SATELLITE COMMUNICATION SYSTEMS/EC E 16

INTRODUCTION TO SATELLITE COMMUNICATION

UNIT-I

Introduction to Satellite Communication: Types of satellites- Satellite orbit- satellite constellation- orbital mechanics- equation of orbit-orbital elements- look angle determination- limits of visibility- eclipse- sub satellite point- sun transit outage- space craft technology structural, primary power, attitude and orbit control, thermal, propulsion, telemetry, tracking and command, communication and antenna subsystems- launching procedures and launch vehicles.

SATELLITE:

A **satellite** is an object that revolves around another object. For example, earth is a satellite of The Sun, and moon is a satellite of earth. **[or]**

A satellite is an object in space that orbits or circles around a bigger object.

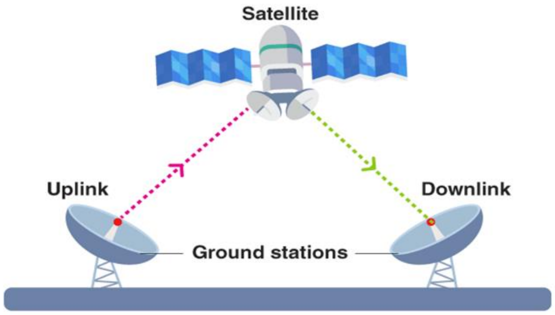
There are two kinds of satellites: natural (such as the moon orbiting the Earth) or artificial (such as the International Space Station orbiting the Earth).

COMMUNICATION:

Communication refers to the exchange or sharing of information between sender and receiver through any medium or channel.

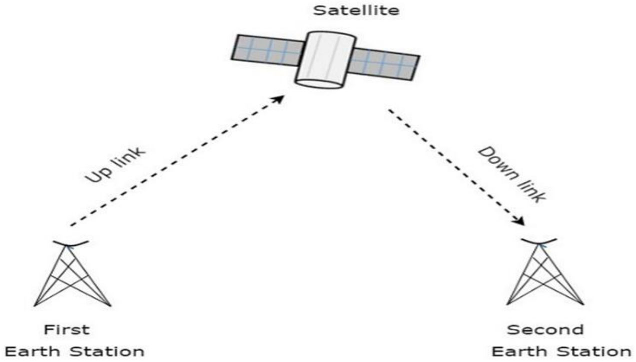
SATELLITE COMMUNICATION:

- If the communication takes place between any two earth stations through a satellite, then it is called as satellite communication.
- In this communication, electromagnetic waves are used as carrier signals.
- These signals carry the information such as voice, audio, video or any other data between ground and space and vice-versa.



BASICS OF SATELLITE COMUNICATION:

- The process of satellite communication begins at an **earth station**.
- Earth stations send information to satellites in the form of high frequency (GHz range) signals.
- The satellites **receive** and **retransmit** the signals back to earth where they are received by other earth stations in the coverage area of the satellite.
- The transmission system from the earth station to the satellite through a channel is called the **uplink**.
- The system from the satellite to the earth station through the channel is called the **downlink**.



NEED FOR SATELLITE COMMUNICATION:

- **Ground wave propagation** – Ground wave propagation is suitable for frequencies up to 30MHz. This method of communication makes use of the troposphere conditions of the earth.
- **Sky wave propagation** – The suitable bandwidth for this type of communication is broadly between 30–40 MHz and it makes use of the ionosphere properties of the earth.
- **Satellite communication**- It overcomes these limitations. In this method, satellites provide communication for long distances, which is well beyond the line of sight.

ADVANTAGES OF SATELLITE COMMUNICATION:

- The Coverage area is very high than that of terrestrial systems.
- The transmission cost is independent of the coverage area.
- Higher bandwidths are possible

DISADVANTAGES OF SATELITE COMUNICATION:

- Launching satellites into orbits is a costly process.
- The bandwidths are gradually used up.
- High propagation delay for satellite systems than the conventional terrestrial systems.

APPLICATION OF SATELLITE COMMUNICATION:

- Military applications and navigations
- Remote sensing applications.
- Weather condition monitoring & Forecasting
- TV broadcasting such as Direct To Home (DTH)
- Internet applications such as providing Internet connection for data transfer, GPS applications, Internet surfing, etc.

TYPES OF SATELLITE:

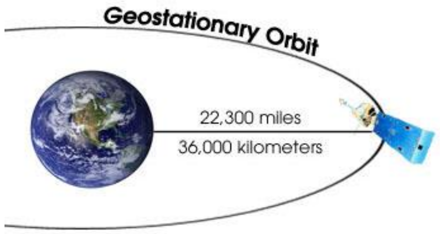
- There are two different types of satellites – **natural and man-made.**

NATURAL SATELLITE	MAN-MADE SATELLITE
The natural satellites are the Earth and Moon and The Earth rotates around the Sun and the Moon rotates around the Earth.	A man-made satellite is a machine that is launched into space and orbits around a body in space.

- Based on the usage purpose the artificial satellite is classified into two types - **Geostationary Satellites** and **Polar Satellites.**

GEO-STATIONARY SATELLITE:

- A satellite that appears to be at a stationary from any point in the sky to an observe on earth is called a geostationary satellite.
- The revolution period of earth and the satellite is same i.e, 24hrs.
- This satellite is located at 36,000KM above the surface of the earth.
- USES:
    - Communication of TV signals and Radio signals.
    - To study the atmospheric changes or weather changes.
    - To find the mineral deposits on the surface on the earth.



POLAR SATELLITE:

- Polar satellites revolve around the earth in a north-south direction around the earth as opposed to east-west like the geostationary satellites.
- **USES:** They are used in weather applications where predicting weather and climate-based disasters can be done in a short time. They are also used as relay stations.

COMMON TYPES OF SATELLITES:

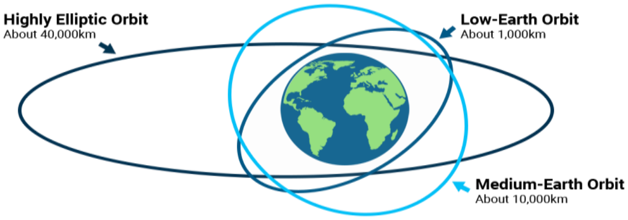
1. Military and civilian Earth observation satellites.
2. Communications satellites.
3. Navigation satellites.
4. Weather satellites.
5. Space telescopes.
6. Space stations and human spacecraft in orbit are also satellites.

TYPES OF SATELLITE OBITS:

- Low Earth orbit (LEO)
- Medium Earth orbit (MEO)
- Geostationary orbit (GEO)

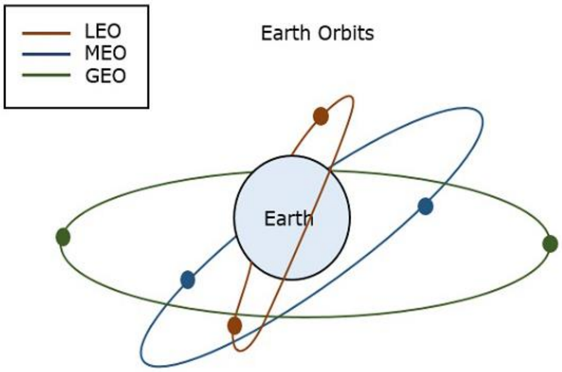
LOW EARTH ORBIT(LEO):

- A low Earth orbit (LEO) is, as the name suggests, an orbit that is relatively close to Earth's surface.
- It is normally at an altitude of less than 1000 km but could be as low as 160 km above Earth.



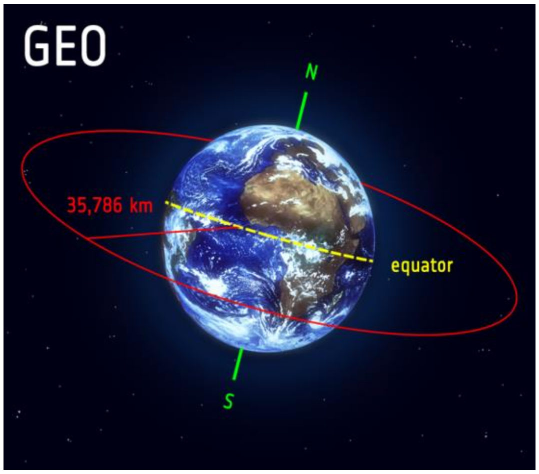
MEDIUM EARTH ORBIT (MEO):

- Medium Earth orbit comprises a wide range of orbits anywhere between LEO and GEO.
- It is similar to LEO in that it also does not need to take specific paths around Earth, and it is used by a variety of satellites with many different applications.

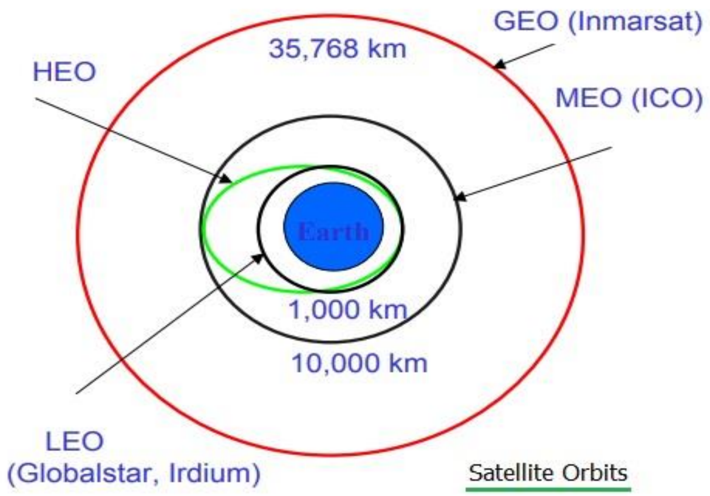


GEOSTATIONARY ORBIT(GEO):

- Satellites in geostationary orbit (GEO) circle Earth above the equator from west to east following Earth's rotation – taking 23 hours 56 minutes and 4 seconds – by travelling at exactly the same rate as Earth.
- This makes satellites in GEO appear to be 'stationary' over a fixed position.
- In order to perfectly match Earth's rotation, the speed of GEO satellites should be about 3 km per second at an altitude of 35 786 km.
- This is much farther from Earth's surface compared to many satellites.



SATELITE ORBITS:



ORBIT MECHANICS:

1. Line of Apsides
2. Ascending Node
3. Descending Node
4. Line of Nodes
5. Inclination
6. Prograde Orbit
7. Retrograde Orbit
8. Semi major axis
9. Eccentricity

1. When satellite is in elliptical orbit, the center of earth is one of the focal points of ellipse. In this type of satellite orbit, distance of satellite from earth varies based on its position.

- Two points are very important viz. highest point and lowest point above earth.

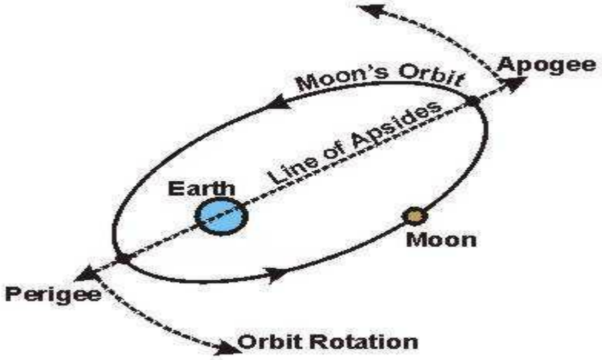
  A) Apogee- The Point farthest from the earth.

  B) Perigee- The Point closest to the earth.

2.ASCENDING NODE:

Line joining perigee and apogee through center of the Earth.

- It is the major axis of the orbit.
- One-half of this line’s length is the semi-major axis equivalents to satellite’s mean distance from the Earth.

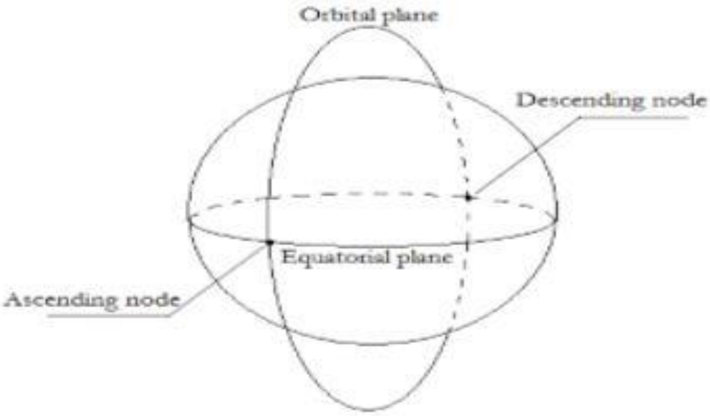


3.ASCENDING NODE:

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

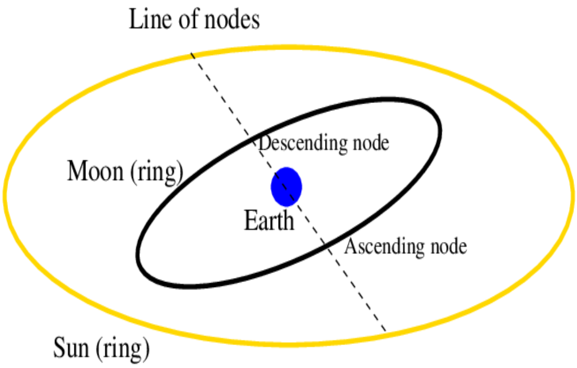
4.DESCENDING NODE:

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



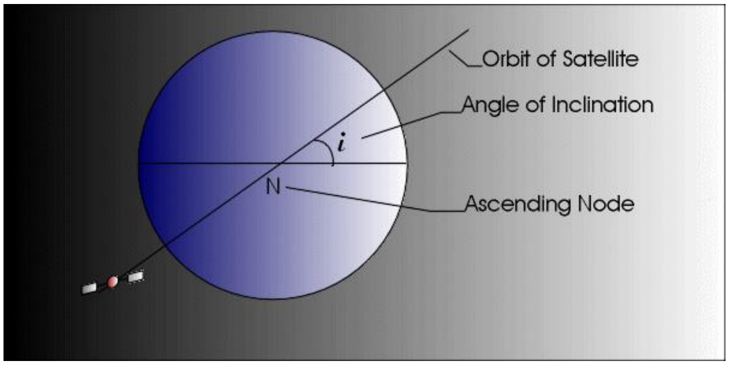
5.LINE OF NODES:

The line joining the ascending and descending nodes through the center of Earth.



6.INCLINATION:

- The angle between the orbital plane and the Earth's equatorial plane.
- It's measured at the ascending node from the equator to the orbit, going from East to North. Also, this angle is commonly denoted as i.



7.PROGRADE ORBIT:

An orbit in which satellite moves in the same direction as the Earth's rotation. Its inclination is always between 0^0 to 90^0. Many satellites follow this path as Earth's velocity makes it easier to lunch these satellites.

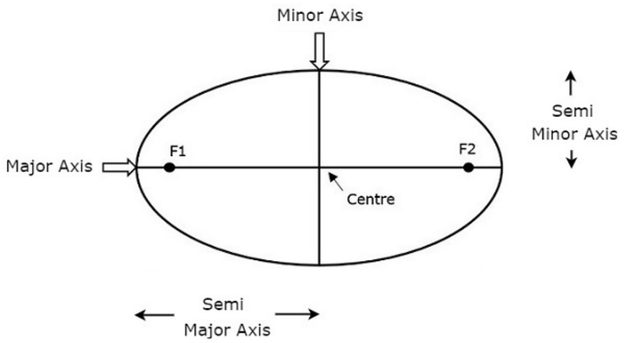
8.RETROGRADE ORBIT:

An orbit in which satellite moves in the same direction counter to the Earth's rotation.

9.SEMI MAJOR AXIS:

- The length of Semi-major axis (a) defines the size of satellite's orbit.
- It is half of the major axis.

- This runs from the center through a focus to the edge of the ellipse.
- So, it is the radius of an orbit at the orbit's two most distant points.

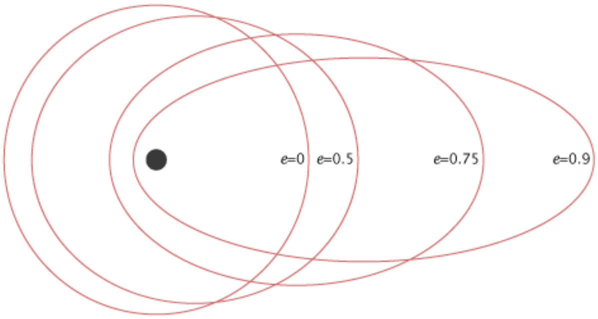


10.ECCENTRICITY:

- The value of **Eccentricity (e)** fixes the shape of satellite’s orbit. This parameter indicates the deviation of the orbit’s shape from a perfect circle.
- If the lengths of semi major axis and semi minor axis of an elliptical orbit are a & b, then the mathematical expression for **eccentricity (e)** will be

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

- The value of eccentricity of a circular orbit is **zero**, since both a & b are equal. Whereas, the value of eccentricity of an elliptical orbit lies between zero and one.



EQUATION OF ORBIT:

1. A satellite, when it revolves around the earth, it undergoes a pulling force from the earth due to earth's gravitational force. This force is known as **Centripetal force (F_1)** because this force tends the satellite towards it.

- Mathematically, the **Centripetal force (F_1)** acting on satellite due to earth can be written as **F1=G M m/R2**

Where,

G is universal gravitational constant and it is equal to 6.673 x 10^{-11} N·m^2/kg^2.

M is mass of the earth and it is equal to 5.98 x 10^{24} Kg.

m is mass of the satellite.

R is the distance from satellite to center of the Earth.

2. A Satellite, when it revolves around the earth, it undergoes a pulling force from the sun and the moon due to their gravitational forces. This force is known as **Centrifugal force** (F_2) because this force tends the satellite away from earth.

- Mathematically, the **Centrifugal force** (F_2) acting on satellite can be written as

F2=m v^2 / R

Where,

v is the orbital velocity of satellite

- Orbital velocity of satellite is the velocity at which, the satellite revolves around earth. Satellite doesn't deviate from its orbit and moves with certain velocity in that orbit, when both Centripetal and Centrifugal forces are balance each other.

- So, **equate Centripetal force (F_1) and Centrifugal force (F_2).**

$$\frac{GMm}{R^2} = \frac{mv^2}{R}$$

$$=> \frac{GM}{R} = v^2$$

$$=> v = \sqrt{\frac{GM}{R}}$$

Therefore, the **orbital velocity** of satellite is

$$v = \sqrt{\frac{GM}{R}}$$

Where,

G is gravitational constant and it is equal to **6.673 x 10^{-11} N·m²/kg².**

M is mass of the earth and it is equal to **5.98 x 10^{24} Kg.**

R is the distance from satellite to center of the Earth.

So, the orbital velocity mainly **depends** on the distance from satellite to center of the Earth (R), since G & M are constants.

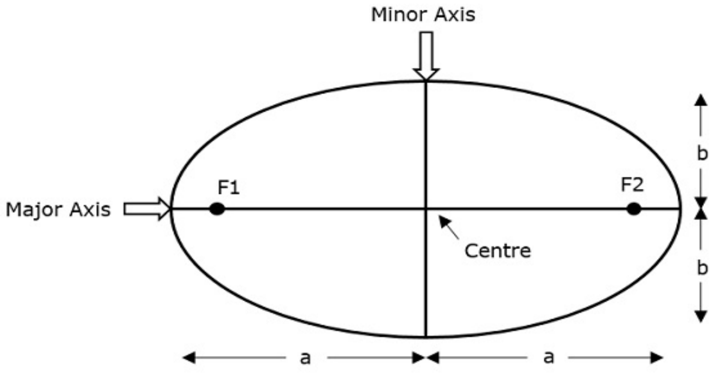
Kepler's Laws:

- We know that satellite revolves around the earth, which is similar to the earth revolves around the sun.
- So, the principles which are applied to earth and its movement around the sun are also applicable to satellite and its movement around the earth.
- Johannes Kepler (1571-1630) was one of the most accepted scientist in describing the principle of a satellite that moves around the earth.

Kepler's First Law:

- ***Kepler's first law states that the path followed by a satellite around its primary (the earth) will be an ellipse.***

This ellipse has two focal points (foci) F1 and F2 as shown in the figure below. Center of mass of the earth will always present at one of the two foci of the ellipse



Kepler's 1st law

- If the distance from the center of the object to a point on its elliptical path is considered, then the farthest point of an ellipse from the center is called as apogee and the shortest point of an ellipse from the center is called as perigee.

- Eccentricity "e" of this system can be written as

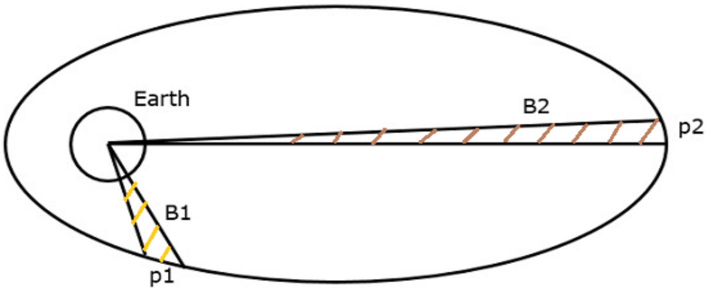
$$e = \frac{\sqrt{a^2 - b^2}}{a}$$

Where, a & b are the lengths of semi major axis and semi minor axis of the ellipse respectively.

- For an elliptical path, the value of eccentricity (e) is always lie in between 0 and 1.
- i.e. $0 < e < 1$, since a is greater than b. Suppose, if the value of eccentricity (e) is zero, then the path will be no more in elliptical shape, rather it will be converted into a circular shape.

Kepler's Second Law:

- ***Kepler's second law states that for equal intervals of time, the area covered by the satellite will be same with respect to center of mass of the earth.***



Kepler's Third Law:

- ***Kepler's third law states that, the square of the periodic time of an elliptical orbit is proportional to the cube of its semi major axis length.***
- Mathematically, it can be written as follows –

$$T^2 \alpha a^3$$

$$=> T^2 = \left(\frac{4\pi^2}{\mu}\right) a^3$$

Where, $\frac{4\pi^2}{\mu}$ is the proportionality constant.

μ is Kepler's constant and its value is equal to 3.986005 x 10^{14} m^3 /sec^2

$$1 = \left(\frac{2\pi}{T}\right)^2 \left(\frac{a^2}{\mu}\right)$$

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

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

Where, **'n'** is the mean motion of the satellite in radians per second.

LOOK ANGLE DETERMINATION:

- Earth station will receive the maximum signal level, if it is located directly under the satellite. Otherwise, it won't receive maximum signal level and that signal level decreases as the difference between the latitude and longitude of earth station increases.
- So, based on the requirement we can place the satellite in a particular orbit.
- The following two angles of earth station antenna combined together are called as look angles.

    1. **Azimuth Angle**
    2. **Elevation Angle**

- These two angles are helpful in order to point at the satellite directly from the earth station antenna. So, the maximum gain of the earth station antenna can be directed at satellite.
- We can calculate the look angles of geostationary orbit by using longitude & latitude of earth station and position of satellite orbit.

1.AZIMUTH ANGLE:

- The angle between local horizontal plane and the plane passing through earth station, satellite and center of earth is called as azimuth angle.
- The formula for Azimuth angle (α) is

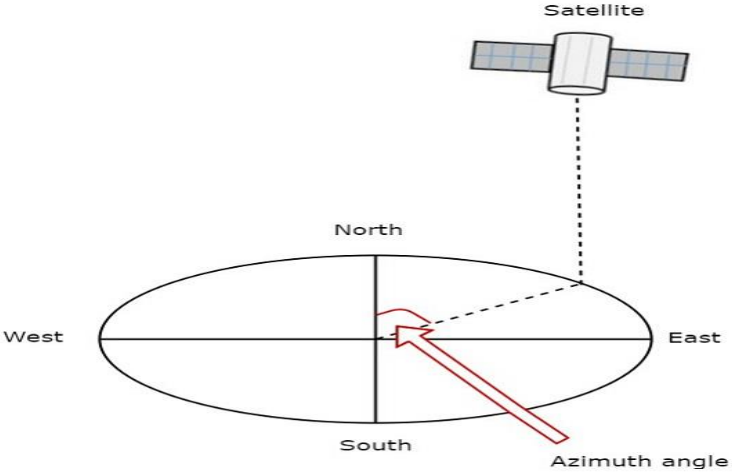
$$\alpha = 180^0 + Tan^{-1}\left(\frac{TanG}{TanL}\right)$$

Where;

L is Latitude of earth station antenna.

G is the difference between position of satellite orbit and earth station antenna.

- Measure the **horizontal angle** at earth station antenna to north pole as shown in figure.
- It represents azimuth angle.
- It is used to track the satellite horizontally.

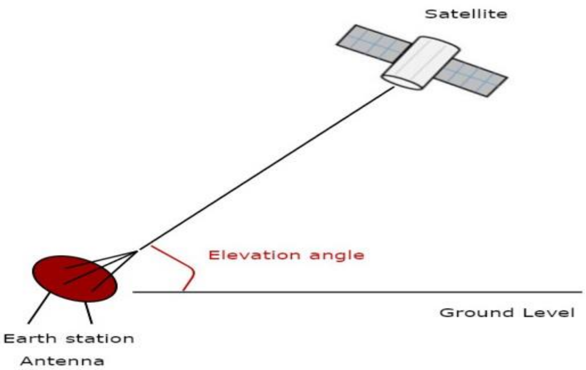


2.ELEVATION ANGLE:

- The angle between vertical plane and line pointing to satellite is known as Elevation angle. Vertical plane is nothing but the plane, which is perpendicular to horizontal plane.
- The formula for Elevation angle (β) is

$$\beta = Tan^{-1}\left(\frac{cosG.\,cosL - 0.15}{\sqrt{1 - cos^2G.\,cos^2L}}\right)$$

- Measure the **vertical angle** at earth station antenna from ground to satellite as shown in the figure.
- It represents elevation angle.



LIMITS OF VISIBILITY:

- The east and west limits of geostationary are visible from any given Earth station.
- These limits are set by the geographic coordinates of the Earth station and antenna elevation.
- The lowest elevation is zero (in theory) but in practice, to avoid reception of excess noise from Earth.
- Some finite minimum value of elevation is issued.
- The earth station can see a satellite over a geostationary arc bounded by +- (81.30) about the earth station's longitude.

Expression for Limits of Visibility:

- **Case 1:** When earth station is at equator
- The limiting angle γmax is given by

$$\cos\gamma_{\max} = \frac{r_E}{r_S} \qquad \therefore \gamma_{\max} = \cos^{-1}\left(\frac{r_E}{r_S}\right)$$

$$\therefore \gamma_{\max} = \cos^{-1}\left(\frac{6378}{42164}\right) \qquad \therefore \gamma_{\max} = 81.3^0$$

- **Case 2:** When earth station is at a non zero latitude (Not on equator)
- In such a case, the limits of visibility are evaluated as follows:

i . Calculate central angle γ as described above.

ii. Use the relation: cosγ = cosλe cosβ where β is the difference between satellite & earth station longitude.

iii. Hence the satellites which are in the limits of visibility of an earth station at a latitude λe would be located between longitudes θe ± β = θe ± β, where θe is the Earth station longitude.

- The maximum central angular separation between earth station and the sub satellite point is limited by:

$$\gamma \leq \cos^{-1}\left(\frac{r_e}{r_s}\right)$$

- Therefore maximum value of γ works out to be 81.30.
- In practice to avoid the reception of excessive noise from earth, some finite minimum value of elevation is used, which will be denoting by El min. A typical value is 5°.

EARTH ECLIPSE OF SATELLITE:

- Satellite is said to be in eclipse when the earth or moon prevents sunlight from reaching it.
- If the earth's equatorial plane coincides with the plane of earth's orbit around sun, the geostationary orbit will be eclipsed by the earth.
- This is called the earth eclipse of satellite.
- For a geostationary satellite, the solar eclipse due to earth occurs during two periods that begin 23 days before equinox and ends 23 days after equinox.
- Because during equinox (autumn and spring) the sun, earth and the satellite are in the same plane.

- Solar eclipses are important as they affect the working of the satellite because during eclipse satellite receives no power from its solar panels and it has to operate on its onboard standby batteries which reduce satellite life.
- Satellite failure is more at such times when satellite enters into eclipse (sudden switch to no solar power region) and when it moves out of eclipse (suddenly large amount of solar power is bombarded on satellite) as this creates thermal stress on satellite.
- Eclipse caused by moon occurs when moon passes in front of sun but that is less important as it takes place for short duration (twice in every 24 hours for an average of few minutes).

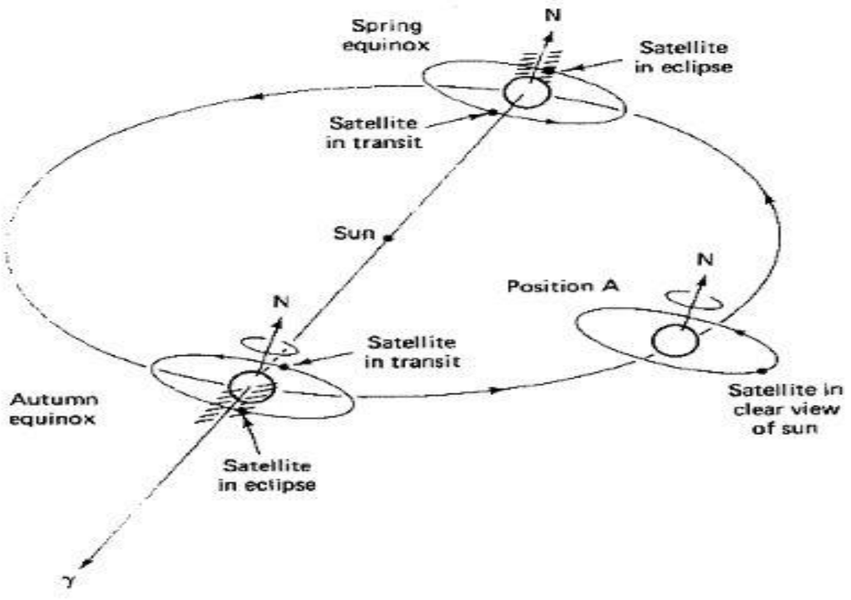


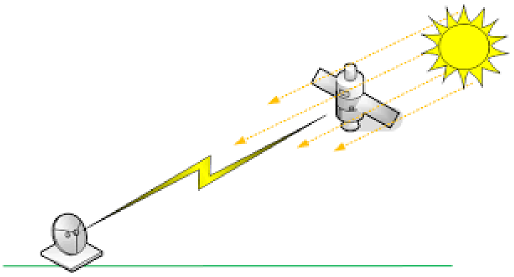
Fig (a)

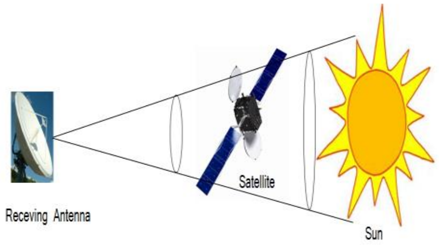
How to avoid eclipse during satellite lifetime:

- The Solar cells do not function during the eclipse and the power must be supplied from batteries.
- If the Satellite longitude is east, then the satellite enters the eclipse during day light hours of the earth station.
- If the Satellite longitude is west of the earth station, then eclipse does not occur until the earth station is in darkness.
- The west longitude of the satellite are desirable than the east.

SUN TRANSIT OUTAGE:

- The Sun transit is nothing but the sun comes within the beam width of earth station antenna.
- During this period the sun behaves like an extremely noisy source and it blanks out all the signal from the satellite.
- This effect is termed as sun transit outage.
- The duration of the sun transit outage depends on the latitude of the earth station, generally maximum of 10 mins per day.

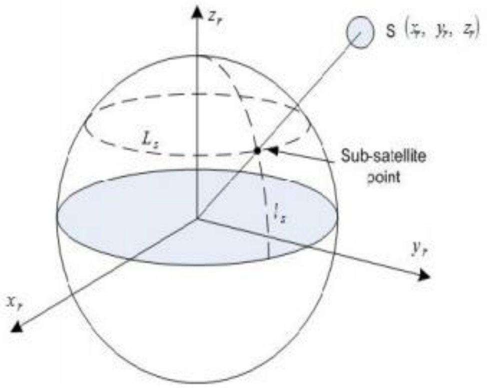




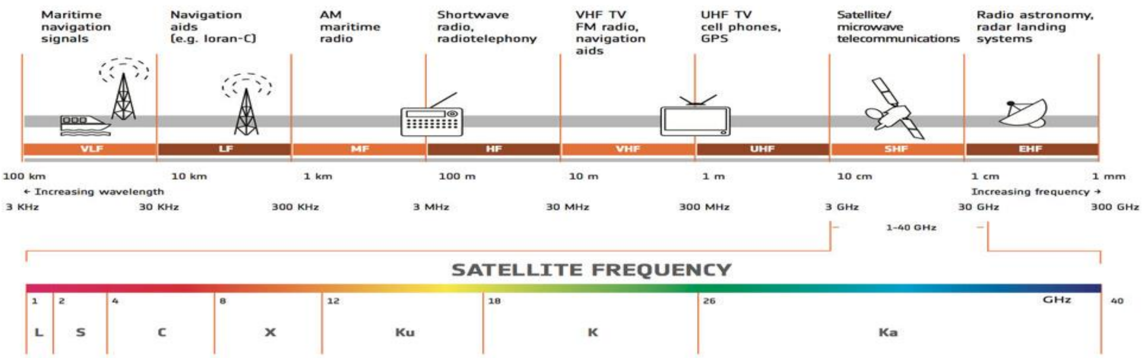
SUB SATELLITE POINT:

- **Point at which a line between the satellite and the center of the Earth intersects the Earth's surface**
- **Location of the point expressed in terms of latitude and longitude**
- **Latitude – degrees north from equator**
- **Longitude – degrees west of the Greenwich meridian**
- **Location of the sub satellite point may be calculated from coordinates of the rotating system as:**

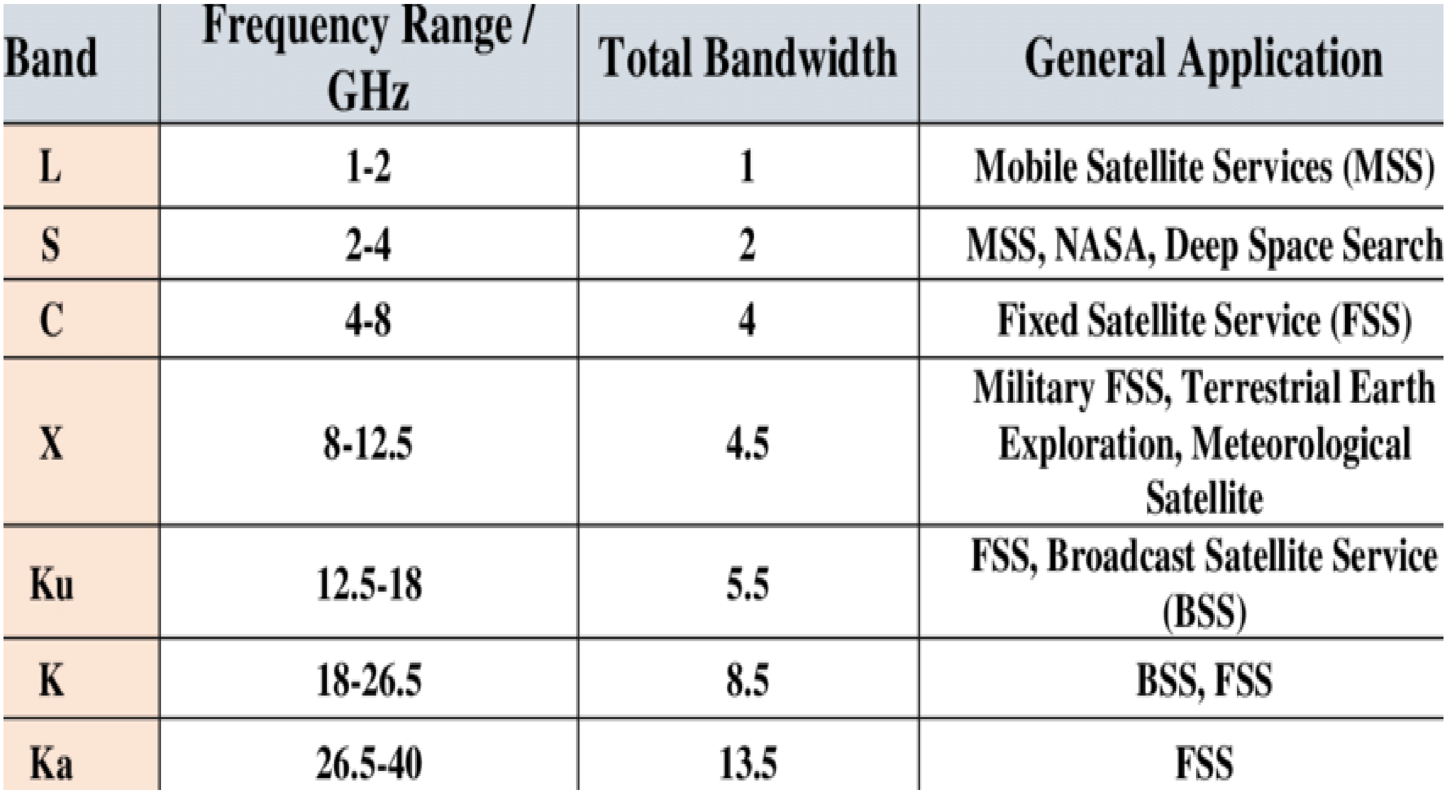
$$L_s = \frac{\pi}{2} - \cos^{-1}\left(\frac{z_r}{\sqrt{x_r^2 + y_r^2 + z_r^2}}\right)$$



SATELLITE FREQUENCY BAND:



FREQUENCY SPECTRUM OF SATELLITE COMMUNICATION:



Band	Frequency Range / GHz	Total Bandwidth	General Application
L	1-2	1	Mobile Satellite Services (MSS)
S	2-4	2	MSS, NASA, Deep Space Search
C	4-8	4	Fixed Satellite Service (FSS)
X	8-12.5	4.5	Military FSS, Terrestrial Earth Exploration, Meteorological Satellite
Ku	12.5-18	5.5	FSS, Broadcast Satellite Service (BSS)
K	18-26.5	8.5	BSS, FSS
Ka	26.5-40	13.5	FSS

- The three most commonly used satellite frequency bands are :

  1. C-band.
  2. Ku-band.
  3. Ka-band.

1.C-BAND:

- C band is a name given to certain portions of the electromagnetic spectrum, as well as a range of wavelengths of light, used for communications.
- Most commercial satellites use this Band.
- The bandwidth allocated is limited to **500 MHz.**
- Up / Down Links (W.R.T Satellite)
- **3.7 to 4.2 GHz** forms the **down-link** (transmit) frequency
- **5.925 to 6.425 GHz** the **up-link** (receive) frequency.
- It's used for certain satellite television broadcasts, and by some WiFi devices, cordless phones, and weather radars.

