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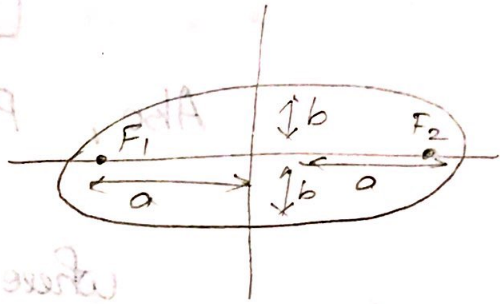
UNIT - I

Kepler's I - law

Kepler's I - law states that "the path followed by the satellite around the primary will be an ellipse. An ellipse has two focal points referred as F_1 & F_2. The centre of mass of the two body system termed the barycentre is always counted on one of the foci." The semi-major axis of the ellipse is denoted by 'a'. The semi-minor axis by 'b'.

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



$0 < e < 1$

If $e = 0$, the orbit is circular

Kepler's II - law

Kepler's II - law states that, 'for equal time intervals, the satellite will sweep out equal areas in its orbital plane focused at the 'barycentre'.

Assuming the satellite travels distances S_1 & S_2 metres in 1 sec, then the areas A_1 & A_2 are equal.

Kepler's III - law

Kepler's III - law states that, 'the square of the periodic time of orbit is proportional to the cube of the mean distance between two bodies.'

Mean distance = semi-major axis 'a'

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

where n - mean motion of the satellite in rad/sec

μ - earth's geo-centric gravitational constant

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

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

where P - orbital period.

*. Calculate the radius of the circular orbit for which the period is 1 day.

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

$$= \frac{2\pi}{24 \times 60 \times 60}$$

$$\boxed{n = 7.27 \times 10^{-5} \ rad/sec}$$

$$a^3 = \frac{\mu}{n^2} = \frac{3.986005 \times 10^{14}}{(7.27 \times 10^{-5})^2}$$

$$\boxed{a = 42,249 \text{ km}}$$

Since the orbit is circular, the semi-major axis is also the radius.

Definitions of terms for earth orbiting satellites

Apogee :-

The point farthest from the earth. Apogee height is shown as h_a.

Perigee :-

The point of closest approach to the earth. The Perigee height is shown as h_p.

Line of apside :-

The line joining the apogee and perigee through the centre of the earth.

Ascending node :-

The point where the orbit crosses the equatorial plane going from south to north.

Descending node :-

The point where the orbit crosses the equatorial plane going from north to south.

Line of nodes :-

The line joining the ascending and descending node through the centre of the earth.

Inclination :-

The angle between the orbital plane and the earth's equatorial plane. It is referred as 'i'.

$i = 0$, Geo-synchronous orbit.

Pro-grade orbit :-

An orbit in which the satellite moves in the same direction as the earth's rotation. It is also referred to as 'direct orbit'.

Retro-grade orbit :-

An orbit in which the satellite moves in a direction counter to the earth's rotation.

Argument of perigee :-

The angle from ascending node to perigee measured in the orbital plane at the earth centre in the direction of satellite motion. The argument of perigee is shown as 'ω'.

Mean anomaly :-

Mean anomaly 'M' gives an average value of the angular position of the satellite with reference to the perigee.

For a circular orbit, M gives the angular position of the satellite in the orbit.

For an elliptical orbit, the position is much more difficult to calculate and M is used as an intermediate step in the calculation.

True anomaly:-

It is the angle from perigee to the satellite position measured at the earth's centre.

Orbital elements

Earth orbiting artificial satellites are defined by 6 orbital elements referred to as the 'Keplerian element set'

→ Eccentricity 'e'
→ Semi-major axis 'a'
} Gives the shape of the orbit

→ Mean anomaly 'M_0' gives the position of the satellite
→ Argument of perigee 'ω' gives the rotation of the
→ Inclination 'i'
→ Right ascension 'Ω'

Description

* Satellite Number - 21263

  Epoch year - 93

  First time derivative of the mean motion - 0.00000187

  Inclination (deg) - 98.6540

  Right ascension of the ascending node (deg) - 250.1949

  Eccentricity - 0.0014053

  Argument of perigee (deg) - 62.4995

  Mean motion (rev/day) - 14.22296917

  Mean anomaly (deg) - 297.7604

  Revolution number at epoch - 11,616

Calculate the semi-major axis for the satellite parameter given.

$$\text{Mean motion } NN = 14.22296917$$

$$n_0 = NN\,2\pi \quad (\text{rad/sec})$$

$$= 1.034 \times 10^{-3} \text{ rad/sec}$$

$$a = \left(\frac{\mu}{n_0^2}\right)^{1/3}$$

$$= \left[\frac{3.986005 \times 10^{14}}{(1.034 \times 10^{-3})^2}\right]^{1/3}$$

$$= 7195.7 \text{ km.}$$

Apogee & Perigee heights

In order to find Apogee & Perigee heights, the radius of the earth must be subtracted from the radii lengths

$$\boxed{\begin{aligned} h_a &= r_a - R_p \\ h_p &= r_p - R_p \end{aligned}}$$

where, $\boxed{\begin{aligned} r_a &= a(1+e) \\ r_p &= a(1-e) \end{aligned}}$

*. Calculate the Apogee & Perigee heights for the orbital parameters given. The earth's polar radius may be taken as 6356.755 km.

$R_p = 6356.755$ km.

$r_a = a(1+e)$

$= 7195.7(1+0.0014053)$

$\boxed{r_a = 7205.812 \text{ km}}$

$h_a = r_a - R_p$

$\boxed{h_a = 849.057 \text{ km}}$

$r_p = a(1-e)$

$= 7195.7(1-0.0014053)$

$$\boxed{r_p = 7185.58 \text{ km}}$$

$h_p = r_p - R_p$

$$\boxed{h_p = 828.832 \text{ km}}$$

Orbit perturbation

The type of orbit described so far referred to as Keplerian orbit, is elliptical for the special case of an artificial satellite orbiting the earth.

However, the Keplerian orbit is ideal in the sense that it assumes that the earth is a uniform spherical mass and that the only force acting is the centrifugal force resulting from the satellite motion balancing the gravitational pull of the earth.

In practice, the other forces which can be significant are the gravitational forces of the sun and the moon and atmospheric drag.

The gravitational pulls of the sun & moon have negligible effect on low orbiting satellites but they do affect satellites in the geo-stationary orbit.

Atmospheric drag on the other hand has negligible effect on geo-stationary satellites but doesnot affect low orbiting satellites below about 1000 km.

Effects of a non-spherical earth:

For a spherical earth of uniform mass, the Kepler's III-law gives the nominal mean motion

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

However, it is known that the earth is not perfectly spherical, there being an equatorial bulge & flattening at the poles, a shape described as an obelate spheroid. When the earth's obelateness is taken into account, the mean motion denoted by the symbol n,

$$n = n_0 \left[1 + \frac{k_1 (1 - 1.5 \sin^2 i)}{a^2 (1-e^2)^{1.5}} \right]$$

$k_1 \rightarrow$ constant

$$\boxed{k_1 = 66,063.1704 \text{ km}^2}$$

Note :-

→ The earth's obelateness has negligible effect on the semi-major axis 'a'.

If a is known, the mean motion is readily calculated.

→ The orbital period taking into account, the earth obelateness is termed to be anomalistic period 'P_A'

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

→ If the n is rad/sec,

$$n - \sqrt{\frac{\mu}{a^3}}\left[1 + \frac{k_1(1 - 1.5\sin^2 i)}{a^2(1-e^2)^{1.5}}\right] = 0$$

*. A satellite is orbiting in the equatorial plane with the period from perigee to apogee of 12 hrs. Given that the eccentricity is 0.002. Calculate the semi-major axis. The earth equatorial radius is 6378.1414 km

Given, $P = 12$ hrs.

$e = 0.002$

$i = 0$ ($\because$ equatorial)

$a_E = 6378.1414$ km

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

$$= \frac{2\pi}{12 \times 60 \times 60}$$

$$\boxed{n = 1.454 \times 10^{-4} \text{ rad/sec}}$$

$$n - \sqrt{\frac{\mu}{a^3}\left(1 + \frac{k_1(1 - 1.5 \sin^2 i)}{a^2(1-e^2)^{1.5}}\right)} = 0$$

$$n - \sqrt{\frac{\mu}{a^3}\left(\frac{1 + k_1}{a^2(1-e^2)^{1.5}}\right)} = 0.$$

$$1.454 \times 10^{-4} - \sqrt{\frac{3.986005 \times 10^{14}}{a^3}\left(\frac{1 + 66063.1704}{a^2(1 - 0.002^2)^{1.5}}\right)} = 0.$$

$$1.454 \times 10^{-4} - \sqrt{\frac{3.986005 \times 10^{14}}{a^3}\left(\frac{1 + 66063.1704}{a^2(0.999)}\right)} = 0$$

$$\frac{3.986005 \times 10^{14}}{a^3}\left(\frac{1 + 66063.1704}{a^2(0.999)}\right)^2 = (1.454 \times 10^{-14})^2$$

$$\frac{3.986005 \times 10^{14}}{a^3}\left(\frac{0.9980 a^4 + 66063.1704}{a^4(0.998)}\right)^2 = (1.454 \times 10^{-4})^2$$

$$\frac{(0.998\,a^4 + 66063.1704)^2}{a^7} = \frac{(1.454 \times 10^{-14})^2 \times 0.998001}{3.986005 \times 10^{14}}.$$

On solving, $\boxed{a = 26\cancel{7}96 \text{ km}}$

The obelateness of the earth also produces two rotations of the orbital plane.

The first of these known as regression of the nodes is where the nodes appear to slide along the equator. In effect, the line of nodes which is in the equatorial plane rotates about the centre of the earth. Thus, 'Ω' right ascension of the ascending node shift its position.

The second effect is the rotation of the apsides in the orbital plane. Both effects depend on the mean motion 'n', the semi-major axis 'a', the eccentricity 'e'. These factors can be grouped into,

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

The change in Ω,

$$\frac{d\Omega}{dt} = -k \cos i$$

The rate of regression of the nodes will have the same units as n.

(*) The rate of (change) of regression of node is negative, if the regression is westward.

The rate is positive, if the regression is eastward.

It will be seen therefore that for eastward expression, it must be greater than 90° or the orbit must be retrograde. Such an orbit is said to be sun-synchronous orbit.

Atmospheric drag

For near-earth satellites, below about 1000 km the effect of atmospheric drag are significant. Because, the drag is greatest at the perigee, the drag acts to reduce the velocity at this point which result that the satellite doesnot reach the same apogee height on successive revolutions. The result is the semi-major axis and the eccentricity are both reduced.

The appropriate expression for the change of semi-major axis is,

$$a \simeq a_0 \left(\frac{n_0}{n_0 + \dots} \right)^{2/3}$$

The mean anomaly is also changed. An approximate expression for the amount by which it changes δM,

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

Inclined orbits

Determination of look-angles and ranges involve the following quantities and concepts.

→ The orbital elements

→ Various measures of time

→ The peri-focal co-ordinate system which is based on the orbital plane.

→ The geo-centric equatorial co-ordinate system which is based on the earth's equatorial plane.

→ The topo-centric horizon coordinate system which is based on the observer's horizontal plane.

The two major co-ordinate transformations which are needed are,

→ Satellite position measured in the peri-focal system is transformed to the geo-centric horizon system in which the earth rotation is measured, thus enabling the satellite position and earth station location to be co-ordinated.

→ The satellite to earth station position vector is transformed to the topo-centric horizon system, which enables the look angle and range to be calculated.

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Geo-stationary orbit

A satellite in a geo-stationary orbit appears to be stationary with respect to the earth. Hence, the name geo-stationary.

These conditions are required for an orbit to be geo-stationary.

→ The satellite must travel eastward direction at the same rotational speed as the earth

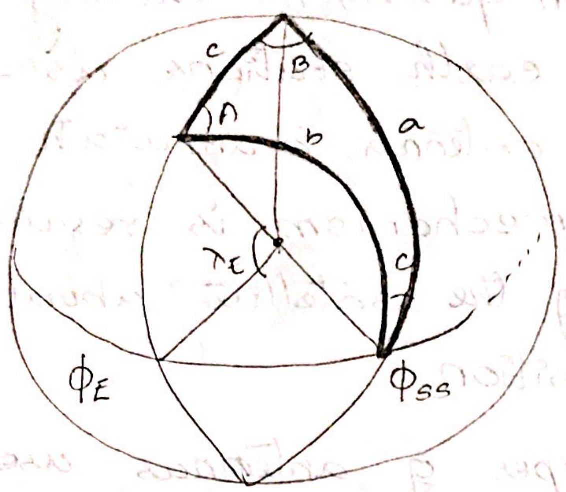
→ the orbit must be circular

→ the inclination of the orbit must be zero.

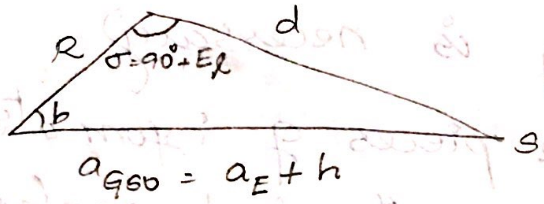
Kepler's III-law may be used to find the radius of the orbit denoting the radius by,

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

The period P for the geo-stationary is 23 hrs 56 min 4 sec mean solar time.



spherical Δ^{le}



Plane Δ^{le}

There are two types of triangles involved in the geometry

→ the spherical Δ^{le}

→ plane Δ^{le}

~~The first sph~~

Side a is the angle ~~subtn~~ b/w the radius to the northpole and the radius to the sub-satellite point and is seen that $a = 90°$.

A spherical Δ^{le} in which one side is 90° is called a quadrantal Δ^{le}.

Angle b is b/w the radius to the earth station and the radius to the sub-satellite point.

Angle c is the angle b/w the radius to the earth station and the radius to the north pole. It seems

$c = 90° - \lambda_E$

There are 6 angles in all, defining the spherical Δ^{le}. The three angles A, B, C are the angles b/w the planes.

Angle A is the angle b/w the plane containing c and the plane containing b.

Angle B is the angle b/w the plane containing c and the plane containing a.

Angle C is the ~~plane~~ angle b/w the plane containing a and the plane containing b.

To summarise, the information known about the spherical Δ^{le} is,

$$a = 90°$$

$$c = 90° - \lambda_E$$

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

According to Napier's rule,

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

Angle A has,

$$A = \arc\sin\left(\frac{\sin|B|}{\sin b}\right)$$

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

The elevation angle,

$$\boxed{E_l = \arc\cos\left(\frac{a_{GSO}}{d}\sin b\right)}$$

*. Determine the angle of tilt required for polar mount used with an earth station at latitude 49°N. Assume a spherical earth of mean radius 6371 km & ignore earth station altitude.

$$a_{GSO} = 42164 \text{ km}$$

$$R = 6371 \text{ km}$$

$$b = \lambda_E = 49^\circ$$

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

$$= \sqrt{(6371)^2 + (42164)^2 - 2(42164)(6371)\cos 49^\circ}$$

$$\boxed{d = 38{,}287.36 \text{ km}}$$

$$(\arc\cos = \cos^{-1})$$

$$E_l = \arc\cos\left(\frac{a_{GSO}}{d}\sin b\right)$$

$$\cos\left(\frac{a_{GSO}}{d}\sin b\right) = \cos\left(\frac{42164}{38287}\sin 49^\circ\right)$$

$$\boxed{E_l = 33.78^\circ}$$

The required angle of tilt, δ is calculated as

$$\delta = 90^\circ - El_0 - \lambda_E$$

$$= 90 - 33.78 - 49^\circ$$

$$\delta = 7.22^\circ$$

$$\boxed{\delta \simeq 7^\circ}$$

Limits of visibility

There will be east and west limits on the geo-stationary arc visible from any given earth station. The limits will be set by the geographic co-ordinates of the earth station and the antenna elevation.

The lowest elevation in theory is 0 when the antenna is pointing along the horizontal.

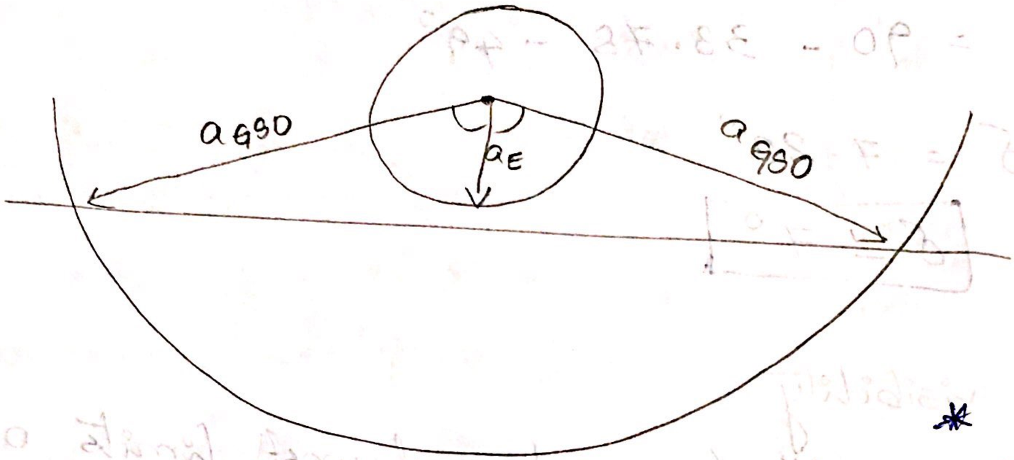
A quick estimate of the longitudinal limits can be made by considering an earth station at the equator with the antenna pointing either west or east along the horizontal.

The limiting angle is given by,

$$\boxed{\theta = \arccos\left(\frac{a_{GSO}}{a_E}\right)}$$

$$\theta = \arccos\left(\frac{6378}{42164}\right)$$

$$\boxed{\theta = 81.29^\circ}$$



*. Find the range and antenna elevation angle for $b = 36.23^\circ$.

$$a_{GSO} = 42164 \text{ km}$$

$$R = 6371 \text{ km}$$

$$b = \lambda_E = 36.23^\circ$$

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

$$= \sqrt{(6371)^2 + (42164)^2 - 2(42164)(6371)\cos(36.23^\circ)}$$

$$\boxed{d = 37215.8 \text{ km}}$$

$$E_l = \text{arc}\cos\left(\frac{a_{GSO}}{d}\sin b\right)$$

$$= \cos^{-1}\left(\frac{42164}{37215.8}\sin 36.23^\circ\right)$$

$$E_l = 47.96^\circ$$

$$\boxed{E_l \simeq 48^\circ}$$

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* Thus for the situation, an earth station could see satellites over a geo-stationary arc bounded by (+ or −) $\pm 81.3^\circ$ about the earth station longitude.

In practice to avoid reception of excessive noise from the earth, some finite minimum value of elevation is used which will be denoted here by "El_{min}". A typical value is 5°.

S represent the angle subtended at the satellite when the angle $\sigma_{min} = 90^\circ + El_{min}$

Applying the sine rule gives,

$$\boxed{S = \text{arc}\sin\left(\frac{R}{a_{GSO}}\sin\sigma_{min}\right)}$$

Once the angle S is known, angle b found from,

$$\boxed{b = 180 - \sigma_{min} - S}$$

So,

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

Once angle B is found, the satellite longitude can be determined by,

$$\boxed{B = \phi_E - \phi_{SS}}$$

* Determine the limits of visibility for an earth station situated at mean sea level at latitude 48.42° N and longitude 89.26° W. Assume a minimum angle of elevation of 5°.

Given, $\lambda_E = 48.42^\circ$ N

$\phi_E = -89.26^\circ$ (since W)

$El_{min} = 5^\circ$

$a_{GSO} = 42164$ km

$R = 6371$ km.

$$\sigma_{min} = 90^\circ + El_{min}$$

$$= 90^\circ + 5^\circ$$

$$\boxed{\sigma_{min} = 95^\circ}$$

$$S = \arc\sin\left(\frac{R}{a_{GSO}} \sin \sigma_{min}\right)$$

$$= \arc\sin\left(\frac{6371}{42164} \sin 95^\circ\right)$$

$$\boxed{S = 8.65^\circ}$$

$$b = 180 - \sigma_{min} - S$$

$$= 180 - 95 - 8.65$$

$$\boxed{b = 76.35^\circ}$$

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

$$= \arc\cos\left(\frac{\cos 76.35^\circ}{\cos(+\cancel{89.26^\circ})\ 48.42^\circ}\right)$$

$$\boxed{B = 69.15^\circ}$$

The satellite limit east of the earth station is at $\phi_E + B$

$$= -89.26^\circ + 69.15^\circ$$

$$= -20.11^\circ.$$

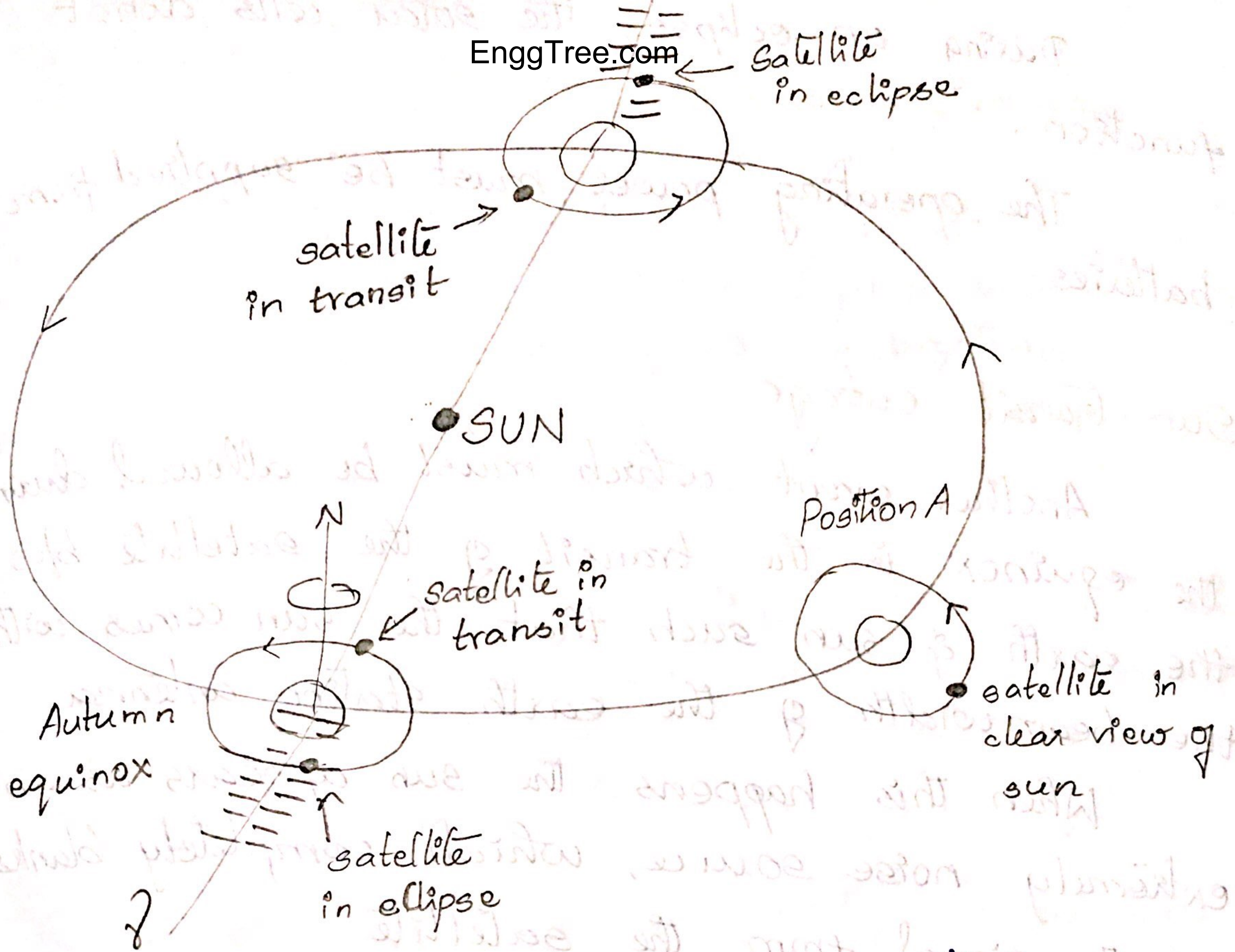
West of the earth station is $\phi_E - B$,

$$= -89.26^\circ - 69.15^\circ$$

$$= -158.41^\circ$$

Earth eclipse of satellite

If the earth equatorial plane coincide with plane of the earth orbit around the sun (the elliptic plane), geostationary satellites would be eclipsed by the earth once each day as it is the equatorial plane is tilted at an angle of 23.4° to the elliptic plane and this keeps the satellite in full view of the sun for most days of the year.



Around the spring & autumnal equinox, when the sun is crossing the equator, the satellite does pass into the earth shadow at certain periods.

The spring equinox is the first day of spring and the autumnal equinox is the first day of autumn.

Eclipses begin 23 days before equinox and end 22 days after equinox.

The eclipse last about 10 min at the beginning and at the end of the eclipse period, it increases to a maximum duration of about 72 min at full eclipse.

During an eclipse, the solar cells donot function.

The operating power must be supplied from batteries.

Sun transit outage

Another event which must be allowed during the equinox is the transit of the satellite b/w the earth & sun such that the sun comes within the beamwidth of the earth station antenna.

When this happens, the sun appears as an extremely noise source, which completely blanks out the signal from the satellite.

This effect is termed as sun transit outage and it lasts for short periods - each day for about 6 days around the equinoxis.

Maximum outage time of 10 min being typical

05/02

UNIT II

SPACE SEGMENT AND SATELLITE LINK DESIGN

Space craft technology - Structure - Primary power - Attitude and orbit control - Thermal control and propulsion - communication payload and supporting subsystems - Telemetry tracking and command - satellite uplink and downlink analysis and design - Link budget - E/N calculation - Performance impairment - system noise, intermodulation and interference - Propagation characteristics and frequency consideration - System reliability and design lifetime.

Space segment

→ Satellite commn. can be broadly divided into two segments - ground segment & space segment

→ Space segment will obviously include the satellites but it also includes the ground facilities, these being referred to as tracking telemetry and command (TT AND C)

→ The payload refers to the equipment used provide the service for which the satellite has been launched.

→ The bus refers not only to the vehicle which carries the payload but also to the various sub-systems which provide the power, attitude control, orbital control, thermal control and command & telemetry functions.

→ The equipment which provides the connecting link b/w the satellite ~~and~~ transmit and receive antenna is referred to as the transponder.

Power Supply

→ The primary electrical power for operating the electronic equipment is obtained from solar cells

→ Individual cells can generate only small amount of power, and therefore array of cells in series, parallel connections are required.

→ HS376

→ The spacecraft is 216 cm in diameter and 660 cm long when fully deployed in orbit.

