PIE Tech

POLLACHI INSTITUTE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE and Affiliated to Anna University) sky is the limit

Department of Electronics and Communication Engineering

Regulation 2021

III Year – V Semester

CEC352- SATELLITE COMMUNICATION

Padeepz App

CEC352 **SATELLITE COMMUNICATION** **L T P C**
3 0 0 3

COURSE OBJECTIVES:

The student should be made to:

- Understand the basics of satellite orbits
- Understand the satellite segment and earth segment
- understand Link Power budget calculation
- Understand the various satellite access and coding technology
- Understand the applications of satellite

UNIT I **SATELLITE ORBITS** **9**

Kepler's Laws, Newton's law, orbital parameters, orbital perturbations, station keeping, geo stationary and non Geo-stationary orbits – Look Angle Determination- Limits of visibility – eclipse-Sub satellite point –Sun transit outage-Launching Procedures - launch vehicles and propulsion.

UNIT II **SPACE SEGMENT** **9**

Spacecraft Technology- Structure, Primary power, Attitude and Orbit control, Thermal control and Propulsion, communication Payload and supporting subsystems, Telemetry, Tracking and command-Transponders Antenna Subsystem.

UNIT III **SATELLITE LINK DESIGN** **9**

Basic link analysis, Uplink and Downlink Design equation, Free space loss-Atmospheric effects, Ionospheric scintillation, Rain induced attenuation and interference, system noise temperature, Link Design with and without frequency reuse.

UNIT IV **SATELLITE ACCESS AND CODINGTechniques** **9**

Modulation and Multiplexing: Voice, Data, Video, Analog – digital transmission system, Digital video Broadcast, multiple access: FDMA, TDMA, CDMA, PAMA and DAMA Assignment Methods, compression – encryption, Coding Schemes.

UNIT V **SATELLITE APPLICATIONS** **9**

INTELSAT Series, INSAT, VSAT, Mobile satellite services: GSM, GPS, LEO, MEO, Satellite Navigational System. GPS-Position Location Principles, Differential GPS, Direct Broadcast satellites (DBS/DTH).

TOTAL:45 PERIODS

COURSE OUTCOMES:

At the end of the course, the student will be able to:

CO1:Identify the satellite orbits
CO2:Analyze the satellite subsystems
CO3:Evaluate the satellite link power budget
CO4:Identify access technology for satellite
CO5:Design various satellite applications

TEXT BOOKS:

1. Dennis Roddy, "Satellite Communication", 4th Edition, Mc Graw Hill International, 2017.
2. Timothy Pratt, Charles, W.Bostain,Jeremy E.Allnutt,"SatelliteCommunication",3rd Edition, Wiley Publications,2021.

REFERENCES:

1. Tri T. Ha, "Digital Satellite Communications", 2nd edition, Mc Graw Hill education, 2017.

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Satellite communication.

Unit I Satellite orbits.

Introduction :-

* satellite communication play main role in day to day of our life.

* Satellites are having unique features than other communication means, because they can cover the entire earth and able to link many users simultaneously.

* Satellites also provide communications to remote areas.

* Satellites are used for many other purposes apart from communications, they are meteorological remote sensing, military and domestic purposes.

* 3 different types of applications

(i) The largest international system established in 1984 (INTELSAT)

(ii) The domestic satellite system in within country used for home (Dom sat) in us voice data video entertainment also

(iii) U.S National oceangraphic and atmospheric administrations (NOAA).

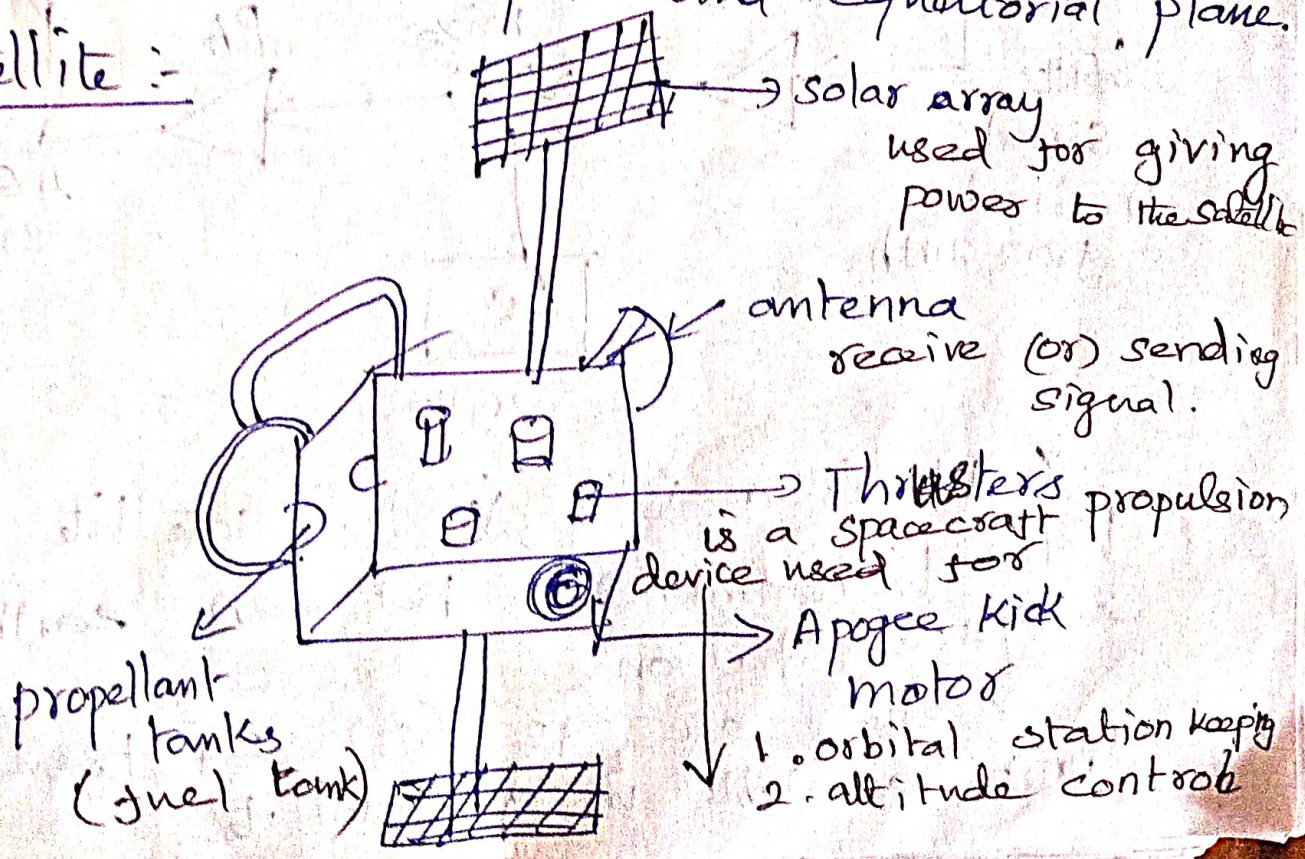
* To allocate the freq. the entire is divided into 3 regions ie done by International telecommunication union (ITU)

1. Region 1 :- It covers Europe, Africa and Mangolia
2. Region 2 :- It covers North and South America and Greenland.
3. Region 3 :- It covers Asia, Australia and South west pacific.

Unit 1 - Satellite orbits

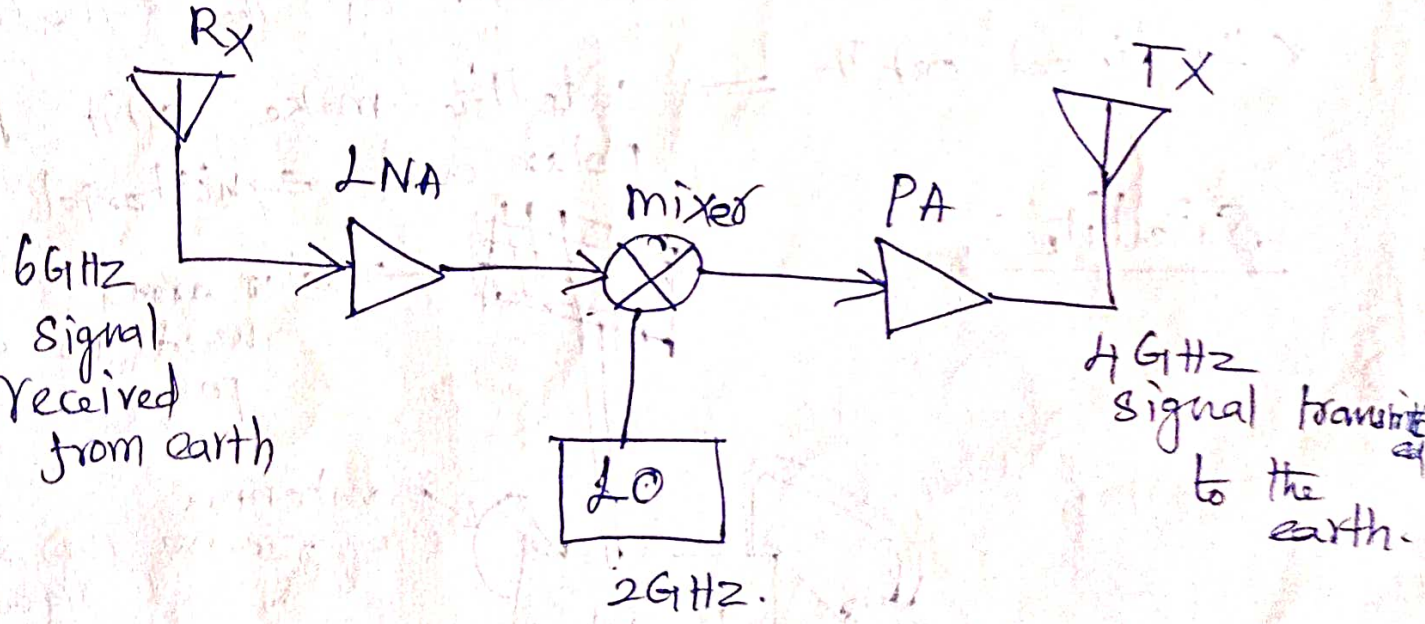
* Satellites revolve around the earth making a path called orbit.
* Orbit may be circular (or) elliptical
* They are classified as polar orbit equitorial orbit (or) inclined orbit.
* polar orbit ⟹ satellite make orbit around the polar hemispheres (north and southpole) of the earth.
* Equatorial orbit ⟹ satellite make orbit around the earth at the equator.
* Inclined orbit ⟹ satellite make orbit between polar and equitorial plane.

Satellite :-



* There are man-made satellites launched into the space for specific purposes.
* Can be take pictures / photos of the other planets and also earth.
* First artificial satellite was sputnik 1 launched by soviet union.
* The function of this satellite is receive signal from earth and transmit the same signal to broad areas of the earth.

Satellite Transponder :-



* It is a Unit in the satellite which helps to communicate between earth station & Space station.
* There are 12 (or) 24 transponders units available in a satellite.

Freq. allocations to satellite service is done by ITU (Internation Telecommn. union) is divided into 3 regions :-

Region 1 :- Europe, Africa, soviet union and Mongolia.

Region 2 :- North & South America and Greenland

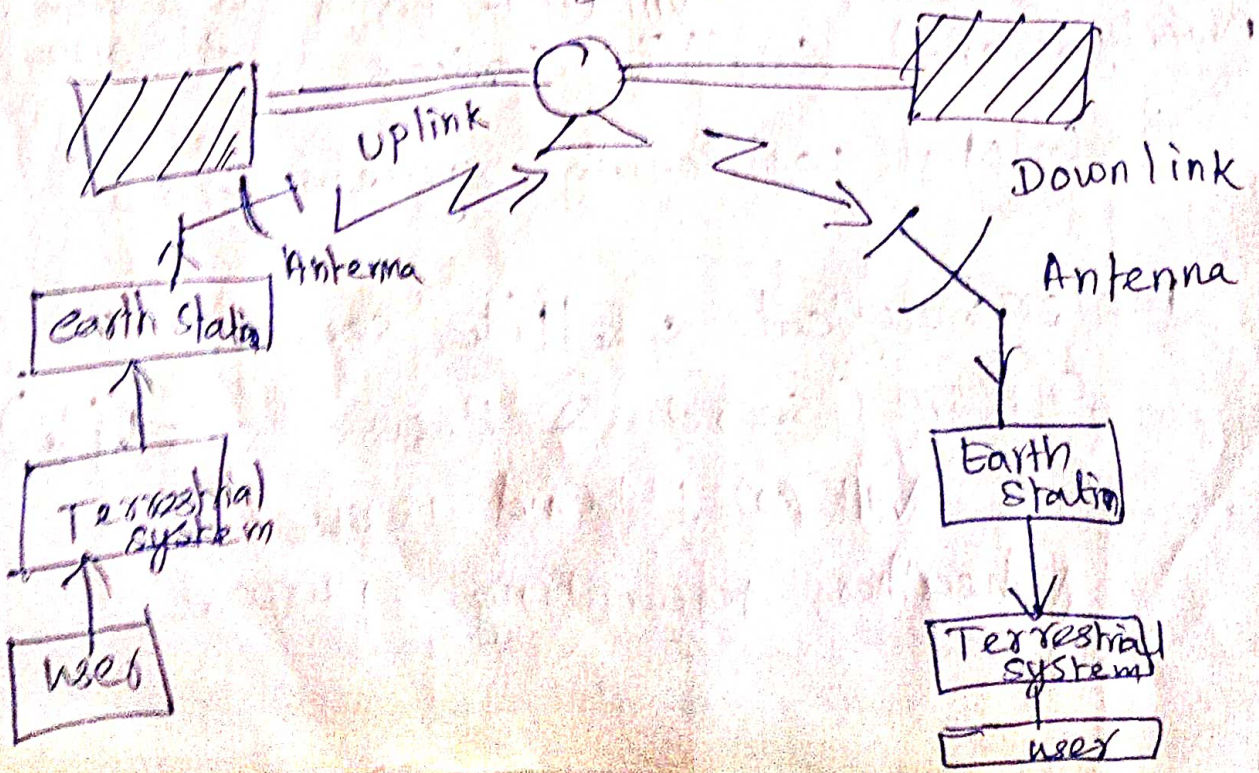
Region 3 :- Asia, Australia and south-west pacific

Types of satellite services :-

* Fixed satellite service (FSS)
  => Telephone N/ws, Transmission of TV signals.
  C band is used for FSS 6/4 GHz
* Broad casting satellite service (BSS)
  DBS (Direct broad cast satellite)
  => Ku band is used 14/12 GHz.
* mobile satellite services
  Land, maritime, Aeronautical mobile service
  VHF (or) L band is used for 2/1 GHz.
* Navigational satellite services
  * Global positioning system (GPS)
* Meteorological satellite services.
  SARSAT (Search & Rescue satellite)
  VHF (or) L band is used
  Wheather forcasting purpose.

GHz	
0.1 — 0.3	VHF
0.3 — 1.0	UHF
1.0 — 2.0	L
2.0 — 4.0	S
4.0 — 8.0	C
8.0 — 12.0	X
12.0 — 18.0	Ku
18.0 — 27.0	K
27.0 — 40.0	Ka
40.0 — 75	V
75-0 — 110	W
110 — 300	mm
300 — 3000	μm

Basic Block of satellite commn. system:



Kepler's Laws :-

Kepler's first law :-

* It states that path followed by a secondary (satellite) around the primary (earth) will be an ellipse.

* An ellipse has 2 focal points F_1 & F_2 The center of the mass of the two-body system is the barycenter is always one focal point.

* The center of the mass coincides with the center of the earth because the huge difference between the masses of earth & satellite

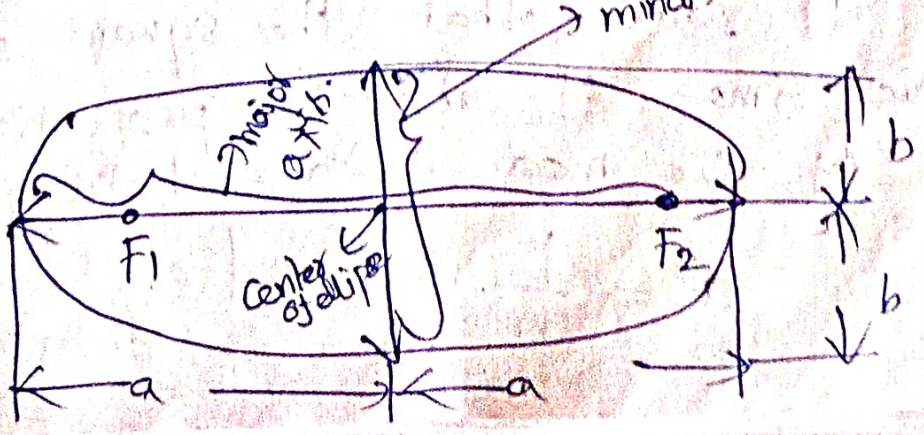
The eccentricity e of the elipise

$$e = \sqrt{a^2 - b^2}$$

a - Semi major axis

b - " minor "





The orbit is elliptical

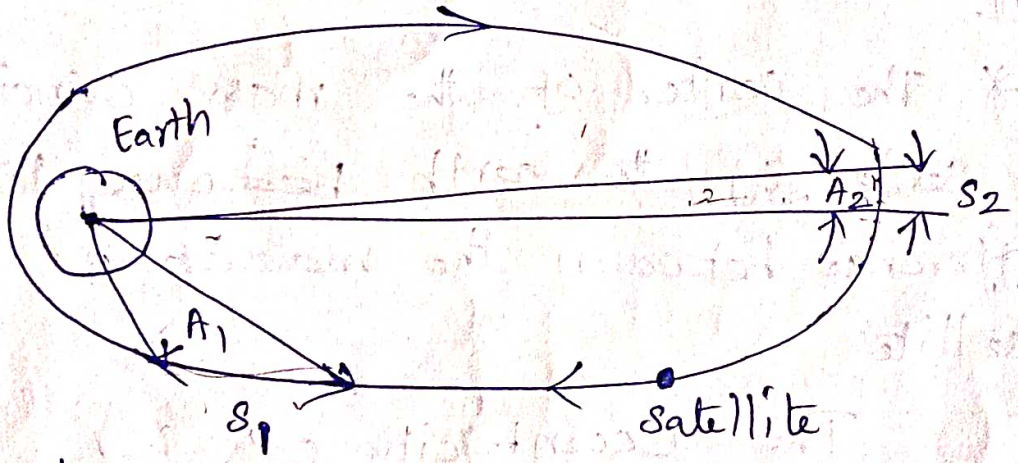
When $0 < e < 1$

The orbit is circular

$e = 0$

Kepler's second Law :-

* It states that, for equal time intervals, a satellite will sweep out equal areas in its oribital plane, focussed at the barycenter.



* when the satellite travels distance S_1 and S_2 meters in 1 Sec then areas covered A_1 & A_2 will be equal.

Kepler's Third Law :-

It states that the square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies

$$a^3 = \frac{\mu}{n^2}$$

$$P^2 \propto a^3$$

P - orbital period

n – ~~orbital period~~ meam motion of the Sallite in radians per sec

μ – Earth's geocentric gravitational Constant

$$\mu = 3.986005 \times 10^{14} \ m^3/s^2$$

orbital period of the earth is

$$P = \frac{2\pi}{n}$$

Newton's Law :-

Newton's First Law :-

Every object will remain at rest or in uniform motion in a stright line unless compelled to change its state by the action of external force

* An object at rest will remain at rest unless acted on by a unbalanced force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force. This law is often called the law of inertia.

Newton's 2nd Law :-

* Acceleration is produced when a force acts on a mass. The greater the mass, the greater the amount of force needed.

$$F = ma$$

m – Net force

a – Acceleration

Newton's Third Law :-

For every action there is an equal and opposite reaction.

Newton's Law of Gravitation :-

$$F = \frac{G m_1 m_2}{r^2}$$

G gravitational constant

The magnitude of the force is directly proportional to the product of the masses of the two particles and inversely proportional to the square of the distance between them.

Orbital parameters :-

1. Subsatellite path (ssp) ⟹ This is the path traced out on the earth's surface directly below the satellite.
2. Apogee (ha) → The farthest point of the satellite from earth
3. perigee (hp) → The shortest point of the satellite from earth
4. Line of apside → The line joining the perigee and apogee thro' the center of the earth.
5. Ascending node :- The point at which the orbit crosses the equatorial plane going from south to north.
6. Descending node :- The point at which the orbit crosses the equatorial plane going from north to south.

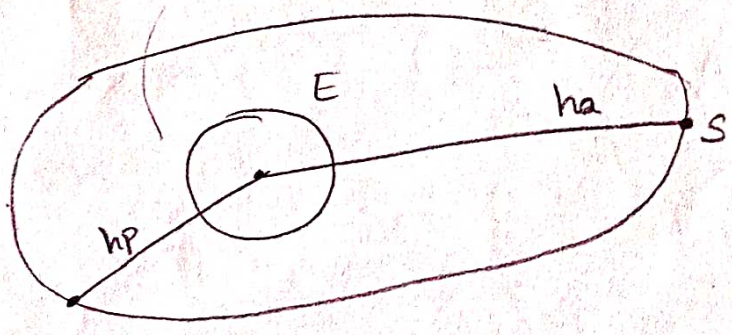
7. Line of nodes :- The line joining the ascending and descending nodes thro' the center of the earth.

8. Inclination :- (i) The angle between orbital plane and earth's equatorial.

9. Prograde :- An orbit in which the satellite moves in the same direction as the earth's rotation.

10. Retrograde :- An orbit in which the satellite moves in the opposite direction to the earth's rotation.

Orbital perturbations :-



Apogee and perigee heights :-

Apogee height $h_a = r_a - R$

perigee height $h_p = r_p - R$

r_a – length of radius vector at apogee

r_p – length " " " at perigee

$r_a = a(1+e)$

$r_p = a(1-e)$

a – semi major axis

e – eccentricity

R – Radius of the earth.

Orbital Perturbations :-

* Effect of sun and moon is more on geostationary earth satellites

* atmospheric drag effect is more on low earth orbit satellites.

Effects of non spherical earth :-

* For a spherical earth of uniform mass mean motion n_0 is

$$n_0 = \sqrt{\frac{\mu}{a^3}}$$

* But earth is not a perfect sphere, it is a oblate spheroid, i bulge at the the equator and flattening at the poles.

oblate spheroid mean motion is given by

$$n = n_0 \left[1 + \frac{K_1 (1 - 1.5 \sin^2 i)}{a^2 (1-e^2)^{1.5}} \right]$$

$K_1 = 66,063.1704 \ Km^2$

Anomalistic period is the orbital period of the earth

$$P_A = \frac{2\pi}{n}$$

n - mean motion.

* The oblateness of the earth produces two rotations orbital plane

* Regression of the nodes
* Rotation of the line of apsides in orbital plane.

Regression of the nodes:-

* The nodes slide along the equator, if it is prograde orbit, nodes slide westward direction, and if it is retrograded orbit, nodes slide eastward directions.

* The nodes move in opposite direction to satellite motion with prograde orbit moving eastward and retrograde orbit moving westward in direction. This is defined as the regression of nodes.

$$K = \frac{n k_1}{a^2 (1-e^2)^2}$$

The rate of change of Ω w.r.t time is given as

$$d\Omega/dt = -k \cos i$$

i - inclination.

(i) For polar orbit ($i = 90^\circ$), the regression is zero

$i < 90^\circ$ $d\Omega/dt$ is -ve, the regression is westward with prograde

$i > 90^\circ$ $d\Omega/dt$ is +ve, " is eastward with retrograde

Rotation of the line of apsides:

The rate of change is

$$\frac{d\omega}{dt} = k(2 - 2.5 \sin^2 i)$$

$i = 63.435^\circ$

$\frac{d\omega}{dt} = k(0) = 0$, $\Rightarrow$ no rotation takeplace.

$$\Omega = \Omega_0 + \frac{d\Omega}{dt}(t - t_0)$$

$$\omega = \omega_0 \frac{d\omega}{dt}(t - t_0)$$

t_0 - epoch time (reference time)

Ω_0 - right ascension of ascending node at epoch

ω_0 - argument of perigee at epoch.

$i = 90^\circ$

Regression of nodes $= 0$

Rate of rotation of the line of apsides $= -k/2$

After one rotation

perigee angle $= -k P_A/2$

Atmospheric drag :-

* This effect is only to the near earth satellites, below 1000 km. This drag reduces the velocity at the perigee, hence the satellite does not reach the same apogee.

$$a = a_0 \left[\frac{n_0}{n_0 + n_0'(t - t_0)} \right]^{2/3}$$

t_0 – epoch time

a_0 – semi major axis.

n_0 – mean motion.

n_0' – first derivative of mean motion.

Mean anamoly (δM) is

$$\delta M = \frac{n_0'}{2}(t - t_0)^2$$

Atmospheric drag changes will be only for long time intervals and it can be ignored for other cases.

Mean anamoly :-

Average value of the angular position of the satellite with reference to the perigee.

Station Keeping :-

* To keep the satellite in its orbit without drifting to the stable points, a station keeping maneuvers are implemented.

* Another method of maintaining in its orbit after being drifted is attitude control.

* For ellipiticity of earth, gravitational pull of satellite sun & moon cause the satellite to drift from its original path.

* Due to this satellites deviates to one of two stable points of 75° E and 105° W

* To nullify the drift, two types of station keeping maneuvers are in practice.

(i) East - west station keeping maneuvers

(ii) North - south " " "

East west station Keeping Maneuvers :-

* An oppositely directed velocity component is provided to the satellite by means of jets, which are pulsed once every 2 or 3 weeks. These are

called as east-west station keeping maneuvers.

* satellites in 6/4 GHz band must be kept within 0.1° of the longitude. and 14/12 GHz band within in 0.05

North south station keeping Maneuvers:

* The geo stationary satellite drift in the Latitude direction, and it is due to the gravitation pull from moon & satellites sun. So the inclination angle i will change at the rate of 0.85° per year.

* If it is left uncorrected the inclination angle leads to 0° to 14.67° in 26.6 years.

* To prevent this, additional jets may be used at the appropriate time.

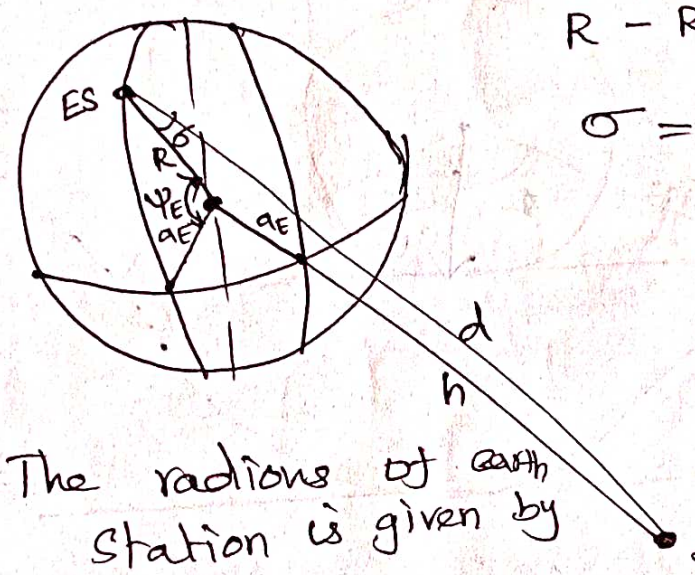
Antenna look angles :-

* The look angles for the ground station antenna are the azimuth and elevation angles.

