In general terms, a satellite is a smaller object that revolves around a larger object in space. For example, moon is a natural satellite of earth.

We know that Communication refers to the exchange (sharing) of information between two or more entities, through any medium or channel. In other words, it is nothing but sending, receiving and processing of information.

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.

Need of Satellite Communication

The following two kinds of propagation are used earlier for communication up to some distance.

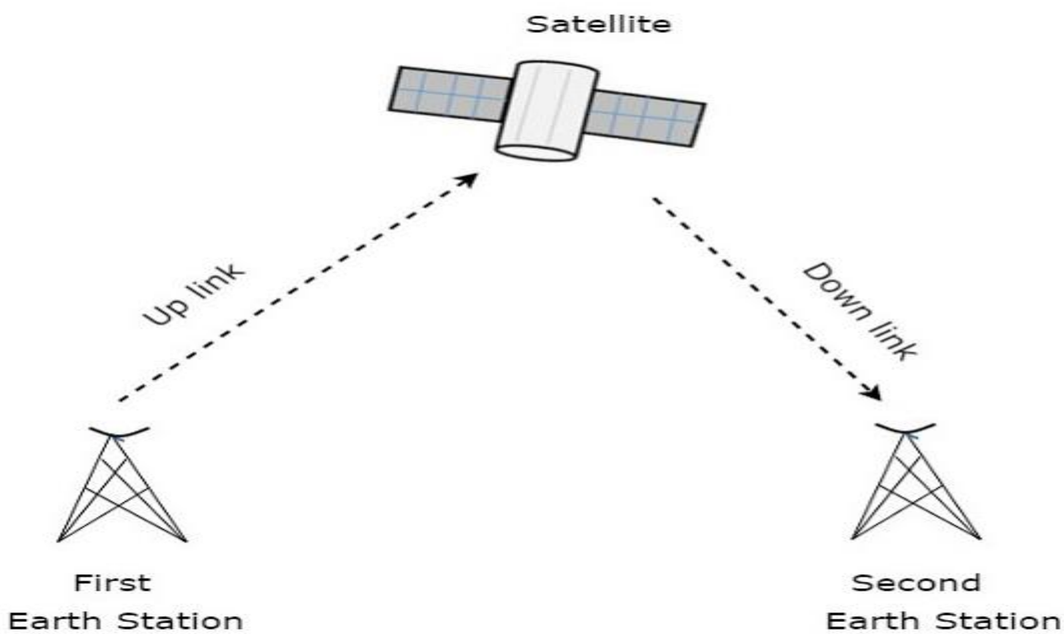
- Ground wave propagation − Ground wave propagation is suitable for frequencies up to 30MHz. This method of communication makes use of the troposphere conditions of the earth.
- Sky wave propagation − The suitable bandwidth for this type of communication is broadly between 30–40 MHz and it makes use of the ionosphere properties of the earth.

The maximum hop or the station distance is limited to 1500KM only in both ground wave propagation and sky wave propagation. Satellite communication overcomes this limitation. In this method, satellites provide communication for long distances, which is well beyond the line of sight.Since the satellites locate at certain height above earth, the communication takes place between any two earth stations easily via satellite. So, it overcomes the limitation of communication between two earth stations due to earth's curvature.

How a Satellite Works

A satellite is a body that moves around another body in a particular path. A communication satellite is nothing but a microwave repeater station in space. It is helpful in telecommunications, radio and television along with internet applications.

A repeater is a circuit, which increases the strength of the received signal and then transmits it. But, this repeater works as a transponder. That means, it changes the frequency band of the transmitted signal from the received one.The frequency with which, the signal is sent into the space is called as Uplink frequency. Similarly, the frequency with which, the signal is sent by the transponder is called as Downlink frequency. The following figure illustrates this concept clearly.



The transmission of signal from first earth station to satellite through a channel is called as uplink. Similarly, the transmission of signal from satellite to second earth station through a channel is called as downlink.

Uplink frequency is the frequency at which, the first earth station is communicating with satellite. The satellite transponder converts this signal into another frequency and sends it down to the second earth station. This frequency is called as Downlink frequency. In similar way, second earth station can also communicate with the first one.

The process of satellite communication begins at an earth station. Here, an installation is designed to transmit and receive signals from a satellite in an orbit around the earth. Earth stations send the information to satellites in the form of high powered, 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. ***Satellite's footprint*** is the area which receives a signal of useful strength from the satellite.

Advantages and Disadvantages of satellite communication.

Following are the **advantages** of using satellite communication:

- Area of coverage is more than that of terrestrial systems
- Each and every corner of the earth can be covered
- Transmission cost is independent of coverage area
- More bandwidth and broadcasting possibilities

Following are the **disadvantages** of using satellite communication −

- Launching of satellites into orbits is a costly process.
- Propagation delay of satellite systems is more than that of conventional terrestrial systems.
- Difficult to provide repairing activities if any problem occurs in a satellite system.
- Free space loss is more.
- Congestion of frequencies.

Applications of Satellite Communication

Satellite communication plays a vital role in our daily life. Following are the applications of satellite communication −

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

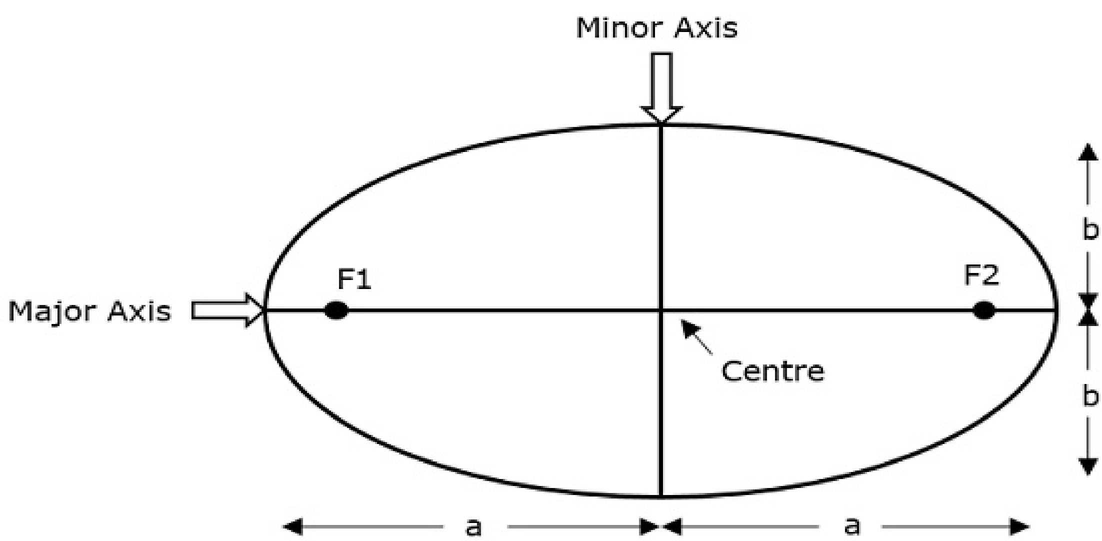
KEPLER'S LAWS

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.

Many scientists have given different types of theories from early times. But, only **Johannes Kepler** (1571-1630) was one of the most accepted scientist in describing the principle of a satellite that moves around the earth.Kepler formulated three laws that changed the whole satellite communication theory and observations. These are popularly known as **Kepler's laws**. These are helpful to visualize the motion through space.

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**.

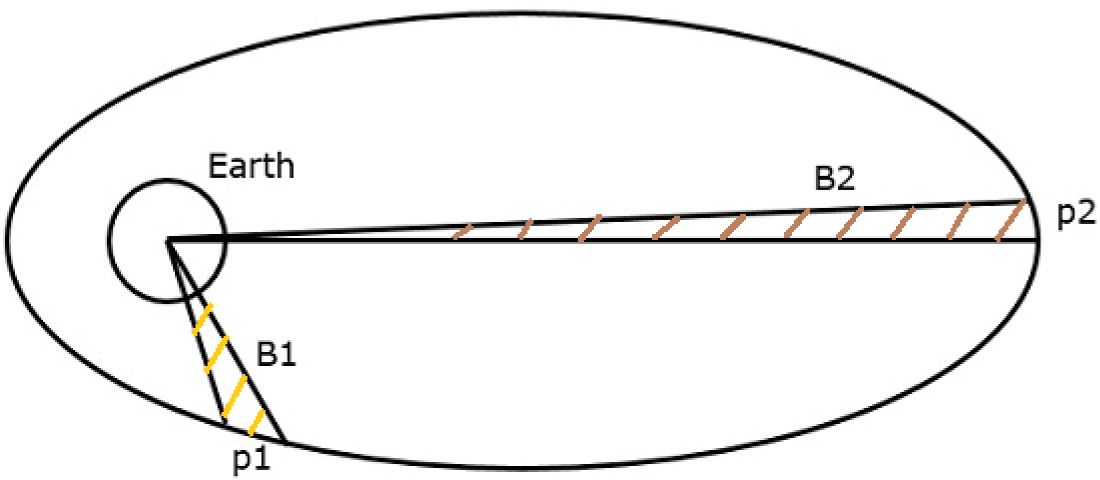
Eccentricity "e" of this system can be written as −

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

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. This can be understood by taking a look at the following figure.