2.KU-BAND:

- Ku band is primarily used for satellite communications.
- The Ku band (pronounced "kay-yoo") is a portion of the electromagnetic spectrum in the microwave range of frequencies.
- This symbol refers to "K-under" (in the original German, "Kurz-unten", with the same meaning)—in other words.
- Future satellites are being designed for the Ku-Band.
- Known as 12 / 14 GHz.
- Up / Down Links (W.R.T. Satellite)
- Either **11.7 to 12.2 GHz** or **10.95 to 11.2** or **11.45 to 11.7 GHz down Link**.
- **14.0 to 14.5 GHz up-link** frequency.
- Ku band satellites are also used for backhauls and particularly for satellite from remote locations back to a television network's studio for editing and broadcasting.

3.Ka-BAND:

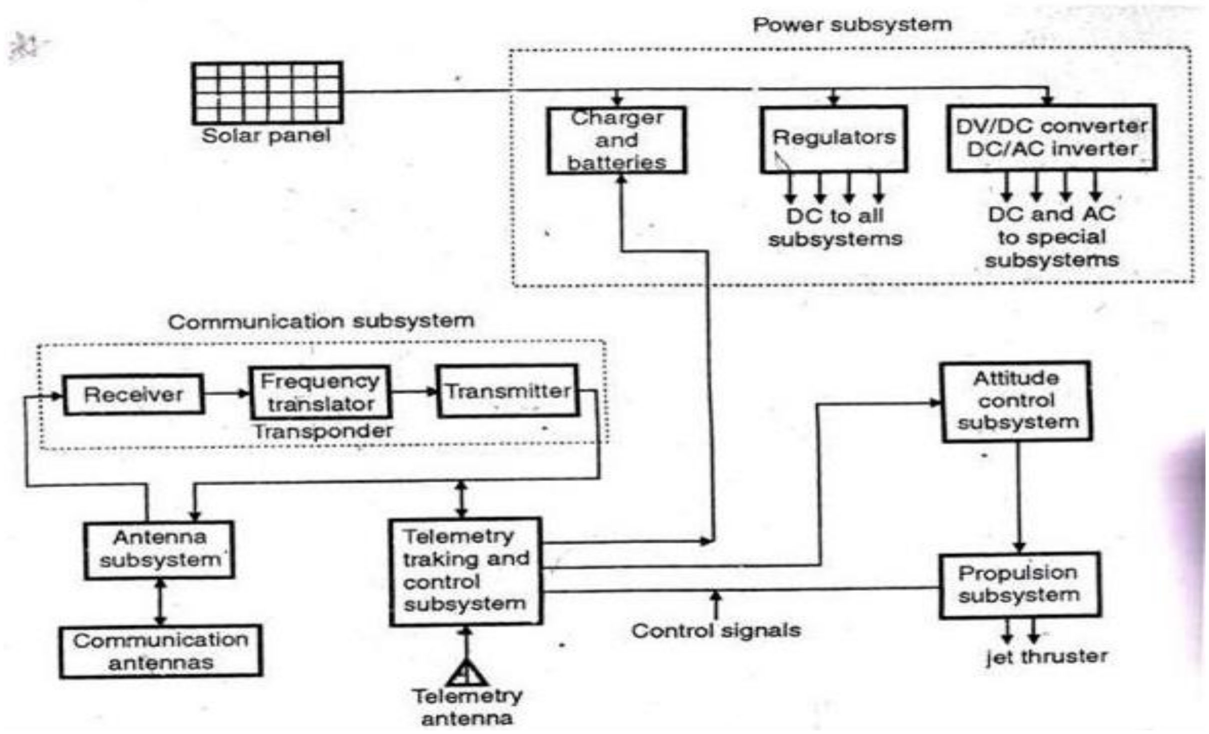
- The Ka band (Pronounced: "Kay-A Band") covers the frequencies of 26.5-40GHz.
- The Ka band is part of the K band of the microwave band of the electromagnetic spectrum.

- The so-called 30/20 GHz band is used in communications satellites, uplink in either the 27.5 GHz and 31 GHz bands, and high resolution, close-range targeting radars aboard military airplanes.
- Some frequencies in this radio band are used for vehicle speed detection by law enforcement.

SPACE CRAFT TECHNOLOGYL:

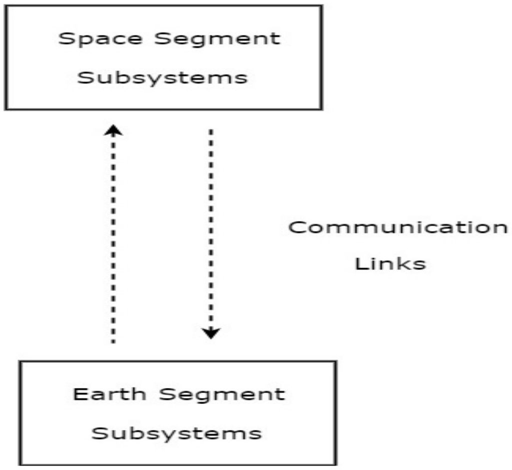
- **Structural subsystems**
- **Power subsystems**
- **Attitude and Orbit Control subsystems. (AOCS)**
- **Thermal Subsystems**
- **Propulsion subsystems**
- **Telemetry, tracking, command (TTC)**
- **Communication and Antenna subsystems.**
- **Launching Procedures and Launch vehicles.**

STRUCTURAL SUBSYSTEM:



- In satellite communication system, various operations take place.
- Among which, the main operations are orbit controlling, altitude of satellite, monitoring and controlling of other subsystems.
- A satellite communication consists of mainly two segments.
- Those are space segment and earth segment.

So, accordingly there will be two types of subsystems namely, space segment subsystems and earth segment subsystems.



SPACE SEGMENT SUBSYSTEMS:

The subsystems present in space segment are called as space segment subsystems. Following are the space segment subsystems.

- AOC Subsystem
- TTCM Subsystem
- Power and Antenna Subsystems
- Transponders

Earth Segment Subsystems:

- The subsystems present in the ground segment have the ability to access the satellite repeater in order to provide the communication between the users.
- Earth segment is also called as ground segment.
- Earth segment performs mainly two functions.

- Those are transmission of a signal to the satellite and reception of signal from the satellite.
- Earth stations are the major subsystems that are present in earth segment.

POWER SUBSYSTEM:

- Power system is a vital subsystem, which provides the power required for working of a satellite.
- Mainly, **the solar cells** (or panels) and **Rechargeable batteries** are used in these systems.

SOLAR CELLS:

- Basically, the solar cells produce electrical power (current) from incident sunlight.
- Therefore, solar cells are used primarily in order to provide power to other subsystems of satellite.
- Individual solar cells generate very less power.
- So, in order to generate more power, group of cells that are present in an array form can be used.
- There are two types of solar arrays that are used in satellites. Those are cylindrical solar arrays and rectangular solar arrays or solar sail.
- Cylindrical solar arrays are used in spinning satellites. Only part of the cylindrical array will be covered under sunshine at any given time. Due to this, electric power gets generated from the partial solar array. This is the drawback of this type.
- The drawback of cylindrical solar arrays is overcome with Solar sail. This one produce more power because all solar cells of solar sail are exposed to sun light.

RECHARGEABLE BATTERIES:

- During eclipses time, it is difficult to get the power from sun light.
- So, in that situation the other subsystems get the power from rechargeable batteries.
- These batteries produce power to other subsystems during launching of satellite also.
- In general, these batteries charge due to excess current, which is generated by solar cells in the presence of sun light.

ATTITUDE AND ORBIT CONTROL SUBSYSTEM(AOCS):

- Attitude and Orbit Control (AOC) subsystem consists of rocket motors, which are capable of placing the satellite into the right orbit, whenever it is deviated from the respective orbit.
- AOC subsystem is helpful in order to make the antennas, which are of narrow beam type points towards earth.
- We can make this AOC subsystem into the following two parts.

1. Attitude Control Subsystem
2. Orbit Control Subsystem

1.ATTITUDE CONTROL SUBSYSTEM:

- Attitude control subsystem takes care of the orientation of satellite in its respective orbit.
- Following are the two methods to make the satellite that is present in an orbit as stable.
    - Spinning the satellite
    - Three axes method

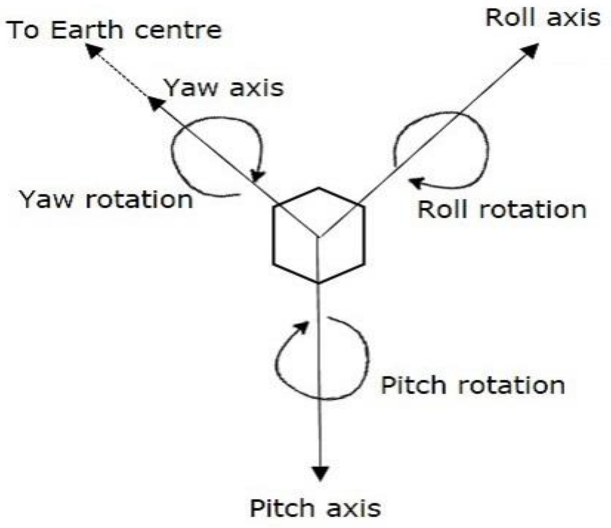
SPINNING THE SATELLITE:

- In this method, the body of the satellite rotates around its spin axis.
- In general, it can be rotated at 30 to 100 rpm in order to produce a force, which is of gyroscopic type.
- Due to this, the spin axis gets stabilized and the satellite will point in the same direction.
- Satellites are of this type are called as spinners.
- Spinner contains a drum, which is of cylindrical shape.
- This drum is covered with solar cells.
- Power systems and rockets are present in this drum.
- Communication subsystem is placed on top of the drum
- An electric motor drives this communication system.

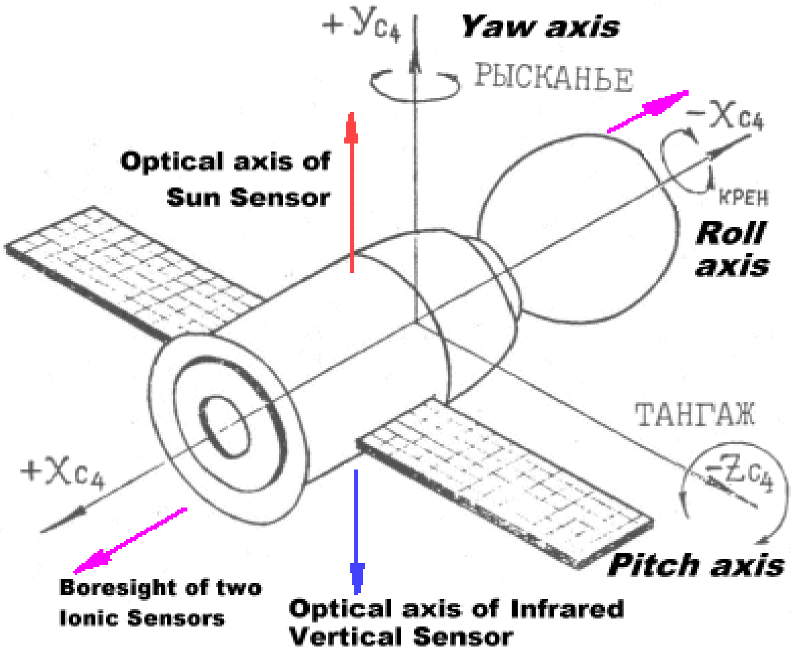
- The direction of this motor will be opposite to the rotation of satellite body, so that the antennas point towards earth.
- The satellites, which perform this kind of operation are called as de-spin.
- During launching phase, the satellite spins when the small radial gas jets are operated.
- After this, the de-spin system operates in order to make the TTCM subsystem antennas point towards earth station.

THREE AXIS METHOD:

- In this method, we can stabilize the satellite by using one or more momentum wheels.
- This method is called as **three-axis method**.
- The advantage of this method is that the orientation of the satellite in three axes will be controlled and no need of rotating satellite's main body.
- In this method, the following **three axes** are considered.
- **Roll axis** is considered in the direction in which the satellite moves in orbital plane.
- **Yaw axis** is considered in the direction towards earth.
- **Pitch axis** is considered in the direction, which is perpendicular to orbital plane.



- Let X_R, Y_R and Z_R are the roll axis, yaw axis and pitch axis respectively.
- These three axis are defined by considering the satellite's position as **reference**.
- These three axes define the altitude of satellite.



- Let X, Y and Z are another set of Cartesian axes.
- This set of three axis provides the information about orientation of the satellite with respect to reference axes.
- If there is a change in altitude of the satellite, then the angles between the respective axes will be changed.
- In this method, each axis contains two gas jets. They will provide the rotation in both directions of the three axes.
- The **first gas jet** will be operated for some period of time, when there is a requirement of satellite's motion in a particular axis direction.
- The **second gas jet** will be operated for same period of time, when the satellite reaches to the desired position.
- So, the second gas jet will stop the motion of satellite in that axis direction.

ORBIT CONTROL SUBSYSTEM:

- Orbit control subsystem is useful in order to bring the satellite into its correct orbit, whenever the satellite gets deviated from its orbit.
- The TTCM subsystem present at earth station monitors the position of satellite.
- If there is any change in satellite orbit, then it sends a signal regarding the correction to Orbit control subsystem.

- Then, it will resolve that issue by bringing the satellite into the correct orbit.
- In this way, the **AOC subsystem** takes care of the satellite position in the right orbit and at right altitude during entire life span of the satellite in space.

TELEMETRY, TRACKING & COMMAND SUBSYSTEM:

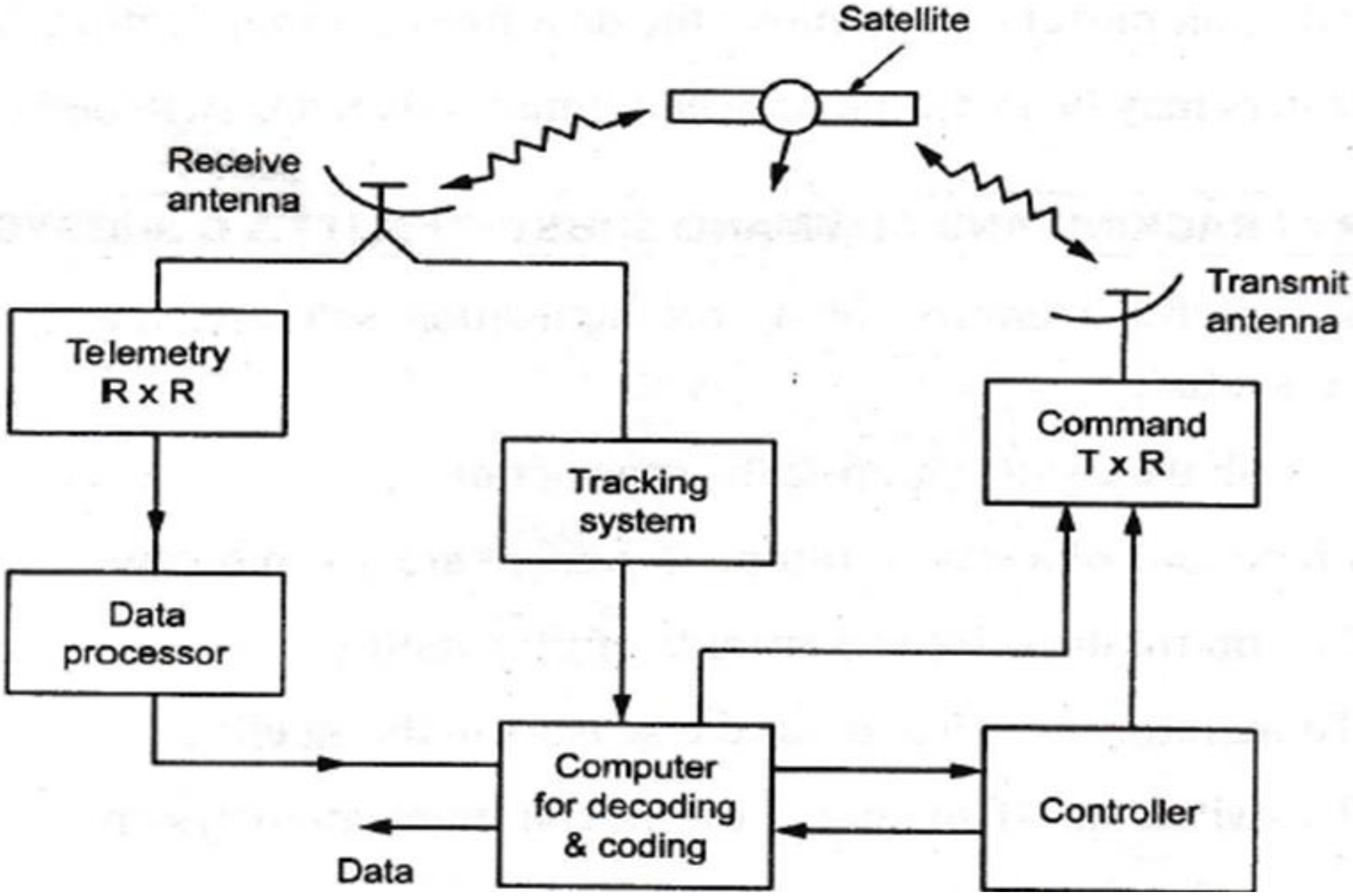
- For the successful operation of a communication satellite, the TT & c subsystem is essential.
- It involves both the earth station & the space craft.
- The main functions of a space craft management are given below:

1. l. To control the orbit and attitude of the satellite
2. To monitor the status of all the sensors in the satellite.
3. To switch on/off some sections in communication system.

TELEMETRY SYSTEM:

- The telemetry system is present in the satellite, this subsystem collects data from many/all sensors present in the satellite and retransmit it into the earth station.
- There are number of sensors located on the space craft to monitor the,
  - ➢ Pressure in fuel tanks
  - ➢ Voltage and current in power conditioning unit
  - ➢ Current drawn by each subsystem
  - ➢ Critical voltage & current in communication electronics
  - ➢ Temperature from all the subsystem.
  - ➢ Status of each subsystem & switch positions.
  - ➢ Monitoring the attitude control and so on.
- The data's from all the sensors are given to the telemetry unit, and this unit digitize the data and transmit the data using FSK or PSK.
- To maintain a high carrier to noise ratio, low data rate is normally used.
- At the controlling earth station a computer can be used to monitor, store and decode the telemetry data, so that the status of the space craft is immediately determined.

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



TRACKING:

- Tracking is nothing but to find the position of the satellite in space.
- Tracking is very important during the transfer orbit & drift phase of the satellite launch.
- We know that lots of disturbing forces may change the attitude and orbits satellite, so it is necessary to track the satellite & send correction signals.
- The satellite position may be determined by various techniques.
    - Velocity & acceleration sensors present in the space craft may give the change in orbit.
    - By using the Doppler shift the earth station may determine the position.
- Range and the angular measurements from the earth station antenna, is used to determine the orbital elements.
- If sufficient number of earth stations with an adequate separation are observing the satellite, by simultaneous range measurement its position may be established.

- The position of a satellite can be determined within 100 m.

COMMAND:

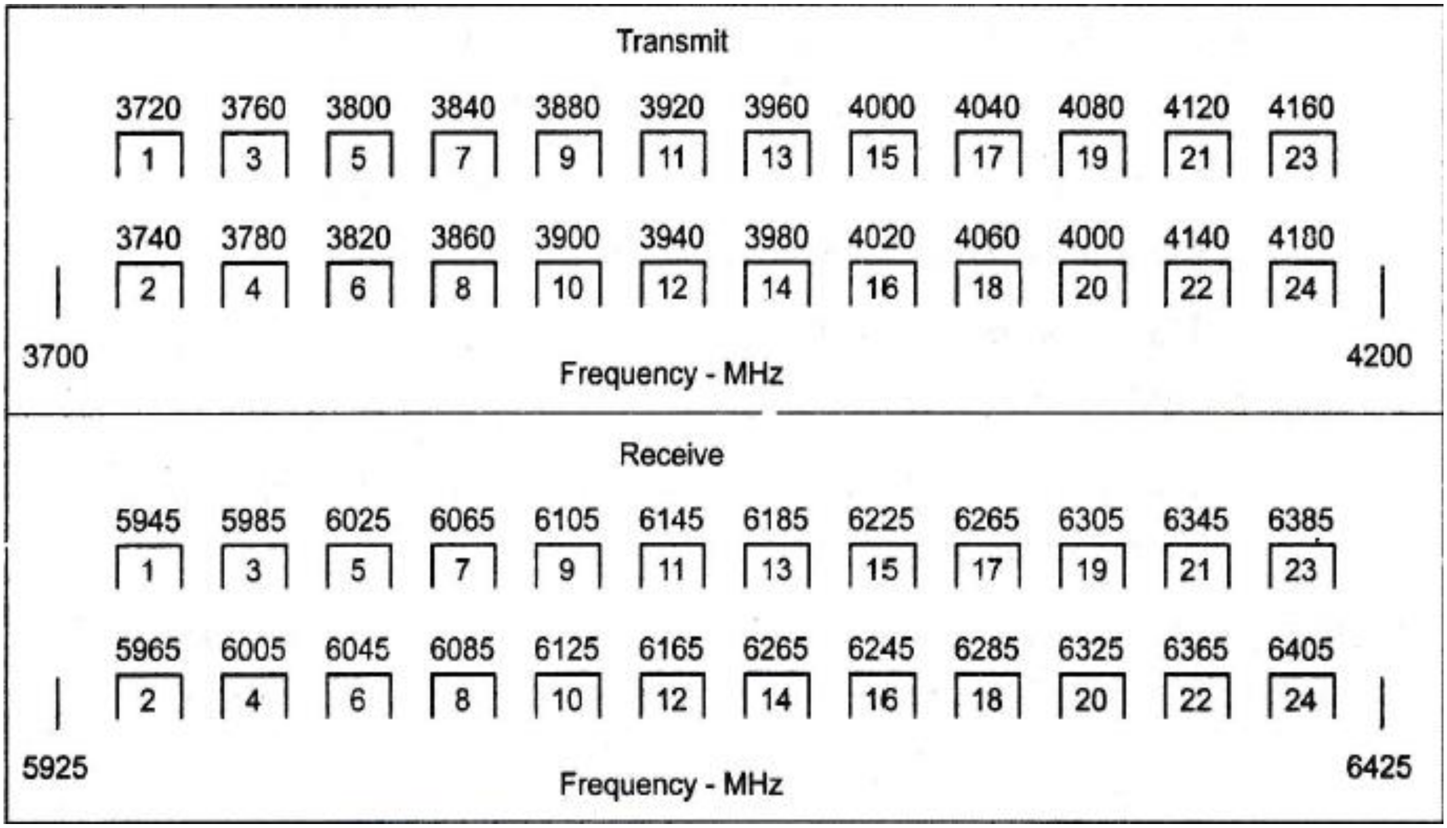
- The command system is used to make changes in attitude and orbit, and also to control the communication subsystem.
- The shows the operation of the command subsystem.
- From the block diagram it is observed that,
- The status of the various subsystems and sensors are transmitted from the satellites to the earth station.
- The data processor convert the received signal in to digital format& decryption encryption are performed here.
- Then the data is given to the controller and the controller will transmit a control code i.e., command word is sent in a TDM frame to the satellite.
- After checking for validity in satellite, the word is again sent back to the control unit, again it is checked in the computer.
- If it is received correctly, then the execute command is sent to the satellite, then the command is executed.
- This process is used to avoid erroneous command and, the entire, process may take 5 or 10 s.
- The command and telemetry link are usually separated from the communication system.
- During the launch phase, the main TT&C system may not operable' because the satellite does not have the correct attitude and it does not expended its solar sails.
- At this time, a back up System is used to control most important sections of the satellites.
- The backup system provide control of
    - Apogee kick motor
    - Attitude & orbit control thrusters
    - Solar sail deployment
    - Power conditioning

- By using the backup, the space craft is injected into geo stationary then hand-over to the main TT & C system.
- The backup system can also be used during the failure of the system.

COMMUNICATION AND ANTENA SUBSYSTEM:

COMMUNICATION SUBSYSTEM:

- In a communication satellite, the communication subsystem is the important subsystem and all the subsystem are used to support the communication subsystem.
- Below Fig. shows the frequency arrangement satellite communication subsystem for the 6/4 GHz band (C band).
- The entire 500 MHz bandwidth is divided up into channels, 36 or 40 MHz wide, each are handled by a separate transponder.



TRANSPONDER:

- A transponder consist a BPF to select the particular channels band of frequencies.
- A down converter to convert 6 GHz frequency to 4 GHz at the output.

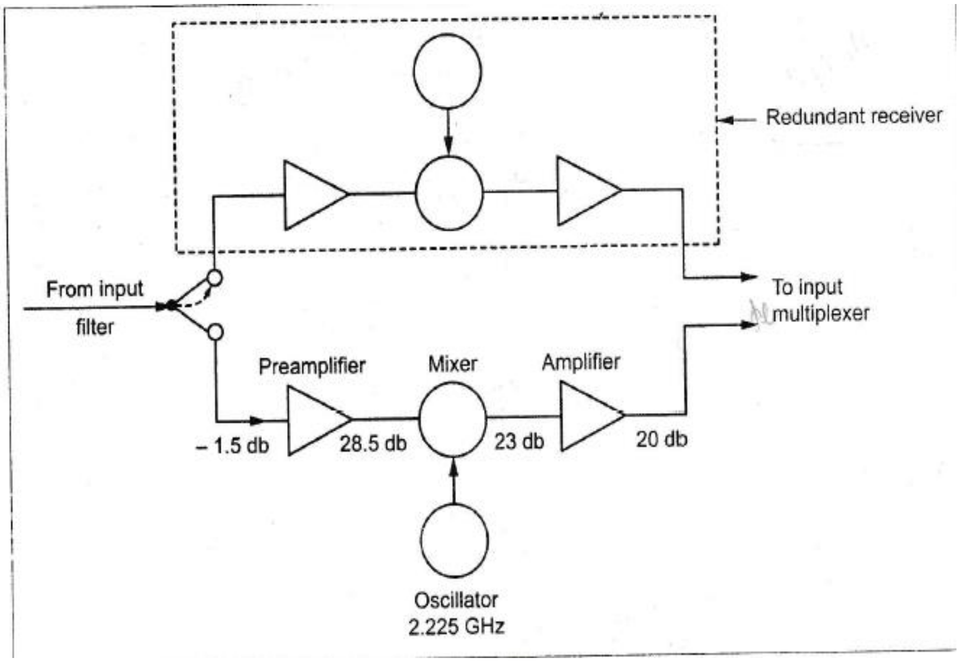
- A communication system may contain make number of transponders, some of them may be spares.
- Typically 12-44 transponders are used. Each transponder are supplied with input from the receive antenna.
- The output of the transponder is given to a switch matrix.
- These switch settings may be controlled from earth station, so that reallocations are possible.

FREQUENCY REUSE:

- The bandwidth allocated for C band service is 500 MHz, this is dividend into sub bands.
- The band width of a typical transponder is 36 MHz and 40 MHz guard band between transponders.
- By using the polarization isolation, the number of transponders used can be doubled.
- Polarization isolation is defined as the same carrier is used with opposite polarization so that the bandwidth may increased.
- For Example the same frequency can be used by more than one transponder.
- If it is linearly polarized, then horizontal & vertical polarization' if it is circularly polarized then right hand polarization or left hand polarization.
- This technique is referred as the frequency reuse.

THE WIDE BAND RECEIVER:

- In the receiver section of a transponder, the concept of redundant receiver is used.
- A duplicate receiver is provided with each original receiver, if one fails the other will automatically switched on.
- But at a time one must be in use.
- The Fig. shows the block diagram of the wide band receiver.



- In that the first stage is a low noise amplifier.
- The LNA adds little noise to the carrier and also it provides amplification, this is for the purpose to override the noise present in the mixer level.
- In satellite, the noise calculations are generally termed in equivalent noise temperature.
- This equivalent noise temperature may be in the order of a few hundred Kelvin's.
- The output of the LNA is given to the mixer stage, and it will also consist of a oscillator.
- This oscillator is used for frequency conversion, the frequency of the oscillator is always stable and it have low noise.
- The signal output from the mixer is given to the second stage amplifier.
- It gives the overall receiver gain of 60 db.
- The wide band receiver utilized only solid state active devices.
- In the amplified section, it may uses tunnel diode amplifiers or the FET amplifiers.
- In the mixer stage diode mixer, or BJT or even FET may also be used.

ANTENNA SUBSYTEM:

- Antennas are present in both satellite and earth station.
- Satellite antennas perform **two types** of functions.
- Those are receiving of signals, which are coming from earth station and transmitting signals to one or more earth stations based on the requirement.
- In other words, the satellite antennas receive uplink signals and transmit downlink signals.
- We know that the length of satellite antennas is inversely proportional to the operating frequency.
- The operating frequency has to be increased in order to reduce the length of satellite antennas.
- Therefore, satellite antennas operate in the order of **GHz** frequencies.
- The type of the antenna used may be directional or Omni directional, it depends upon the type of usage.
- Generally for telecommunication purposes and broadcasting, highly directional antennas are required.
- The parabolic reflector type antennas are used to produce the directional beams.

Satellite Antennas

- For the global coverage, simple horn antenna is used at 6/4 GHz band.
- The biconical dipole antenna is used for tracking and control purposes.
- To transmit and receive the signals, the same type of horn is used, the signals are separated by using a device called diplexer.
- The antennas, which are used in satellite are known as satellite antennas. There are mainly four **types of Antennas**. They are:

    1. Wire Antennas
    2. Horn Antennas
    3. Array Antennas
    4. Reflector Antennas

1.WIRE ANTENNAS:

- Wire antennas are the basic antennas. **Mono pole** and **dipole antennas** come under this category.
- These are used in very high frequencies in order to provide the communication for TTCM subsystem.
- **Wire antennas** are suitable for covering its range of access and to provide signal strength in all directions.
- That means, wire antennas are Omni-directional antennas.

2.HORN ANTENNAS:

- **Horn antenna** is used in satellites in order to cover more area on earth.
- Horn antennas are used in **microwave** frequency range.
- The same feed horn can be used for both transmitting and receiving the signals. A device named duplexer, which separates these two signals.

3.ARRAY ANTENNAS:

- Array antennas are used in satellites to form multiple beams from single aperture.

4.REFLECTOR ANTENNAS:

- Reflector antennas are suitable for producing beams, which have more signal strength in one particular direction.
- That means, these are highly directional antennas.
- So, **Parabolic reflectors** increase the gain of antennas in satellite communication system.

LAUNCHING PROCEDURES:

- The Satellite is used for various applications such as communication, space and earth exploration etc.
- The satellite is launched in the space with the help of launch vehicle.
- It is used so that satellite will cross the earth's atmosphere as well as gravitational pull.
- There are two types of launch vehicles viz. expendable type or reusable type.

- The expendable type of vehicles gets destroyed in space after placing the satellite in orbit.
- Arianne and Delta are expendable type of launch vehicles.
- The re-usable type returns to the earth after leaving it at certain altitude above the earth.
- The examples of reusable type are GSLV and PSLV.
- Navigation and guidance of the launch vehicle are important so that satellite can attain needed altitude, orbit path and essential kinematics requirements.
- The satellite launch vehicle is a complex system and consists of following functional modules:
  - ➢ Propulsion systems
  - ➢ Auto piloting.
  - ➢ Aerodynamic structure
  - ➢ Interactive steering subsystem

SATELLITE LAUNCH PROCEDURE:

- There are various steps or procedure followed in order to launch satellite in its parking space.
- The four orbit stages involved in the satellite launch procedure are as follows:
  1. Circular low earth orbit
  2. Hohmann elliptical transfer orbit
  3. Intermediate drift orbit
  4. Circular Geostationary orbit.

Satellite launch procedure followed by space companies such as ISRO:

Step-1:

- The launch vehicle takes the satellite into low earth orbit.
- The satellite is injected into desired 3-axes stabilized mode to achieve gyro condition using commands issued by launch vehicle to carry pyro firing.

Step-2:

- After satellite reaches apogee AKM is fired for long duration to take satellite to intermediate orbit.

- This intermediate orbit is referred as transfer orbit.
- AKM is the short form of Apogee Kick Motor which contains liquid fuel.

Step-3:

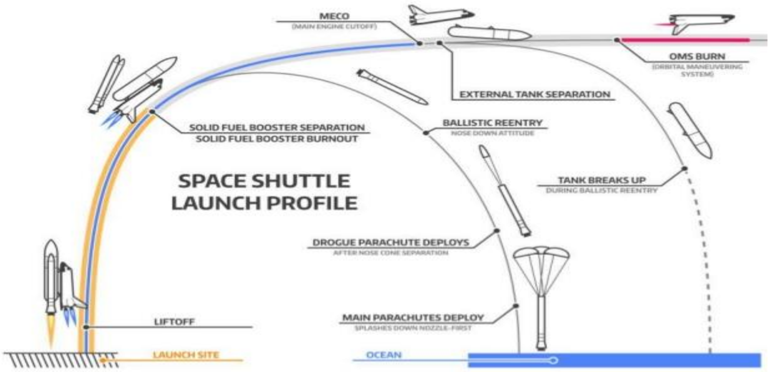
- The second apogee motor firing is carried out so that satellite attains needed angular velocity and acceleration for Geo-synchronization.
- This helps satellite to be in LOS from central earth stations.
- If required it is tracked through other countries earth stations.