* For geo stationary satellite, the look angles will be controlled by a computer. but for home systems they will made manually.

a_E – Earth equatorial radius
R – Radious at the earth station.

$\sigma = 90 + E_L$



* The radious of earth station is given by

$$l = \left(\frac{a_E}{\sqrt{1 - e_E^2 \sin^2 \lambda_E}} + H \right) \cos \lambda_E$$

λ_E – Geodetic latitude.

$$z = \left(\frac{a_E}{1 - e_E^2 \sin^2 \lambda_E} + H \right) \sin \lambda_E$$

$$R = \sqrt{l^2 + z^2}$$

Geocentric angle ψ_E is

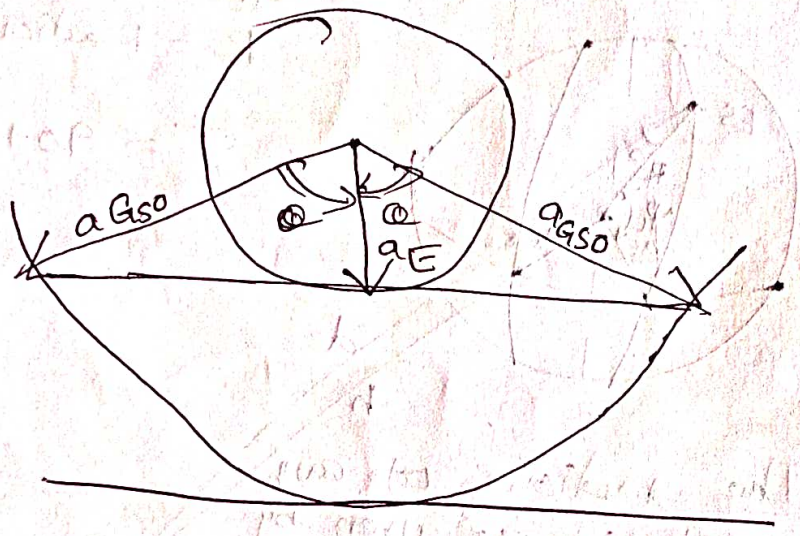
$$\psi_E = \text{arc tan } \frac{z}{l}$$

Limits of Visibility :-

* The east & west limits of geostationary are visible from any given earth station.

* These limits are set by the geographic coordinates of the earth station and antenna elevation.

*



$$\theta = \arccos \frac{a_E}{a_{GSO}}$$

arc cos means inverse cosine angle

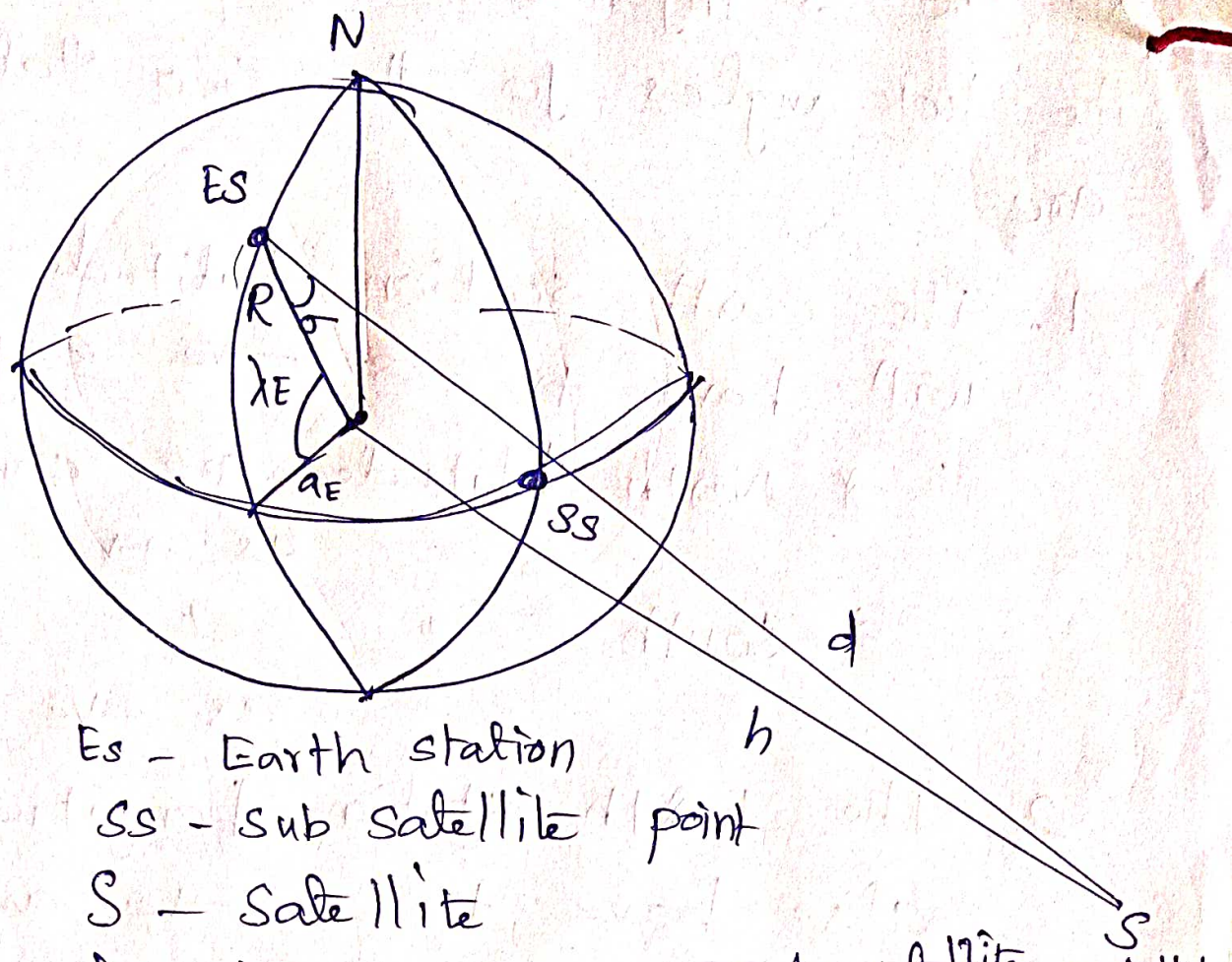
$$= \arccos \frac{6378}{42164}$$

$$= 81.3^\circ$$

The earth station can see a satellite over a geostationary arc bounded by $\pm 81.3^\circ$ about its earth's longitude.

* The 3 information require to determine the look angles for the Geo Stationary orbit are

1. The earth station latitude (λ_E) will have +ve & -ve angles
   * North latitudes are considered as +ve angles.
   * South " " " as -ve angles.
2. The Earth station Longitude (ϕ_E) also have +ve & -ve angles.
   * East Longitude of Greenwich meridian are considered as +ve angles.
   * west longitude of Greenwich meridian are considered as Negative angles.
3. The longitude of the subsatellite point ϕ_{ss}.



Let Es - Earth station
SS - sub satellite point
S - Satellite
d - distance from ES to satellite Satellite
R - Radions of Earth.

* The height of the satellite

$$h = Hss + hss$$

Hss — height of terrain from SS
hss — " " satellite from terrain.

* The radions of the earth

$$R = \sqrt{l^2 + z^2}$$

$$l = \left[\frac{q_E}{\sqrt{1 - e_E^2 \sin^2 \lambda_E}} + H \right] \cos \lambda_E$$

λ_E = Geodeclic latitude

H - Height up to terrain from SS

a_E - radious of Earth.

e_E - eccentricity of Earth.

$$Z = \left[\frac{a_E}{\sqrt{1 - e_E^2 \sin^2 \lambda_E}} + H \right] \sin \lambda_E$$

* Geo centric angle ψ_E is

$$\psi_E \rightarrow \text{arc tan } (Z/\ell)$$

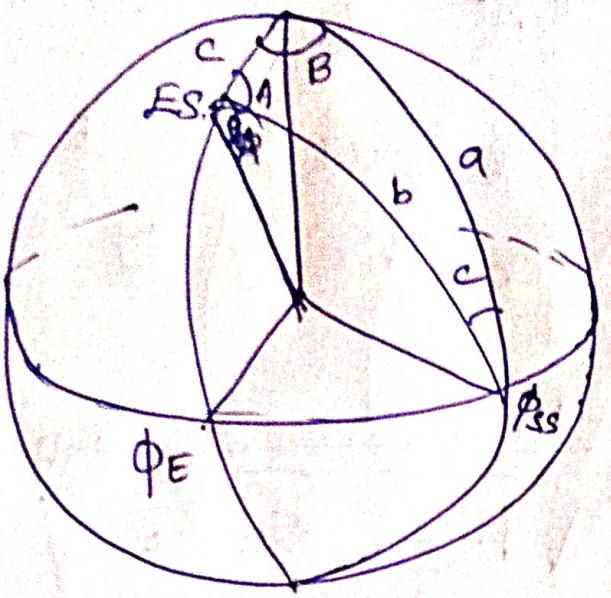
$$\psi_E = \tan^{-1} \left(\frac{Z}{\ell} \right)$$

* To find azimuth & elevation angle consider peject sphere.

⇒ Two types of triangles are involved

1. spherical triangle ⇒ determine azimuth angle
2. plane " ⇒ determine elevation angle

Azimuth angle from spherical triangle :-



a – angle b/w radians of the north pole and subsatellite point $a = 90^\circ$

b – angle b/w radians to Es & SS point.

C – " " Es and north pole
$C = 90^\circ - \lambda_E$

A – angle b/w meridian plane, c and great circle plane of Es

B – " " " " " SS

C – Angle b/w two great circles a and b.

$a = 90^\circ$

$C = 90^\circ - \lambda_E$

$B = \phi_E - \phi_{ss}$

When Es is west of ss point

$\Rightarrow$ B is negative

When Es is East of ss point

$\Rightarrow$ B is positive

When Es is at northern hemisphere

$C \leq 90$

When Es is at southern "

$C > 90^\circ$

* By applying Napiers rule, the sperical triangle can be solved

$$b = \arccos(\cos B \cos \lambda_E)$$

$$= \cos^{-1}(\cos B \cos \lambda_E)$$

$$A = \sin^{-1}\left(\frac{\sin|B|}{\sin b}\right)$$

a) $A < 90^\circ$, $\lambda_E < 0^\circ$ and angle $B < 0^\circ$

$$A_Z = A.$$

b) $A < 90^\circ$ $\lambda_E < 0^\circ$ and angle $B > 0^\circ$

$$A_Z = 360 - A.$$

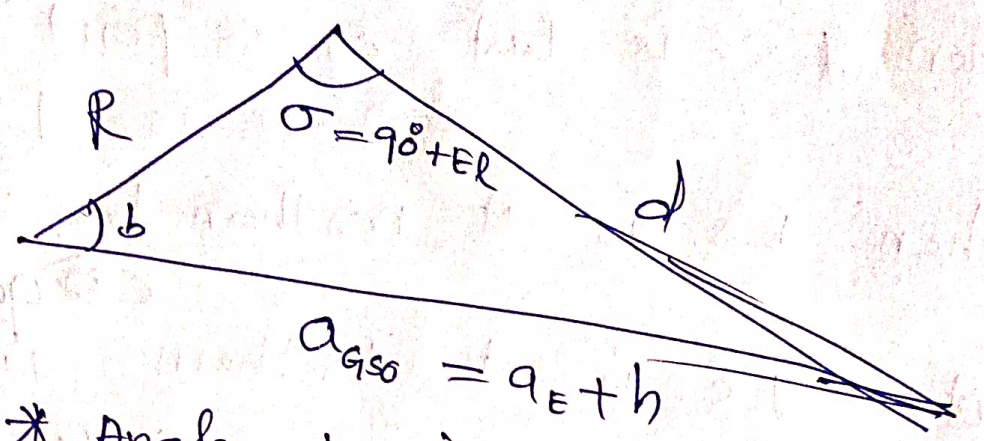
c) $A < 90^\circ$ $\lambda_E > 0^\circ$ $B < 0^\circ$

$$A_Z = 180^\circ - A$$

d) $A > 90^\circ$, $\lambda_E < 0^\circ$, $B > 0^\circ$

$$A_Z = 180^\circ + A$$

Elevation angle from plane triangle :-



* Angle b is obtained from Napiers rule

$$b = \cos^{-1}(\cos B \cos \lambda_E)$$

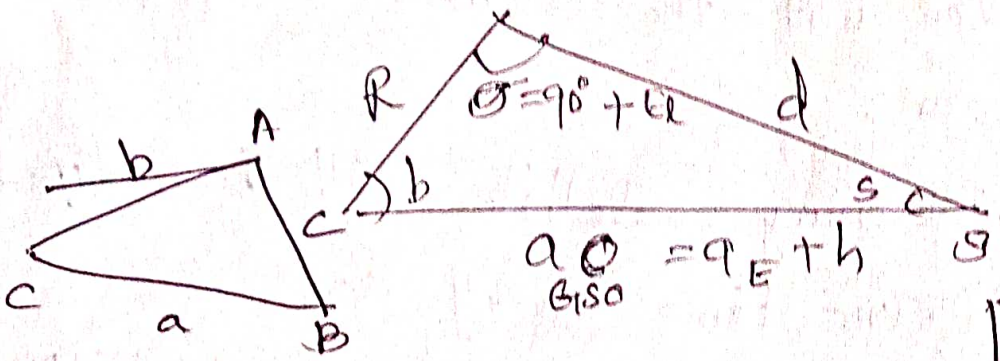
* Applying cosine rule

$$d = \sqrt{R^2 + a_{GSO}^2 - 2R\, a_{GSO} \cos b}$$

* Applying sine rule

$$El = \cos^{-1}\left(\frac{a_{GSO}}{d} \sin b\right)$$

* Latitude limits can be calculated using earth station latitude.



Sine rule

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$\frac{\sin S}{R} = \frac{\sin b}{d} = \frac{\sin \sigma}{a_{G,SO}}$$

$\sigma_{min} = 90° + EL_{min}$

EL_{min} — minimum elevation angle

lowest elevation is zero.

Applying sine rule

$$S = \arcsin\left(\frac{R}{a_{G,SO}} \sin \sigma_{min}\right)$$

$$b = 180° - \sigma_{min} - S$$

$$B = \arccos\left(\frac{\cos b}{\cos \lambda_E}\right)$$

$b = \arccos(\cos B \; \lambda_E)$

$\phi_{ss} = \phi \pm B$

Satellite limit East of ES

$\phi_{ss} = \phi_E + B$

Satellite limit west of ES

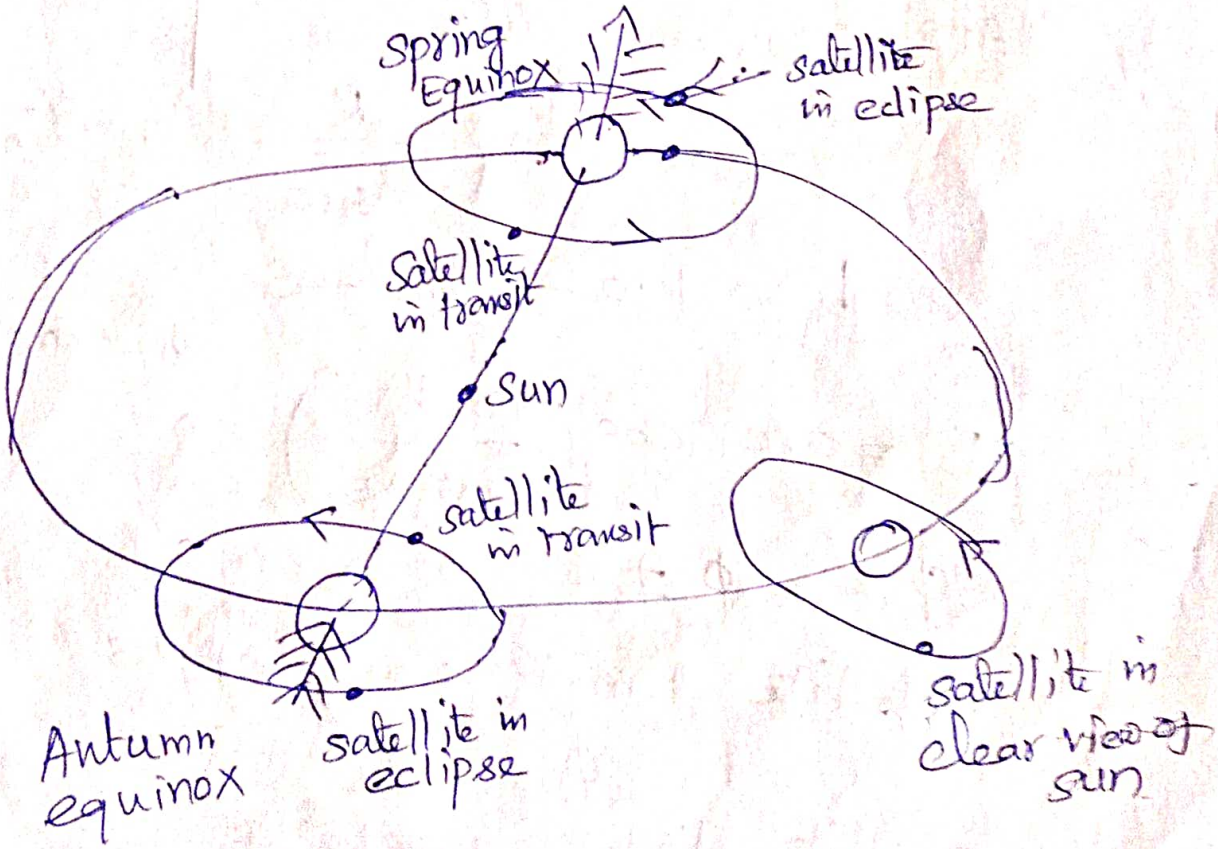
$\phi_{ss} = \phi_E - B$

Earth Eclipse of satellite

* It occurs when the earth's equatorial plane coincides with the earth's orbital plane around the sun.

* Geo stationary satellite will be eclipsed by the earth one time every day.

* Since the equatorial plane is tilted at an angle of 23.4° to the ecliptic plane, which keeps the satellite in full view of the sun for most days of the year.



* During the spring and autumnal equinox when Sun crosses the equator, the satellite will be under the shadow of earth for few time period, this time period is eclipse period.

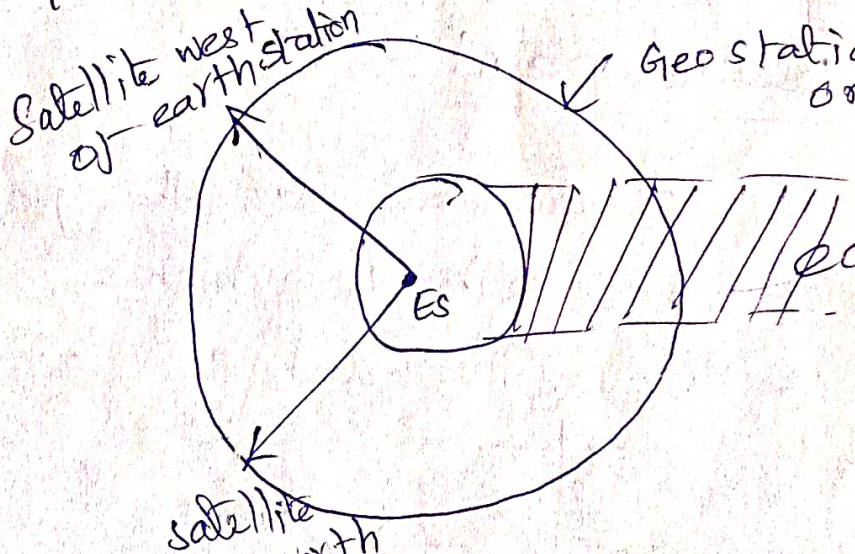
* Equinox – Equal times day and night.

Spring Equinox – First day of spring. (season b/w winter & summer)

Autumn " – " " autumn. (season b/w summer & winter)

* Eclipses begin 23 days before equinox and after equinox.

* The min. & max. duration of eclipse is 10 min and 72 min.



* A satellite at east of earth station enters eclipse during daylight and early evening hours.

* A satellite at west of earth station enters eclipse during night and early morning hours.

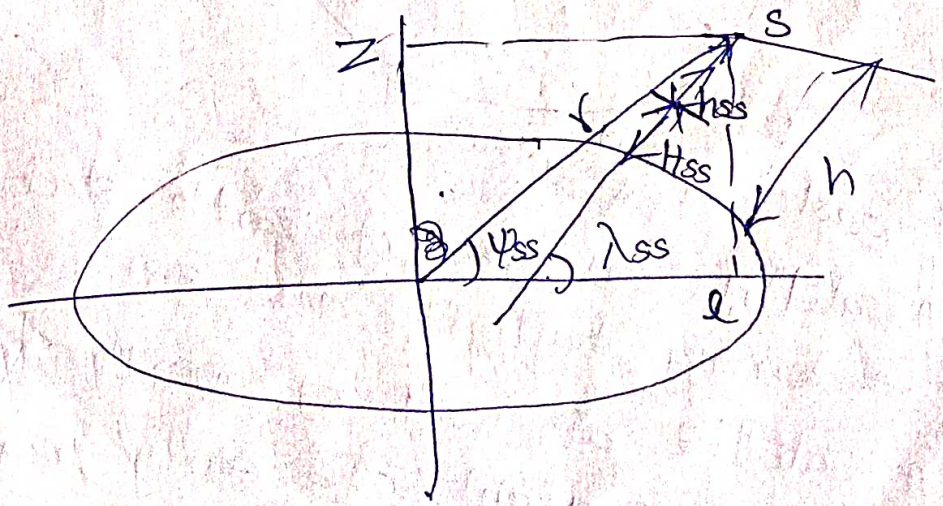
* During eclipse, the solar cells will not function, hence power supplied using batteries to the satellite.

* when the satellite is around the east of earth station, it enters into eclipse during day light and early evening hrs which requires more battery power.

* when the satellite is around the west of earth station, it enters into eclipse during night hrs and early morning hrs. which does not require battery power all time, so this is more desirable.

Sub satellite point :-

* It is defined as the point on the surface of the earth in which a line drawn between earth's center and the satellite.

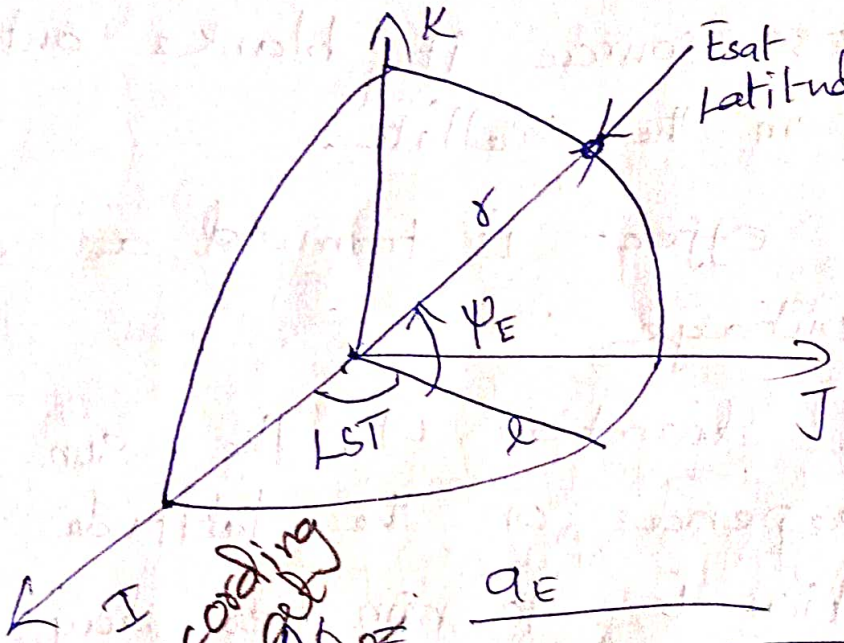


The total height of the satellite above the reference ellipsoid is

$$h = H_{ss} + h_{ss}$$

H_{ss} – height of the terrain

h_{ss} – " " " satellite from terrain.



GST – Green which sidereal time

LST is the time according to the stars. It is the hour angle

$$\frac{a_E}{\sqrt{1 - e_E^2 \sin^2 \lambda_{ss}}}$$

$$r_I = (N+h) \cos \lambda_{ss} \cos LST$$

$$r_J = (N+h) \cos \lambda_{ss} \sin LST$$

$$r_K = (N(1 - e_E^2) + h) \sin \lambda_{ss}$$

The east longitude can be obtained from

$$EL = LST - GST$$

LST – Local side real time

GST – Greenwich " "

Sun transit outage :-

* The sun transit is nothing but the sun comes with in the beam width of the earth station antenna.

* During this period the sun behaves like noise source it blanks out all the signal from the satellite.

* This effect is termed as sun transit outage.

* The duration of the sun transit outage depends on the latitude of the earth station ie 10 min per day.

Launching procedures :-

* To achieve geosynchronous orbit the satellite must be accelerated to a velocity of 3070 m/s in a zero-inclination orbit and raised to a distance of 42242 km from the center of the earth.

* This may be achieved by using the launch vehicles.

* Launch vehicles may be classified into two types as

* Expandable launch vehicles
* Space transportation system

Eg: 1. US – Atlass – centaur and Delta rockets.
2. European – Ariene rockets.