Assume, the satellite covers p1 and p2 distances in the same time interval. Then, the areas B1 and B2 covered by the satellite at those two instances are equal.

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 −

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 $10^{14} m^3 /sec^2$

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

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

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

SATELLITE ORBITS

Most of the *orbital* satellites are *non-synchronous.*Non-synchronous satellites rotate around Earth in an elliptical or circular patternas shown in Figure 2a and b. In a circular orbit, the speed or rotation is constant; however,in elliptical orbits the speed depends on the height the satellite is above Earth. The speed ofthe satellite is greater when it is close to Earth than when it is farther away.If the satellite is orbiting in the same direction as Earth's rotation (counterclockwise) andat an angular velocity greater than that of Earth ($\omega s > \omega e$), the orbit is called a *prograde* or*posigrade* orbit.

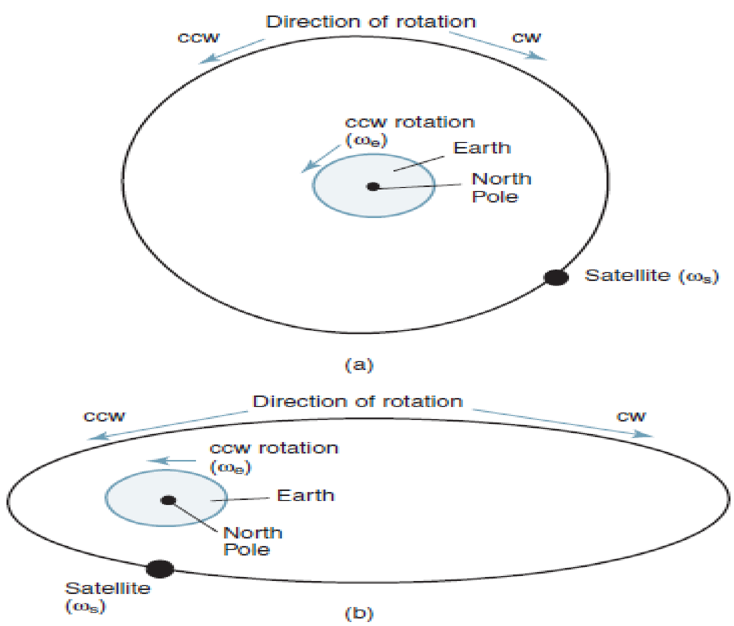


FIGURE 2 Satellite orbits: [a] circular; [b] elliptical

If the satellite is orbiting in the opposite direction as Earth's rotation and at an angular velocity less than that of Earth ($\omega s<\omega e$), the orbit is called a *retrograde*orbit. Most non-synchronous satellites revolve around Earth in a prograde orbit. Therefore,the position of satellites in non-synchronous orbits is continuously changing in respect toa fixed position on Earth. Another disadvantage of orbital satellites isthe need for complicated and expensive tracking equipment at the earth stations so they can locatethe satellite and then lock its antenna onto the satelliteand track it as it passes overhead.Amajor advantage of orbital satellites, however, is that propulsionrockets are not required on board the satellites to keep them in their respective orbits.

ORBITAL EFFECTS

There are a number of perturbing forces that cause an orbit satellite to depart from ideal Keplerianorbit. The most effecting ones are gravitational fields of sun and moon, non-spherical shapeof the Earth, reaction of the satellite itself to motor movements within the satellites.Thus the earth station keeps directing the satellite to maintain its position within a set ofnominal geostationary coordinates. Thus the exact GEO is not attainable in practice and theorbital parameters vary with time. Hence these satellites are called "Geosynchronous"satellites or "Near-Geostationary satellites".

Doppler Effect

To a stationary observer, the frequency of a moving radio transmitter varies with thetransmitter's velocity relative to the observer. If the true transmitter frequency (i.e., thefrequency that the transmitter would send when at rest) is fT, the received frequency fR ishigher than fT when the transmitter is moving toward the receiver and lower than fT when thetransmitter is moving away from the receiver.

Range variations

Even with the best station keeping systems available for geostationary satellites, the positionof a satellite with respect to earth exhibits a cyclic daily variation. The variation in positionwill lead to a variation in range between the satellite and user terminals. If time divisionmultiple access(TDMA) is being used, careful attention must be paid to the timing of theframes within the TDMA bursts so that the individual user frames arrive at the satellite in thecorrect sequence and at the correct time.

Earth Eclipse of a Satellite

When the satellite longitude is east of the earth station, the satellite enters eclipse during daylight (and early evening) hours of the earth station. This can be undesirable if the satellite has to operate on reduced battery power. When the satellite longitude is west of the earth station, eclipse does not occur until the earth station is in darkness, when usage is likely to be low. Thus, Satellite longitudes, which are west, rather than east, of the earth station, are more desirable.

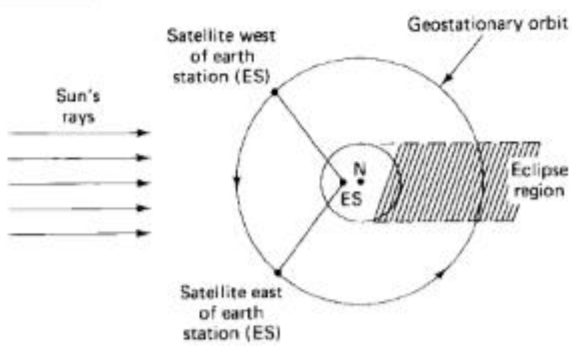


Figure: A satellite east of the earth station enters eclipse during daylight (busy) hours at the earth station. A satellite west of the earth station enters eclipse during night and early morning (non busy) hours.

Sun Transit Outage

Sun transit outage is an interruption or distortion of geostationary satellite signals causedby interference from solar radiation. Sun appears to be an extremely noisy source whichcompletely blanks out the signal from satellite. This effect lasts for 6 days. They occur for a maximum period of 10 minutes.Generally, sun outages occur in February, March, September and October. At these times, the apparent path of the sun across the sky takes itdirectly behind the line of sight between an earth station and a satellite. As the sun radiatesstrongly at the microwave frequencies used to communicate with satellites (C-band, Ka bandand Ku band) the sun swamps the signal from the satellite.The effects of a sun outage can include partial degradation, that is, an increase in the errorrate, or total destruction of the signal.

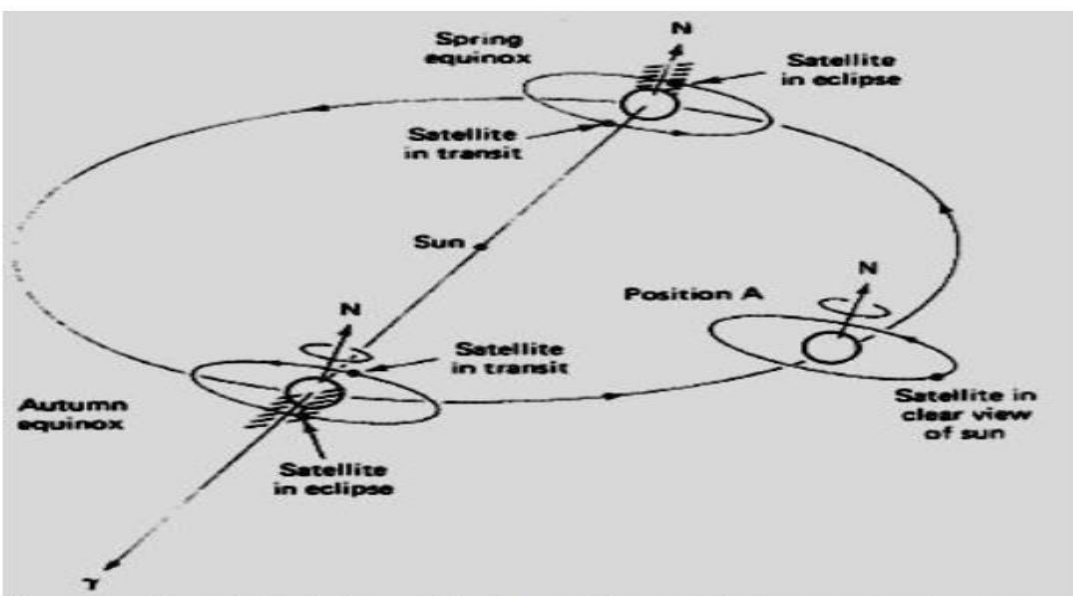


Figure: Earth Eclipse of a Satellite and Sun transit Outage

ORBITAL PERTURBATIONS

- Theoretically, an orbit described by Kepler is ideal as Earth is considered to be a perfect sphere and the force acting around the Earth is the centrifugal force. This force is supposed to balance the gravitational pull of the earth.