→ During the launch sequence, the outer cylinder is telescoped over the inner one to reduce the overall length.

→ In geostationary orbit, the telescoped panel is fully extended so that both are exposed to sunlight

→ At the beginning of life, the panels produce 940 W DC power, which may be dropped to 760 W at the end of 10 years.

→ During eclipse, power is provided by two nickel cadmium batteries which will deliver 830W

HS601

→ The solar sails must be folded during the launch phase and extended when in geo-stationary orbit.

→ The solar sails are fold up on each side and when fully extended, they stretch to 67 feet from tip to tip.

→ The HS601 can be designed to provide DC power from 2 to 6 kW.

Attitude control

→ The attitude of the satellite refer to its orientation in space.

→ It is necessary to ensure that directional antennas point in the proper direction.

→ A no. of forces referred to as disturbance torque can alter the attitude, someeg& being, the gravitational field of earth & moon, solar radiation and meteoroid impact.

→ Controlling torques can be generated in no. of ways:

i) Passive

ii) Active

Passive attitude control

→ refers to the use of mechanisms which stabilize the satellite without putting a drain on the satellite's energy supplies.

→ Its types are
- Thruster jet
- Spin stabilization
- Gravity gradient stabilization

Active attitude control

→ With this, there is no overall stabilizing torque present to resist the disturbance torques.

→ Instead corrective torques are applied as required in response to disturbance torques.

→ Its types are
- Momentum wheels
- Electromagnetic coil
- Mass expulsion devices
- Gas jet
- Ion thrusters

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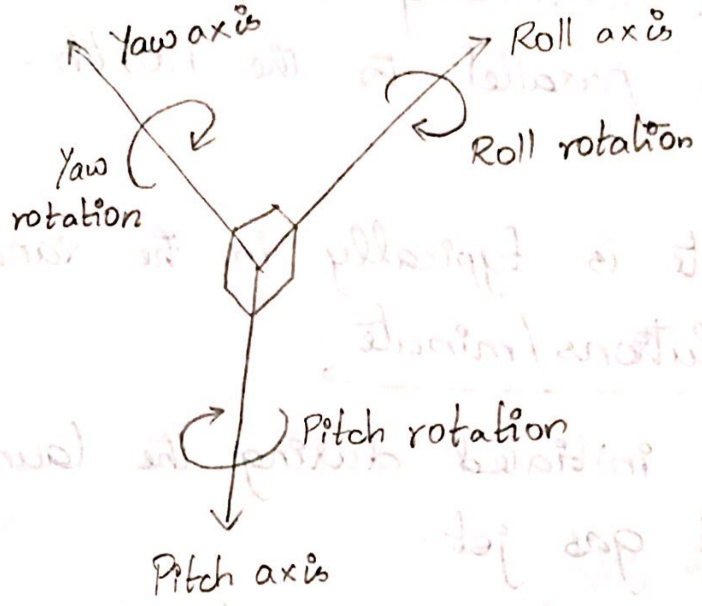
Momentum of wheels



The 3 axes which define the satellite attitude are its roll, pitch & yaw. All 3 axis pass through the centre of gravity of satellite for an equatorial orbit movement of the satellite about the roll axis moves the antenna foot point north & south.

Movement about the pitch axis moves the foot-print east to west.

Movement about the yaw axis rotates the antenna footprint.

Spinning Satellite stabilization

Spin stabilization may be achieved with cylindrical satellites.

The satellite is constructed so that it is mechanically balanced about one particular axis and is then set spinning around the axis.

For geo-stationary satellite, the spin axis is adjusted to be parallel to the north-south axis of the earth.

Spin rate is typically in the range of

500-100 revolutions/minute.

Spin is initiated during the launch phase by means of small gas jet.

Disturbance torque can be generated in no of ways both external & internal to the satellite.

External disturbances

Solar radiation

Gravitational gradient

Meteoroid impact

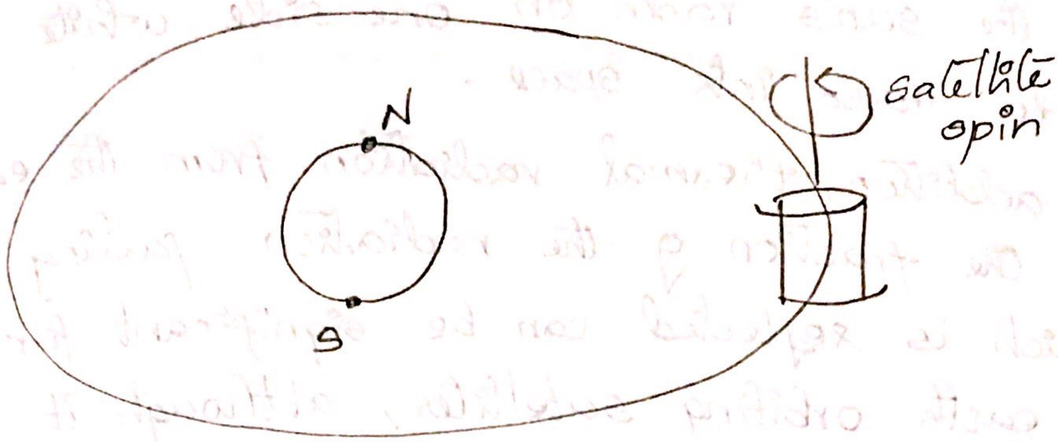
Internal disturbances

Motor bearing friction

Movement of satellite elements such as antennas

The overall effect is that the spin rate will decrease and the direction of the angular spin axis will change.

Impulse type thrusters or jets can be used to increase the spin rate again and to shift the axis back to its correct ~~N-S~~ orientation.



Station keeping

In addition to having its attitude controlled, it is important that the geostationary satellite be kept in its correct orbital slot.

The equatorial ellipticity of the earth causes geo-stationary satellites to drift slowly along the orbit to one of the two stable points at 75°E & 105°W.

To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jet which are pulsed once every two or three weeks.

This results in the satellite drifting back to the nominal station position coming to a stop and recommencing the drift along the orbit until the jets are pulsed once again.

These maneuvers are termed as east/west station keeping maneuvers.

Thermal control

Satellites are subject to large thermal gradients receiving the sun's radn on one side while the other side faces into space.

In addition, thermal radiation from the earth, which is the fraction of the radiation falling on the earth which is reflected can be significant for low altitude earth orbiting satellites, although it is negligible for geo-stationary satellites.

Equipments in the satellite also generate heat which has to be removed.

Various steps are taken to achieve this are thermal blankets and shield to provide insulation.

Radiation mirrors are often used to remove heat from communication payload.

Transponder

It is a series of interconnected units which form a single communication channel b/w the Rx & Tx antenna in a commn. satellite.

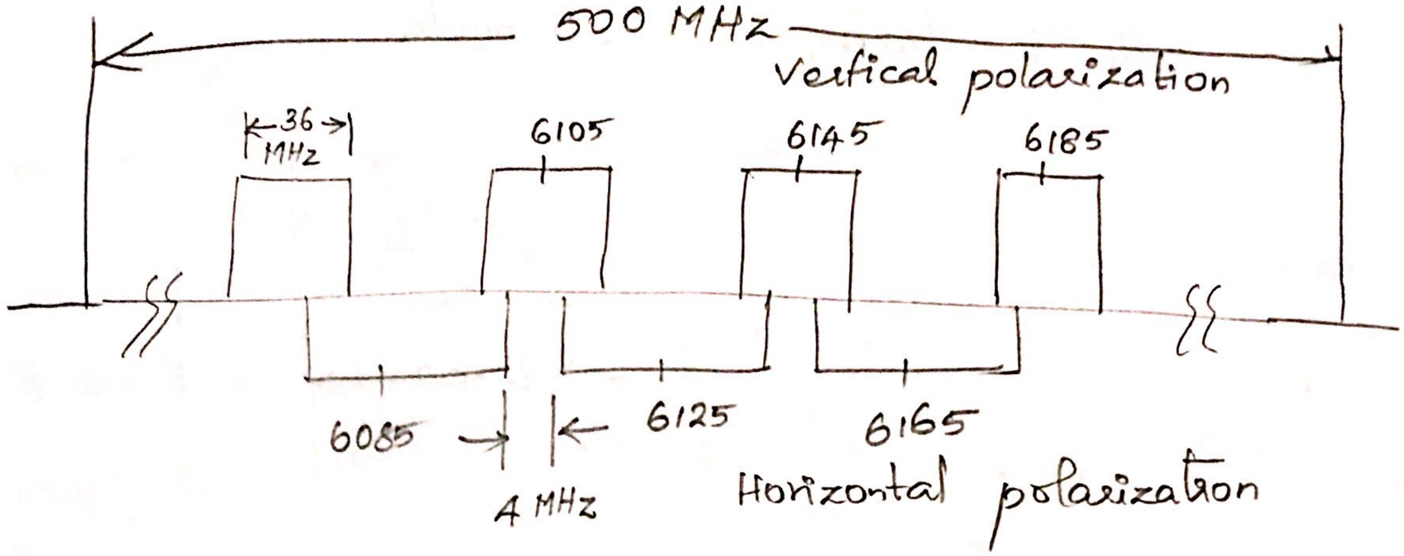
C-band satellite

BW allocated for C-band service is 500MHz

This is divided into sub-bands, one for each transponder.

A typical transponder BW is 36 MHz and allowing for a 4 MHz b/w transponders.

12 such transponders can be accomodated in the 500 MHz BW.



~~Pol~~ By making use of polarization isolation, this number can be doubled.

Polarisation isolation refers to the fact the carriers which may be on the same frequency but with the opposite senses of polarization can be isolated from one another by receiving antennas matched with the incoming polarization.

Linear polarization → Vertical
→ Horizontal

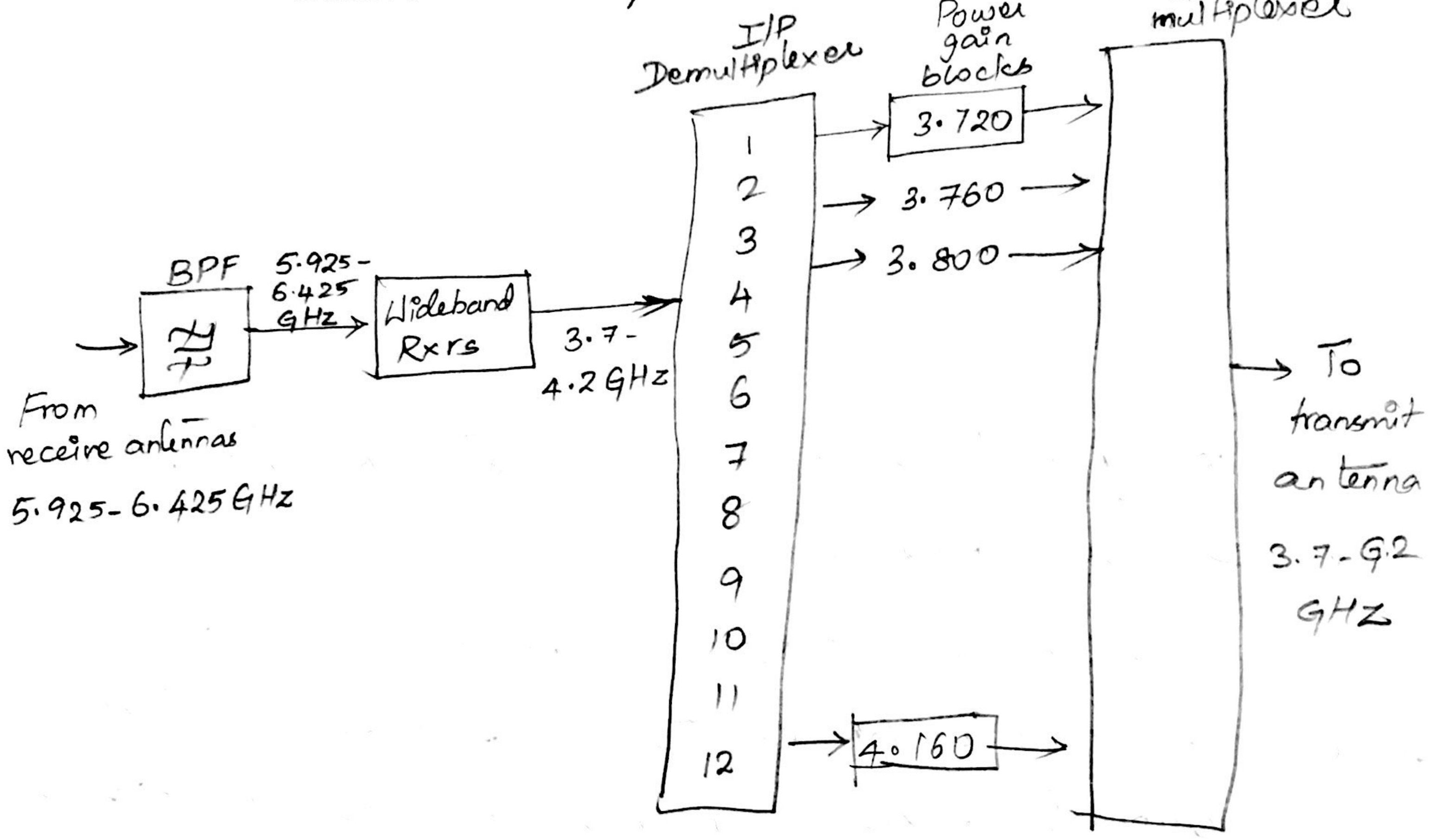
Circular polarization → Left circular
→ Right "

This is referred to as frequency reuse.

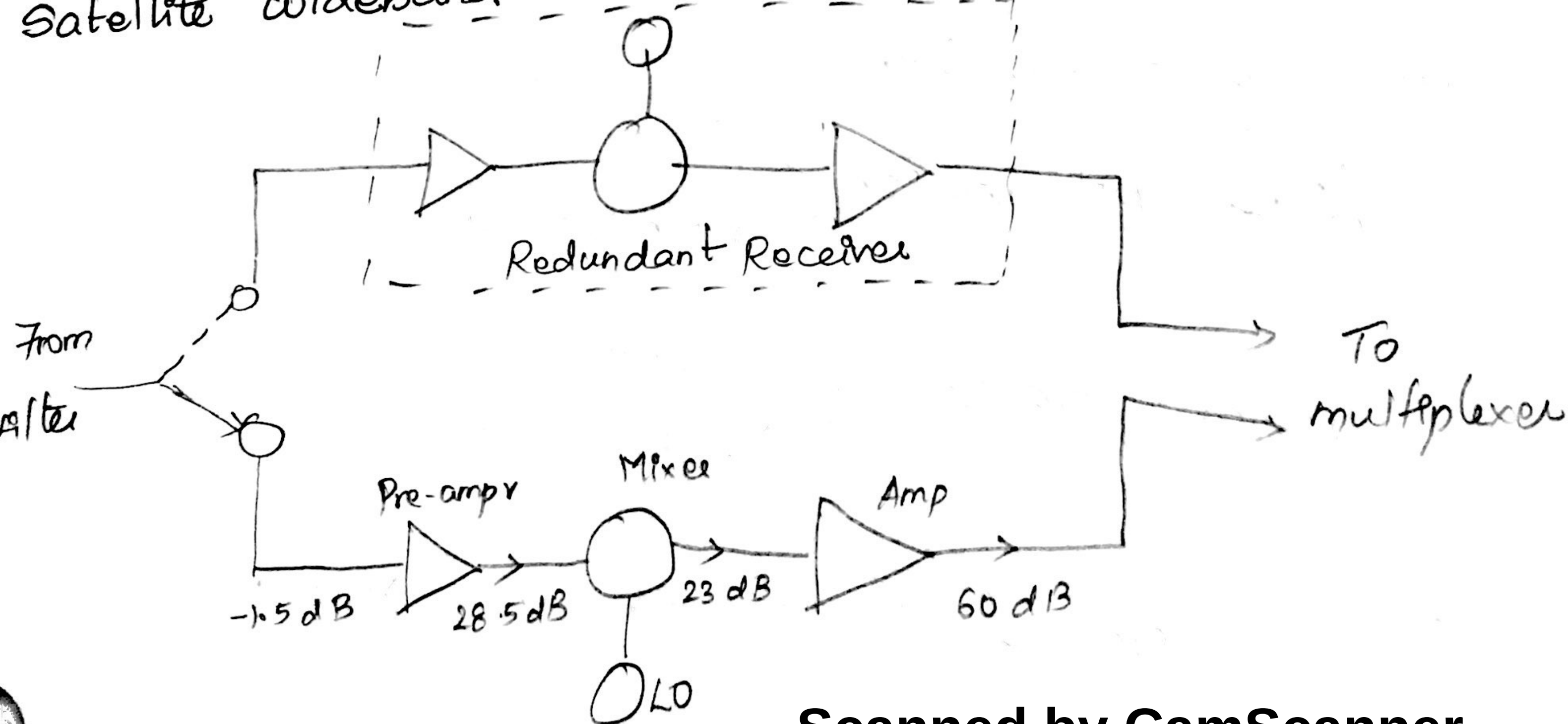
The incoming/uplink frequency range is 5.925 GHz - 6.425 GHz.

The downlink freq. range is 3.7 GHz - 4.2 GHz

Satellite transponder channels



Satellite wideband Receiver.



The wideband Rxr utilises only solidstate active devices.

In some designs, tunnel diode amplifiers have been used for the pre-amplifier at 6 GHz in 6/4 GHz transponder & for the parametric amplifiers, 14 GHz in 14/12 GHz transponder.

With the advances in the field effect transistor technology, FET amprs which offer equal or better performance are now available for both bands.

Diode mixer stages are used.

The ampr following the mixer may utilize bipolar junction transistors at 4 GHz and FET at 12 GHz.

9/2

Space Link

Link Budget Calculation

This is usually made in decibels or decilogs quantities.

The key parameter in link budget calculation is the equivalent isotropic radiated power (EIRP). The max. power flux density at some distance 'r' from a transmitting antenna of gain G is,

$$\boxed{\Psi_M = \frac{GP_s}{4\pi r^2}} \longrightarrow (1)$$

An isotropic radiator with an I/P power equal to GP_s would produce the same flux density.

This product is referred to as EIRP.

$$\boxed{EIRP = GP_s} \longrightarrow (2)$$

EIRP is often expressed in decibels relative to 1 W or dB watts.

Let P_s in watts, then EIRP in decibel is,

$$\boxed{[EIRP] = [P_s] + [G] \text{ dB W}} \longrightarrow (3)$$

For a paraboloidal antenna, the isotropic power gain is given by,

$$\boxed{G = \eta (10.472 fD)^2} \longrightarrow (4)$$

where $f \rightarrow$ carrier freq. in GHz

$D \rightarrow$ reflector diameter in metre

$\eta \rightarrow$ Aperture efficiency.

A typical value of η is 0.55

With diameter D in feet,

$$\boxed{G = \eta (3.192 fD)^2} \longrightarrow (5)$$

Free space transmission

The first steps in the calculation is to determine the losses for the clear sky conditn.

The power flux density at the receiving antenna is,

$$\boxed{\psi_M = \frac{EIRP}{4\pi r^2}} \rightarrow (6)$$

The power delivered to a matched Rxr is the power flux density multiplied by the effective aperture of the receiving antenna.

The received power P_R,

$$\boxed{P_R = \psi_M \cdot A_{eff}} \rightarrow (7)$$

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

$$\boxed{P_R = (EIRP)(G_R)\left(\frac{\lambda}{4\pi r}\right)^2}$$

$G_R \rightarrow$ isotropic power Gain of the receiving antenna

$r \rightarrow$ Range b/w the transmit & receive antenna

In dB notation, the eqn becomes,

$$\boxed{[P_R] = [EIRP] + [G_R] - 10 \log \left(\frac{4\pi r}{\lambda}\right)^2} \rightarrow (8)$$

The free space loss component in dB is given by

$$\boxed{[FSL] = 10 \log \left(\frac{4\pi r}{\lambda}\right)^2} \longrightarrow (9)$$

The free space loss is given by,

$$\boxed{FSL = 32.4 + 20 \log r + 20 \log f} \longrightarrow (10)$$

$$\boxed{[P_R] = [EIRP] + [G_R] - [FSL]} \longrightarrow (11)$$

Feeder losses

Losses will occur ~~when~~ in the connection b/w the receive antenna & the receiver proper. Such losses will occur ~~within~~ the connecting waveguides, filters and couplers. These will be denoted by [RFL]

Antenna misalignment losses

- When a satellite link is established, the ideal situation is to have the earth station & satellite antenna aligned for max. gain

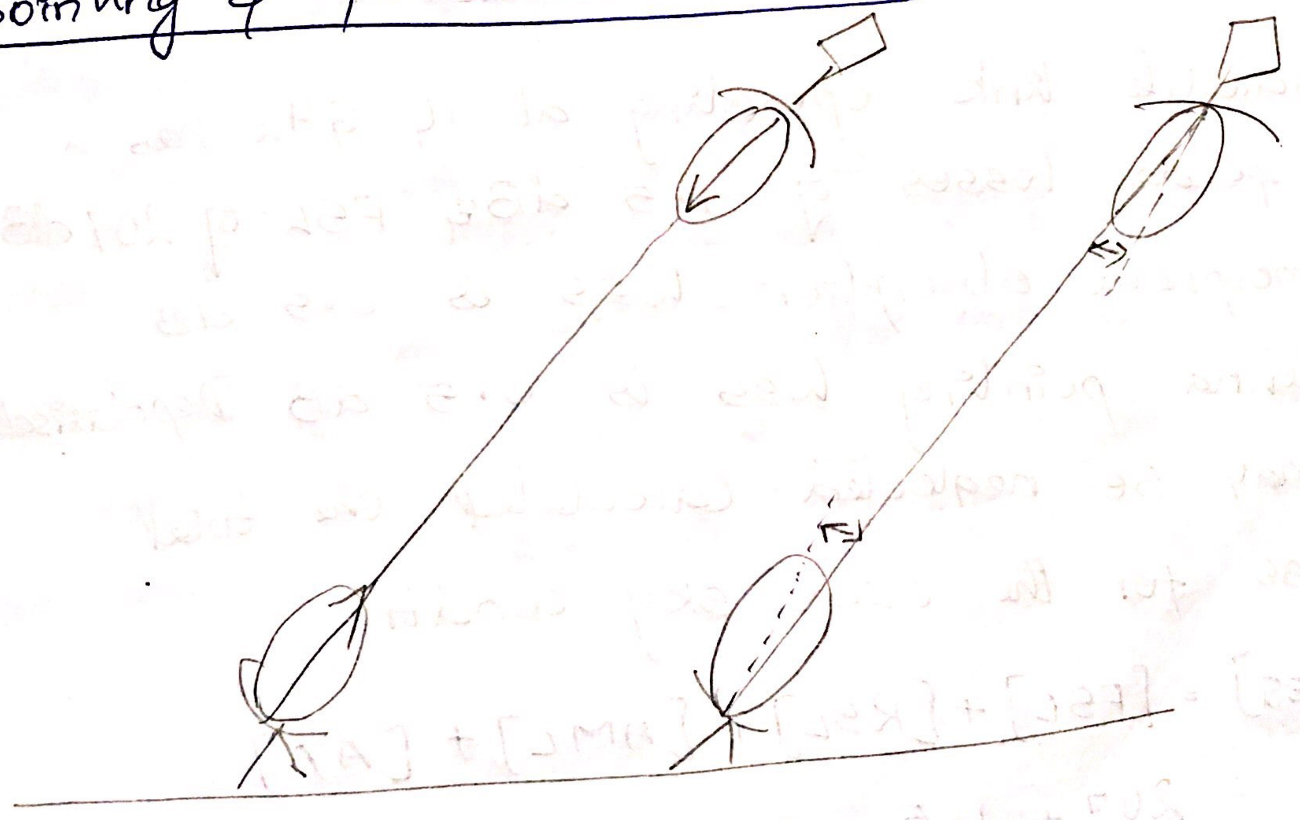
There are 2 possible sources of 'off axis loss' one at the satellite & one at the earth station.

The off axis loss at the satellite is taken into account by designing the link for operation on the actual satellite antenna contour.

The off axis loss at the earth station is referred to as antenna pointing loss.

In addition to pointing losses, losses may result at the antenna from the misalignment of the polarisation direction.

The polarisation misalignment losses are usually small & it will be assumed that the antenna misalignment losses denoted by AML include both pointing & polarisation losses.



Fixed atmospheric & ionospheric losses.

Atmospheric gases result in losses by absorption. These losses usually amount to a fraction of decibels, the decibel value will be denoted by AA.

The ionosphere introduces a depolarization loss, the decibel value will be ~~donetd~~ by PL.

The link power budget eqn is,

$$\boxed{[LOSSES] = [FSL] + [RFL] + [AML] + [AA] + [PL]} \rightarrow (12)$$

Received power P_R in dB,

$$\boxed{[P_R] = [EIRP] + [G_R] - [LOSSES]} \longrightarrow (13)$$

*. A satellite link operating at 14 GHz has a receiver feeder losses of 1.5 dB & FSL of 207 dB. The atmospheric absorption loss is 0.5 dB and antenna pointing loss is 0.5 dB. Depolarisa[tion] losses may be neglected. Calculated the total link loss for the clear sky condtn.

$$[LOSSES] = [FSL] + [RSL] + [AML] + [AA]$$

$$= 207 + 1.5 + 0.5 + 0.5$$

$$= 209.5 \text{ dB}$$

System noise

The receiver power on the satellite link is very small in the order of pico watts. This by itself would be no problem because amplification would be used to bring the signal strength upto the acceptable level.

However electrical noise is always present at the I/P and unless the signal is significantly greater than the noise, amplification will be of no help bcoz it will amplify signal and noise to the same extent.

The major source of electrical noise in an equipment is that which arises from the random thermal motion of e^-s in various resistive and active devices in the Rxr.

Thermal noise is also generated in the lossy components of antennas & thermal like noise is picked up by the antenna as the radiation.

The available noise power from the thermal noise source is given by,

$$\boxed{P_N = K T_N B_N} \longrightarrow (14)$$

$K \rightarrow$ Boltzmann constant

$T_N \rightarrow$ equivalent noise temperature

$B_N \rightarrow$ " " BW

Noise spectral density N_0 is given by,

$$\boxed{N_0 = \frac{P_N}{B_N} = kT_N} \rightarrow (15)$$

Antenna noise

Antenna operating in the receiving mode introduce noise in the satellite circuit.