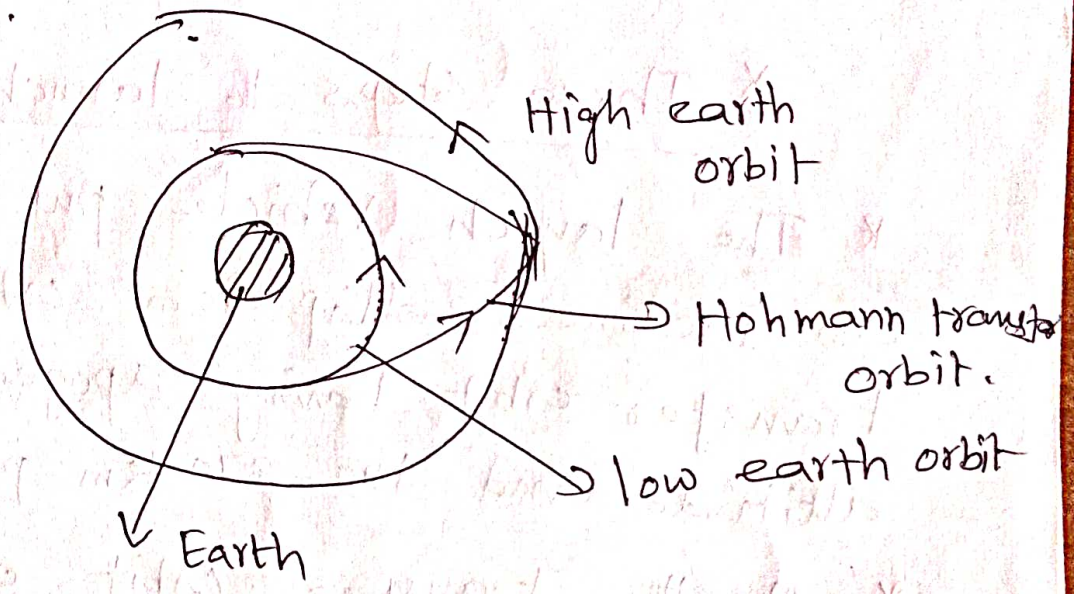
* Three steps to lamching of a satellite:

* The lamich vehicle put the satellite in an inclined ellipitical orbit called transfer orbit having apogee at geosynchronous altitude and 180 – 370 Km perigee.
* At the transfer orbit, a rocket engine called Apogee kick motor (AKM) puts the satellite into a circular geosynchronous orbit with zero inclination.
* The transfer orbit is used to minimize the energy required for transfer and that orbit is termed as Hohmann transfer orbit.
* The satellite must carry a perigee kick motor, changes the velocity of the satellite to be placed in the circular orbit.

* These are steps for launching a satellite in geosynchronous orbit. For satellite to be fully operational it will take 1 to 2 months.

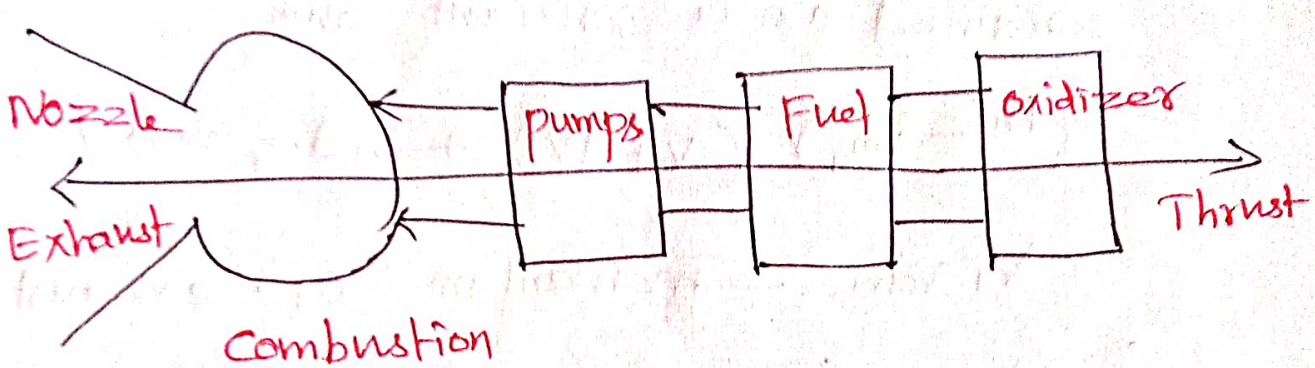
* During this launching process the earthstations are required to perform the tracking, telemetry and command function.

*



Launch vehicles and propulsion :-

* Satellite launching is very complex operation.
* It is very costly also.



F – Thrust

V_e – Exhaust velocity relative to the Vehicle

* The thrust F has been developed by the rocket engine by expelling gas at the high V_e.

* Here fuel and oxidizer are burned in a combustion chamber and high exhaust has been produced.

* In satellite propulsion system cold gases are stored under high pressure.

m – Instantaneous mass of the rocket and propellant.

V – Velocity of the rocket in an internal Coordinate system.

dm_1 – mass of the propellant expelled during the period of the rocket velocity changes from V to V+dV

* The total momentum must be remained as a constant one

$$(m - dm_1)(v + dv) + V_1 dm_1 = mv$$

$V_1 V dm_1$ – momentum of exhaust

$(m - dm_1)(v + dv)$ – momentum of the rocket and propellant.

V_e – exhaust velocity related to the rocket.

$$\frac{dv}{dm} = \frac{-V_e}{m}$$

$m = m_o \quad V = V_o$

$$\Delta V = V - V_o$$

$$\boxed{\Delta V = V_e \ln \frac{m_o}{m}}$$

This is known as rocket equation.

* Mass ratio is

$$\mu = \frac{m_o}{m}.$$

* propellent mass

$$\Delta m = m_o - m.$$

Divided by m_o

$$\frac{\Delta m}{m_0} = \frac{m_0}{m_0} - \frac{m}{m_0}$$

$$\frac{\Delta m}{m_0} = 1 - \frac{m}{m_0}$$

$$\frac{m}{m_0} = 1 - \frac{\Delta m}{m_0}$$

$$\Delta V = V_e \ln \frac{m_0}{m}$$

$$\Delta V = -V_e \ln \frac{m}{m_0}$$

$$\Delta V = -V_e \ln \left(1 - \frac{\Delta m}{m_0}\right)$$

* Propellant mass fraction is given as

$$I = \frac{\Delta m}{m_0} = 1 - \frac{1}{\mu}$$

$$\frac{\Delta V}{-V_e} = \ln\left(1 - \frac{\Delta m}{m_0}\right)$$

$$\text{Exp}\left(\frac{\Delta V}{-V_e}\right) = 1 - \frac{\Delta m}{m_0}$$

$$\boxed{\Delta m = m_0 \left[1 - \exp\left(\frac{\Delta V}{-V_e}\right)\right]}$$

Geo stationary orbit :-

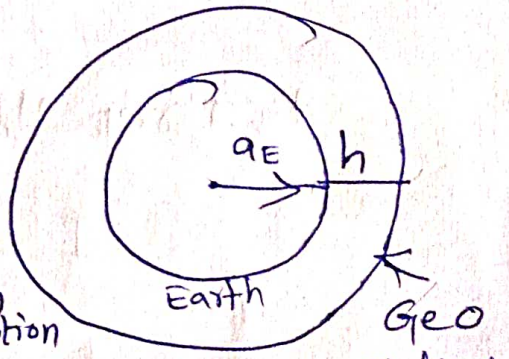
* Geo stationary orbit is one in which a satellite orbits the earth at exactly same speed as the earth rotation at the same latitude.
* A satellite in a geostationary orbit appears to be stationary w.r.t earth observer.
* 3 conditions required

1. satellite must travel eastward at the same rotational speed as the earth.
2. The orbit must be circular.
3. The inclination of the orbit must be zero.

$a = b = a_E + h$

$n = \frac{2\pi}{P}$

$a_{GSO} = \left(\frac{\mu P^2}{4\pi^2}\right)^{1/3}$, $n = \frac{2\pi}{P}$ (periodic time)



$a_E = 6378$ km

$h_{GISO} = a_{GSO} - a_E$

$= 42164 - 6378$

$= 35786$ km.

True Anomaly is the angle from the perigee to the satellite position measured at the earth's center.

Unit - II Space Segment

⟹ Space Craft Technology
⟹ structure, primary power
⟹ Attitude and orbit control
⟹ Thermal control and propulsion
⟹ communication pay load and supporting subsystems.
⟹ Telemetry, Tracking and command.
⟹ Transponders Antenna subsystem.

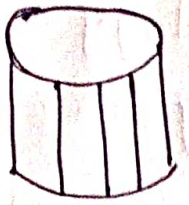
Space Craft Technology :-

* Structure
* primary power

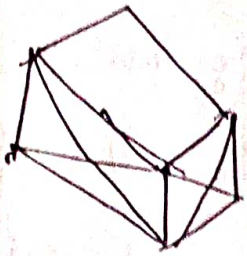
Structure :-

* The space craft must be designed to withstand a variety of loads.
* Because of during launch and transfer, there are vibrations, aerodynamics loads, acceleration, centrifugal, stresses, operating thurst, seperation shocks etc.
* In operating orbit, there are operating thrust and thermal stresses and expose to charged particle radiation etc.

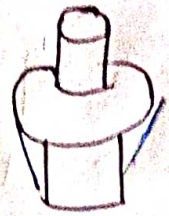
* The various sturcture of space craft



Longeron



Truss



Thrust tube

* The % of the total space craft mass represented by its structure is less than 20%.

* Some space craft structure materials are

⇒ Aluminium
⇒ magnesium
⇒ Invar
⇒ titanium
⇒ fiber glass epoxy
⇒ beryllium
⇒ Stainless steel.

primary power :-

* The sources of primary power of satellite are

⇒ nuclear
⇒ Solar

The nuclear power sources has two types.

Type I :- (Stream generating stations)

* The system is used, a small nuclear reactor heats a boiler with a working fluid (eg mercury) and the vapour is used to drive the combination of turbine-alternator. (Brayton cycle)

Type II :- (Small power supply)

* It has single radio isotope thermo electric generator. It heats lead telluride thermo couples to generate electricity. this type is frequently used for smaller power supplying.

* There is no need of battery during eclipse for above two types.

Disadvantages :-

* Some substantial shielding is needed to protect the spacecraft electronics system from radiation damage.

* Nuclear fuels curium 244 and plutonium are easy to handle and needs Scheduling. It is expensive.

* strontium 90 is easily available and cheap, it is difficult to handle It is hazardous one.

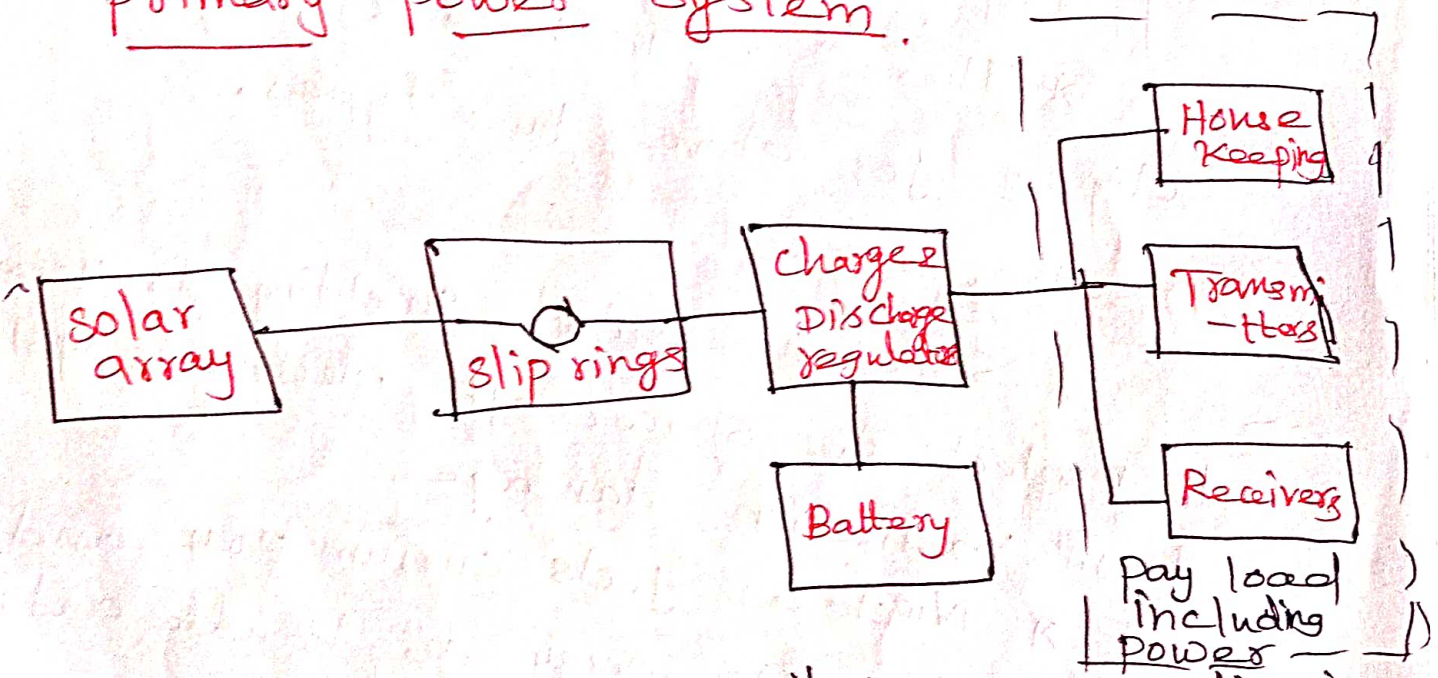
power during eclipse.

Estimating primary power needs :

* In this, we have to consider where the solar array is mounted, weather on the flat panels of 3 axis stablized satellite or on the drum of spin stabilized satellite.

* The type of transmitter receiver power, house keeping, Power battery service during eclipse are the various factors used to estimate the power requirement

Block diagram of basic satellite primary power system.



n_k — no...of k^{th} transmitter

P_k — R_F transmitted power

η_k — efficiency.

* The total transmitted power is

$$P = \sum_{k=1}^{n} n_k \frac{P_k}{D_k}$$

P_r - receiver power

A - factor.

* Total transponder power is given as

$$P_T = P + P_r = a P_k$$

$a = 1.05$ for large satellites

$a = 1.10$ for smaller (or) more Complicated transponder

* It includes remaining primary power for frequency convertors and local oscillators

P_H - House Keeping power.

* It includes power for telemetry, tracking and command sub system

P_{HO} - constant

$$h P_T \propto P_T$$

$$P_H = P_{HO} + h P_T$$

* Eclipse period occur when the sun is near the vernal or autumnal equinox

$$P_H = P_{HO} + P_{He} + h P_T$$

P_{He} → eclipse heater power

P_E - power to be provided by the battery during eclipse.

$$P_E = \frac{eP_T + P_H}{\eta_B}$$

e – eclipse factor

η_B – Battery discharging η

C – Battery capacity

* $$C = \frac{(P_E \times T_E)/d}{V_d}$$

T_E – maximum eclipse period (1.2 hrs)

d – depth of discharge.

V_d – discharge voltage.

* charging power is

$$P_c = \frac{d\left(\frac{P_E T_E}{d}\right)}{\eta_c T_c}$$

T_c – charging time

η_c – " efficiency

* Total primary power must be provided by the solar array is

$$P = K(P_T + P_H + P_E)$$

K – Design margin factor (1.05 or 1.11)

Attitude control and orbit control

* The satellite orientation in space is refered to the attitude of the satellite.

* In satellite most of the equipment is used for the purpose of attitude control.

* Attitude control includes the proper orientation of antenna towards the earth station.

* The disturbance torques, such as
  - ⇒ gravitational field of the earth
  - ⇒ moon may affect or alter the attitude.

* To find the deviation or shift, infrared sensors are used, these are referred to as horizon detectors and a corresponding control signal is generated which activates a restoring torque.

* The controlling torques is generated by two ways
  - ⇒ passive attitude control
  - ⇒ active attitude control.

Passive attitude control :-

* The satellite stablization is achieved without putting a drain on the satellites energy.

* eg :- spin stabilization
gravity gradient stablization.

* Gravity gradient depends on the gravitational stabilization.

spin stabilization is mainly used in communication satellites.

Active attitude control :-

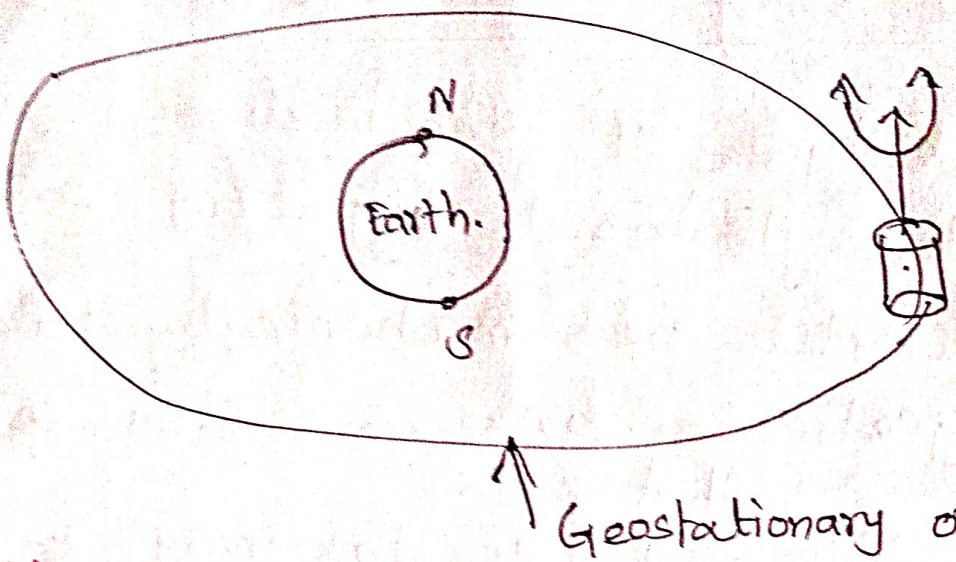
* In this technique corrective torques are applied in response to the disturbance torque.

* momentum wheels, EM coils and mass expulsion dwices are used to generate control torques.

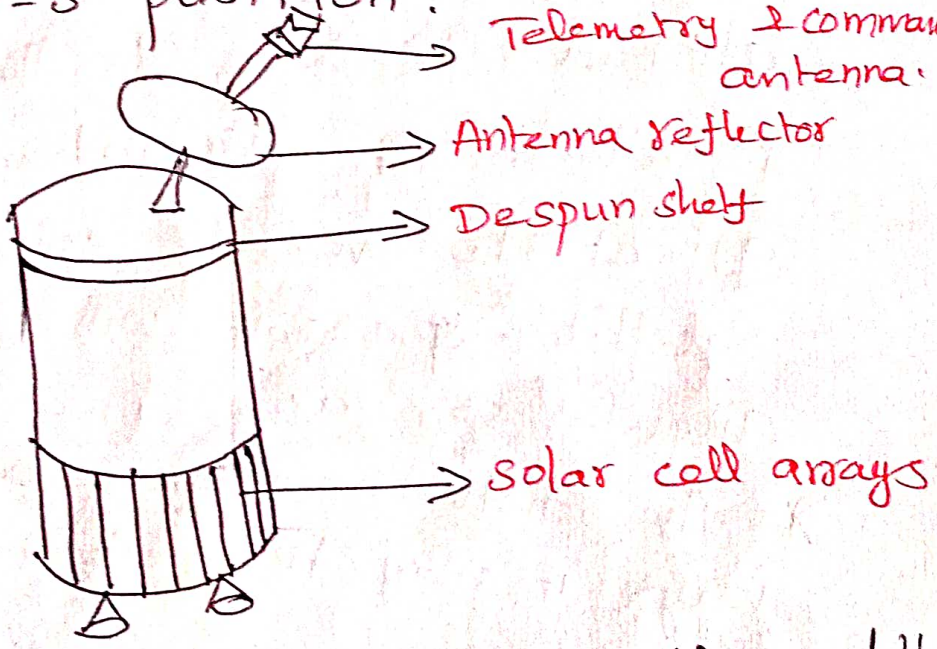
* Momenten wheel control is used in three axis stabilization.

Spinning satellite (stabilization)

* This type of stabilization is applied to the cylindrical type of satellites.
* Satellites are mechanically balanced in particular axis and then spinning around that axis.
* Spin axis of geostationary satellites are parallel to the N-S axis of the earth.
* In the absence of disturbance torque the satellite would maintain its correct altitude relative to the earth.
* When the disturbance arises it will affect the overall spinning rate of the satellite. i.e spin rate will decrease and the angular spin axis direction will also change.
* The disturbance may be from number of ways it may be external or internal.
* The gravitation force of the sun and moon, solar radiation the examples for external disturbances.
* sometimes the disturbances may be internal ie movement of the satellite, antenna motor bearing friction also gives rise to disturbances.



* The impulse type thrusters or jets can be used to increase the spin rate, and to shift the axis back to its to correct N-S position.



* In the spin stabilization entire satellite rotates about an axis. If a omni directional antenna is used then it will also rotates with the satellite.

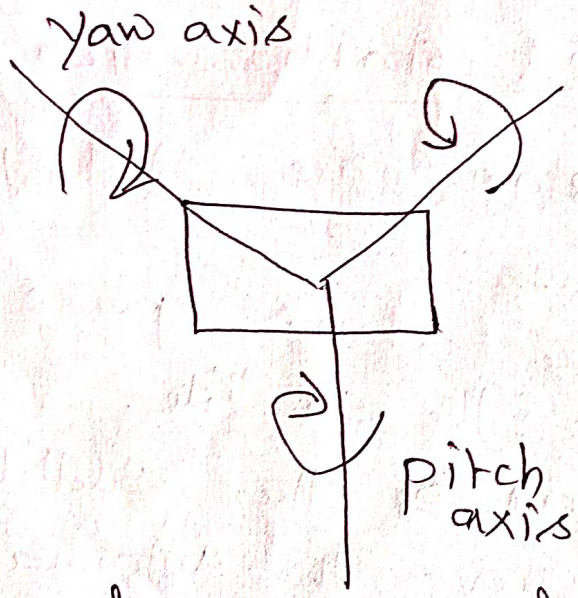
* If a directional antenna is used, then the antenna must be made despun. This gives rise to dual spin construction.
* An electric motor drive is used for despinning the antenna subsystem.
* The above complete assembly is known as Bearing and power transfer assembly (BAPTA).

Three axis stablization

* The 3 axis are, roll, pitch and yaw (RPY axis).
* All the 3 axis pass thro' the centre of the satellite.
* movement of the satellite about the roll axis moves the antenna foot print north & south.
* movement of the pitch axis moves the foot print east and west.
* movement about yaw rotates the antenna foot print.
* The body of the satellite remains fixed to the earth, so, the 3 axis stabilization is also referred to as

body stabilization

* There are seperate stabilizing elements for each of the 3 axis
* Active attitude control is used here
* The reaction wheel is stationary but it reacts when a torque tends to shift the orientation or attitude.

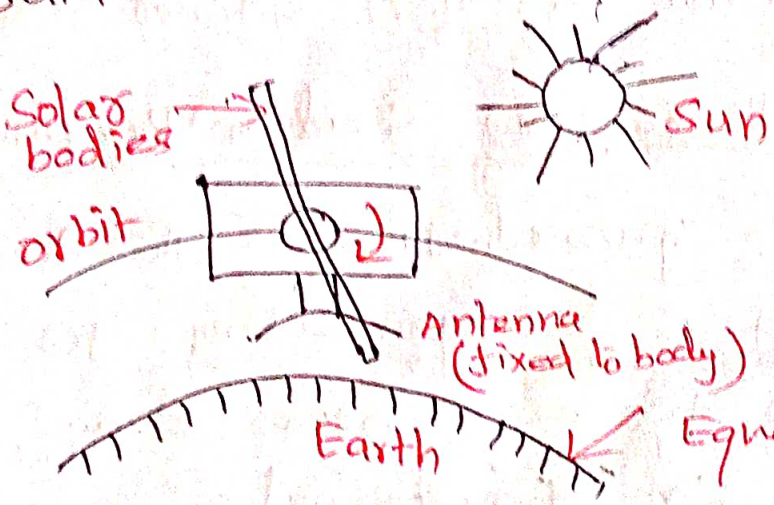


* But always the disturbance torque cause a cumulative increase in wheel momentum, at some point wheel get saturated.
* Some mass expulsion devices are used to unload the wheel ie to remove the momentum from it.

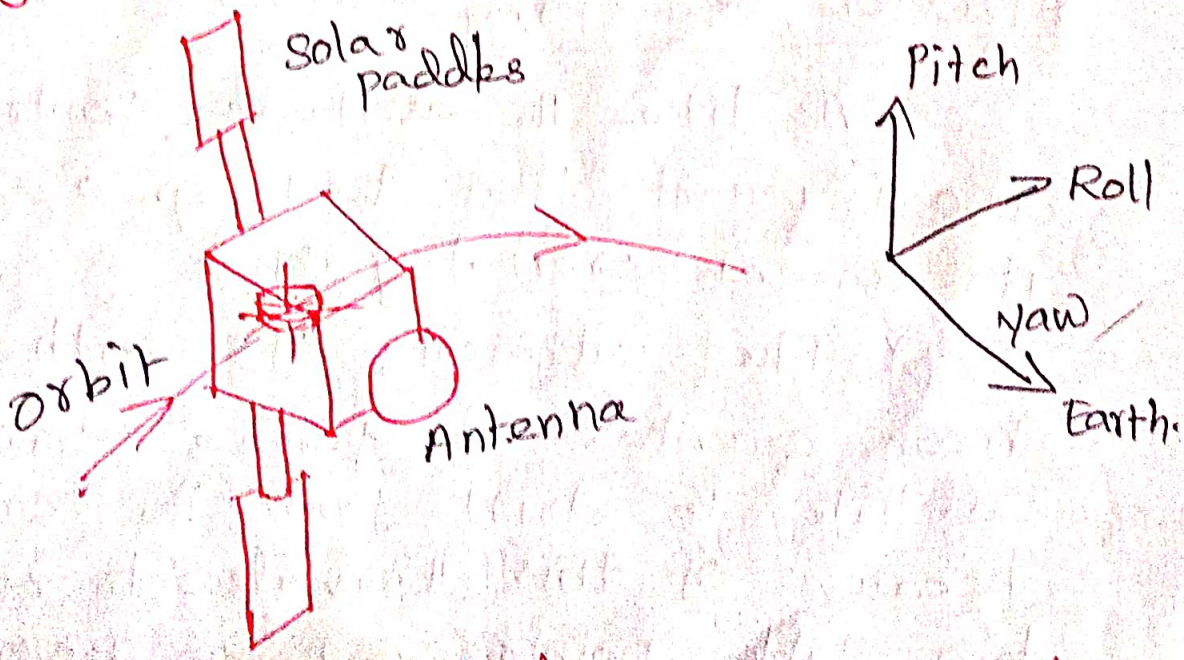
orbital control

orbit changes :-

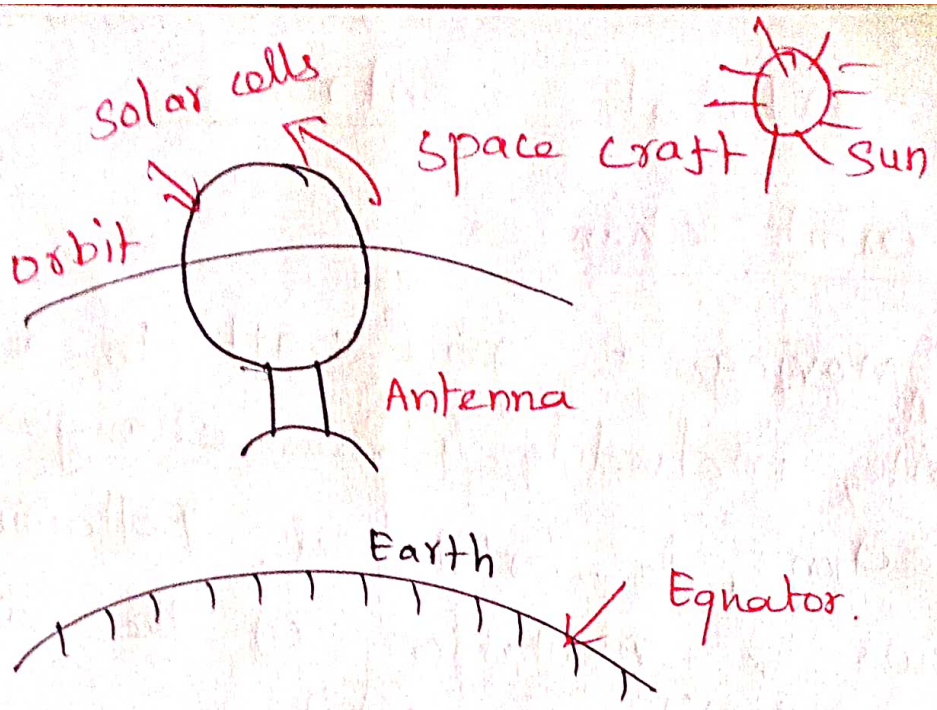
* Moving a space craft to a desired orbit, including plane changes, orbit injection, de-orbit, et. Following figures shows the orientation of the above ~~sta~~ said satellite in orbit.