- As the shape of Earth is not a perfect sphere, it causes some variations in the path followed by the satellites around the primary. The forces resulting from the Earth which act on the satellite produce a change in the orbital parameters.This causes the satellite to drift and leads to rotation of the line of apsides. As the orbit itself is moving with respect to the Earth, the resultant changes are seen in the values of argument of perigee and right ascension of ascending node.

- In reality, other forces also play an important role and affect the motion of the satellite. These forces are ***the gravitational forces of Sun and Moon along with the atmospheric drag.***

Following are the orbital perturbations due to gravitational and non-gravitational forces or parameters.

- Irregular gravitational force around the Earth due to non-uniform mass distribution. Earth's magnetic field to causes orbital perturbations.
- Main external perturbations come from Sun and Moon. When a satellite is near to these external bodies, it receives a stronger gravitational pull.
- Low-orbit satellites get affected due to friction caused by collision with atoms and ions.
- Solar radiation pressure affects large GEO satellites, which use large solar arrays.
- Self-generated torques and pressures caused by RF radiation from the antenna.

Effect of Sun and Moon is more pronounced on geostationary earth satellites where as the atmospheric drag effect is more pronounced for low earth orbit satellites.Due to the non-spherical shape of Earth, one more effect called as the "Satellite Graveyard" is seen. Working satellites are made to drift back to their position but *out-of-service satellites are eventually drifted to these points*, and making that point a Satellite Graveyard.

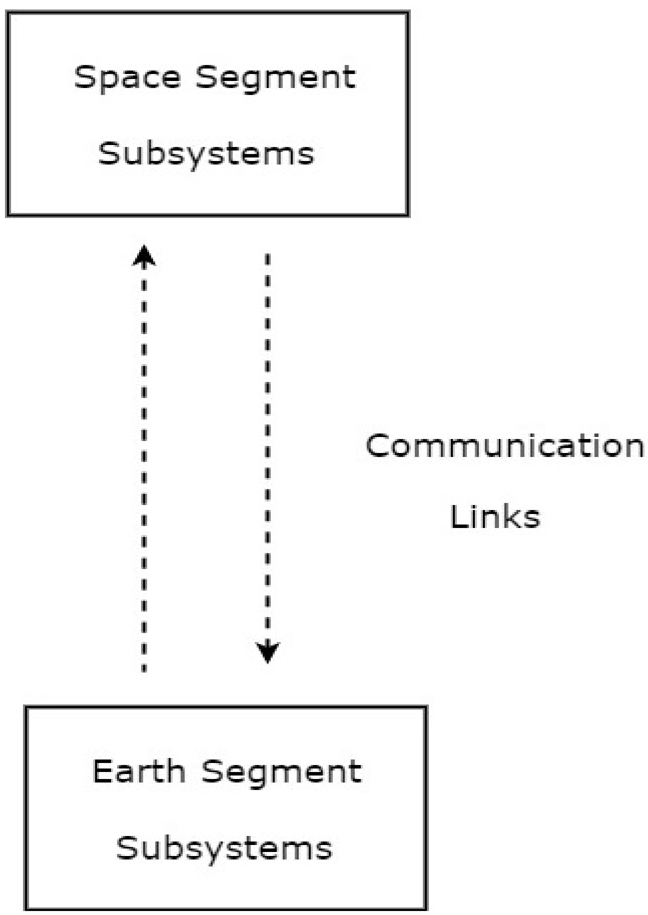
Atmospheric Drag

- For Low Earth orbiting satellites, the effect of atmospheric drag is more pronounces.The impact of this drag is maximum at the point of perigee. Drag (pull towards theEarth) has an effect on velocity of Satellite (velocity reduces).This causes the satellite to not reach the apogee height in successive revolutions. Thisleads to a change in value of semi-major axis and eccentricity. Satellites in service aremaneuvered by the earth station back to their original orbital position.

SATELLITE SUB SYSTEMS

In satellite communication system, various operations take place. Among which, the main operations are orbit controlling, altitude controlling 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. The following figure illustrates this concept.



As shown in the figure, the communication takes place between space segment subsystems and earth segment subsystems through communication links.

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.

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

Altitude and Orbit Control (AOC) subsystem

We know that satellite may deviates from its orbit due to the gravitational forces from sun, moon and other planets. These forces change cyclically over a 24-hour period, since the satellite moves around the earth.

Altitude 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.

- Altitude Control Subsystem
- Orbit Control Subsystem

Altitude Control Subsystem

Altitude 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. After this, the de-spin system operates in order to make the TTCM subsystem antennas point towards earth station.

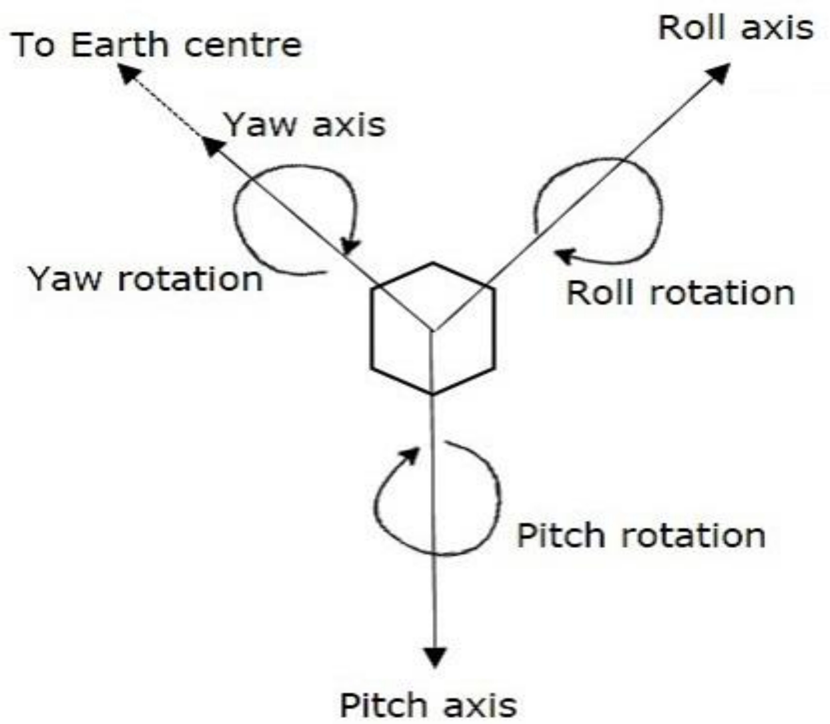
Three Axis Method

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.

These three axes are shown in below figure.



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, Commanding and Monitoring (TTCM) subsystem

Telemetry, Tracking, Commanding and Monitoring (TTCM) subsystem is present in both satellite and earth station. In general, satellite gets data through sensors. So, Telemetry subsystem present in the satellite sends this data to earth station(s). Therefore, TTCM subsystem is very much necessary for any communication satellite in order to operate it successfully.It is the responsibility of satellite operator to control the satellite in its life time, after placing it in the proper orbit. This can be done with the help of TTCM subsystem.

TTCM subsystem into the following three parts.

- Telemetry and Monitoring Subsystem
- Tracking Subsystem
- Commanding Subsystem

Telemetry and Monitoring Subsystem

The word ‘Telemetry’ means measurement at a distance. Mainly, the following operations take place in ‘Telemetry’.

- Generation of an electrical signal, which is proportional to the quantity to be measured.
- Encoding the electrical signal.
- Transmitting this code to a far distance.

Telemetry subsystem present in the satellite performs mainly two functions −

- Receiving data from sensors
- Transmitting that data to an earth station.

Satellites have quite a few sensors to monitor different parameters such as pressure, temperature, status and etc., of various subsystems. In general, the telemetry data is transmitted as FSK or PSK.Telemetry subsystem is a remote controlled system. It sends monitoring data from satellite to earth station. Generally, the telemetry signals carry the information related to altitude, environment and satellite.

Tracking Subsystem

Tracking subsystem is useful to know the position of the satellite and its current orbit. Satellite Control Center (SCC) monitors the working and status of space segment subsystems with the help of telemetry downlink. It controls those subsystems using command uplink.

We know that the tracking subsystem is also present in an earth station. Number of techniques that are using in order to track the satellite. For example, change in the orbital position of satellite can be identified by using the data obtained from velocity and acceleration sensors that are present on satellite.

The tracking subsystem that is present in an earth station keeps tracking of satellite, when it is released from last stage of Launch vehicle. It performs the functions like, locating of satellite in initial orbit and transfer orbit.

Commanding Subsystem

Commanding subsystem is necessary in order to launch the satellite in an orbit and its working in that orbit. This subsystem adjusts the altitude and orbit of satellite, whenever there is a deviation in those values. It also controls the communication subsystem. This commanding subsystem is responsible for turning ON / OFF of other subsystems present in the satellite based on the data getting from telemetry and tracking subsystems.

In general, control codes are converted into command words. These command words are used to send in the form of TDM frames. Initially, the validity of command words is checked in the satellite. After this, these command words can be sent back to earth station. Here, these command words are checked once again.

If the earth station also receives the same (correct) command word, then it sends an execute instruction to satellite. So, it executes that command.Functionality wise, the Telemetry subsystem and commanding subsystem are opposite to each other. Since, the first one transmits the satellite's information to earth station and second one receives command signals from earth station.