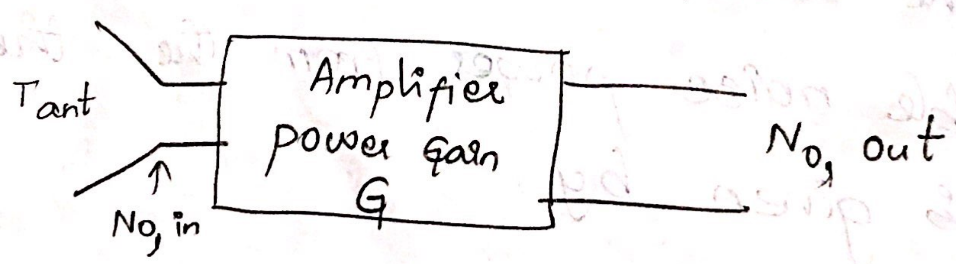
The antenna noise is broadly classified as two groups

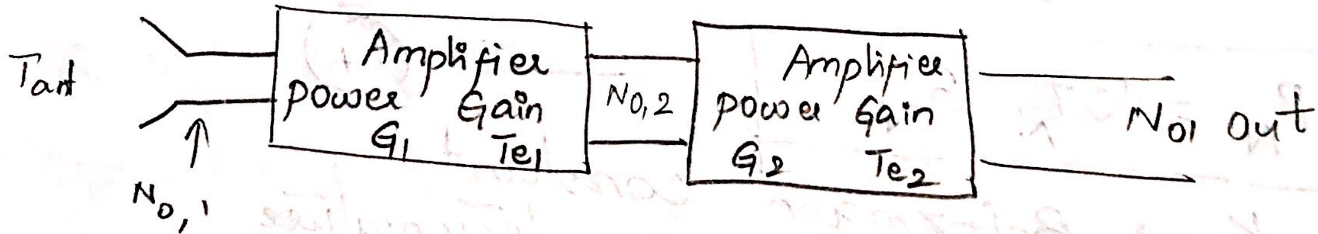
→ Noise originating from antenna losses

→ Sky noise

Sky noise is the term used to describe the μwave radiation which is present throughout the universe and which appears to originate from matter in any form at finite temperature.

Amplifier noise temperature





The available power gain of the ampr is denoted by G and noise power o/p as P_{no}

The input noise energy coming from the antenna is,

$$\boxed{N_{0,ant} = kT_{ant}} \rightarrow (16)$$

The o/p noise energy is,

$$\boxed{N_{0,out} = Gk(T_{ant} + T_e)} \rightarrow (17)$$

$T_e \rightarrow$ eq. noise temp for the amplifier.

The total noise referred to the I/P is simply, given by $N_{0,out}/G$

$$\boxed{N_{0,in} = k(T_{ant} + T_e)} \rightarrow (18)$$

Amplifiers in cascade.

The overall gain is,

$$\boxed{G = G_1 G_2} \rightarrow (19)$$

The total noise energy referred to ampr 2 I/P is,

$$N_{0,2} = G_1 k(T_{ant} + T_{e_1}) + kT_{e_2} \rightarrow (20)$$

$$N_{0,1} = \frac{N_{0,2}}{G_1}$$

$$\boxed{N_{0,1} = k(T_{ant} + T_{e1}) + \frac{k T_{e2}}{G_1}} \rightarrow (21)$$

$$\boxed{N_{0,1} = k T_S} \rightarrow (22)$$

$T_S \rightarrow$ system noise temperature

$$\boxed{T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1}} \rightarrow (23)$$

If N stages are cascaded,

$$\boxed{T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \cdots} \rightarrow (24)$$

Noise factor

An alternative way of representing amplifier noise is by means of its noise factor F.

In defining the noise factor of an ampr, the source is taken to be at room temp T_0 usually taken as 290 K.

The I/P noise from such a source is kT_0

and o/p noise from the ampr is,

$$\boxed{N_{o,\,out} = FGKT_0} \longrightarrow (25)$$

Let T_e be the noise temp. of the ampr and let the source be at room temp. as required by the definition of F.

This means that $T_{ant} = T_0$

Since the same o/p noise must be available whatever representation it follows that,

$$\boxed{GK(T_0 + T_e) = FGKT_0}$$

From this,

$$\boxed{T_e = (F-1)\,T_0} \longrightarrow (26)$$

The noise figure is simply F expressed in dB as,

$$\text{Noise fig.} = \boxed{[F] = 10 \log F} \longrightarrow (27)$$

Overall system noise temperature (T_s)

$$\boxed{T_s = T_{ant} + T_{e_1} + \frac{(L-1)\,T_0}{G_1} + \frac{(L(F-1))\,T_0}{G_1}} \rightarrow (32)$$

Carrier to Noise ratio

Ratio of carrier power to noise power at the Rxr I/P

Conventionally, the ratio is denoted by C/N which is equivalent to P_R/P_N

Interms of dB,

$$\boxed{\left[\frac{C}{N}\right] = [P_R] - [P_N]} \longrightarrow (33)$$

$$\boxed{\left[\frac{C}{N}\right] = [EIRP] + [G_R] - [LOSSES] - [k] - [T_S] - [B_N]} \longrightarrow (34)$$

Now,

$$\boxed{\left[G/T\right] = [G_R] - [T_S] \quad dB\,K^{-1}} \longrightarrow (35)$$

Therefore,

$$\boxed{\left[C/N\right] = [EIRP] + [G/T] - [LOSSES] - [k] - [B_N]} \longrightarrow (3$$

→ The ratio of carrier power to noise power density P_R/N_0 may be the quantity actually required.

→ Since $P_N = kT_N B_N$ which is equal to $N_0 B_N$,

$$\left[\frac{C}{N}\right] = \left[\frac{C}{N_0 B_N}\right]$$

$$\left[\frac{C}{N}\right] = \left[\frac{C}{N_0}\right] - [B_N]$$

$$\therefore \boxed{\left[\frac{C}{N_0}\right] = \left[\frac{C}{N}\right] + [B_N]} \longrightarrow (37)$$

$$\boxed{\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right] - [LOSSES] - [K]} \longrightarrow (38)$$

The uplink

The uplink of a satellite ckt is the one in which the earth station is transmitting the sgnl & the satellite is receiving it.

$$\left[\frac{C}{N_0}\right]_U = [EIRP]_U + \left[\frac{G}{T}\right]_U - [LOSSES]_U - [K] \rightarrow (39)$$

Saturation flux density

Flux density interms of EIRP is,

$$\Psi_M = \frac{EIRP}{4\pi r^2}$$

In dB,

$$\boxed{[\Psi_M] = [EIRP] + 10\log\left(\frac{1}{4\pi r^2}\right)} \rightarrow (40)$$

From eqn (9), the free space loss is,

$$\boxed{-[FSL] = 10\log\frac{\lambda^2}{4\pi} + 10\log\frac{1}{4\pi r^2}} \rightarrow (41)$$

Sub in eqn (40),

$$\boxed{\Psi_M = [EIRP] - [FSL] - 10\log\left(\frac{\lambda^2}{4\pi}\right)} \rightarrow (42)$$

$\lambda^2/4\pi$ term has dimensions of area, it is the effective area of the isotropic antenna, denoting this by A_0 gives,

$$\boxed{[A_0] = 10\log\frac{\lambda^2}{4\pi}} \longrightarrow (43)$$

In terms of freq,

$$\boxed{[A_0] = -(21.45 + 20\log f)} \rightarrow (44)$$

Combining (44) with (42) & rearranging slightly gives,

$$[EIRP] = [\psi_M] + [A_0] + [FSL] \longrightarrow (45)$$

Including other losses,

$$[EIRP] = [\psi_M] + [A_0] + [FSL] + [AA] + [PL] + [AML] \longrightarrow (46)$$

In terms of total losses, it becomes,

$$[EIRP] = [\psi_M] + [A_0] + [LOSSES] - [RFL] \longrightarrow (47)$$

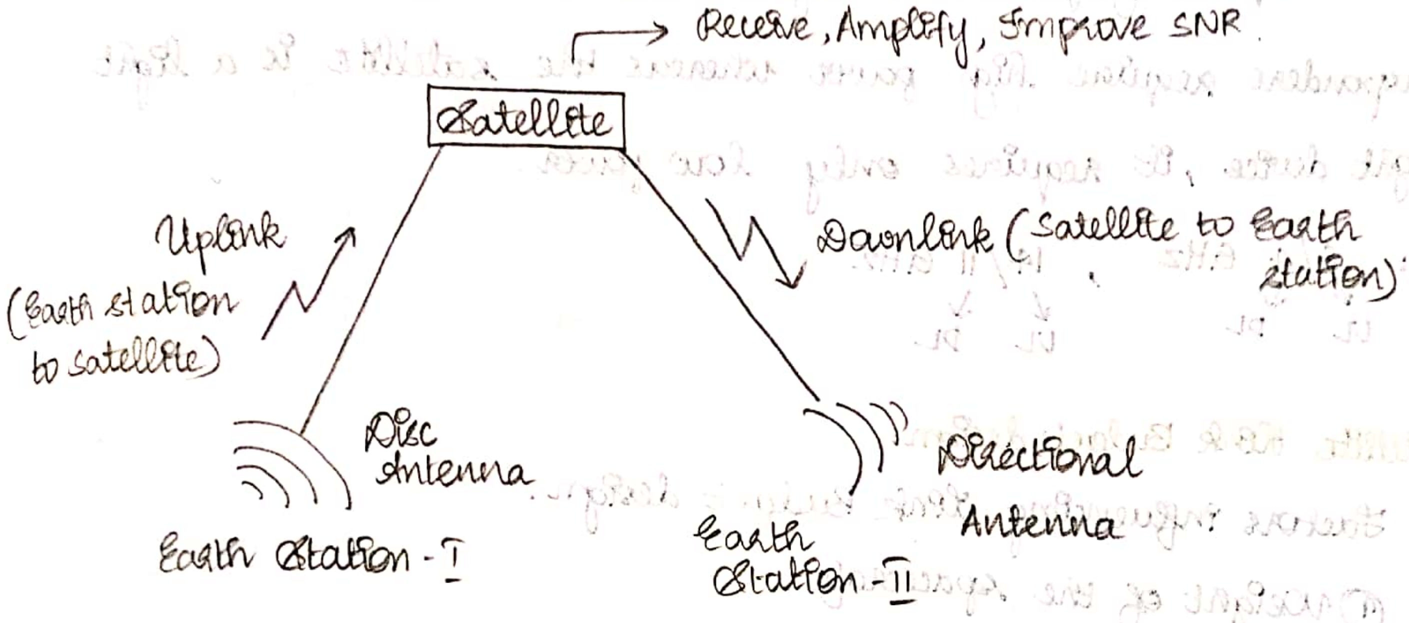
$$\boxed{[EIRP_S]_U = [\psi_S] + [A_0] + [LOSSES]_U - [RFL]} \longrightarrow (48)$$

$[EIRP_S]_U \rightarrow$ EIRP saturated for uplink

20.2.2021

UNIT - III - LINK BUDGET DESIGN

Basic block diagram:



→ Used to calculate receiver power w.r. to distance.

Frequencies used in Satellite Communication:

1 GHz – 2 GHz → L Band

2 GHz – 4 GHz → S Band

4 GHz – 8 GHz → C Band (Most frequently used band in Satellite commn)

8 GHz – 12 GHz → X Band

12 GHz – 18 GHz → K_u Band

18 GHz – 26 GHz → K Band

26 GHz – 40 GHz → K_a Band

Uplink frequencies are always greater than Downlink frequencies. Justify.

Uplink frequencies are higher since the Earth station transponders require high power whereas the satellite is a light weight device, it requires only low power.

Eg: 6/4 GHz, 14/11 GHz

6 → UL, 4 → DL; 14 → UL, 11 → DL

Satellite Link Budget design:

Factors influencing link Budget design.

1. Weight of the spacecraft
2. Frequency usage
3. Atmospheric attenuation
4. Multiple Access schemes

Power calculation:

$$\text{dB (or) dBW} = 10\log_{10}(\text{Power})$$

$$\text{dBm} = 10\log_{10}(\text{Power} \times 10^{3} \times 10^{-3})$$

$$\text{dBm} = 10\log_{10}(\text{Power} \times 10^{3})$$

Power → mW

$$\text{dB}\mu = 10\log_{10}(\text{Power} \times 10^{6})$$

Power → μW

Eg: Power = 10 kW.

$$dB = 10 \log_{10}(10\times10^3) = 10 \log_{10}(10^4)$$

$$dB = 40\ dB \leftrightarrow 10\ kW.$$

$$dBm = 10 \log_{10}(10\times10^3\times10^3) = 10 \log_{10}(10^7)$$

$$10\ kW \rightarrow 70\ dBm.$$

$$\boxed{dBm = dB + 30}$$

$$\boxed{dB = dBm - 30}$$

$-100\ dBm \leftrightarrow -130\ dB \longrightarrow$ Mobile phone strength

$$dBm = 10 \log_{10}(\text{Power}\times10^3)$$

$$-100 = 10 \log_{10}(\text{Power}\times10^3)$$

$$(\text{Power}\times10^3) = 10^{-100/10}$$

$$(\text{Power}\times10^3) = 10^{-10}$$

$$\text{Power} = 10^{-13} = \boxed{0.1\ pW}$$

Typical mobile phone signal strength varies from $\boxed{-85 \text{ to } -115\ dBm}$.

Observation:

Typically, mobile phone signal strength varies from -85 to -115 dBm. (or) 10^{-11} watts to 10^{-15} watts.

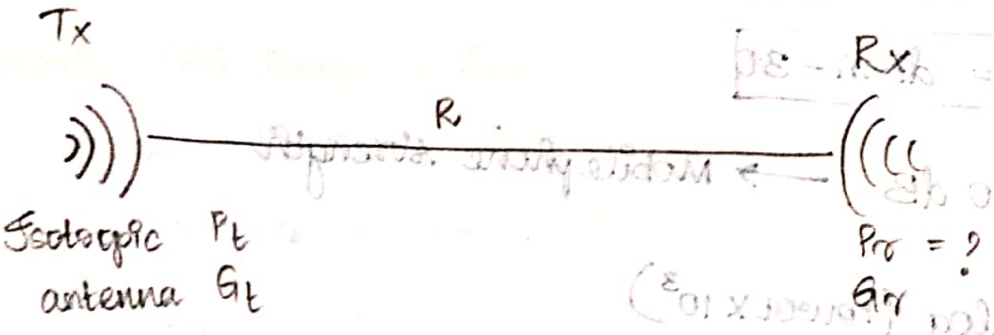
Derivation of Link Budget equation:

It is used to calculate the received power from satellite to earth station.

Consider an isotropic antenna (source) radiates a power (P_t) with gain (G_t) which is separated by a distance R.

The power flux density (F)

=



$$EIRP = P_t \cdot G_t$$

Inorder to find the power flux density which is power distributed throughout the area.

$$\text{Power flux density (F)} = \frac{\text{Power}}{\text{Area}}$$

$$F = \frac{P_t}{4\pi R^2}$$

By including gain (G_t),

$$F = \frac{P_t G_t}{4\pi R^2} \text{ watts}/m^2.$$

Inorder to find the received power at the earth station, F has to be multiplied by effective aperture of the receiving antenna.

$$P_r = F \times A_{eff}$$

$$P_r = \frac{P_t G_t A_{eff}}{4\pi R^2} \longrightarrow ①$$

P_r is independent of frequency

$$\text{gain } (G_r) = \frac{4\pi A_{eff}}{\lambda^2}$$

$$A_{eff} = \frac{G_r \lambda^2}{4\pi} \longrightarrow ②$$

where $\lambda = c/f$

sub ② in ①

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi R^2)(4\pi)} \longrightarrow ③$$

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

$$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi R}{\lambda}\right)^2} \longrightarrow ④$$

By rearranging eqn ④, EIRP = $P_t G_t$, Path loss $(L_p) = \left(\frac{4\pi R}{\lambda}\right)^2$

$$P_r = \frac{EIRP \times G_r}{L_p} \text{ (or) } \frac{EIRP \times G_r}{\left(\frac{4\pi R}{\lambda}\right)^2} \longrightarrow ⑤$$

To convert into dB.

$$10 \log_{10} (P_r) = 10 \log \left[\frac{EIRP\, G_r}{\left(\frac{4\pi R}{\lambda}\right)^2} \right]$$

$$\boxed{\begin{aligned} P_r\big|_{dB} &= EIRP\big|_{dB} + G_r\big|_{dB} - 10 \log \left(\frac{4\pi R}{\lambda}\right)^2 \rightarrow (6) \\ P_r\big|_{dB} &= EIRP\big|_{dB} + G_r\big|_{dB} - L_p\big|_{dB} \rightarrow (7) \end{aligned}}$$

Eqn (5), (6), (7), (4), (1) is known as link Budget equation or Friis equation or Satellite LOS equation or microwave link equation.

In addition to path loss, due to atmospheric condition and other microwave devices, new losses also may exist. Some of them are

1. Atmospheric and Ionospheric losses (L_u)
2. Antenna misalignment losses. (L_a)
3. Feeder and Branching losses (L_{bf})
4. Polarization losses (L_{PO})
5. Back-off loss (L_{BO})

$$(7) \Rightarrow P_r\big|_{dB} = EIRP\big|_{dB} + G_r\big|_{dB} - \left[L_p\big|_{dB} + L_{others}\big|_{dB} \right]$$

where $EIRP = P_t G_t$ and $L_p = \left(\frac{4\pi R}{\lambda}\right)^2$.

$$L_{others} = L_u + L_a + L_{bf} + L_{po} + L_{BO}.$$

Problem:

① The gain of an antenna to be 48 dB at the frequency of 4 GHz. Find the gain at 6 GHz.

$freq|_{old} = 4\ GHz \quad gain|_{old} = 48\ dB$

$freq|_{new} = 6\ GHz \quad gain|_{new} = ?$

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

$$G = \frac{4\pi A_e f^2}{c^2}$$

$$\boxed{G \propto f^2}$$

$$\frac{G_{new}}{G_{old}} = \frac{f^2_{new}}{f^2_{old}}$$

$$G_{new} = G_{old} \times \frac{f^2_{new}}{f^2_{old}}$$

$$G_{new}|_{dB} = G_{old}|_{dB} + 20 \log\left(\frac{f_{new}}{f_{old}}\right)$$

$$G_{new}|_{dB} = 48 + 20 \log\left(\frac{6}{4}\right)$$

$$\boxed{G_{new}|_{dB} = 51.52\ dB}$$

(3) A satellite at a distance of 40,000 km from the earth surface radiates a power of 10 watts with gain 17 dB in the direction of observer.

(i) Find the flux density at the receiving point.

(ii) Power received by an antenna at this receiving point with an effective area of $10\ m^2$.

(iii) If the satellite operates at a frequency of 11 GHz, the receiving antenna has a gain of 52.3 dB. Find the received power.

Given: $R = 40,000\ km = 4 \times 10^7\ m$.

$P_t = 10$ watts

$G_t = 17$ dB

(i) Flux density, $F = \dfrac{P_t G_t}{4\pi R^2}$

$10 \log_{10}(G_t) = 17$ dB

$G_t = 10^{17/10} = 10^{1.7}$

$\boxed{G_t = 50}$

$F = \dfrac{10 \times 50}{4\pi (4 \times 10^7)^2}$

$F =$ watts$/m^2$

(ii) Received power, $P_r = F \times A_{eff}$ (watts)

(iii) $P_r = \dfrac{P_t G_t G_r}{\left(\dfrac{4\pi R}{\lambda}\right)^2}$

23.9.2021

Method - I :

$G_r = 52.3$ dB $P_t = 10W$, $G_t = 17$ dB.

$R = 4 \times 10^7$ m; $\lambda = \dfrac{c}{f} = \dfrac{3 \times 10^8}{11 \times 10^9} = 0.02$ m.

$10 \log_{10}(G_r) = 52.3$

$G_r = 10^{52.3/10}$

$\boxed{G_r = 10^{5.23}}$

$P_r = \dfrac{10 \times 50 \times 10^{5.23}}{\left[\dfrac{4\pi \times 4 \times 10^7}{0.02}\right]^2}$

$\boxed{P_r = 1.34 \times 10^{-13} \text{ watts.}}$

$P_r|_{dB} = 10 \log(1.34 \times 10^{-13})$.

$\boxed{P_r|_{dB} = -128.8 \text{ dB}}$

Method - II :

$$P_r|_{dB} = P_t|_{dB} + G_t|_{dB} + G_r|_{dB} - 10\log\left(\frac{4\pi R}{\lambda}\right)^2.$$

$$= 10\log(P_t) + 17 + 52.3 - 10\log\left[6.31\times10^{20}\right]$$

$$= 10\log(10) + 17 + 52.3 - 208$$

$$= 10 + 17 + 52.3 - 208$$

$$\boxed{P_r|_{dB} = -128.7\ dB}$$

③ A geostationary satellite carries ~~a transponder~~ the power of 10 watts with a gain of 30 dB. An earth station is 38,500 km distance away from the satellite. Find the following.

① Flux density

② The power received by an antenna with a gain of 39 dB if the operating frequency is 4 GHz.

Given:

$P_t = 10$ watts

$G_t = 30$ dB

$R = 38500$ km.

$R = 385\times10^5$ m

① Flux density, $F = \dfrac{P_t G_t}{4\pi R^2}$

$$10\log_{10}(G_t) = 30\ dB$$

$$\boxed{G_t = 10^3}$$

$$F = \frac{10\times10^3}{4\pi\times(385\times10^5)^2}$$

$$\boxed{F = 5.37\times10^{-13}\ \text{watts}/m^2}$$

② Received power, $P_r|_{dB} = P_t|_{dB} + G_t|_{dB} + G_r|_{dB} - 10\log\left(\frac{4\pi R}{\lambda}\right)^2$

$$P_r|_{dB} = 10 + 30 + 39 - 10\log\left[\frac{4\pi \times 385 \times 10^5}{\frac{3\times10^8}{4\times10^9}}\right]^2 \qquad \boxed{\lambda = \frac{c}{\lambda}}$$

$$P_r|_{dB} = 10 + 30 + 39 - 10\log\left(4.156 \times 10^{19}\right)$$

$$P_r|_{dB} = 10 + 30 + 39 - 196.18$$

$$\boxed{P_r|_{dB} = -117.18 \text{ dB}}$$

③ Find the EIRP in dB.

$$EIRP = P_t \cdot G_t$$

$$EIRP|_{dB} = P_t|_{dB} + G_t|_{dB}$$

$$= 10 + 30$$

$$\boxed{EIRP|_{dB} = 40 \text{ dB}}$$

Observation: In the problem,

→ Power will always be given in watts. → Convert into dB.

$$P_t|_{dB} = 10\log(P_t)$$

→ Gain will be given in dB.

(4) The range b/w a ground station and a satellite is 42,000 km.
i) Calculate the free space loss at 6 GHz.
ii) Calculate the total link loss when the receiver has feeder losses of 1.5 dB, atmospheric absorption loss of 0.5 dB, antenna pointing loss of 0.5 dB, polarization loss of 1 dB.

Given:
$R = 42000\,km$
$R = 42 \times 10^6\,m$
$\boxed{\lambda = \frac{c}{f}}$

(i) Free space loss (Path loss).

$$L_p = \left(\frac{4\pi R}{\lambda}\right)^2$$

$$L_p|_{dB} = 10 \log \left(\frac{4\pi R}{\lambda}\right)^2$$

$$= 10 \log \left[\frac{4\pi \times 42 \times 10^6}{\frac{3 \times 10^8}{6 \times 10^9}}\right]^2$$

$$FSL|_{dB} \text{ (or) } L_p|_{dB} = \boxed{200.46\ dB}$$

(ii) Total link loss:

$$L_{total} = FSL|_{dB} + L_a + L_{bf} + L_u + L_{po}$$

(or)

$$L_{total} = FSL|_{dB} + RFL|_{dB} + AAL|_{dB} + AL|_{dB} + PL|_{dB}$$

$$L_{total} = 200.46 + 1.5 + 0.5 + 0.5 + 1$$

$$\boxed{L_{total} = 203.96}\ dB$$

Noise power :

In satellite communication, noise temperature plays a vital role, which produces thermal noise. At microwave frequencies, a black body with a temperature of T_p generates electrical noise over a wider bandwidth is known as thermal noise. The thermal noise power is given by

$$P_N = K T_p B_n \text{ watts.}$$

$K \rightarrow$ Boltzman constant $\rightarrow 1.38 \times 10^{-23}$ J/K
$\hookrightarrow (-228.6$ dB J/K$)$.

$T \rightarrow$ Temperature in Kelvin

$B_n \rightarrow$ Noise Bandwidth (Hz)

In above eqn, KT_p is known as Noise Power Spectral density.

24.2.2021

By converting noise power into dB,

$$10 \log (P_N) = 10 \log (K T_p B_n)$$

$$P_N \Big|_{dB} = K \Big|_{dB} + T_p \Big|_{dB} + B_n \Big|_{dB}$$

$$\boxed{[P_N] = [K] + [T_p] + [B_n]}$$

Carrier signal to noise ratio :

In order to assess the performance of any satellite link the ratio of carrier power to the noise power is needed.

For calculating C/N ratio, link budget eqns are helpful.

$$\frac{C}{N} = \frac{P_r}{P_n}$$

$$\frac{C}{N}\Big|_{dB} = 10\log\left(\frac{P_r}{P_n}\right)$$

$$= P_r|_{dB} - P_n|_{dB}$$

$$\left[\frac{C}{N}\right] = [P_r] - [P_n] \longrightarrow (1)$$

$$P_r|_{dB} = EIRP|_{dB} + G_r|_{dB} - Losses|_{dB} \longrightarrow (2)$$

$$P_n|_{dB} = K|_{dB} + T_p|_{dB} + B_n|_{dB} \longrightarrow (3)$$

sub (2), (3) in (1)

$$\boxed{\left[\frac{C}{N}\right] = [EIRP] + [G_r] - [Losses] - [K] - [T_p] - [B_n]} \longrightarrow (4)$$

$$\boxed{\left[\frac{C}{N}\right] = [EIRP] + \left[\frac{G_r}{T_p}\right] - [Losses] - [K] - [B_n]} \longrightarrow (5)$$

Carrier power to noise power. where $\left[\frac{G_r}{T_p}\right] = [G_r] - [T_p]$

In general, carrier power to the noise power spectral density is the quantity that the people will use.

$$N_0 = KT_p$$

$$\therefore \quad P_N = N_0 B_n$$

$$\frac{C}{N} = \left[\frac{C}{N_0 B_n}\right]$$

$$\left[\frac{C}{N}\right] = \left[\frac{C}{N_0}\right] - [B_n]$$

$$\left[\frac{C}{N_0}\right] = \left[\frac{C}{N}\right] + [B_n] \rightarrow (6)$$

sub (5) in (6),

$$\boxed{\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G_r}{T_p}\right] - [losses] - [K]} \rightarrow (7)$$

Problem:

In a link budget calculation, at 12 GHz, free space loss is 206 dB, the antenna misalignment loss is 1 dB, atmospheric absorption loss is 2 dB. The receiver G/T ratio is 19.5 dB/Kelvin and the receiver feeder loss is 1 dB. The EIRP is 48 dB watts. Calculate the carrier to noise power spectral density ratio.