Body stablized satellite



axis for body stablized satellite



Drum Stabilized (or) spinner satellite.

orbit maintence (or) Station Keeping :-

* Keeping a spacecraft in the desired mission orbit ie compensating for effects of disurbing forces like drag, sdar wind, gravitation force etc.

Station keeping :-

* As like the attitude control, it is also important that to keep a satellite in its correct orbital path.

* The ellipticity of earth, sun and moon gravitational forces causes the satellite to drift from its original path because of this it deviates to one of the two stable points 75° E or 105° W

* To nullify the drift, two type of maneuvers are in practice, they are

1. East-west station keeping maneuvers
2. North-South station " "

East-west station Keeping :-

* The satellites drift slowly to one of the two stable points 75° E and 105° W.
* This should be controlled and this is known as station Keeping.
* To overcome this, an oppositely directed velocity component is imputed to the satellite usually they are jets.
* These jets are pulsed once every 2 to 3 weeks.
* The designated longitude for satellites in 6/4 GHz band is ± 0.1° and for 14/12 GHz with in ± 0.5°

North-South station Keeping Maneuvers :-

* The geostationary satellites also drift in the latitude direction, these may be because of the gravitational force of the moon & sun.
* If it is left uncorrected, then the inclination change will go from 0-14.67° in 26.6 years.

* The satellite is placed in an inclined orbit of about 2.5 to 3°

* This type of inclination will dispense the north and south station keeping manoeuvres.

* This allows the communication payload to be increased. But this requires tracking antennas at the ground station.

Thermal control and propulsion.

* The satellites are affected by thermal radiation from the sun and the earth and also from the earth reflections.

* Thermal radiation from earth and earth's reflection are negligible in geostationary satellite. and only it will affect the low earth orbit satellites.

* The equipments present in the satellite will also produce heat and they must be removed.

* To operate the satellite in temperature stable environment, the following things are used.

* use of thermal blankets
* Radiation mirrors — to remove the the heat from communication payload
* Heaters may be switched on when transponders are switched off.

Need of propulsion :-

* place payloads into orbit :- launch propulsion is used.
* Send payloads to the moon or to the planets :- space propulsion is used.
* position, adjust and maintain orbits of space crafts by orbit control
  ⟹ auxiliary propulsion is used.
* orient spacecraft by attitude control
  ⟹ axiliary propulsion also called reaction — control systems is used.

pay load :

The pay load is the revenue-producing portion of a spacecraft load, eg:- passengers and cargo such as scientific experiments, TV transmitters, earth observation equipment like photo cameras etc.

Telemetry Tracking and Command subsystem (TT & C subsystem)

* For the successful operation of a communication satellite, TT & C sub system is essential.
* It involves both the earth station and space craft.
* The main function of a space craft management are given below.
  1. To control the orbit and attitude of the satellite.
  2. To monitor the status of all the sensors in the satellite.
  3. To switch on/off some sections in communication systems.

Telemetry :-

* The telemetry system is present in the satellite, this subsystem collects data from many/all sensors present in the satellite and retransmit it into the earth station.

* There are no.. of sensors located on the space craft to monitor the

⇒ pressure in fuel tanks

⇒ voltage and current in power conditioning unit.

⇒ current drawn by each subsystem

⇒ critical voltage and current in communication electronics.

⇒ temperature from all the subsystem

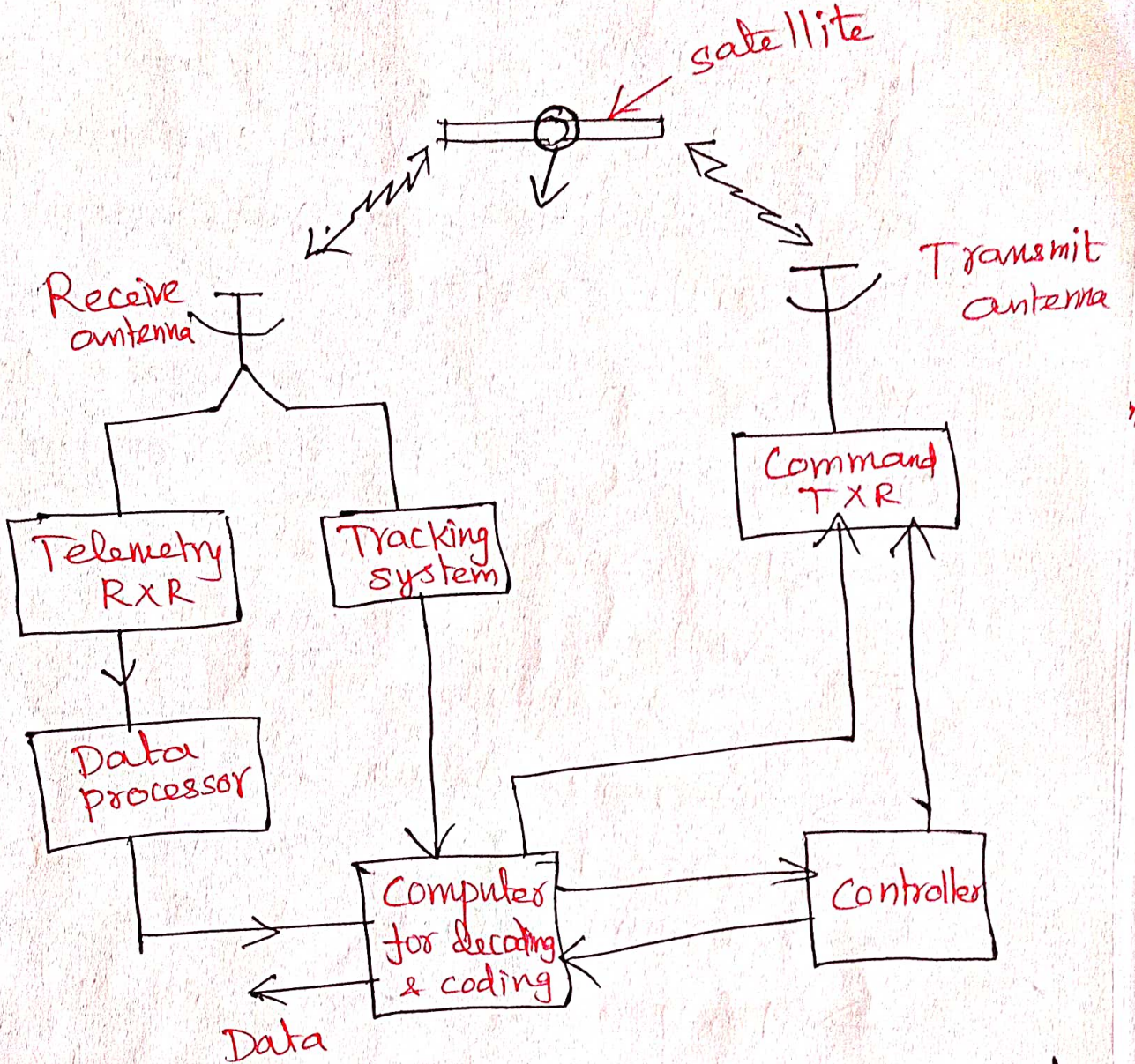
⇒ status of each subsystem & switch positions.

⇒ monitoring the attitude control and so on.

* The data from all the sensors are given to the telemetry unit and this unit digitize the data and transmit the data and transmit the data using FSK or PSK.

Pay load :

* To maintain a high carrier to noise ratio, Low data rate is normally used.



* At the controlling earth station a computer can be used to monitor, store and decode the telemetry data, so that the status of the space craft is immediately determined.

* Alarms can be used if any parameter goes outside the allowable limits.

Tracking :

* Tracking is to find the position of the satellite in space.

* Tracking is very important during the transfer orbit and drift phase of the Satellite launch.

* We know that lots of disturbances may change the attitude and orbit of a satellite, so it is necessary to track the satellite and send correction signals.

* The satellite position may be determined by various techniques.

⟹ Velocity & acceleration sensors present in the space craft may give the change in orbit.

⟹ By using doppler shift the earth station determine the position.

⟹ Range and the angular measurements from earth station antenna, is used to determine the orbital elements.

⟹ The position of a satellite can be determined with 100 m.

Command :-

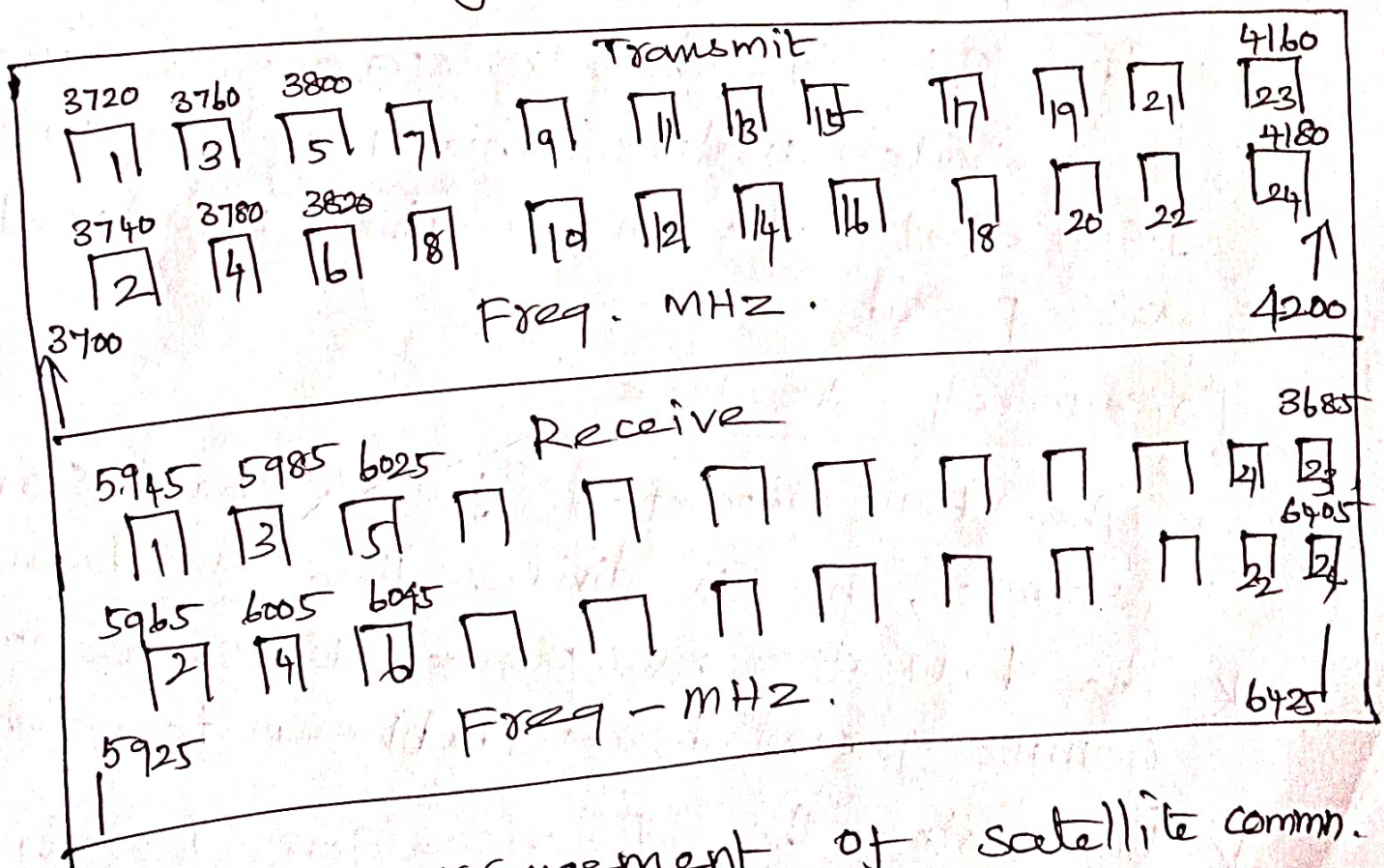
* The command system is used to make changes in altitude and orbit and also to control the communication subsystem.
* The status of the various subsystems and sensors are transmitted from the satellite to the earth station.
* The data processor converts the received signal into digital format & decryption encryption is performed here.
* Then the data is given to the controller will transmit a control code ie command word is sent in a TDM frame to the Satellite.
* If it is received correctly then the execute command is sent to the satellite then the command is executed.
* This process is used to avoid erroneous command and the entire process may take 5 or 10 s.
* The command and telemetry link are usually separated from the communication systems.

* The backup system provide control of

⟹ apogee kick motor
⟹ Attitude and orbit control thrusters.
⟹ solar sail deployment.
⟹ power conditioning.

Communication pay load subsystem.

* In comm. satellite, the comm. sybsystem is the important subsystem and all the subsystem are used to support the comm. subsystion.



* Freq. arrangement of satellite comm. subystem for the 6/4 GHz band (c band)

Transponders :-

* A transponders consist of BPF to select the particular channels band of frequencies.
* A down converter to convert 6g Hz to 4 GHz at the o/p.
* A commn. system may contain no.. of transponders, some of them may be spares.
* 12-44 transponders are used. Each transponder are supplied with i/p from the receive antenna.
* The o/p of the transponder is given to a switch matrix. This may be controlled from earth station, so that reallocations are possible.

Frequency re use :-

* The B.W allocated for C band service is 500 MHz, this is divided into sub bands.
* The b.w of transponder is 36 MHz and 4 MHz guard band between transponders.
* By using the polarization isolation the no.. of transponders used can be doubled.

* polarization isolation is defined as the same carrier is used with opposite polarization so that the B.W may increase.

* For eg:- same freq. can be used by more than one transponder, it its is linearly polarized.

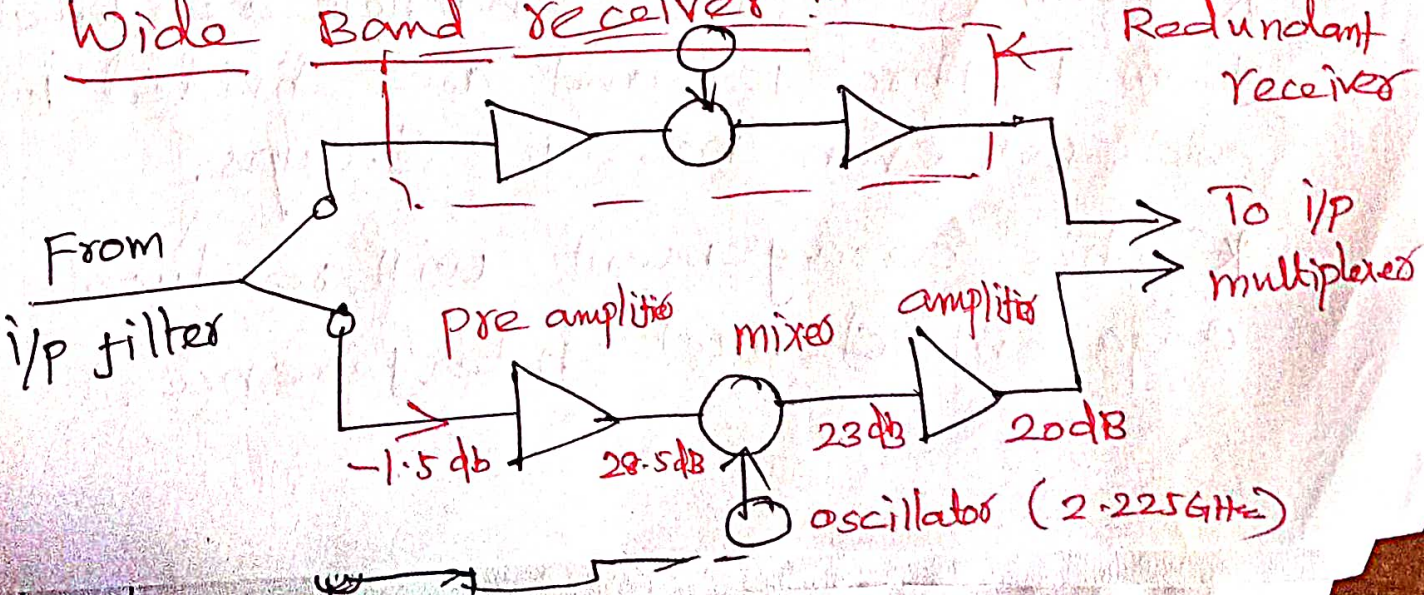
* Then horizontal & vertical polarization if it is critically polarized then right hand polarization (or) left hand polarization.

* This technique is referred as the frequency reuse.

* A transponder consists of

1. wide band receiver
2. Demultiplexer
3. power amplifier.

Wide Band receiver :-



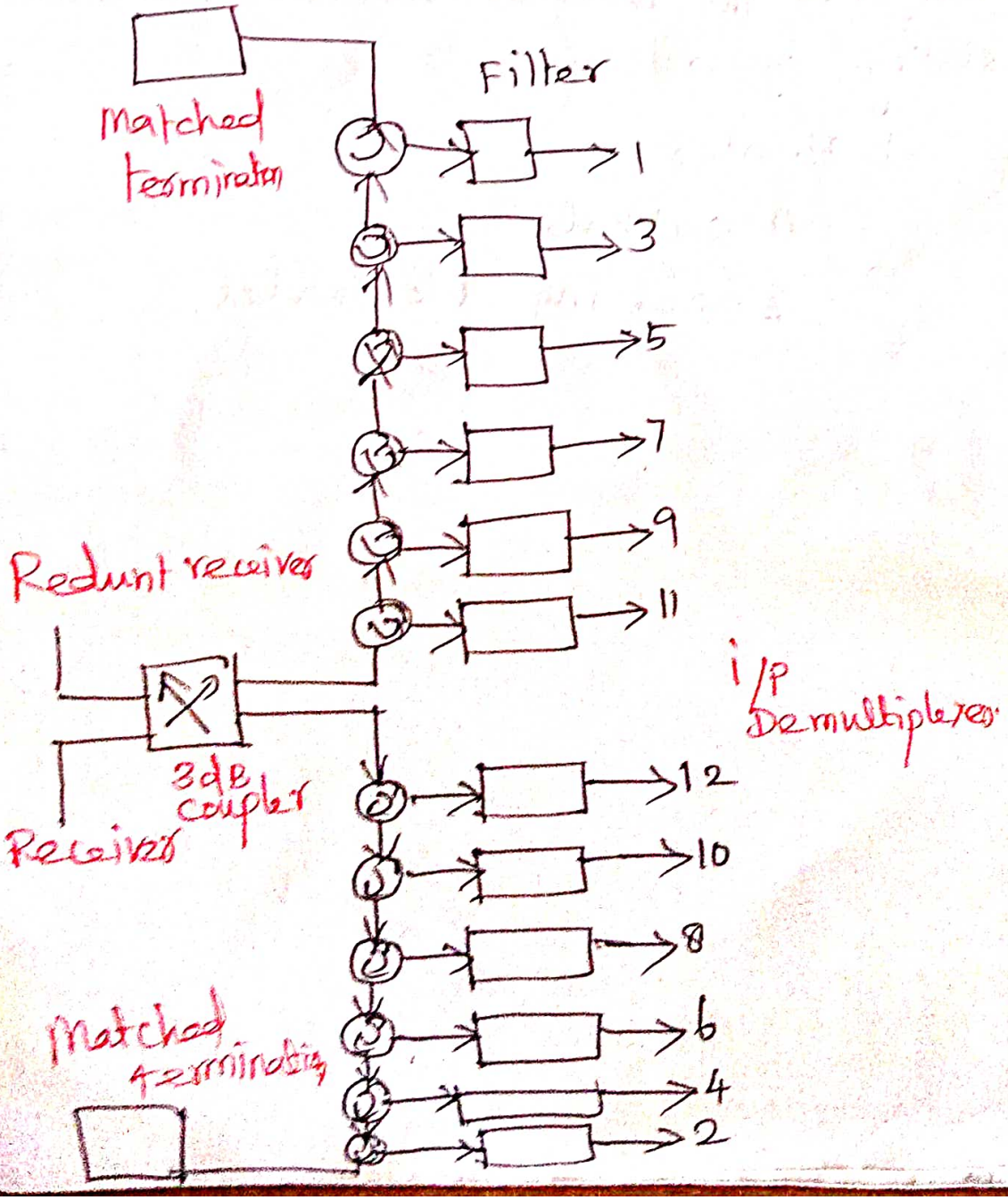
* In the receiver section of a transponder the redundant receiver is used.
* A duplicate receiver is provided with each original receiver, if one fails the other will automatically switched on. But at a time one must be in use.
* The LNA adds little noise to the carrier and also it provides amplification. This is for the purpose of override the noise present in the mixer level.
* The o/p of LNA is given to mixer stage and it will also consists of a oscillator.
* The signal o/p is from the mixer is given to the 2nd stage amplifier.

Input Demultiplexer:-

* The i/p demultiplexer is used to separate the incoming signals corresponding to the transponder freq.
* From this the channels are labeled from 1 thro' 12 and are divided into odd & even no. of Groups.
* This arrangement will reduce adjacent channel interference.

* The o/p of the receiver is given to the power splitter and output from the power splitter is given to 2 sets of circular chains.

* Each circulator is connected by a channel filter having a B.W of 36 mHz and they are tuned to the appropriate center freq.



The power amplifier :-

* Each transponder have seperate power amplifier.

* These power amplifiers are proceeded by a attennator, it may fixed or variable

* The device used as power amplifier is TWTA (Travelling wave tube amplifier)

* In this the electron beam gun assembly Consisting of a

1. Heater
2. A cathode
3. Focusing Electrodes.

Unit-III Satellite link Design

⇒ Basic link analysis.

⇒ Uplink and Down link Design equation.

⇒ Free space loss

⇒ Atmospheric effects.

⇒ Ionospheric scintillation.

⇒ Rain induced attenuation and Interference

⇒ System noise temperature.

⇒ Link design with and without freq. reuse.

Basic link analysis :-

* Link analysis determines properties of satellite equipment (antennas, amplifiers data rate etc)

* Two links are

up link → from ground to satellite

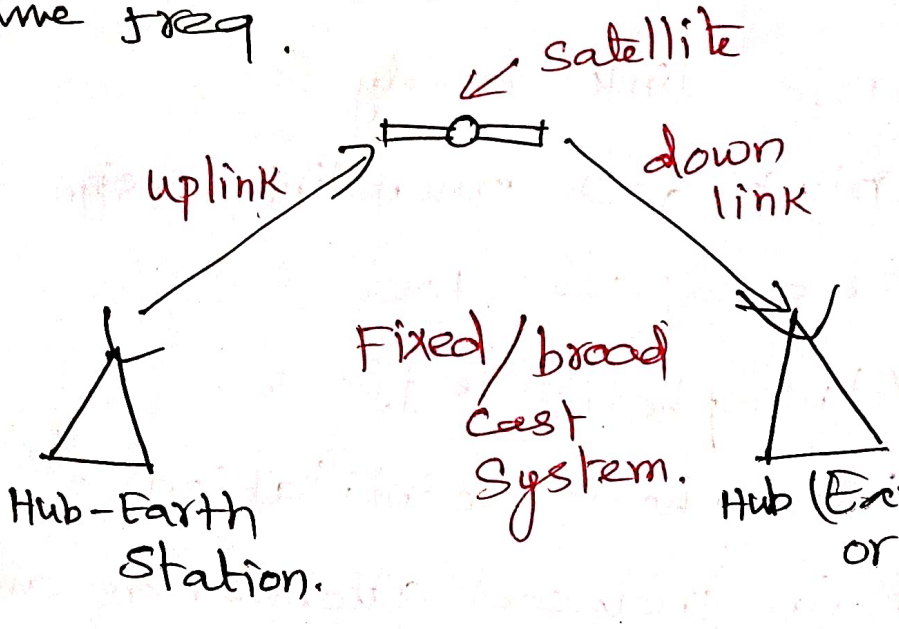
down link → from satellite to ground.

* Two way communication — 4 links

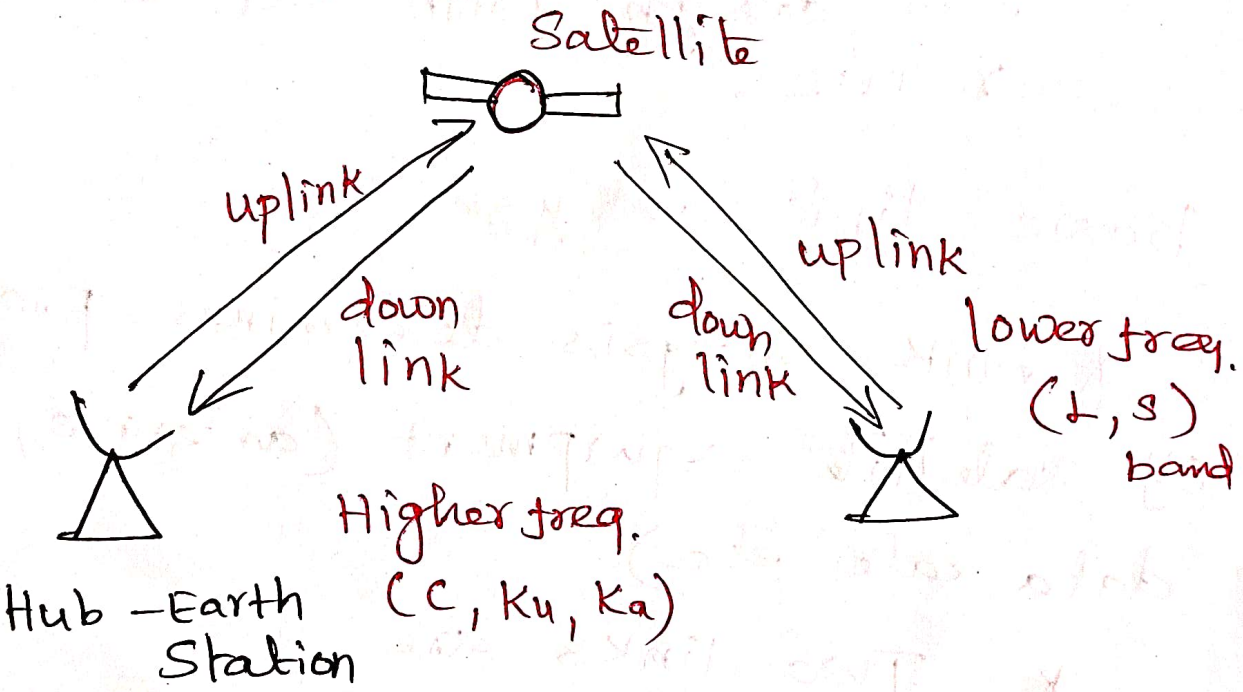
one way communication — 2 links.

eg (TV broadcast)

* Two links are not at the same freq.