Power Systems

We know that the satellite present in an orbit should be operated continuously during its life span. So, the satellite requires internal power in order to operate various electronic systems and communications payload that are present in it.**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.We know that 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.

Solar Arrays

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.

Antenna Subsystems

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.

Transponder

The subsystem, which provides the connecting link between transmitting and receiving antennas of a satellite is known as **Transponder**. Transponder performs the functions of both transmitter and receiver (Responder) in a satellite. Hence, the word 'Transponder' is obtained by the combining few letters of two words, Transmitter **(Trans)** and Responder **(ponder)**.

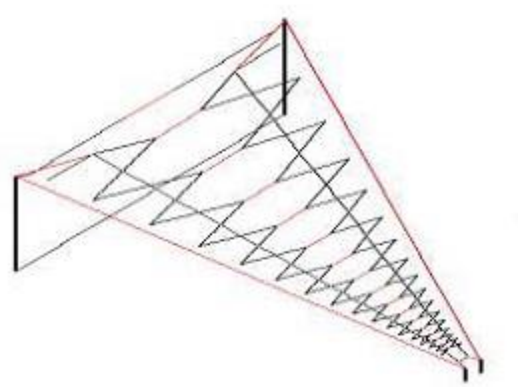
Transponder performs mainly **two functions**. Those are amplifying the received input signal and translates the frequency of it. In general, different frequency values are chosen for both uplink and down link in order to avoid the interference between the transmitted and received signals.

Satellite Antennas

The antennas, which are used in satellite are known as satellite antennas. There are mainly four **types of Antennas**. They are:

- Wire Antennas
- Horn Antennas
- Array Antennas
- Reflector Antennas

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.The length of the total wire, which is being used as a dipole, if equals half of the wave length (i.e., $l = \lambda/2$), such an antenna is called as **half-wave dipole antenna**.

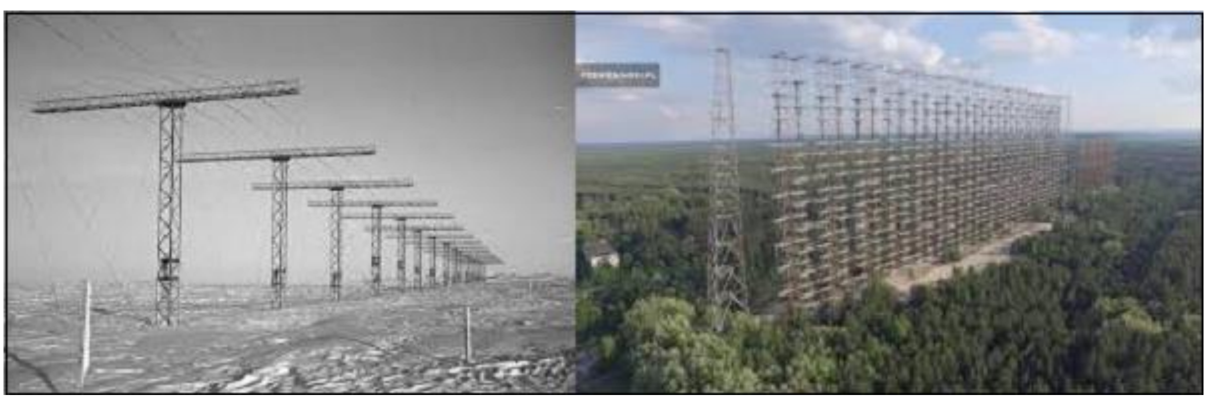
Wire antennas are suitable for covering its range of access and to provide signal strength in all directions. That means, wire antennas are Omni-directional antennas.

Horn Antennas

An Antenna with an aperture at the end can be termed as an **Aperture antenna**. The edge of a transmission line when terminated with an opening, radiates energy. This opening which is an aperture, makes it as an aperture antenna.**Horn antenna** is an example of aperture antenna. It 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.

Array Antennas

An antenna when individually can radiate an amount of energy, in a particular direction, resulting in better transmission, how it would be if few more elements are added it, to produce more efficient output. It is exactly this idea, which lead to the invention of **Array Antennas** or Antenna arrays. Array antennas are used in satellites to form multiple beams from single aperture.



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. Hence, these are used in telecommunications and broadcasting.

If a Parabolic Reflector antenna is used for **transmitting** a signal, the signal from the feed, comes out of a dipole or a horn antenna, to focus the wave on to the parabola. It means that, the waves come out of the focal point and strikes the Paraboloidal reflector. This wave now gets reflected as collimated wave front.

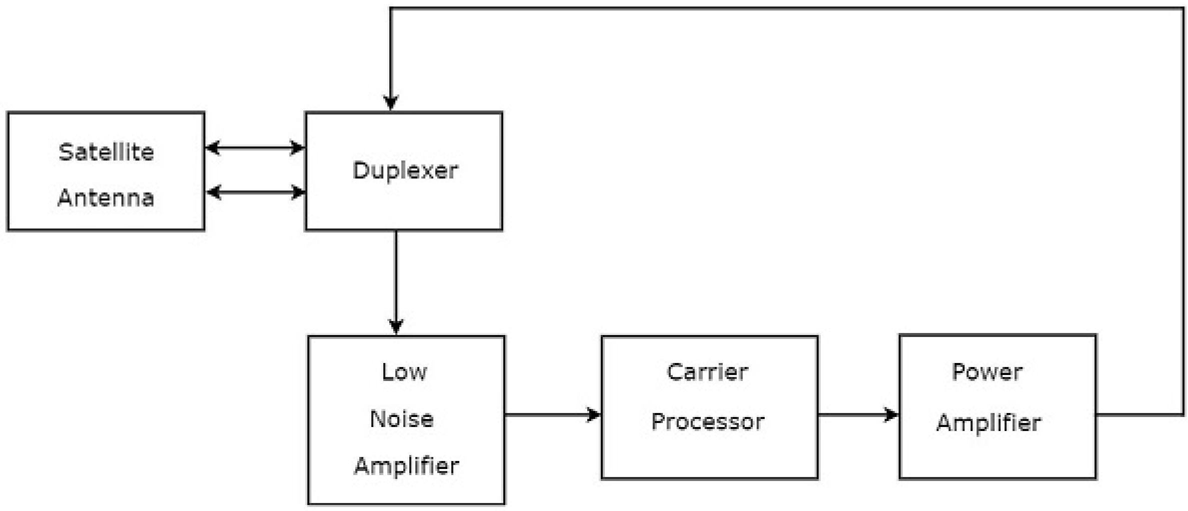
If the same antenna is used as a **receiver**, the electromagnetic wave when hits the shape of the parabola, the wave gets reflected onto the feed point. The dipole or the horn antenna, which acts as the receiver antenna at its feed, receives this signal, convert it into electric signal and forwards it to the receiver circuitry.

Transponder

The subsystem, which provides the connecting link between transmitting and receiving antennas of a satellite is known as Transponder. It is one of the most important subsystem of space segment subsystems.Transponder performs the functions of both transmitter and receiver (Responder) in a satellite. Hence, the word 'Transponder' is obtained by the combining few letters of two words, Transmitter (Trans) and Responder (ponder).

Block diagram of Transponder

Transponder performs mainly two functions. Those are amplifying the received input signal and translates the frequency of it. In general, different frequency values are chosen for both uplink and down link in order to avoid the interference between the transmitted and received signals.The block diagram of transponder is shown in below figure.



We can easily understand the operation of Transponder from the block diagram itself. The function of each block is mentioned below.

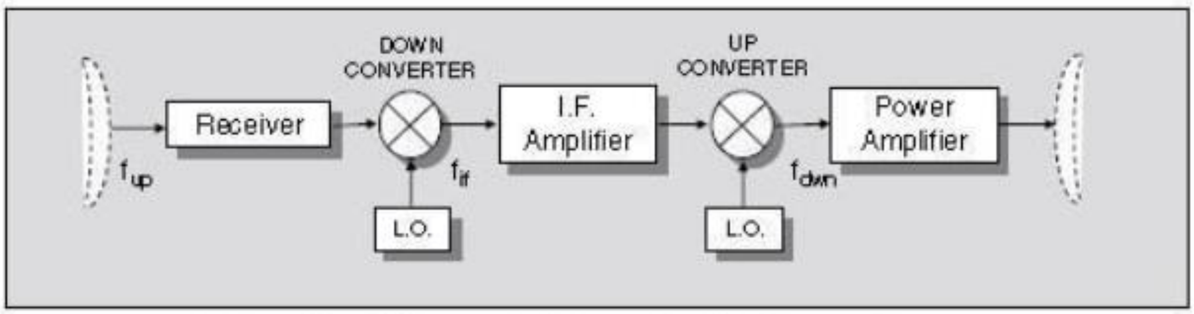
- Duplexer is a two-way microwave gate. It receives uplink signal from the satellite antenna and transmits downlink signal to the satellite antenna.
- Low Noise Amplifier (LNA) amplifies the weak received signal.
- Carrier Processor performs the frequency down conversion of received signal (uplink). This block determines the type of transponder.
- Power Amplifier amplifies the power of frequency down converted signal (down link) to the required level.