Given:

$EIRP = 48$ dB watts

$\left[\frac{G}{T}\right] = 19.5$ dB

+

$[K] = -228.6$ dB J/K

$[FSL] = 206$ dB

$[AML] = 1$ dB

$[AAL] = 2$ dB $\quad [RFL] = 1$ dB

+

(−)

Soln:

$$\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right] - [Losses] - [K]$$

$$\left[\frac{C}{N_0}\right] = 48 + 19.5 + 228.6 - 206 - 1 - 2 - 1$$

$$\boxed{\left[\frac{C}{N_0}\right] = 86.1 \text{ dB Hz}}$$

Link Budget Analysis:

Uplink Design:

A link budget is a tabular method for evaluating the received power and noise power in a radio link, by doing addition and subtraction.

$$\left[\frac{C}{N_0}\right]_U = [EIRP]_U + \left[\frac{G}{T}\right]_U - [Losses]_U - [K]_U$$

Saturation flux density:

$$\text{Flux density, } \Psi_m = \frac{P_t G_t}{4\pi R^2}$$

$$\Psi_m = \frac{EIRP}{4\pi R^2}$$

$$\Psi_m\Big|_{dB} = 10 \log \left[\frac{EIRP}{4\pi R^2}\right]$$

$$[\Psi_m]_{dB} = [EIRP]_{dB} + 10 \log \left[\frac{1}{4\pi R^2}\right] \longrightarrow (1)$$

Path loss (FSL) $= \left(\frac{4\pi R}{\lambda}\right)^2$

$$-[FSL] = 10\log\left(\frac{\lambda}{4\pi R}\right)^2$$

$$-[FSL] = 10\log\left(\frac{\lambda^2}{4\pi}\right) + 10\log\left(\frac{1}{4\pi R^2}\right) \rightarrow (2)$$

Add & sub by $10\log\left(\frac{\lambda^2}{4\pi}\right)$ in eqn (1)

$$[\Psi_m] = [EIRP]_{dB} + 10\log\left(\frac{1}{4\pi R^2}\right) + 10\log\left(\frac{\lambda^2}{4\pi}\right) - 10\log\left(\frac{\lambda^2}{4\pi}\right)$$

From eqn (2)

$$[\Psi_m] = [EIRP]_{dB} - [FSL]_{dB} - [A_0]_{dB}.$$

$$\boxed{[EIRP]_{dB} = [\Psi_m] + [FSL]_{dB} + [A_0]_{dB}} \rightarrow (3)$$

By including all other losses in eqn (3),

$$\boxed{[EIRP]_{dB} = [\Psi_m] + [A_0]_{dB} + [losses] - [RFL]}$$

Receiver feeder loss due to transmission

where losses = FSL + AAL + AML + PL + BL.

$$A_0 = 10\log\left(\frac{\lambda^2}{4\pi}\right)$$

$$\boxed{\underbrace{[EIRP_{sat}]}_{uplink} = [\Psi_s] + [A_0] + [losses]_{uplink} - [RFL]} \rightarrow (2)$$

Input Backoff:

$$[EIRP]_U = [EIRP_S]_U - [Bo]_i \longrightarrow (3)$$

sub (2) in (3)

$$\boxed{[EIRP]_U = [\Psi_S] + [A_0] + [losses]_U - [RFL] - [Bo]_i} \longrightarrow (4)$$

By substituting [EIRP] in $\left[\frac{C}{N_0}\right]$ ratio equation,

$$\left[\frac{C}{N_0}\right] = [EIRP]_U + \left[\frac{G}{T}\right]_U - [K] - [losses]_U$$

sub eqn (4),

$$\left[\frac{C}{N_0}\right] = [\Psi_S] + [A_0] + [losses]_U - [RFL] - [Bo]_i + \left[\frac{G}{T}\right]_U - [K] - [losses]_U$$

(*) $$\boxed{\left[\frac{C}{N_0}\right] = [\Psi_S] + [A_0] + \left[\frac{G}{T}\right] - [K] - [Bo]_i - [RFL]}$$

Problem:

An uplink at 14 GHz requires a saturation flux density of -91.4 dB watts/m^2 and an input Bo of 11 dB. The satellite $\left[\frac{G}{T}\right]$ ratio is -6.7 dB/K and RFL is 0.6 dB. Calculate the carrier to noise power spectral density ratio.

Given:

$[\Psi_S] = -91.4$ dBW/m^2, $[RFL] = 0.6$ dB.

$[Bo]_i = 11$ dB

$\left[\frac{G}{T}\right] = -6.7$ dB/K

Soln:

$$\left[\frac{C}{N_0}\right] = [\Psi_S] + [A_0] + \left[\frac{G}{T}\right] - [K] - [B_0]_i - [RFL]$$

$$\left.\begin{aligned}[\Psi_S] &= -91.4 \text{ dB watts}/m^2 \\ [A_0] &= -44.4 \text{ dB} \\ \left[\frac{G}{T}\right] &= -6.7 \text{ dB/K}\end{aligned}\right\} (+)\ -142.5$$

$$\left.\begin{aligned}[RFL] &= 0.6 \text{ dB} \\ [B_0]_i &= 11 \text{ dB} \\ [K] &= -228.6 \text{ dBJ/K}\end{aligned}\right\} (+)\ -217$$

$(-)$ $\boxed{74.5 \text{ dBHz}}$

$$A_0 = 10 \log\left(\frac{\lambda^2}{4\pi}\right) = 10 \log\left(\frac{c^2}{f^2 4\pi}\right)$$

$$A_0 = 10 \log\left[\frac{(3\times10^8)^2}{(14\times10^9)^2 \times 4\pi}\right]$$

$$\boxed{A_0 = -44.4 \text{ dB}}$$

Ans: $\left[\frac{C}{N_0}\right] = 74.5$ dB Hz.

Downlink link Budget equation:

As we know that carrier to noise ratio for downlink satellite communication is

$$\left[\frac{C}{N}\right]_D = [EIRP]_D + \left[\frac{G}{T}\right]_D - [losses] - [K] - [B_N]_D \longrightarrow (1)$$

$$\left[\frac{C}{N_0}\right]_D = [EIRP]_D + \left[\frac{G}{T}\right]_D - [losses] - [K] \longrightarrow (2)$$

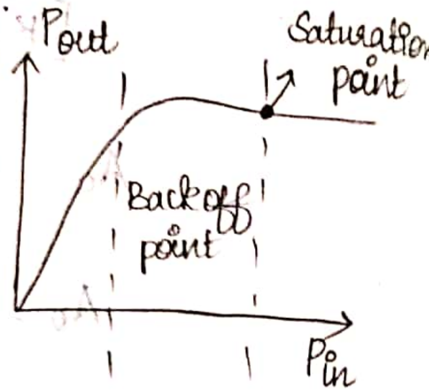
By including output Backoff power,

$$[EIRP] = [EIRP_{sat}] - [BO]_{output} \longrightarrow (3)$$

In the downlink output Backoff power is only included.

$$\boxed{\left[\frac{C}{N_0}\right] = [EIRP_{sat}]_D + \left[\frac{G}{T}\right]_D - [losses] - [K] - [BO]_{output}} \longrightarrow (4)$$

where $[BO]_{output} = [BO]_{input} - 5\ dB$.



Problem:

The specified parameters for a downlink satellite communication is are

EIRP = 25 dBW

Output BO = 6 dB

FSL = 196 dB

Other downlink losses = 1.5 dB.

$\left[\frac{G}{T}\right] = 41\ dB/K$

Calculate the carrier to noise density ratio at the earth station.

Soln:

$$\left[\frac{C}{N_0}\right] = [EIRP_S]_D + \left[\frac{G}{T}\right]_D - [losses] - [K] - [BO]_{output}$$

$$\left.\begin{array}{l}[EIRP_S]_D = 25\ dBW \\ \left[\frac{G}{T}\right]_D = 41\ dB/K\end{array}\right\}(+)\ 66$$

$$\left.\begin{array}{l}[FSL] = 196\ dB \\ [losses] = 1.5\ dB \\ [Bo]_{output} = 6\ dB \\ [K] = -228.6\ dB\ J/K.\end{array}\right\}(+)\ -25.1$$

$(-)$ $\boxed{91.1\ dB\ Hz}$

Ans: $\frac{C}{N_0} = 91.1\ dB\ Hz$.

A satellite TV signal occupies the full Bandwidth of 36 MHz and it must provide C/N ratio at the destination earth station (downlink) of 22 dB. Given that the total transmission losses are 200 dB and $\frac{G}{T}$ ratio is 31 dB/K. Calculate the satellite EIRP required.

Given:

$$\frac{C}{N} = 22\ dB$$

$$\frac{G}{T} = 31\ dB/K.$$

$$Losses = 200\ dB$$

$$Bo = 36\ MHz.$$

$$K = -228.6\ dB\ J/K.$$

$$\left[\frac{C}{N}\right]_D = [EIRP]_D + \left[\frac{G}{T}\right]_D - [losses] - [K] - [B_0]^N_{D\ output}.$$

Determine carrier to noise density Ratio at Satellite input For uplink as the Follwing parameters

operating Frequency → 6GHz

Saturation Flux density → -95 dBw/m2

Input BO → 11 dB

$\left[\frac{G}{T}\right]$ → -7 dB/K

RFL → 0.5 dB

Solution

$$\left[\frac{C}{N_o}\right] = [EIRP] + \left[\frac{G}{T}\right] - [Losses] - [K]$$

$$\left[\frac{C}{N_0}\right] = [\Psi_S] + [A_0] + \left[\frac{G}{T}\right] - [RFL] - [K] - [B_0]_i$$

where

$$[EIRP] = [\Psi_S] + [A_0] + [Losses] - [B_0]_i - [RFL]$$

Given

$\Psi_S = -95 \text{ dBW/m}^2$

$A_0 = 10 \log\left(\frac{\lambda^2}{4\pi}\right)$

$= -37.012 \text{ dB}$

$\left[\frac{G}{T}\right] = -7 \text{ dB K}^{-1}$

RFL 0.5 dB

$[B_0]_i$ 11 dB

$[K]$ 228.6 dB J/K

-51

217.1

$= 78.1 \text{ dBHz}$

2) $\left[\frac{C}{N}\right]$ ratio is 20dB

Frequency is 30 GHz

BW - 72 MHz → 78.57 dB

$\left[\frac{G}{T}\right]$ - 14.5 dB/K

Input [Bo] - 11 dB

RFL - 1 dB

To Find Saturation Flux density Ψ_s

$$\left[\frac{C}{N}\right] = [\Psi_s] + [A_0] + \left[\frac{G}{T}\right] - [RFL] - [K] - [Bo]_i - [B_n]$$

3) For a Satellite downlink ~~Saturation~~

$[EIRP]_{Sat}$ = 22.5 dBW

FSL = 195 dB

Other losses = 1.5dB

$\left[\frac{G}{T}\right]$ = 37.5dB/K

Calculate $\left[\frac{C}{N_0}\right]_D$ earth station $= [EIRP] + \left[\frac{G}{T}\right] - [Losses] - [K]$

If output BO of 6 dB applied is applied a $\left[\frac{C}{N_0}\right]$ ratio

$$\left[\frac{C}{N_0}\right]_D = [EIRP_{sat}] + \left[\frac{G}{T}\right] - [Losses] - [K] - [B_0]_{output}$$

4) For a satellite circuit $\left[\frac{C}{N}\right]$ values for uplink & down link given as 25 dB & 15 dB respectively. Calculate overall $\left[\frac{C}{N}\right]$ value

(x). $$\left[\frac{C}{N}\right] = \left[\frac{C}{N}\right]_{up} + \left[\frac{C}{N}\right]_{Down}$$

Effects of Rain

Rain induce attenuation

So far $\left[\frac{C}{N_0}\right]$ is calculated under clear sky conditions (in the absence of Rain)

In C band (4 GHz to 8 GHz)

Ku band 12 GHz to 18 GHzs

→ Rain Fall is most significant cause of Reducing the signal strength

→ Rain Falla results in attenuation of EM waves by scattering and absorption of energy

→ Rain attenuation increases with increase Frequency

→ Rain attenuation data are available in Form of table or graph

→ Rain attenuation increases with increase in frequency.

→ The rain attenuation data are available in the form of tables or graphs.

Rain attenuation:

Location	Rain attenuation in dB		
	1%	0.5%	0.1%
Cat lake	0.2	0.4	1.4
Fort severn	0.0	0.1	0.4
Geraldton	0.1	0.2	0.9

At Cat lake, the rain attenuation exceeds, on average throughout the year, 0.2 dB for 1% of time, 0.4 dB for 0.5% of time, 1.4 dB for 0.1% of time. It implies the attenuation will be equal to or less than 0.2 dB for 99% of time.

Rain droplets are elliptical in shape rather than spherical shape. When EM wave with some arbitrary polarization passes through rain drops, the component of electric field will be affected because the rain droplets are elliptically polarized. It leads to fading in the received signal strength.

Uplink rain-fade margin:

Rainfall results in attenuation of the signal and increase in noise temperature degrades the C/N_0 value. Inorder to reduce the noise temperature the high power amplifiers must be used. Inorder to control the uplink carrier power at the satellite for certain modes of operation, high power control devices must be enabled at the uplink.

Downlink rain-fade margin:

Let [A] dB be the rain attenuation caused by absorption and scattering. The corresponding power loss ratio is

$A = 10^{[A]/10}$.

Noise temperature with respect to power loss is given by

$$T_N = T_x\left(1 - \frac{1}{L}\right)$$ where L is loss (Power loss)

$T_x \rightarrow$ ~~Noise~~ Source temperature.

$T_N \rightarrow$ Noise temperature.

Here, effective noise temperature of the rain is

$$T_{rain} = T_a\left(1 - \frac{1}{A}\right)$$

where $T_a \rightarrow$ Atmospheric temperature / Apparent Absorber Temperature

$A \rightarrow$ Power loss.

The Total sky noise temperature is the sum of Rain temperature and clear sky temperature.

$$T_{sky} = T_{CS} + T_{rain}$$

Inference:

Thus, C/No degrades by the rain attenuation in 2 ways.

① Attenuation of the carrier wave

② Increasing the noise temperature.

Combined Uplink and Downlink C/N ratio:

When more than one C/N ratio is present in the link, we can add the individual C/N ratios reciprocally to obtain the overall C/N ratio.

$$\left[\frac{C}{N}\right]_{overall} = \frac{1}{\frac{1}{\left[\frac{C}{N}\right]_1} + \frac{1}{\left[\frac{C}{N}\right]_2} + \cdots + \frac{1}{\left[\frac{C}{N}\right]_m}}$$

$$\left[\frac{C}{N}\right]_{overall} = \frac{1}{\left[\frac{N}{C}\right]_1 + \left[\frac{N}{C}\right]_2 + \cdots + \left[\frac{N}{C}\right]_m}$$

In general, the carrier power is constant for all the links

$$\therefore \left[\frac{C}{N}\right]_{overall} = \frac{1}{\left[\frac{N_1}{C}\right] + \left[\frac{N_2}{C}\right] + \cdots + \left[\frac{N_m}{C}\right]}$$

$$\left[\frac{C}{N}\right]_{overall} = \frac{C}{[N_1] + [N_2] + \cdots + [N_m]}$$

Problem:

For a satellite circuit, the individual link carrier to noise spectral density ratios are uplink 100 dB Hz ; downlink 87 dBHz. Calculate the combined C/N_0 ratio.

Soln:

$$\left(\frac{C}{N}\right)_{overall} = \frac{1}{\frac{1}{\left(\frac{C}{N}\right)_U} + \frac{1}{\left(\frac{C}{N}\right)_D}}$$

477.32×10^6

$10 \log \left[\frac{C}{N}\right]_U = 100$

$\left[\frac{C}{N}\right]_U = 10^{10}$

$10 \log \left[\frac{C}{N}\right]_D = 87$

$\left[\frac{C}{N}\right]_D = 10^{8.7}$

$$= \frac{1}{\frac{1}{10^{10}} + \frac{1}{10^{8.7}}}$$

$$= \frac{1}{\frac{10^{8.7} + 10^{10}}{10^{10} \times 10^{8.7}}}$$

$$= \frac{10^{18.7}}{10^{8.7} + 10^{10}}$$

$$\left[\frac{C}{N}\right]_{overall} = 477.32 \times 10^6 \text{ Hz}$$

$$\left[\frac{C}{N}\right]_{\substack{overall \\ dB}} = 10 \log (477.32 \times 10^6) = \boxed{86.79 \text{ dBHz}}.$$

ANALOG SIGNALS:

Analog signals are electrical replicas of the original signals such as audio and video.

Baseband signals are those signals which occupy the lowest or baseband of frequencies, in the frequency spectrum used by the telecommunication network.

A baseband signal consist of one or more information signal.

Natural speech, including that of male & female voices, covers a frequency range of about 80 to 8000 HZ. The range of 300 to 3400 HZ is accepted as the standard speech signal for telephone quality, which is termed as speech baseband.

SOURCE SIGNALS: Voice, Data and video.

* These are ~~are~~ telephone speech signal, data signals of various types and video signals, both for broadcast quality and business teleconferencing quality.

(i) The telephone speech signal:

The telephone speech signal is one of a class of audio signals with bandwidth of upto about 20KHz. It results as an electrical signal by talking into a telephone handset, which acts as the acoustic-to-electric transducer. The bandwidth restriction of 200 to 3400 HZ between acceptable quality & economy, ... the case in practical engineering

It was brought about by the design of the telephone set & historically evolved interconnecting analog transmission system.

Illustrative characteristics of telephone speech signal.

Bandwidth occupied	- 300-3400 HZ
Nominal frequency spacing per channel	- 4 KHZ
SNR	→ ≃ 45 dB
Interference levels	- 60 to 65 dB
Speech activity.	- 30-40 %.

A useful measure of performance in telephone speech is SNR of the received signal, together with the received power level at the telephone handset. The telephone speech signals exhibit an amplitude distribution. From this distribution, it can be determined that a practical peak to average ratio of 19 dB is acceptable. It should be realized that the 3% peak clipping only applies to the loudest talkers. The average activity or duty cycle in the speech signal is about 30 to 40% active and thus 70 to 60% idle time.

There are two additional parameters specified to determine the ultimate quality of the reconstructed analog speech signal. They are transmission rate of bits per second and bit error rate.

The BER required to support speech telephony is normally considered to have a threshold of about 10^{-4}. If the BER exceeds 10^{-4}, the speech quality has been often judged to be unacceptable. ∴ an error rate of 10^{-4} is typically used as the design threshold for digital speech telephony systems.

(ii) Data signals:

Data signals can be broadly classified into three ranges: narrow band (≤ 300 b/s), voice band data (300 b/s to 19 kb/s) and wideband data (> 19 kb/s). Classifying data applications into these three categories, by speed, approximately matches the transmission facilities used to support them.

Narrow band data begin at telegraphy rates & include a wide range of communication applications, with terminals and teleprinters usually implemented over wire facilities requiring no special precautions. Data of many types such as fascimile & transactional services are supported at rates upto 19 kb/s using data modems operating within the voice band (300-3400 Hz).

Wide band data applications, such as electronic mail, high speed file transfer, computer aided design & video, teleconferencing & Imaging utilize the efficient ... capabilities.

(iii) Video Signals:

There are two types of video signals transmitted via satellite circuits. The first is broadcast-quality commercial television and the second is television used for business teleconferencing.
The commercial broadcast quality signals are high resolution, high quality signals and thus require large analog bandwidths or high data rates.
The business video signal employs typically much lower data rates (≤ 1.544 Mb/s).

Television signals contain information in electrical form from which a picture can be recreated. To translate a complete picture into electrical signal, the electronic image of that picture is scanned at high speed. Such scanning is done horizontally starting at upper left corner. The intensity of the light in each part of the image is called luminance and is represented by the magnitude of the waveform representing each scan line.

ANALOG TRANSMISSION SYSTEMS

This systems are used to transmit signals via satellite. Here, the focus is on the transmission of telephony signals because data and video signals use essentially the same techniques.

Analog transmission via satellite is accomplished by two techniques.

(i) MCPC - Multiple channel per carrier technique employing carriers amplitude modulated by group of multiplexed voice channels from terrestrial systems.

(ii) SCPC - Single channel per carrier technique wherein a single voice channel is assigned its own individual carrier.

Example Analog systems:

* AM & DSB-SC-AM system (Describe it).
* FM, WBFM (Describe it).
* Give general block diagram of analog systems.

DIGITAL TRANSMISSION SYSTEMS.

The merging of computer and communication technologies has been so strong that it has dramatic shifts in the methods of transmission from analog to digital.

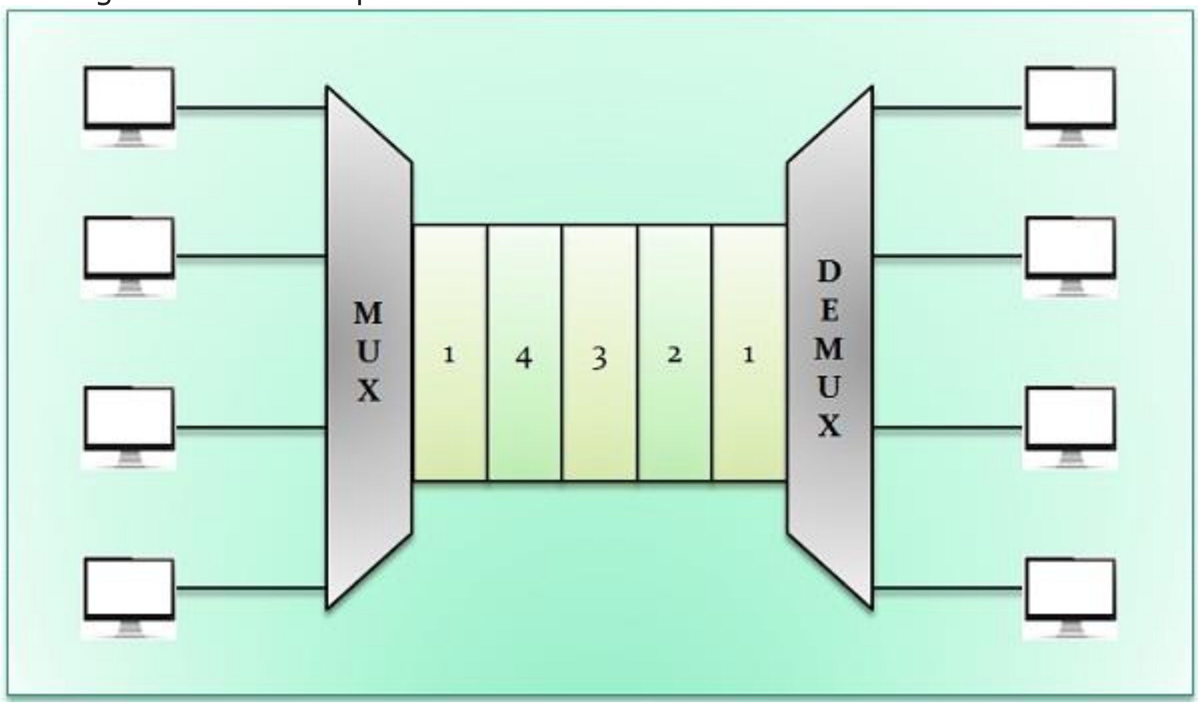
Some of the reasons that digital technologies have gained wide acceptance because of Ruggedness, power trade-off, video/data integration, Security etc.

System types: Digital transmission systems are in use on satellites in both SCPC & MCPC applications. A digital SCPC is implemented by first converting the analog voice frequency (VF) signal into digital form using one of several coding techniques like PCM, DM, Adaptive coding techniques (ADPCM). In MCPC systems, multiple digital voice signals, after analog to digital conversion are combined using TDM.

→ Describe PCM, ADPCM & DM.

→ Digital modulation techniques like like BPSK, QPSK. (Describe it).

Time-division multiplexing (TDM) is considered to be a digital procedure which can be employed when the transmission medium data rate quantity is higher than the data rate requisite of the transmitting and receiving devices. In TDM, corresponding frames carry data to be transmitted from the different sources. Each frame consists of a set of time slots, and portions of each source is assigned a time slot per frame.



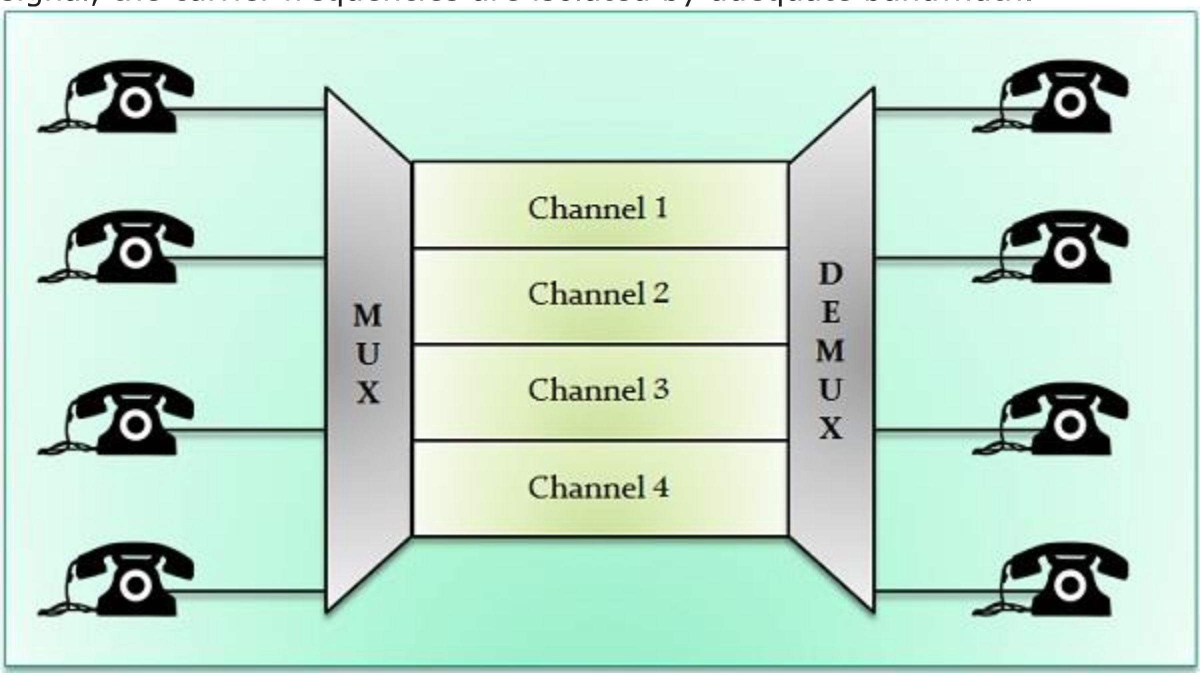
Types of TDM :

- **Synchronous Time-Division Multiplexing** – In this type the synchronous term signifies that the multiplexer is going to assign precisely the same slot to each device at every time even if a device has anything to send or not. If it doesn't have something, the time slot would be empty. TDM uses **frames**to group time slots which covers a complete cycle of time slots. Synchronous TDM uses a concept, i.e., **interleaving** for building a frame in which a multiplexer can take one data unit at a time from each device, then another data unit from each device and so on. The order of the receipt notifies the demultiplexer where to direct each time slot, which eliminates the need of addressing. To recover from timing inconsistencies **Framing bits** are used which are usually appended to the beginning of each frame. **Bit stuffing** is used to force speed relationships to equalize the speed between several devices into an integer multiple of each other. In bit stuffing, the multiplexer appends additional bits to device's source stream.
- **Asynchronous Time-Division Multiplexing** – Synchronous TDM waste the unused space in the link hence it does not assure the efficient use of the full capacity of the link. This gave rise to Asynchronous TDM. Here

Asynchronous means flexible not fixed. In Asynchronous TDM several low rate input lines are multiplexed to a single higher speed line. In Asynchronous TDM, the number of slots in a frame is less than the number of data lines. On the contrary, In Synchronous TDM the number of slots must be equal to the number of data lines. That's why it, avoids the wastage of the link capacity.