One way communication



Two way communi-cation.

Satellite uplink and down link analysis and Design.

* The Fundamental relationship for RF link performance is given by

$$\frac{C}{N_o} = \frac{EIRP}{losses}\left(\frac{G_R}{T_S}\right)\left(\frac{1}{K}\right)$$

* (C/N_o) ratio in decibles.

$$\left(\frac{C}{N_o}\right) = [EIRP] - [losses] + \left[\frac{G_R}{T_S}\right] - [K]$$

This eqn is same for uplink and down link.

But the operation values of EIRP and G/T ratio may be different.

$\frac{C}{N_o}$ – Carrier to Noise power in dB Hz

[EIRP] – equivalent Isotropic Radiated power. in dBW

[Losses] – Free space loss and other losses.

$[G_R/T_S]$ – Receiver antenna gain to system noise temperature

[B] – noise Bandwidth.

* The communication link established between the earth station and Satellite is referred as uplink.
* Satellite to earth station link is referred to as down link.

Uplink :-

* ψ_m – magnetic flux density generates maximum saturated transponder output for a single carrier.
* The flux density received at Satellite is

$$\phi = \frac{EIRP\ (earth\ station)}{4\pi r^2}$$

r – distance.

$$= \frac{EIRP}{LOSSES} \frac{4\pi}{\lambda^2}$$

* In decibels

$$[\phi] = [EIRP] - [LOSSES] + \left[\frac{4\pi}{\lambda^2}\right] \ dBW/m^2$$

* If $\phi = \psi$.

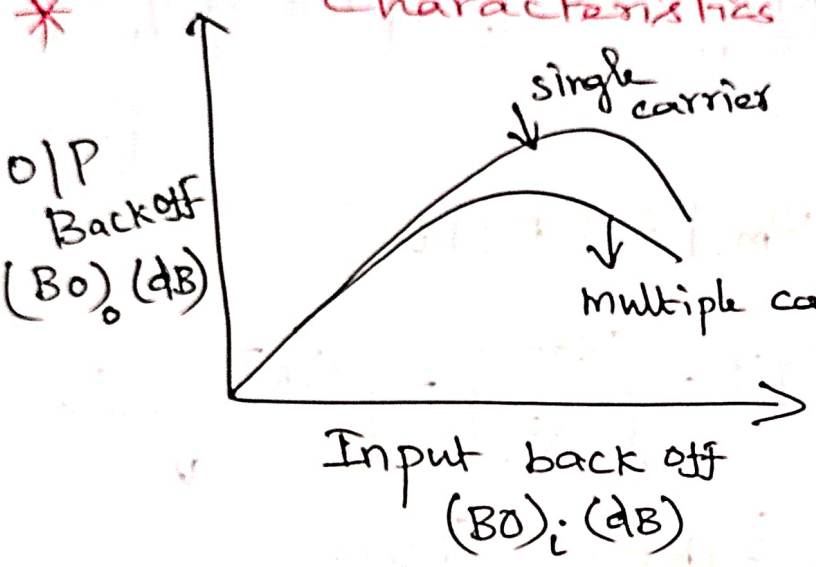
$$\left[\frac{C}{N_0}\right]_U = [\phi] - \left[\frac{4\pi}{\lambda^2}\right] + \left[\frac{G_R}{T_S}\right]_U - [k]$$

Down link

* $\left[\frac{C}{N_0}\right]_D = [EIRP]_D - [Losses]_D + \left[\frac{G_R}{T_s}\right]_D - [K]$

* All amplifiers have a maximum or saturated power output, due to their non linear characteristics

* Characteristics of single & multiple carrier



* When more than one carrier access to transponder, and if the high power amplifier generates same max. output power as for single carrier, it results in intermodulation effects.

* So it is practice to reduce the operating point of TWT less than its saturated o/p and it is referred to as Back off.

Input Back off $(BO)_i$ uplink :-

* The uplink $(C/N_0)_0$ eqn with $(BO)_i$ is

$$\left[\frac{C}{N_0}\right]_0 = [\psi_M] - \left[\frac{4\pi}{\lambda^2}\right] + \left[\frac{G_R}{T_S}\right]_0 - [K] - [BO]_i$$

$$\left[\frac{C}{N_0}\right]_0 = [EIRP]_0 - [BO]_i - [\text{Lass ES}]_0 + \left(\frac{G_R}{T_S}\right)_0 - [K]$$

$$[\phi] = [\psi_m] - [BO]_i$$

$$\left[\frac{C}{N_0}\right]_0 = [\phi] - \left[\frac{4\pi}{\lambda^2}\right] + \left[\frac{G_R}{T_S}\right]_0 - [K]$$

$$[EIRP]_0 = [EIRP_s]_0 - [BO]_i$$

$[EIRP_s]_0$ — saturation flux density for a single carrier.

* i/p BO will be specified for multiple carrier operation

$$[EIRP]_0 = [EIRP_s]_0 - [BO]_i$$

$$\left[\frac{C}{N_0}\right]_0 = [\psi_s] + [A_e] - [BO]_i + \left[\frac{G_R}{T_S}\right]_0 - [K] - [RFL]$$

$A_e - 10\log_{10}\left[\frac{\lambda^2}{4\pi}\right] \Rightarrow$ effective Aperture.

RFL – Receiver Feeder loss.

Earth station High power amplifier

* The earth station has to provide the radiated power and the transmit Feeder loss

$$[P_{HPA}] = [EIRP] + [TFL] - [G_T]$$

$[TFL]$ – Transmit Feeder Loss

$[P_{HPA}]$ – HPA power o/p

$[G_T]$ – Transmitter antenna gain.

* Saturated P_{HPA} is given as.

$$[P_{HPA}]_{sat} = [P_{HPA}] + [BO]_i$$

Output Back off $(BO)_o$ – Down link

* BO at the earth station is dependant on any back off requirement at the Satellite transponder

The down link carriers to noise ratio is given by

$$\left[\frac{C}{N_0}\right] = [EIRP]_D + \left[\frac{G_R}{T_S}\right] - [Losses] - [K]$$

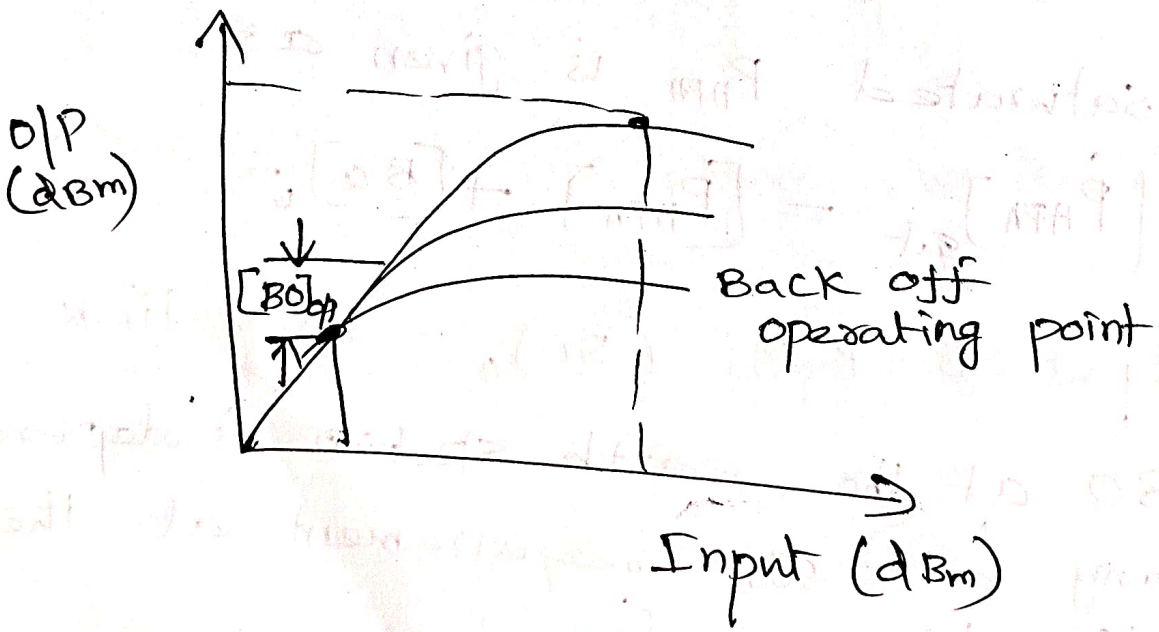
* Assuming signal bandwidth, it is included in this eqn.

$$\left[\frac{C}{N_0}\right]_D = [EIRP]_D + \left[\frac{G_R}{T_S}\right]_D - [Losses]_D - [K] - [B]$$

$$[EIRP]_D = [EIRP_s]_D - [BO]_o + \left[\frac{G_R}{T_S}\right]_D - [Losses]_D - [K]$$

* The relation between input and output back off is

$$[BO]_o = [BO]_i - 5\ dB.$$



* The satellite high power amplifier TWTA

$$[P_{TWTA}] = [EIRP]_D - [GT]_D + [TFL]_D$$

* The saturated power output rate is given as

$$[P_{TWTA}]_S = [P_{TWTA}] + [BO]_D$$

Link power Budget equation.

* If losses for the link is identified the power at the receiver, may be calculated in decibel as

$$[P_R] = [EIRP] - [LOSSES] - [G_R]$$

* The major sources of loss in any ground satellite link is the Free space spreading loss (FSL).

* The losses for clear sky conditions are

$$[LOSSES] = [FSL] + [RFL] + [AML] + [AA] + [PL]$$

G_R – Receiver antenna gain, dB

P_R – Received power dBW

EIRP – Equivalent Isotropic radiated power dBW

FSL – Free space spreading loss dB

RFL – Receiver Feeder loss dB

AML – Antenna misalignment Loss dB

AA – Aspnospheric absorption Loss dB

PL – polarization mismatch Loss dB

System noise :-

* Noise temperature is important in receiver, using this thermal noise produced by active and passive devices in the receiver can be calculated.

$$P_n = K T_n B_n$$

P_n — noise power

K — Boltziman constant (1.38×10^{-23} J/K)

T_n — noise temperature in kelvin

B_n — Bandwidth in Hz.

$K T_n = N_0$ — Noise spectral density

$$\boxed{P_n = N_0 B}$$

* The noise power is also given as.

$$P_n = K \cdot T_s B_n \cdot G$$

G – gain of the receiver from RF i/p to demodulated i/p.

Antenna Noise :- (Atmospheric effects)

* Antenna noise is generated both by satellite antenna and the earth station receiving antenna. The two types are

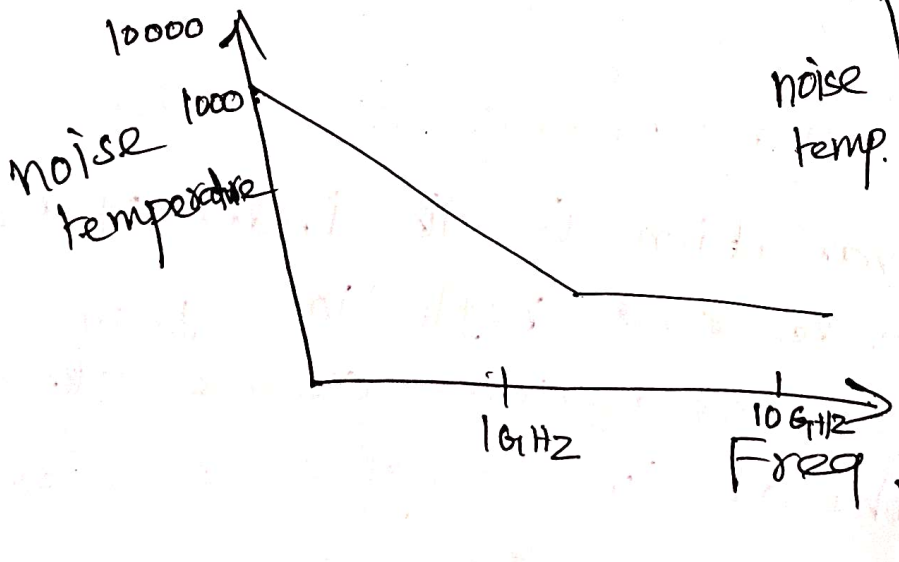
1. Noise due to antenna Losses.
2. Sky noise.

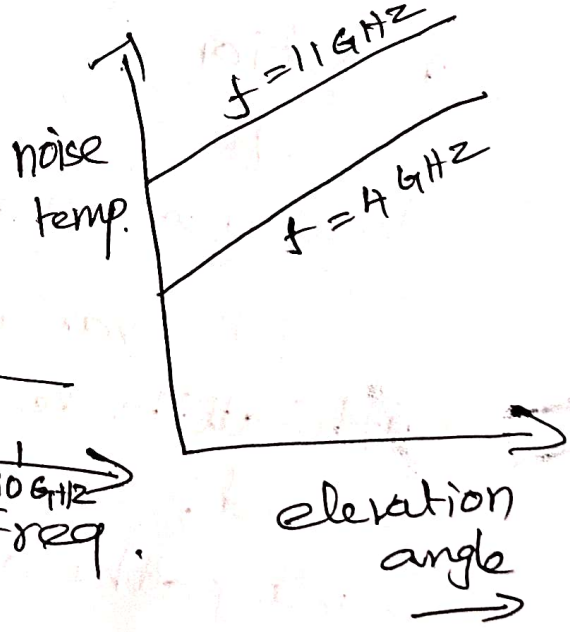
Sky noise :-

* Sky noise generates due to wave attenuation, when it passes thro' the atmosphere.

* This wave attenuation may be due to atmospheric gases and rain, snow and galactic etc.

* Below 1 GHz galactic noise effect is more.





Inospheric scintillation :-

* Due to the Refractive index variations in the ionosphere (at freq < 1000 MHz) there can be short term amplitude and phase fluctuations that need a small margin.
* At high frequencies smallest angle of elevation can experience scintillation.

Faraday rotation :-

* The electrons in the ionosphere together with the earth's magnetic field cause a rotation in the plane of polarization is referred as Faraday rotation.

Variable Atmospheric refraction :-

* Variation in the index of refraction with altitude and reflections from the ground, or sea can cause atmospheric multipaths at low angles of elevation and low frequencies.
* These problems are familiar to microwave radio and mobile system.

Rain Depolarization :-

* The dominant effect of rain is to attenuate the signal and because of its behaviour as a lossy attennator to increase the system noise temperature.

* Also rain has a depolarizing effect which creates a cross polarized component with linear polarization and a loss in circularity with circular polarization.

* Essentially the effect is same for both kinds of signals is as much as circular polarization. It can be considered as two linearly polarized waves in time and space quadrature.

Rain induced attenuation and interference

* Interference may be defined as the effect of an unwanted signal on the reception of wanted signal.

* Interference is both inevitable and ubiquations, given the wide variety of uses of the radio spectrum.

* Detectability of interference depends on the characteristics of the wanted signals and the communication system.

* For analog systems, three characteristics are

⟹ The received power levels

⟹ The spectral power distributed of wanted and unwanted signals.

⟹ The spectral sensitivity of the system.

* Interference is not only degradation in a communication system, thermal noise and other impairments may also affect the system.

* The carrier to interference ratio may be calculated at any point in the system but convenient and useful point is the receiver input.

* The carrier level may be calculated as

$$C = P_t + G_t - L + G_r \text{ dB}$$

$$C = E - L + G_r \text{ dB}$$

P_t – Transmitter power dBW

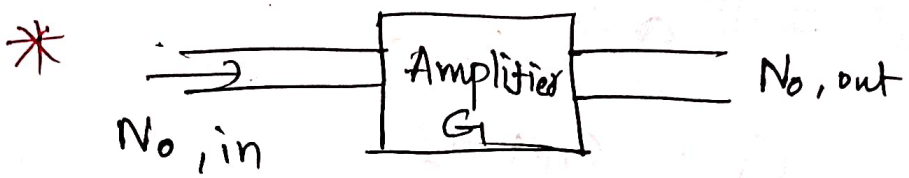
G_t – Transmitter antenna gain dB

L – Free space loss dB

G_r – Receiver antenna gain dB

E – EIRP dB W

System noise temperature :-



$$N_{o,out} = G \cdot N_{o,in}$$

G – power gain of the amplifier

$N_{o,in}$ = input noise energy

$N_{o,out}$ – output noise energy.

$$N_{o,a} = K \cdot T_a$$

↳ i/p noise energy coming from antenna

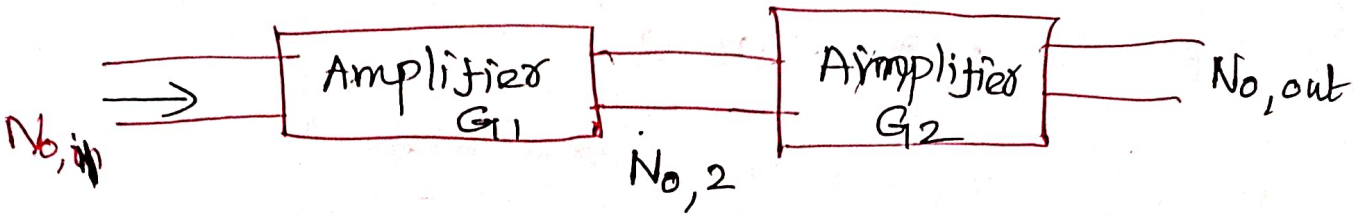
T_a – antenna noise temperature

$$N_{o,out} = G \cdot K \cdot (T_a + T_e)$$

T_e – i/p noise temperature for the amplifier.

$$N_{o,in} = K (T_a + T_e)$$

Amplifier in cascade :-



Overall gain = G

$$G = G_1 + G_2$$

$$N_{o,2} = G_1 k (T_a + T_{e_1}) + k \cdot T_{e_2}$$

$$N_{o,i} = \frac{N_{o,2}}{G_1}$$

$$= k\left(T_a + T_{e_1} + \frac{T_{e_2}}{G_1}\right)$$

$$N_{o,i} = k \cdot T_s$$

T_s – system noise temperature

$$\boxed{T_s = T_a + T_{e_1} + \frac{T_{e_2}}{G_1}}$$

$$\text{Noise factor} = \frac{(SNR)_{i/p}}{(SNR)_{o/p}}$$

$$N_{o,out} = k T_o G F$$

T_o room temp

k – Boltzmann's constant

Free space Loss :-

* In Telecommn. free path loss is the signal strength of an electromagnetic wave that would result from a line of sight path through free space, with no obstacles nearby to cause reflection or diffraction.

* Free space path loss is proportional to the square of the distance between transmitter and Receiver and also proportional to the square of the freq of the radio signal.

* For satellite commn. this is the primary mode of signal loss.

* Even if no other sources of attenuation or impairment are assumed, a transmitted signal attenuates over distance because the signal is spread over a larger area This form of attennation is known as free space loss.

* For the ideal isotropic antenna, free space loss is

$$P_t/P_r = \frac{(4\pi d)^2}{\lambda^2}$$

$$= \frac{(4\pi df)^2}{c^2}$$

λ – wave length in meters

f – signal freq in Hz

d – distance from the transmitter

c – speed of light in vacuum

$c = 3 \times 10^8$ m/s.

Free-space path loss in decibels

$$L_{dB} = 10 \log \frac{P_t}{P_r}$$

$$= 10 \log \left(\frac{4\pi df}{c}\right)^2$$

$$= 20 \log \left(\frac{4\pi df}{c}\right)$$

$$= 20 \log (d) + 20 \log (f) + 20 \log \left(\frac{4\pi}{c}\right)$$

$$= 20 \log (d) + 20 \log (f) - 147.55.$$

* For other antenna, into account the gain of the antenna,

$$P_t/P_r = \frac{(4\pi)^2 (d)^2}{G_t G_r \lambda^2}$$

$$= \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

G_t – gain of transmitting antenna
G_r – " " receiving "

A_t – effective area of transmitting antenna
A_r – " " receiving "

Loss in dB $= 10 \log \frac{P_t}{P_r}$

$$= 10 \log \frac{(\lambda d)^2}{A_r A_t}$$

$$= 20 \log \left(\frac{\lambda d}{A_r A_t}\right)$$

$$= 20 \log [\lambda] + 20 \log [d] - 10 \log [A_r A_t]$$

$$A_e = \frac{\lambda^2}{4\pi} G_1.$$

Unit IV Satellite access and Coding Techniques

⟹ Modulation & multiplexing voice, Data Video

⟹ Analog - digital transmission system

⟹ Digital video broad cast

⟹ multiple access FDMA, TDMA, CDMA

⟹ PAMA & DAMA

⟹ Assignment methods

⟹ Compression

⟹ encryption

⟹ Coding schemes.

Modulation and multiplexing :-

* The various signal processing techniques such as encoding, modulating, combining and formatting performed for transmission to satellite from earth station is performed.
* The first is the initial analog signal either speech from the telephone or modulated data from a low speed data terminal such as pc model transmitted thro' local telephone cable.

* The second level of processing occurs the analog signal is converted to a digital signal or freq. shifted, in both cases for subsequent multiplexing.

* The 3rd & 4th levels of processing occur when a composite, multiplexed multichannel signal has been formed for bulk transport at a switching node such as end office (EO) or of an inter exchange carrier (IC)

Voice, Data and Video signal :-

* There are types of signal transmitted over satellite channels.

1. Telephone speech (or) voice signal
2. Datal signals of various types.
3. video signal both broadcast quality and teleconferencing quality

* The telephone signal is an audio signal occupying a B.W upto 20KHz. It results as electrical signal by talking into telephone handset which acts as acoustic to the electric transducer

* Characteristics of telephone signal

* Bandwidth — 300 — 3400 Hz.
* Nominal freq. spacing / channe - 4KHz.
* SNR - 50 dB
* Dynamic ~~range~~ = ~ 45 dB
* Interference level — 60 — 65 dB
* Speech activity = 30 - 40%.
* peak to average ratio = 19 dB
* Transmission rate = 4.8 to 64 kb/s
* Bit error rate = 10^{-4}

* Transmission rate and bit error rate are the characteristics for digital signal.

DATA signal :-

* Alphabetical ~~characteristics~~, numerals special characters, text and image are data. It is classified into 3 ranges.
  - ⟹ narrow band data ($\leq$ 300 b/s)
  - ⟹ Voice band data (300 b/s to 19 kb/s)
  - ⟹ wide band data > 19 kb/s.

* Narrow band data begins at telegraphy rates include a wide range of common applications.

* Data of many types such as facsimile and transaction services are supported at rates up to 19Kbps using data modem.

* Wide band data application such as e-mail, file transfer, computed aided design and video and teleconference utilize high speed transmission capabilities offered by satellite, fiber optics and digital radio channels.

Video signal :-

* There are two types of video signal transmitted thro satellite.

1. Broadcast quality commercial television
2. Business teleconference television.

* The commercial broadcast signals are high resolution, high quality signals requires large analog b.w or high data

* The business video signal uses much lower data rate (< 1.5 mb/s) and a great deal of signal processing is required to reduce the data rate.

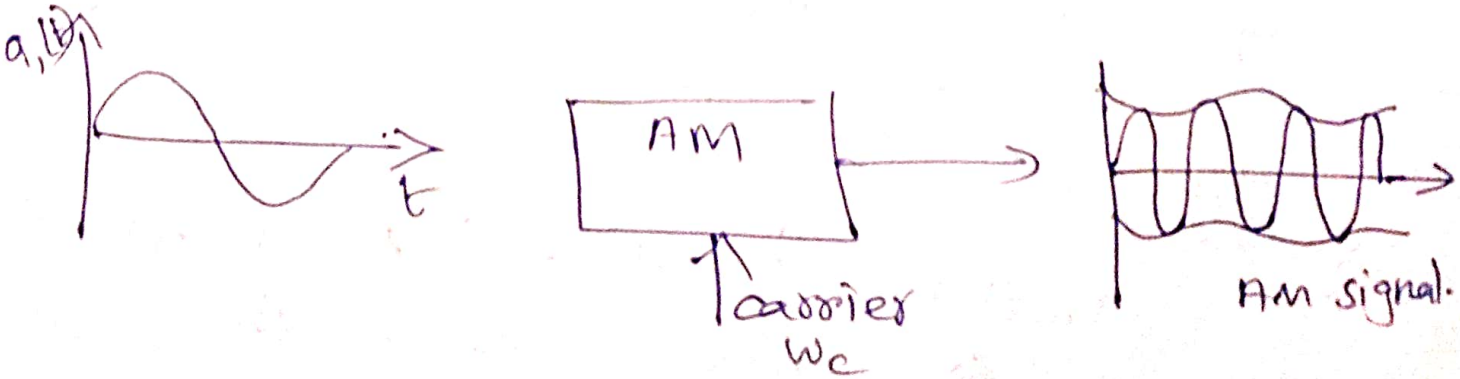
Analog Transmission System :-

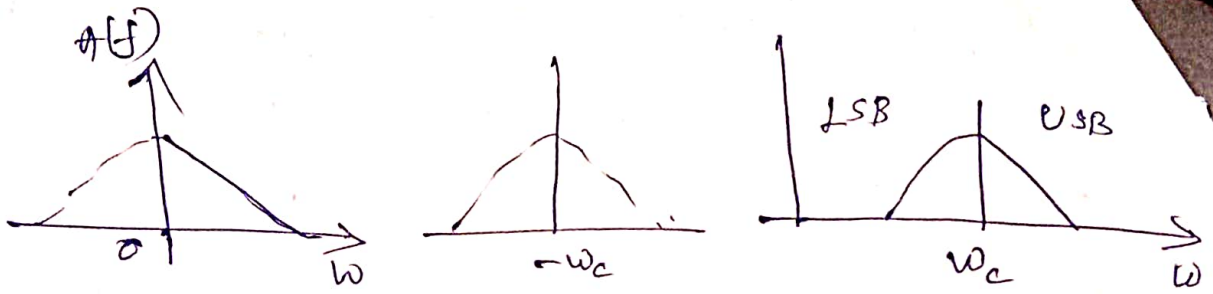
* Analog transmission through satellite is accomplished by two techniques.

1. multiple channel per carrier (mcpc) uses Amplitude modulation
2. single channel per carrier (scpc) uses frequency modulation.