Step-4:

- Further stabilization and attitude control is achieved using control of momentum/reaction wheels.
- Antennas and transponders are turned on which brings satellite into stabilized geostationary orbit.
- Examples of geostationary satellites are INTELSAT, COMSAT, INSAT etc.

Once the satellite is placed in the parking space(i.e. designated orbit), following activities need to be performed as part of maintenance.

- Orbit maintenance.
- Attitude maintenance.
- Thermal management.
- Power management.
- battery maintenance.
- Payload operations.
- Software requirement.



LAUNCH VEHICLE:

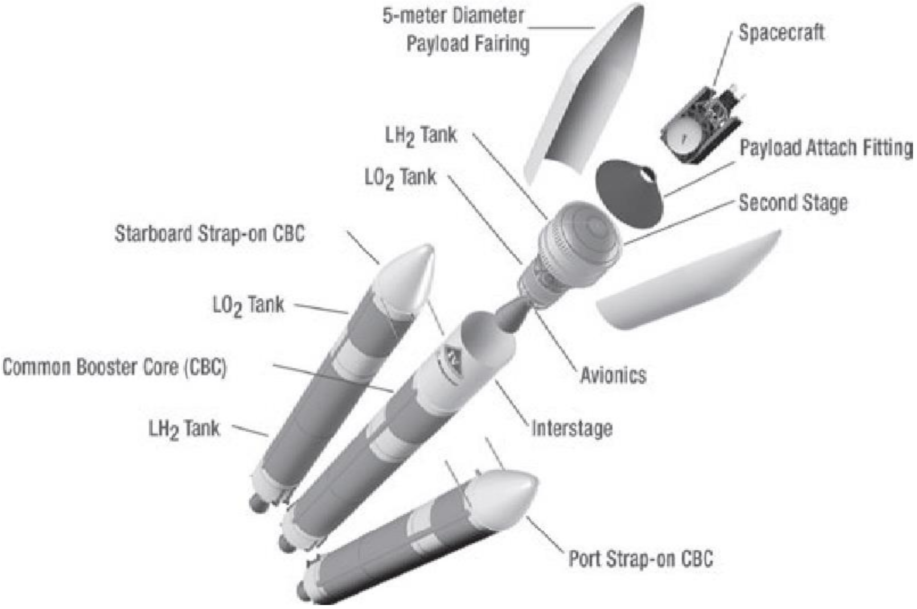
- A launch vehicle or carrier rocket is a rocket-propelled vehicle used to carry a payload from Earth's surface to space, usually to Earth orbit or beyond.
- A launch system includes the launch vehicle, launch pad, vehicle assembly and fuelling systems, range safety, and other related infrastructure.

Types of satellite launch vehicles:

- Satellite launch vehicles launch the satellites into a particular orbit based on the requirement. Satellite launch vehicles are nothing but multi stage rockets. Following are the two types of satellite launch vehicles.
    1. Expendable Launch Vehicles (ELV)
    2. Reusable Launch Vehicles (RLV)

1.Expendable Launch Vehicles:

- Expendable launch vehicles (ELV) get destroyed after leaving the satellites in space.
- The ELV contains three stages.
- First and second stages of ELV raise the satellite to an about 50 miles and 100 miles.
- Third stage of ELV places the satellite in transfer orbit.
- The task of ELV will be completed and its spare parts will be fallen to earth, when the satellite reached to transfer orbit.
- The following image shows how an ELV looks.

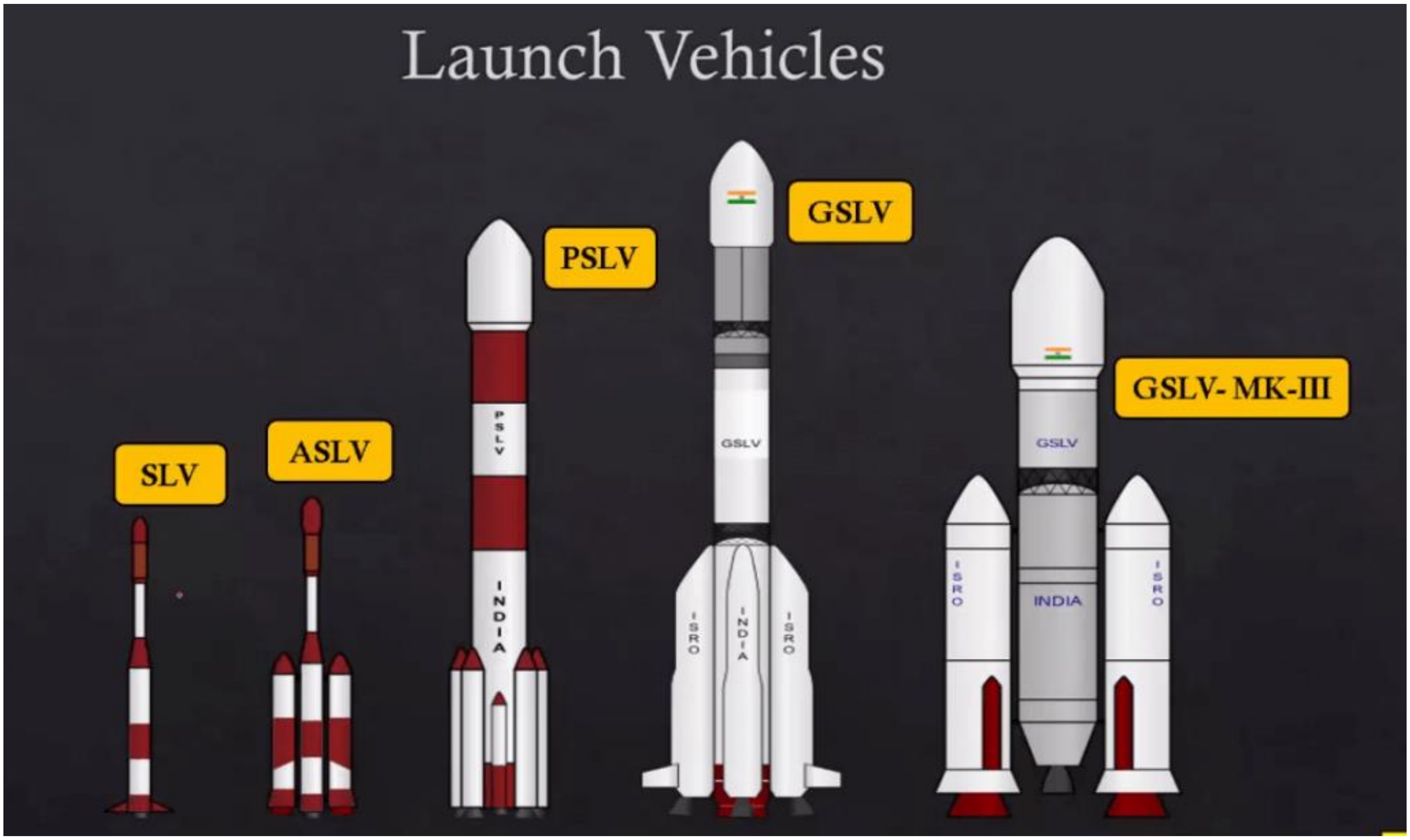


2.REUSABLE LAUNCH VEHICLES:

- Reusable launch vehicles (RLV) can be used **multiple times** for launching satellites.
- Generally, this type of launch vehicles will return back to earth after leaving the satellite in space.
- The following image shows a reusable launch vehicle.
- It is also known as **space shuttle**.
- The functions of **space shuttle** are similar to the functions of first and second stages of ELV.
- Satellite along with the third stage of space shuttle are mounted in the cargo bay.
- It is ejected from the cargo bay when the space shuttle reaches to an elevation of 150 to 200 miles.
- Then, the third stage of space shuttle gets fired and places the satellite into a transfer orbit.
- After this, the space shuttle will return back to earth for **reuse**.

SATELLITE IMAGES:

LAUNCH VEHICLES:



EARTH STATION TECHNOLOGY AND SATELLITE LINK DESIGN

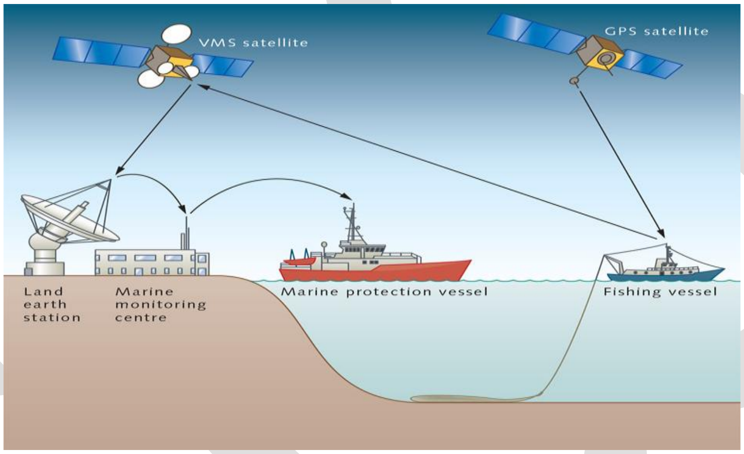
UNIT-II

Earth Station Technology and Satellite Link Design: Earth station technology- terrestrial interface, receiver and transmitter, antenna systems-Basic transmission theory-satellite uplink and down link analysis and design for IMMARSAT, INTELSAT etc. Link budget and Eb/No calculation. Performance impairments – system noise, inter modulation and interference. Propagation characteristics and frequency consideration- system reliability and design lifetime.

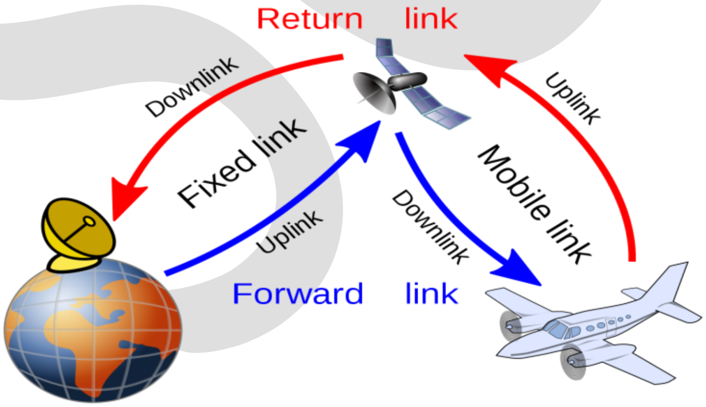
Earth station technology- Terrestrial Interface:

- The earth segment of a satellite communications system consists of the transmit and receive earth stations.
- The simplest of these are the home TV receive-only (TVRO) systems, and the most complex are the terminal stations used for international communications networks.
- Also included in the earth segment are those stations which are on ships at sea, and commercial and military land and aeronautical mobile stations.
- Earth station is a vital element in any satellite communication network.
- The function of an earth station is to receive information from or transmit information to, the satellite network in the most cost-effective and reliable manner while retaining the desired signal quality.
- The design of earth station configuration depends upon many factors and its location.
- But it is fundamentally governed by its Location.
    - **In land**
    - **On a ship at sea**
    - **Onboard aircraft**

Land Earth Station



At Sea



At Air craft

The Depending factors are:

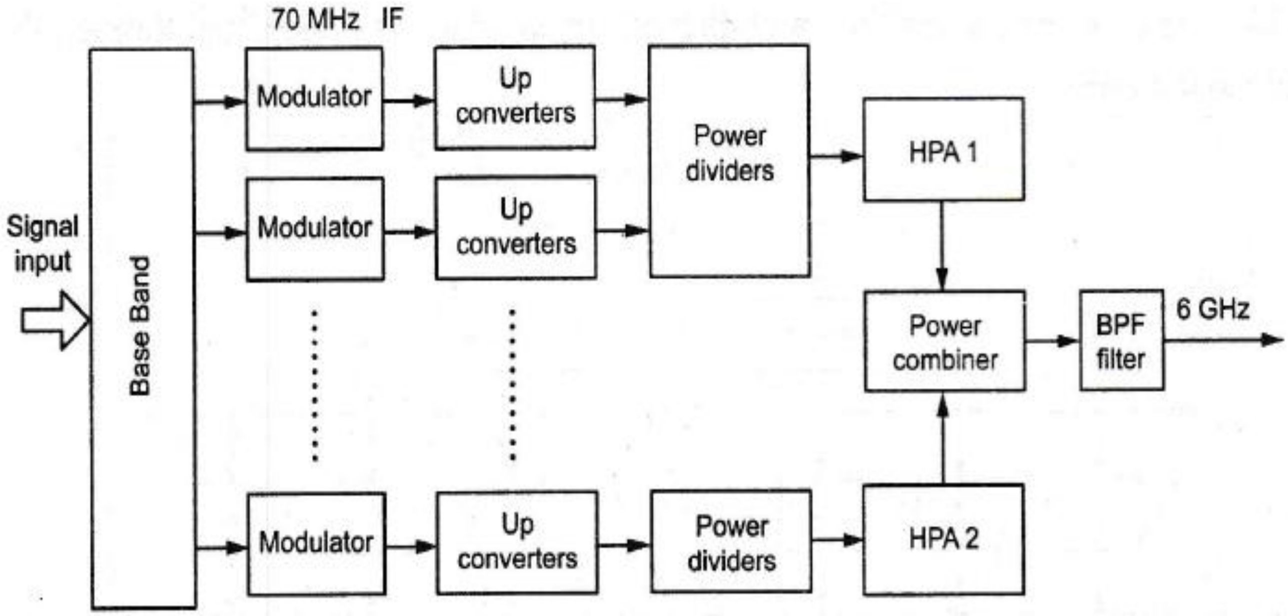
- Type of services
- Frequency bands used
- Function of the transmitter
- Function of the receiver
- Antenna characteristics

Block Diagram of Earth Station:

- **Designing of an Earth station depends not only on the location of earth station but also on some other factors.**
- **The location of earth stations could be on land, on ships in sea and on aircraft.**

TRANSMITTER PART:

- In the transmitter, the signal to be transmitted is converted to uplink frequency with proper encoding and modulation.
- It is then amplified and directed to the appropriate polarization of the antenna feed. The simple block diagram of a earth station transmitter is shown in Fig.
- For a large earth station, there will be many transmitters as well as receivers multiplexed together onto one antenna to provide channelized communication through satellite transponders.
- As the earth station requires the transmission of microwave power, they use High Power Amplifiers (HPAs) such as TWTs and multi cavity Klystrons.
- When compared to Klystrons, TWTA’s allow high powers over a wide bandwidth.
- When there are several HPA's working their output may be combined through band pass filters and circulators or by means of hybrids.

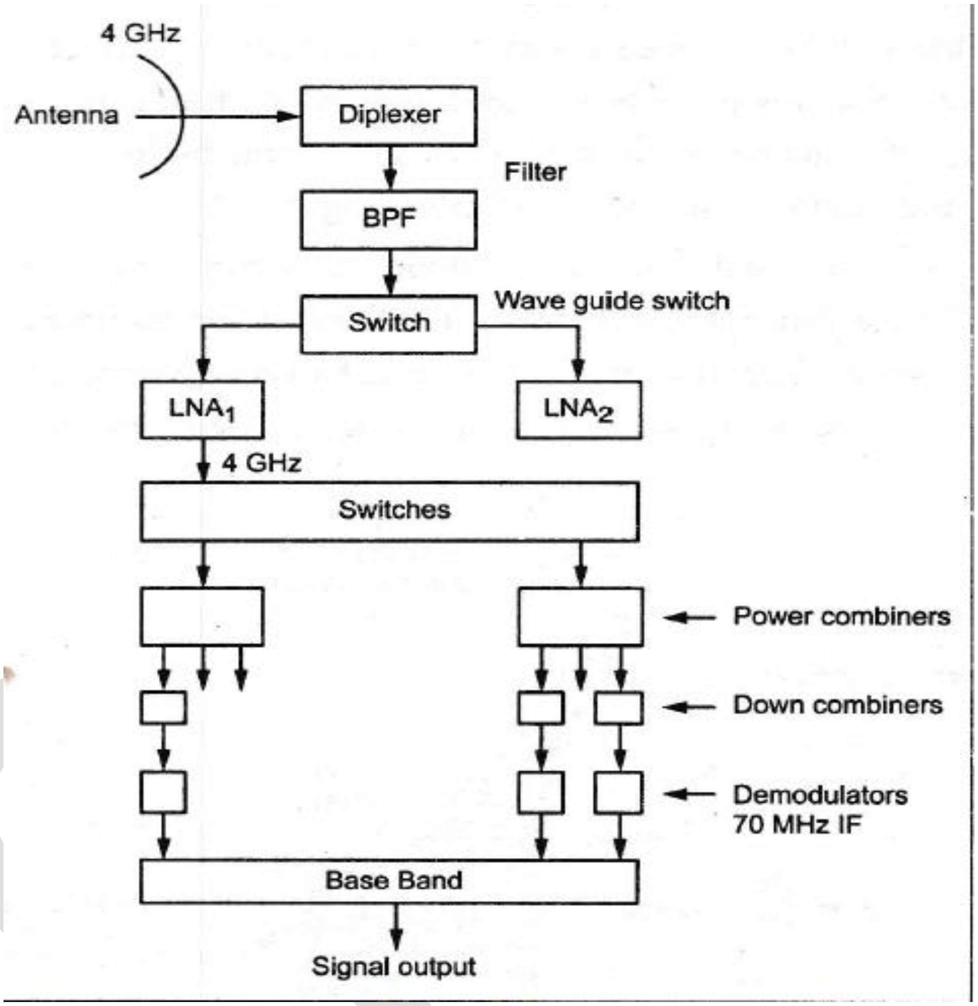


- The modified version of earth station transmitter is shown in the above Fig.
- The modulation is performed at 70MHz IF which is then up converted.
- The configuration for HPAs to be employed depend on the number of carriers to be transmitted and whether these are FDM or TDM signals.
- The most common configuration employs one HPA for each transponder to be used.
- The reliability is the most important requirement in satellite communication.
- The equipments in transmitters always employ some sort of redundancy configuration with automatic switch over.
- In the event of failure this redundancy configuration comes into work.

RECEIVER PART:

- The basic block diagram of a earth station receiver is illustrated in Fig.
- The receiver of an earth station employs mainly Low Noise Amplifier (LNA), down converter, demodulator, decoder and baseband signal treatment equipments.
- In the receiver chain of the earth station, the weak signals from the satellite are accepted by the same feed that carries the transmitter output.
- These two signals which differ in power by several orders of magnitude are kept separate in the frequency domain as they are assigned to uplink and downlink bands.

- The diplexers are used to enhance the separation in the frequency domain.
- The noise consideration is also a important factor for the design requirement of downlink.



- The receiver should have first stage with very low noise and sufficiently high gain.
- The large earth stations require very low noise amplifiers.
- For this reason, the cryogenically cooled parametric amplifiers are widely used with liquid helium cooling at 4°K above absolute zero to achieve temperatures of 20 to 40 K at 4 GHz.
- The small and medium earth stations use Ga As FET amplifiers with no cooling or electron thermal cooling.
- For this reason the amplifiers have noise temperatures in the range 50 to 120 K at 4 GHz and 120 to 300 K at 11 GHz.
- The receiver system also has some sort of redundancy configuration.

- The LNAs used in earth stations usually cover the 500 MHz fixed service band at 4 GHz and 750 MHz at 11 GHz.

EARTH STATION ANTENNAS:

- The most important subsystems of the RF terminal is the earth station antenna.
- It provides a means of transmitting the modulated RF carrier to the satellite with uplink frequency spectrum and receives the RF carrier from the satellite within the downlink frequency spectrum.

The basic requirements of an earth station below:

1. The antenna must have a high directive gain.

- The antenna must focus its radiated energy into a narrow beam to illuminate the satellite antenna in both the transmit and receive modes to provide the required uplink and downlink carrier power.

2. The antenna radiation pattern must have a low side lobe level to reduce interference from unwanted signals and also to minimize interference into other satellites and terrestrial systems.

3. The antenna must be rotated or steered easily so that a tracking system can be employed to point the antenna beam accurately.

4. The antenna must have a low noise temperature.

- The ohmic losses of the antenna must also be minimum.

BASIC TRANSMISSION THEORY:

- In satellite communication systems, there are two types of power calculations.
- Those are transmitting power and receiving power calculations.
- In general, these calculations are called as **Link budget calculations**.
- The unit of power is **decibel**.

1. Equivalent Isotropic Radiated Power (EIRP)

- Maximum power flux density at the distance r from the transmitting antenna is given as,

$$\psi = \frac{G \cdot P}{4 \pi r^2}$$

where, G = Gain of the transmitting antenna

P = Transmit power

r = Distance

- Here, G.P is known as EIRP,

EIRP = G.P

- An isotropic radiator with G.P as input power will produce the same flux density.
- If EIRP is given in decibel, then,

[EIRP] = [G] + [P] dB W

- [G] is in dB
- [P] is in dB W
- If the power is given in watts, then, convert it into dB W using l0 log (P in watts)
- For paraboloidal antenna, G is given as,

$$\boxed{G = \eta (10.472 f_C D)^2}$$

η = Aperture efficiency

f_C = Carrier frequency

D = Reflector diameter (in meters)

If D is in feets, then, $\boxed{G = \eta (3.192 f_c D)^2}$

TRANSMISSION LOSSES:

- Power is applied at the one end of the transmission link.
- Due to various losses, the power received at the other end will be varied.
- These losses are mostly depend upon the rainfall.
- Various calculations are given below.

FREE- SPACE TRANSMISSION LOSS:

Power flux density at the receiving antenna is given as

$$\psi = \frac{GP}{4\pi r^2} = \frac{\text{EIRP}}{4\pi r^2}$$

Power delivered to the matched receiver is given as

$$P_R = \psi \cdot A_e$$

$$A_e = \text{Effective Aperture}$$

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

$$G_R = \text{Isotropic power gain of the receiving antenna.}$$

$$P_R = \underset{\substack{\big\downarrow \\ \text{Related to} \\ \text{transmitter}}}{(\text{EIRP})}\ \underset{\substack{\searrow \\ \text{related to} \\ \text{receiver}}}{(G_R)}\ \underset{\substack{\searrow \\ \text{related to} \\ \text{free space}}}{\left(\frac{\lambda}{4\pi r}\right)^2}$$

We can write the same equation in decibel as,

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

$$\underset{\text{in dbW}}{\underset{\downarrow}{[EIRP]}} \quad \underset{\text{in dB}}{\underset{\downarrow}{[G_R]}} \quad \underset{\text{free space loss in dB}}{\underset{\downarrow}{10 \log \left(\frac{4 \pi r}{\lambda}\right)^2}}$$

$$[\text{Free space Loss}] = 10 \log \left(\frac{4 \pi r}{\lambda}\right)^2$$

$$= 10 \log \left(\frac{4 \pi r f}{C}\right)^2$$

$$= 20 \log \left(\frac{4 \pi r f}{C}\right)$$

$$= 32.4 + 20 \log r + 20 \log f$$

$$C = f \cdot \lambda$$

$$\lambda = \frac{C}{f}$$

$$C = 3 \times 10^8 \text{ m/s}$$

$$\boxed{[P_R] = [EIRP] + [G_R] - [\text{Free space loss}]}$$

Free space loss is inversely proportional to λ^2.

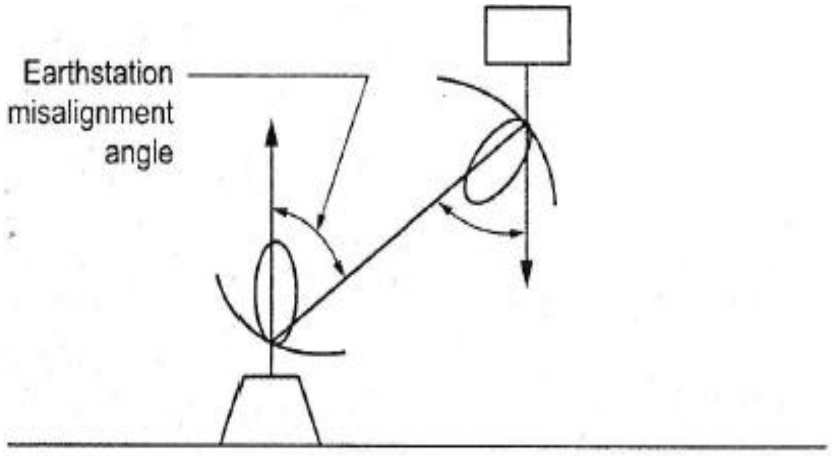
FEEDER LOSSES:

- Some losses occur in connecting waveguides, filters, couplers. etc.
- These losses are known as receiver feeder loss (ML).
- It is added with free space loss.

ANTENNA MISALIGNMENT LOSSES:

- After establishing the satellite link, satellite antennas are aligned with the earth station to get the maximum gain.

- There are two sources of off-axis loss. One at the satellite, second at the earth station. Off-axis loss at the satellite is shown in Fig



- The off axis loss at the earth station is known as antenna pointing loss.
- Antenna misalignment losses include pointing loss and polarization loss.
- For uplink and downlink, separate antenna misalignment losses to be taken.

FIXED ATMOSPHERIC AND IONOSPHERIC LOSSES:

- Absorption loss is due to atmospheric gases. Absorption loss is given as

  [AA] = [AA]90 Cosec θ

- [AA]090: Absorption loss at vertical incidence
- θ = Angle of elevation of radio path
- Depolarization loss is introduced by ionosphere. Depolarization loss is given as

$$\boxed{[\mathrm{DPL}] = 20 \log (\cos \theta_f)}$$

θ_f = Faraday rotation angle

THE LINK POWER BUDGET EQUATION:

Power output of the link is the power at the receiver. The basic link power-budget equation is given as

$$[P_R] = [EIRP] + [G_R] - [L]$$

$[P_R]$ = Received power in dBW

$[L]$ = Losses

$[L]$ = [Free space Loss] + [Receiver feeder loss] + [Antenna misalignment loss] + [Atmospheric absorption loss] + [Polarization mismatch loss]

All these losses are in dB unit

$[EIRP]$ = Equivalent Isotropic radiated power (dBW)

$[G_R]$ = Gain of the receiver antenna

SYSTEM NOISE:

- Noise temperature is very important concept in receivers.
- By using this, thermal noise which is generated by active and passive devices in the receiver can be calculated:

Noise power:

The noise power is given by,

$$P_n = K \cdot T_n B$$

P_n = Noise power

K = Boltzman's constant $(1.38 \times 10^{-23}$ J/K)

T_n = Noise temperature of source (in Kelvin)

B = Bandwidth in Hz.

$K \cdot T_n = N$ = Noise spectral density

$\boxed{P_n = N \cdot B}$ N = constant upto 300 GHz

- Usually, in the receiver, noise temperature should be maintained as low as possible.
- Front-end-amplifier is immersed in liquid helium to maintain its physical temperature around 4°K.
- It is done in large earth stations.
- Ts =System noise temperature
- Ts is a noise temperature of the noise source located at the input of the noiseless receiver.
- It can give the same noise power as the original receiver.

The noise power is given as,

$$P_n = K \cdot T_S \cdot B \cdot G$$

G = Gain of the receiver from RF input to demodulator input.

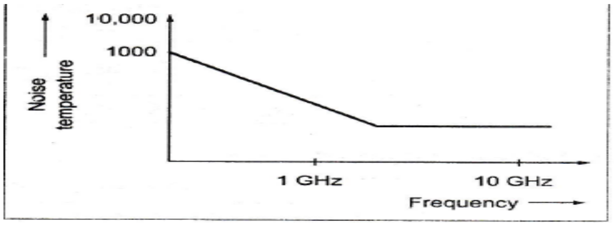
ANTENNA NOISE:

- Antenna noise is introduced by the satellite antenna and the ground station receiving antenna.
- Antenna noise is classified into two groups.
- Antenna Noise →Noise due to antenna losses

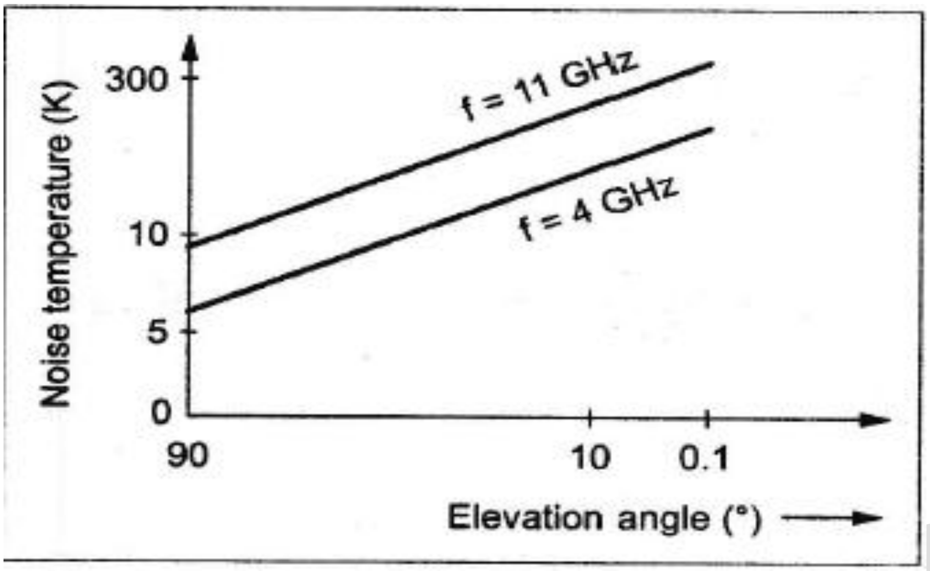
→Sky noise

SKY NOISE:

- Sky noise arises due to the attenuation of a wave when it passes through the atmosphere.
- This attenuation may be due to atmospheric gases and rain, snow and galactic, etc.
- Below 1 GHz, galactic noise effect is more.
- The below figure shows the same.



Sky noise increases at low elevation angles:



Amplifier Noise Temperature:

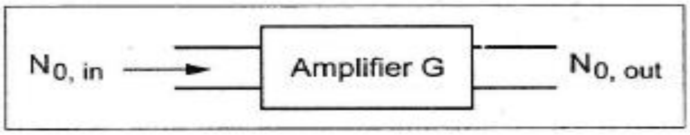


Fig. 6.4. An amplifier circuit to find out noise temperature.

G = Power gain of the amplifier

$N_{0,\,in}$ = Input noise energy

$N_{0,\,out}$ = Output noise energy

$N_{0,\,out} = G \cdot N_{0,\,in}$

$N_{0,\,a} = K \cdot T_a$

$N_{0,\,a}$ = Input noise energy coming from antenna

T_a = Antenna noise temperature

$N_{0,\,out} = G \cdot K \cdot (T_a + T_e)$

T_e = Input noise temperature for the amplifier.

$$\boxed{N_{0,\,in} = K\,(T_a + T_e)}$$

Amplifier in Cascade:

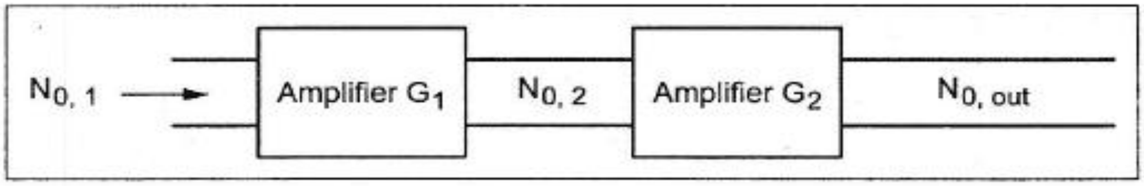


Fig. 6.5. Cascade connection of amplifier

Here, Overall gain = G

$$G = G_1 + G_2$$

$$N_{0,2} = G_1 K (T_a + T_{e1}) + K \cdot T_{e2}$$

$$N_{0,1} = \frac{N_{0,2}}{G_1} \Rightarrow N_{0,1} = K\left(T_a + T_{e1} + \frac{T_{e2}}{G_1}\right)$$

System noise temperature is T_S

$$N_{0,1} = K \cdot T_s$$

$$\boxed{T_s = T_a + T_{e1} + \frac{T_{e2}}{G_1}}$$

Noise Factor:

Noise factor is given as F.

$$\boxed{N_{0,\text{out}} = (K\,T_0)(G)(F)}$$

T_0 = Room temperature

K = Boltzmann's constant

$N_{0,\text{out}}$ = The output noise from the amplifier

Equation (1) is written as, ①

$$G\cancel{K}(T_0 + T_e) = (\cancel{K}\,T_0)(G)(F)$$

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

$$\boxed{F = 1 + \frac{T_e}{T_0}} \quad \boxed{T_e = (F-1)\cdot T_0}$$

[F] = Noise figure ⇒ [F] = 10 log F

Noise Temperature of Absorptive Networks:

- A network which contain resistive elements is known as absorptive network,
- E.g: Transmissive lines, waveguides. It generates thermal noise.

$$N_{0,\,out} = \frac{KT}{L} + KT_{nw,o/p}$$

$N_{0,\,out}$ = Total output noise

L = Power loss

T = Source is at this temperature

$\frac{KT}{L}$ = Source contribution to output noise

$T_{nw,o/p}$ = Noise temperature of the network referred to the output

The network is matched to the source. So, $N_{o,\,out} = KT$, put it in (1)

$$KT = \frac{KT}{L} + KT_{nw,o/p}$$

$$\boxed{T_{nw,o/p} = T\left(1 - \frac{1}{L}\right)}$$

$$T_{nw,i/p} = L\,T_{nw,o/p} = T(L-1)$$

$T_{nw,i/p}$ = Noise temperature referred to its input.

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

Compare this with equation (2)

$$T_{nw,i/p} = T(L-1)$$

If $T = T_0$, then $\boxed{F = L}$

Overall System Noise Temperature:

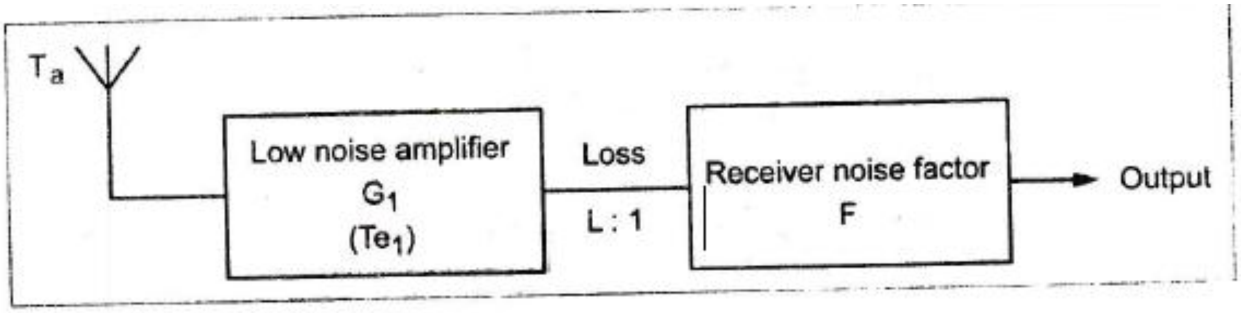


Fig. 6.6. Connection to find overall system noise temperature

It is given as
$$\boxed{T_S = T_a + T_{ei} + \frac{(L-1)\,T_0}{G_1} + \frac{L\,(F-1)\,T_0}{G_1}}$$

T_S = System temperature

F = Noise factor

G_1 = Gain of an amplifier

T_a = Antenna temperature

T_{el} = Amplifier temperature

CARRIER TO NOISE RATIO:

- Performance of satellite line is measured by carrier to noise ratio, it is given as CNR or C/N

$\frac{C}{N}$ in db is given as $\left[\frac{C}{N}\right]$

$$\left[\frac{C}{N}\right] = [P_R] - [P_N]$$

$$\left[\frac{C}{N}\right] = [EIRP] + [G_R] - [L] - [K] - [T_S] - [$$

$$\left[\frac{G}{T}\right] = [G_R] - [T_S]\,\frac{dB}{K}$$

So, $$\left[\frac{C}{N}\right] = [EIRP] + \left[\frac{G}{T}\right] - [L] - [K] - [B_N]$$

$$P_N = K\,T_N\,B_N = N_0\,B_N$$

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

$$\left[\frac{C}{N_0}\right] = \left[\frac{C}{N}\right] + [B_N] \quad dB\,Hz.$$

$$\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right] - [L] - [K]\ dB \cdot Hz$$

Eb/No Calculation:

- It is the ratio of signal to noise ratio of the system.
- It can be calculated as follows.
- Available Eb/N_O = Over all downlink (C/N_o) / Input data rate
- Available Eb/N_O (dB)= Over all downlink (C/N_o)(dB) - Input data rate (dB)
- = Over all downlink(C/N_o)(dB) - 10log (input data rate in KB*10^3).