Types of Transponders

Basically, there are two types of transponders. Those are Bent pipe transponders and Regenerative transponders.

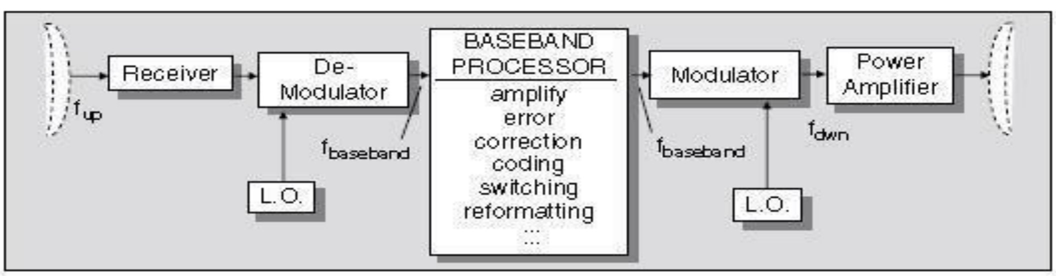
Bent Pipe Transponders

Bent pipe transponder receives microwave frequency signal. It converts the frequency of input signal to RF/ IF frequency and then amplifies it.Bent pipe transponder is also called as repeater and conventional transponder. It is suitable for both analog and digital signals.



- Frequency Translation Transponder, also called
  - Repeater
  - Non-Regenerative Satellite
  - 'Bent Pipe'
- The dominant type of transponder currently in use
  - FSS, BSS, MSS
- Uplinks and downlinks are codependent

Regenerative Transponders



- On-Board Processing Transponder, also called
  - Regenerative Repeater
  - Demod/Remod Transponder
  - 'Smart Satellite'
- First generation systems:
  - ACTS, MILSTAR, IRIDIUM, . . .
- Uplinks and downlinks are independent

Figure 3.9 On-board processing transponder

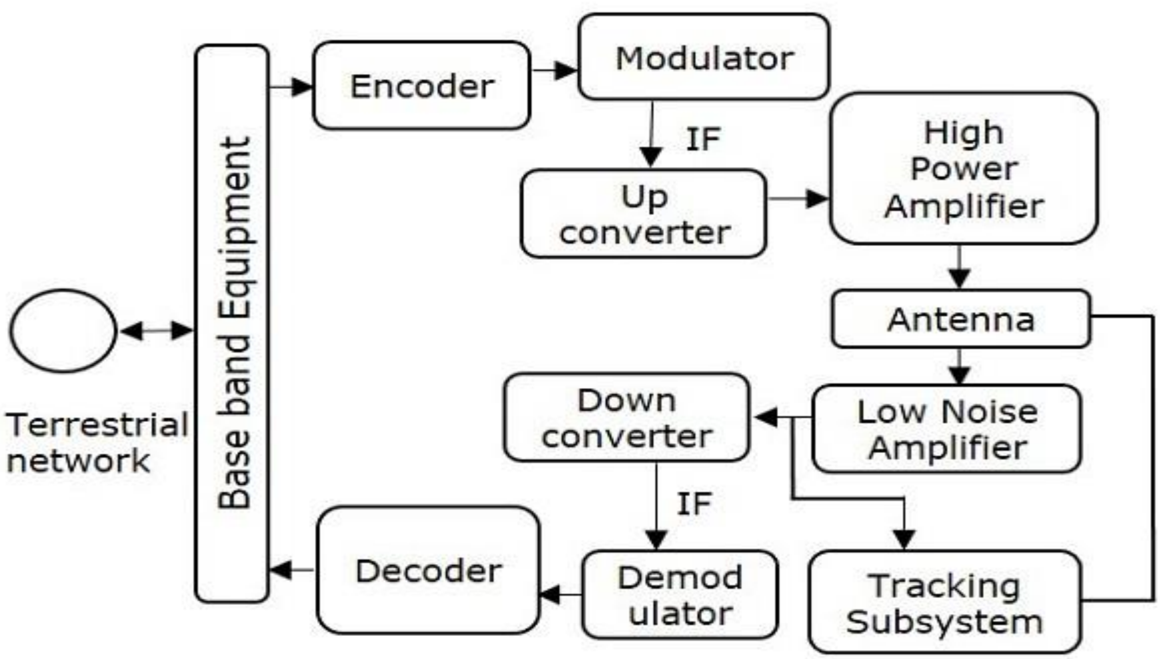
Regenerative transponder performs the functions of Bent pipe transponder. i.e., frequency translation and amplification. In addition to these two functions, Regenerative transponder also performs the demodulation of RF carrier to baseband, regeneration of signals and modulation.Regenerative transponder is also called as Processing transponder. It is suitable only for digital signals. The main advantages of Regenerative transponders are improvement in Signal to Noise Ratio (SNR) and have more flexibility in implementation.

Earth station technology

The **earth segment** of satellite communication system mainly consists of two earth stations. Those are transmitting earth station and receiving earth station.The transmitting **earth station** transmits the information signals to satellite. Whereas, the receiving earth station receives the information signals from satellite. Sometimes, the same earth station can be used for both transmitting and receiving purposes.Voice signals and video signals either in analog form or digital form.

Initially, the analog modulation technique, named **FM modulation** is used for transmitting both voice and video signals, which are in analog form. Later, digital modulation techniques, namely Frequency Shift Keying **(FSK)** and Phase Shift Keying **(PSK)** are used for transmitting those signals. Because, both voice and video signals are used to represent in digital by converting them from analog.

Block Diagram of Earth Station



The **block diagram** of digital earth station is shown in figure.

We can easily understand the working of earth station from above figure. There are four major **subsystems** that are present in any earth station. Those are transmitter, receiver, antenna and tracking subsystem.

Transmitter

The binary (digital) information enters at base band equipment of earth station from terrestrial network. **Encoder** includes error correction bits in order to minimize the bit error rate.In satellite communication, the Intermediate Frequency **(IF)** can be chosen as 70 MHz by using a transponder having bandwidth of 36 MHz. Similarly, the IF can also be chosen as 140 MHz by using a transponder having bandwidth of either 54 MHz or 72 MHz.Up converter performs the frequency conversion of modulated signal to higher frequency. This signal will be amplified by using High power amplifier. The earth station antenna transmits this signal.

Receiver

During **reception**, the earth station antenna receives downlink signal. This is a low-level modulated RF signal. In general, the received signal will be having less signal strength. So, in order to amplify this signal, Low Noise Amplifier **(LNA)** is used. Due to this, there is an improvement in Signal to Noise Ratio (SNR) value.

RF signal can be **down converted** to the Intermediate Frequency (IF) value, which is either 70 or 140 MHz. Because, it is easy to demodulate at these intermediate frequencies.The function of the **decoder** is just opposite to that of encoder. So, the decoder produces an error free binary information by removing error correction bits and correcting the bit positions if any.This binary information is given to base band equipment for further processing and then delivers to terrestrial network.

Earth Station Antenna

The major parts of **Earth station Antenna** are feed system and Antenna reflector. These two parts combined together radiates or receives electromagnetic waves. Since the feed system obeys reciprocity theorem, the earth station antennas are suitable for both transmitting and receiving electromagnetic waves.

Parabolic reflectors are used as the main antenna in earth stations. The gain of these reflectors is high. They have the ability of focusing a parallel beam into a point at the focus, where the feed system is located.

Tracking Subsystem

The **Tracking subsystem** keeps track with the satellite and make sure that the beam comes towards it in order to establish the communication. The Tracking system present in the earth station performs mainly **two functions**. Those are satellite acquisition and tracking of satellite. This tracking can be done by automatic tracking, manual tracking & program tracking.

LINK CALCULATION

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**.

BASIC TERMINOLOGY

An **isotropic radiator** (antenna) radiates equally in all directions. But, it doesn't exist practically. It is just a theoretical antenna. We can compare the performance of all real (practical) antennas with respect to this antenna.

Power flux density

Assume an isotropic radiator is situated at the center of the sphere having radius, r. We know that power flux density is the ratio of power flow per unit area.

Power flux density, Ψ_i of an isotropic radiator is

$$\Psi_i = \frac{p_s}{4\pi r^2}$$

Where, Ps is the power flow. In general, the power flux density of a practical antenna varies with direction. But, it's **maximum value** will be in one particular direction only.

Antenna Gain

The **gain** of practical antenna is defined as the ratio of maximum power flux density of practical antenna to the power flux density of isotropic antenna.

Therefore, the Gain of Antenna or **Antenna gain**, G is

$$G = \frac{\Psi_m}{\Psi_i}$$

Where, Ψm is the maximum power flux density of practical antenna. And, ΨiΨiis the power flux density of isotropic radiator (antenna).

Equivalent Isotropic Radiated Power

Equivalent isotropic radiated power (EIRP) is the main parameter that is used in measurement of link budget. **Mathematically**, it can be written as

$$EIRP = G\ P_s$$

We can represent EIRP in **decibels** as

$$[EIRP] = [G] + [P_s]\, dBW$$

Where, **G** is the Gain of Transmitting antenna and Ps is the power of transmitter.