Amplitude modulation :-

* Amplitude modulation is generated using a product modulator. The amplitude of the carrier is varied with the message signal.





freq. domain.

* conventional AM is not efficient. Since it transmits the information less signal carrier which consumes more transmitted power
* It is improved by attenuating the carrier signal prior to transmission.
* If carrier can be recovered by a narrow band filter, coherent detection performed.

DSB-SC :- (Double side band suppressed carrier)

* B.W = $2f_m$
* This AM signal may be demodulated after passing thro a channel using envelope detection.

SNR :-

$$a_m(t) = \{k\, a_s(t) + 1\}\, A_c \sin(\omega_c t + \alpha)$$

α - phase angle of the carrier

K - Scaling factor

$a_s(t)$ - modulating payload signal

f_c - carrier freq.

A_c - Unmodulated carrier.

* For AM, $Ka_s(t) + 1$ can not be allowed to go below zero.

* When the modulating signal is a sine wave with angular freq. w_s and $K = m$

$$a_m(t) = (m \sin w_s t + 1) A_c \sin w_c t$$

m - modulation index.

$m = 1$, 100% modulation is achieved.

* The effective amplitude of modulated carrier is 0 to 2A

* The total signal power is given by

$$P = \frac{3}{2} C$$

C - power at carrier freq.

* The side band power divided between the 2 side band as C/4

* The total poise power in the receiver is

$$N = N_0 2f_m$$

N_0 – uniform power spectral density

* This noise appears at the output of the demodulator as a noise power

$$N_b = KN$$

* If S_U & S_L are upper & lower side band powers

$$S_b = S_L = C/4$$

* Each of these produce demodulate signal power

$$S_{bu} = S_{bl} = K\,C/4$$

* Each of these produce demodulate signal power

$$S_{bu} = S_{bl} = K\,C/4$$

* However each side band is an image of the identical modulating signal & thus the o/p signal power is

$$S_b = 2(S_{bu} + S_{bL}) = KC$$

For $m=1$ and CNR are

$$S_b/N_b = C/N = \frac{C}{N_0 B}$$

$$B = 2f_m$$

$$\frac{S_b}{N_b} = m^2 \frac{C}{N}$$

Frequency modulation :-

* It is used for commercial satellite communication for telephony and video transmission.

FM is generated by varying the frequency of carrier w.r.t the amplitude of the message signal.



* B.W expansion is directly proportional to the modulation index.

$$B.W = 2f_m(m+1)$$

$$S/N = 3m^2 \frac{B}{2f_m} \frac{C}{N} P.W$$

P - factor for improvement due to pre-emphasis

W - corresponding factor for noise weighting.

* If $m > 0.6$ FM delivers noise performance superior to AM for equal power and equal noise power density

* If signal power is uniform at all frequencies, SNR in high freq. part of the spectrum is poor compared to that for lower freq. components.

* To equalize the performance over the full range of base band frequencies, pre-emphasis / de-emphasis is used.

* pre-emphasis shapes the modulating signal spectrum by amplifying the higher freq. signals relative to the lower freq. signals.

* In satellite telephony transmission, FM is used in SCPC and MCPC.

* In MCPC system, multichannel FDM baseband assembles are modulated on FM carriers.

$$\frac{S}{N} = \left(\frac{f}{f_m}\right)^2 \left(\frac{B}{b}\right) \left(\frac{S}{N}\right) \text{ P.W}$$

$\frac{S}{N}$ – signal to noise ratio in voice band

f – Equivalent single channel rms test tone deviation

f_m – highest modulating freq.

B – RF B.w of modulated signal.

b – Voice signal bandwidth.

$(C/N)_t$ – carrier to noise ratio required to exceed FM Threshold

P – Pre-emphasis improvement.

W – Subjective weighting improvement.

* overall performance is given by

$$S/N = 3\left(f/f_m\right)^2 \left(\frac{B}{2f_m}\right)\left(C/N\right)_t I_c \cdot P \cdot W$$

I_c – is the additional factor due to the addition of two deviation cases in the end-to-end circuit.

Digital transmission systems :-

Advantages of digital systems :-

* Digital signals are less susceptible to waveform distortions, cross talk, noise when compared to analog signals.
* If the transmission rate is increased, the quality is improved.
* Analog signal is converted to digital signal. so various types of voice, data video signals can be combined.

* Digital switching technology reduces the cost and increases the efficiciency
* Digital signals are secured.
* flexibility is good

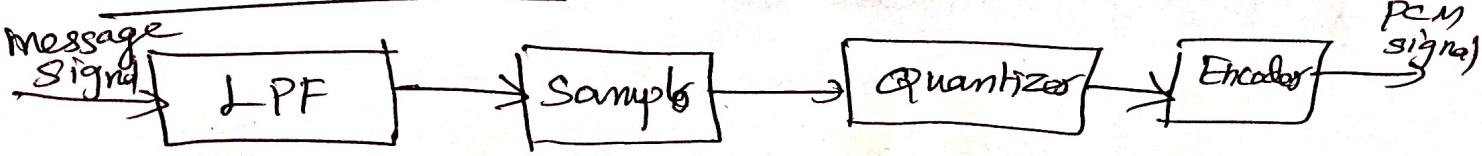
System types :-

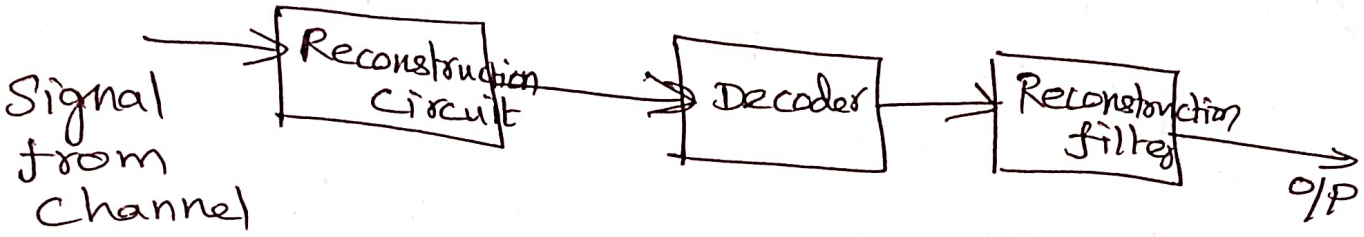
* Digital systems are used in SCPC and MCPC systems.
* FDMA, TDMA are used in INTELSAT network.
* In digital SCPC system analog voice freq. signal is converted into digital form using some coding techniques (PCM, Delta modulation; etc).
* In MCPC system, after converting analog into digital multiple voice signals are combined using TDM.

Source coding :-

PCM : Pulse code modulation :-

Transmitter :-





* It is a digital modulation Techniques. It converts the analog speech waveform into sequence of multi digit binary numbers (PCM converts the llel bits obtained due to quantization process to a serial bit stream)
* This bit stream is seqnence of binary 1's and zero's. This bit stream then modulates some carrier and then is transmitted.
* PCM coder/decoder is known as CODEC.
* It is used to reconstruct the analog signal on the receiving side.
* Because of conversion of an analog to signal to digital, some noise is permanently introduced in the signal.
* Noise reduction cannot be completely eliminated

* $q = 2$

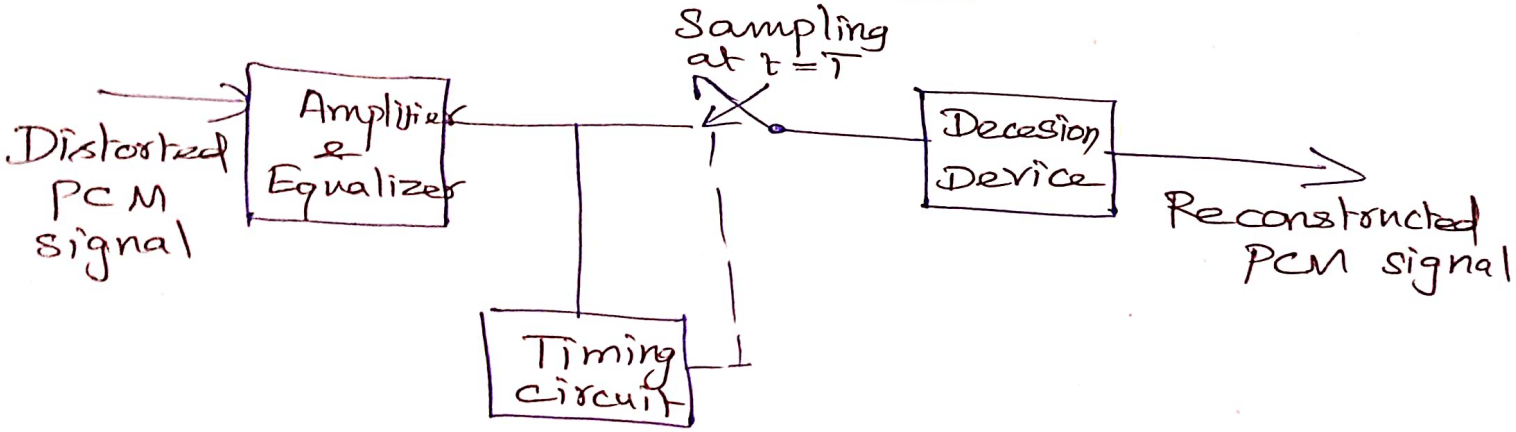
v – no. of bits per sample

f_s – sample per second

No. of bits per second = (No. of bits/sample) × (no. of sample/sec)

$= v f_s$.

Regenerative Repeater :-

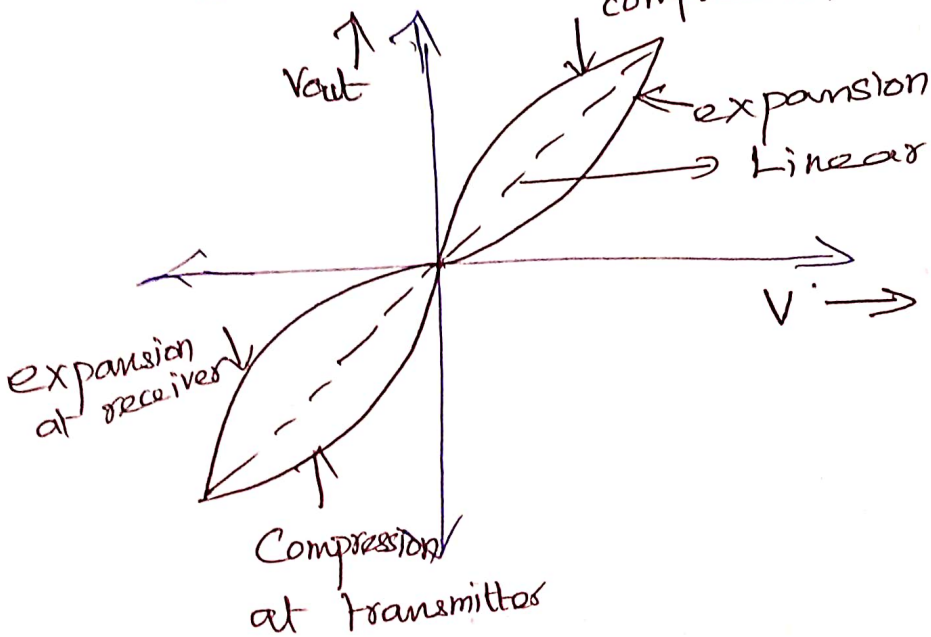


* When the PCM signal is transmitted over the channel, it gets distorted due to channel noise.
* Hence regenerative repeaters are used at regular spacing to reconstruct the PCM signal back.
* It receives the noisy PCM signal with the help of timing circuit, performs amplification and equalization on it and construct new PCM signal with help of timing circuits.

Companding in PCM :-

* The compression of the signal at transmitter and expansion at receiver is commonly called as companding.

1. μ-Law companding for speech signals
2. A-law Companding.



Advantages :-

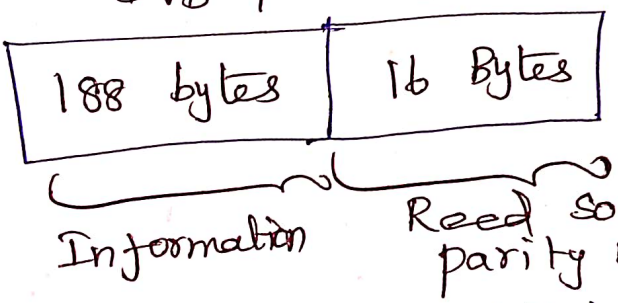
* Robustness to noise and interference.
* Efficient regeneration
* Efficient SNR and b/w trade-off
* Uniform format
* Ease add and drop
* Secure.

Digital Video Broadcast :-

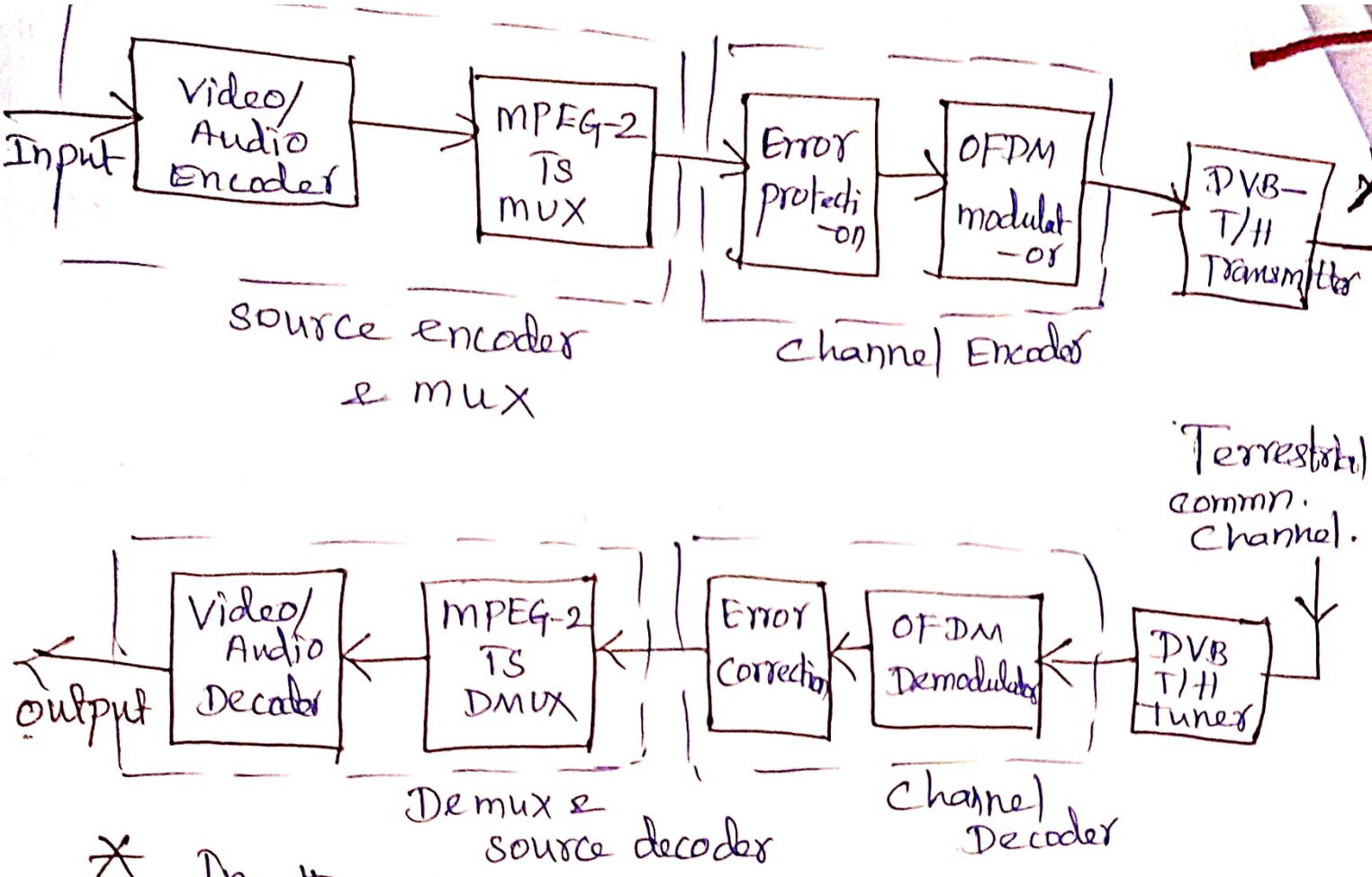
* The DVB project was launched on 10th September 1993 & 1995 it was finished.
* DVB aims to provide standards and specifications for digital television by using satellite, cable, terrestrial microwave, DSL, etc.
* Several sub-standards are
    * DVB -S (satellite) - using QPSK - 40 Mb/s
    * DVB -T (Terrestrial) - QAM - 50 Mb/s
    * DVB -C (Cable) - OFDM - 24 Mb/s
* DVB is actually a supporting mechanism for MPEG.
* One MPEG stream which needs higher instantaneous data can steal capacity from another with spare capacity.
* The DVB stream consists of a series of fixed length packets which make up a Transport Stream. It consists of a series of packets.
* It carries higher layer packets derived from MPEG stream.

* Blocks of data is used to carry signalling and controlling information.
* DVB packets format consists of 204 bytes 188 bytes carry information and the other 16 bytes carry an outer Reed Solomon code.
* The pocket is short and can survive a noisy channel subject to interference.

DVB packet format.



* DVB-T means for Digital videobroadcasting - Terrestrial. It is the DVB European consortium standard for the broadcast transmission of digital terrestrial television
* This system transmits a compressed digital audio/video stream, using OFDM modulation with concatenated channel coding ie (COFDM)
* The adopted source coding methods are MPEG-2 and H.264.
* The transmitter consists of source encoder with multiplexer, channel encoder and Transmitter



* In the terrestrial transmission of digital television signals, according to the DVB T/H standard, the modulation method is COFDM modulation (coded orthogonal Freq. Division multiplex. It means that OFDM modulation is preceded by channel coding FEC.

* AWGN (Additive white Gaussian noise) is always present during all the processing.

* Then the signal is transmitted via terrestrial transmission link with multi-path reception with various echo paths caused by reflection, additive noise AWGN, narrow band (or) wide-band interference

sources and Doppler effect and its frequency shift.

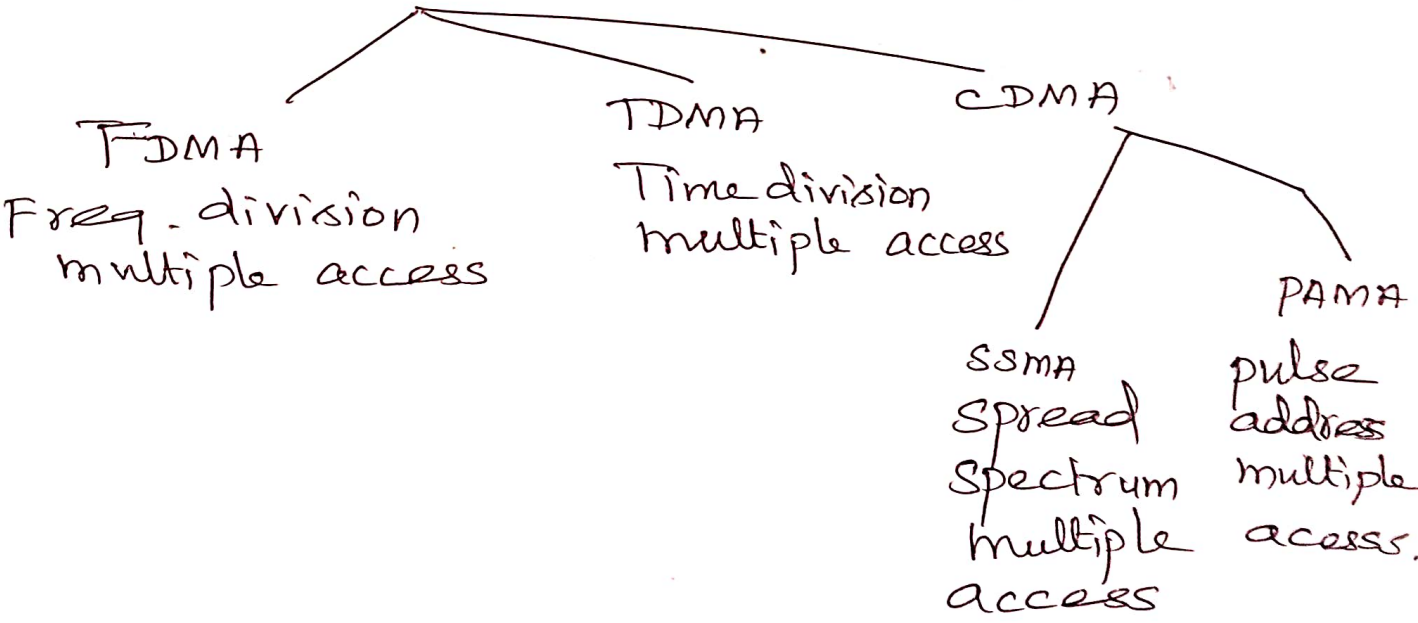
* The receiver consists of TV tuner with low noise level, channel encoder and de-multiplexer with selected program de-multiplexing and source decoding.
* DVB-T/H signal carries a pilot signals which can be used as measuring signals for channel estimation and channel correction in the receiver.
* Measuring the amplitude and phase distortion can be used to eliminate the transmission distortion.

Multiple access :-

FDMA, TDMA, CDMA.

* A transponder channel loaded with a single transmission from an earth station is known as single access mode of operation.
* A transponder is loaded with more than one number of carriers. This is known as multiple access.

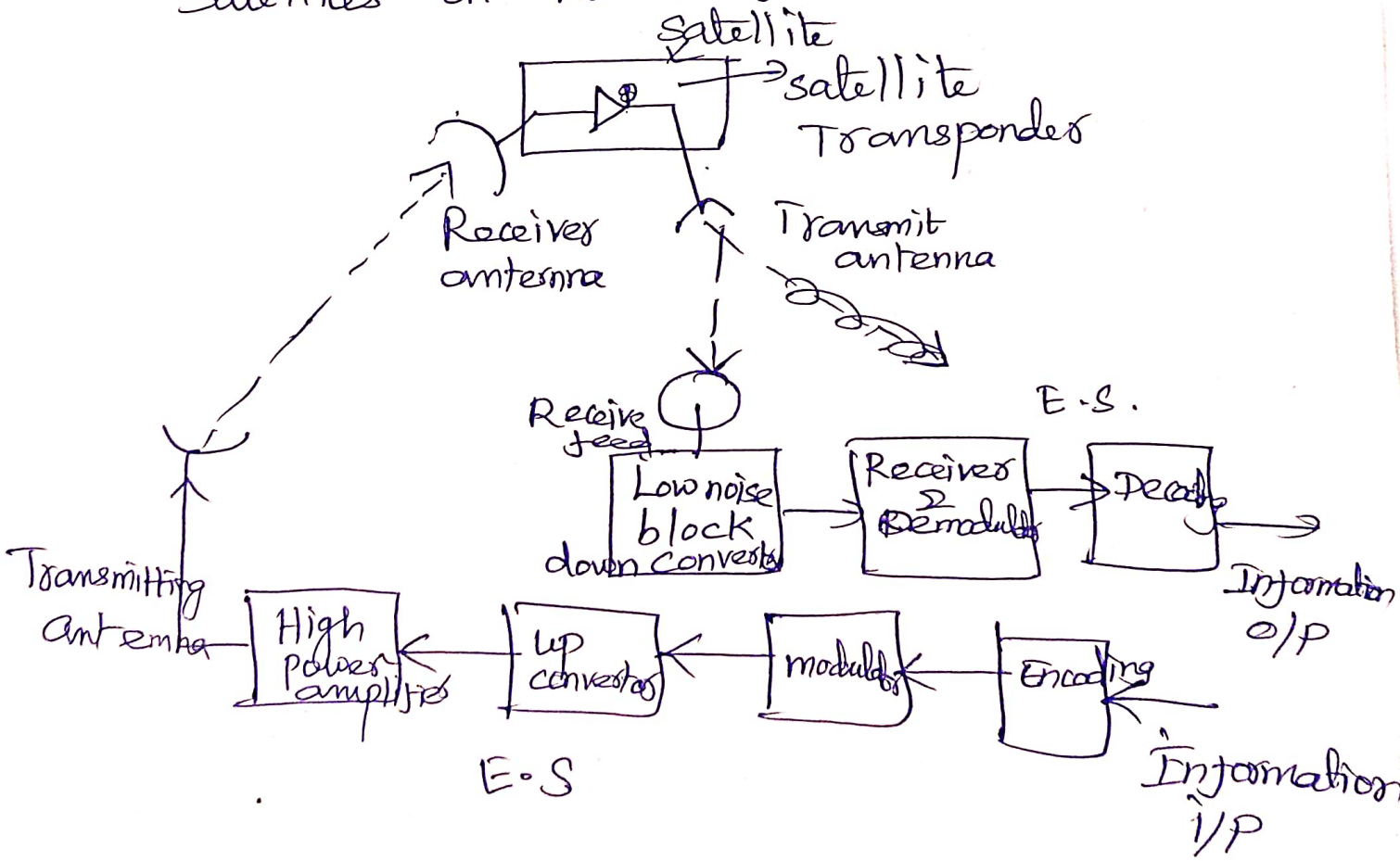
Types of multiple access :-



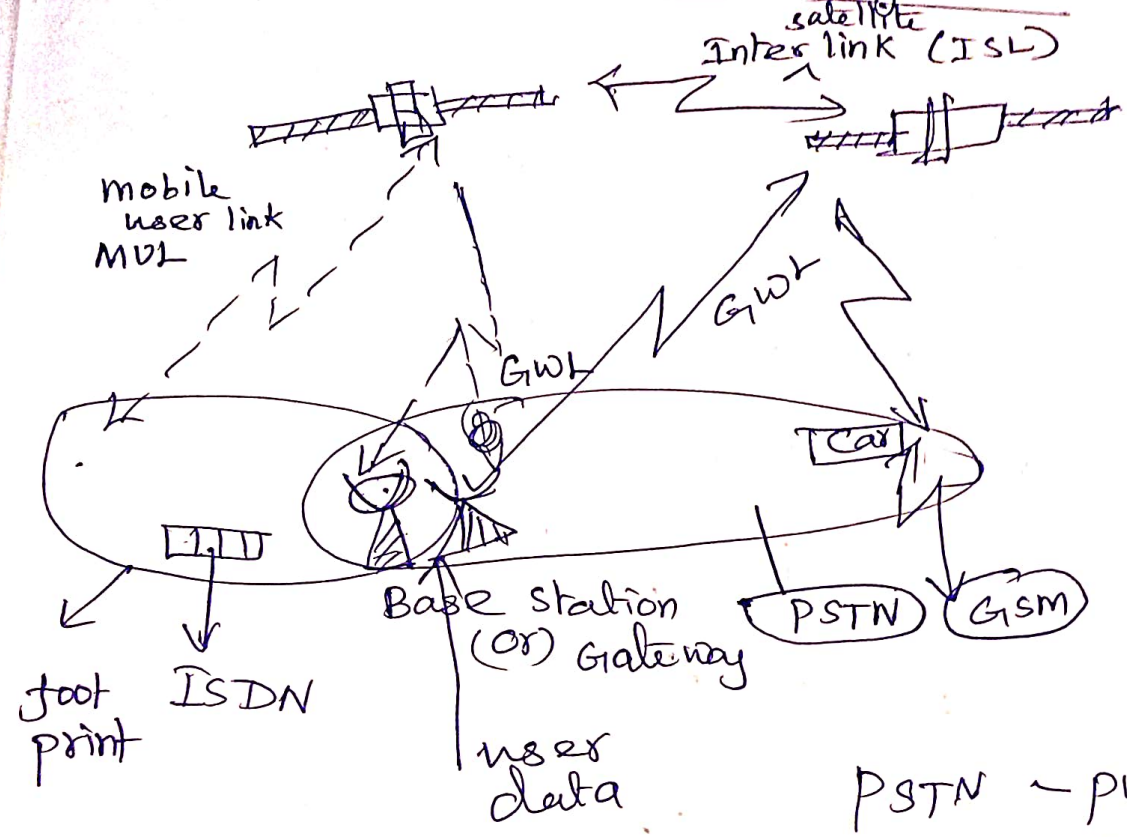
Link design with and without freq reuse

* Intra - orbital links : consecutive satellites on the same orbits.