UPLINK ANALYSIS:

- The link through which the earth station transmits the signal and the satellite receive the same is known as uplink. [C/No] equation in the last title carrier to noise ratio can be applied to uplink.

$$\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right] - [L] - [K] \text{ dB} \cdot \text{Hz}$$

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

Here, the subscript u is used to denote the uplink.

$\left[\frac{C}{N_0}\right]$ ratio appears at satellite receiver.

$[EIRP]_u$ = Earth station EIRP

$\left[\frac{G}{T}\right]_u$ = Satellite receiver $\frac{G}{T}$

Saturation Flux Density:

- The flux density which is required at the receiving antenna to produce the saturation of the TWTA is known as saturation flux density.

$$\text{Flux density} = \overset{F}{\psi} = \frac{\text{EIRP}}{4\pi r^2}$$

In decibel,
$$\overset{F}{[\psi]} = [\text{EIRP}] - 10\log(4\pi r^2) \qquad \ldots (1)$$

$$[\psi] = [\text{EIRP}] + 10\log\left(\frac{1}{4\pi r^2}\right) \qquad \ldots (2)$$

$$[\text{Free space loss}] = 10\log\left(\frac{4\pi r}{\lambda}\right)^2$$

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

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

$$-[\text{Free space loss}] = 10\log\left(\frac{1}{4\pi r^2}\right) + 10\log\left(\frac{\lambda^2}{4\pi}\right) \qquad \ldots (3)$$

Put (3) in (2),
$$[\psi] = [\text{EIRP}] - [\text{Free space loss}] - 10\log\left(\frac{\lambda^2}{4\pi}\right) \qquad \ldots (4)$$

$$\frac{\lambda^2}{4\pi} = \text{Effective area of an isotropic antenna}$$

So,
$$[\text{A}] = 10\log\left(\frac{\lambda^2}{4\pi}\right) = -(21.45 + 20\log f)$$

Take equation (4),

$$[\text{EIRP}] = [\psi] + [\text{Free space loss}] + [\text{A}] \qquad \ldots (5)$$

If we include other losses with equation (5), we can get,

$$[\text{EIRP}] = [\psi] + [\text{A}] + [\text{Free space loss}] + [\text{Antenna misalignment loss}] + [\text{Atmospheric absorption loss}] + [\text{Polarization mismatch loss}]$$

or we can write,

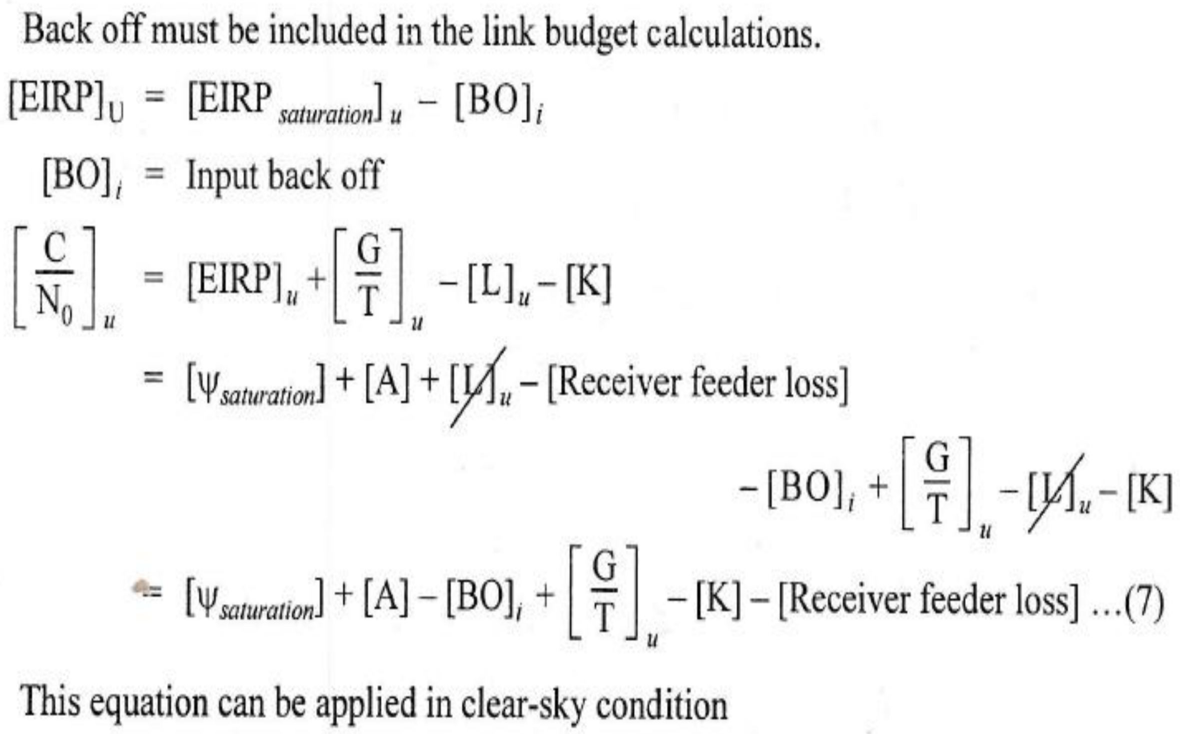
$$[\text{EIRP}] = [\psi] + [\text{A}] + [\text{L}] - [\text{Receiver feeder loss}] \qquad \ldots (6)$$

$$[\text{L}] = \text{Total losses}$$

Equation (6) can give the minimum [EIRP] value must be provided by the earth station to produce given flux density at the satellite in the clear sky condition. Equation (6) can be written as,

$$[\text{EIRP}_{saturation}]_u = [\psi_{saturation}] + [\text{A}] + [\text{L}]_u - [\text{Receiver feeder loss}]$$

Input Back off:



Back off must be included in the link budget calculations.

$$[\mathrm{EIRP}]_U = [\mathrm{EIRP}_{saturation}]_u - [\mathrm{BO}]_i$$

$$[\mathrm{BO}]_i = \text{Input back off}$$

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

$$= [\psi_{saturation}] + [A] + [\cancel{L}]_u - [\text{Receiver feeder loss}]$$

$$- [\mathrm{BO}]_i + \left[\frac{G}{T}\right]_u - [\cancel{L}]_u - [K]$$

$$= [\psi_{saturation}] + [A] - [\mathrm{BO}]_i + \left[\frac{G}{T}\right]_u - [K] - [\text{Receiver feeder loss}] \ldots(7)$$

This equation can be applied in clear-sky condition

- Input Back-Off (IPBO) is the power level at the input of RF amplifier relative to input power which produces maximum output power.
- Input power level causes max. output power = -20dBm
  Actual input power level = -25dBm
  Input back off (IPBO)= 5Db

The Earth Station HPA (High Power Amptifier):

The earth station high power amplifies have to provide the radiated power and the transmit feeder loss.

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

$$[TFL] = [\text{Tansmit Feeder Loss}]$$

$$[P_{HPA}] = \text{HPA power output}$$

Saturated P_{HPA} is given as,

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

BO at the earth station is to be dependent of any back off requirement at the satellite transponder.

DOWNLINK ANALYSIS:

- **The link through which the satellite transmit the signal and the earth station receive it,**
- **Subscript D is used to indicate the downlink in the following equation.**

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

Signal bandwidth is included in this equation, then, it becomes,

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

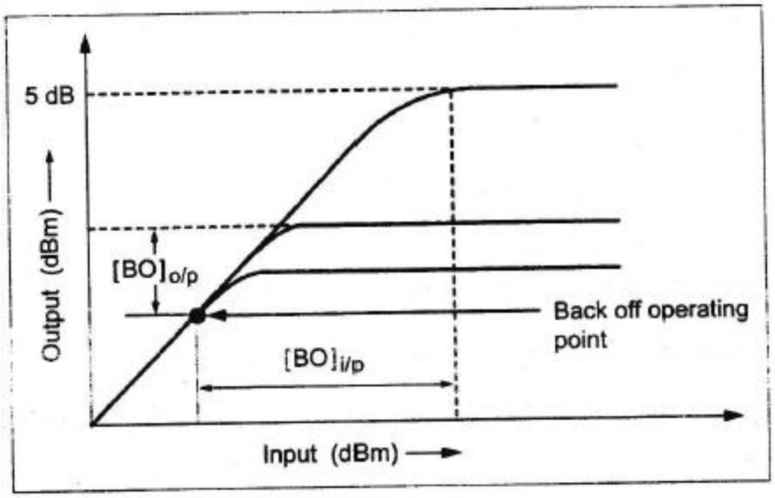
Output Back-off:

The relationship between input and output back off is given as,

$$[BO]_{o/p} = [BO]_{i/p} - 5 \text{ dB}$$

$$[EIRP]_D = [EIRP_{saturation}]_D - [BO]_{o/p}$$

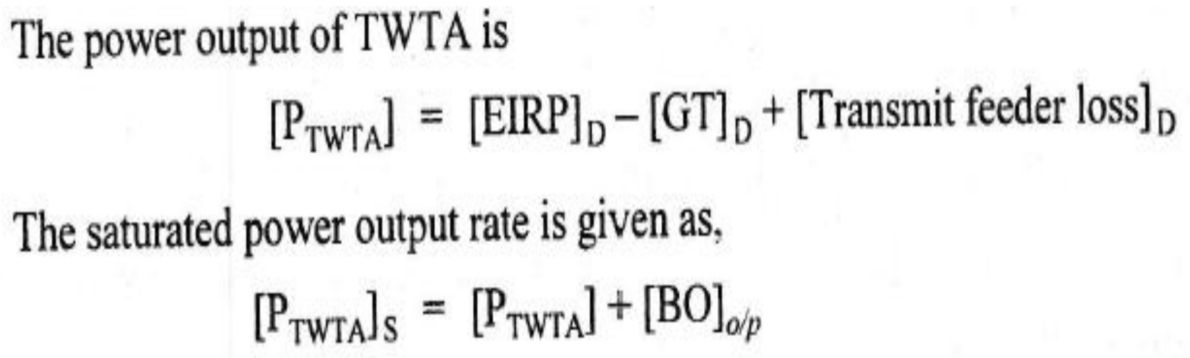
$$\left[\frac{C}{N_0}\right]_D = [EIRP_{saturation}]_D - [BO]_{o/p} + \left[\frac{G}{T}\right]_D - [L]_D - [K]$$



Output Back-Off (OPBO):

- Output Back-Off (OPBO) is the power level at the output of RF amplifier relative to maximum output level possible using the RF amplifier.
- EXAMPLE:
- Maximum output level = +40dB m
- Measured output level of RF Amplifier = +34dBm
- Output Backoff(OPBO)= 6dB

Satellite TWTA Output:



The power output of TWTA is

$$[P_{TWTA}] = [EIRP]_D - [GT]_D + [\text{Transmit feeder loss}]_D$$

The saturated power output rate is given as,

$$[P_{TWTA}]_S = [P_{TWTA}] + [BO]_{o/p}$$

EFFECTS OF RAIN:

- Above 10 GHz, the rain is very important factor that affects the satellite propagation.
- If a largeflat-bottomedvessels open to the rain, the rain rate is defined as the rate at which the water level in the container is rising.
- Its unit is millimeter/hour.
- It is measured for short duration.

Uplink Rain Fade Margin:

- Signal is attenuated and noise temperature is increased due to rain fall.
- [C/No] also decreased due to rain fall.
- The uplink carrier power at the satellite must be within certain limits for some specified mode of operation.
- Uplink power control mechanism is needed to compensate for rain fades.
- The output power from the satellite is monitored by a central control station and by each earth station.
- The output power of the earth station can be increased to compensate the effect of fading.
- The HPA of earth station must have sufficient power to meet the requirement of fade margin.

Downlink Rain Fade Margin:

- The total sky noise temperature is equal to addition of clear sky temperature and rain temperature.

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

- So, received [C/No] is degraded due to rainfall by two ways,
- By attenuating the carrier wave.
- By increasing the sky noise temperature.
- Noise to carrier ratios are related to clear sky value by using this equation,

$$\left(\frac{N}{C}\right)_{rain} = \left(\frac{N}{C}\right)_{clear\ sky} \left[A + (A-1) \frac{T_a}{T_{sys,\ clear\ sky}} \right]$$

where,

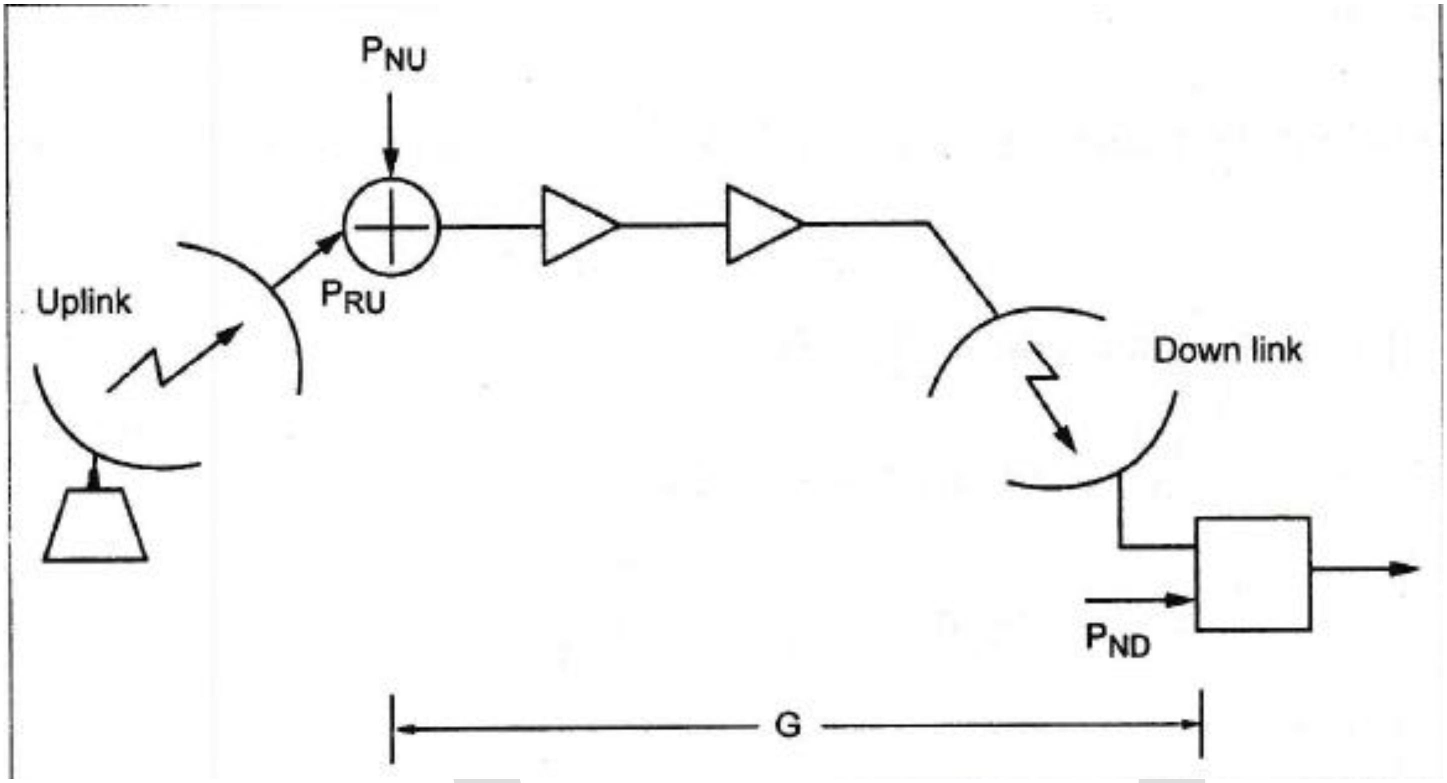
T_a = Apparent absorber temperature

A = Rain attenuation

$T_{sys,\ clearsky}$ = System noise temperature under clear sky condition

- The rain attenuation is entirely absorptive at low frequencies (6/4 GHz) and at 1 mm/h of rainfall rate.
- At higher frequencies, scattering and absorption are having significant values.
- For digital signals, the required [C/No] ratio is determined by BER value.
- To provide the required rain-fade margin, the gain of the receiving antenna is increased.

COMBINED UPLINK AND DOWNLINK C/N RATIO:



COMBINED UPLINK AND DOWNLINK C/N RATIO:

- PRU = Receiver power
- PNU = Noise power
- G = System power gain from satellite i/p to earth station i/p
- Satellite circuit consists of uplink and downlink.
- Noise power (PN) is introduced in the uplink.

$$\text{Carrier-to-noise ratio is } \left(\frac{C}{N_0}\right)_u = \frac{P_{RU}}{P_{NU}}$$

Here. [ ] notation is not used here.

The noise at the satellite input appeared in the earth station also.

The earth station introduces its own noise P_{ND}.

$$\text{The noise at the end of link} = G\,P_{NU} + P_{ND}$$

$$\text{Noise to carrier ratio} = \left(\frac{N_0}{c}\right)$$

$$\left(\frac{N_0}{c}\right)_u = \text{Noise to carrier ratio for uplink}$$

$$\left(\frac{N_0}{c}\right)_D = \text{Noise to carrier ratio for downlink}$$

$$\frac{N_0}{c} = \frac{P_N}{P_R}$$

$$= \frac{G\,P_{NU} + P_{ND}}{P_R}$$

$$= G \cdot \frac{P_{NU}}{P_R} + \frac{P_{ND}}{P_R} = \frac{G{\cdot}P_{NU}}{G{\cdot}P_{RU}} + \frac{P_{HD}}{P_R}$$

$$= \left(\frac{N_0}{c}\right)_u + \left(\frac{N_0}{c}\right)_D$$

Performance Impairments-
Inter Modulation Noise (Interference):

- When multiple carriers are passed through the device with non linear characteristics, inter modulation noise occur.
- It is mostly happened in the travelling wave tube high performance amplifier.
- Amplitude and phase non linearities increase inter modulation products.

Now, $$\frac{N_0}{c} = \left(\frac{N_0}{C}\right)_u + \left(\frac{N_0}{C}\right)_D + \left(\frac{N_0}{C}\right)$$

$\left(\frac{N_0}{C}\right)_I$ ⇒ Here I denotes inter modulation.

- To reduce inter modulation noise, the TWT is to be operated in specified back off condition.

Propagation Characteristics and Frequency considerations:

- A number of factors resulting from changes in the atmosphere have to be taken into account when designing a satellite communications system in order to avoid impairment of the wanted signal.
- Generally, a margin in the required carrier-to-noise ratio is incorporated to accommodate such effects.

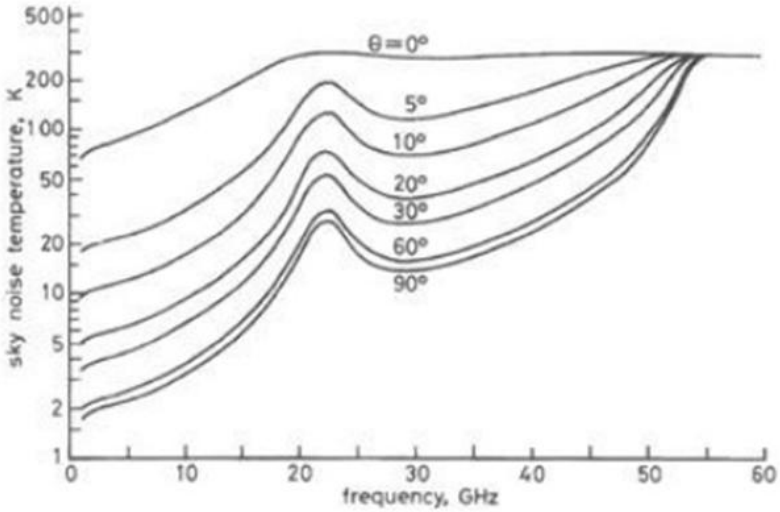
Radio Noise:

- Radio noise emitted by matter is used as a source of information in radio astronomy and in remote sensing.
- Noise of a thermal origin has a continuous spectrum, but several other radiation mechanisms cause the emission to have a spectral-line structure.
- Atoms and molecules are distinguished by their different spectral lines.

Propagation Characteristics and Frequency considerations:

- For other services such as satellite communications noise is a limiting factor for the receiving system;
- Generally, it is inappropriate to use receiving systems with noise temperatures which are much less than those specified by the minimum external noise.
- From about 30 MHz to about 1 GHz cosmic noise predominates over atmospheric noise except during local thunderstorms, but will generally be exceeded by man-made noise in populated areas.
- In the bands of strong gaseous absorption, the noise temperature reaches maximum values of some 290 K.

- At times, precipitation will also increase the noise temperature at frequencies above 5 GHz.
- The below figure gives an indication of sky noise at various elevation angles and frequencies.



System reliability:

- Satellites are designed to operate dependably throughout their operational life, usually a number of years.
- This is achieved through stringent quality control and testing of parts and subsystems before they are used in the construction of the satellite.
- Redundancy of key components is often built in so that if a particular part or subassembly fails, another can perform its functions.

- In addition, hardware and software on the satellite are often designed so that ground controllers can reconfigure the satellite to work around a part that has failed.

SATELLITE COMMUNICATION SYSTEMS/EC E 16

SATELLITE ACCESS

UNIT-3

Satellite Access: Types- FDMA concepts- inter modulation and back off- SPADE system- TDMA concept- frame and burst structure- satellite switch TDMA- CDMA concept- DS & FH CDMA system- comparison of multipleaccessscheme.

SATELLITE ACCESS:

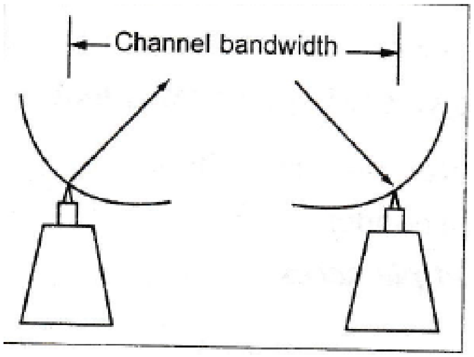
The techniques used to access a satellite so that the satellite spectrum and power are shared efficiently between a large number of users. This is called Satellite Access.

TYPES OF SATELLITE ACCESS:

1. Single access
2. Multiple access

SINGLE ACCESS:

- A transponder channel loaded with a single transmission from an earth station is known as single access mode of operation.
- Single access operation is used on heavy traffic routes.
- It needs large earth station antennas.
- Each transponder channel can carry 60 one way voice circuits.



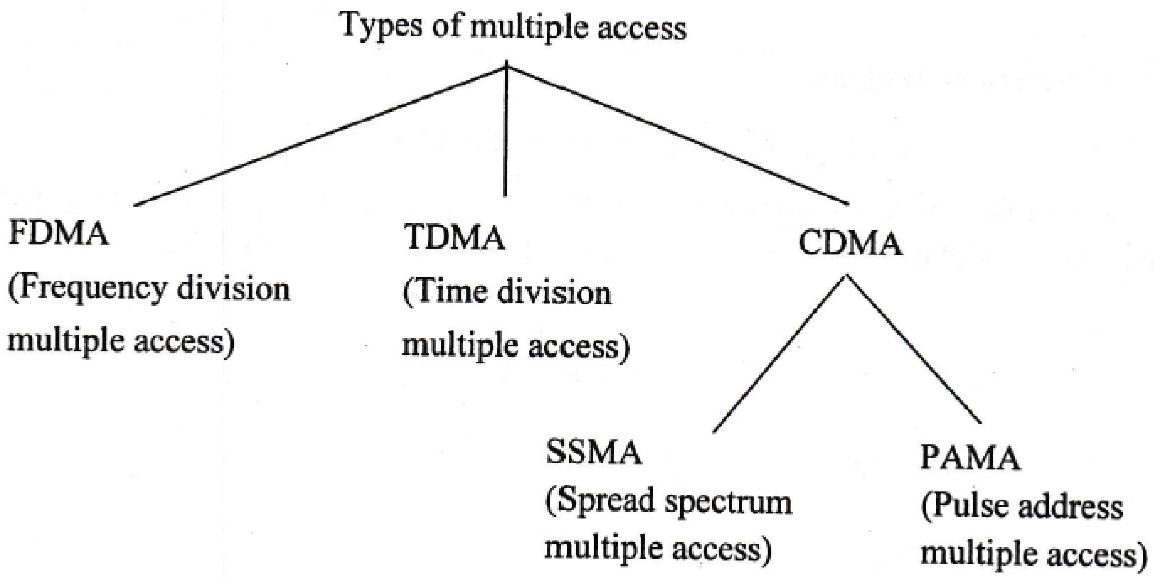
MULTIPLE ACCESS:

- Various earth stations may transmit more number of carriers.
- At that time, a transponder is loaded with more than one number of carriers. This is known as multiple access.

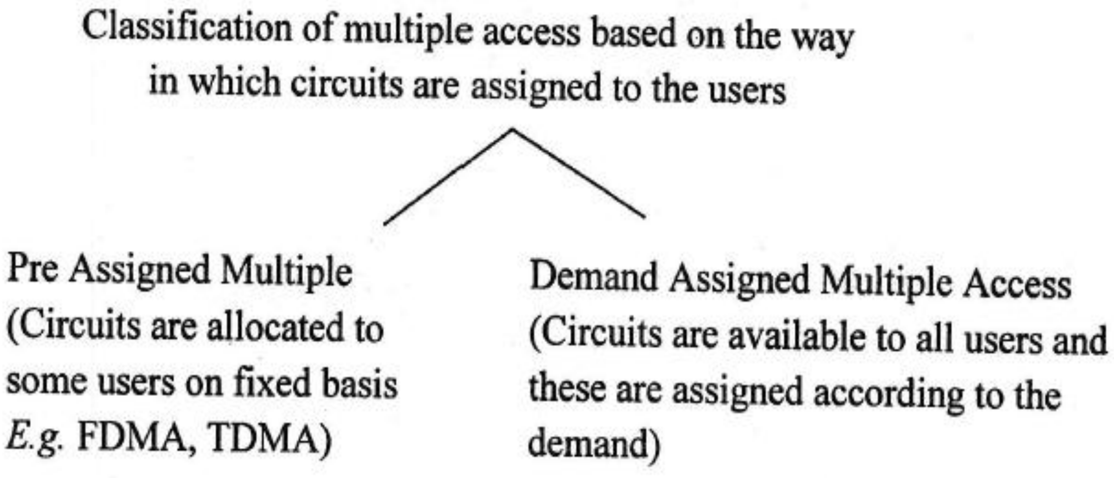
Multiple access scheme must be able to optimize the following parameters:

1. Satellite Radiated Power
2. Rf Spectrum
3. Connectivity
4. Adaptability To Traffic And Network Growth
5. Handling Of Different Types Of Traffic
6. Economics
7. Ground Station Complexity
8. Secrecy (For Some Applications).

Types of Multiple Access



- Classification of Multiple Access Based on the Way in which Circuits are Assigned to the Users.

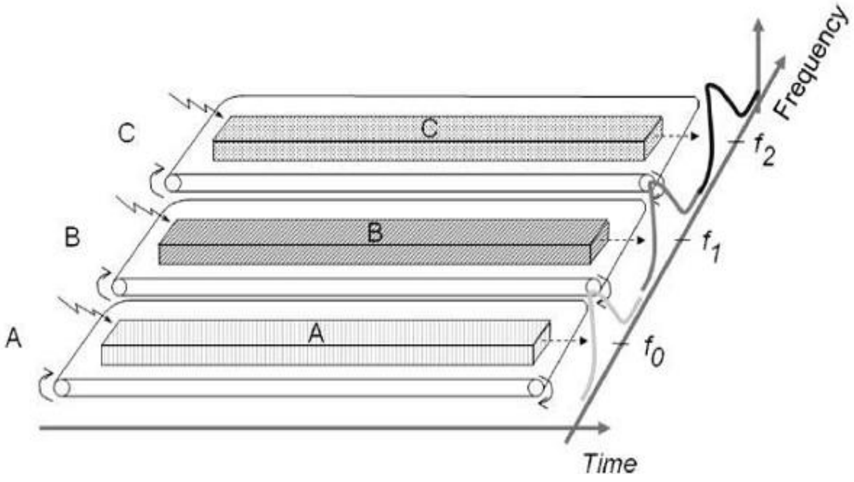


FREQUENCY RESUE:

- The satellite can carry more than one number of transponder.
- Each transponder has a different frequency channel.
- The transponder can be operated at some frequency and it can be connected to different spot beam antennas.
- The earth stations separated geographically (transmit at the same frequency) can access the satellite.
- This is known as frequency reuse.
- This access technique is known as space division multiple access.

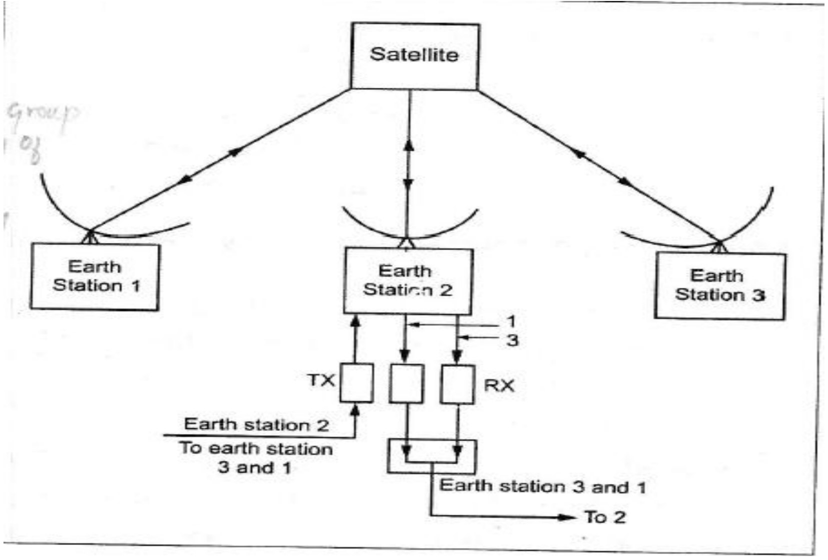
Frequency Division Multiple Access(FDMA):

- In this type of multiple access, we assign each signal a different type of frequency band (range).
- So, any two signals should not have same type of frequency range.
- Hence, there won't be any interference between them, even if we send those signals in one channel.
- One perfect example of this type of access is our radio channels.
- We can see that each station has been given a different frequency band in order to operate
- Let's take three stations A, B and C.
- We want to access them through FDMA technique.
- So we assigned them different frequency bands.
- As shown in the figure, satellite station A has been kept under the frequency range of 0 to 20 HZ.
- Similarly, stations B and C have been assigned the frequency range of 30-60 Hz and 70-90 Hz respectively.
- There is no interference between them.



➢ PREASSIGNED FDMA:

- Frequency slots are pre assigned to analog and digital signals.
- Each earth station is assumed to transmit a 60 channel super group.
- Each group is frequency modulated then it is converted to a frequency in the uplink band.



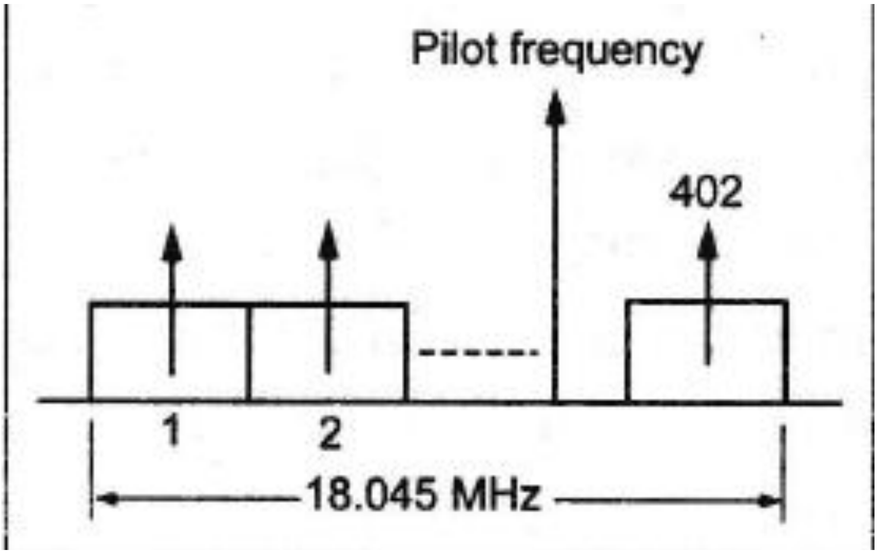
- In Fig, three earth stations are shown.
- These three earth stations access a single satellite transponder channel simultaneously.
- Each earth station communicates with other.
- Each earth station transmits one uplink carrier and two downlink carriers.
- If uplink frequencies for 3 earth stations are 6253 MHz, 6273 MHz and 6278 MHz, then the down link frequencies will be 4028 MHz, 4048 MHz, 4053 MHz.
- Here, frequency allowance of 15 MHz is required for 3 earth stations.
- In the transponder bandwidth the remainder is unused.
- It may be occupied by some other carriers.

➢ SINGLE CHANNEL PER CARRIER(SCPC):

- Pre assignment may be done by SCPC.
- In SCPC, single voice channel is allotted per carrier.
- These carriers are frequency modulated or phase modulated.
- Each earth station may transmit more than one number of SCPC signals.
- In Intel sat SCPC channeling scheme, the transponder bandwidth is divided into 800-channels.
- Each channel bandwidth is 45 KHz.
- In duplex operation, the frequency pairs are separated by 18.045 MHz.
- The pilot frequency is transmitted for frequency control.
- The adjacent channel slots are vacant to avoid interference.
- Any one of the earth station act as primary station.
- The pilot frequency is transmitted from this primary station.
- It provides a reference for AFC (Automatic frequency control) system of the transmitter frequency synthesizers and local oscillators of the receivers.

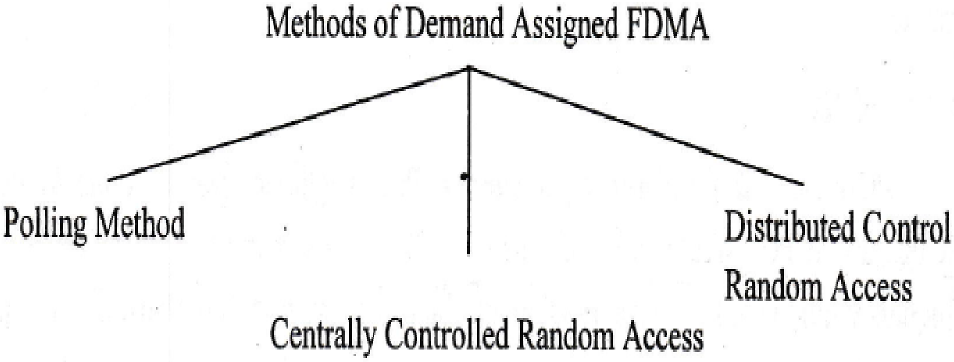
- If primary station is failured, then the pilot frequency is transmitted from the back up station.
- In Intel sat SCPC system, each channel is voice activated.
- In 2-way telephone conversation, only one carrier is operative at any one time.
- For telephone calls, the one way utilization time is equal to 40 % of the call duration.
- SCPC systems are mostly used on lightly loaded routes.
- This type of service is known as thin route service.

➢ Arrangement of channelsin SCPC system:



➢ DEMAND ASSIGNED FDMA:

- In this mode, the transponder frequency bandwidth is divided into various channels.
- The channel is assigned to each carrier.
- The carrier may be frequency modulated with message signal. (FM/SCPC).



POLLING METHOD:

- One master earth station is there.
- It continuously polls all the earth stations.
- If a call request occur, then frequency slots are assigned.
- If the number of earth stations is increased, then polling delay is increased.

CENTRALLY CONTROLLED RANDOM ACCESS:

- In this method, earth request calls through the master earth station.
- Frequencies are assigned by the master station.
- If there is no frequencies are available, the call request will be placed in queue.

DISTRIBUTED CONTROL RANDOM ACCESS:

- In this method, control is at each earth station.
- Spade system (operated by Intelsat) is the example for this method.