Transmission Losses

The difference between the power sent at one end and received at the receiving station is known as **Transmission losses**. The losses can be categorized into 2 types.

- Constant losses
- Variable losses

The losses which are constant such as feeder losses are known as **constant losses**. No matter what precautions we might have taken, still these losses are bound to occur.Another type of loses are **variable loss**. The sky and weather condition is an example of this type of loss. Means if the sky is not clear signal will not reach effectively to the satellite or vice versa.

Therefore, our procedure includes the calculation of losses due to clear weather or clear sky condition as 1^{st} because these losses are constant. They will not change with time. Then in 2^{nd} step, we can calculate the losses due to foul weather condition.

Link budget calculations

There are two types of link budget calculations since there are two links namely, **uplink** and **downlink**.

Earth Station Uplink

It is the process in which earth is transmitting the signal to the satellite and satellite is receiving it. Its **mathematical equation** can be written as

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

Where,

- $\left[\frac{C}{N_0}\right]$ is the carrier to noise density ratio
- $\left[\frac{G}{T}\right]$ is the satellite receiver G/T ratio and units are dB/K

Here, Losses represent the satellite receiver feeder losses. The losses which depend upon the frequency are all taken into the consideration.The EIRP value should be as low as possible for effective UPLINK. And this is possible when we get a clear sky condition.Here we have used the (subscript) notation "U", which represents the uplink phenomena.

Satellite Downlink

In this process, satellite sends the signal and the earth station receives it. The equation is same as the satellite uplink with a difference that we use the abbreviation "D" everywhere instead of "U" to denote the downlink phenomena.

Its **mathematical** equation can be written as;

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

Where,

- $\left[\frac{C}{N_0}\right]$ is the carrier to noise density ratio
- $\left[\frac{G}{T}\right]$ is the earth station receiver G/T ratio and units are dB/K

Here, all the losses that are present around earth stations.

In the above equation we have not included the signal bandwidth B. However, if we include that the equation will be modified as follows.

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

LINK BUDGET

If we are taking ground satellite in to consideration, then the free space spreading loss (FSP) should also be taken into consideration.If antenna is not aligned properly then losses can occur. so we take **AML**(Antenna misalignment losses) into account. Similarly, when signal comes from the satellite towards earth it collides with earth surface and some of them get absorbed. These are taken care by atmospheric absorption loss given by **"AA"** and measured in db.

Now, we can write the loss equation for free sky as

Losses=FSL+RFL+AML+AA+PL

Where,

- RFL stands for received feeder loss and units are db.

- PL stands for polarization mismatch loss.

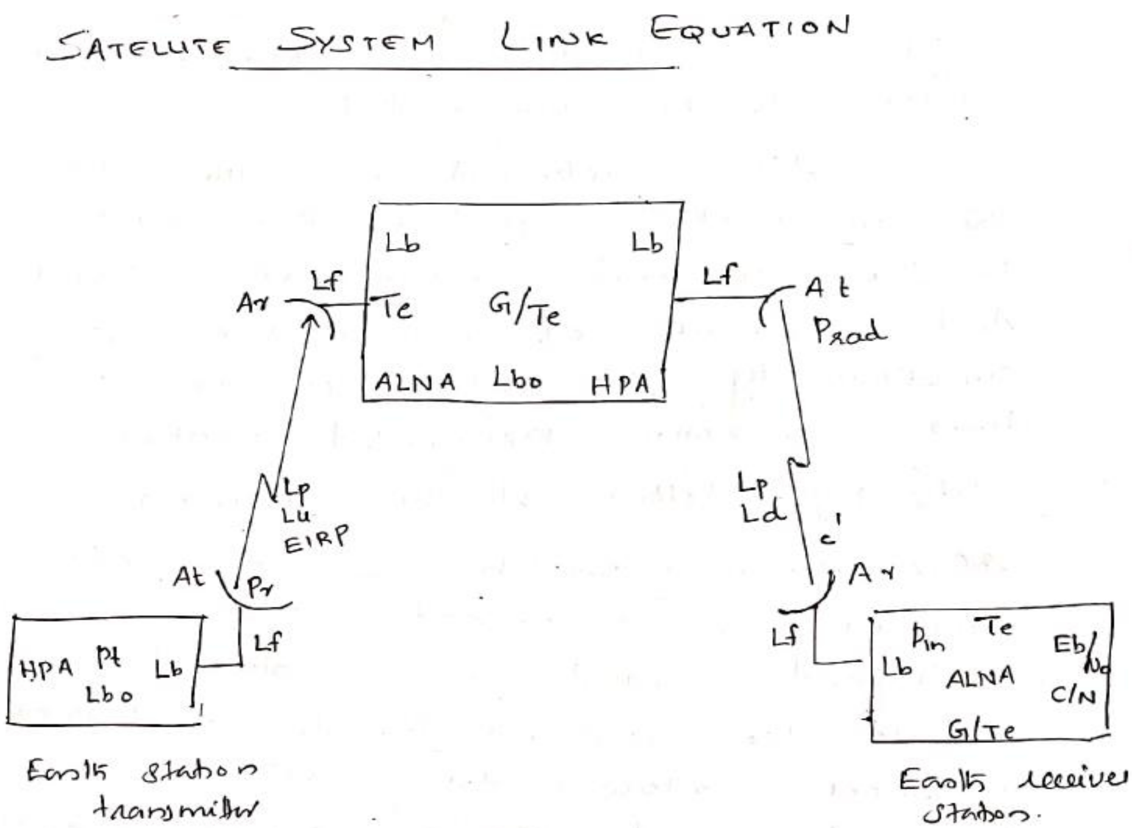
Now the **decibel equation** for received power can be written as

$$\mathbf{P_R = EIRP + G_R + Losses}$$

Where,

- P_R stands for the received power, which is measured in dBW.
- G_R is the receiver antenna gain.

The designing of down link is more critical than the designing of uplink. Because of limitations in power required for transmitting and gain of the antenna.



HPA : high power amplifier

Pt : HPA output power

Lbo : back-off loss

Lf : feeder loss

Lb : branching loss

At : transmit antenna gain

Pr : total radiated power = Pt − Lbo − Lb − Lf

EIRP : effective isotropic radiated power

= Prad · At

Lu : additional up link losses

Lp : path loss

Ar : receive antenna gain

G/T_e : Gain to equivalent noise ratio.

Ld : additional down link loss due to atmosphere.

LNA : low noise amplifier

C/T_e : carrier to equivalent noise ratio

C/N_0 : Carrier to noise density ratio

E_b/N_0 : energy of bit to noise density ratio

C/N : Carrier to noise ratio

Ld + Lu : additional uplink/downlink atm. losses.

Up link Equation

$$\frac{C}{N_o} = \frac{A_t \cdot P_{in} (L_p L_u) A_r}{k T_e} = \frac{A_t P_{in} (L_p L_u)}{k} \times \frac{G}{T_e} \quad -(1)$$

The uplink and downlink signals must pass through Earth atmosphere, where they are partially absorbed by the moisture, oxygen, and particulates in the air.

Depending on the elevation angle, the distance the RF signal travels through the atmosphere varies from one earth station to another.

G/T_e is the receive antenna gain plus the gain of the LNA divided by the equivalent input noise temperature.

input noise temperature

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

(1) in dB =>

$$\frac{C}{N_o} = \underbrace{10 \log A_t P_{in}}_{\text{EIRP earth station}} - \underbrace{20 \log \left(\frac{4\pi D}{\lambda}\right)}_{\text{free space path loss } L_p} + \underbrace{10 \log \left(\frac{G}{T_e}\right)}_{\text{satellite } G/T_e} -$$

$$10\log L_u \;(\text{additional atm. loss}) - 10\log k \;(\text{Boltzman constant})$$

$$= EIRP\,(dBW) - L_p\,(dB) + \frac{G}{T_e}\,(dBK^{-1}) - L_u\,(dB) - k\,(dBWK)$$

Downlink Equation

$$\frac{C}{N_o} = \frac{A_t P_{in} (L_p L_d) A_r}{k T_e} = \frac{A_t P_{in} (L_p L_d)}{k} \times \frac{G}{T_e} \quad \text{--- (2)}$$

In dB

$$\frac{C}{N_o} = 10\log A_t P_{in} \;(\text{EIRP satellite}) - 20\log\left(\frac{4\pi D}{\lambda}\right) \;(\text{free space path loss } L_p) + 10\log\left(\frac{G}{T_e}\right) \;(\text{earth station } G/T_e) -$$

$$10\log L_d \;(\text{additional atm. losses}) - 10\log k \;(\text{Boltzmann's constant})$$

$$= EIRP\,(dBW) - L_p\,(dB) + \frac{G}{T_e}\,(dBK^{-1}) - L_d\,(dB) - k\,(dBWK)$$

SATELLITE APPLICATIONS

GLOBAL POSITIONING SYSTEM (GPS) :

The Global Positioning System (GPS) is a satellite based navigation system thatcan be used to locate positions anywhere on earth. Designed and operated by the U.S.Department of Defense, it consists of satellites, control andmonitor stations, and receivers. GPS receivers take information transmittedfrom the satellites and uses trilatration to calculate a user's exact location.