Definition of FDM

Frequency-division multiplexing (FDM) is an analog technique which is implemented only when the bandwidth of the link is higher than the merged bandwidth of the signals to be transmitted. Each sending device produces signals which modulate at distinct carrier frequencies. To hold the modulated signal, the carrier frequencies are isolated by adequate bandwidth.



The modulated signals are then merged into one compound signal that can be transferred by the link. The signals travel through the bandwidth ranges referred to as channels.

Signals overlapping can be controlled by using unutilized bandwidth strips for segregating the channels, these are known as **guard bands**. Also, carrier frequencies should not interrupt with the original data frequencies. If any condition fails to adhere, the original signals cannot be recovered.

Key Differences Between TDM and FDM

1. The time-division multiplexing (TDM) includes sharing of the time through utilizing time slots for the signals. On the other hand, frequency-division

multiplexing (FDM) involves the distribution of the frequencies, where the channel is divided into various bandwidth ranges (channels).

2. Analog signal or Digital signal any could be utilized for the TDM while FDM works with Analog signals only.
3. **Framing bits** (Sync Pulses) are used in TDM at the start of a frame in order to enable synchronization. As against, FDM uses **Guardbands** to separate the signals and prevent its overlapping.
4. FDM system generates different carriers for the different channels, and also each occupies a distinct frequency band. In addition, different bandpass filters are required. Conversely, the TDM system requires identical circuits. As a result, the circuitry needed in FDM is more complex than needed in TDM.
5. The **non–linear** character of the various amplifier in the FDM system produces **harmonic distortion**, and this introduces the **interference**. In contrast, in TDM system time slots are allotted to various signals; as the multiple signals are not inserted simultaneously in a link. Although, the non-linear requirements of both the systems are same, but TDM is immune to interference (crosstalk).
6. The utilization of physical link in case of TDM is more efficient than in FDM. The reason behind this is that the FDM system divides the link in multiple channels which does not make use of full channel capacity.

Conclusion

TDM and FDM, both are the techniques used for multiplexing. FDM uses analog signals, and TDM uses Analog and digital both types of signals. However, the efficiency of TDM is much greater than FDM.

MULTIPLE ACCESS

Multiple access is defined as the techniques wherein more than one pair of earth stations can use simultaneously a single transponder.

It is the technique used to exploit the satellite's geometric advantage. A transponder may be accessed by single or multiple carriers. These carriers may be modulated by single or multiple channel basebands, which include voice, data or video communication signals.

The basic multiple access techniques used in Commercial Communication satellite systems are of three types. FDMA, TDMA and CDMA.

Frequency Division Multiple Access: FDMA.

In FDMA, the channel bandwidth is subdivided into a number of subchannels. It assigns individual channel to individual users generally. These systems channelize a trasponder using multiple carriers. It can use either analog or digital transmission in either continuous or burst mode. The original FDMA method using multiple channels per carrier (MCPC) was derived from terrestial frequency division multiplex systems. FDMA system may accomodate both MCPC and SCPC techniques.

- Analog MCPC (FM/FDMA):

It is the first multiple access technique to be employed in satellite communication. It is mainly designed for analog transmission.

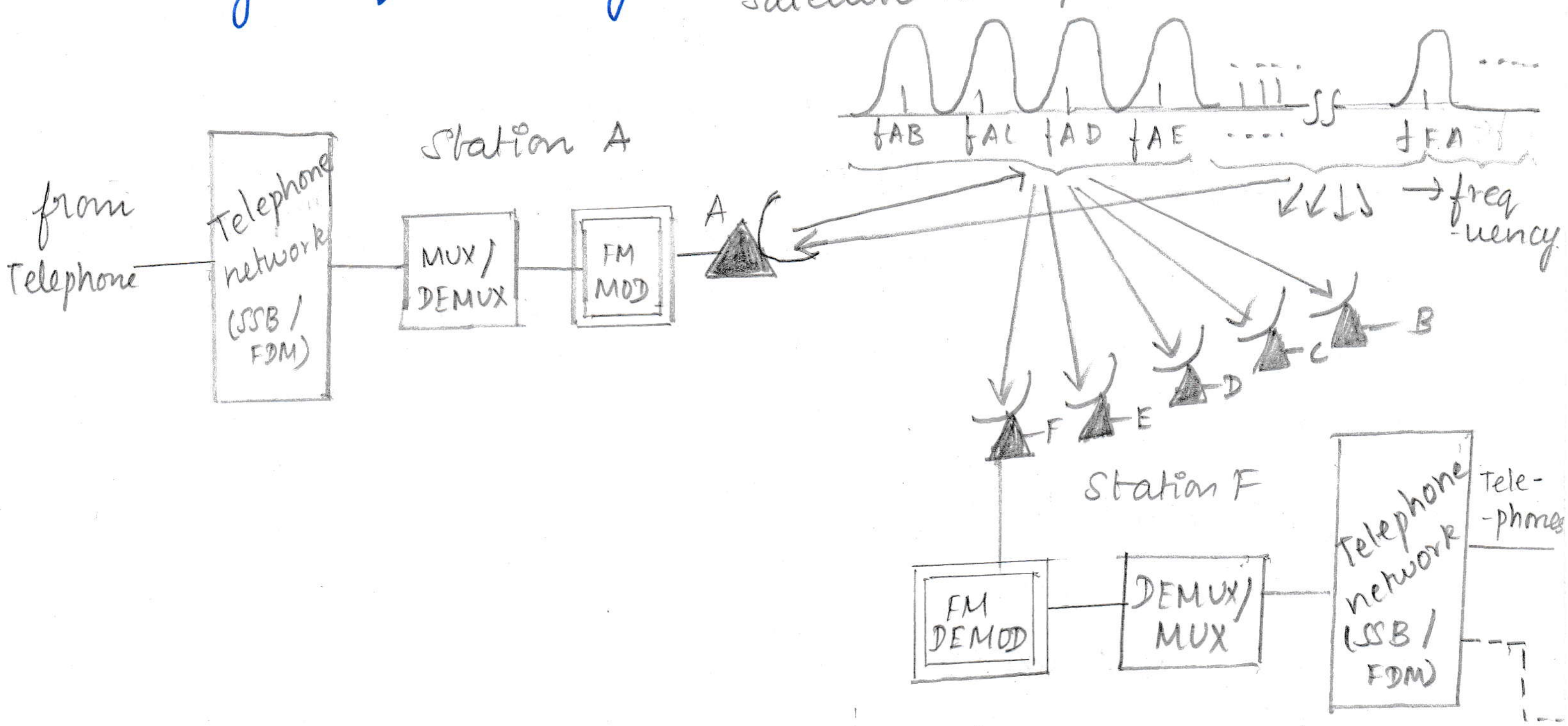


Fig: Preassigned multidestinational SSB/FDM/FDMA.

Figure shows a typical implementation of the system. Individual voice band channels are first SSB modulated on terrestrial frequency division multiple carriers to form FDM baseband assemblies. These channel assemblies are interconnected at a satellite ES in accordance with a frequency assignment plan. Here assuming a symmetrical 6-station traffic mesh. At the station, FDM basebands are frequency modulated on preassigned carriers and transmitted through the satellite in an appropriate portion of transponder bandwidth.

Receiving stations demodulate each received carrier and using FDM tecnique, pass only those channel assemblies assigned to that particular station.

Digital MCPC: It is used for transmission of digitally encoded baseband signals. The baseband information for each carrier typically Consists of multichannel PCM - TDM bit streams The operational requirement are similar to those used in analog FDM transmission, requiring no network clock synchronization and Only the rather simple frequency coordination typical of FDMA systems

The required carrier to noise ratio is,

$$(C/N)_t = (Eb/No)_t - B_N + R + M_I + M_A$$

$(C/N)_t$ is carrier to noise ratio at the threshold error rate.

(Eb/No) is the bit energy to noise density ratio at the threshold error rate.

B_N - Noise Bandwidth., R - data rate of the digital signal, M_I - margin associated with implementation of modem. $M_A \Rightarrow$ margin for adjacent channel interference.

Carrier to Noise density is $(C/N_0)_t = (C/N)_t + B_N$.

SCPC system in FDMA!

Another important class of FDMA systems employs scpc techniques wherein each voice and/or data channel is modulated on a separate radio-frequency carrier. No multiplexing is involved except within the transponder bandwidth, where frequency division is used to channelize individual carriers, each supporting the information from a single channel.

Associated with each incoming signal is a channel unit, which contains all the equipment required to convert the voiceband or digital data signal into a PSK modulated RF carrier for transmission over the satellite channel using only that station's assigned part of the transponder bandwidth.

To establish a conversation b/w two locations, a pair of channel frequencies is selected, one for each direction of transmission. On the receive side, the channel unit associated with each RF carrier contains all the equipment required to demodulate RF carrier and deliver either a voiceband signal or a digital signal to the terrestrial end links.

KEY FEATURES OF FDMA:

* FDMA gives user an individual allocation of one or several frequency bands.
* It requires high-performing filters in the radio hardware in contrast to TDMA & CDMA.
* It is not Vulnerable to the timing problems.
* Due to the frequency filtering, FDMA is not sensitive to near far problem which is pronounced for CDMA.
* Each user transmits and receives at different frequencies as each user gets a unique frequency slot.
* It is important to distinguish between FDMA and FDD (frequency division duplexing). While FDMA allows multiple users simultaneous access to a certain System, FDD refers to how the radio channel is shared between the uplink and downlink instances.
* It supports demand assignment in addition to fixed assignment.
* In this scheme, a bandwidth is assigned to an earth station and is divided into n segments to manage the network traffic.
* We know that the basic two categories of the scheme are MCPC and SCPC.
* It is necessary to include guard bands to minimize the adjacent channel Interference at the Base station the same antenna

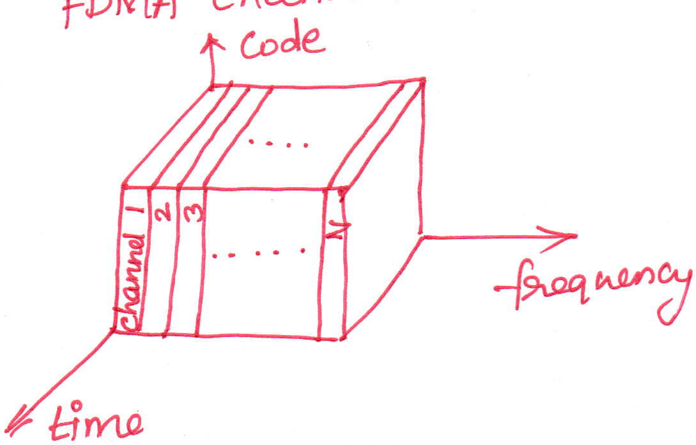
* There are two factors which limit the number of FDMA accesses through a transponder. They are intermodulation noise and spectrum utilization efficiency.

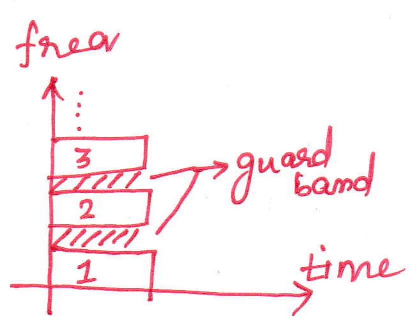
* It is cost Efficient
* Network timing is not required, hence making the system less complex.
* Demand assign is more preffered over pre assigned method, as a reducting in cost is possible through sharing of equipments.
* The main disadvantage is the presence of intermodulation noise in the transponder which leads to interference with other links.

Flexibility in channel allocation is less.

Uplink power control is required to maintain the link quality.

FDMA Channels.





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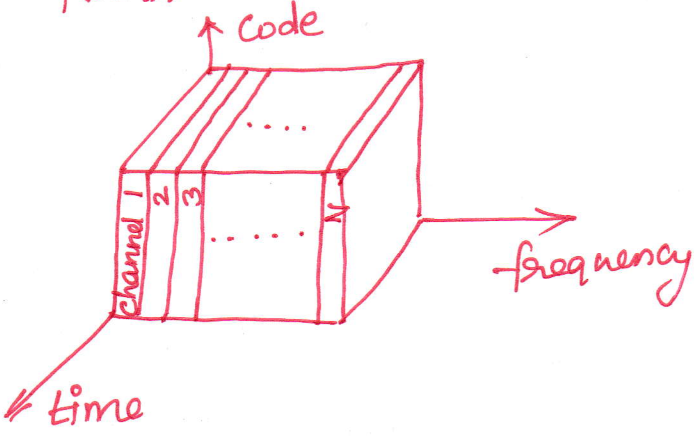

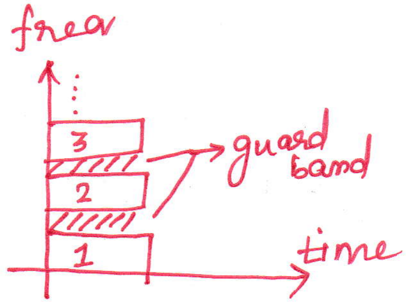

Preassigned FDMA :-

Frequency slots may be preassigned to analog and digital signals and to illustrate the method, analog signals in FDM / FM / FDMA format will be considered first. In general, the voice frequency signals are first SSB SC amplitude modulated onto voice carriers inorder to generate the single sidebands needed for the FDM. Each Earth Station will be assumed to transmit 60-channel supergroup. Each 60 channel supergroup is then frequency modulated onto a carrier which is then upconverted to a frequency in the satellite uplink band.

Ex: Preassignment : Suppose an earth station can transmit upto 60 voice circuits and that of these are preassigned to the particular route. If these 40 circuits are fully loaded, additional calls on the route will be blocked even though there may be idle circuits on the other preassigned routes. It may also be made on the basis of SCPC.

Demand assigned FDMA :-

In this mode, the transponder frequency bandwidth is subdivided into a number of channels. A channel is assigned to each carrier in use, giving rise to the SCPC mode of operation.

As in the preassigned access mode, carriers may be frequency modulated with analog information signals, these being designated FM/SCPC.
This assigned may be carried out in polling method. In the polling method, a master ES continuously polls all the earth station in sequence, and if a call request is encountered, frequency slots are assigned from the pool of available frequencies. The polling delay with such a system tends to become excessive as the number of participating earth station increases.

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TIME DIVISION MULTIPLE ACCESS TECHNIQUE (TDMA)

With TDMA, only one carrier uses the transponder at any one time, and therefore, intermodulation products, which result from the non-linear amplification of multiple carriers are absent.
In TDMA, the digital data can be assembled into burst format for transmission and reassembled from the received bursts through the use of digital buffer memories. The basic concept of TDMA is as follows. In TDMA, the stations transmit bursts in sequence.

Burst synchronization is required in this system which is illustrated in the following figure.

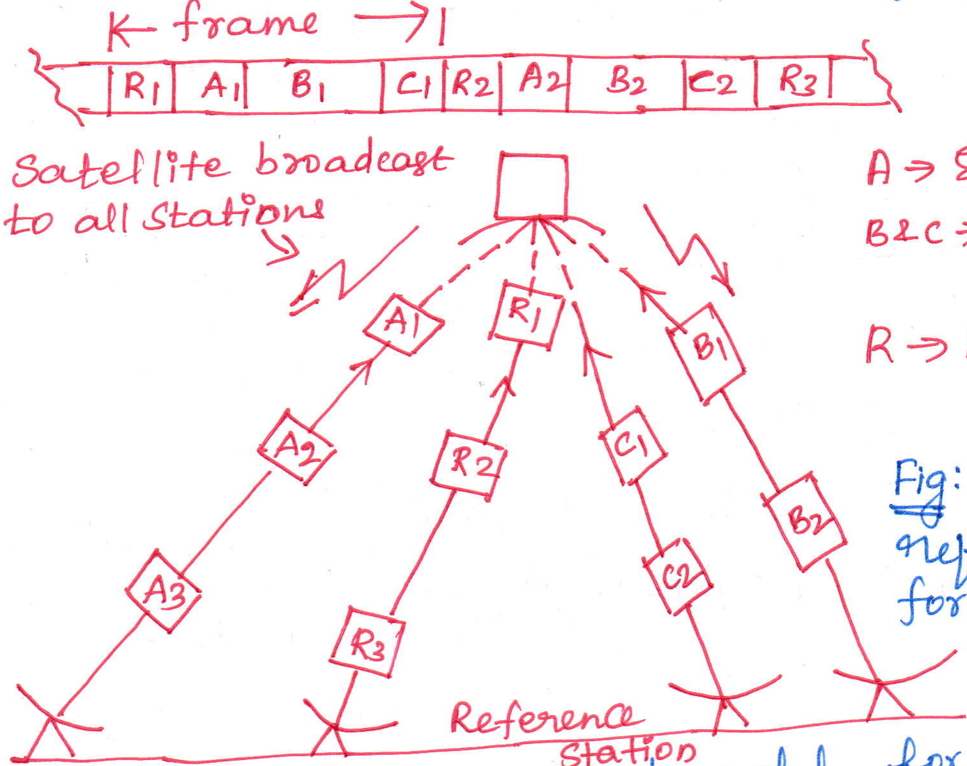
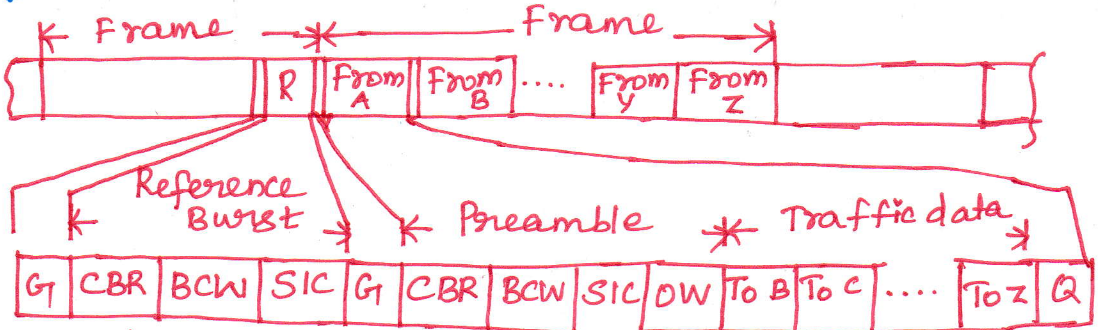


Fig: TDMA using a reference station for burst synchronization

Here one station is assigned solely for the purpose of transmitting reference bursts to which the others can be synchronized. The time interval from the start of one reference burst to the next is termed a frame. A frame contains the reference burst R and the bursts from the other earth stations, these being shown as A, B and C in the fig.

Certain time slots at the beginning of each burst are used to carry timing & synchronizing information. These slots are collectively called as Preamble. The complete burst containing the preamble & traffic data is used to modulate the carrier.

Frame and burst format for TDMA.



G - guard time
CBR - Carrier & Bit timing recovery
BCW - Burst code word
SIC - Station Identification code
Q - Postamble
OW - order wire.

* A reference burst is required at the begining of each frame to provide timing information for the acquisition & synchronization of bursts. The reference burst is subdivided into time slots or channels used for various functions

i) Guard time: It is necessary between bursts to Prevent the bursts from overlapping. It will vary from burst to burst depending on the accuracy with which the various bursts canbe positioned within each frame

ii) Carrier and Bit timing recovery: A coherent carrier signal must be recovered from the burst for performing coherent demodulation.

An unmodulated carrier is provided during the first part of CBR timeslot. The carrier in the part of CBR time slot is modulated by a known phase change sequence which enables the bit timing to be recovered.

iii) Burst code word (BCR): or Unique word (UW).

This is a binary word, a copy of which is stored at each earth station. By comparing the incoming bits in a burst with the stored version of the BCW, the receiver can detect when a group of received bits matches BCW.

iv) Station Identification code (SIC): This identifies the transmitting station.

Frame Efficiency: It is a measure of the fraction of frame time used for the transmission of traffic. It may be defined as, Frame Efficiency $\eta_F = \dfrac{\text{traffic bits}}{\text{total bits}}$.

(or) $\eta_F = 1 - \dfrac{\text{overhead bits}}{\text{total bits}}$.

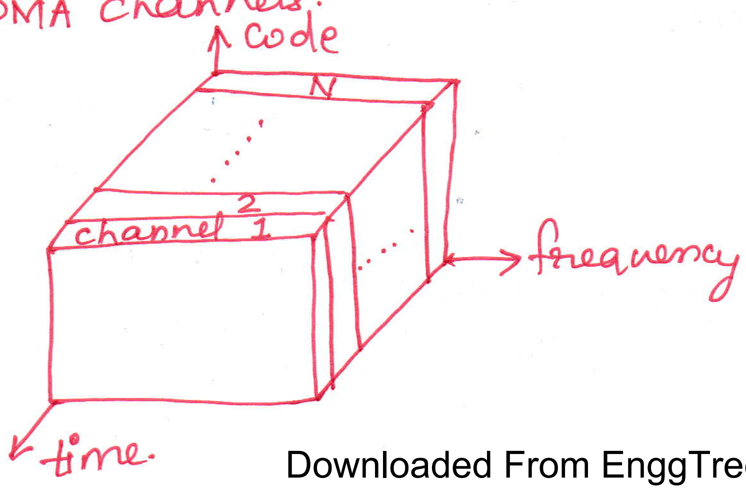
Preassigned TDMA: It can accomodate upto 49 Earth stations in the Network plus one reference station, making a maximum of 50 burst in a frame. All the bursts are of equal length. Each burst contains 128 bits and occupies a 1ms time slot. Thus the bit rate is 128 kbps.

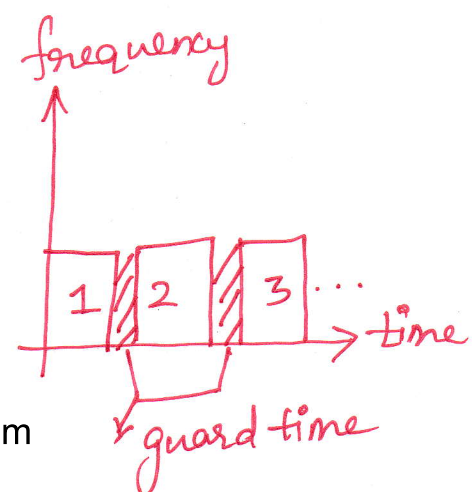
Demand assigned TDMA: When compared with FDMA network, TDMA networks have more flexibility in reassigning channels and the changes can be made more quickly and easily. The burst length assigned to a station may be varied as the traffic demand varies. Alternatively, each station may determine its own burst length requirements.

Features of TDMA:

* TDMA allows sevaral users to share the same frequency channel by dividing the signal into different time slots. i.e it shares single carrier frequency with multiple users.
* Non-Continuous transmission makes handoff simpler.
* Slots can be assigned on demand in dynamic TDMA.
* Higher synchronization overhead than CDMA.
* Advanced equalization is necessary for high data rates.
* Complex in frequency/slot allocation.
* In Commercial satellite applications classic TDMA is implemented which allocate a specific time slot for transmission due to which overlapping is avoided.
* Increased system capacity.
* An earth station has a full access to a transponder during its allocated time slot.
* Guard time is used to separate time-slots.
* It also works on demand-assign method.

TDMA channels.





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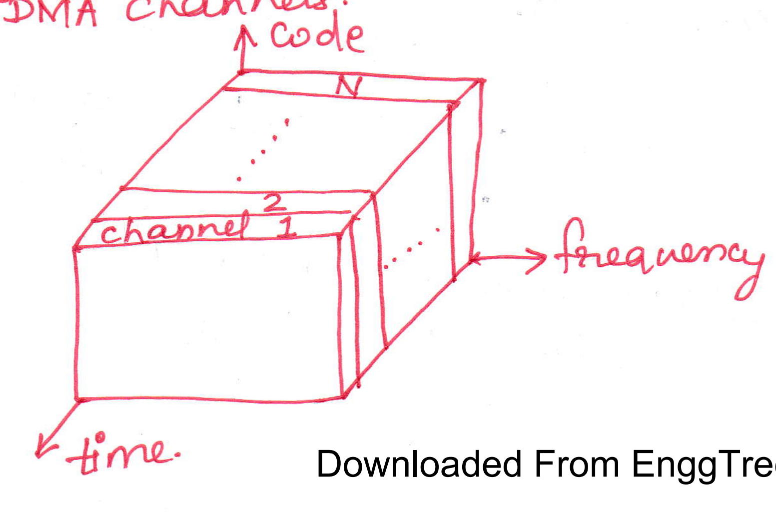
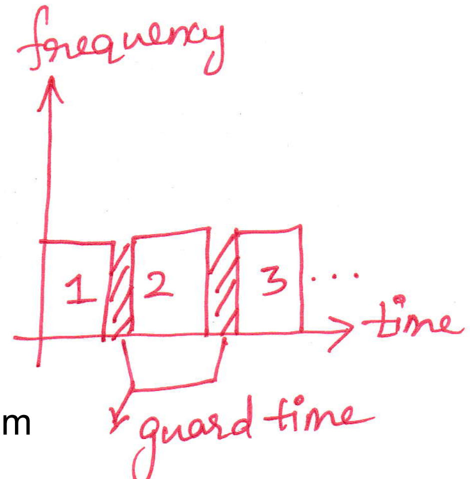
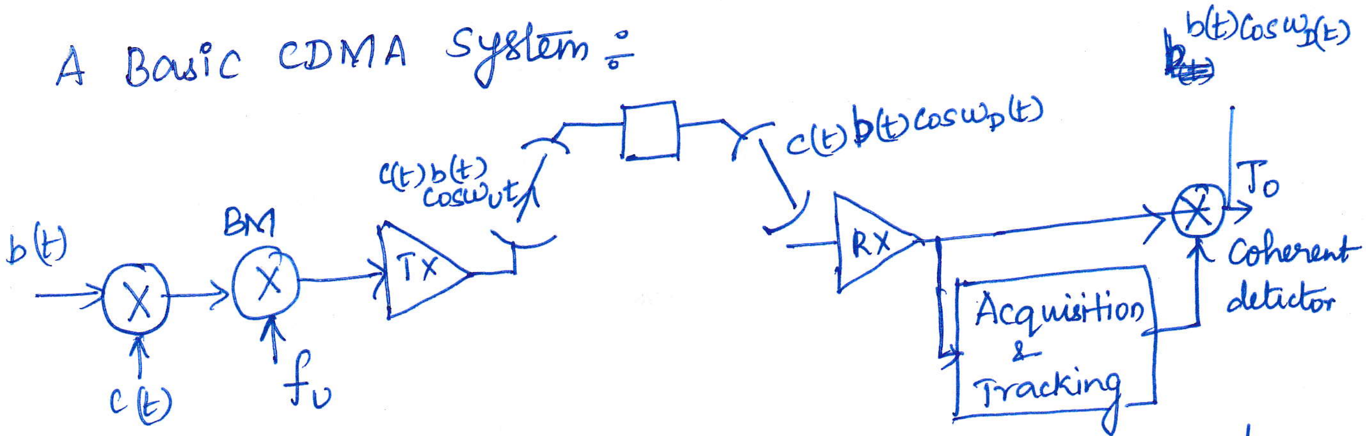




BASIC CDMA.

