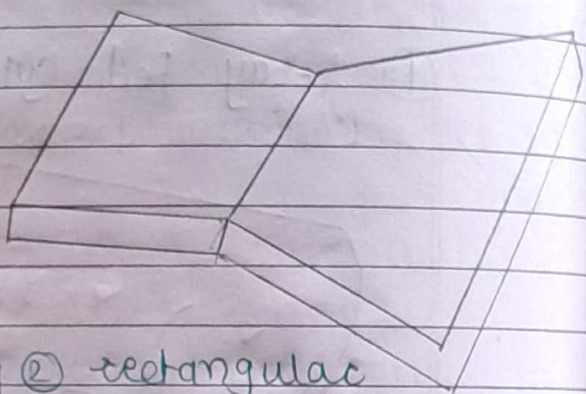


fig (2) rectangular pyramidal horn antenna.

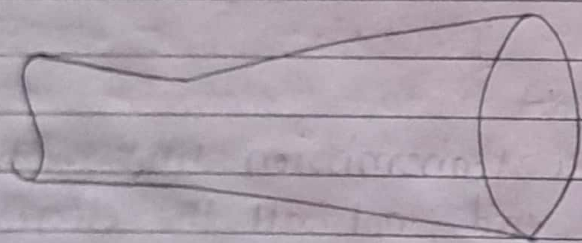


fig (3) Conical horn antenna

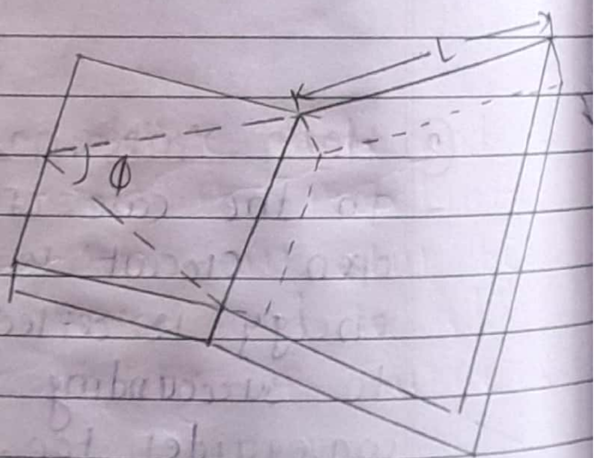


fig (4) important design parameters of a horn antenna

③ Helical Antennas :-

- Helical antenna is a broadband very high freqⁿ (VHF) and ultra high frequency (UHF) antenna. In addition to its broadband capability, it has found most of its characteristics applications due to the circularly polarized wave it produces.
- VHF and UHF propagation undergoes a random change in its polarization as it propagates through the atmosphere due to various factor's like Earth's magnetic field, ionization diff region.

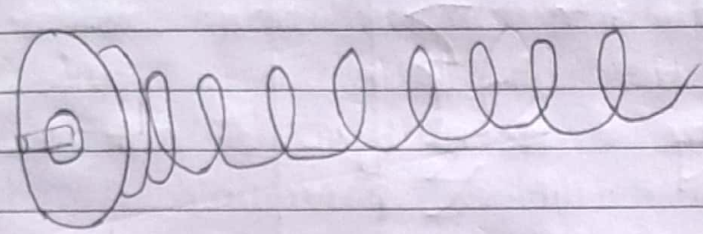


Fig :- Typical helical antenna.

④ Lens Antenna :-

- Like reflector antennas, lens antennas are another example of application of rules of optics to micro-wave antennas. While reflector antennas rely on the law of reflection, the lens antennas depend for their operation on the refraction phenomenon. Lens antennas are made of dielectric material.
- A point source of radiation is placed at the force of the lens. The ray arriving closer to the edges of lens encounter a larger curvature.

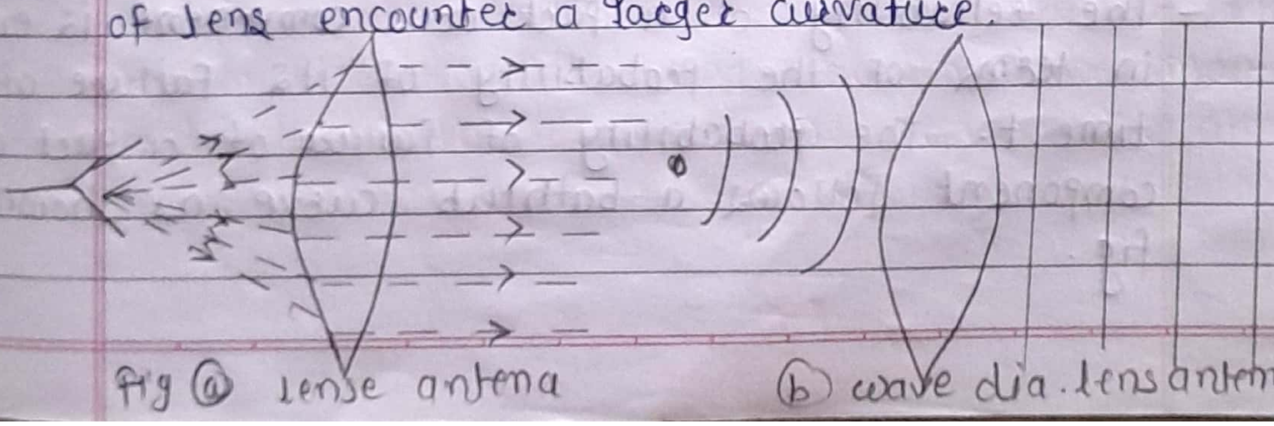


Fig ⓐ Lense antena ⓑ wave dia. lens antenna.