GPS is used on incidents in a variety of ways, such as:

- To determine position of locations; for example, you need to radio ahelicopter pilot the coordinates of your position location so the pilot can pick youup.
- To navigate from one location to another; for example, you need to travel from alookout to the fire perimeter.
- To create digitized maps; for example, you are assigned to plot the fire perimeterand hot spots.
- To determine distance between two points or how far you are from anotherlocation.

Three Segments of GPS:

Space Segment — Satellites orbiting the earth

The space segment consists of 24 satellites circling the earth every 12 hours at12,000 miles in altitude. This high altitude allows the signals to cover a greater area. Thesatellites are arranged in their orbits so a GPS receiver on earth can receive a signal fromat least four satellites at any given time. Each satellite contains several atomic clocks.

Control Segment — The control and monitoring stations

The control segment tracks the satellites and then provides them with correctedorbital and time information. The control segment consists of five unmanned monitorstations and one Master Control Station. The five unmanned stations monitor GPSsatellite signals and then send that information to the Master Control Station whereanomalies are corrected and sent back to the GPS satellites through ground antennas.

User Segment — The GPS receivers owned by civilians and military

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

GPS Codes

Following are the two types of GPS codes.

- Coarse Acquisition code or C/A code
- Precise code or P code

Each GPS satellite transmits two signals, **L_1 and L_2** are of different frequencies.The signal, L_1 is modulated with 1.023 Mbps pseudo random bit sequence. This code is called as Coarse Acquisition code or **C/A code** and it is used by the public.

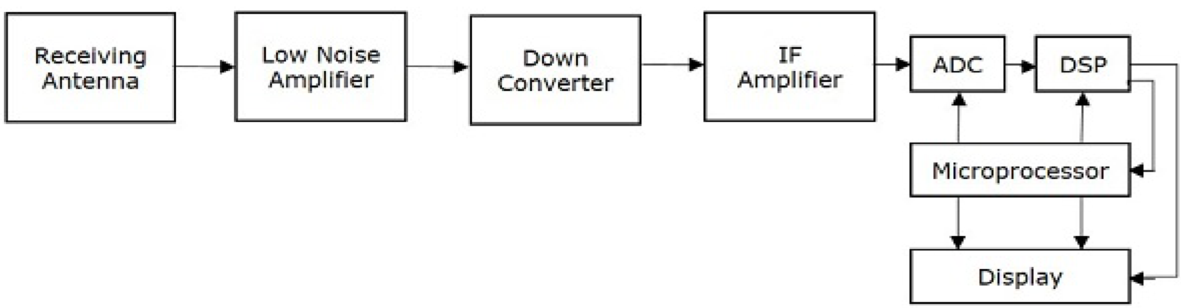
The signal, L_2 is modulated with 10.23 Mbps pseudo random bit sequence. This code is called as Precise code or **P code** and it is used in military positioning systems. Generally, this P code is transmitted in an encrypted format and it is called as **Y code.**

The P code gives better measurement accuracy when compared to C/A code, since the bit rate of P code is greater than the bit rate of C/A code.

GPS Receiver

There exists only one-way transmission from satellite to users in GPS system. Hence, the individual user does not need the transmitter, but only a **GPS receiver**. It is mainly used to find the accurate location of an object. It performs this task by using the signals received from satellites.

The **block diagram** of GPS receiver is shown in below figure.



The function of each block present in GPS receiver is mentioned below.

- **Receiving Antenna** receives the satellite signals. It is mainly, a circularly polarized antenna.
- **Low Noise Amplifier** (LNA) amplifies the weak received signal
- **Down converter** converts the frequency of received signal to an Intermediate Frequency (IF) signal.
- **IF Amplifier** amplifies the Intermediate Frequency (IF) signal.
- **ADC** performs the conversion of analog signal, which is obtained from IF amplifier to digital. Assume, the sampling & quantization blocks are also present in ADC (Analog to Digital Converter).
- **DSP** (Digital Signal Processor) generates the C/A code.

- **Microprocessor** performs the calculation of position and provides the timing signals in order to control the operation of other digital blocks. It sends the useful information to Display unit in order to display it on the screen.

POSITION DETERMINATION:

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

Precise location of satellites

When a GPS receiver is first turned on, it downloads orbit information from all thesatellites. This process, the first time, can take as long as 12 minutes;but once this information is downloaded, it is stored in the receiver's memory for futureuse.

Distance from each satellite

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

Trilatration to determine position

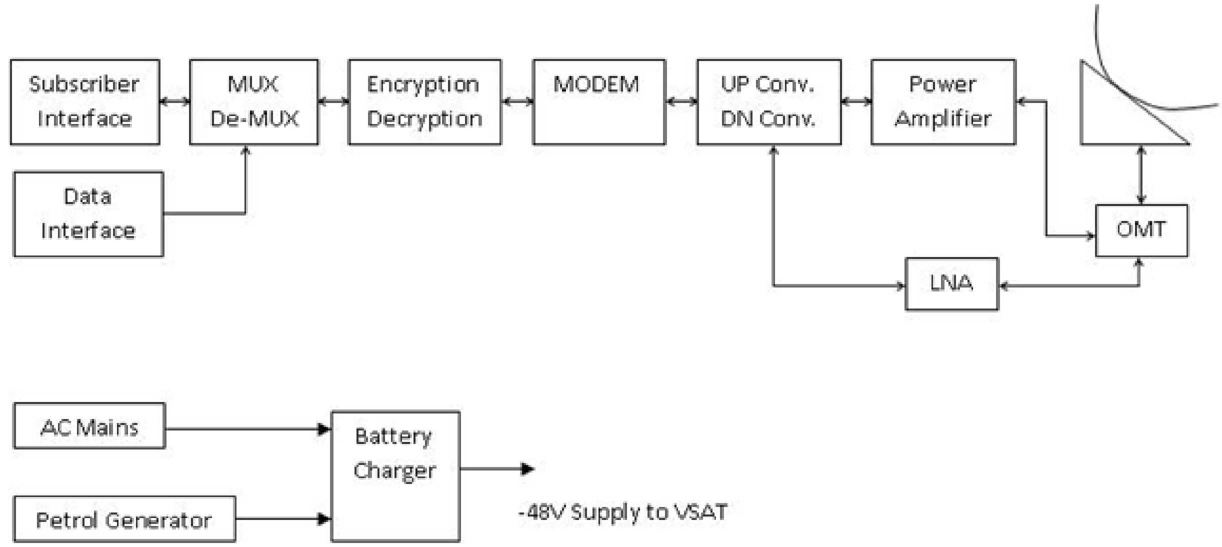
The receiver determines position by using trilatration. When it receives signalsfrom at least three satellites, the receiver should be able to calculate its approximateposition (a 2D position). The receiver needs at least four or more satellites to calculate amore accurate 3D position.

VERY SMALL APERTURETERMINAL SYSTEM (VSAT)

A **very small aperture terminal** (**VSAT**) is a two-way satellite ground station with a dish antenna that is smaller than 3.8 meters. The majority of VSAT antennas range from 75 cm to 1.2 m. Data rates, in most cases, range from 4 kbit/s up to 16 Mbit/s. VSATs access satellites in geosynchronous orbit or geostationary orbit to relay data from small remote terminals to other terminals.VSAT is used for many applications which include Internet access,distance education,telemedicine,telephony,banking,video conferencing and more. It makes use of already launched satellites to provide all these facilities.

VSAT system overview

As shown in the figure, VSAT system composed of two main parts ODU(Outdoor Unit) and IDU(Indoor Unit). ODU and IDU are interfaced using cable. ODU consists of LNA,Power Amplifier,Transceiver,Antenna and Ortho Mode Transducer. IDU consists of Modem,MUX-DEMUX and subscriber interface.



RF transceiver:

RF Transceiver is basically a frequency converter. It consists of two parts frequency up converter and frequency down converter. Up converter converts modulator frequency usually in either 70/140 MHz to satellite frequency bands (C,Ku,Ka) as per satellite in use for particular location/application. Down converter does reverse of the up converter. In addition to frequency conversion both provide gain to the signal as per VSAT link budget and the same need to be adjusted as per need of the link using attenuation settings available in RF transceiver in both up/down link.

RF power amplifier:

RF Power amplifier is the unit which provide power amplification without any frequency change before signal is transmitted to the antenna and consecutively to the air.

RF LNA:

RF LNA is the low noise amplifier used in VSAT. As the signal is received by antenna is composed of noise as well as useful information signal part. In addition it is very low in the power level. LNA's job is to boost this low level of signal to the sufficient level considering less amplification of noise part, so that adequate C/N is maintained.

Satellite modem:

Satellite modem provides two major functionalities in the VSAT. The first one is it makes link reliable by adding forward error correction functionality using various techniques such as convolution coding/turbo coding and so on. The second one is that it does task of modulation and demodulation. There are various modulation techniques used in modem, the most popular among them are QPSK/8PSK.