A Basic CDMA System:



* b(t) is an NRz binary information signal and c(t) is a NRz binary code (PN code) signal. These two signals from the inputs to a multiplier, the output of which is proportional to the product b(t). c(t). This product signal is applied to a second modulator (Balanced modulator - BM), the output of which is a BPSK signal at the carrier frequency. Consider the carrier is the uplink frequency, hency the ~~upp~~ uplink carrier is described as,

$$e_U(t) = c(t)\, b(t) \cos \omega_U t$$

The corresponding downlink carrier is,

$$e_D(t) = c(t)\, b(t) \cos \omega_D t$$

At the receiver, an identical c(t) generator is synchronized to the c(t) of the downlink carrier. This synchronization is carried out in the acquisition and tracking block.

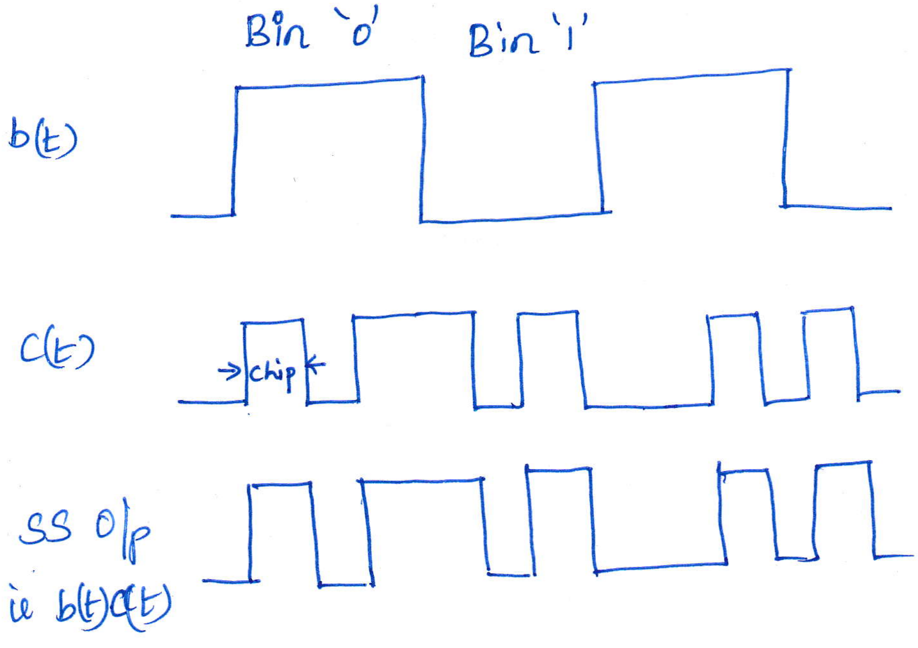
With $c(t)$ a polar NRZ type, and $c(t)$ exactly in synchronism with the transmitted $c(t)$, the product $c^2(t) = 1$, thus the output from the multiplier at Receiver is,

$$c(t) \cdot e_D(t) = c^2(t) \cdot b(t) \cos\omega_D t$$
$$= b(t) \cos\omega_D t.$$

The binary symbols used in the codes are referred to as chips.

Here PN generator are also known as maximal length generator which generate maximal sequence or m-sequence codes. A code generator employing an n-stage shift register can generate a maximum sequence of N chips, where

$$N = 2^n - 1.$$



CODE Division Multiple Access: (CDMA)

Features:

* It could be used as a multiple access system by giving each user a unique pseudo random code rather than a unique carrier frequency or time slot. CDMA can be used with analog & digital signals.

* With CDMA, the individual carriers may be present simultaneously within the same Rf bandwidth, but each carrier carries a unique code waveform that allows it to be separated from all the others at the receiver. The carrier is modulated in the normal way by the information waveform and then is further modulated by the code waveform to spread the spectrum over the available RF bandwidth.

* CDMA uses a modulation technique called spread spectrum. Spreading is acheived by a code which is independent of data sequence. The same code is used at the receiver to dispread the received signal.

CDMA and SPREAD SPECTRUM

* Implementing CDMA: CDMA technique could be implemented in two forms i) Direct sequence spread spectrum (ii) Frequency hopping spread spectrum

Pseudrandom Sequence (PN-pseudo noise sequence):-

A periodic binary sequence with a noise like waveform

Pseudo random codeword is approximately orthogonal to all other codewords. In order to use ... PN sequence in digita form, shift registers are required. A shift register made up of 'm' flip flops and logic circuit that are interconnected to for a multiloop feedback circuit. The maximum length of the code be $2^m - 1$, where 'm' number of shift register used.

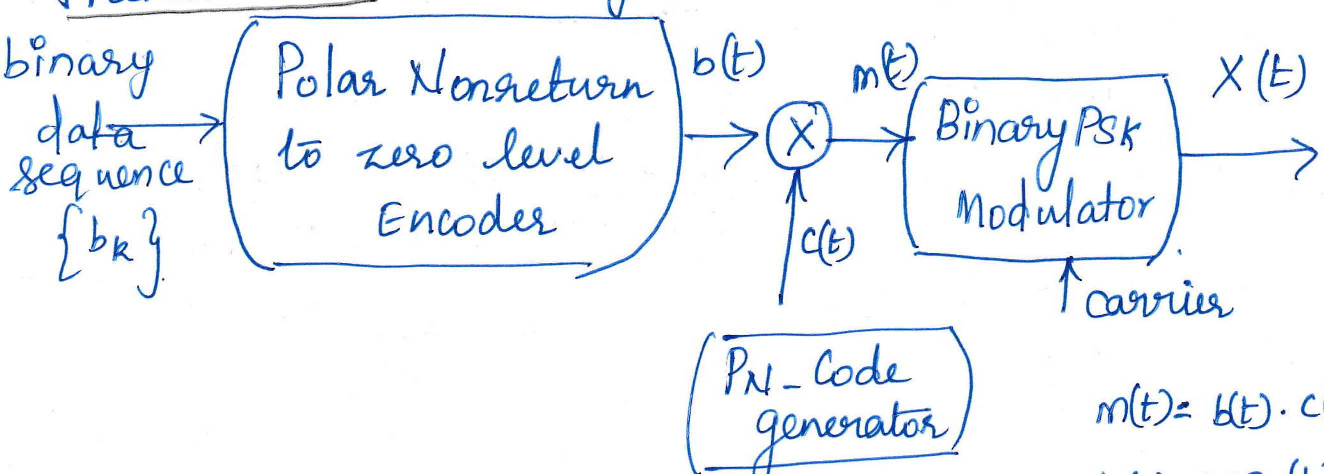
* Direct sequence spread spectrum (DS-SS)

In this technique, two stages of modulation are used.

(i) The incoming data sequence is used to modulate a wideband code. This code transforms the narrowband data sequence into a noise like wideband signal.

(ii) This resulting wideband signal undergoes a second modulation using a phase shift keying technique.

Transmitter: Fig: DS-BPSK Modulator/transmitter



$m(t) = b(t) \cdot c(t)$

$x(t) \simeq m_p(t)$

$m_p(t) \rightarrow$ PSK modulated signal.

$b(t) \rightarrow$ NRZ binary signal

$c(t) \rightarrow$ Pseudo noise code signal

$m(t) \rightarrow$ Spread spectrum modulated signal

$X(t) \rightarrow$ ~~DSS~~ Direct-sequence spread Binary

The transmitter first converts the incoming binary data sequence $\{b_k\}$ into a NRZ waveform $b(t)$. Then $b(t)$ and PN signal $c(t)$ are multiplied by the product modulator or multiplier.

The output $m(t)$ is modulated with Binary PSK modulation. The phase modulation of $x(t)$ has two values 0 and π depending on the polarities of message signal and PN signal. The transmitted $x(t)$ is a Direct-sequence spread spectrum BPSK signal.

Receiver :-

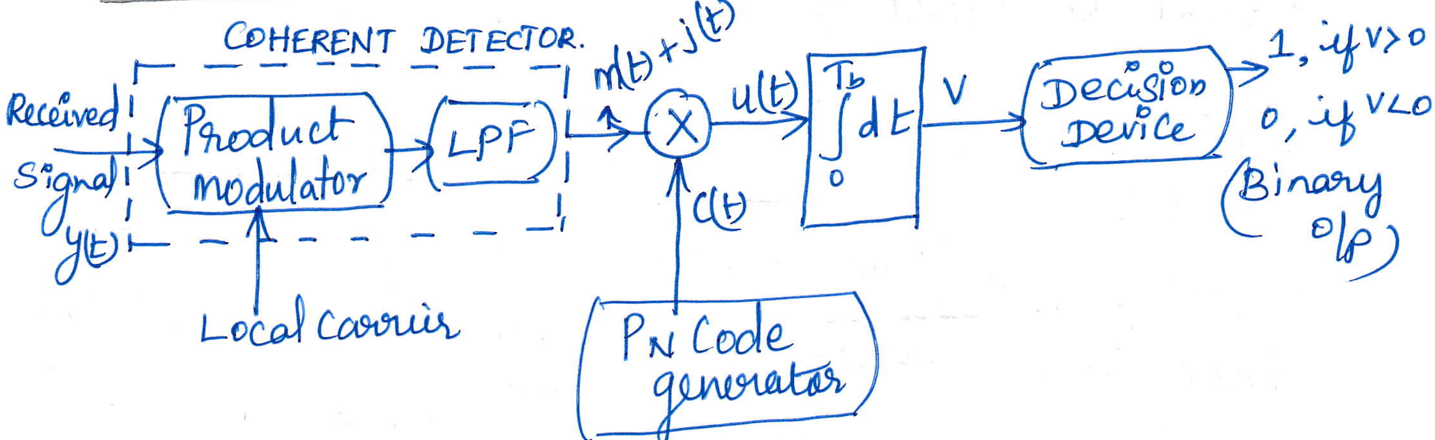


Fig: DS-BPSK Receiver.

The channel output is given by,

$$y(t) = x(t) + j(t)$$

where $j(t) \rightarrow$ interference.

$$\therefore \quad y(t) = m_p(t) + j(t) \quad (\because m_p(t) \simeq x(t))$$

Coherent detector is used to recover $m(t)$ from the received signal.

From the diagram,
$$u(t) = (m(t) + j(t))\, c(t)$$
$$= [c(t) \cdot b(t) + j(t)] \cdot c(t).$$
$$(\because m(t) = c(t) \cdot b(t))$$
$$= c^2(t) \cdot b(t) + c(t) \cdot j(t)$$

But $c^2(t) = 1$ and multiplying interference with the any signal is an interference / noise

$$\therefore u(t) = b(t) + j(t) \cdot c(t)$$

The signal u(t) may be integrated and decision device make decision whether the signal be binary 1 or 0.

* Frequency Hop Spread spectrum (FH-SS)

* An alternative system for attaining maximum Processing gain than DS-SS to combat jamming.
* It is the process of randomly hopping the modulated data carrier from one frequency to other. Due to this, the spectrum of the transmitted signal sequentially spreaded rather than instantaneously.
* This is Complex and expensive system which needs expensive frequency synthesizers.

Modulation : F-MFSK is the combination of frequency hopping and FSK technique used. Depending on the rate of frequency hopping, FH systems are classified into two categories.

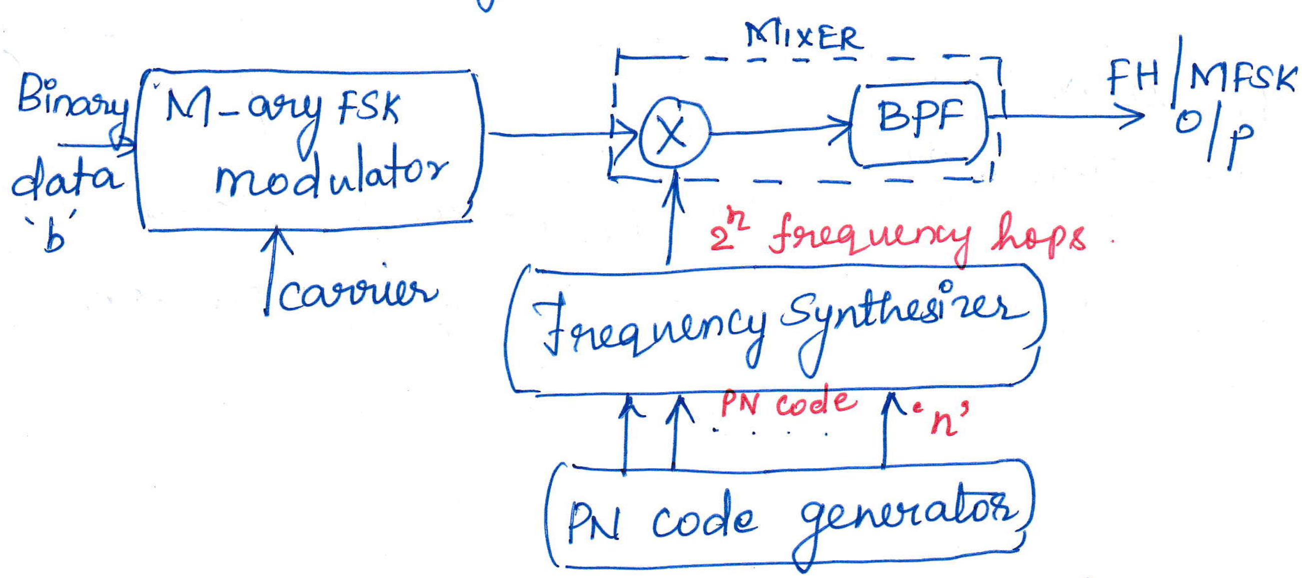
(i) Slow frequency hopping
(ii) Fast frequency hopping.

Slow frequency hopping (SFH) :

Def: The symbol rate (R_s) of the MFSK signal is an integer multiple of the hop rate R_h. So several symbols are transmitted corresponding to each frequency hop.

Transmitter :

fig: FH/F-MSK transmitter.



The binary data (0 or 1) is applied as an input the M-ary FSK modulator. Hence

$M = 2^k$; $M = 2^1 = 2$ ($\because k = 1$) M-ary FSK ... Binary FSK modulator.

The frequency synthesizer output at a given instant of time is called as frequency hops.
The frequency hops at the output of the synthesizer are controlled by the successive bits at the output of the PN code generator. Hency frequency hops produced will vary in a random manner.
If the number of successive bits at the output of PN generator is 'n', then the total number of frequency hops will be 2^n.
MFSK modulator o/ps the signal which is given as I/p to the mixer which has an another I/p as frequency hops.
Multiplier is used to produce sum and difference of the two frequency components.
BPF is designed to select the sum frequency components and it is transmitted.
The total Bandwidth of FH/MFSK signal is equal to the sum of all the frequency hops.

Receiver:

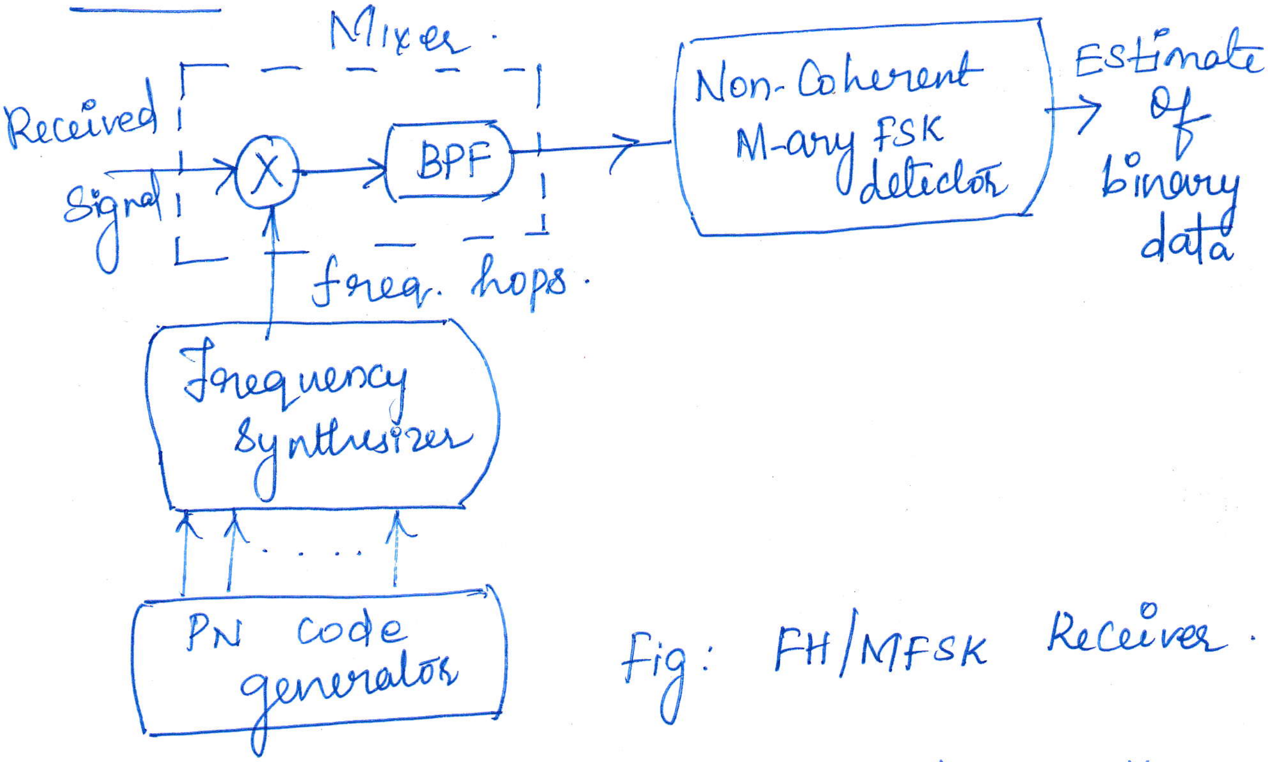


Fig: FH/MFSK Receiver.

The received signal is mixed with the other frequency from the synthesizer. The frequency hops produced at the synthesizer will be identical to those at the transmitter.

The multiplier Produces sum and ~~d~~ difference frequency Components. The difference frequency Components is selected by BPF. This signal is called MFSK signal which will be applied to the ~~noncoh~~ noncoherent detector.

In FH/MFSK, the receiver is unable to maintain the coherence over successive hops. Hence most of the FH system uses the non Coherent schemes

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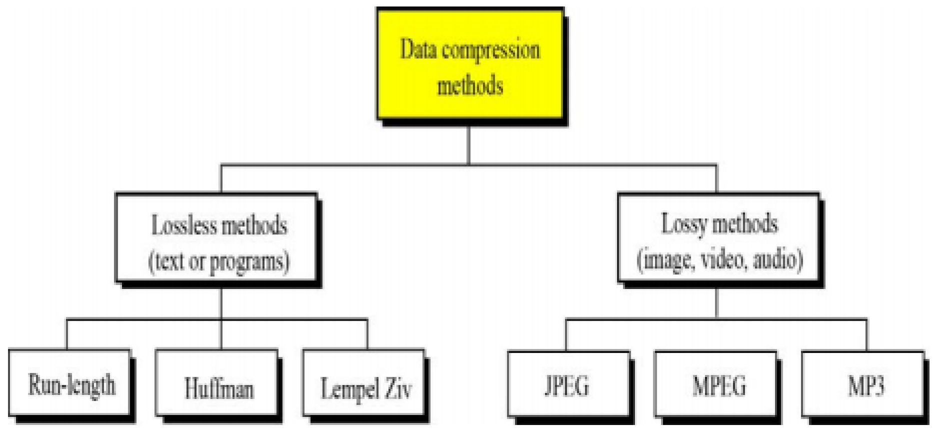
COMPRESSION

Data compression is the process of modifying, encoding or converting the bits structure of data in such a way that it consumes less space on disk. Data compression is particularly useful in communications because it enables devices to transmit or store the same amount of data in fewer bits.



Data compression methods

Compression may be classified into two types.

1.Losssless compression 2.Lossy compression

1.Losssless compression

In the technique of Lossless compression with the compressing of data that is when get decompressed, will be the same replica of actual data. In this case, when the binary data like the documents, executable etc. are get compressed. This required to be reproduced exactly when get decompressed again. A resemblance of the actual image is sufficient for the most objective, as far as the error or problems between the actual and compressed image is avoidable or tolerable. These types of compression are also known as noiseless as they never add noise to signal or image. It is also termed as the entropy coding as it uses the techniques of decomposition/statistics to remove/reduce the redundancy. It is also used only for the some specific applications along with the rigid needs like a medical-imaging. Below mentioned techniques consists in the lossless compression:

Huffman encoding 2. Run length encoding 3. Arithmetic coding 4. Dictionary Techniques a) a)LZ77 b) b)LZ78 c) c)LZW 5. Bit Plane coding

2 Lossy Compression:

In the technique of Lossy compression, it decreases the bits by recognizing the not required information and by eliminating it.The system of decreasing the size of the file of data is commonly termed as the data-compression, though its formal name is the source-coding that is coding get done at source of data before it gets stored or sent. In these methods few loss of the information is acceptable. Dropping non-essential information from the source of data can save the storage area. As an example, the human eye is very sensitive to slight variations in the luminance as compare that there are so many variations in the color. The Lossy image compression technique is used in the digital cameras, to raise the storage ability with the minimal decline of the quality of picture. Similarly in the DVDs which uses the lossy MPEG-2 Video codec technique for the compression of the video. In the lossy audio compression, the techniques of psycho acoustics have been used to eliminate the non-audible or less audible components of signal.

Example:JPEG Standard:

JPEG is an image compression standard that was developed by the “Joint Photographic Experts Group”. JPEG was formally accepted as an international standard in 1992.

• JPEG is a lossy image compression method. It employs a transform coding method using the DCT (Discrete Cosine Transform).

An image is a function of i and j (or conventionally x and y) in the spatial domain.

The 2D DCT is used as one step in JPEG in order to yield a frequency response which is a function F(u, v) in the spatial frequency domain, indexed by two integers u and v.

Image compression:

When the encoder receives the original image file, the image file will be converted into a series of binary data, which is called the bit-stream. The decoder then receives the encoded bit-stream and decodes it to form the decoded image. If the total data quantity of the bit-stream is less than the total data quantity of the original image, then this is called as Compression/image compression. The compression flow is as shown in following Figure.

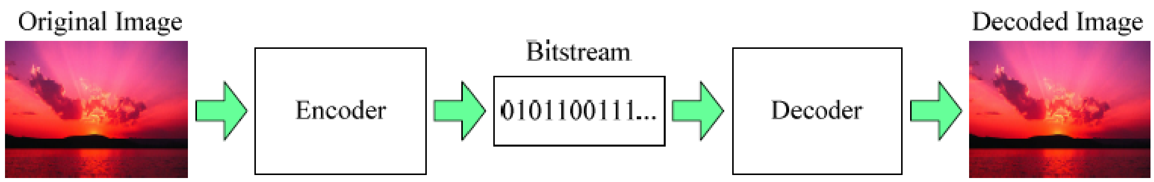


Fig. Basic flow of image compression coding

The best-known methods are as follows:
1) **Predictive Coding**: Predictive Coding such as DPCM (Differential Pulse Code Modulation) is a lossless coding method, which means that the decoded image and the original image have the same value for every corresponding element.
2)**Orthogonal Transform**: Karhunen-Loeve Transform (KLT) and Discrete Cosine Transform (DCT) are the two most well-known orthogonal transforms. The DCT-based image compression standard such as JPEG is a lossy coding method that will result in some loss of details and
unrecoverable distortion.
3)**Subband Coding**: Subband Coding such as Discrete Wavelet Transform (DWT) is also a lossy coding method. The objective of subband coding is to divide the spectrum of one image into the lowpass and the highpass components. JPEG 2000 is a 2-dimension DWT based image compression
standard.

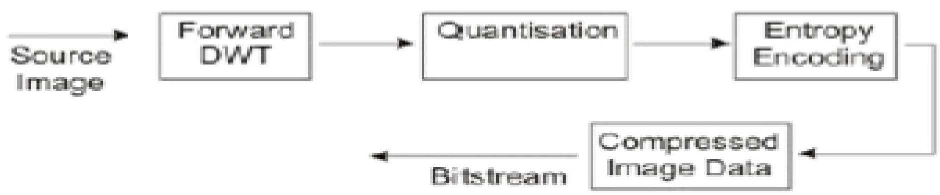


Fig.ENCODER

The objective of quantization is to reduce the precision and to achieve higher compression ratio. The image compression standards such as JPEG and JPEG 2000 have their own quantization methods.
The main objective of entropy coding is to achieve less average length of the image. Entropy coding assigns codewords to the corresponding symbols according to the probability of the symbols. In general, the entropy encoders are used to compress the data by replacing symbols represented by equal-length codes with the codewords whose length is inverse proportional to corresponding probability.