➢ ADVANTAGES OF FDMA:

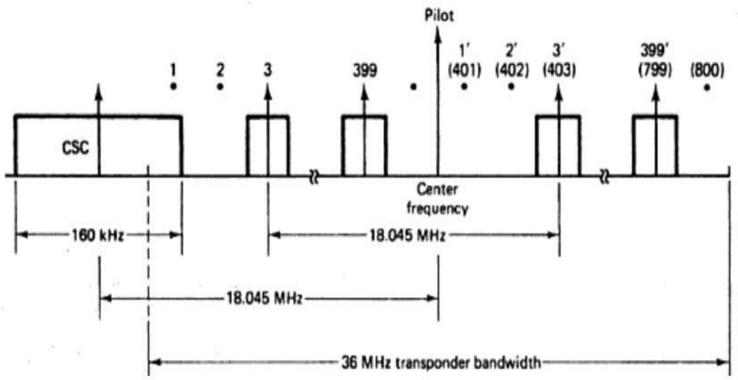
- Simple to implement
- It reduces the cost and lowers the inter symbol interference (ISI)
- Since the transmission is continuous, less number of bits are required for synchronization and framing.

➢ DISADVANTAGES OF FDMA:

- It does not differ significantly from analog systems; improving the capacity depends on the signal-to-interference reduction, or a signal-to-noise ratio (SNR).
- The maximum flow rate per channel is fixed and small.
- Guard bands lead to a waste of capacity.
- Hardware implies narrowband filters, which cannot be realized in VLSI and therefore increases the cost.

SPADE SYSTEM:

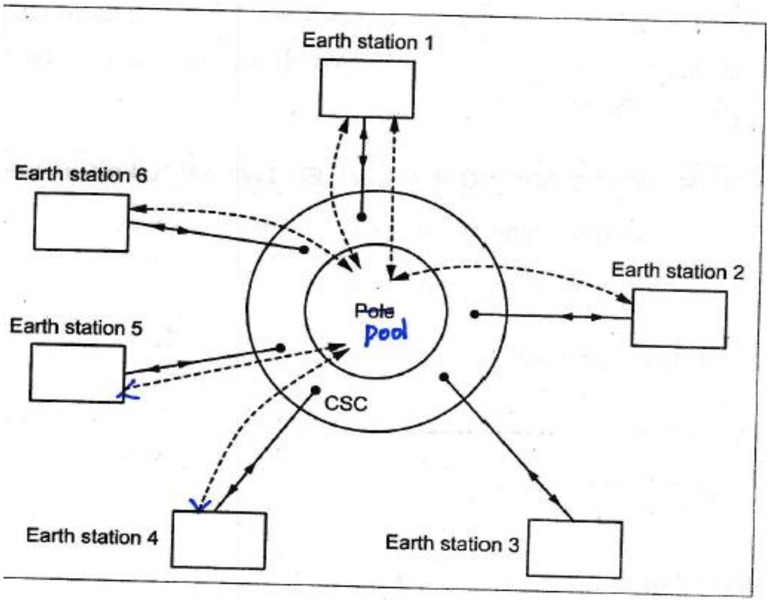
- Spade Single channel per carrier Pulse code modulated Multiple Access Demand Equipment
- It was developed by comsat. (to use on Intelsat satellites)



Channeling scheme for spade system:

- Common signaling channel (CSC) is needed in this system.
- CSC bandwidth: 160 KHz; Center frequency: 18.045 MHz.
- Voice channel I and channel 2 are left vacant to avoid interference. The corresponding channels 401 and 402 are left vacant.
- Channel 400 and Channel 800 are left vacant to avoid interference.
- So, totally 6 channels are left vacant.
- 794 channels are used.
- All the earth stations are permanently connected through CSC.

SPADE COMMUNICATION SYSTEM:

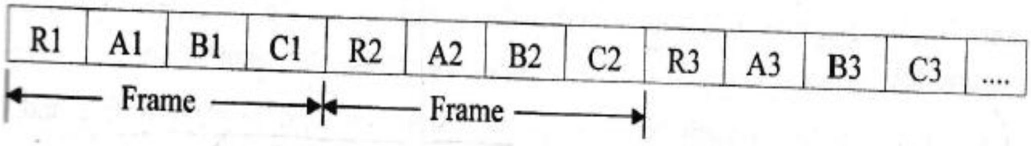


- Six earth stations are connected through CSC.
- Each earth station can generate any one of 794 carrier frequencies using frequency synthesizers.
- The list of currently available frequencies are available with each earth station.
- It is continuously updated.
- For example, a call to earth station 6 is initiated from earth station 3.
- Then station 3 select a currently available frequency pair randomly, and signal this message to station 6 through CSC.
- Station 6 give acknowledgement through CSC.
- Once the circuit is established, the other earth stations are informed to remove the Selected frequency pair from the available list (through csc).
- The round trip time between earth station 3 initiate a call and station 6 acknowledge it will be 600 ms.
- During this round trip time the selected frequency pair may be assigned to another circuit.
- At that time, CSC give the information to earth station 3 to update and to choose another frequency randomly.

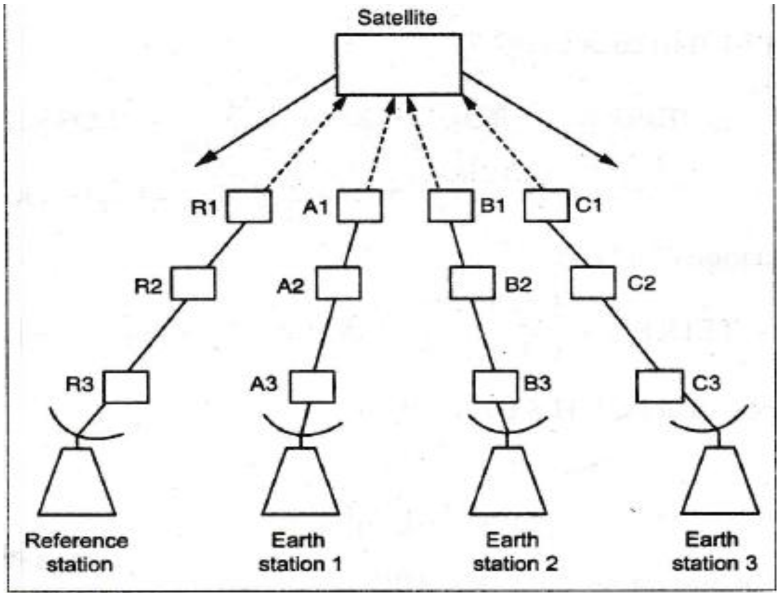
- lf a call is completed, then the circuit will be disconnected and the frequency will be returned to the Pool.
- So, signaling information is routed through the CSC.
- Each earth station has DASS unit (Demand Assignment Signaling and Switching unit).
- It is used to perform the functions needed by the CSC.

Time-division multiple access (TDMA):

- **Time-division multiple access** (**TDMA**) is a channel access method for shared-medium networks.
- It allows several users to share the same frequency channel by dividing the signal into different time slots.
- In this access, only one carrier uses the transponder at any one time.
- So, inter modulation noise is reduced.
- The transponder TWT (Travelling wave tube) can be operated at maximum output power.
- In TDMA method, the earth station transmit bursts sequence.
- One earth station is assigned for transmitting reference burst sequence.
- It is used for the synchronizing other sequence.
- The time interval between the starting time of one reference burst to the next reference burst is known as frame.



- The above figure is the Frame format of TDMA
- R1, R2, R3 ... → Reference bursts
- A1, A2, A3…→ Burst from station I
- B1, B2, B3 ... → Burst from station 2
- C1, C2, C3 ... → Burst from station 3
- A **TDMA frame** contains small time slots where each radio is allowed to transmit in.
- The data transmitted during a single time slot is known as a **burst** and a collection of **bursts** forms a frame.
- A **guard time** is a short **time** interval that is added between the **TDMA** slots.
- **Guard times** of 30-50 µs between **time** slots are commonly used in **TDMA** based systems



For TDMA:-

- Required buffer capacity = Input bit rate x Frame time

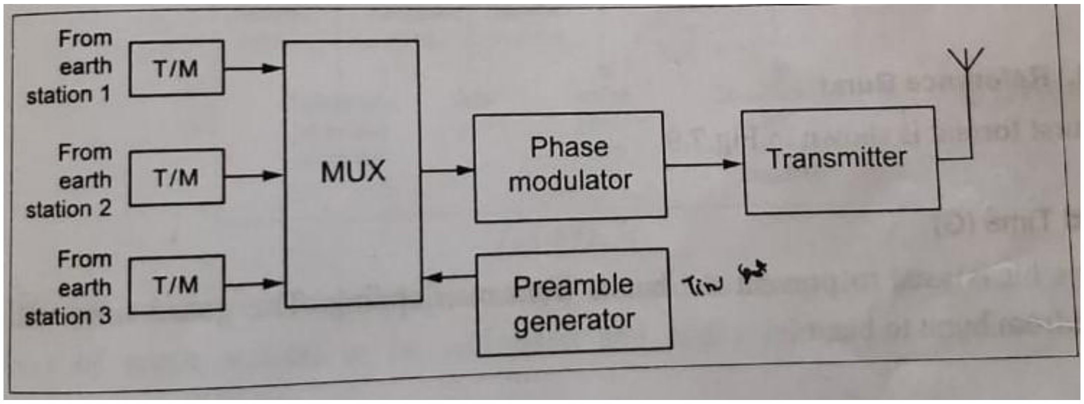
Burst Rates:

- Burst Rate = Required buffer capacity/ Burst time

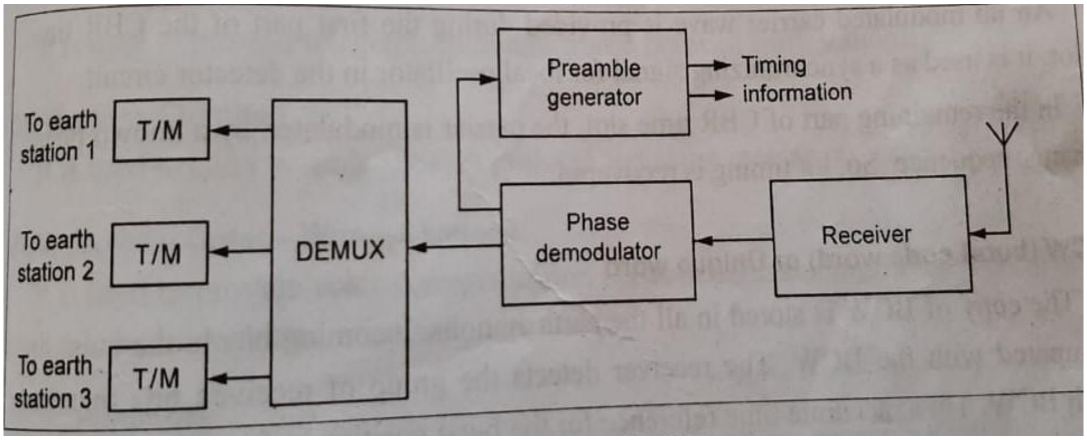
Required buffer capacity = Average Bit Rate /Frame time

Block Diagram of TDMA system:

TRANSMITTER:

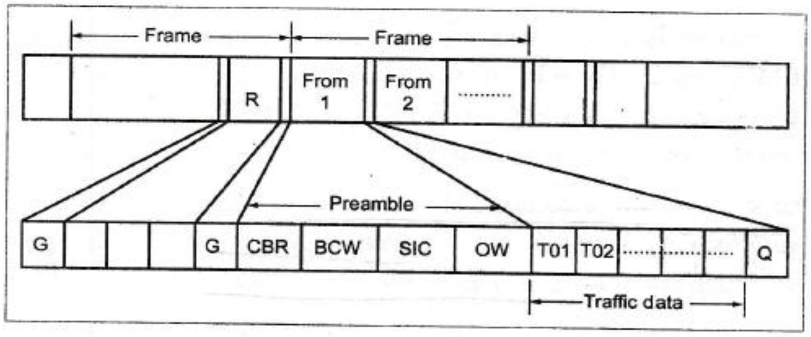


RECEIVER:



- Continuous bit-rate signal is converted into the burst mode signal by using transmit terrestrial interface module (TIM).
- These burst mode signals are multiplexed by using MUX block.
- The signal for each station appears in its assigned time slot.
- At the beginning of the each burst, some time slots are used to carry timing and synchronizing information.
- These time slots are known as preamble.
- The output of MUX is given to phase modulator then to transmitter.
- Finally the burst information is transmitted.
- In the receiver side, multiplexed burst signals are received and given to phase demodulator.
- RF carrier frequency is converted to intermediate frequency and then it is demodulated.
- Preamble detector is used to transmit timing information.
- Demodulated signal is given to DEMUX block. From the demultiplexer, the signal is given to all the earth stations.
- Reference burst is needed at the beginning of each frame for providing timing information for the acquisition and synchronization of burst signal.
- In Intelsat system, two reference stations are there. These are known as primary reference stations.
- One of this is known as Master Primary.
- Each primary station has an alternative which is known as secondary reference station.
- Two reference bursts are transmitted in each frame.
- First reference burst is transmitted by the primary reference station for acquisition and synchronization.
- Second reference burst is transmitted by the secondary reference station which is used for synchronization purpose.

Frame and Burst Structure of TDMA system:



G = Guard time
CBR = Carrier and bit timing recovery
BCW = Burst code word
SIC = Station identification code
Q = Post amble

Guard Time (G):

- This bit is used to prevent the bursts from overlapping.
- The guard time will be varied from burst to burst.

CBR (Carrier and bit timing recovery):

- An un modulated carrier wave is provided during the first part of the CBR time slot.
- It is used as a synchronizing signal for local oscillator in the detector circuit.
- In the remaining part of CBR time slot the carrier is modulated by a known phase change sequence.
- So bit timing is recovered.

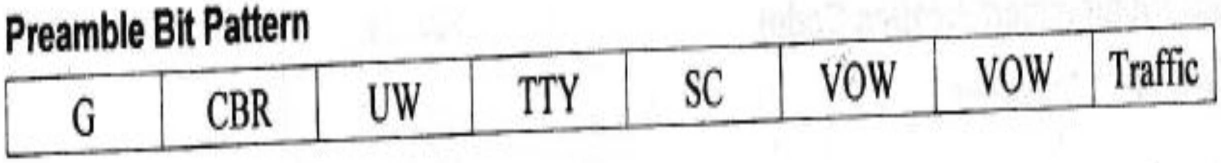
BCW (burst code word) or Unique word:

- The copy of the BCW is stored in all the earth stations.
- Incoming bits in the burst are compared with the BCW.
- The receiver detects the group of received bits matched with BCW.
- Then, accurate time reference for burst position in frame is provided.

PREAMBLE:

- Preamble is the starting portion of a traffic burst.
- It will not carry any traffic.
- The difference between preamble and reference burst is that the preamble can provide order wire channel.
- In the Fig. preamble provide CDC.
- CDC→CDC (co-ordination and delay channel) is used is used to carry the ID (Identification number) of earth station to be addressed and codes related to acquisition and synchronization of bursts.

Preamble Bit Pattern



Frame Efficiency and Channel Capacity:

$$\text{Frame efficiency} = \eta_f = \frac{\text{Traffic bits}}{\text{Total bits}} = 1 - \frac{\text{Overhead bits}}{\text{Total bits}}$$

- Overhead bits means sum of preamble, post amble, guard intervals and the reference burst bits Per frame.
- Higher efficiency can be achieved for low overhead bits.

Capacity of the channel:

- **If, R = bit rate of voice channel**
- **n = total number of voice channels shared between the earth stations.**

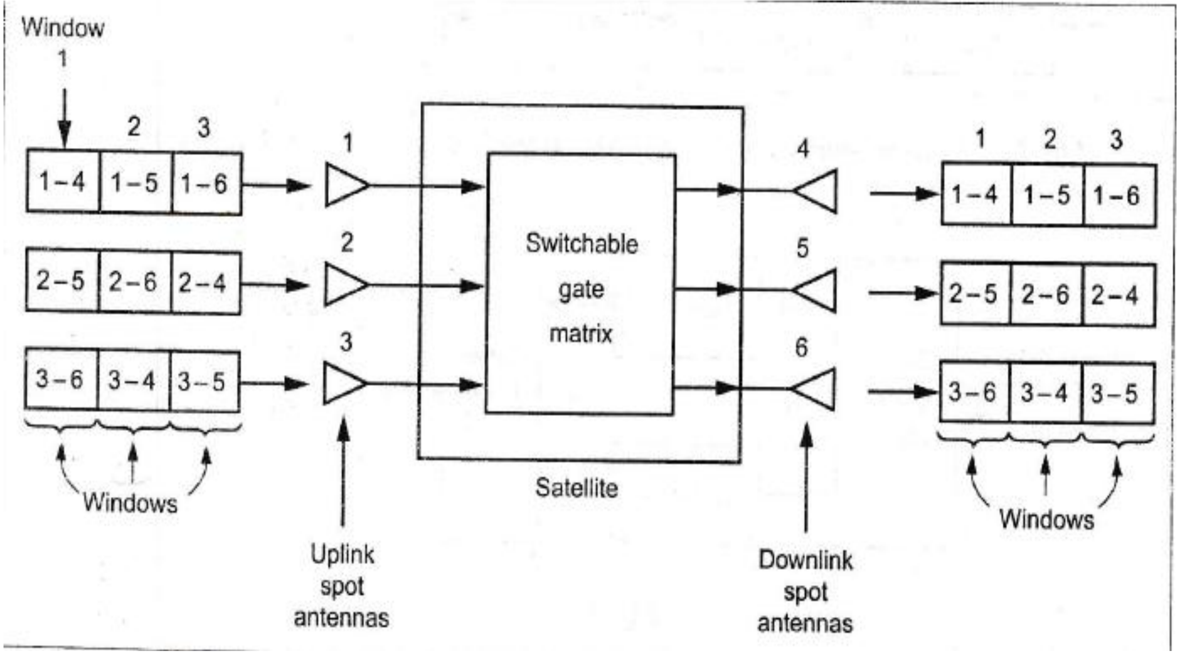
$$\left.\begin{array}{r}\text{Total incoming traffic}\\ \text{bit rate to a frame}\end{array}\right\} = \text{The traffic bit rate of the frame } (\eta_f \cdot R_t)$$

$$nR = \eta_f \cdot R_t$$

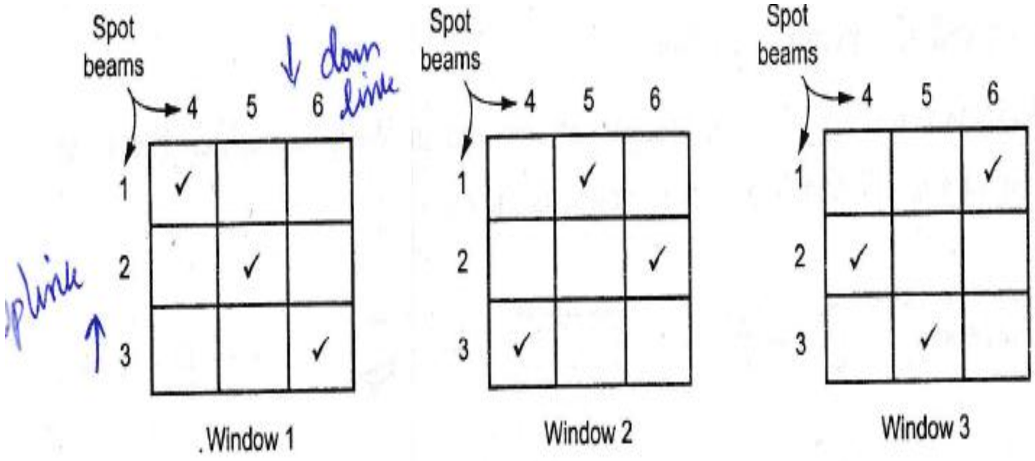
$$\boxed{n = \frac{\eta_f \cdot R_t}{R}}$$

SATELLITE SWITCHED TDMA:

- It is necessary to apply spot beam switching at the satellite which is used to get the TDMA spot beam advantages.
- This concept is known as Satellite Switched TDMA (or) SS-TDMA.
- It restores the network connectivity test by spot beaming.
- A microwave switch is used in the satellite to sequentially interconnect specific uplink beam to specific downlink beam.
- The block diagram of SS-TDMA is shown below.



- A diode switch matrix establishes the necessary connections of uplink spots to downlink spot.
- In the first window of the frame, uplink spot 1 is interconnected with downlink spot 4.
- Uplink spot 2 is interconnected with the downlink spot 5.
- Uplink spot 3 is interconnected with the downlink spot 6.
- It is shown below.



- Frame slots of earth stations in the uplink spots are available during that window, to the receiving stations in the interconnected downlink spot.
- In the second window, the matrix switch is reconnected in such a way that, uplink spot 1 is interconnected to downlink spot 5.
- Uplink spot 2 is interconnected with downlink spot 6.
- Uplink spot 3 is interconnected with downlink spot 4.
- If the matrix cycles through all windows during a frame, an uplink station cycles through all possible receiving stations during a frame.
- SS-TDMA system operates as a set of parallel TDMA links with the parallel connections switching each window.
- SS-TDMA needs multiple spot beams.
- The switching matrix is programmed to switch at fixed window times.
- If a single uplink earth station operates in each uplink beam, then, only one slot per window is needed.
- Here, the switching is done at slot rates and a given earth station transmits in every slot, but to a different receiver in each slot.
- The programmable switch matrix operates in microsecond rate.

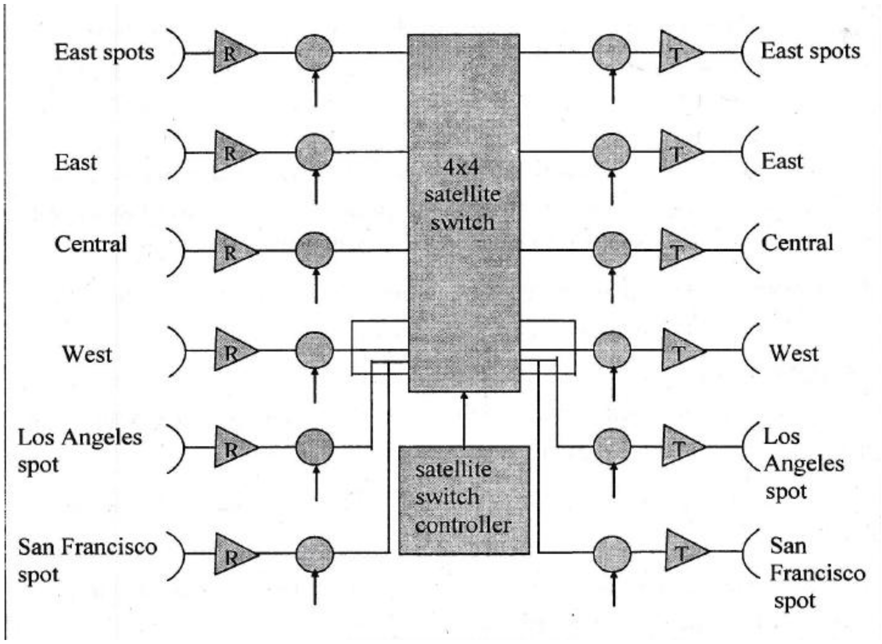
Advantages:

- The advantage of SS-TDMA is that a transmitting station can adjust its transmission in each slot for the type of receiver that will occur for that slot.
- Transmitting at slower rates and higher power for weak receivers and at faster rates for strong receivers.
- Due to the fact that, both transmitters and receivers are synchronized to the switching program.
- SS-TDMA can be made adaptive instantaneously with respect to matching stations.
- SS-TDMA has complicated network synchronization operation.
- In SS-TDMA, no markers are used, but the gating action of satellite switch measures the timing error at the satellite and loops back the result for timing correction.

- Spot beam operation of TDMA can be operated with a single switchable satellite beam instead of with multiple beams.

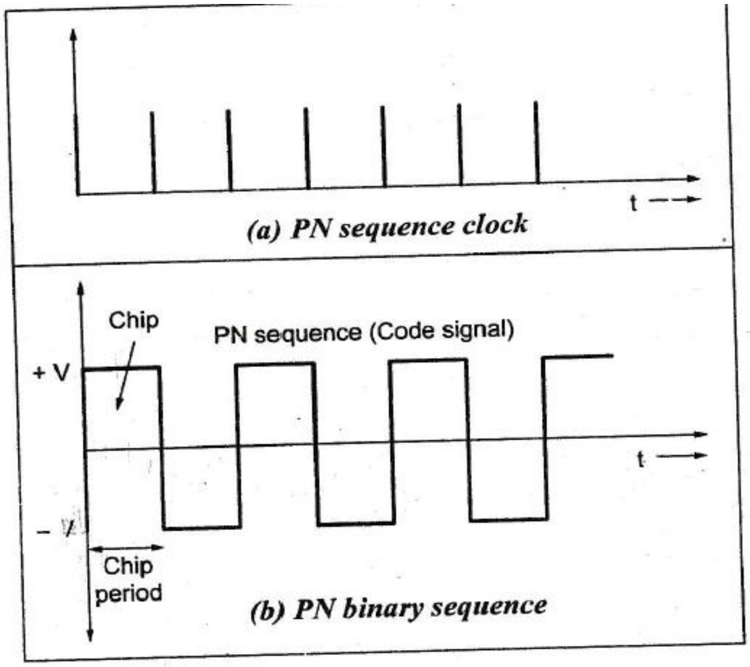
- SS-TDMA format with multiple beams is used in Westar satellite.
- The block diagram of a SS-TDMA in a westar satellite is shown below.

SS-TDMA in a Westar satellite:



CDMA concept:

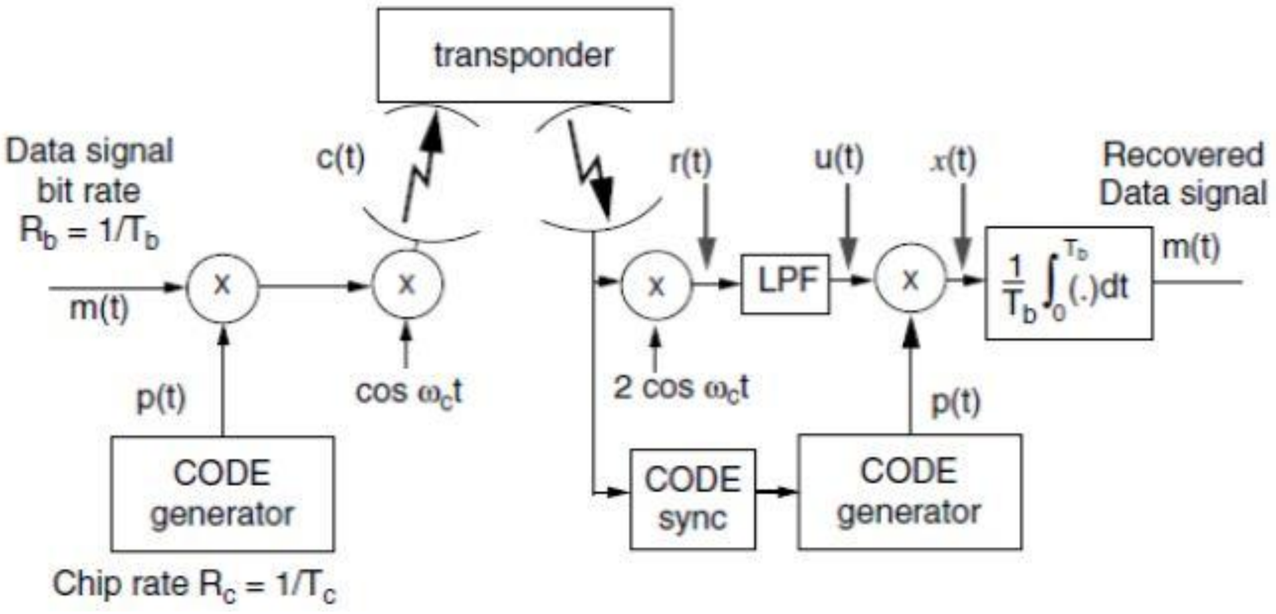
- In code-division multiple access (CDMA) satellite system, uplink stations are identified by uniquely, separable address codes embedded within the carrier waveform.
- Thus, any uplink earth station can access the entire bandwidth of a transponder whenever desired.
- In other words a number of uplink earth stations can access the entire bandwidth of a transponder all the time superimposing their waveforms on the downlink.
- Unlike the DAMA system the CDMA system does not require a centralized satellite network.
- A receiving earth station identifies the carrier intended for it with the proper address code.
- These address codes are usually in the form of periodic binary sequences that either modulate the carriers directly or change the frequency state of the carriers.
- If the address code directly modulates the carrier, then the system is referred to as the direct sequence CDMA(DS-CDMA).
- If the address code continually changes the frequency of the carrier, then the system is referred to as the Frequency hopped CDMA (FH-CDMA).
- Super imposing the address codes on modulated, uplink carriers generally increase the bandwidth.
- Due to this spreading of the carrier spectrum, the CDMA system is also referred to as the Spread-Spectrum Multiple Access (SSMA) system.



DSSS transmitter:

- In this modulation of a carrier is being done by a digital code sequence whose bit rateis much higher than the information signal band width.
- Here the output of several DS spread spectrum modulators, say N are using their own codes pi(t) where i=1,2... N.
- After combining these together these are transmitted.
- It should be noted that each of the user is transmitting data at the carrier frequency and each pseudo-random frequency pi(t) has the same chip rate.
- The data rate for each user is also the same Fb.
- It is clear that multiplication of m1(t) produces a signal whose spectrum is the convolution of the spectrum of s1(t) with the spectrum of p1(t).
- Thus assuming that the signal m1(t) is relatively narrow band compared with the code or spreading signal g1(t), the product p1(t)*m1(t) will be approximately the bandwidth of p1(t).

DSSS Block diagram:



DSSS RECEIVER:

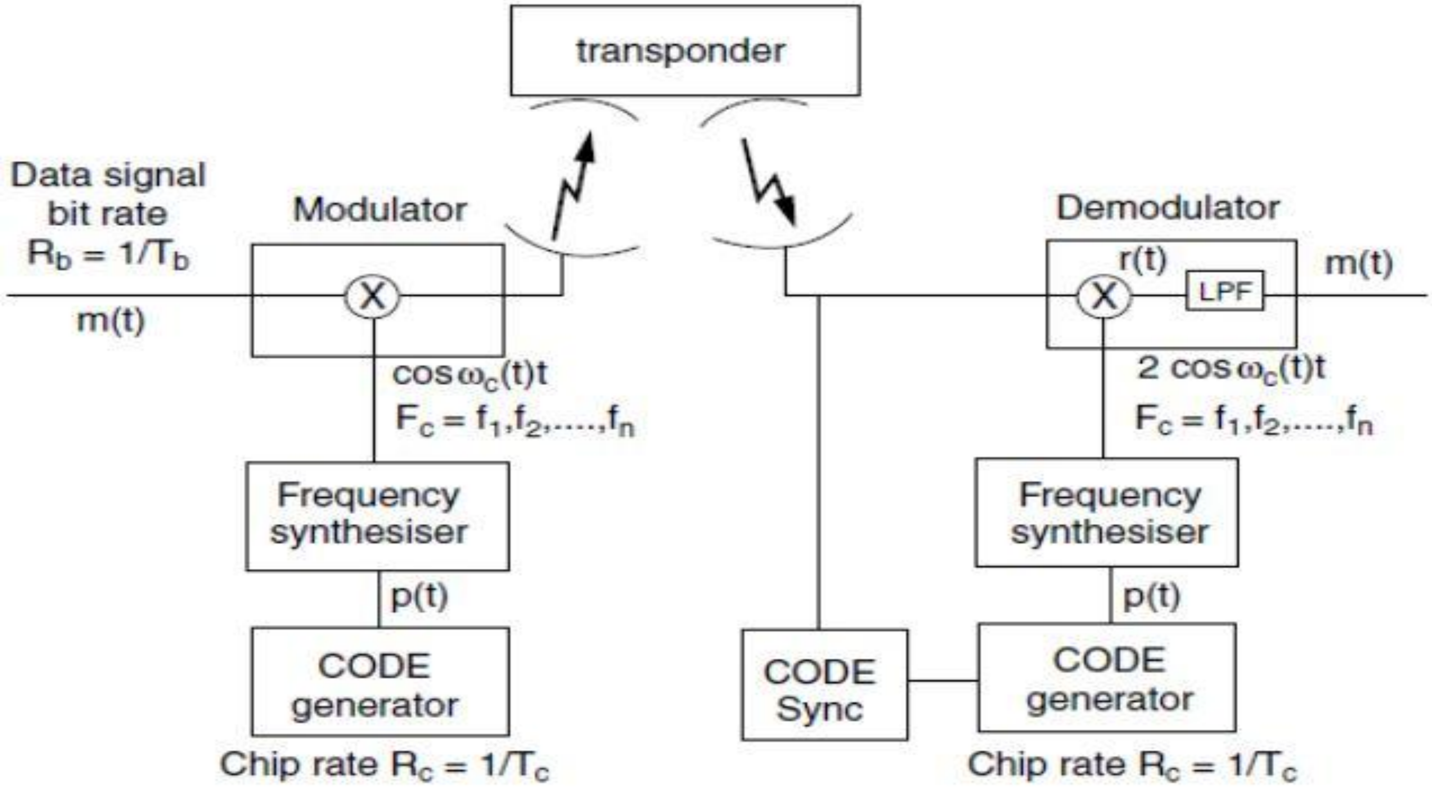
- At the receiver side arrangements are being made to receive the message from the desired group.
- Here the corresponding p1(t) is generated at the receiver and is perfectly synchronised with the received signal from the corresponding user.
- The first step in the receiving process is to multiply the incoming signal by p1(t).
- Suppose that signal of p1(t) is to be received, than at the receiver side the incoming signal would be multiplied by p1(t).
- The RF signal is first down converted to IF and then the p1(t) is multiplied to this IF signal and then the product is compared with the received IF signal in the correlator.
- The function of the correlator is to compare the two signals and recover the original signal data.
- Essentially the correlator subtracts the recovered PSK carrier + chip code from the received PSK carrier + chip code + data.
- The resultant is data.
- In fact the output of correlator which is the desired signal occupies the information bandwidth centered at the intermediate frequency.
- It is applied to conventional demodulator with bandwidth just wide enough to accommodate the desperado signal.
- The conventional demodulator has been represented by unit bit decision.

FH-CDMA:

- With frequency hopping, each earth station within a CDMA network is assigned a different frequency hopping pattern.
- Each transmitter switches from one frequency band to the next according to their preassigned pattern.

FH CDMA Transmitter:

- Here in first sequence, frequency band F2 transmits in time slot t1.
- F4 in time slot t2
- F3 in time slot t3
- F5 in time slot t4
- F1 in time slot t5
- F2 in time slot t6
- The resultant pattern is called frequency hopping pattern.
- Actually these FH pattern is determined by a binary code and each station uses a different code sequence.
- It uses a FSK modulator. Thus FH spread spectrum is FM or FSK technique.
- The code pattern generator consists of PN code generator and a frequency synthesiser capable of responding to the coded output from the code generator.
- It must be remembered that the signal to be frequency hopped is usually a BPSK signal although M-ary FSK, MSK may be employed.



RECEIVER:

- A simple block diagram of FH receiver is shown in the figure.
- Here a local frequency synthesizer is switched with a synchronised replica of the transmitted PN code and the resultant signal is multiplied to the received FHSS signal.
- This multiplication removes the frequency hops on the received signal and thus the original modulated signals remains untouched.
- This signal is then applied to the conventional demodulator to get the orthogonal data/information.

Advantages of CDMA:

- It is simple to operate since it does not require any transmission synchronisation between stations. The only synchronisation is that of the receiver to the sequence of the received carrier.
- It offers useful protection properties against interference from other systems and interference due to multiple paths; this makes it attractive for networks of small stations with large antenna beam width and for satellite communication with mobiles.
- It is highly secure.

LASER SATELLITE COMMUNICATION

UNIT-4

Laser Satellite Communication: Inter satellite links- optical communication for satellite networks- laser cross link analysis- optical beam acquisition, tracking and pointing.

LASER SATELLITE COMMUNICATION:

- Laser communication in space, is the use of free-space optical communication in outer space.
- Communication may be fully in space (an inter-satellite laser link) or in a ground-to-satellite or satellite-to-ground application.