Q. Explain Equipment reli... ...cation

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⑤ Phased Array Antenna :-

- A phase array antenna is one where the radiated beam can be steered electronically without any physical movement of the antenna structure. This is done by feeding the elements of the array with signals having a certain fixed phase difference betn adjacent elements of the array during transn.

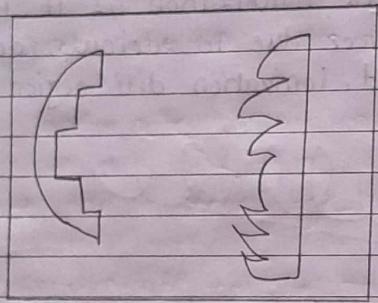

fig :- Zoned lenses.

o Equipment reliability and space qualification :-

Equipment reliability :-

- The reliability of difference satellite parts and subsystems is calculated to know the probability that the part or the subsystem will still be working after a given time period and to add redundancy where the probability of failure is large.
- The reliability of a part or a component is expressed in terms of the probability of its failure after time t. The probability of failure of a part or a component follows a bathtub curve as shown in fig

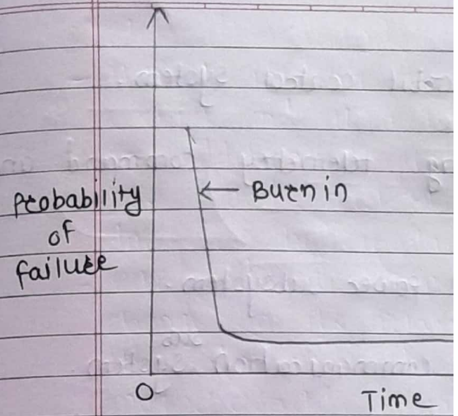

fig :- Probabilit

o Space qualificatior

- The geostationary
hostile environment
orbiting in low ear
operate in total va
falling on the surf
of 1.5 kW/m².
- The selection of com
satellite is a multi
is selection of and
components that are
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dualy or as a su
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tested as system. Th
control", or "Quality

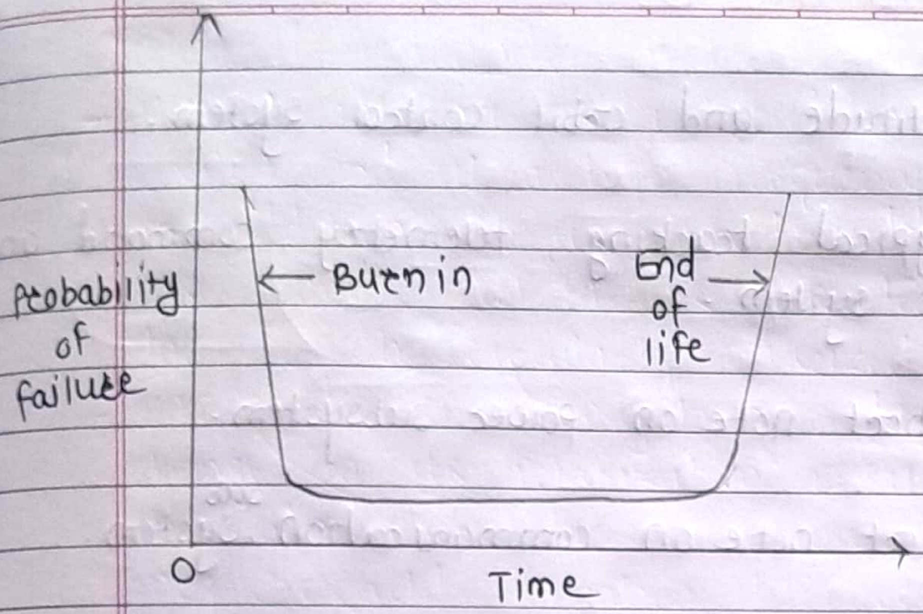

fig :- Probability of failure curve

- Space qualification :-

- The geostationary satellites are subjected to more hostile environment as compared to the satellites orbiting in low earths orbits. Geostationary satellite operate in total vaccum & the sun irradiance falling on the surface of the satellite is of order of $1.5\ kW/m^2$.
- The selection of components to be used on board a satellite is a multistage process. The first stage is selection of and screening of components. Components that are space worthy are selected. In the second stage, each component is tested individualy or as a subsystem to ensure its proper functioning. After each component and subsystem is tested individually, the complete satellite is tested as system. This process is referred as "Quality control", or "Quality Assurance".

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Assignment No. 3

Q.1 Explain attitude and orbit control system.

Q.2 Explain typical tracking, telemetry, command and monitoring system.

Q.3 Write a short note on power subsystem.

Q.4 Write a short note on communication sub system.

Q.5 Write a short note on antenna subsystem.

Q.6 What are the different types of antennas? Explain

Q.7 Explain Equipment reliability & space qualification.

Q.8 With neat diagram explain transponder & its type.