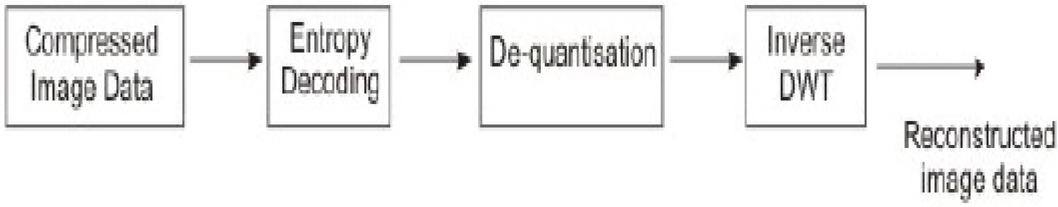


Fig.DECODER

Merits of image compression :

- It enables a reliable cost of savings that is included withthe sending of less data on the network of switched telephone in which the cost of call is normally dependent on its duration.
- It is not only to decrease the requirements of storage but also decrease the entire time of execution.
- It decreases the chances of the errors transmission as some bits have got transferred.
- It enables a level of the secu+rity against monitoring the unlawful Activities

UNIT V SATELLITE APPLICATIONS

5.1 INTELSAT Series:

INTELSATstandsfor*InternationalTelecommunicationsSatellite*.Theorganizationwas created in 1964 and currently has over 140 member countries and more than 40 investing entities (see http://www.intelsat.com/ for moredetails).

InJuly2001INTELSATbecameaprivatecompanyandinMay2002thecompanybegan providing end-to-end solutions through a network of teleports, leased fiber, and *points of presence* (PoPs) around theglobe.

Starting with the Early Bird satellite in 1965, a succes- sion of satellites has beenlaunched at intervals of a few years. Figure 1.1 illustrates the evolution of some of the INTELSATsatellites.Asthefigureshows,thecapacity,intermsofnumberofvoicechannels, increaseddramaticallywitheachsucceedinglaunch,aswellasthedesignlifetime.

Thesesatellitesareinge*ostationaryorbit,* meaningthattheyappeartobestationaryin relation to the earth. At this point it may be noted that geostationary satellites orbit in the earth's equatorial plane and their position is specified by theirlongitude.

For international traffic, INTELSAT covers three main regions—the *Atlantic Ocean Region*(AOR),the*IndianOceanRegion*(IOR),andthe*PacificOceanRegion*(POR)andwhatis termed *Intelsat America'sRegion*.

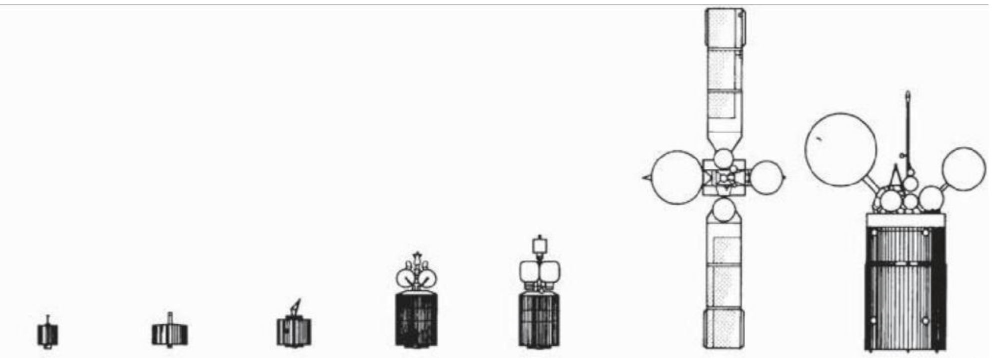
For the ocean regions the satellites are positioned in geostationary orbit above the particular ocean, where they provide a transoceanic telecommunications route. For example, INTELSAT satellite 905 is positioned at 335.5° east longitude.

The INTELSAT VII-VII/A series was launched over a period from October1993toJune1996.TheconstructionissimilartothatfortheVandVA/VBseries,showninFig. 1 inthattheVIIserieshassolarsailsratherthanacylindricalbody.

TheVIIserieswasplannedforserviceinthePORandalsoforsomeofthelessdemanding services in the AOR. The antenna beam coverage is appropriate for that of the POR. Figure 1 showstheantennabeamfootprintsfortheC-bandhemisphericcover-ageandzonecoverage,as wellasthespotbeamcoveragepossiblewiththeKu-bandantennas(Lilly,1990;Sachdevetal., 1990). When used in the AOR, the VII series satellite is inverted north for south (Lilly, 1990), minor adjustments then being needed only to optimize the antenna pat- terns for this region. The lifetime of these satellites ranges from 10 to 15 years depending on the launchvehicle.

RecentfiguresfromtheINTELSATWebsitegivethecapacityforthe INTELSATVIIas18,000two-waytelephonecircuitsandthreeTVchannels;upto90,000 two-way telephone circuits can be achieved with the use of “digital circuit multiplication.”

TheINTELSATVII/Ahasacapacityof22,500two-waytelephonecircuitsandthreeTV channels; up to 112,500 two-way tele- phone circuits can be achieved with the use of digital circuitmultipli-cation.AsofMay1999,foursatelliteswereinserviceovertheAOR,oneinthe IOR, and two in thePOR.



Designation: Intelsat	I	II	III	IV	IV A	V	V A/V B	VI
Year of first launch	1965	1966	1968	1971	1975	1980	1984/85	1986/87
Prime contractor	Hughes	Hughes	TRW	Hughes	Hughes	Ford Aerospace	Ford Aerospace	Hughes
Width (m)	0.7	1.4	1.4	2.4	2.4	2.0	2.0	3.6
Height (m)	0.6	0.7	1.0	5.3	6.8	6.4	6.4	6.4
Launch vehicles		Thor Delta		Atlas-Centaur		Atlas-Centaur and Ariane	Atlas-Centaur and Ariane	STS and Ariane
Spacecraft mass in transfer orbit (kg)	68	182	293	1385	1489	1946	2140	12,100/3720
Communications payload mass (kg)	13	36	56	185	190	235	280	800
End-of-life (EOL) power of equinox (W)	40	75	134	480	800	1270	1270	2200
Design lifetime (years)	1.5	3	5	7	7	7	7	10
Capacity (number of voice channels)	480	480	2400	8000	12,000	25,000	30,000	80,000
Bandwidth (MHz)	50	130	300	500	800	2137	2480	3520

INTELSAT Series

TheINTELSATVIII-VII/AseriesofsatelliteswaslaunchedovertheperiodFebruary 1997toJune1998.SatellitesinthisserieshavesimilarcapacityastheVII/Aseries,andthe lifetime is 14 to 17years.

It is standard practice to have a spare satellite in orbit on highreliability routes (which can carry preemptible traffic) and to have a ground spare in case of launch failure.

Thus the cost for large international schemes can be high; for example, series IX, described later, represents a total investment of approximately $1 billion.

5.2INSAT:

INSAT or the ***Indian National Satellite System*** is a series of multipurpose geo-stationary satellites launched by ISRO to satisfy the telecommunications, broadcasting,meteorology, and search and rescue operations.

Commissionedin1983,INSATisthelargestdomesticcommunicationsystemintheAsia Pacific Region. It is a joint venture of the Department of Space, Department of Telecommunications, India Meteorological Department, All India Radio and Doordarshan. The overall coordination and management of INSAT system rests with the Secretary-level INSAT CoordinationCommittee.

INSAT satellites provide transponders in various bands (C, S, Extended C and K_u) to servethetelevisionandcommunicationneedsofIndia.SomeofthesatellitesalsohavetheVery HighResolutionRadiometer(VHRR),CCDcamerasformetrologicalimaging.

The satellites also incorporate transponder(s) for receiving distress alert signals for searchandrescuemissionsintheSouthAsianandIndianOceanRegion,asISROisamember of the Cospas-Sarsatprogramme.

INSATSystem:

The Indian National Satellite (INSAT) System Was Commissioned With The Launch Of INSAT-1B In August 1983 (INSAT-1A, The First Satellite Was Launched In April 1982 But Could Not Fulfil The Mission).

INSATSystemUsheredInARevolutionInIndia’sTelevisionAndRadioBroadcasting, TelecommunicationsAndMeteorologicalSectors.ItEnabledTheRapidExpansionOfTVAnd ModernTelecommunicationFacilitiesToEvenTheRemoteAreasAndOff-ShoreIslands.

Satellites In Service:

Of The 24 Satellites Launched In The Course Of The INSAT Program, 10 Are Still In Operation.INSAT-2 E

It Is The Last Of The Five Satellites In INSAT-2 Series{Prateek }. It Carries Seventeen C-BandAndLowerExtendedC-BandTranspondersProvidingZonalAndGlobalCoverageWith An Effective Isotropic Radiated Power (EIRP) Of 36Dbw.

It Also Carries A Very High Resolution Radiometer (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 2x2 Km, 8x8 Km And 8x8 Km Ground Resolution Respectively.

INSAT-3 A

The Multipurpose Satellite, INSAT-3A, Was Launched By Ariane In April 2003. It Is Located At 93.5 Degree East Longitude. The Payloads On INSAT-3 A Are As Follows:

12NormalC-BandTransponders(9ChannelsProvideExpandedCoverageFromMiddle East To South East Asia With An EIRP Of 38 Dbw, 3 Channels Provide India Coverage With An EIRP Of 36 Dbw And 6 Extended C-Band Transponders Provide India Coverage With An EIRP Of 36Dbw).

ACCDCameraProvides1x1KmGroundResolution,InTheVisible(0.630.69µm),Near Infrared (0.77-0.86 µm) And Shortwave Infrared (1.55-1.70 µm)Bands.

INSAT-3 D

Launched In July 2013, INSAT-3D Is Positioned At 82 Degree East Longitude. INSAT-3D Payloads Include Imager, Sounder, Data Relay Transponder And Search & Rescue Transponder. All The Transponders Provide Coverage Over Large Part Of The Indian Ocean Region CoveringIndia,Bangladesh, Bhutan,Maldives, Nepal, Seychelles, Sri Lanka And Tanzania For Rendering Distress AlertServices.

INSAT-3E

LaunchedInSeptember2003,INSAT-3EIsPositionedAt55DegreeEastLongitudeAnd Carries24NormalC-BandTranspondersProvideAnEdgeOfCoverageEIRPOf37DbwOver India And 12 Extended C-Band Transponders Provide An Edge Of Coverage EIRP Of 38 Dbw OverIndia.

KALPANA-1

KALPANA-1IsAnExclusiveMeteorologicalSatelliteLaunchedByPSLVInSeptember 2002.ItCarriesVeryHighResolutionRadiometerAndDRTPayloadsToProvideMeteorological Services. It Is Located At 74 Degree East Longitude. Its First Name Was METSAT. It Was Later Renamed As KALPANA1 To Commemorate KalpanaChawla.

Edusat

Configured For Audio-Visual Medium Employing Digital InteractiveClassroomLessonsAndMultimediaContent,EDUSATWasLaunchedByGSLVInSeptember 2004.ItsTranspondersAndTheirGroundCoverageAreSpeciallyConfiguredToCaterToThe educationalRequirements.

GSAT-2

LaunchedByTheSecondFlightOfGSLVInMay2003,GSAT-2IsLocatedAt48Degree EastLongitudeAndCarriesFourNormalC-BandTranspondersToProvide36DbwEIRPWith India Coverage, Two K_u Band Transponders With 42 Dbw EIRP Over India And An MSS Payload Similar To Those On INSAT-3B And INSAT-3C.

INSAT-4 Series :

EXPLODED VIEW OF INSAT 4A S/C

INSAT-4A is positioned at 83 degree East longitude along with INSAT-2 E and INSAT-3B.Itcarries12$K_u$band36MHzbandwidthtranspondersemploying140WTWTAstoprovide an EIRP of 52 dBW at the edge of coverage polygon with footprint covering Indian main land and 12 C-band 36 MHz bandwidth transponders provide an EIRP of 39 dBW at the edge of coverage with expanded radiation patterns encompassing Indian geographical boundary, area beyondIndiainsoutheastandnorthwestregions.[8]TataSky,ajointventurebetweentheTATA Group and STAR uses INSAT-4A for distributing their DTHservice.

- INSAT-4A
- INSAT-4B
- Glitch In INSAT4B
- China-StuxnetConnection
- INSAT-4 CR
- GSAT-8 / INSAT-4G
- GSAT-12/GSAT-10

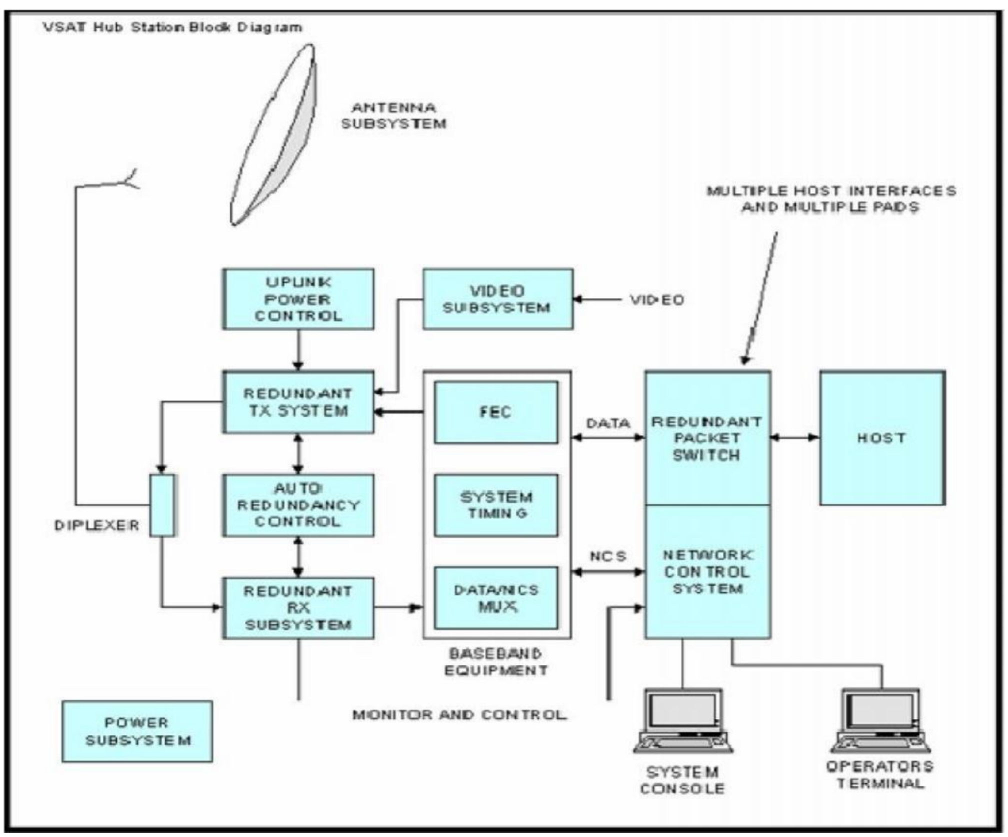
5.3 VSAT:

VSATstandsfor*verysmallapertureterminal*system.Thisisthedistinguishingfeature of a VSAT system, the earth-station antennas being typically less than 2.4 m in diameter (Rana et al., 1990). The trend is toward even smaller dishes, not more than 1.5 m in diameter (Hughes et al.,1993).

In this sense, the small TVRO terminals for direct broadcast satellites could be labeled as VSATs, but the appellation is usually reserved for private networks, mostly providing two-way communications facilities.

Typicalusergroupsincludebankingandfinancialinstitutions,airlineandhotelbooking agencies, and large retail stores with geographically dispersedoutlets.

VSAT Block Diagram



VSAT network:

The basic structure of a VSAT network consists of a hub station which provides a broadcast facility to all the VSATs in the network and the VSATs themselves which access the satellite in some form of multiple access mode.

The hub station is operated by the service provider, and it may be shared among a number of users, but of course, each user organization has exclusive access to its own VSAT network. Time division mul- tiplex is the normal downlink mode of transmission from hub to the VSATs, and the transmission can be broadcast for reception by all the VSATs in a network, or address coding can be used to direct messages to selected VSATs.

Aformofdemandassignedmultipleaccess(DAMA)isemployedinsomesystemsinwhich channel capacity is assigned in response to the fluctuating demands of theVSATsinthenetwork.
Most VSAT systems operate in the Ku band, although there are some Cband systems in existence (Rana et al., 1990).

Applications:

- Supermarket shops (tills, ATM machines, stock sale updates and stockordering).
- Chemistshops– ShoppersDrug Mart -Pharmaprix.
- Broadbanddirecttothehome.E.g.DownloadingMP3audiotoaudioplayers.
- Broadband direct small business, office etc, sharing local use with manyPCs.
- Internet access from on board ship Cruise ships with internet cafes, commercial shippingcommunications.

Mobile satelliteservices

5.4 GSM:

Services and Architecture:

Ifyourworkinvolves(orislikelytoinvolve)someformofwirelesspubliccommunications, you are likely to encounter the GSM standards. Initially developed to support a standardized approach to digital cellular communications in Europe, the "Global System for Mobile Communications"(GSM)protocolsarerapidlybeingadoptedtothenextgenerationofwireless telecommunicationssystems.

In the US, its main competition appears to be the cellular TDMA systems based on the IS-54 standards. Since the GSM systems consist of a wide range of components, standards,and protocols.

The GSM and its companion standard DCS1800 (for the UK, where the 900 MHz frequenciesarenotavailableforGSM)havebeendevelopedoverthelastdecadetoallowcellular communicationssystemstomovebeyondthelimitationsposedbytheolderanalogsystems.
Analog system capacities are being stressed with more users that can be effectively supported by the available frequency allocations. Compatibility between types of systems had been limited, if non-existent.

By using digital encoding techniques, more users can share the same frequencies than had been available in the analog systems. As compared to the digital cellular systems in the US (CDMA[IS-95]andTDMA[IS-54]),theGSMmarkethashadimpressivesuccess.Estimatesof the numbers of telephones run from 7.5 million GSM phones to .5 million IS54 phones to .3 million forIS95.

GSM has gained in acceptance from its initial beginnings in Europe to other parts of the world including Australia, New Zealand, countries in the Middle East and the far east. Beyond itsuseincellularfrequencies(900MHzforGSM,1800MHzforDCS1800),portionsoftheGSM signaling protocols are finding their way into the newly developing PCS and LEO Satellite communicationssystems.

While the frequencies and link characteristics of these systems differ from the standard GSM air interface, all of these systems must deal with users roaming from one cell (or satellite beam) to another, and bridge services to public communication networks including the Public Switched Telephone Network (PSTN), and public data networks (PDN).

The GSM architecture includes several subsystems:

TheMobileStation(MS)--Thesedigitaltelephonesincludevehicle,portableandhand- held terminals. A device called the Subscriber Identity Module (SIM) that is basically a smart- card provides custom information about users such as the services they've subscribed to and their identification in thenetwork

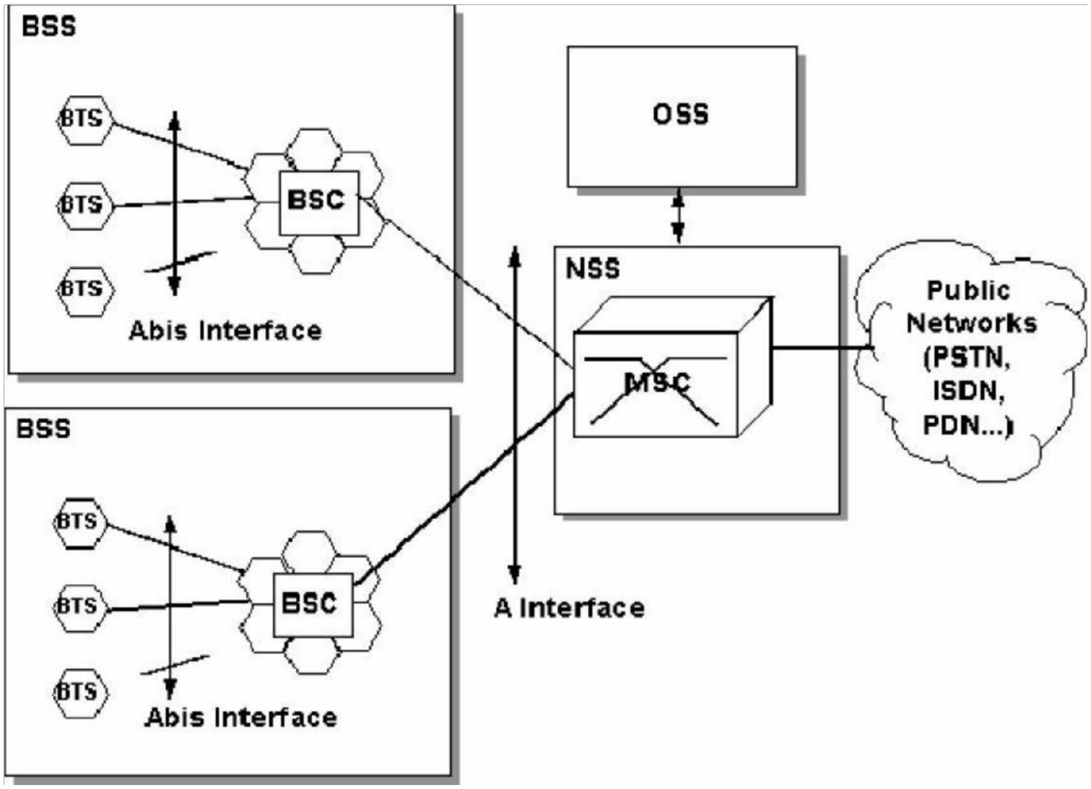
The Base Station Sub-System (BSS) -- The BSS is the collection of devices that support the switching networks radio interface. Major components of the BSS include the Base Transceiver Station (BTS) that consists of the radio modems and antenna equipment.

In OSI terms, the BTS provides the physical interface to the MS where the BSC is responsible for the link layer services to the MS. Logically the transcoding equipment is in the BTS, however, an additional component.

TheNetworkandSwitchingSub-System(NSS)--TheNSSprovidestheswitching between the GSM subsystem and external networks along with the databases used for additional subscriber and mobilitymanagement.

MajorcomponentsintheNSSincludetheMobileServicesSwitchingCenter(MSC),Home and Visiting Location Registers (HLR, VLR). The HLR and VLR databases are interconnected through the telecomm standard Signaling System 7 (SS7) controlnetwork.

The Operation Sub-System (OSS) -- The OSS provides the support functions responsible for the management of network maintenance and services. Components of the OSS areresponsible for network operation and maintenance, mobile equipment management, and subscription management andcharging.



GSM Block Diagram

Several channels are used in theair interface:

FCCH - the frequency correction channel - provides frequency synchronization information in aburst
SCH - Synchronization Channel - shortly following the FCCH burst (8 bits later), provides a reference to all slots on a givenfrequency
PAGCH - Paging and Access Grant Channel used for the transmission of paging information requesting the setup of a call to aMS.
RACH - Random Access Channel - an inbound channel used by the MS to request connections from the ground network. Since this is used for the first access attempt by usersofthenetwork,arandomaccessschemeisusedtoaidinavoidingcollisions.
CBCH - Cell Broadcast Channel - used for infrequent transmission of broadcasts by the groundnetwork.
BCCH - Broadcast Control Channel - provides access status information to the MS. The information provided on this channel is used by the MS to determine whether or not to request a transition to a newcell
FACCH - Fast Associated Control Channel for the control ofhandovers
TCH/F-TrafficChannel,FullRateforspeechat13kbpsordataat12,6,or3.6kbps
TCH/H - Traffic Channel, Half Rate for speech at 7 kbps, or data at 6or 3.6kbps

Mobility Management:

One of the major features used in all classes of GSM networks (cellular, PCS and Satellite)istheabilitytosupportroamingusers.Throughthecontrolsignalingnetwork,the MSCsinteracttolocateandconnecttousersthroughoutthenetwork.

"Location Registers" are included in the MSC databases to assist in the role of determining how, and whether connections are to be made to roaming users. Each user of a GSMMSisassignedaHomeLocationRegister(HLR)thatisusedtocontaintheuser'slocation and subscribedservices.

Difficulties facing the operators can include;

- Remote/Rural Areas. To service remote areas, it is often economically unfeasible toprovidebackhaulfacilities(BTStoBSC)viaterrestriallines(fiber/microwave).
- Time to deploy. Terrestrial build-outs can take years to plan andimplement.
- Areasof'minor'interest.Thesecanincludesmallisolatedcenterssuchastouristresorts, islands, mines, oil exploration sites, hydro-electricfacilities.
- Temporary Coverage. Special events, even in urban areas, can overload the existing infrastructure.

GSM servicesecurity:

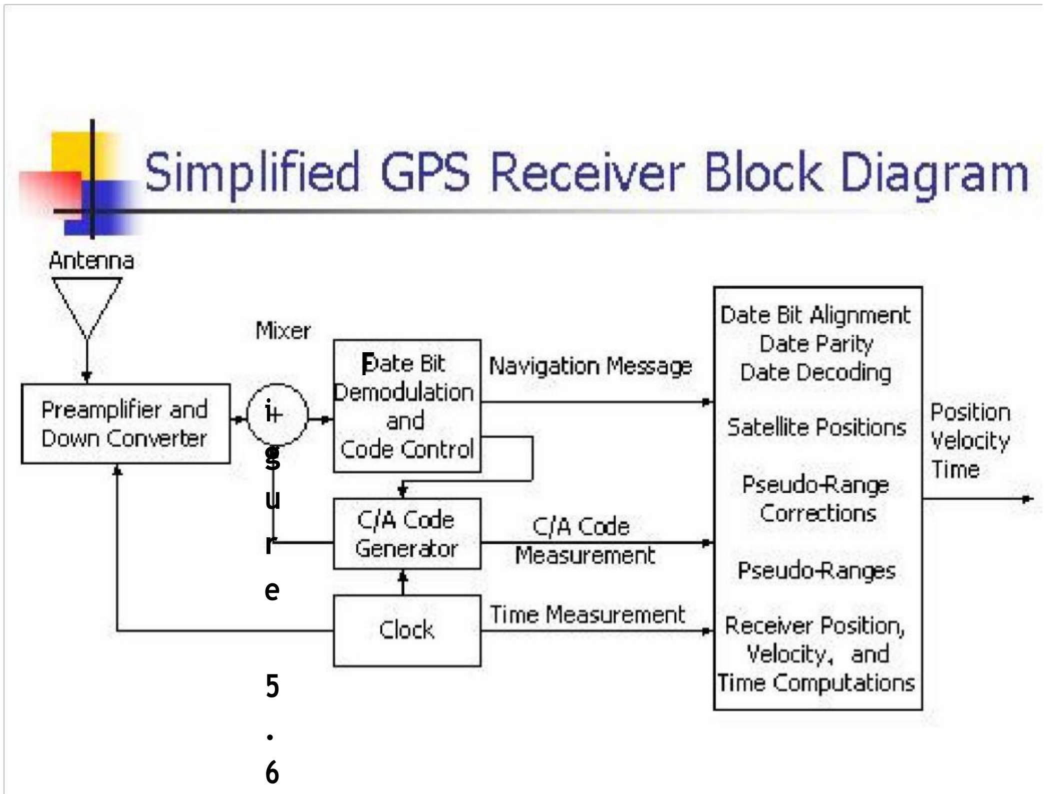
GSM was designed with a moderate level of service security. GSM uses several cryptographicalgorithmsforsecurity.The A5/1,A5/2,andA5/3streamciphersareusedfor ensuring over-the-air voiceprivacy.