ADVANTAGES OF LASER SATELLITE COMMUNICATION:

- Laser communication could ultimately be cheaper because narrower waves require smaller antennas.
- Laser communication can potentially transmit a much higher volume of data than radio.
- The main advantage of using laser communication over radio waves is increased bandwidth, enabling the transfer of more data in less time.

SATELLITE COMMUNICATION Vs OPTICAL COMMUNICATION:

S. No.	Satellite communication	Optical communication
1	Satellite communication uses electromagnetic waves as a medium for propagation.	Optical communication uses the light rays as a medium of propagation.
2	In satellite communication, satellites as a relay station are used for communication.	In optical communication, communication happens via optical fiber.
3	In satellite communication, for transmission and reception of signals special type of antennas are needed.	In optical communication, no special antennas are needed for communication.

S. No	Satellite communication	Optical communication
4	Air is the transmission medium in satellite communication.	While in optical communication, fiber is the transmission medium.
5	Each transponder in satellite communication supports a bandwidth of 36 MHz and hold 12 channels simultaneously.	Optical fiber supports a bandwidth of very large range and one cable combines many fibers.
6	Satellite communication is convenient and effective for very long distance communication.	For point to point short distance communication, optical communication is appropriate and effective.
7	Cost of installation is very expensive.	Cost of installation is very less as compared to satellite communication.

LIMITING FACTORS FOR LASER IN SATELLITE COMMUNICATION:

- Fog (10 to ~100 dB/km attenuation)
- Beam dispersion.
- Atmospheric absorption.
- Rain.
- Snow.
- Terrestrial scintillation.
- Interference from background light sources (including the sun)
- Shadowing.

MODULATION TECHNIQUES FOR STAELLITE COMMUNICATION:

The most fundamental digital modulation schemes are :-

- Amplitude-shift keying (ASK),
- Phase-shift keying (PSK),
- Frequency-shift keying (FSK), and
- Quadrature amplitude modulation (QAM).

TYPES OF LASER COMMUNICATION:

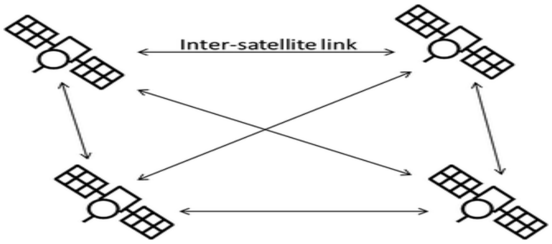
- Semiconductor lasers and gas lasers are the most used in solid-state lasers.
- The type of laser is chosen according to the characteristics of the link that is implemented, such as distance, altitude, the environmental conditions and the power level required in the receiver.

THE RANGE OF THE LASER NETWORK:

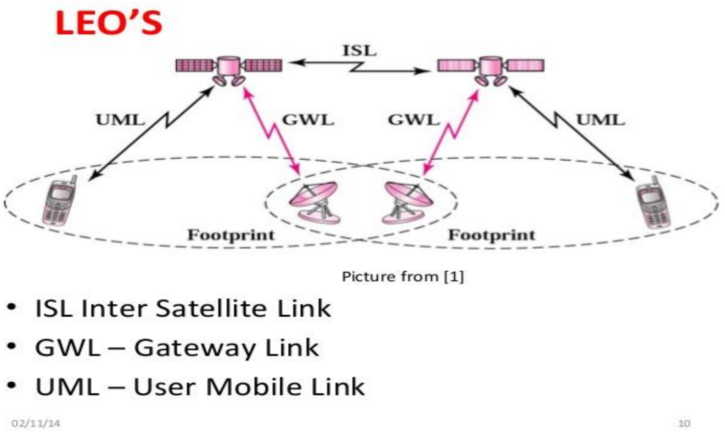
- Laser can provide a fast 100 Mb to 1 Gb, secure connectivity for data, voice and video over short distances typically up to 1 Km.

INTER SATELLITE LINK:

- Also known as "cross linking“
- Intersatellite communication allows satellites in a constellation to link to one another.
- Since small satellite constellations in low earth orbit are not in constant contact with the ground, intersatellite links allow data to be shared between adjacent satellites.
- An inter-satellite link (ISL) is a wireless link between satellites, and ISLs are now being established in communication satellite constellations and global navigation satellite systems (GNSSs).
- Inter-satellite links (ISLs) are used for ranging and communication between navigation satellites and can also serve space users that are outside the navigation constellation.



LEO’s ISL:



LEO’S

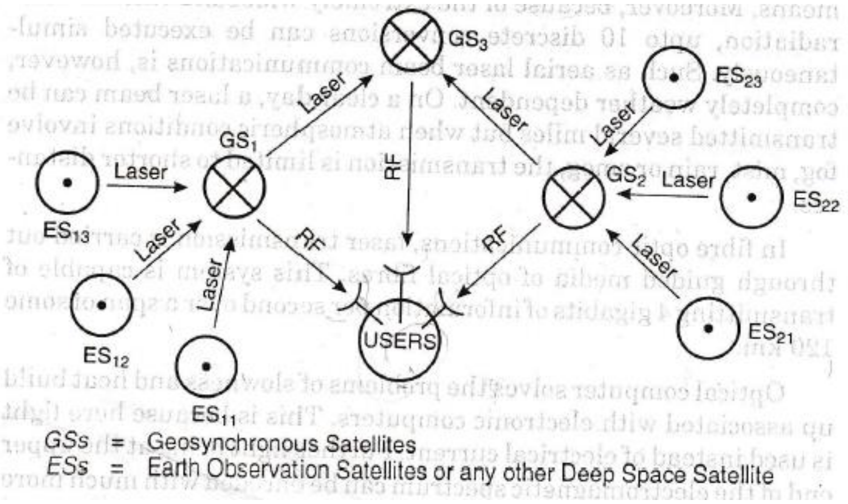
Picture from [1]

- ISL Inter Satellite Link
- GWL – Gateway Link
- UML – User Mobile Link

ISL:

- Laser satellite communication involves transmission at frequencies in the 10^14 (optical) range which is around seven or eight orders of magnitude higher than the radio frequency (RF) systems.
- Transmission at such frequencies provides three main advantages, namely the greater bandwidth, smaller beam divergence angles and smaller antennas.
- On a clear day, a laser beam can be transmitted several miles but when atmospheric conditions involve fog, mist, rain or smog, the transmission is limited to shorter distances.
- In fibre optic communications, laser transmission is carried out through guided media of optical fibres.
- This system is capable of transmitting 4 gigabits of information per second over a span of some 120 km.
- Optical computer solves the problems of slowness and heat build up associated with electronic computers.
- This is because here light is used instead of electrical current.
- Further light being at the upper end of the electromagnetic spectrum can be encoded with much more information.
- Also an optical circuit has a zero resistance to flow and therefore is capable to carry much more information than the equivalent sized electronic circuit.
- There is no problem in using optical signals in parallel channels.
- Being atmospheric dependent, laser communication therefore cannot be used for communication between earth station and a geosynchronous satellite.

- However, it is quite suitable for communication between the satellites themselves or deep space communication.
- A typical example for such a cross satellite laser communication is that shown in Fig.
- Here GSs are the geosynchronous satellites whereas
- ESS are some other satellites (e.g. earth observation or special purpose satellites).
- These ESs communicate to GSs with laser communication and eventually the GSs communicate with the earth station through RF microwave communication.
- The optical transmitters and receiver packages are smaller and lighter than the equivalent RF microwave subsystems.
- This helps in reducing the spacecraft cost and weight.
- For deep space communication where the planets desired to be communicated with the earth are quite far, the received signals are very weak and then this intersatellite laser communication solves problem.
- Here the deep space-craft will have deep space optical link with a geosynchronous satellite which provides microwave link to the earth station.
- Conclusively, therefore the laser satellite communication serves for intersatellite communications and here the analysis of cross optical link is necessary.



LASER CROSS LINK ANALYSIS:

1. Atmospheric Effects
2. Complete Link Analysis

1.ATMOSPHERIC EFFECTS:

- While analyzing the satellite cross-link, the effects of earth's atmosphere on the laser signals should be carefully studied.
- The earth's atmosphere affects the optical signals in a variety of ways such as:

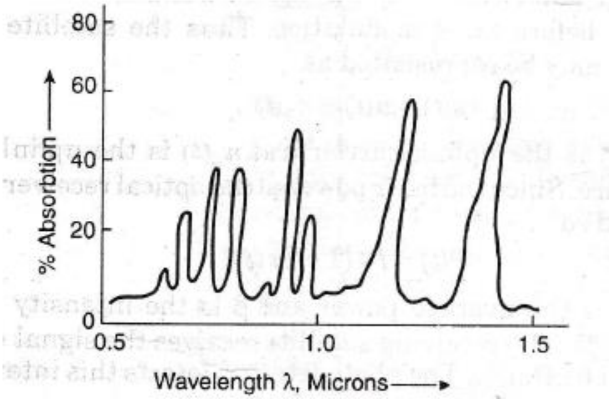
➢ attenuation due to energy absorption,

➢ beam spreading due to scattering of light waves,

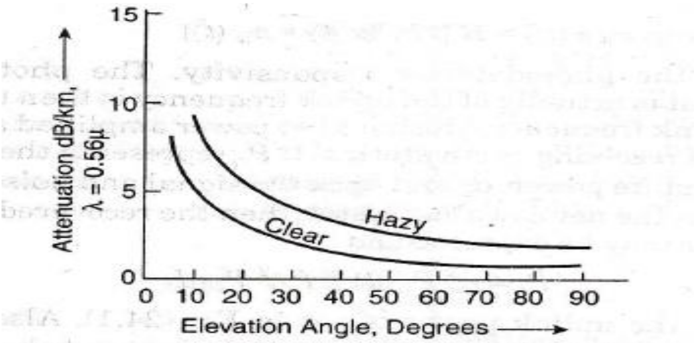
➢ beams bending due to refocusing of optical beams and

➢ beam breakup due to loss of field coherence over the beam front.

➢ The atmospheric attenuation is dependent on the wavelength as shown in Fig



- It is also dependent on the elevation angle particularly for satellite optical downlink as shown in Fig



(b) as a function of elevation angle.

- The beam spreading caused by atmospheric scattering results into weakening of power received at the optical receiver.
- In fact the received downlink beam appears to be about 10μ radians larger.

2.COMPLETE LINK ANALYSIS:

- Satellite optical cross link analysis given below is suitable to the case when the effects of atmosphere are considered to be negligible in satellite cross links (e.g. the space between two satellites).

- Here it has been assumed that the RF link is used for uplink and downlink transmission to the satellite and the crosslink between two satellites is optical link that uses direct detection system.
- Thus when the satellite receives uplink, it directly intensity modulates the uplink carrier bandwidth onto the optical carrier for the crosslink.
- For this it is essential that the upper limit of the uplink frequency band is within the receiving photo detector bandwidth otherwise then the uplink bandwidth is firstly down connected before laser modulation.
- The satellite RF uplink waveform may be represented as s(t)=u(t)+ nu (t)
- where u(t) is the uplink carrier and nu(t) is the uplink noise and interference.
- Since the laser power at the optical receiver is intensity modulated so

$$P(t) = P_r (1 + \beta s (t))$$

- where P, is the average power and β is the intensity modulation index (β< 1).
- The photo detector detects this intensity modulated signal as

$$R [\beta P_r s (t)] = R \beta P_r [u (t) + n_u (t)]$$

- The photo detected waveform that is actually of the uplink frequency is then translated to the downlink frequency which is then power amplified and transmitted to the receiving earth station.
- If Pr represents the available downlink satellite power, as the signal and noise suppressions αs & αn and L as the net downlink losses.
- The recovered downlink carrier power may be expressed as

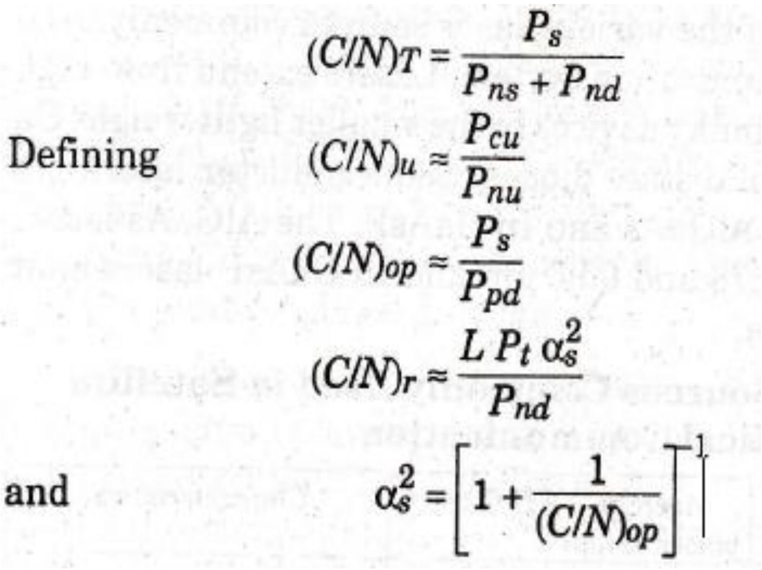
$$P_s = \alpha_s^2 P_t [(R \beta P_r)^2 P_{cu}]L$$

- where Pcu is the uplink power of u(t).
- Also the total downlink retransmitted noise power (uplink plus total photo detector noise) can be expressed as

$$P_{ns} = \alpha_n^2 P_t [(R P_r \beta)^2 P_{nu} + P_{PD})]L$$

- where Pnu is the uplink noise power and Ppd is the combined photo detector noise power (shot, dark current, and thermal) in the satellite bandwidth.

- In addition the downlink receiver adds its thermal noise Pnd.
- Hence the resulting downlink signal to noise ratio (C/N)d, after uplink, crosslink and downlink transmission is finally



$$(C/N)_T = \frac{P_s}{P_{ns} + P_{nd}}$$

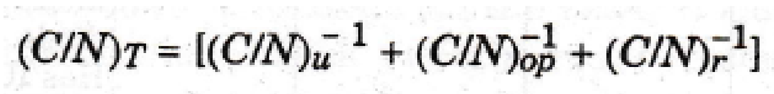
Defining $$(C/N)_u \approx \frac{P_{cu}}{P_{nu}}$$

$$(C/N)_{op} \approx \frac{P_s}{P_{pd}}$$

$$(C/N)_r \approx \frac{L\, P_t\, \alpha_s^2}{P_{nd}}$$

and $$\alpha_s^2 = \left[1 + \frac{1}{(C/N)_{op}}\right]^{-1}$$

- One may write (C /N)T as



$$(C/N)_T = [(C/N)_u^{-1} + (C/N)_{op}^{-1} + (C/N)_r^{-1}]$$

- Here one needs two more information, the information bit rate and the system link margin (for degradation).
- This margin is usually taken for satellite cross links as one or two dB.
- The required error probability in digital satellite communication is of the order of 10 ^-5.

OPTICAL COMMUNICATION FOR SATELLITE NETWORKS:

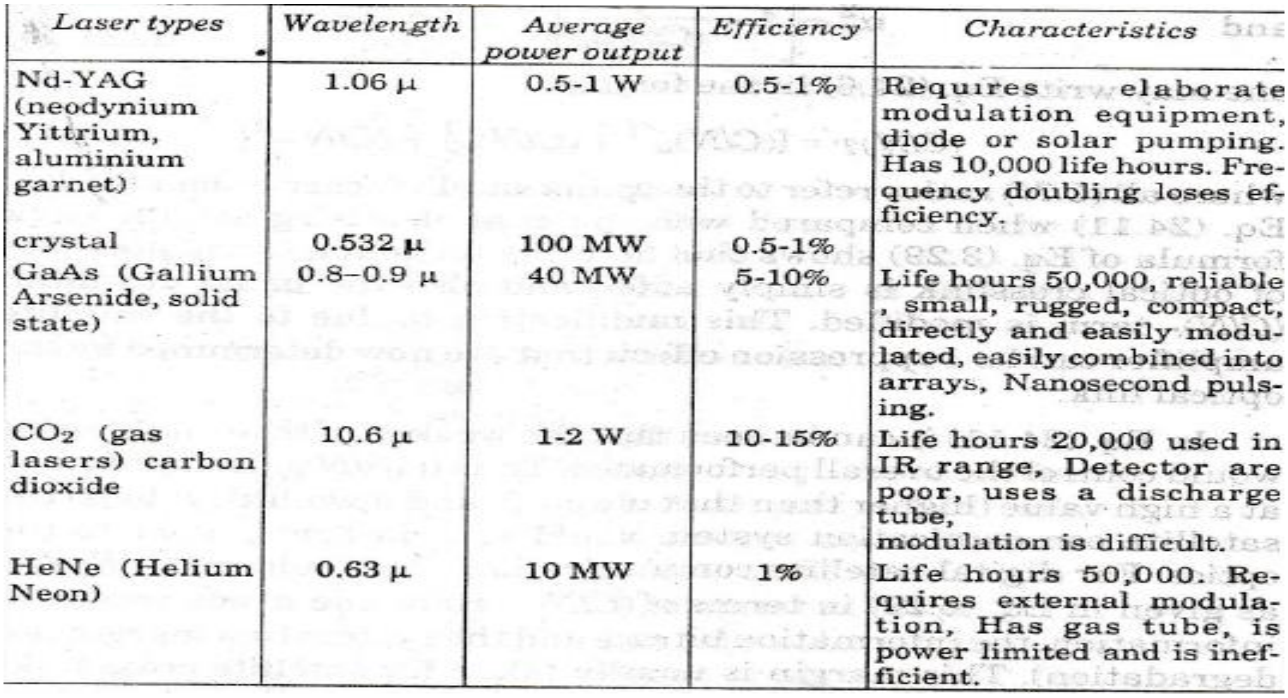
- An optical communication system uses a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal.

OPTICAL SATELLITE LINK TRANSMITTER:

1. Basically the transmitter part of an optical satellite link consists of a
2. laser source
3. modulator and
4. antenna along with some data handling electronics

1.LASER SOURCE:

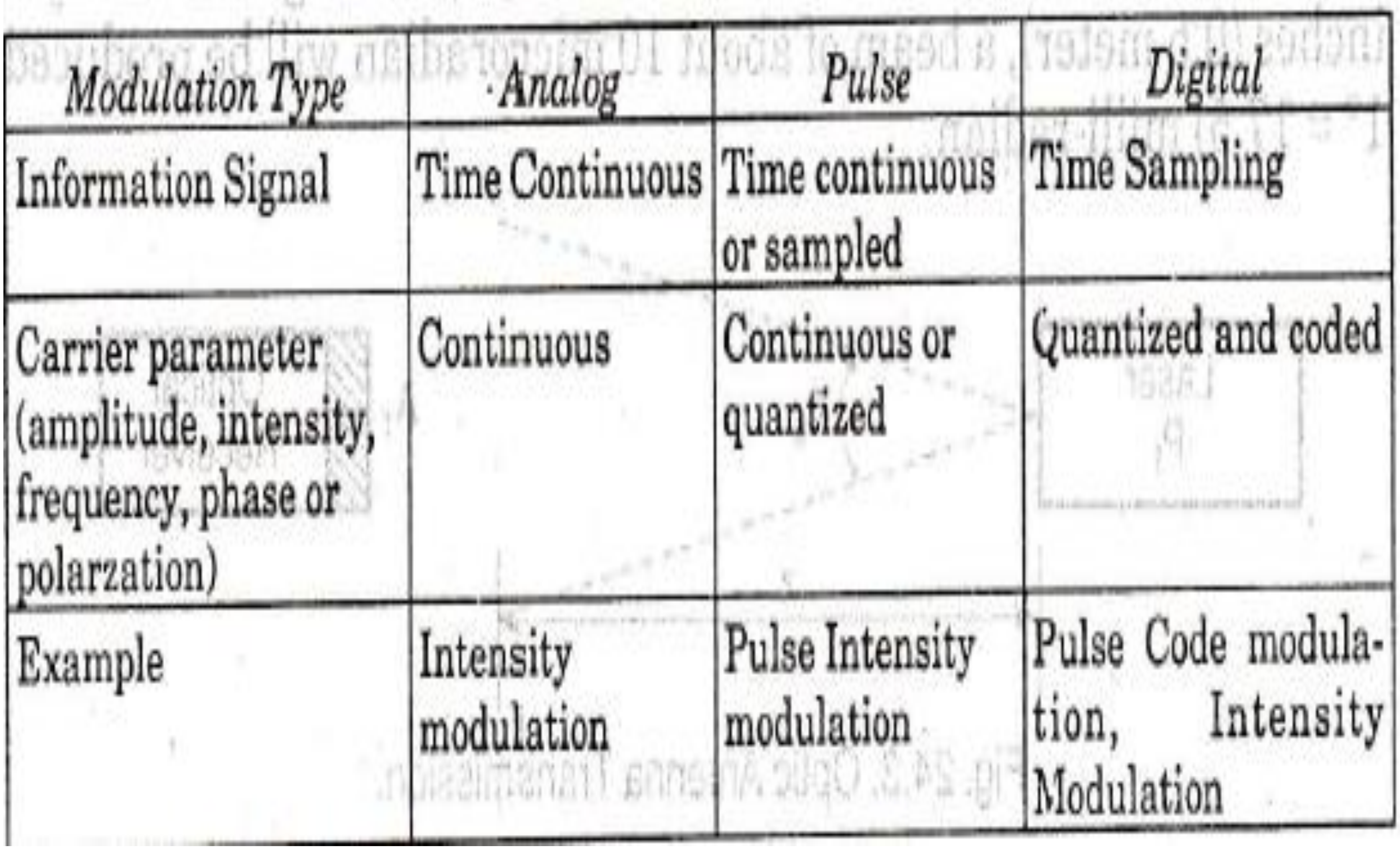
- A variety of laser sources may be used for optical satellite communication systems.
- These may be gas lasers, solid state lasers and semi-conductor lasers.
- Selection of laser source is dependent upon a number of factors that include link range, propagation medium, data rate and platform limitations.
- Lasers extend from high powered, low efficiency, bulky devices to the smaller light weight Ga-As (gallium arsenide) solid state diodes.
- Semiconductor lasers are also being used such as AlGaAs and In Ga-AsP.
- The AlGaAs lasers emit reliably between 0.78 and 0.86 µm and In GaAsp lasers emit between 1.2 and 1.65µm.
- The satellite crosslink uses preferably the laser diodes because of their light weight.
- But since these are low powered devices (output power on the order of tens of milliwatts), the laser diodes are arranged in the satellite payloads to form arrays so that the laser source output power increases.
- The laser diode has long potential life (~10^5 hr).
- The main disadvantage of the laser diode is the limited power per diode so that most applications require the use of diode arrays, leading to the beam-combining problems.



Laser types	*Wavelength*	*Average power output*	*Efficiency*	*Characteristics*
Nd-YAG (neodynium Yittrium, aluminium garnet)	1.06 µ	0.5-1 W	0.5-1%	Requires elaborate modulation equipment, diode or solar pumping. Has 10,000 life hours. Frequency doubling loses efficiency.
crystal	0.532 µ	100 MW	0.5-1%	
GaAs (Gallium Arsenide, solid state)	0.8–0.9 µ	40 MW	5-10%	Life hours 50,000, reliable , small, rugged, compact, directly and easily modulated, easily combined into arrays, Nanosecond pulsing.
CO_2 (gas lasers) carbon dioxide	10.6 µ	1-2 W	10-15%	Life hours 20,000 used in IR range, Detector are poor, uses a discharge tube, modulation is difficult.
HeNe (Helium Neon)	0.63 µ	10 MW	1%	Life hours 50,000. Requires external modulation, Has gas tube, is power limited and is inefficient.

2.MODULATORS:

- In laser space communication the most preferable modulation is direct intensity modulation.
- Various methods that can be used to modulate laser can be as that given in table.
- These are the direct modulation methods.
- Here the driving current of the laser is varied in accordance with the type of modulation required.
- Modulation rate of about (1Gbits/s) with the laser diodes have also been achieved.
- Other light sources e.g. gas lasers may not be capable of being modulated at all.
- This makes external modulators attractive.
- Solid state lasers such as Nd-YAG which are capable of achieving a modulation rate of more than 1 Gbit/s also require external modulators.



Modulation Type	*Analog*	*Pulse*	*Digital*
Information Signal	Time Continuous	Time continuous or sampled	Time Sampling
Carrier parameter (amplitude, intensity, frequency, phase or polarzation)	Continuous	Continuous or quantized	Quantized and coded
Example	Intensity modulation	Pulse Intensity modulation	Pulse Code modulation, Intensity Modulation

3. ANTENNAS:

- As with the RF communication systems, the laser satellite communication systems also utilize antennas to direct the transmitted energy.
- Here the antennas are nothing more than the conventional design telescopes where the size and geometry are dictated by the wavelength and system requirements.
- Thus, the optical satellite communication system requires narrow light beam widths (fractions of a degree) instead of antenna gain patterns of several degrees needed by RF systems.
- Here a laser source generates a light wave which is focussed into an optical beam and then propagates a distance z over a free space path to a collecting area Ar.

$$\phi_b \approx \frac{\lambda}{d_t}$$

- Where, λ is the wavelength of the laser light and d, is the diameter of the transmitting optics of the laser.

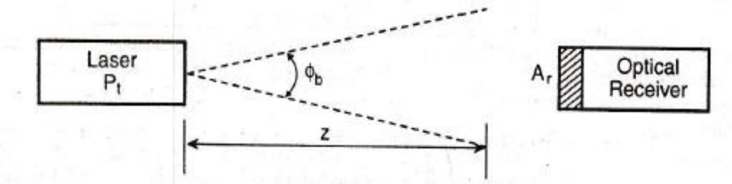


Fig. Optic Antenna Transmission.

- Compared to RF systems, a laser transmitter produces beams widths several orders of magnitude narrower which is measured in terms of micro radians instead of degrees.
- The basic calculations for beam power etc, however, may be easily carried out as per conventional RF communication system.
- Let the laser source power Pt be distributed over the beam front at the distance z.
- The optical power collected over the collecting area Ar at the receiving side would be then

$$P_r = \frac{P_t A_r}{\phi_b^2 z^2}$$

- Above equation, may be rewritten in terms of antenna gain values and propagation losses as being done in RF link analysis by using

$$g_t = \frac{4\pi}{\phi_b^2}$$

$$L_p \approx (4\pi/\lambda z)^2$$

- But since here the focusing parameters are also involved so the results given by above Equation for optical antennas would become misleading.
- Therefore,these two equations are not used.
- Instead, that gives

$$P_r = \frac{P_t (d_t d_r)^2}{\lambda^2 z^2}$$

- where dr is the diameter of the receiving optics.

OPTICAL SATELLITE RECEIVER:

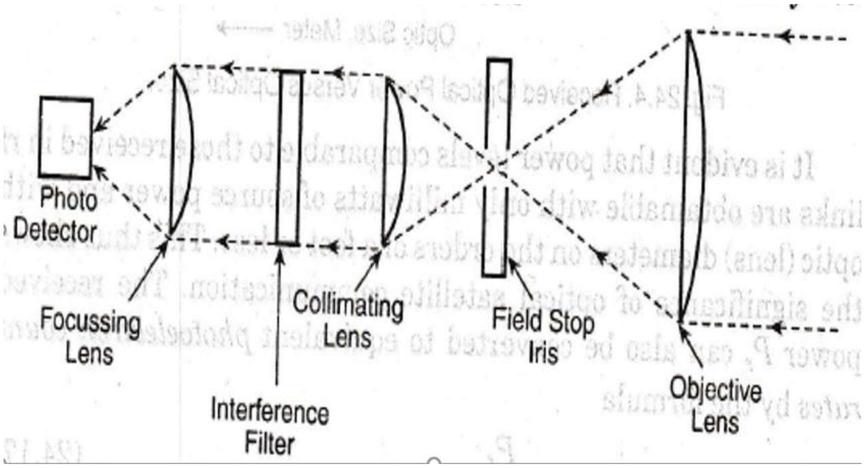
- The optical receiver consists of an antenna, filter, photo detector and then conventional receive electronic system.
- Receive antennas are also the telescopes whose main purpose is to focus the optical signal onto the photo detector.
- And to reject as much as of the background radiation.
- The receive optical filters (also known as interference filters) are employed to eliminate background radiation that is not of the same wavelength as the optical signal.
- The range of wavelengths around the laser wavelength allowed by the optical filter is called optical bandwidth.
- In terms of wavelength this optical bandwidth Δλ around wavelength λo is related to the optical bandwidth Bo in Hz around the frequency fo corresponding to λo by

$$\frac{\Delta\lambda}{\lambda_0} \approx \frac{B_0}{f_0}$$

- Typical optical filter bandwidths at 1 micron generally range from 10-100 angstroms (1 angstrom = 10^- 4 microns) corresponding to an equivalent frequency bandwidth of about Bo = 10^-11 to 10^-12 Hz, (100-1000 GHz).

OPTICAL DETECTION SYSTEM:

- Optical detection systems are of two types namely the direct detection system and the heterodyne system.
- Direct detection systems respond to the signal intensity and are the most widely used in optical communications systems.



HETERODYNE DETECTION SYSTEM:

- In the heterodyne detection system the optical signal is combined with a local oscillator beam and then both the signals are focused onto the same detector.
- Heterodyne detection systems are used primarily in the far-infrared region and they respond to signal amplitude.

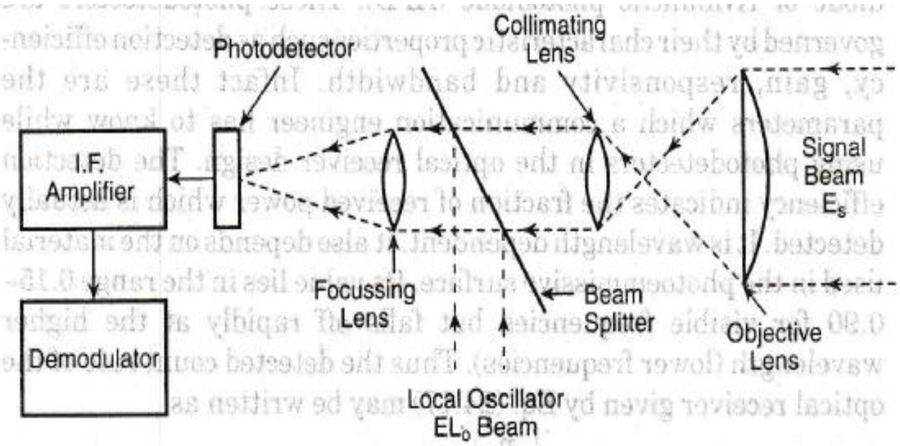


PHOTO DETECTOR:

- Photo detector normally used in optical detection may be PIN diode or Avalanche photodiode (APD).
- These photo detectors are governed by characteristic properties such as Detection efficiency, Gain, Responsivity and bandwidth.
- The Gain of photo detector is increased by cascading the photo emissive surface but this increases the noise.

RESPONSIVITY:

- The responsivity of photodiode indicates as to how much current will be produced for a given power input.
- It is indicated by amps/watts.

BANDWIDTH:

- The bandwidth of photo detector is different than the optical bandwidth.
- The photo detector bandwidth actually determines the rate of power variation that can be detected.
- It indicates the highest frequency at which the power can be varied and have the variation detected by the output current.
- Typical bandwidth are usually 1-10 GHz.

MODULATION SYSTEM:

- The modulation system for the laser satellite transmitter to use modulation techniques other than intensity modulation such as phase modulation, frequency modulation or amplitude modulation.

OPTICAL BEAM ACQUISITION, TRACKING AND POINTING:

- In Optical Satellite Communication the transmitting beam should be quite narrow because it would have maximum power spectrum.
- The narrowness of the optical beam is typically 5 micro radians.
- Notice that this width is several orders of magnitude less than that of a radio beam and this is an advantage for protection against interference between systems.

- But it is also a disadvantage since the beam width is much less than the precision of satellite attitude control (typically 0.1_ or 1.75 m rad).
- Consequently an advanced pointing device is necessary; this is probably the most difficult technical problem.

1.ACQUISITION:

- The beam must be as wide as possible in order to reduce the acquisition time.
- But this requires a high-power laser transmitter.
- A laser of lower mean power can be used which emits pulses of high peak power with a low duty cycle.
- The beam scans the region of space where the receiver is expected to be located.
- When the receiver receives the signal, it enters a tracking phase and transmits in the direction of the received signal.
- On receiving the return signal from the receiver, the transmitter also enters the tracking phase.
- The typical duration of this phase is 10 seconds.
- Before communication can commence, a high power beam laser located on LEO end has to scan over the region of uncertainty until it illuminates the GEO terminal and is detected.
- Once the GEO terminal receives the LEO communication beam it switches from the beacon to the forward link communication beam.
- Communication link between the LEO and GEO space craft is established.

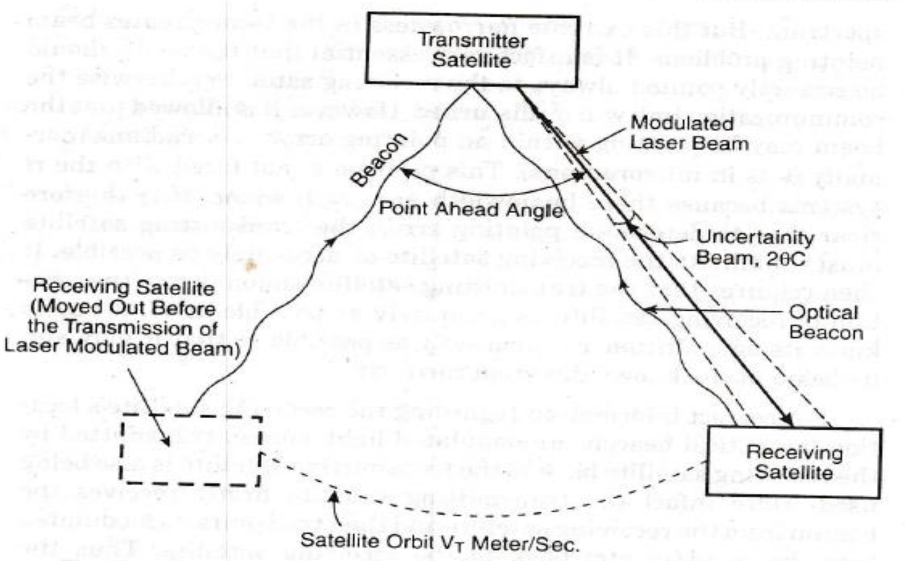
2.TRACKING:

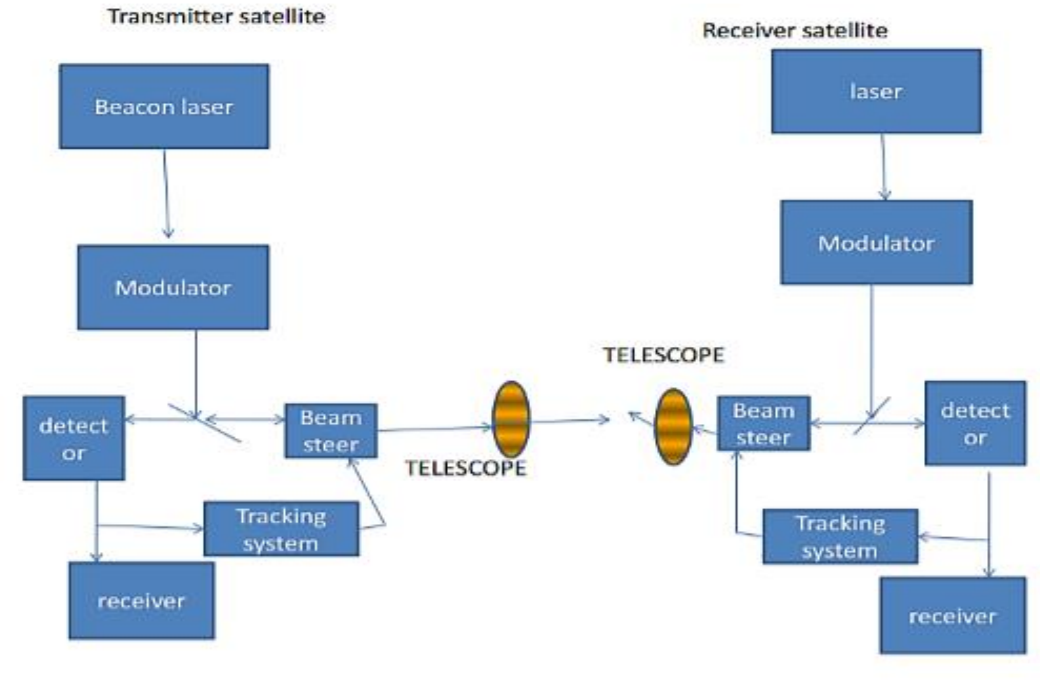
- The beams are reduced to their nominal width.
- Laser transmission becomes continuous.
- In this phase, which extends throughout the following, the pointing error control device must allow for movements of the platform and relative movements of the two satellites.
- In addition, since the relative velocity of the two satellites is not zero, a lead-ahead angle exists between the receiver line of sight and the transmitter line of sight.