* Inter orbital links : Connect two satellites on the different orbits.



Classical satellite system :



PSTN – public Telephone Switched n/w

ISDN – Integrated servic digital n/w.

Foot print – means

It is the area of the earth Visible to the satellite

foot print covers 3000 km diameter

GPS satellite covers 12,000 km dia meter

$$k(T_0 + T_e) = k T_0 (\text{G}) F$$

$$F = \frac{T_0 + T_e}{T_0} = 1 + \frac{T_e}{T_0}$$

$$F = 1 + \frac{T_e}{T_0}$$

$$T_e = (F - 1) \cdot T_0$$

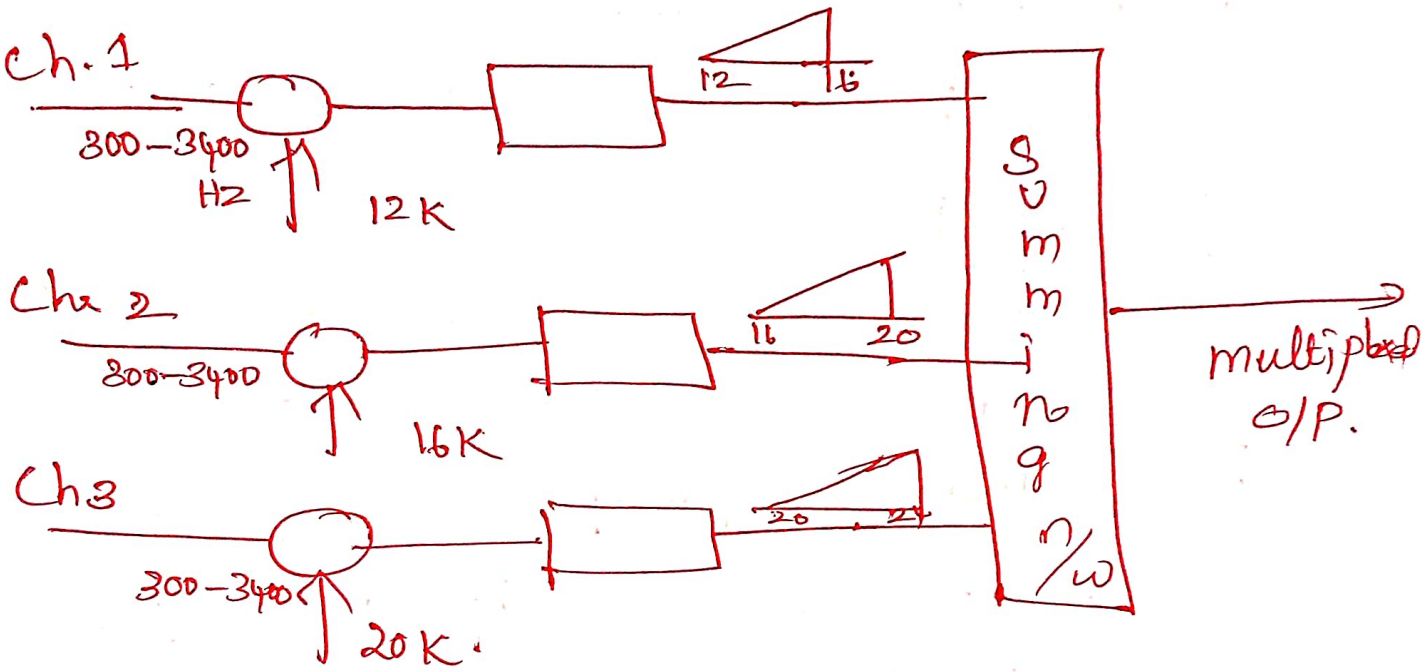
[F] – noise figure

$$[F] = 10 \log F$$

FDM : Freq. Division Multiplexing.

⇒ FDM is a technique in which large no.. of signals are combined for transmission in a single commn. channel.

⇒



⇒ Each telephone base band signal is modulated, on to a seperate subcarrier

⇒ The upper side bands are combined to form the freq. multiplexed signals.

⇒ The sub carrier freq. operation is 4KHz.

⇒ The upper side bands are selected by means of filtering.

⇒ 4 three channel multiplexed are termed as pre groups which is combind to form the 12 channel group

Group :- It consists of 12 voice freq. Channel each occupying 4KHz B.W in the multiplexed o/p

B.W = 60 to 108 KHz.

Super group :-

It consists of 60 voice freq. Channel

B.W = 312 to 552 KHz.

Basic master group :-

⇒ It is formed by FDM five super group together.

⇒ It consists of 300 voice freq. Chanel. It allows 8 KHz guard band b/w channels.

B.W = 812 to 2044 KHz.

Super master group :-

⇒ It is formed by FDM 3 basic master group. It consists of 900 VF channel

⇒ It allows 8 KHz for guard band b/w sidebands

B.W = 8516 to 12388 KHz.

Digital transmission system

⇒ Digital signals are coded representation of information.

⇒ binary code has two symbols 0 & 1

Binary waveforms for encoding digital data :-

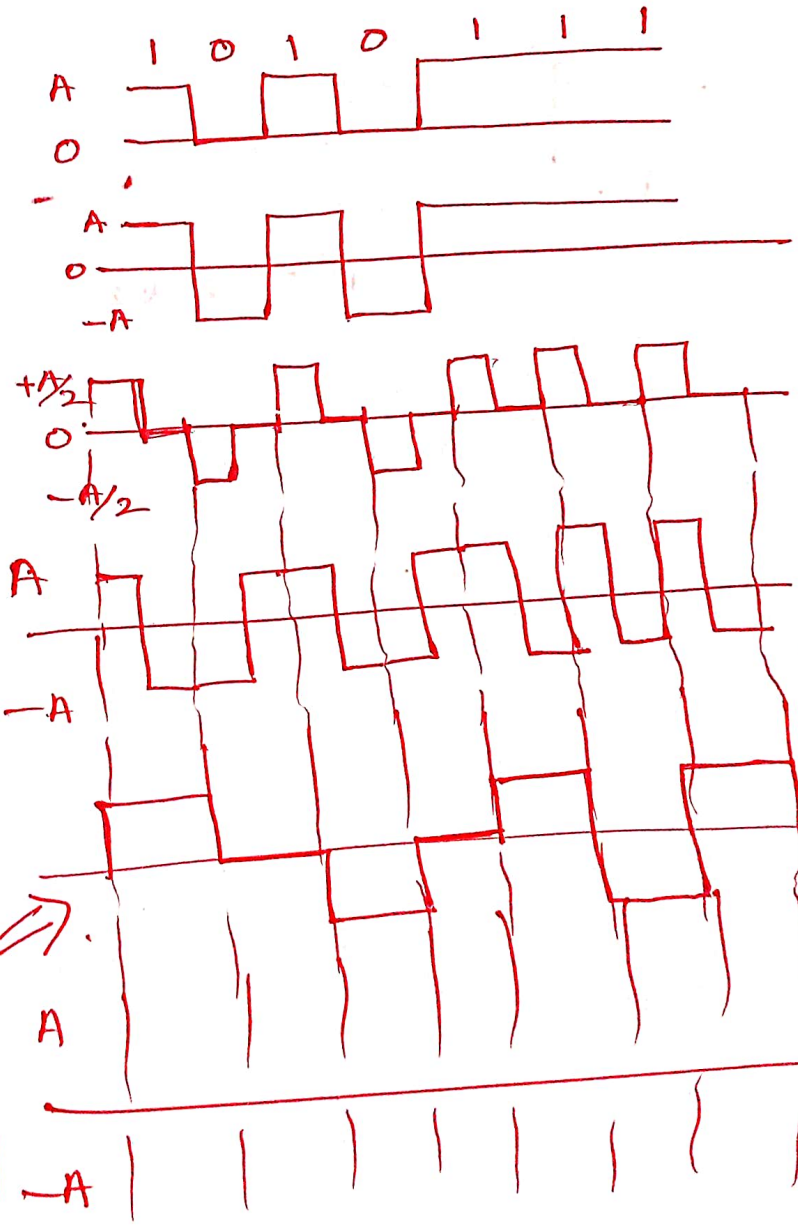
Unipolar NRZ

polar NRZ

polar RZ

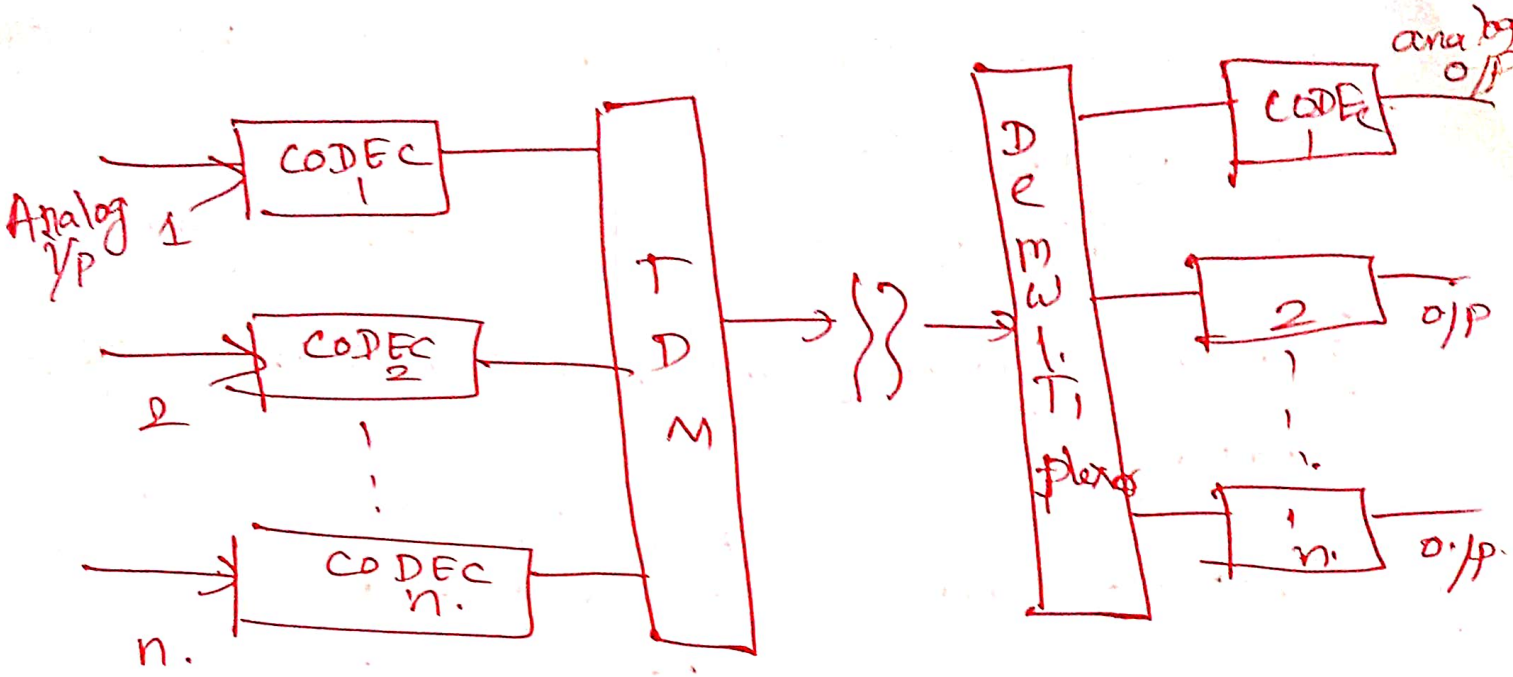
Split ~~ap~~ phase Manchester

Bipolar NRZ also called as Alternate mark inversion



PCM

See in commn. systems note



bit rate = 1.544 mbps.

Unit-V Satellite Applications.

⟹ INTET SAT
⟹ INSAT
⟹ VSAT
⟹ mobile satellite services
⟹ GSM, GPS, LEO, MEO
⟹ Satellite Navigational system
⟹ GPS - position location principles
⟹ Differential GPS.
⟹ Direct broadcast satellites
⟹ DBS/DTH.

INTEL SAT Series :-

* INTELSAT → stands for International Telecommunication satellite.

* It was created in 1964 and currently has over 140 member countries and more than 40 investing entities.

* INTELSAT satellites with increase in following parameters

* The capacity
* The no. of voice channels
* The design life time.

* Intel sat satellites are in geostationary orbit, they appear to be stationary to earth.

Regions :

* INTELSAT covers three main regions

⇒ The Atlantic Ocean Region (AOR)
⇒ The Indian Ocean Region (IOR)
⇒ The pacific Ocean Region (POR)

INTELSAT VII — VII/A Series :

* The series launched from Oct 1993 to June 1996.

VII series :

* planned for service in the POR and also for less demanding services in AOR
* When used in the AOR, the VII series satellite is inverted north for south. life time of these satellites ranges from 10 to 15 years depending on launch vehicles.

VII / A series:-

* It has a capacity of 22,500 two-way telephone circuits and 3 TV channels

* up to 112,500 two-way telephone circuits can be achieved with the use of digital circuit multiplication.

INTELSAT VIII – VII/A Series :-

* It was lamched over the period Feb 1997 to Jun 1998. Satellites in this series have similar capacity as the VII/A series, and the life time is 14 to 17 years.

INSAT :-

* INSAT – the Indian National satellite system is a series of multipurpose geostationary satellites lamched by ISRO to satisfy the telecommunications, broadcasting meteorology, and search and rescue operation.

* INSAT is the largest domestic communication system in the Asia pacific Region.

* It is joint Venture of the
⇒ Department of space
⇒ " " Telecommunications
⇒ " " India Meteorological
⇒ All india Radio and Doordarshan.

* INSAT provide Transponders in various bands (C, S, Extended C and Ku) to serve the television and communication needs of India.

INSAT 1 series :-

* INSAT system was commissioned with the launch of INSAT-1B in Aug 1983 (INSAT-1A, the first satellite was launched in April 1982 but could not fulfill the mission).

* INSAT made a revolution in India's television and radio broadcasting, telecommunications and meteorological sectors.

INSAT 2 series :-

* Among the 24 satellites launched in the course of the INSAT program, 10 are in still in operation.

* It is also carries a very resolution Radio meter (VHRR) with imaging capacity in the visible (0.55 – 0.75 μm), Thermal infrared (10.5 – 12.5 μm) and water vapour (5.7 – 7.1 μm) Channels and provides 2×2 km, 8×8 km and 8×8 km ground resolution respectively.

INSAT 3 series :-

* The multipurpose satellite, INSAR-3A was launched by ariane in april 2003. It is located at 93.5° east longitude

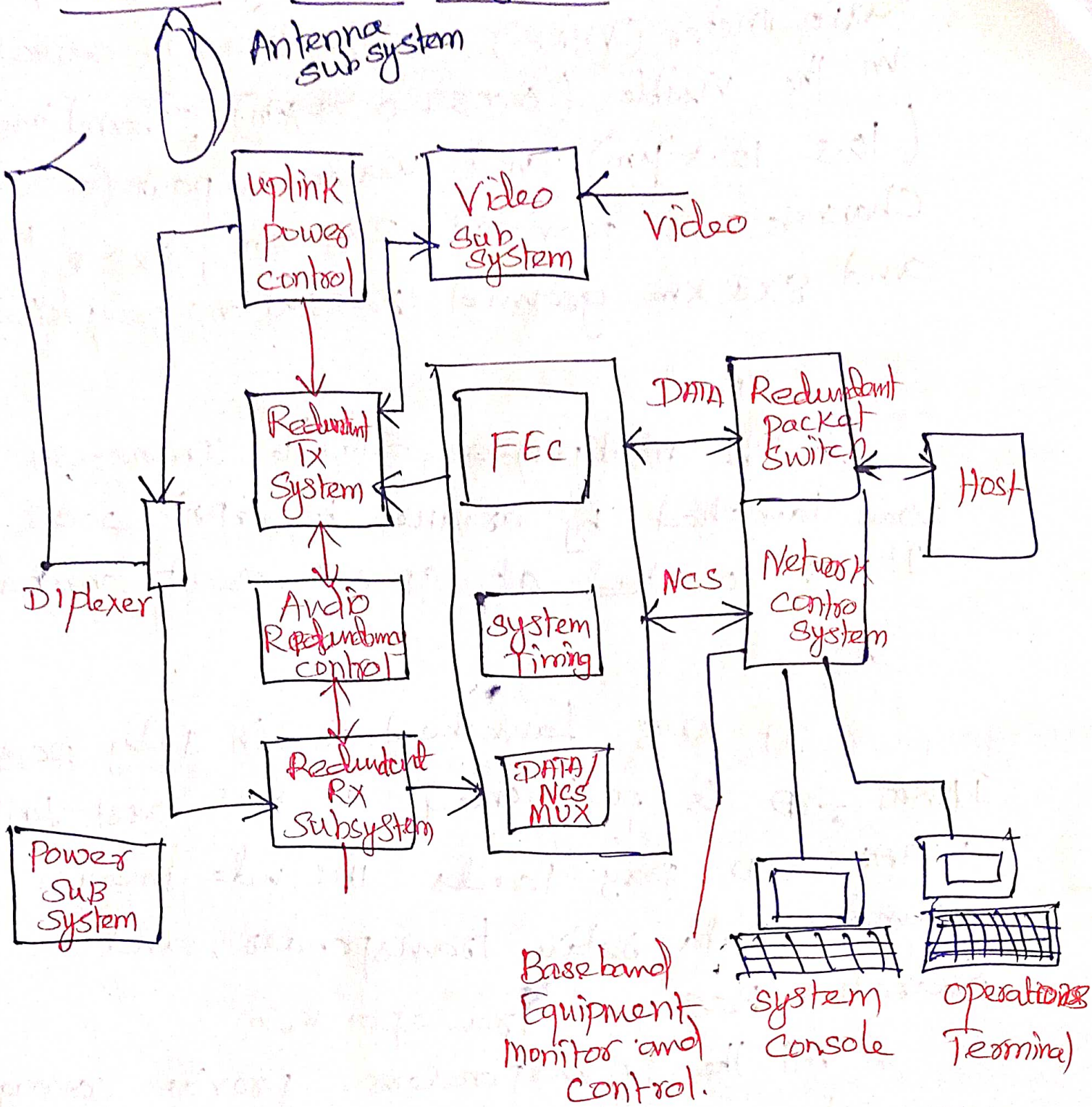
INSAT-3D :-

* It was launched in in July 2013 INSAT-3D is positioned at 82° east longitude. INSAT-3D pay loads include imager, sounder, Data relay transponder and Search & Rescue transponder.

* All the transponders provide coverage over large part of the Indian ocean region covering India, Bangaladesh, Bhutan, maldives Nepal, Srilanka for rendering distress alert services.

Telecomm. in 1982.

VSAT :- Block diagram



* VSAT stands for very small aperture terminal system. The trend is toward even smaller dishes not more than 1-5 m in diameter.

* VSAT n/w consists of a hub station which provides a broadcast facility to all the VSATs in the network. and VSAT

Applications :-

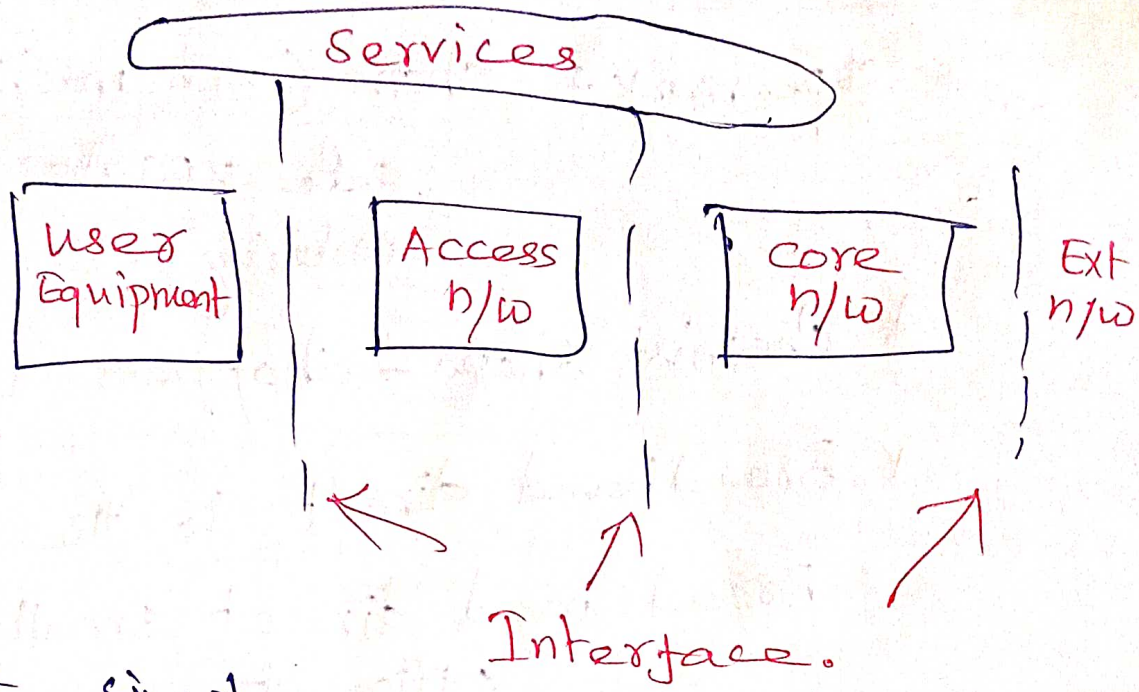
* Supermarket shops (ATM machines, stock sale updates and stock ordering)
* chemist shops - Shoppers Drug mart - pharmaprix.
* Broadband direct to the home
  Broad band direct small business office etc.
* Internet access from on board ship.

Mobile Satellite Services :-

* mobile satellite services (MSS) refers to n/ws of commn. satellite intended for use with mobile and potable wireless telephones.
* 3 major types
  1. Aeronautical MSS
  2. Land MSS
  3. Maritime MSS.

Global system for mobile commn. (GSM)

* mobile commn. was presented to ECPT (European conference of postal and Telecommn. in 1982.



* A simple n/w architecture for GSM which includes

* User equipment
* Access n/w
* Core n/w
* Interface

* User equipment

* It ~~interfaces~~ the user, handles radio freq and contains SIM & mobile equipment called as mobile station.

1. SIM
2. mobile equipmen] → MS (mobile station).

SIM (subscriber Identity module) contains encryption key and personal data.

* User is identified thro' IMSI (International mobile subscriber identity)

* Access network :- It provides radio access to the n/w and it contains BTS and BSC

BTS (Base transceiver Station / Base station)
⇒ coverage area of one BTS is a cell

BSC (Base Station controller)
⇒ controls number of BTS

* Core network :- It contains MSC & Gmsc

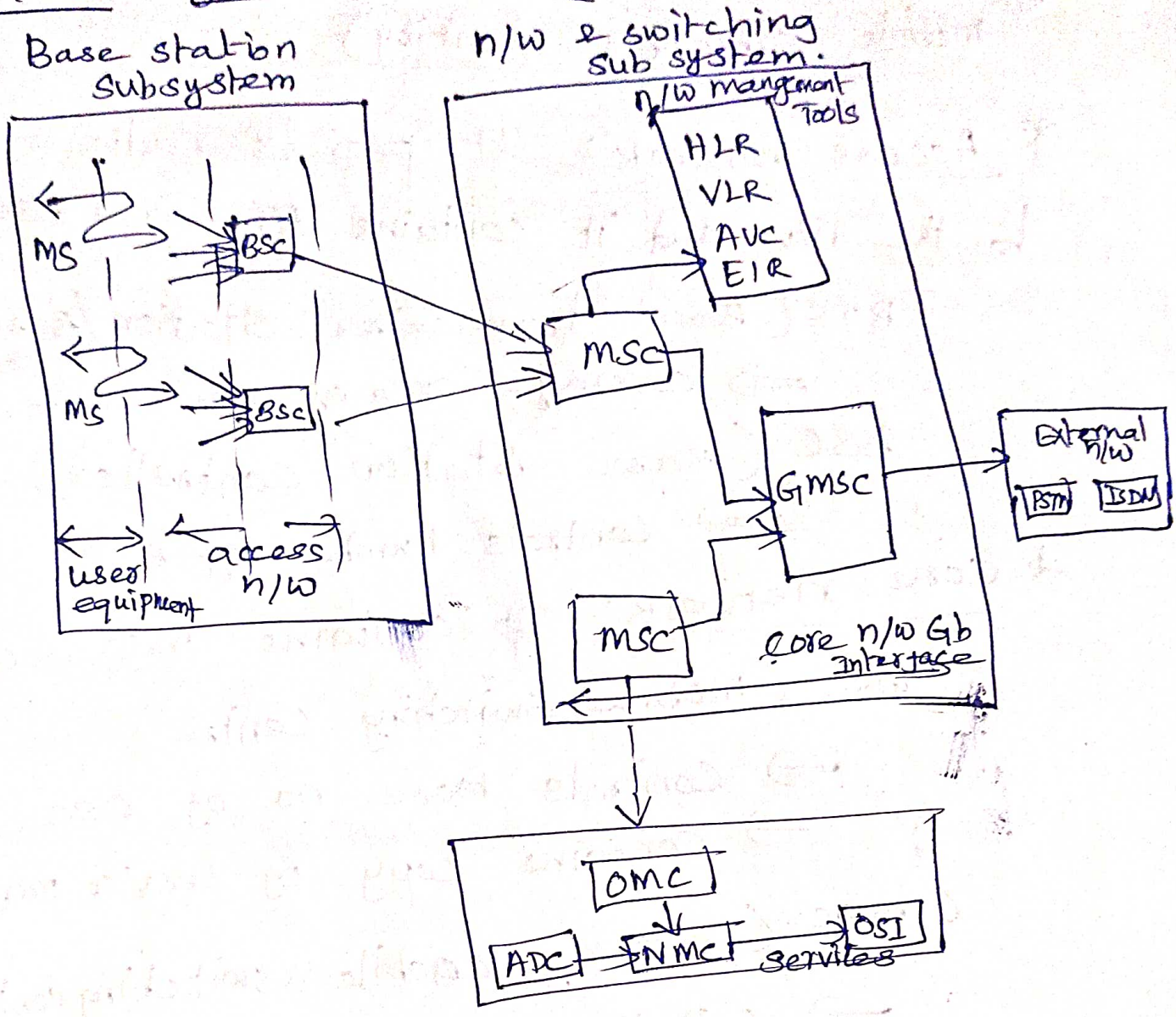
MSC (mobile switching centre)
⇒ controls more no.. of BSC
⇒ contains copy of service profile

Gmsc (Gateway mobile switching centre)
⇒ switching utles
⇒ connection to external networks like PSTN (or) ISDN

* Interface There ar four types of Interface

Um – air interface between MS & BS
Abis – air " " BTS & BSC
A – air interface access and core n/w
Gb – air interface b/w access & packet switched core n/w.