GSMusesGeneralPacketRadioService(GPRS)fordatatransmissionslikebrowsing the web. The most commonly deployed GPRS ciphers were publicly broken in2011The researchersrevealedflawsinthecommonlyusedGEA/1.

5.5 Global Positioning System (GPS):

The Global Positioning System (GPS) is a satellite based navigation system that can be used to locate positions anywhere on earth. Designed and operated by the U.S. Department of Defense,itconsistsofsatellites,controlandmonitorstations,andreceivers.GPSreceiverstake informationtransmittedfromthesatellitesandusestriangulationtocalculateauser'sexact location. GPS is used on incidents in a variety of ways, suchas:

- To determine position locations; for example, you need to radio a helicopter pilot the coordinatesofyourpositionlocationsothepilotcanpickyouup.
- Tonavigatefromonelocationtoanother;forexample,youneedtotravelfromalookout to the fireperimeter.
- Tocreatedigitizedmaps;forexample,youare assignedtoplotthefireperimeterandhot spots.
- To determine distance between two points or how far you are from anotherlocation.



GPS Block Diagram

Three Segments of GPS:

i)Space Segment — Satellites orbiting the earth

The space segment consists of 29 satellites circling the earth every 12 hours at 12,000 miles in altitude. This high altitude allows the signals to cover a greater area. The satellites are arranged in their orbits so a GPS receiver on earth can receive a signal from at least four satellites at any given time. Each satellite contains several atomic clocks.

ii)Control Segment — The control and monitoring stations

The control segment tracks the satellites and then provides them with corrected orbital and time information. The control segment consists of five unmanned monitor stations and one Master Control Station. The five unmanned stations monitor GPS satellite signals and then send that information to the Master Control Station where anomalies are corrected and sent back to the GPS satellites through groundantennas.

iii)User Segment — The GPS receivers owned by civilians and military

The user segment consists of the users and their GPS receivers. The number of simultaneous users is limitless.

How GPS Determines a Position:

The GPS receiver uses the following information to determine a position.

Precise location ofsatellites:

When a GPS receiver is first turned on, it downloads orbit information from all the satellites called an almanac. This process, the first time, can take as long as 12 minutes; butoncethisinformationisdownloaded,itisstoredinthereceiver'smemoryforfuture use.

Distance from eachsatellite

The GPS receiver calculates the distance from each satellite to the receiver by using the distance formula: distance = velocity x time. The receiver already knows the velocity, which is the speed of a radio wave or 186,000 miles per second (the speed of light).

Triangulation to determineposition:

Thereceiverdeterminespositionbyusingtriangulation.Whenitreceivessignalsfromat least three satellites the receiver should be able to calculate its approximate position (a 2D position). The receiver needs at least four or more satellites to calculate a more accurate 3D position.

Using a GPS Receiver :

There are several different models and types of GPS receivers. Refer to the owner's manual for your GPS receiver and practice using it to become proficient.

When working on an incident with a GPS receiver it is importantto:

Always have a compass and amap.

Have a GPS downloadcable.

Have extrabatteries.

KnowmemorycapacityoftheGPSreceivertopreventlossofdata,decreaseinaccuracy of data,or otherproblems.

Use an external antennae whenever possible, especially under tree canopy, in canyons, or while flying ordriving.

Set up GPS receiver according to incident or agency standard regulation; coordinate system.

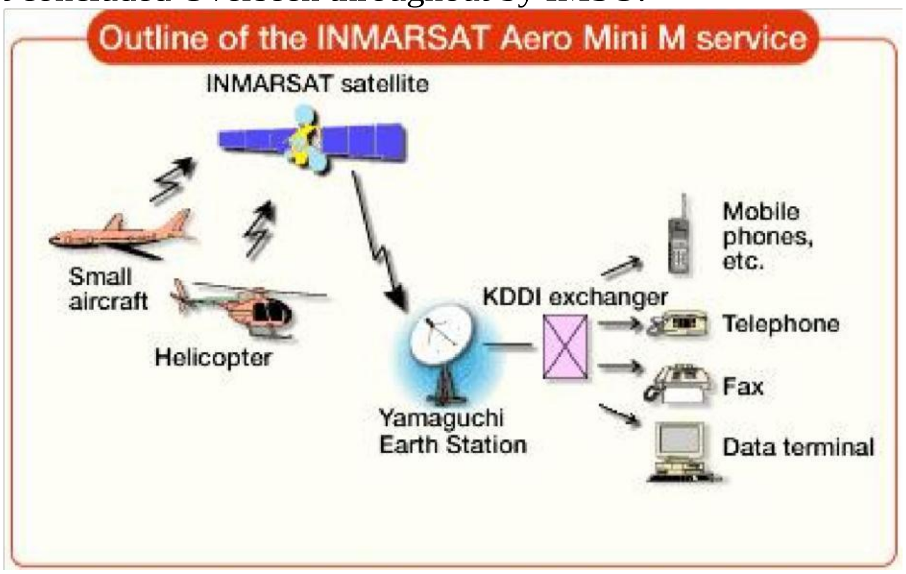
Takenotesthatdescribewhatyouaresavingintthereceiver.

5.6 INMARSAT:

Inmarsat-Indian Maritime SATellite is still the sole IMO-mandated provider of satellite communications for the GMDSS.

Availability for GMDSS is a minimum of99.9%

Inmarsat has constantly and consistently exceeded this figure & Independently audited by IMSO and reported on to IMO.NowInmarsatcommercialservicesusethesamesatellitesandnetwork&Inmarsat A closes at midnight on 31 December 2007 Agreed by IMO – MSC/Circ.1076. Successful closure programme almost concluded Overseen throughout by IMSO.



INMARSAT Satellite Service

GMDSS services continue to be provided by:

Inmarsat B, Inmarsat C/mini-C and InmarsatFleetF77 Potential for GMDSS on FleetBroadband beingassessed

The IMO Criteria for the Provision of Mobile Satellite Communications Systems in the Global Maritime Distress and Safety System (GMDSS)

Amendments were proposed; potentially to make it simpler for other satellite systems to be approved

The original requirements remain and were approved by MSC 83

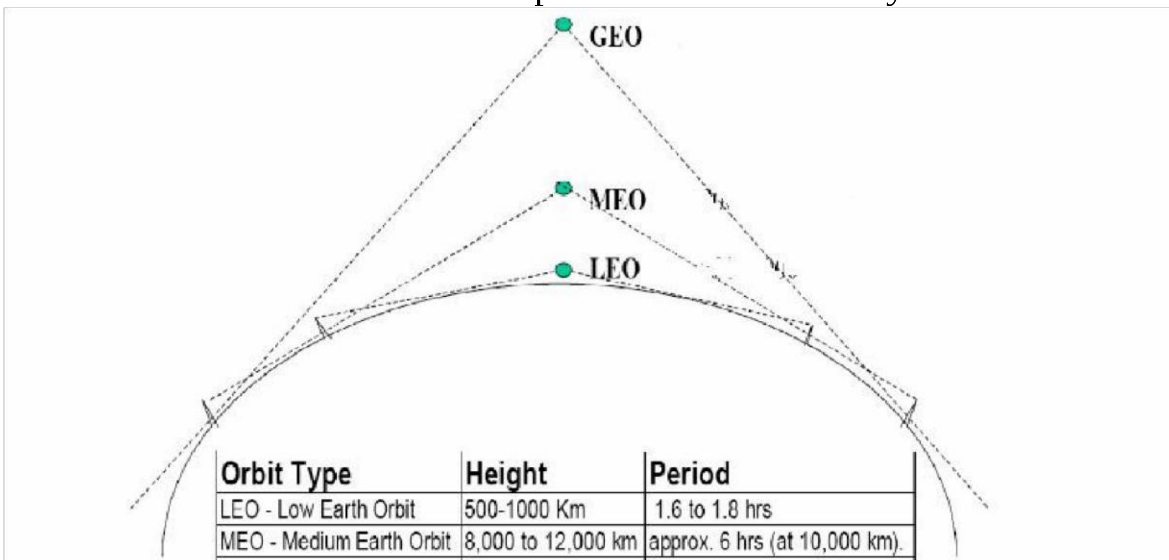
No dilution ofstandards

Minoramendmentsonly;replacementResolutionexpectedtobeapprovedbytheIMO25th Assembly

Inmarsat remains the sole, approved satcom provider for the GMDSS

5.7 LEO,MEO and GEO

LEO: Low Earth Orbit satellites have a small area of coverage. They are positioned in an orbit approximately 3000km from the surface of theearth
They complete one orbit every 90minutes
Thelargemajorityofsatellitesareinlowearthorbit
The Iridium system utilizes LEO satellites (780kmhigh)
ThesatelliteinLEOorbitisvisibletoapointontheearthforaveryshorttime



Orbit Type	Height	Period
LEO - Low Earth Orbit	500-1000 Km	1.6 to 1.8 hrs
MEO - Medium Earth Orbit	8,000 to 12,000 km	approx. 6 hrs (at 10,000 km).
GEO - Geostationary	approx. 36,870 km	approx. 24 hrs

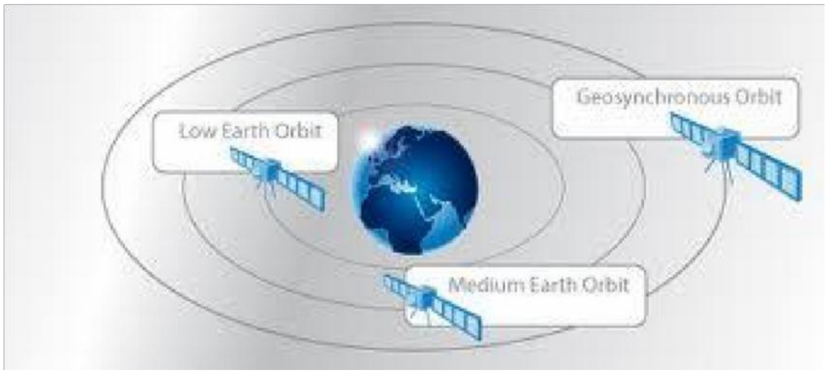
Figure 5.8 LEO, MEO & GEO range

MEO:
*MediumEarthOrbit*satelliteshaveorbitalaltitudesbetween3,000and30,000km.
They are commonly used used in navigation systems such asGPS

GEO:
*Geosynchronous(Geostationary)EarthOrbit*satellitesarepositionedovertheequator. The orbital altitude is around 30,000-40 ,000km
There is only one geostationary orbit possible around the earth
Lying on the earth's equatorialplane.
Thesatelliteorbitingatthesamespeedastherotationalspeedoftheearthonits axis.
They complete one orbit every 24 hours. This causes the satellite to appear stationary with respect to a point on the earth, allowing one satellite to provide continual coverage to a given area on the earth'ssurface
OneGEOsatellitecancoverapproximately1/3oftheworld'ssurface.
They are commonly used in communication systems

Advantages:
Simple ground stationtracking,Nearly constantrange, Very small frequencyshift.
Disadvantages:
Transmission delay ofthe order of 250 m s e c ,Large free spaceloss ,No polarcoverage

Satellite orbits in terms of the orbitalheight:
According to distance fromearth:
Geosynchronous Earth Orbit (GEO),
Medium Earth Orbit(MEO),
Low Earth Orbit(LEO)



LEO, MEO & GEO Orbits

LEO / MEO / GEO / HEO (cont.)

	Name	Number	Panel	No./Panel	altitude	deg.
LEO	STARSYS	24	6	4	1300km	60
	ORBCOMM	24	4	6	785km	45
	GLOBALSTAR	48	8	6	1400km	52
	IRIDIUM	66	6	11	765km	86
MEO	Name	Number	Panel	No./Panel	altitude	deg.
	INMARSAT P	10	2	5	10300km	45
	ODYSEEY	12	3	4	10370km	55
	GPS	24	6	4	20200km	55
	GLONASS	24	3	8	19132km	64.8
HEO	Name	Number	Panel	No./Panel	altitude	deg.
	ELLIPSO	24	4	6	A:7800km P:520km	63.4
	MOLNIYA	4	1	4	A:39863km P:504km	63.4
	ARCHIMEDES	4	4	1	A:39447km P:926km	63.4

9

Difference between LEO,MEO&GEOOrbits

GEO:35,786kmabovetheearth, MEO:8,000-20,000kmabovetheearth&LEO:5002,000kmabove the earth.

5.8 Benefits of Satellite Navigational System:

Enhanced Safety
Increased Capacity
Reduced Delays

Advantage:
Increased Flight Efficiencies
Increased Schedule Predictability
Environmentally Beneficial Procedures

5.9 Direct Broadcast satellites(DBS):

Satellites provide broadcast transmissions in the fullest sense of the word, because antenna footprints can be made to cover large areas of the earth. Theideaofusingsatellitestoprovidedirecttransmissionsintothehomehasbeenaround for many years, and the services pro- vided are known generally as direct broadcast satellite (DBS)services.

Broadcast services include audio, television, and Internet services.

Power Rating and Number ofTransponders:

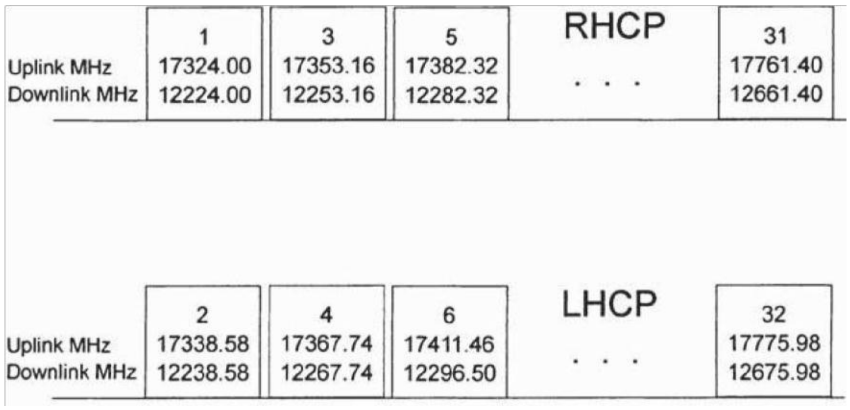
It will be seen that satellites primarily intended for DBS have a higher [EIRP] than for the other categories, being in the range 51 to 60 dBW. At a Regional AdministrativeRadioCouncil(RARC)meetingin1983,thevalueestablishedforDBSwas57 dBW (Mead,2000). Transponders are rated by the power output of their high-poweramplifiers.

Typically, a satellite may carry 32 transponders. If all 32 are in use, each will operate at the lower power rating of 120 W.

Theavailablebandwidth(uplinkanddownlink)isseentobe500MHz.Atotalnumberof 32 transponder channels, each of bandwidth 24 MHz, can beaccommodated.

The bandwidth is sometimes specified as 27 MHz, but this includes a 3MHz guardband allowance. Therefore, when calculating bit-rate capacity, the 24 MHz value is used.

The total of 32 transponders requires the use of both right- hand circular polarization (RHCP) and left-hand circular polarization (LHCP) in order to permit frequency reuse, and guard bands are inserted between channels of a given polarization.



DBS Service

Bit Rates for DigitalTelevision:

The bit rate for digital television depends very much on the picture format. One way of estimating the uncompressed bit rate is to multiply the number of pixels in a frame by the numberofframespersecond,andmultiplythisbythenumberofbitsusedtoencodeeachpixel.

MPEG CompressionStandards:

MPEGisagroupwithintheInternationalStandardsOrganizationandtheInternational Electrochemical Commission (ISO/IEC) that undertook the job of defining standards for the transmission and storage of moving pictures andsound.
The MPEG standards currently available are MPEG-1, MPEG-2, MPEG-4 , and MPEG-7.

5.10 Direct to home Broadcast (DTH):

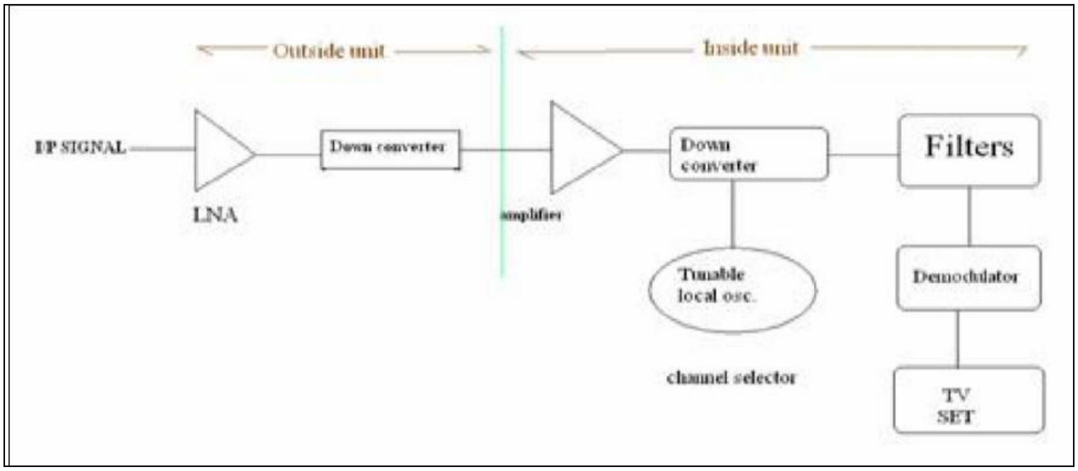
DTH stands for Direct-To-Home television. DTH is defined as the reception of satellite programmes with a personal dish in an individual home.

DTHBroadcastingtohomeTVreceiverstakeplaceinthekuband(12GHz).Thisservice is known as Direct To Homeservice.
DTH services were first proposed in India in1996.Finally in 2000, DTH wasallowed.
Thenewpolicyrequiresalloperatorstosetupearthstationsin India
within 12 months of getting a license. DTH licenses in India will cost $2.14 million and will be valid for 10 years.
Working principal of DTH is the satellite communication. Broadcaster modulates the received signal and transmits it to the satellite in KU Band and from satellite one can receive signal by dish and set top box.

DTH BlockDiagram:

A DTH network consists of a broadcasting centre, satellites, encoders, multiplexers, modulators and DTHreceivers. The encoder converts the audio, video and data signals into the digital format andthe multiplexer mixes thesesignals.

It is used to provide the DTH service in high populated area A Multi Switch is basically a box that contains signal splitters and A/B switches. An output of group of DTH LNBs is connected to the A and B inputs of the Multi Switch.



DTH Service

Advantage:

DTHalsooffersdigitalqualitysignalswhichdonotdegradethepictureorsoundquality.
It also offers interactive channels and program guides with customers having the choice to block out programming which they considerundesirable
One of the great advantages of the cable industry has been the ability to provide local channels,butthishandicaphasbeenovercomebymanyDTHprovidersusingotherlocal channels or localfeeds.
The other advantage of DTH is the availability of satellite broadcast in rural and semi- urban areas where cable is difficult toinstall.

5.11. Digital audio broadcast (DAB):

DAB Project is an industry-led consortium of over 300 companies

The DAB Project was launched on 10th September,1993

In1995itwasbasicallyfinishedandbecameoperational

There are several sub-standards of the DAB standard oDAB-S (Satellite) using QPSK40 Mb/s
o DAB-T (Terrestrial) ,using QAM – 50 Mb/s o DAB-C (Cable),using OFDM – 24Mb/s

These three sub-standards basically differ only in the specifications to the physical representation,modulation,transmissionandreceptionofthesignal.

The DAB stream consists of a series of fixed length packets which make up a Transport Stream(TS).Thepacketssupport'streams'or'datasections'.

Streams carry higher layer packets derived from an MPEG stream & Data sections are blocks of data carrying signaling and controldata.

DAB is actually a support mechanism for MPEG.& One MPEG stream needing higher instantaneousdatacan'steal'capacityfromanotherwithsparecapacity.

Worldspace services

WorldSpace (Nasdaq: WRSP) is the world's only global media and entertainment company positioned to offer a satellite radio experience to consumers in more than 130 countries with five billion people, driving 300 million cars. WorldSpace delivers the latest tunes, trends and information from around the world and around the corner.

WorldSpace subscribers benefit from a unique combination of local programming, original WorldSpace content and content from leading brands around the globe, including theBBC,CNN,VirginRadio,NDTVandRFI.WorldSpace'ssatellitescovertwo-thirdsofthe globe with sixbeams.

Each beam is capable of delivering up to 80 channels of high quality digital audio and multimedia programming directly to WorldSpace Satellite Radios anytime and virtually anywhere in its coverage area. WorldSpace is a pioneer of satellite-based digital radio services (DARS) and was instrumental in the development of the technology infrastructure used today by XM Satellite Radio. For more information, visit http://www.worldspace.com.

5.12 Business Television (BTV) - Adaptations forEducation:

Business television (BTV) is the production and distribution, via satellite, of video programs for closed user group audiences. It often has two-way audio interaction component made through a simple telephone line. It is being used by many industries including brokerage firms, pizza houses, car dealers and delivery services.

BTV is an increasingly popular method of information delivery for corporations and institutions.Privatenetworks,accountforabout70percentofallBTVnetworks.Itisestimated thatbythemid-1990sBTVhasthepotentialtogrowtoa$1.6billionmarketinNorthAmericawithmoreandmoreFortune 1,000companiesgettinginvolved.TheincreaseinuseofBTVhas beendramatic.

Institutionupdates,news,training,meetingsandothereventscanbebroadcastliveto multiplelocations.Theexpertiseofthebestinstructorscanbedeliveredtothousandsofpeople withoutrequiringtrainerstogotothesite.Informationcanbedisseminatedtoallemployeesat once, not just a few at a time. Delivery to the workplace at low cost provides the access to trainingthathasbeendeniedlowerlevelemployees.Itmaybethekeytore-trainingAmerica's workforce.

Television has been used to deliver training and information within businesses for more than 40 years. Its recent growth began with the introduction of the video cassette in the early 1970s. Even though most programming is produced for video cassette distribution, business is using BTV to provide efficient delivery of specialized programs via satellite.

The advent of smaller receiving stations - called very small aperture terminals (VSATs) has made private communication networks much more economical to operate. BTV has a number of tangible benefits, such as reducing travel, immediate delivery of time-critical messages, and eliminating cassette duplication and distribution hassles.

TheprogrammingonBTVnetworksisextremelycost-effectivecomparedtoseminarfees and downtime for travel. It is an excellent way to get solid and current information very fast. Some people prefer to attend seminars and conferences where they can read, see, hear and ask questions in person. BTV provides yet another piece of the education menu and is another way to provide professionaldevelopment.

A key advantage is that its format allows viewers to interact with presenters by telephone, enabling viewers to become a part of the program. The satellite effectively places people in the same room, so that sales personnel in the field can learn about new products at the sametime.

Speed of transmission may well be the competitive edge which some firms need as they introduce new products and services. BTV enables employees in many locations to focus on common problems or issues that might develop into crises without quick communication and resolution.
BTV networks transmit information every business day on a broad range of topics, and provide instructional courses on various products, market trends, selling and motivation. Networks give subscribers the tools to apply the information they have to real world situations.

5.13 GRAMSAT:

ISRO has come up with the concept of dedicated GRAMSAT satellites, keeping in mind the urgent need to eradicate illiteracy in the rural belt which is necessary for the all round development of the nation.

This Gramsat satellite is carrying six to eight high powered C-band transponders, which together with video compression techniques can disseminate regional and cultural specific audio-visual programmes of relevance in each of the regional languages through rebroadcast mode on an ordinary TV set.

The high power in C-band has enabled even remote area viewers outside the reach ofthe TVtransmitterstoreceiveprogrammersoftheirchoiceinadirectreceptionmodewithasimple .dish antenna.

The salient features of GRAMSAT projects are:

Its communications networks are at the state level connecting the state capital to districts, blocks and enabling a reach tovillages.
It is also providing computer connectivity data broadcasting,TV-broadcasting facilities having applications like e- governance, development information, teleconferencing, helping disaster management.

Providing rural-educationbroadcasting.

However, the Gramsat projects have an appropriate combination of following activities.

Interactive training at district and block levels employing suitable configuration

Broadcasting services for ruraldevelopment

Computer interconnectivity and data exchangeservices

Tele-health and tele-medicineservices.

Specialized services

5.14.Satellite-email services:

The addition of Internet Access enables Astrium to act as an Internet Service Provider(ISP) capable of offering Inmarsat users a tailor-made Internet connection.

WithInternetservicesaddedtoourrangeofterrestrialnetworks,youwillnolongerneed to subscribe to a third party for Internet access (available for Inmarsat A, B, M, mini-M, Fleet, GAN, Regional BGAN & SWIFTnetworks).

We treat Internet in the same way as the other terrestrial networks we provide, and thus offer unrestricted access to this service. There is no timeconsuming log-on procedure, as users are not required to submit a user-ID or password.

Description of E-mail Service:

Astrium's E-Mail service allows Inmarsat users to send and receive e-mail directly through the Internet without accessing a public telephone network.

Features and Benefits

Noneedtoconfigureane-mailclienttoaccessaAstriume-mailaccount

ServiceoptimizedforusewithlowbandwidthInmarsatterminals

Filter e-mail by previewing the Inbox and deleting any unwanted e-mails prior to downloading

No surcharge or monthly subscriptionfees

Service billed according to standard airtime prices for Inmarsat serviceused

5.15. Video Conferencing (medium resolution):

Videoconferencingtechnologycanbeusedtoprovidethesamefull,twowayinteractivity of satellite broadcast at much lower cost. For Multi-Site meetings, video conferencing uses bridgingsystemstoconnecteachsitetotheothers.

Itispossibletoconfigureavideoconferencebridgetoshowallsitesatthesametimeon aprojectionscreenormonitor.Or,asismoretypical,abridgecanshowjustthesitefromwhich a person is speaking or making apresentation.

Thetechnologythatmakesinteractivevideoconferencingpossible,compressesvideoand audiosignals,thuscreatinganimagequalitylowerthanthatofsatellitebroadcasts.

5.16. Satellite Internet access:

Satellite Internet access is Internet access provided through communications satellites.ModernsatelliteInternetserviceistypicallyprovidedtousersthroughgeostationary satellites that can offer high data speeds, with newer satellites using Ka band to achieve downstream data speeds up to 50Mbps.

Satellite Internet generally relies on three primary components: a satellite in geostationaryorbit(sometimesreferredtoasageosynchronousEarthorbit,orGEO),anumber of ground stations known as gateways that relay Internet data to and from the satellite via radio waves(microwave),andaVSAT(very-smallapertureterminal)dishantennawithatransceiver, located at the subscriber'spremises.

OthercomponentsofasatelliteInternetsystemincludeamodemattheuserendwhich links the user's network with the transceiver, and a centralized network operations center (NOC) for monitoring the entiresystem.