- As demonstrated below, the lead-ahead angle is larger than the beam width and must be accurately determined.
- In this mode the on-board disturbances which introduce pointing fitter into the communication beam are alternated by means of a fine pointing control loop (FPL) to enable acceptable communications to be obtained.
- These disturbances are due to thruster firings, solar arrays drive mechanisms, instrument harmonics and other effects.

3.POINT AHEAD ANGLE:

- This is needed because of the relative orbital motion between the satellites which calls for the transmitted beam to be aimed at a point in space where the receiving terminal will be at the time of arrival of the beam
- Point ahead angle= 2Vt /c
- Vt = transverse Velocity component of the satellite.
- C = Speed of light





Optical Link Model

POINTING:

Pointing depends on

- accuracy to which one satellite knows the location of the other
- accuracy to which it knows its own attitude
- accuracy to which it can aim its beam knowing the required direction

1.Which modulation technique is used in satellite communication?

- Trellis coded 16-Phase Shift Keying (PSK) and 16-Quadrature Amplitude Modulation (QAM) modulation systems are used for satellite communications.

2.Why QPSK is used in satellite communication?

- In one such approach, quadrature phase-shift-keying (QPSK) modulation provides both spectral and power efficiency.
- In a QPSK modulator, two data streams simultaneously modulate a carrier signal.
- For optimum use of available satellite power, an unbalanced QPSK (UQPSK) modulator is often used.

UNIT V

DIRECT BROADCAST SATELLITE SERVICES

5.1 INTRODUCTION

Planned broadcasting directly to home TV receivers using satellites is known as ***direct broadcast satellite* (DBS) *service***. Broadcast services include audio, television and Internet services. Direct broadcast television is also known as ***digital TV*** or ***Direct-to-home (DTH) TV***.

5.2 ORBITAL SPACING

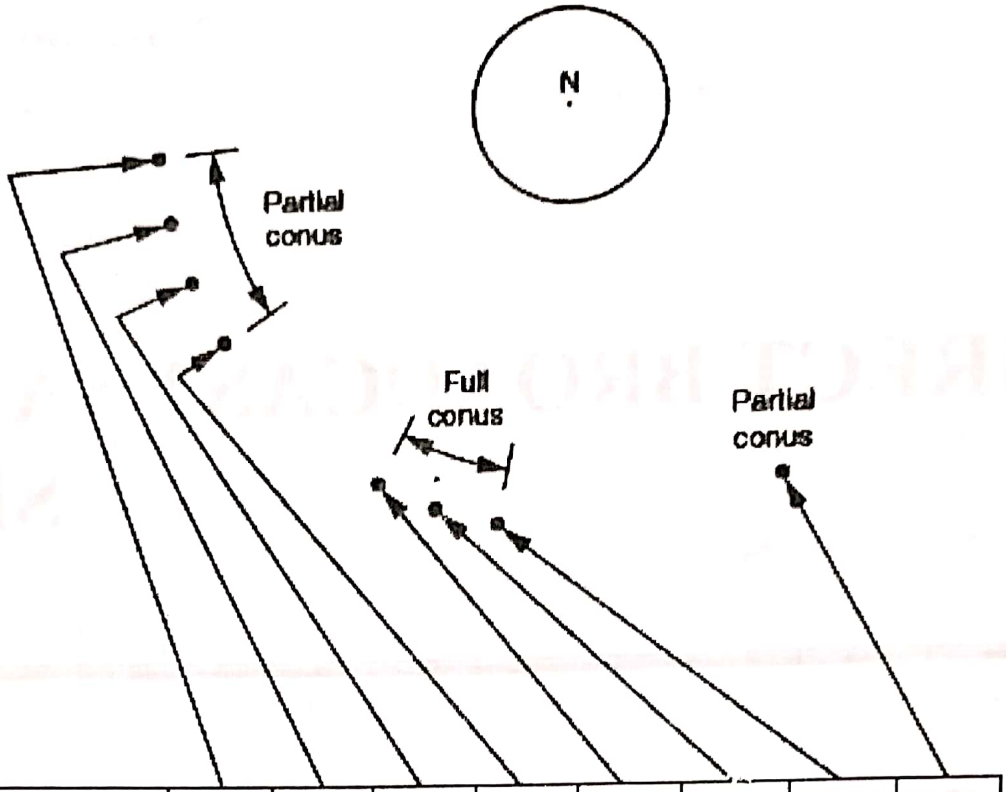
The minimum orbital spacing for the satellites is 2^0 and maximum is 9^0. The orbital spacing for DBS or high power satellites is 9^0. So, there is no adjacent satellite ***interference***.

Examples:

The DBS orbital positions and the transponder allocations for the United States are shown in fig 5.1.

Although the DBS services are spaced by 9^0, clusters of satellites occupy the nominal orbital positions. ***Clusters of satellite*** means more than one satellite at an assigned orbital position. For example, the following satellites are located at 119^0W longitude:

- EchoStar VI – Launched on July 14, 200
- EchoStar IV – Launched on May 8, 1998
- EchoStar II – Launched on September 10, 1996
- EchoStar I – Launched on December 28, 1995



Satellite location	175°	166°	157°	148°	119°	110°	101°	61.5°
Company	Transponder totals							
Continental		11						11
DBSC	11							11
DirecTV			27				27	
Dominion		8						8
Echostar				24				
Echostar/Directsat	11	11			21	1		
MCI						28		
TCI/Tempo					11			
USSB				8		3	5	
Unassigned	10	2	5					2

Figure 5.1 DBS Orbital Positions for the United Sates

5.3 POWER RATING AND NUMBER OF TRANSPONDERS

Two important parameters in a satellite are,

- Power Rating and
- Number of transponders.

5.3.1 Power Rating

The power rating of a satellite is decided by the ***Equivalent Isotropic Radiated Power*** [EIRP]. The range of [EIRP] for DBS is 51 to 60 dBW. In the year 1983, a Regional Administrative Radio Council (RARC) established the EIRP value for DBS as 57 dBW. Also, the power rating has a direct effect on the bit rate.

5.3.2 Number of Transponders

Typically, a satellite may carry *32* transponders. Theses transponders are rated by the power output of their high-power amplifiers.

- If all 32 transponders are in use, each will operate at a low power rating of 120 W.
- But, if the number of transponders is reduced to 16 by doubling the number of high-power amplifiers, then each transponder operates at a high power rating of 240 W.

5.4 FREQUENCIES AND POLARIZATION

The frequency range and the types of polarization used for DBS are explained below.

5.4.1 Frequencies for DBS

DBS services take place in the Ku band and the frequencies vary from region to region throughout the world.

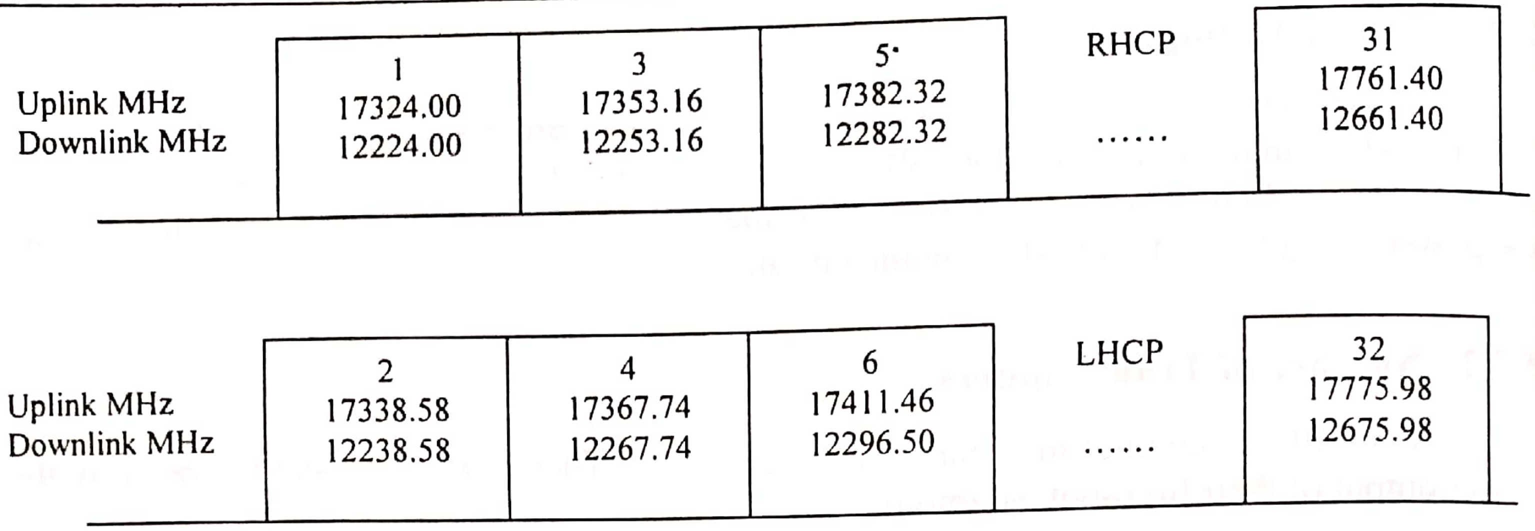
i) High-power Satellites.

- Primary use – DBS service
- Uplink frequency range : 17.3 to 17.8 GHz
- Downlink frequency range : 12.2 to 12.7 GHz

ii) Medium-Power Satellites.

- Primary use – point-to-point applications.
- Additional use – DBS service.
- Uplink frequency range : 14 to 14.5 GHz
- Downlink frequency range : 11.7 to 12.2 GHz

The DBS ***frequency plan*** for region 2 is shown in fig 5.2



RHCP → Right Hand Circular Polarization

LHCP → Left Hand Circular Polarization

Figure 5.2 The DBS frequency plan for Region 2

5.4.2 Polarization for DBS

- The available bandwidth for a DBS service is 500 MHz. This accommodates a total number of 32 transponder channels each with 24 MHz bandwidth.
- In order to permit ***frequency reuse***, the 32 transponders require the use of two types of polarizations:
  - i) Right-Hand Circular Polarization (RHCP)
  - ii) Left-Hand Circular Polarization (LHCP)
- In some cases, bandwidth is specified as 27 MHz, which includes a ***guard band*** of 3 MHz to avoid interference between channels for a given polarization.

5.5 TRANSPONDER CAPACITY

The bandwidth of a transponder is 24 MHz. This can carry only one analog television channel. But, DBS television requires many number of channels so, that digital television is developed.

5.5.1 Signal Compression

Digitizing the audio and video components of a television program allows signal compression to be applied. This greatly reduces the required bandwidth. The signal compression used in DBS is a very complex process.

5.5.2 Symbol Rate

The ***symbol rate*** that can be transmitted in a given bandwidth is

$$R_{sym} = \frac{B_{IF}}{1+\rho} \qquad \_\_\_\_\_ \ (5.1)$$

Where, $\rho \rightarrow$ ***Rolloff factor*** $= 0.2$ here

$B_{IF} \rightarrow$ Bandwidth $= 24$ MHz

$$\therefore \qquad R_{sym} = \frac{24 \times 10^6}{1+0.2} = 20 \times 10^6 \text{ symbols / s}$$

5.5.3 Number of Bits / Symbol

Satellite digital television uses quadrature phase shift keying (QSPK). In this case, the number of bits in each symbol is,

$$m = \log_2 M \qquad \_\_\_\_\_ \ (5.2)$$

Where, M → Number of levels in the waveform

If $M = 4 \Rightarrow m = \log_2 4 = 2$

5.5.4 Bit Rate

Now, the ***bit rate*** is given by,

$$R_b = m \times R_{sym} \qquad \_\_\_\_\_ \ (5.3)$$

$$= 2 \times 20 \times 10^6$$

$$\therefore \qquad R_b = 40 \text{ Mbps}$$

This is the bit rate that can be carried in the 24 MHz channel using QPSK.

5.6 BIT RATES FOR DIGITAL TELEVISION

The bit rate for digital television depends on the picture format.

5.6.1 Uncompressed Bit Rate

There are a number of ways to estimate the uncompressed bit rate. One way is,

Uncompressed bit rate = (number of pixels) × (number of frames per second) × (number of bits used to encode each pixel)

Here, the number of bits per pixel depends on the ***color depth*** per pixel.

Example: 16 bits per pixel ⇒ color depth : $2^{16} = 65536$ colors.

Some of the estimated uncompressed bit rates are shown in Table 5.1

SNo	***Format type***	***Name***	***Aspect Ratio***	***Resolution Pixels***	***Frames per second***	***Uncompressed bit rate, Mbps***
1	SDTV	480i	4:3	640 × 480	30	148
2	EDTV	480p	4:3	640 × 480	24	118
3	EDTV	480p	4:3	640 × 480	60	295
4	EDTV	480i	4:3	704 × 480	30	162
5	EDTV	480p	16:9	704 × 480	60	324
6	HDTV	720p	16:9	1280 × 720	24	334
7	HDTV	720p	16:9	1280 × 720	60	885
8	HDTV	1080i	16:9	1920 × 1080	30	995
9	HDTV	1080p	16:9	1920 × 1080	24	796
10	HDTV	1080p	16:9	1920 × 1080	30	995

SDTV → Standard Definition Television

EDTV → Enhanced Definition Television

HDTV → High Definition Television

p → Progressive Scanning

i → Interlaced Scanning

Table 5.1 Uncompressed bit rates of ATSC (Advanced Television Systems Committee)

As seen from the table, the uncompressed bit rate ranges from 148Mbps for SDTV to 995Mbps for HDTV, which has the highest resolution.

5.6.2 Need for Compression

A single DBS transponder has to carry four to eight TV programs. This programs may originate from a variety of sources like film, analog TV, videocassette etc.

Therefore, before transmission, these program signals must undergo the following processes.

- Digitization

- Compression
- Time Division Multiplexing (TDM)

At last, the TDM baseband signal is applied to the uplink carrier and reaches the given transponder.

5.6.3 Compressed Bit Rate

The compressed bit rate depends on the type of program material. Therefore, the number of channels that are carried also depends on this. Compression is carried out according to the Moving Pictures Expert Group (MPEG) standards.

Typical values for SDTV

- Movie channel – 4 Mbps
- Variety channel – 5 Mbps
- Sports channel – 6 Mbps

[illegible]

[illegible]

5.7 MPEG COMPRESSION STANDARDS

MPEG is a group within the ***International Standards Organization*** and the ***International Electrochemical Commission (ISO/IEC).*** This ISO/IEC defines the standards for the transmission and storage of moving pictures and sound.

- These standards are concerned only with the bit stream syntax and the decoding process.
- The syntax covers bit rate, picture resolution, time frames for audio and the packet details for transmission.
- The currently available MPEG standards are MPEG -1, MPEG -2 , MPEG -4 and MPEG – 7.

In DBS systems,

- MPEG – 2 → used for video compression
- MPEG – 1 →used for audio compression

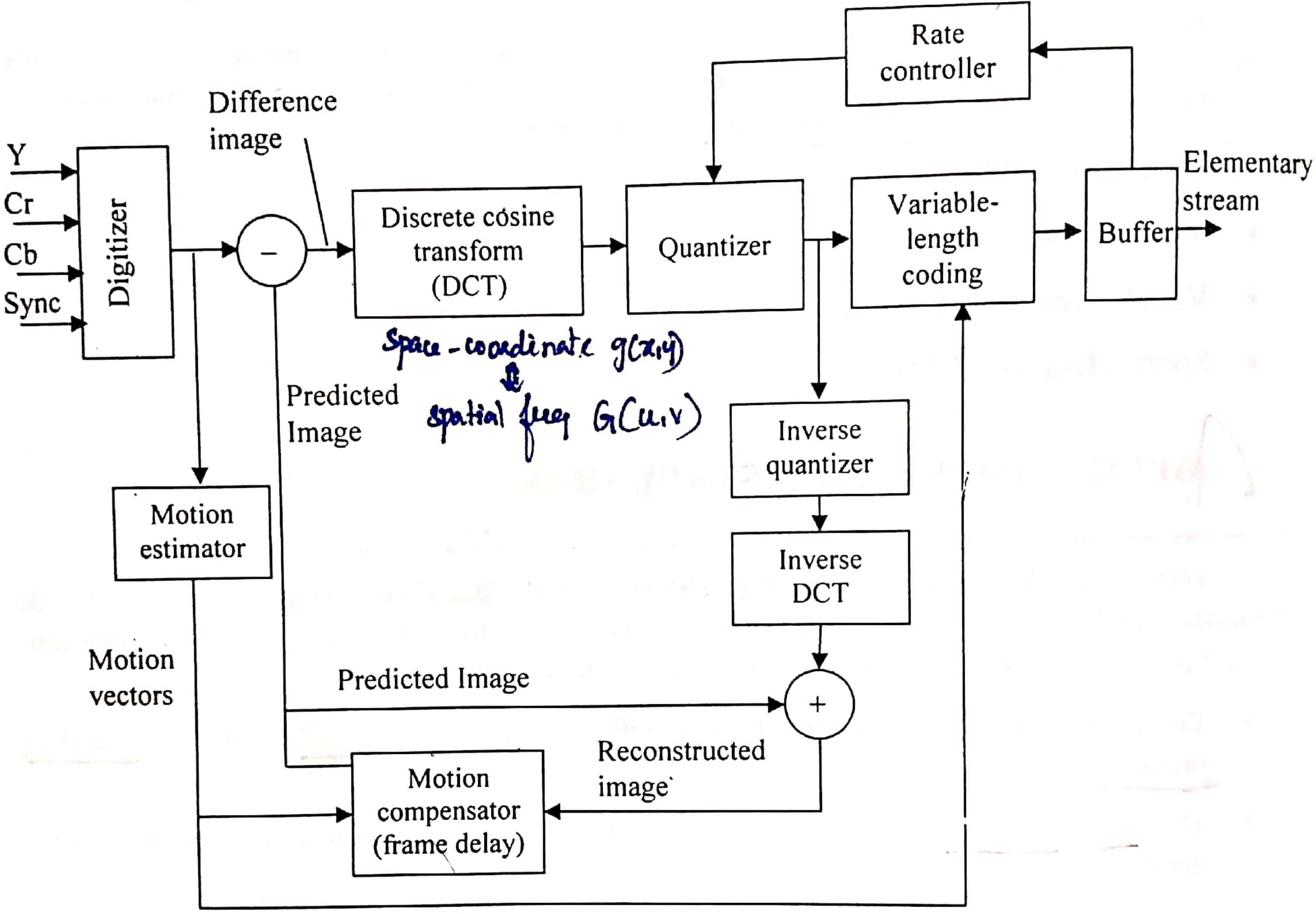
5.7.1 Video Compression

MPEG – 2 is used for video compression in DBS systems. The block schematic is shown in fig 5.3.

i. ***Preprocessing step***

As a first step, the analog outputs from red (R), green (G) and blue (B) cameras are converted to a luminance component (Y) and two chrominance components (C_r and C_b). In matrix notation, the Y, Cr and Cb components and the three primary colors R, G, B are related as,

$$\begin{bmatrix} Y \\ C_r \\ C_b \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.418688 & -0.081312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad \text{—— (5.4)}$$



Space-coordinate $g(x,y)$
$\Updownarrow$
spatial freq $G(u,v)$

Figure 5.3 MPEG -2 encoder paths

ii. Digitizer

The Y, C_r and C_b analog signals are sampled in the digitizer. Since, human eye is less sensitive to the resolution in C_r and C_b, lower sampling rate is used for these color components. This is known as ***chroma subsampling***.

Y: U: V Ratio

Sampling is indicated by this Y:U:V ratio, where,

Y → luminance or luma sampling rate

U → C_b sampling rate

V → C_r Sampling rate

The commonly used ratios in digital TV are

4 : 4 : 4 →	Means that the sampling rate of Y, C_b, C_r are equal. Each pixel would get 3 digital words, one for each component signal.
4 : 2 : 2 →	Means the C_b and C_r are sampled at half the sampling rate. Every two pixels would have 2 bytes for Y, 1 byte for C_b and 1 byte for the C_r signal.
4 : 2 : 0 →	Means that C_b and C_r are sampled at half the Y sampling rate, but they are sampled on alternate scan lines only. Thus vertical and horizontal resolution is reduced by half

iii. *Discrete Cosine Transform (DCT)*

The inputs to the DCT block are difference signals as shown in the fig 5.3. The DCT transforms these space coordinates g(x, y) into spatial frequencies G (u,v) in the spatial domain.

ie. $$g(x,y) \overset{\text{DCT}}{\Leftrightarrow} G(u,v)$$

All the variables here are discrete functions

iv. *Quantizer*

The quantizer quantizes the discrete values of G(u,v) into predetermined levels. This provides compression by reducing the number of levels to be transmitted.

v. *Motion Estimation*

Motion estimation is also used to achieve compression. This process leads to 3 basic types of encoded output ***frames***. They are:

I frame →	Independent or Intra frame; it can be reconstructed without referring any other frame
P frame→	Previous or Predictive frame; It is compared as macroblocks with the previous I frame. If there is any change, only that frame is encoded
B frame→	Bidirectional frame; It is compared with the previous I or P frame and with the next P frame. Only the changes resulting are encoded. This leads to further compression.

vi. *Encoding and Decoding*

Encoding process is complex and expensive. It depends on the digital decision making circuitry.

Decoding process is much simpler and it is carried out in the integrated receiver decoder (IRD) unit.

5.7.2 Audio Compression

MPEG-1 is used for audio compression in DBS systems. This supports mono ie. single and two channel stereos.

5.7.2.1 Need for Audio Compression

The need can be known by considering the bit rate required for high quality audio. The ***bit rate*** is given by

$$R_b = f_s \times n \qquad \text{\_\_\_\_\_ (5.5)}$$

Where, f_s → sampling frequency

n → number of bits per sample

For stereo CD recording, $f_s = 44.1$ kHz and $n = 16$. Since stereo has two channels,

$$R_b = 44.1 \times 10^3 \times 16 \times 2$$

$$= 1411.2 \text{ kbps}$$

$$\approx 1.4 \text{ Mbps}$$

This is very high compared to the total bit rate allowed per channel. Therefore, audio compression is also needed.

5.7.2.2 Frequency Masking

Frequency masking is an important ***perceptual phenomena*** in the human auditory system which is used in audio compression.

i. Masking Threshold

A loud sound at one particular frequency will mask a less intense sound at a nearby frequency. The loud tone is known as the ***masking tone*** and the tone being masked is known as the ***test tone***. The dB level at which the test tone becomes inaudible is known as the masking threshold.

ii. Signal-to-quantization Noise Ratio

The noise may arise from quantization process. The signal to quantization noise ratio is given by

$$\left[\frac{S}{N}\right]_q = 2^{2n} \qquad \text{\_\_\_\_\_ (5.6)}$$

Where, n → number of bits per sample

In decibels,

$$\left(\frac{S}{N}\right)_q = 10 \log 2^{2n} \qquad \text{\_\_\_\_\_ (5.7)}$$

$$\cong 6n \text{ dB}$$

Therefore, 1-bit decrease in 'n' increase the quantization noise (N) by 6 dB.

iii. Temporal Masking

If the effect of masking lasts in a short period after the masking signal is removed, it is known as temporal masking.

5.7.2.3 MPEG-1 Schematic

In MPEG-1 , two processes take place in parallel as shown in fig 5.4.

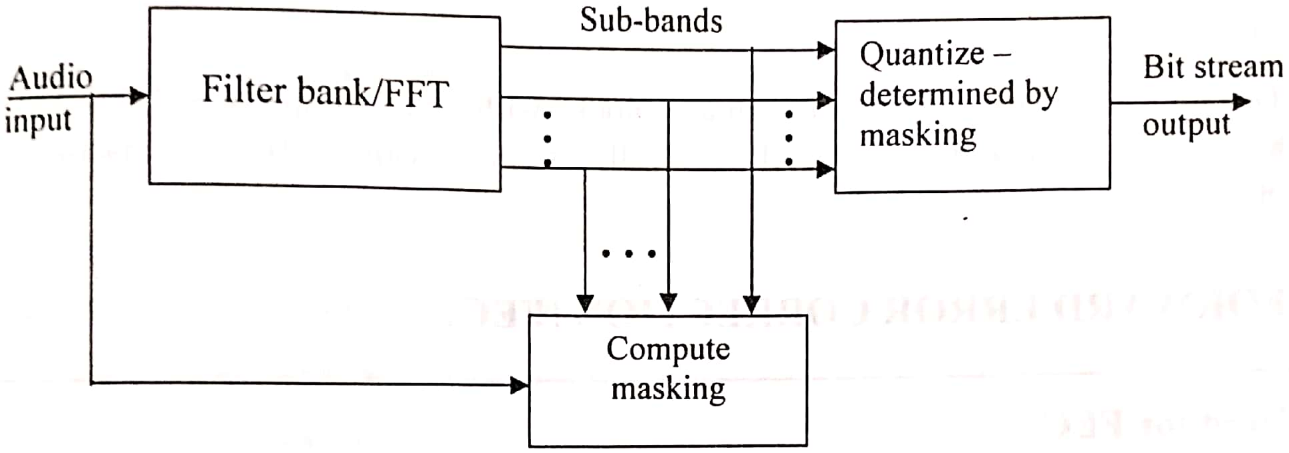


Figure 5.4 Block Schematic of MPEG -1

Here, the filter bank divides the spectrum of the incoming signal into subbands. In parallel with this, the spectrum is analyzed for masking levels. Then the masking information is passed to the quantizer. The quantizer quantizes the subbands according to the noise factor.

5.7.3 MPEG-4

MPEG – 4 was developed by the ***Video Coding Experts Group (VCEG)*** of the International Telecommunication Union (ITU) and Telecommunication Standardization Sector (ITU-T). MPEG-4 is also known as H.264, ISO/ISE 14496-10 etc.

Applications

The areas of application of MPEG-4 include:

- Video telephony
- Video storage and retrieval
- Digital video broadcast etc

Matrix Notation

Similar to the matrix in eqn. (5.4) for MPEG-2, the three primary colors red (R), green (G), blue (B), the luminance component (Y) and the chrominance components C_r and C_b can be related as

$$\begin{bmatrix} Y \\ C_r \\ C_b \end{bmatrix} = \begin{bmatrix} 0.2126 & 0.587 & 0.0722 \\ -0.119977 & -0.331264 & 0.523589 \\ 0.561626 & -0.418688 & -0.051498 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \text{\_\_\_\_\_ (5.8)}$$

Advantages

- Interactivity for viewer is provided where objects within a scene can be manipulated from the point of view of satellite television. This facility is not available in MPEG-2.
- Bit rate is very much reduced.
- This allows for comparisons of submacroblocks with pixel groups 16 × 8, 8 × 16, 8 × 8, 8 × 4, 4 × 8 and 4 × 4. But MPEG-2 allows comparison of 16 × 16 macroblocks only

5.8 FORWARD ERROR CORRECTION (FEC)

5.8.1 Need for FEC

FEC is a must, because,

- Since the DBS signal is highly compressed, there is a little ***redundancy*** in the information being transmitted.
- Compressed signal is more severely affected by ***bit errors*** than a non compressed bit stream.

5.8.2 Concatenated coding

Concatenated coding is used for FEC. The two codes are concatenated as below.

- The ***outer code*** is a Reed-Solomon Code
    - This corrects block errors and the inner decoder utilizes the Viterbi decoding algorithm.
- The ***inner code*** is a convolution code
    - This corrects random errors.

5.8.3 Coding Overheads

The FEC bits add overhead to the bit stream.

- The ***high power*** 240W transponders with 40Mbps bit capacity may have a payload of 30 Mbps and coding overheads of 10 Mbps
- The ***low power*** 120W transponders have a payload of 23 Mbps and coding overheads of 17Mbps. They have high overheads for compensating the low power.

UNIT V – SATELLITE SERVICES

PACKET SATELLITE SERVICES

- The satellite system using packet communication is usually in the form of networks and the most common name of such networks is packet satellite networks. These networks use packet switching for accessing the satellite channel.
- The first kind of such packet network was ARPANET but the use of satellite for packet communication started with the development of ALOHA systems.
- Packet switching involves dividing the data messages into small bursts or information and transmitting them through communication networks to their intended destinations using computer controlled switches.
- A variety of data formats and services may be provided by satellite networks. These may be such as telephony signals, TV (Visual and audio) signals, computer generated signal(computer communication), broadcast data for computer communications, teleprinter, larger screen teleconferencing, interactive education, medical data, emergency services, electronic mail, newspaper boardcast, control data for power systems and utilities, traffic information, weather and land surveillance,navigational data for ships and airplanes and military strategic data
- Satellite channel used with packet switching employs random access. Each station tries to access the satellite through random access in time domain and thus it is multi access broadcast type. In the basic form of random access no network timing is present and each station transmits bursts of packets as necessary at random and some bursts overlap.
- Random access is inefficient because retransmission must occur when packets collide and hence modifications in ALOHA systems have also been developed.

ALOHA

- Here the packets are not being sent in FDMA or TDMA i.e. the user does not wait his 'turn' as in TDMA nor is he assigned a narrow bandwidth as in FDMA. Each station transmits a packet whenever its buffer has one and the stations do not need synchronization.
- The random multiple access schemes works on four different steps, namely the transmission, listening, retransmission and time out. In the transmission step which is the first step, users transmit at any time they desire encoding their transmission with an error detection code.
- In the next step known as listening, the user listens an acknowledgement (ACK) from the receiver. There is a possibility that the packets sent from the different terminals may overlap and result in transmission error. For such a situation of overlapping packets are said to have *collided* and the users receive a negative acknowledgement (NAK).
- After having received NAK, the third step of random access technique is followed by retransmission of collided packets. In order that these retransmitted packets may not collide again, the interval of packet retransmission is randomized in each terminal. In other words now the users retransmit after a *random delay.*

- In case if after a transmission the user does not receive either an ACK or NAK within a specified time, the user retransmits the message. This is the final step of random multiple access and is termed time out. T
- The analysis of ALOHA system involves message arrival statistics. Thus in the above pure ALOHA system only 18% of the channel capacity would be utilized. In other words though in such random access technique control mechanism is simple, the channel capacity gets wasted (or not fully utilized).

Slotted ALOHA (S-ALOHA)

- To improve the usage of channel capacity of Pure ALOHA stem, discussed above, a technique termed *slotted* ALOHA (S-ALOHA) is being utilized. Here a sequence of synchronization pulses is broadcast to all stations and the messages are required to be sent in the slot time between synchronization pulses.
- Messages are transmitted only at the beginning of a time slot and as with the pure ALOHA, packet lengths are constant. This technique reduces the collision rates of packets by half since only messages transmitted in the same slot can interfere with one another.
- A sequence of synchronization pulses is broadcast to all stations and the messages are required to be sent in the slot time between synchronization pulses. It must be remembered that the messages can be started only at the beginning of a time slot and as with the pure ALOHA, packet lengths are constant. This technique reduces the collision rates of packets by half since only messages transmitted in the same slot can interfere with one another.
- The plot of Normalized traffic Vs normalized throughput is shown in fig. Here the maximum value of p is 1/e = 0.37 which shows an improvement of two times over pure Aloha system.
- Thus in slotted Aloha if a negative Acknowledgement (NAK) occurs; the user retransmits after a random delay of an integer number of slot times.
- The slotted Aloha shows only 36% utilization of the satellite channel.

Reservation-ALOHA(R-ALOHA)

- To increase the utilization of this channel capacity in ALOHA system another scheme known as reservation-ALOHA(R-ALOHA) was utilized.
- The objective of this slot reservation scheme is to reserve a particular time slot for a given station which would ensure that no collision would take place. This reservation of time slot would result in some overhead cost and/or increased complexity of the control mechanisms intransmitting stations.
- These reservation schemes in Aloha system may be implicitor explicit .Actually it is the implicit reservation scheme of Aloha protocol that is called R-ALOHA. In this scheme whenever a station successfully transmits its packets in a slot, all the stations internally assign that slot in subsequent frames for exclusive use by the successful station.

CARRIER SENSE MULTIPLE ACCESS (CSMA):

- In the CSMA collisions of packet are avoided by listening to the carrier due to transmission from another user before transmitting and inhibiting transmission if the channel is sensed busy. Alternately in the carrier sense multiple access (CSMA) scheme each user tunes a receiver to the common carrier frequency employed by all the users.

- Before transmitting, a user will listen, to determine if any of the otherusers is transmitting.If no other user is transmitting he will transmit his packets. In case there is no collision between packets, throughput in CSMA may reach unity.
- CSMA being used in Computer Communication can be*nonpersistent or persistent* type.
- Nonpersistent type is the simplest one and the transmission of packets is done by the user only when the channel is found to be idle.
- Persistent CSMA is of several types such as 1-persistent of p-persistent etc. p is the probability that a ready packet persists.
- Further improvement has been obtained by the detection of collisions too. This is known as Carrier Sense Multiple Access with Collision Detection(CSMA-CD).In this technique when transmitting users detect interference among several transmissions(including their own),they abort the transmission of colliding packets.

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- CSMA being used in Computer Communication can be*nonpersistent or persistent* type. Nonpersistent type is the simplest one and the transmission of packets is done by the user only when the channel is found to be idle.
- Persistent CSMA is of several types such as 1-persistent of p-persistent etc. p is the probability that a ready packet persists. But in these techniques too there is some chance of packet collisions.
- Further improvement has been obtained by the detection of collisions too. This is known as Carrier Sense Multiple Access with Collision Detection(CSMA-CD).In this technique when transmitting users detect interference among several transmissions(including their own),they abort the transmission of colliding packets.

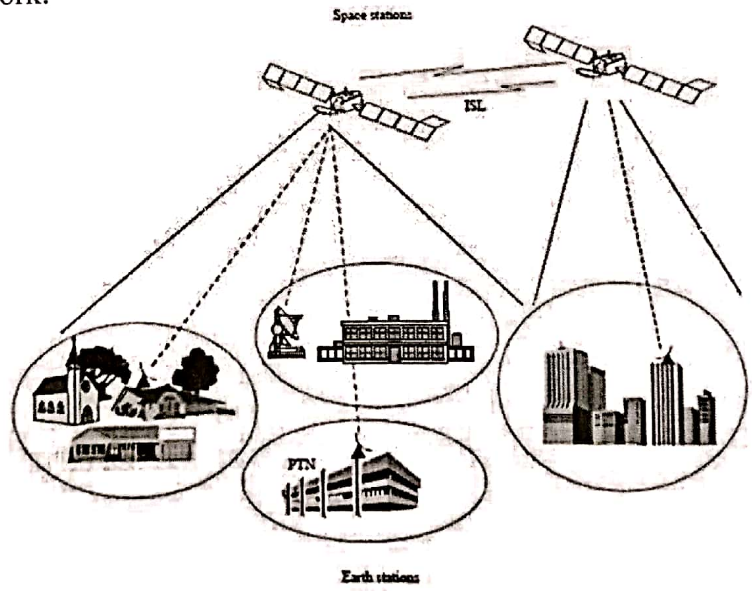
PACKET NETWORK STANDARDS

- **ALOHA.** As mentioned earlier it is a satellite based network developed in 1970 at the University of Hawaii. Its experiments were widely know as PACSAT experiments and utilized packet switching for the first time in satellite communication systems.
- **SATNET.** It is Atlantic packet satellite network. In fact it was the most expensive field trail as of 1979 of packet satellite concept, designs, developments and international cooperation.
- **WDPSN.** It is wideband domestic packet satellite network. It uses SATNET technology in US Domestic PSN.
- **Data Retransmission.** Here random access protocol is used and the satellite systems such as LANDSAT, NOAA/GOES etc use it.