GSM system overview :-



GPS system :-

* The location information can be obtained by the GPS system using the two systems.

1. Navigation system
2. position calculation system.

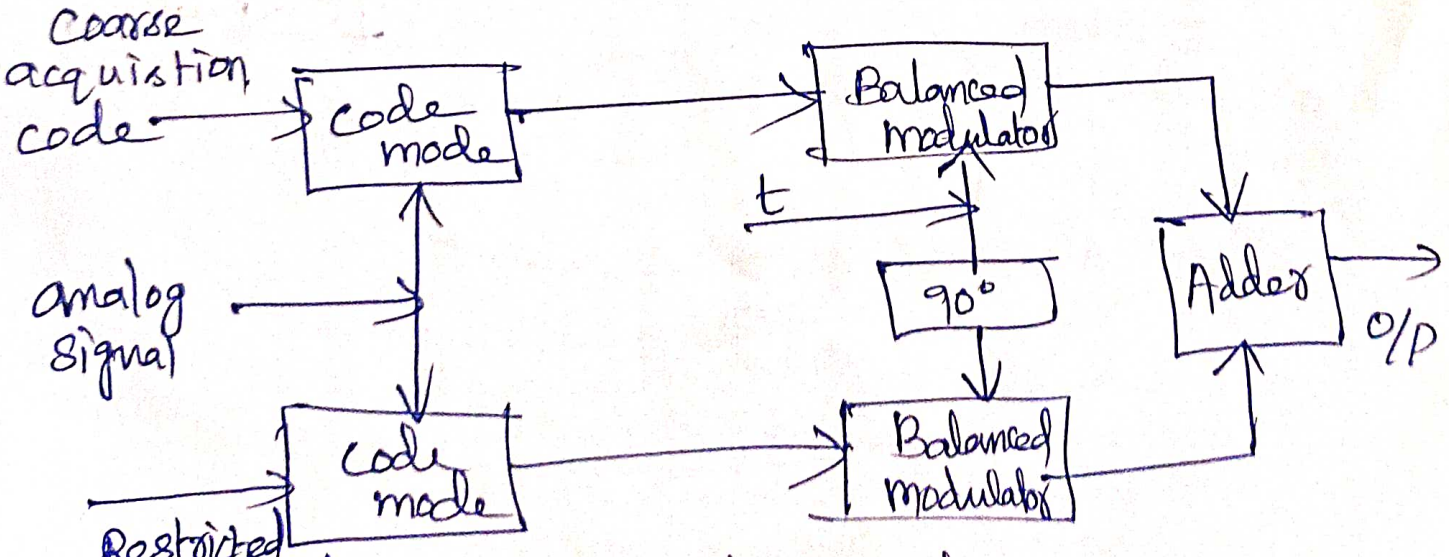
Navigation system :-

* This systems sends two types of data

1. Almanac → sends time of station Information.
2. Ephemeris → sends orbital Information.

* 37500 bits navigational message in 12.5 min at 50 bps is transmitted.

* Two types of codes are used.

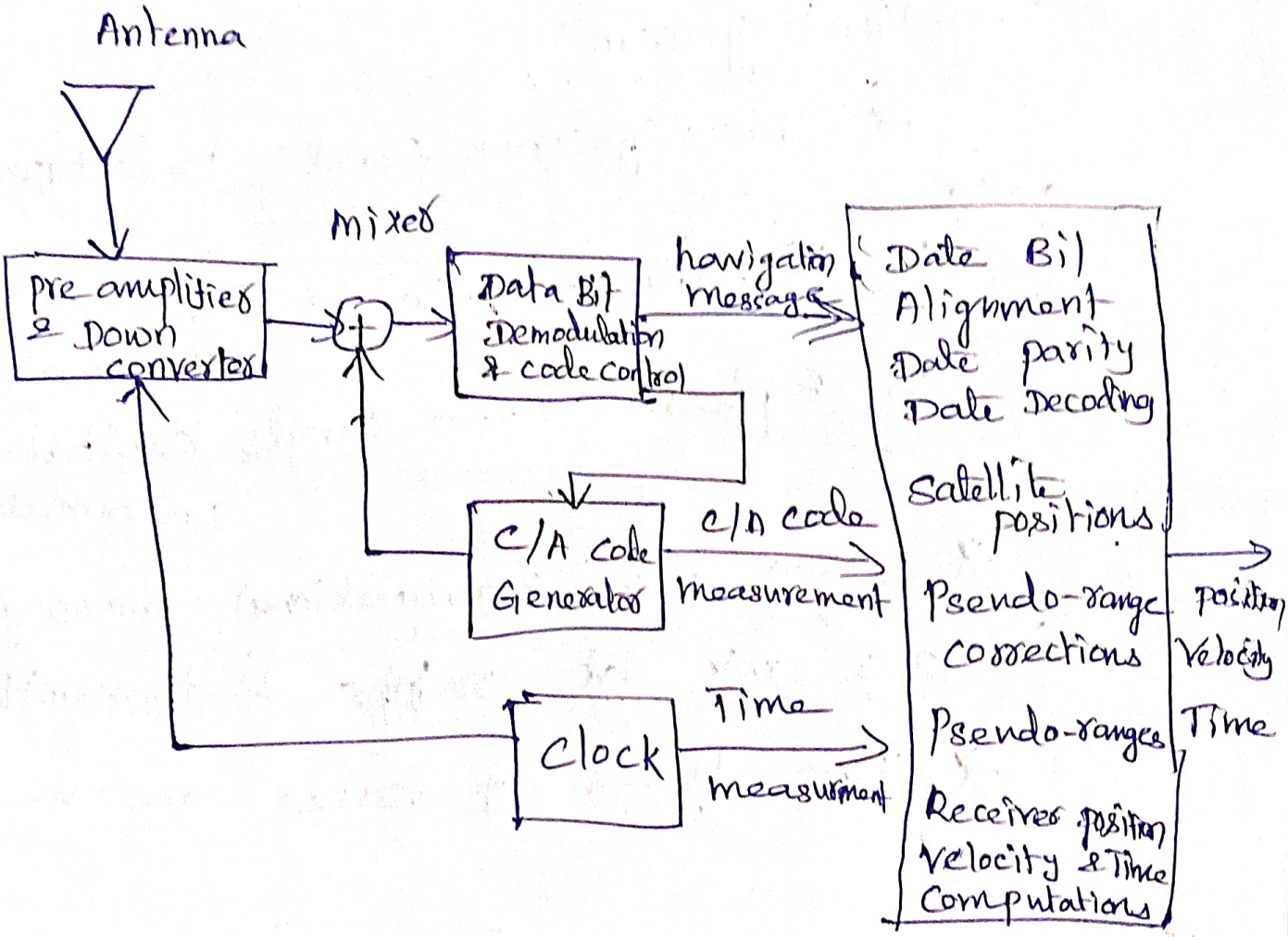


signal generator.

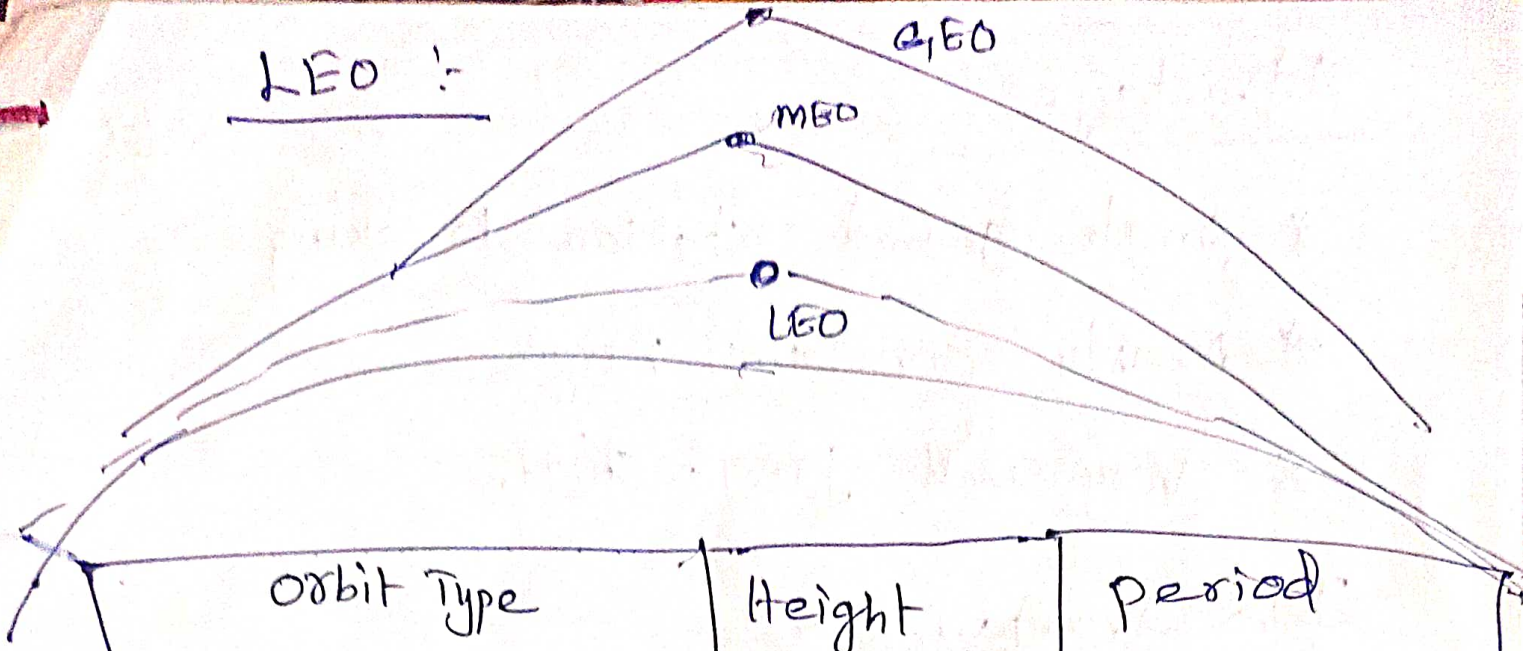
⇒ C/A code → public uses, 1.023 MHz code broadcast → repeats every ms

⇒ RP code → military purpose
10.23 MHz code broadcast
Repeats once in a week.

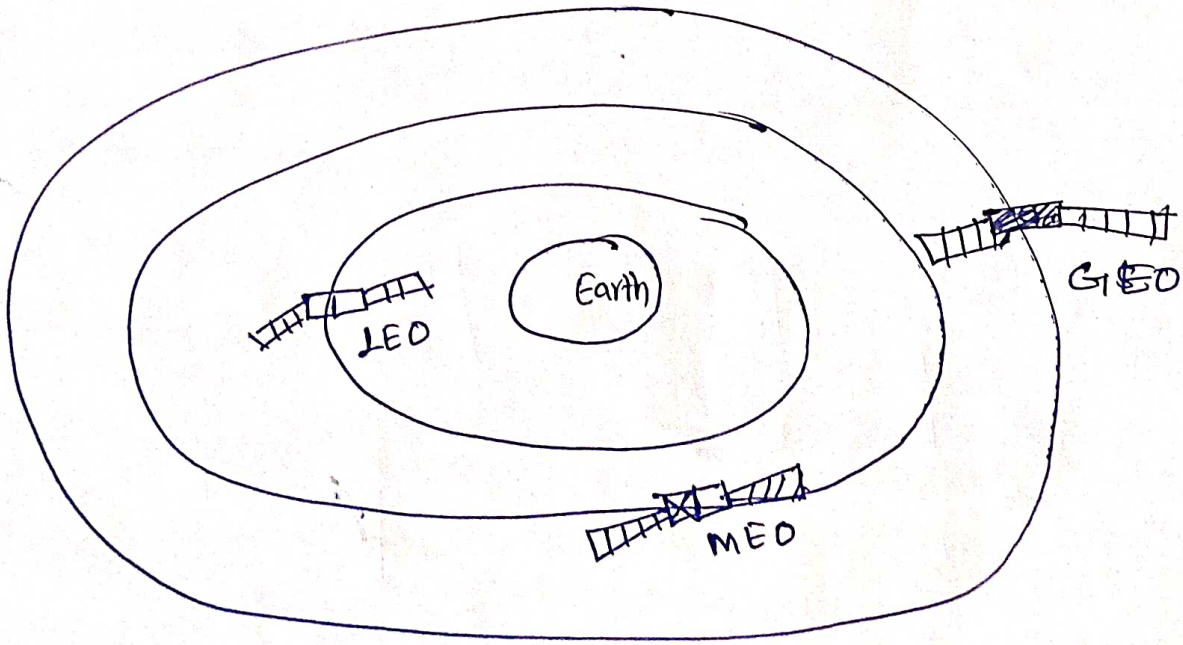
GPS Block diagram :-



LEO :-



Orbit Type	Height	period
LEO – Low earth orbit	500 – 1000 km	1.6 to 1.8 hrs
MEO – medium earth orbit	8000 – 12000 km	6 hrs
GEO – Geo stationary orbit	36000 km	24 hrs



Advantages :-

* Simple ground station tracking
* Nearly constant range
* Very small freq. shift.

Disadvantages :-

* Transmission delay in order of 250ms
* Large free space loss
* No polar coverage

Satellite Navigational systems

Benifits :-

* Enhanced safety
* Increased capacity
* Reduced Delays.
* Increased flight Effiiciencies.
* Increased schedule predictability
* Environmentally Beneficial procedures.
* Using ICAO GNSS Implementation strategy and ICAO standards and Recommended practices.
* GPS Aviation Use approved for over a Decade.

Aircraft Based Augmentation systems (ABAS)

* Space Based Augmentation system (SBAS)

Since 2003

Wide Area Augmentation system (WAAS)

Augmenting GPS

* Development of GNSS Ground Based Augmentation system (GBAS) continues.
* Local area Augmentation system (LAAS)
* GNSS is cornerstone for National Airspace system.

Bit rate $= 2 \times 20 \times 10^6 = 40$ mbps

Direct broad cast satellites :- (DBS)

* satellite provides broadcast transmission by making antenna foot prints cover large areas of the earth.

* The idea of using satellite to provide direct transmissions into the home has been around for many years and the services provided are known as Direct broadcast satellites service includes audio, video and television and Internet services.

orbital Spacing :-

* orbital spacing is 90° for high power satellites, considering the interference

* It should be noted that although the DBS services are spaced by 90° clusters of satellites occupy the nominal orbital positions.

power Rating & no. of transponders

* power :- 51 - 60 dBW ie 57 dBW

* 32 transponders used.

* If all 32 are in use, each will operates at the lower power rating of 120w.

* By doubling up (240 w) the power, the no. of transponder is reduced to half (ie 16)

Frequencies and polarization :-

* For High power satellites :-
  * uplink freq 17.3 to 17.8 GHz
  * Downlink " 12.2 to 12.7 GHz

* For medium power satellites use in point to point comm. with additional use of DBS.
  * uplink freq - 14 to 14.5 GHz
  * Downlink freq - 11.7 to 12.2 GHz

Transponder capacity :-

For 24 MHz

$$R_{sym} = \frac{B_{IF}}{1+\rho}$$

ρ - roll off factor $= 0.2$

$$R_{sym} = \frac{24 \times 10^6}{1+0.2} = 20 \times 10^6 \text{ sym/sec}$$

Bit rate $= 2 \times 20 \times 10^6 = 40$ mbps

* Bit rate for digital TV

* The bit rate for digital TV depends very much on picture format.

* For eg

⟹ 16 bits per pixel = 2^{16} = 65536 colours

⟹ HDTV has a resolution format of 1920 x 1080 pixels.

MPEG Compression standards :-

* MPEG is a Group International Standards of organisation (ISO / IEC) that undertook job of defining Standards for transmission and Storage of moving pictures and Sound.

* There are many version of MPEG such as

MPEG-1
MPEG-2
MPEG-4
MPEG-7.

* In DBS system MPEG-2 is used for video compressions. Here analog components from Red, blue, Green is converted into luminance (Y) and 2 chrominance components (C_r & C_b).

$$\begin{bmatrix} Y \\ C_r \\ C_b \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.4186 & -0.0813 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

* Compression is also achieved thro motion estimation. Frames in MPEG-2 are designed as I, P, B frames.

I - frame is independent frame and it is not comparable.

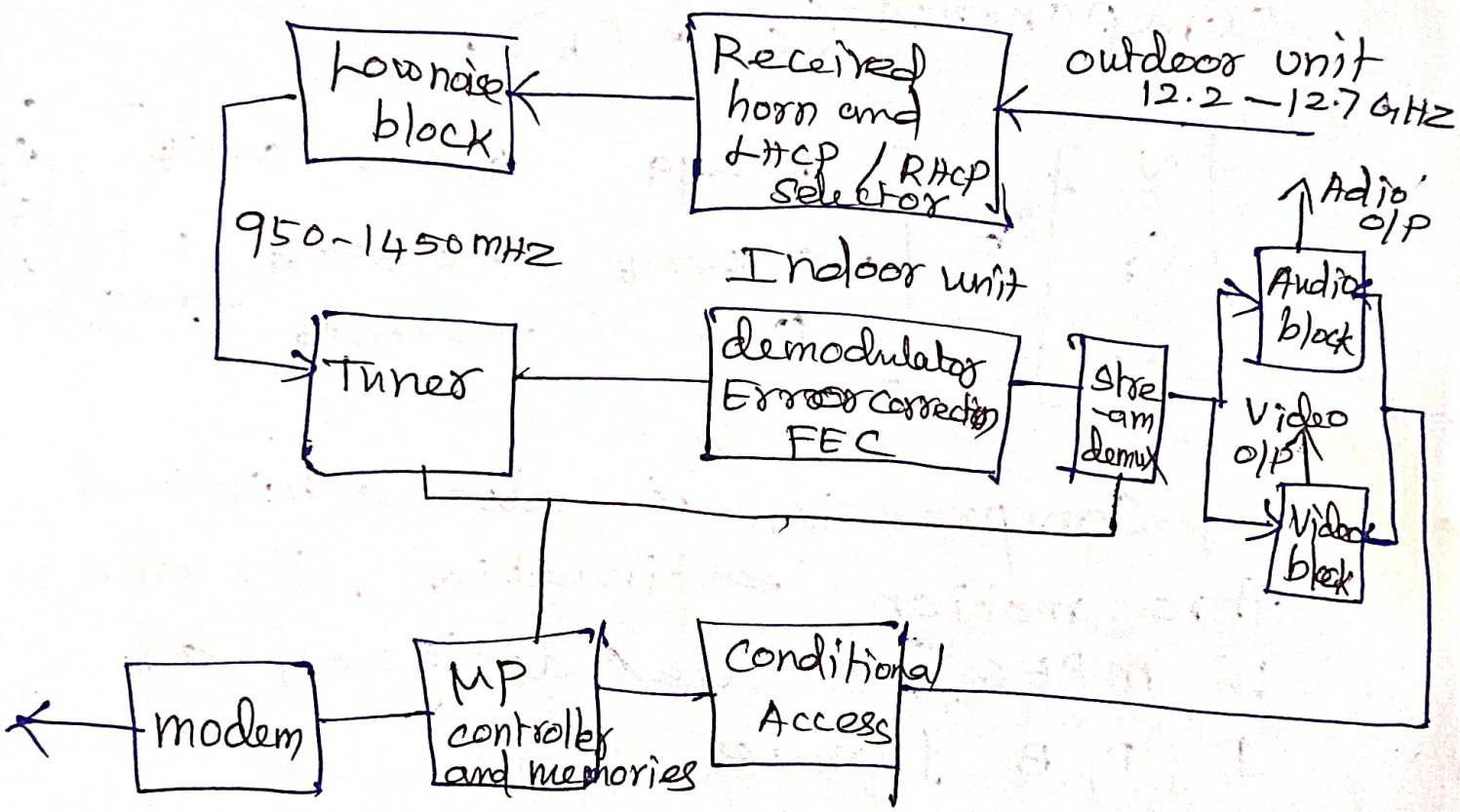
P - frame is compared with previous frame.

B - frame is compared with previous frame and next frame.

$R_b = f_s \times n$

f_s - Sampling freq.

n - no. of bits / sample.



Home Receiver outdoor unit :-

* down link signal of freq. 12.2 to 12.7 GHz is focussed by antenna into receive horn. The horn feeds into a polarizer that can switch either to (LHCP or RHCP).

* The low noise block follows the polarizer contains low-noise amplifier. The down convertor that converts to 950 to 1450 mHz. which is very suitable to send via transmission lines.

* The reduction in gain is given by

$$b_{rms} = e^{8.80/\lambda}$$

Indoor unit :- (IDU) :-

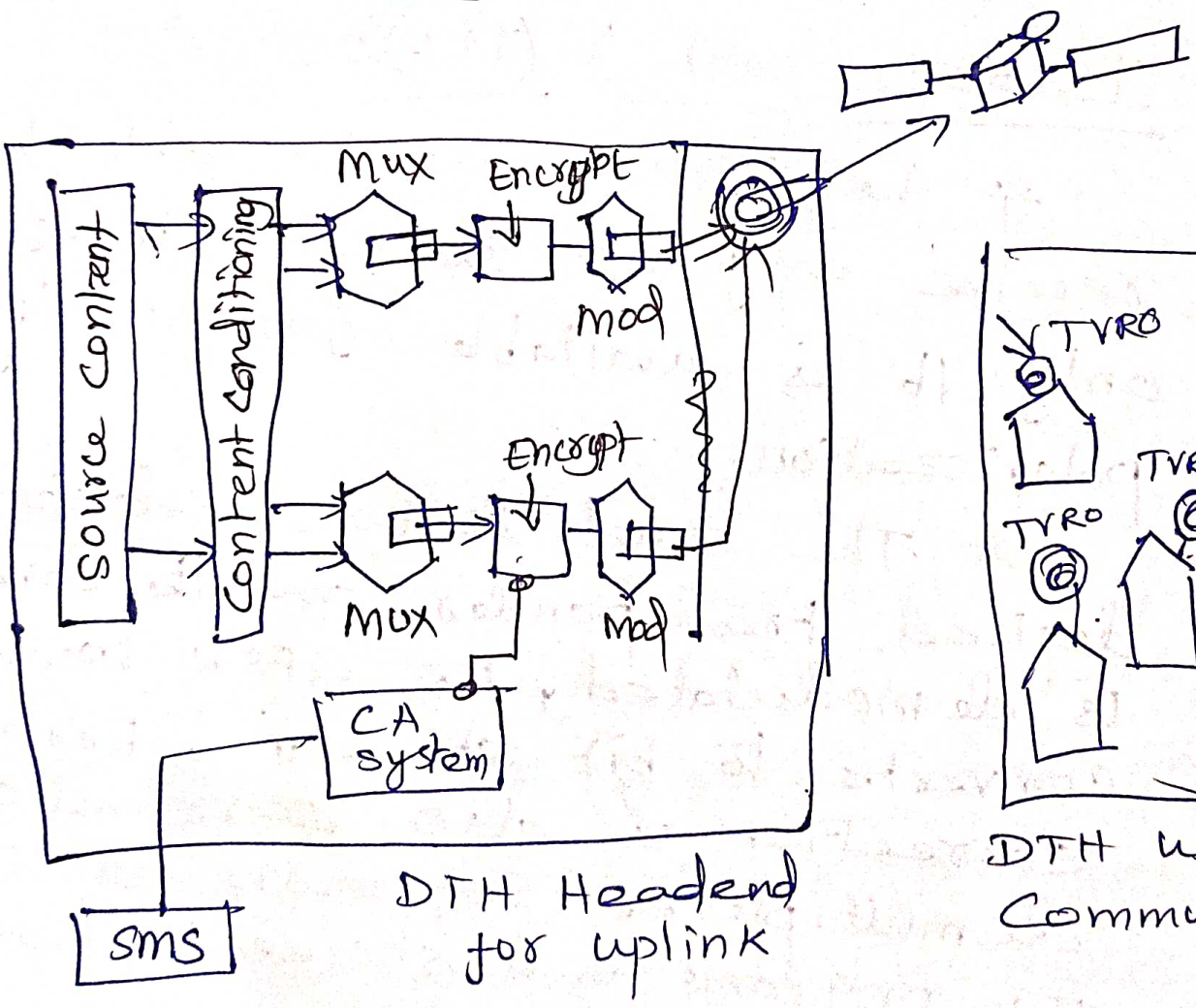
* The IDU must be able to receive any of the 32 transponders only. 1b is available for a single polarization.

* The tuner selects selects desired transponder and the carrier is demodulated, the QPSK modulation converts to bit stream. Error correction is also carried out, demultiplexer seperates all the TV programs and stores in Buffer.

Direct to Home broadcast (DTH)

* DTH is defined as the reception of satellite programmes with a personal dish in an individual home.
* Ku band (12 GHz) is used.
* DTH were first proposed in India in 1996.
* Finally in 2000, DTH was allowed.

Architecture :-



Transcoding :-

* The content is in encoded format such as MPEG 2 at certain data rate. If a format other than MPEG 2 is required such as MPEG 4, the video needs to be transcoded.

Transrating :-

* If the format is correct but data rate is too high, a transrating equipment is required.

Encryption :-

* The content is encrypted to avoid unauthorized access.

Modulation & Transmission :-

* The content is then modulated and transmitted from DTH headphone to the satellite for broadcasting to the customers.

* To view the content, a customer needs TVRO (TV Receive only) antenna a LNB (Low noise block) & authorized STB (Set Top Box)

Content licensing :-

* A DTH service provider requires a licensing authority from the programmers before distributing content to customers.

Video Encoding :- (compression)

* A video cannot be transmitted in uncompressed format, it consume more bits, example

(requires 270 mbps) SDTV — std. Definition TV

HDTV — High " "

(1.495 Gbps)