- **GPSN.** It is a general purpose packet satellite network.
- **SARSAT.** It is search and rescue Satellite Aided Tracking System.

FIXED SATELLITE SERVICES

- According to the Radio Regulations, the FSS is a radio communication service between given positions on the Earth's surface when one or more satellites are used. These stations located at given positions on the Earth's surface are called earth stations of the FSS.
- The given position may be a specified fixed point or any fixed point within specified areas. Stations located on board the satellites, mainly consisting of the satellite transponders and associated antennas, are called space stations of the FSS.
- At the present time, with very few exceptions, all links between a transmitting earth station and a receiving earth station are effected through a single satellite. These links are comprised of two parts, an uplink between the transmitting station and the satellite and a downlink between the satellite and the receiving station.
- In the future, it is envisaged that links between two earth stations could use two or more satellites directly interconnected without an intermediate earth station. Such a link between two earth stations using satellite-to-satellite links would be called a multi-satellite link.
- The satellite-to-satellite links will form a part of the inter-satellite service (ISS). Inter-satellite links (ISLs) of the ISS may be employed to provide connections between earth stations in the service area of one satellite to earth stations in the service area of another satellite, when neither of the satellites covers both sets of earth stations.
- A set of space stations and earth stations working together to provide radio communications is called a satellite system. For the sake of convenience, a distinction 94 is made in the particular case of a satellite system, or a part of a satellite system, consisting of only one satellite and the associated earth station which is called a satellite network.



Generic illustration of FSSM

- The FSS also includes feeder links, i.e. links from an earth station located at a specific fixed point to a space station, or vice versa, conveying information for a space radio communication service other than for the FSS. This category includes, in particular, uplinks to the satellites of the broad casting satellite service (BSS) and up and downlinks between fixed earth stations and satellites of the mobile satellite service (MSS).

- All types of telecommunications signals can be transmitted via FSS links: telephony, facsimile (fax), data, video (or a mix of these signals in the framework of integrated services data networks (ISDN)), television and sound programmes, etc.
- The latest communications satellite generations, operating in FSS frequency bands are equipped with high-power transponders, which makes it possible to implement broadcasting services direct to the general public for individual reception (direct-to-home (DTH) applications) through very small receiving antennas (television receiving only (TVRO)), and for community reception (professional applications and domestic applications).

SATELLITE MOBILE SERVICES

Still there are large areas and population groups that have very limited access to telecommunication services. This is the main reason for the development of satellite mobile services.

Advantages of Satellite Services

1. Ground facilities are not needed for satellite services. But, developing a telephone network on the ground is time consuming and expensive either it is wired or cellular.
2. Also, civil infrastructure needs installation or upgradation including roads and utilities such as water and electricity. There is no need for these in satellite services.
3. Once satellite are deployed in orbit, they can provide wide area service for telephone, facsimile and internet whenever needed.

GSM

Most of the systems provide telephone services with dual mode phones that operate to GSM standards.

1. GSM stands for global system for mobile communications. It was orginally, group special mobile.
2. It is the most widely used standard for cellular and personal communications.
3. Frequency bands used: L band (1-2 GHZ)
   S band(2-4 GHZ)

The three different satellite mobile services which are explained below are

1. Asian cellular system
2. Thuraya
3. MSAT

ASIAN CELLULAR SYSTEM(AceS)

Some of the features of AceS are:

SATELLITE USED : Garuda geosynchronous satellite

LOCATION OF SATELLITE : 123^0E longitude $\pm 3^0$N and S

SATELLITE CAPACITY : 11,000 simultaneous telephone channels

ANTENNAS USED : Two 12 meter, L-band antennas that generate 140 spot beams

AREA COVERAGE : Asia pacific area of 11 million square miles.

FOOTPRINT RANGE : China in the north to Indonesia in the south: philippiness and papua, New Guinnia in the east to India and Pakistan in the west.

SERVICES : Voice telephony, internet connectivity, data and alerting and paging

STATION KEEPING : Achieved by N-S station keeping maneuvers; since there is no needfor fuel for these maneuvers, weight is saved and thuscommunication payloadcan be increased.

FREQUENCIES USED : A) for mobile links → L-band

Uplink: 1625.5-1660.5MHZ
Downlink: 1525-1559MHZ

B) for gateway services which provide access to the national telephone networks → C-band

Uplink: 6.425 – 6.725GHZ

Downlink: 3.400 – 3.700GHZ

ONBOARD DIGITAL SWITCHING is provided to route calls between beams

DUAL-MODE PHONE is provided that can be switched between satellite and modes of operation.

THURAYA

The important features of thuraya satellite system are

SATELLITES USED: geosynchronous satellites

a) Thuraya 1- launced on october 21,2000

b)Thuraya 2- launced on june 10, 2003

c)Thuraya 3- being built

LOCATION OF SATELLITE : $44^0 and 28.5^0$E longitude, 6.3^0 inclination.

METWORK CAPACITY : 13,750 telephone channels

ANTENNAS USED : $12.25 \times 16m$elliptical antenna that generates 250 to 300 spot beams.

AREA COVERAGE : between $20^0 wto100^0 Elongitudeand60^0 Nto2^0 S$ latitude.

FOOTPRINT RANGE : Spans to Europe, north, central Africa and large parts of southern Africa

SERVICES : Voice telephony, fax, data, short messaging, location determination, emergency services and

STATION KEEPING : Achieved with N-S station- keeping maneuvers

FREQUENCIES USED : A) For mobile links→ $Lband$

Uplink: 1625.5 – 1660.5 MHZ

Downlink: 1525 – 1559 MHZ

B) gateway frequencies → $c - band$

Uplink: 6.425 – 6.725 GHZ

Downlink: 3.400 – 3.700 GHZ

DUAL-MODE HANDSETS are used that can be switched between GSM and satellite mode.

MODULATION USED : Quaternary phase shift keying with frequency division multiple access (FDMA) / Time Division multiple access (TDMA).

The system operates with a 10-db fade margin to allow for shadowing of handheld units.

MSAT

This system is operated by Mobile Satellite Ventures (MSV) which has offices in reston, VA, Ottawa, Ontario and Canada. Satellite operation and maintenance is carried out by Telesat, Canada. Some of the features of MSAT are:

SATELLITES USED: two geostationary satellites

a) MSAT -1
b) MSAT-2

ANTENNAS USED: two 5.7m ×4.7m L-band msh reflector antennas with EIRP of 57.3 dbw.

AREA COVERAGE: north and central america, northern south america, the caribbean, hawaii and coastal waters.

SERVICES: tracking and managing trucking fleets, wireless phone, data and fax, dispatch radio services and differential GPS .

FREQUENCIES USED: for satellite services – L band

Uplink: 1631.5 – 1660.5 MHZ

Downlink: 1530 – 1559 MHZ

For feeder links to the ground segment which connects public and private telephone and data networks Ku band.

Uplink : 13.0 – 13.15 GHZ and 13.2 to 12.5 GHZ

Downlink : 10.75 – 10.95 GHZ

TRANSPONDER: 2 FOR Ku- band to L band forward link;

1 for L-band to Ku band return link

POWER OUTPUT: L band – 600w

Ku band – 110w

VSATs:

VSAT stands for very small aperture terminal system. The specialty of this system is that the size of the earth station antennas used are less than 2.4m in diameter. The concept behind most VSAT system is to give telecommunications service directly to the end user without any intermediate distribution hierarchy.

Users:

User groups of VSAT systems include.

- Banking and financial institutions
- Airline and hotel booking agencies and
- Large retail stores with geographically dispersed outlets

Hub Stations:

The basic structure of a VSAT network consists of a hub station which functions as follows:

- Hub station provides broadcast facility to all the VSATs in the network.
- The service provider operates the hub station.
- It could be shared among a number of users.
- The downlink transmission from hub to the VSATs is done by TDMA.
- Address coding can also be used to direct messages to selected VSATs from the hub.

Basic Techniques:

Accessing the hub from VSATs is a very complicated task. Some of the methods used for this are:

1. Frequency-Division Multiple Access (FDMA)

2. Time-Division Multiple Access (TDMA)

3. Demand Assigned Multiple Access (DAMA)

4. Code-Division Multiple Access (CDMA)

1.Frequency Division Multiple Access

This is the most popular access method and it allows the use of low power terminals.

2. Time Division Multiple Access

This method is not efficient for low density uplink traffic from the VSAT. If the traffic is data transfer of a bursty nature, then TDMA mode leads to low channel occupancy.

Example for **bursty data transfer**

- Inventory Control
- Credit verification
- Reservation requests
- Infrequent intervals

3. Demand Assigned Multiple Access

This method is used in some systems where the channel capacity is assigned according to the varying demands of the VSATs in the network. DAMA can be used with FDMA and TDMA.

Disadvantages

VSATs should make requests for channel allocation. For this purpose, a reserve channel is needed to be established in this method and this channel should be accessed efficiently.

4. Code Division Multiple Access

This method is presented by Abramson (1990).It uses spread spectrum techniques with the Aloha protocol.

Aloha Method

- This is a random access method.
- In this method, packets are transmitted at random in defined time slots.
- It is used where the packet time is smaller than the slot time.
- Packet collisions can also be dealt.
- It provides the highest throughput for small earth stations.
- This method is called '***spread Aloha***' by Abramson.

Network Configuration

Two main configurations of the VSAT network are:

1. Star configuration
2. Mesh configuration

1. Star Configuration

Here, the connection of one VSAT to another is made through a hub.So, a double hop circuit is required. The topology of star network is shown in fig.5.7.

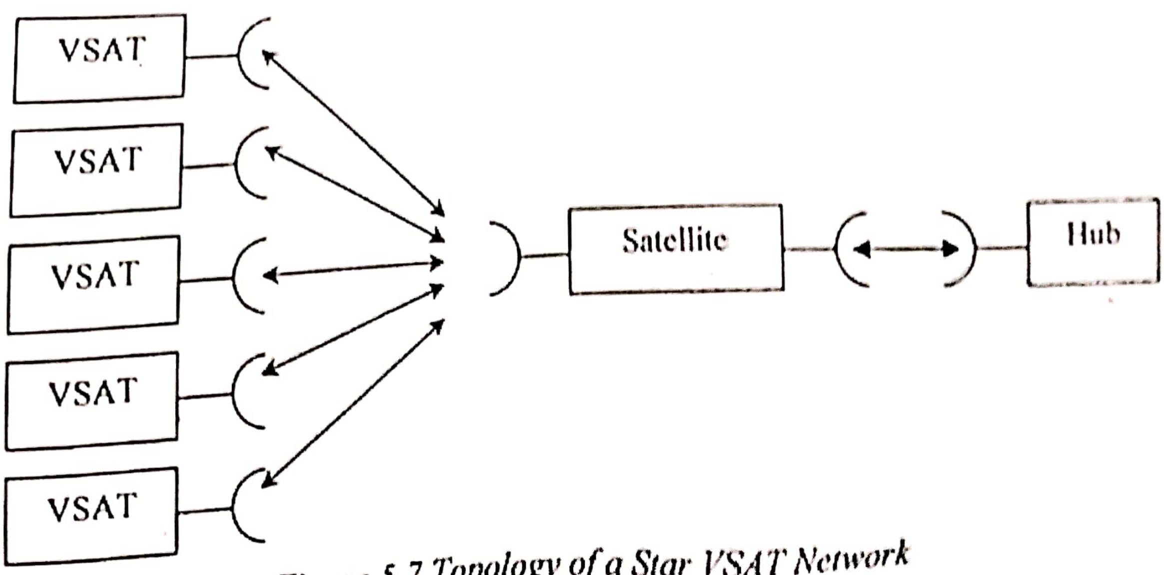


Figure 5.7 Topology of a Star VSAT Network

Disadvantage

The propagation delay and the needed satellite capacity is increased than a single hop circuit.

2. Mesh Configuration

In this configuration, the VSATs are connected to each other through the satellite in a single hop. The topology of such a network is shown in fig.

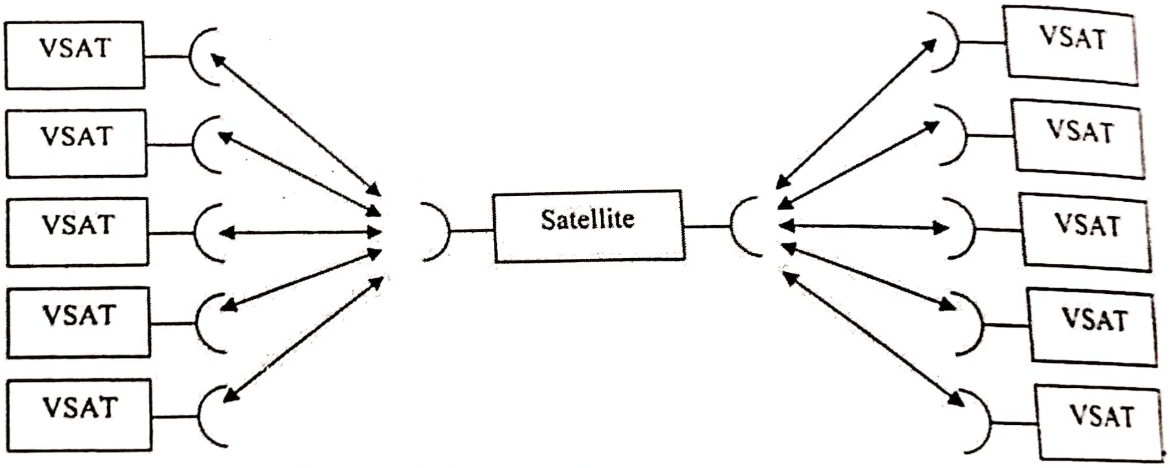


Figure 5.8 Topology of a Mesh VSAT Network

Fixed-Area Coverage - Advantages

Ku band is used for the operation of most VSAT systems. The following are the advantages of fixed area coverage by the satellite beam.

- System performance is independent of the carrier frequency.
- Beamwidth and k/D ratio are constant.
- Satellite antenna gain is constant.
- For a given HPA output, satellite EIRP remains constant.

- For a given earth - station antenna size and fixed EIRP, the received power at the earth station is independent of frequency.

Drawbacks of VSAT Systems

(i) High initial costs

(ii) The tendency towards optimizing systems for large networks (>500 VSATs).

(iii) No direct VSAT-to-VSAT links are available.

GLOBAL POSITIONING SATELLITE SYSTEM (GPS)

In the GPS system, at an altitude of 20,000 km, a constellation ie. a group of 24 satellites circle the earth in six near circular inclined orbits, with 4 in each orbit. The ascending nodes of the orbits are separated by 60° and the inclination of each orbit is 55°. By receiving signals from any four of these satellites, the receiver position in latitude, longitude and altitude can be determined accurately.

Terrestrial Surveying Method

In terrestrial surveying method, geodetic position markers are used instead of satellites. In this method, it's enough to have only 3 markers to determine the latitude, longitude and altitude. This is done by means of triangulation.

But in GPS, a time marker is also required in addition with the position markers to get simultaneous measurements from 4 satellites.

Requirements

- The GPS system uses one-way transmissions ie. from satellites to users. Therefore, the user needs only a GPS receiver, not a transmitter.
- The receiver should be able to measure time. From this time, the propagation delay and hence the range to each satellite can be determined.
- Each satellite broadcast its ephemerisie the table of its orbital elements. From this, the satellite position can be calculated. From all these, the position of the observer (user) can be computed accurately.

ECEF Coordinate System

The GPS uses the geocentric-equatorial coordinate system. It is called the earth-centered, earth fixed (ECEF) coordinate system. Here, the range from an observer to a satellite ρ_{on} is obtained from,

$$\rho_{on}^2 = (x_n - x_o)^2 + (y_n - y_o)^2 + (z_n - z_o)^2 \qquad -(1)$$

Where,(x_n, y_n, z_n) –Coordinates for the satellite 'n'

(x_o, y_o, z_o) – Coordinates for the observer 'o'

Using this, the position of the observer can be calculated.

Since the satellites are moving, their positions must be tracked accurately. Also, the satellite orbits can be predicted from the orbital parameters and these parameters are continually updated and sent to the satellites by a master control station.

GPS Transmitter and Receiver

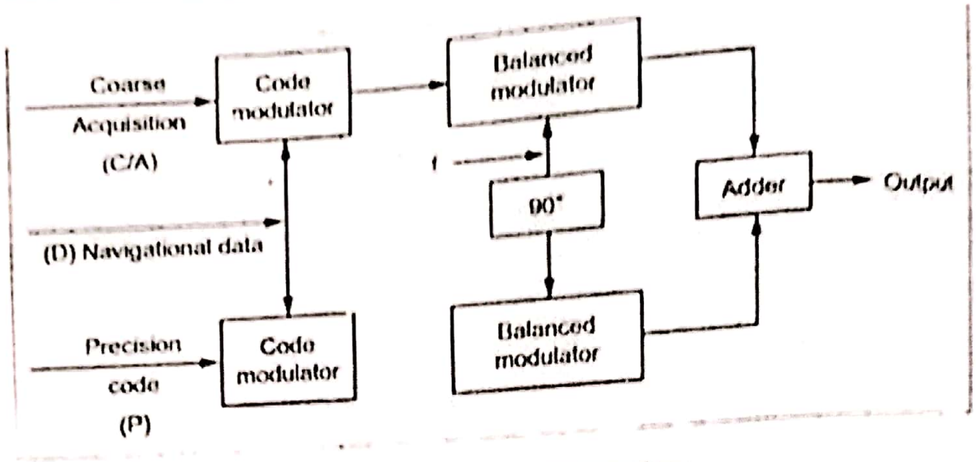


Fig. 8.9. GPS signal generator

GPS RECEIVER

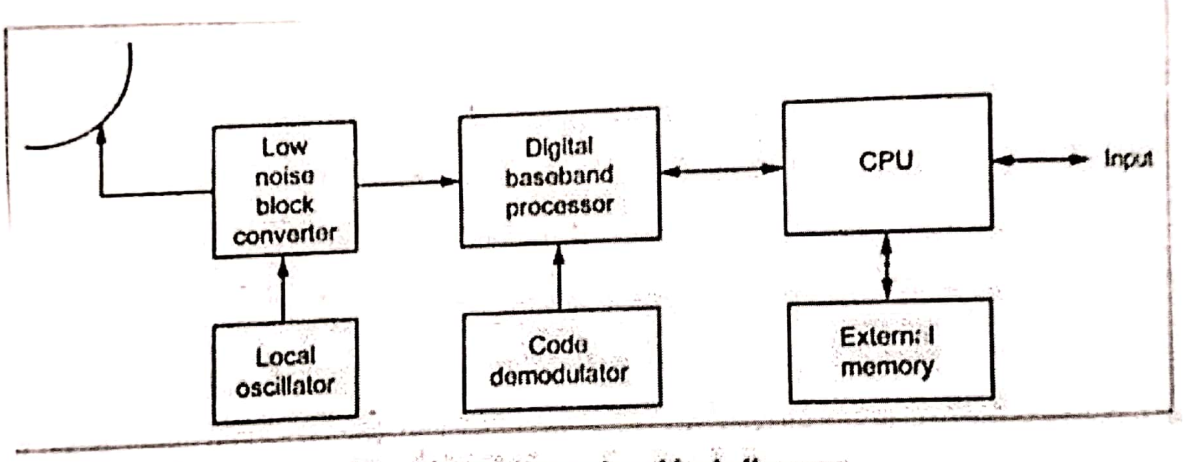


Fig. 8.10. GPS receiver block diagram

DOP Factor

Better accuracy in the GPS system is obtained by using reference points which are well separated in space. Position calculations involve range differences. Therefore, if the ranges are nearly equal, any error will be magnified in the difference. This is because of the satellites geometry known as dilution of precision (DOP). The range errors occur from any causes like timing errors are magnified by this geometric effect.

PDOP factor

In the GPS system, the dilution of precision is taken into account through a factor known as the ***position dilution of precision (PDOP)***. The GPS system is designed to keep the PDOP factor less than 6. Also, the 4 satellites in each orbit are irregularly spaced to keep the PDOP factor within the limits. The position error can be obtained as, Range error x PDOP factor = Position error (2)

Time plays an Important role in the position determination in two ways:

- GPS time
- Time markers

GPS Time

The ***standard timekeeper*** is an atomic standard which is maintained at the U.S. Naval observatory and the resulting time is known as GPS time.

- Each and every satellite carries its own atomic clock.
- The control station monitors the time broadcast from the satellites.
- If there is any error relative to the GPS time, it will be detected and sent back to the satellites.
- The satellites rebroadcast the error information to the user stations.
- User stations make the corrections in the calculations. Therefore, the satellite position relative to the ECEF coordinate system will be accurately known.

Time Markers

- The time at which transmissions leave the satellite is shown by the time markers. Then, by measuring the propagation delay and speed of propagation, the ranges can be determined. But, there is no direct way to know the time at which transmissions start from the satellite. This problem can be overcome by the following process.
- The satellite transmits a continuous wave carrier
- The wave is modulated by a pseudo random code; the timing for the carrier and the code is derived from the atomic clock.
- At the user station, a replica ie. duplicate of the modulated signal is generated by the receiver from its own, nonatomic clock.
- A ***correlator*** correlates the generated signal and the received signal.
- Now, a delay is introduced into the replica signal path and it is adjusted until the two signals show maximum correlation.
- If the receiver clock and satellite clock timings are same, the delay in replica path would be equal to the propagation delay.

Location Determination

Assume that there is some unknown difference Δt between the start times of satellite clock and receiver clock. The difference can be calculated from.

$$t_n = t_{dn} - \Delta t \qquad (3)$$

Where,t_n-True Propagation time from satellite 'n' to the observer

t_{dn}-delay time measured by the correlator

Now, the range to the satellite 'n' is,

$$\rho_{on} = ct_n = c(t_{dn} - \Delta t) \qquad (4)$$

Where,c-speed of light

Substituting eqn (4) in (1) gives,

$$(x_n - x_o)^2 + (y_n - y_o)^2 + (z_n - z_o)^2 = c^2(t_{dn} - \Delta t)^2$$

$$(x_n - x_o)^2 + (y_n - y_o)^2 + (z_n - z_o)^2 - c^2(t_{dn} - \Delta t)^2 = 0 \quad (5)$$

The 4 unknowns here are the observer's location $(x_o, y_o, z_o)$and the time difference Δt. Therefore, the receiver should measure t_{dn}, for four satellites simultaneously. This will give 4 equations in the form of eqn (5).

The equations can be solved to find Δt and $(x_o, y_o, z_o\ )$ which are then converted into local coordinatesie. latitude, longitude and altitude.

Value of c

Since the radio waves travel through the ionosphere and the troposphere, the free-space value for c should not be used. Because, it may introduce errors.

Differential GPS (DGPS)

The satellite clock timing errors and the dilution of precision errors may be combined and set a limit on the accuracy of location determination. Differential GPS is used in places where very ***high accuracy*** is needed.

In this system, ***two receivers*** are used. One of the receiver is placed at an exactly known location. Therefore, all the coordinates are known and the range ρ_{on}can be calculated from eqn (1). Now, the errors can be determined by comparing the reference and the receiver correlator value and they are corrected. The distance between the two receivers may be upto a few 100 kilometers.

ATM over satellite

Asynchronous Transfer Mode (ATM)

- When information is transferred through a network it passes through a number of stages. The information is assembled into *packets*, and in broadband networks the packets are multiplexed to form a single bit stream.
- Then there is the actual transmission of signals from node to node, and at the nodes the signals will undergo some form of switching. The complete process of getting information from source to destination is referred to as a *transfer mode*.
- With the ATM, the packets originating from an individual user do not have to be transmitted at periodic intervals. This is what is meant by *asynchronous*. For comparison, the time division multiplexing described in Sec. 10.4 is a form of *synchronous* transmission.

- Asynchronous transfer mode is commonly denoted by ATM, and the "packets"are known as *cells*. Cells can be given time slots on demand as and when required.
- The ATM is used in terrestrial networks, to carry a mixture of signals, for example voice, data, video, and images.
- A natural development is to extend the ATM networks to include satellite links to bring the services of ATM to remote or isolated users, and also to provide broadcast facilities.
- Satellite links have the additional advantage of enabling *local area networks* (LANs) that are widely separated geographically to be linked together, thus forming a *wide area network* (WAN).
- ATM over satellite is usually abbreviated as SATM in the literature (for satellite ATM). Satellites may be incorporated into ATM networks in a number of ways, but there are certain problems unique to satellite links that have to be addressed in all cases.
- ATM satellite networks can be broadly classified as
    - *bent pipe architecture*
    - *On-board processing architecture*.

Bent pipe architecture

- The satellite acts as a conduit between two earth stations, which may be fixed or mobile.
- Bent pipe *relay architecture* illustrated in Fig.
- This makes use of geostationary satellites, where the satellite link can be thought of as replacing a terrestrial link between two fixed points.
- The satellite link is likely to operate at a lower bit rate than the terrestrial ATM services connecting through it and some rate adaptation will be necessary. This is provided by the modems.
- The *ATM link accelerator* (ALA), provides the adaptive error-control coding mentioned earlier. Cell switching (using the VPI and VCI fields) is carried out at the ATM end stations, not in the satellite.

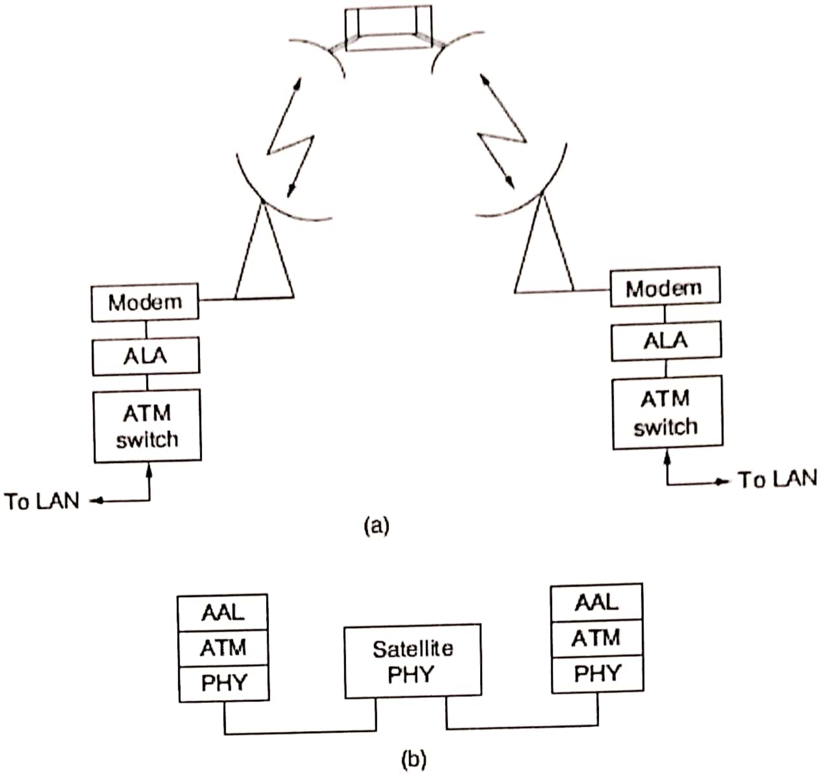


Figure 15.6 (a) "Bent pipe" satellite relay; (b) layer architecture.

On-board processing architecture (OBP)

- With the *on-board processing* architecture, ATM switches form part of the transponder in the satellite, which allows for on-board switching based on the VPI and VCI fields.
- The use of OBP provides greater connectivity, reduces transmission delay, and permits the use of smaller and cheaper user terminals, but of course all this is at the cost of a more complex satellite structure..
- The most complex arrangement, which applies only to OBP satellites, is called *full mesh.* Here the satellites themselves form an ATM network in space, in which the full complement of ATM functions operate.
- This includes traffic switching, flow and congestion control, connection setup and teardown, and quality of service requirements, where mobile operations have to be supported, mobility management functions are provided by a *mobility enhanced UNI layer* at the end

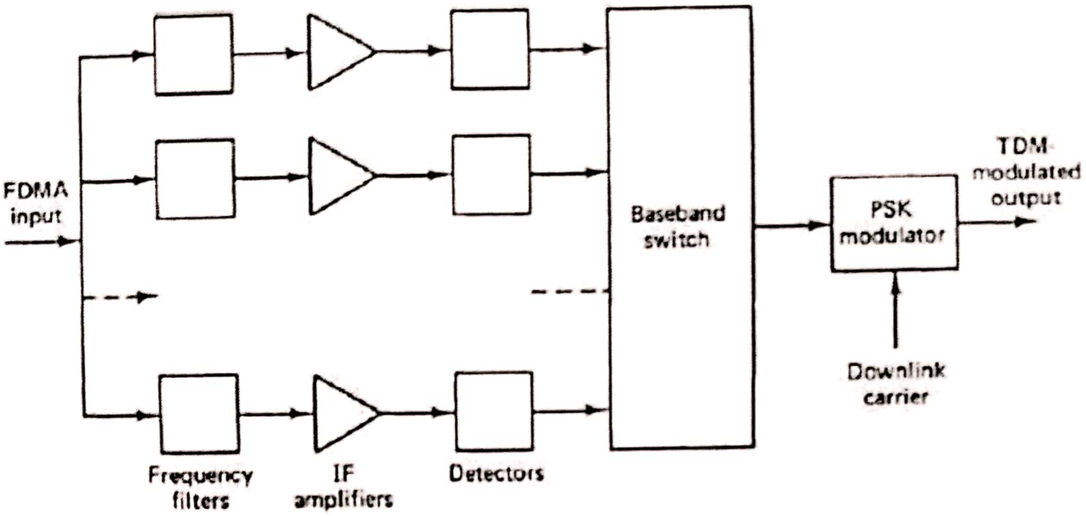


Fig. Conventional on board processing approach

THE FUTURE OF SATELLITE COMMUNICATION

- In a relatively short span of time, satellite technology has developed from the experimental (Sputnik in 1957) to the sophisticated and powerful.
- Future communication satellites will have more onboard processing capabilities, more power, and larger-aperture antennas that will enable satellites to handle more bandwidth. Further improvements in satellites' propulsion and power systems will increase their service life to 20–30 years from the current 10–15 years.
- In addition, other technical innovations such as low-cost reusable launch vehicles are in development. With increasing video, voice, and data traffic requiring larger amounts of bandwidth, there is no dearth of emerging applications that will drive demand for the satellite services in the years to come.
- The demand for more bandwidth, coupled with the continuing innovation and development of satellite technology, will ensure the long-term viability of the commercial satellite industry well into the 21st century. {ANOTHER SOURCE} In recent years, the horizons of mobile satellite communications have been expanding with ever-increasing speed, and there are several different options for the design and capability of new services. The adoption by the IMO Assembly of Resolution A.1001 (25) - Criteria for the Provision of Mobile-Satellite Communication Systems in the Global Maritime Distress and Safety System (GMDSS), provided a clear indication of IMO's intention to consider opening up provision of GMDSS services to any satellite operator whose system fits these Criteria.
- Expansion of the market is most likely to happen in the context of a revision of Chapter IV (Radio communications) of the Safety of Live at Sea (SOLAS) Convention and will provide the opportunity for specifying more effective services in a way that permits the use of evolutionary capabilities and non-geostationary satellite constellations. However, that remains in the future.
- At present, Inmarsat Ltd., with the satellite communications system which it operates, is the sole global provider of these services, although, after the restructuring of Inmarsat, the process of liberalization and privatization of global and regional satellite communications services is fast developing.

FUTURE Satellite Technology

- Tiny earth-orbiting spacecraft known as nanosatellites are now possible due to breakthroughs in micro electro mechanics that permit engineers to build extremely small yet fully functional devices.
- With today's satellite launch costs averaging around $20,000 per pound lifted into space, nanosatellites could revolutionize the future of space access by significantly reducing the size, mass, power requirements, complexity and ultimately the costs of space systems.
- The small satellite concept fosters a faster evolution in space science and introduces and tests state-of-the-art space technology. Of the technologies required to design a miniaturized and yet autonomous vehicle, nanoelectronics is at the forefront. The field of nanoelectronics is primarily concerned with integrated circuit (IC) technology for scale sizes well below 100 nanometres.
- It is in this realm that the quantum - mechanical nature of the electron becomes of paramount importance. With the tools of quantum physics, reduction in the size of individual transistors has yielded the quantum dot; a three-dimensional structure for confinement of a single electron. The theoretical study in this thesis will show that the

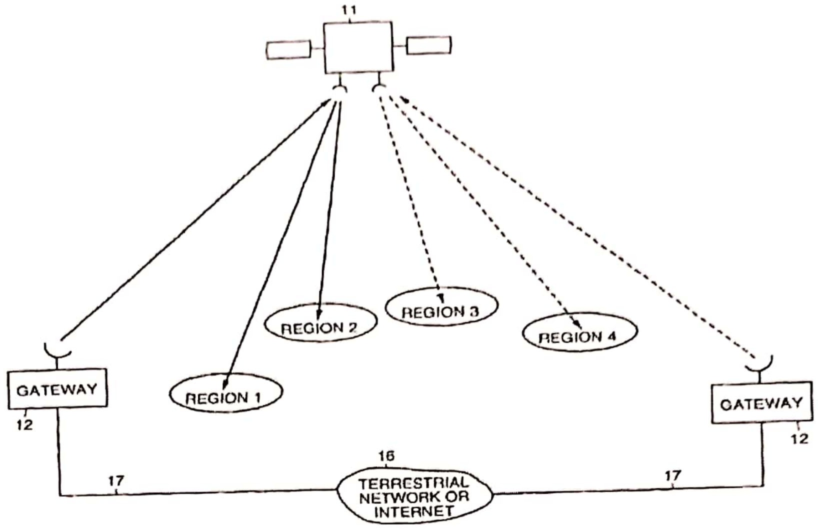
width in p-n junctions is generally underestimated for curved interfaces by textbook formulas.

- This result is significant for semi-cylindrical quantum dots which is the logical result of continued down scaling in semiconductor devices.

GATEWAY

In telecommunications, the term **gateway** has the following meaning:

- In a communications network, a network node equipped for interfacing with another network that uses different protocols.
- A gateway may contain devices such as protocol translators, impedance matching devices, rate converters, fault isolators, or signal translators as necessary to provide systeminteroperability. It also requires the establishment of mutually acceptable administrative procedures between both networks.
- A protocol translation/mapping gateway interconnects networks with different network protocol technologies by performing the required protocol conversions.
- Loosely, a computer or computer program configured to perform the tasks of a gateway. For a specific case, see default gateway.
- Gateways, also called protocol converters, can operate at any network layer. The activities of a gateway are more complex than that of the router or switch as it communicates using more than one protocol.
- Both the computers of Internet users and the computers that serve pages to users are host nodes, while the nodes that connect the networks in between are gateways. For example, the computers that control traffic between company networks or the computers used by internet service providers (ISPs) to connect users to the internet are gateway nodes.
- In the network for an enterprise, a computer server acting as a gateway node is often also acting as a proxy server and a firewall server. A gateway is often associated with both a router, which knows where to direct a given packet of data that arrives at the gateway, and a switch, which furnishes the actual path in and out of the gateway for a given packet.
- On an IP network, clients should automatically send IP packets with a destination outside a given subnet mask to a network gateway. A subnet mask defines the IP range of a private network. For example, if a private network has a base IP address of 192.168.0.0 and has a subnet mask of 255.255.255.0, then any data going to an IP address outside of 192.168.0.X will be sent to that network's gateway. While forwarding an IP packet to another network, the gateway might or might not perform Network Address Translation.
- A gateway is an essential feature of most routers, although other devices (such as any PC or server) can function as a gateway. A gateway may contain devices such as protocol translators, impedance matching devices, rate converters, fault isolators, or signal translators as necessary to provide system interoperability. It also requires the establishment of mutually acceptable administrative procedures between both networks.



- Most computer operating systems use the terms described above. Microsoft Windows, however, describes this standard networking feature as Internet Connection Sharing, which acts as a gateway, offering a connection between the Internet and an internal network. Such a system might also act as a DHCP server.
- Dynamic Host Configuration Protocol (DHCP) is a protocol used by networked devices (clients) to obtain various parameters necessary for the clients to operate in an Internet Protocol (IP) network.
- By using this protocol, system administration workload greatly decreases, and devices can be added to the network with minimal or no manual configurations.