Antenna:

Antenna is basically a electro-magnetic frequency transducer. It sends and receives EM waves of various frequency bands. Antenna diameter and aperture vary band to band. Hence C band antenna design is different than Ku band. The signal to be transmitted will be provided to antenna by Power Amplifier. The signal received by Antenna is fed to LNA/LNB through OMT as shown in the figure.

Orthomode transducer (**OMT**)

An orthomode transducer (OMT) is a waveguide component. It is commonly referred to as a polarization duplexer. Orthomode transducers serve either to combine or to separate two orthogonally polarized microwave signal paths.

VSAT network architecture

VSAT network architecture is the way Hub station and/or VSATs are interfaced with satellite to provide the service. There are five main topologies exist, viz. **broadcast, point to point, point to multipoint(star), mesh, hybrid**.

In **Broadcast type**, there is a single broadcasting station interfaced with satellite and satellite will relay signals to all the VSATs. Here broadcasting station-satellite-all VSATs link exist.

In **point to point type** of topology, two VSATs communicate via satellite using dedicated assigned channel. So here VSAT1-Satellite-VSAT2 dedicated link exist.

In **Star topology**, there are three entities hub station(usually with larger antenna), VSATs and Satellite. All the communications between VSATs happen through Hub station. Hence here if VSAT1 and VSAT2 need to communicate,link is VSAT1-satellite-Hub-Satellite-VSAT2. Hence two hop communication is needed to communicate between any two VSATs in the network.

In **Mesh type of topology**, VSATs can communicate with one another directly and no Hub station is needed . But each VSAT need to be complex owing to more functionalities required similar to the Hub station. Also antenna specifications need to be different than star type of topology.

In **Hybrid type** is the combination of both star and mesh type. Here few of the VSATs communicate via Hub and few can communicate directly with one another.

DIRECT TO HOME SATELLITE SYSTEMS

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

- DTH Broadcasting to home TV receivers take place in the ku band(12GHz). This service is known as Direct To Home service.
- DTH services were first proposed in India in 1996. Finally in 2000, DTH was allowed.
- The new policy requires all operators to set up earth stations in Indiawithin 12 months of getting a license. DTH licenses in India will cost$2.14 million and will be valid for 10 years.

Working principal of DTH is the satellite communication. Broadcaster modulatesthe received signal and transmit it to the satellite in KU Band and from satellite one canreceive signal by dish and set top box.

DTH Block Diagram:

- A DTH network consists of a broadcasting centre, satellites, encoders,multiplexers, modulators and DTH receivers
- The encoder converts the audio, video and data signals into the digitalformat and the multiplexer mixes these signals.

DTH Receiver

The block diagram of DTH TV system can be divided into two sections:

- Outdoor Unit
- Indoor Unit

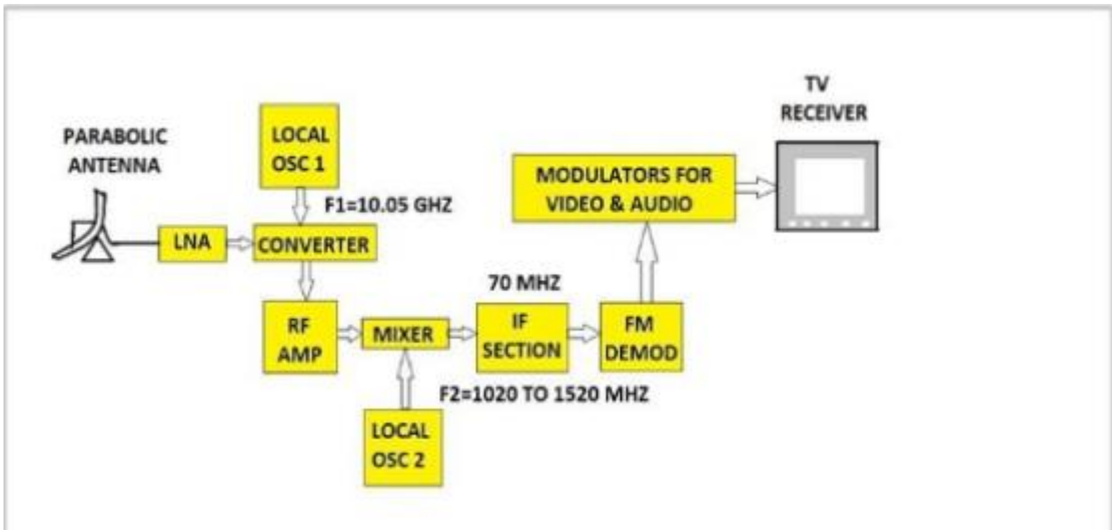
OUTDOOR UNIT

The outdoor unit consist of:

1) The parabolic satellite antenna
2) Low noise amplifier(LNA)

3) Converter

- The receiver antenna is a parabolic reflector horn antenna which is directed directly to the satellite to receive the signal.
- The received signal from satellite by the antenna is applied to the low noise amplifier(LNA) which is a wide band amplifier.
- LNA amplifies all the frequencies received from the antenna and applies them to a converter.
- The second input to this converter is from the local oscillator 1.
- The converter output consist of a UHF signal having a frequency range from 950-1450 MHz with a bandwidth of 500 MHz.
- The output of converter is applied to the RF amplifier.



Indoor Unit

- It consist of an RF amplifier which is applied to a channel selector to select the desired channel with the help of the mixer & local oscillator too.
- An IF frequency of 70MHz is produced.
- The RF amplifier applied these to video-audio detector which separates the video , audio & synchronous pulses.
- The TV receiver then works as usual.
- A DBS(Directly Broadcast Satellite) concept is used in DTH system.

Advantage:

- DTH also offers digital quality signals which do not degrade the picture or soundquality.

- It also offers interactive channels and program guides with customers having thechoice to block programming which they consider undesirable
- One of the great advantages of the cable industry has been the ability toprovide local channels, but this handicap has been overcome by manyDTHproviders using other local channels or local feeds.
- The other advantage of DTH is the availability of satellite broadcast inrural and semi-urban areas where cable is difficult to install.

Geosynchronous satellites

Geosynchronous satellites orbit Earth above the equator with the same angular velocity as earth. Hence it is also called stationary or geo-stationary satellites. It appear to remain in a fixed location above one spot on Earth's surface, so no special antenna tracking equipment is necessary, earth station antennas are simply pointed at the satellite.

Satellites remain in orbit as a result of a balance between centrifugal and gravitational forces. If a satellite is travelling at too high a velocity, its centrifugal force will overcome Earth's gravitational pull, and the satellite will break out of orbit and escape in to space.

At lower velocities, the satellite centrifugal force is insufficient, and gravity tends to pull the vehicle towards earth. So there is a balance b/w acceleration, speed and distance that will exactly balance the effects of centrifugal and gravitational forces.

The closer to earth a satellite rotates, the greater the gravitational pull and the greater the velocity required to keep it from being pulled to earth.

Geosynchronous orbits are circular, therefore the speed of rotation is constant throughout the orbit.

Ideally geosynchronous satellite should remain stationary above a chosen location over the equator in an equatorial orbit. But the sun and the moon exert gravitational forces, and earth is not perfectly spherical too. So these unbalanced forces cause geosynchronous satellites to drift slowly away from their assigned locations. Ground controllers must periodically adjust satellite positions to counteract these forces.

Requirement

* Geosynchronous satellite must have a 0° angle of inclination ie satellite vehicle must be orbiting directly above earth's equatorial plane.

- The satellite must be orbiting in the same direction as earth's rotation with same angular velocity i.e one revolution per day.

The semimajor axis of a geosynchronous earth orbit is the distance from a satellite revolving in the geosynchronous orbit to the centre of earth

Using Kepler's third law

$$\alpha = A P^{2/3}$$

A = constant

α = semimajor axis

P = mean solar earth days

A = 42241.0977

P = 0.9972

$\alpha = A P^{2/3}$

$= (42241.0977)(0.9972)^{2/3}$

$= 42{,}164$ km

Hence geosynchronous earth orbit satellites revolve around earth in a circular pattern directly above the equator 42,164 km from the centre of earth.

Earth equatorial radius = 6378 km

Height above mean sea level (h) of a satellite in a geosynchronous orbit around earth is

$h = 42164\ km - 6378\ km$

$= 35\ 786\ km$

Orbital velocity (v)

Circumference of a geosynchronous orbit is

$c = 2\pi\ (42,164)\ km$

$= 264,790\ km$

Velocity $v = \frac{264,790\ km}{24\ hr}$

$= 11,033\ km/hr$

Round trip Time delay :- between a satellite and earth station, $t = \frac{d}{c}$

$= \frac{2 \times 35,768\ km}{3 \times 10^5\ km/s}$

$= 238\ ms$

Advantages

* It remains almost stationary, so expensive tracking equipment is not required.
* Effects of doppler shift is negligible.
* No need to switch from one satellite to another as they orbit overhead, so there are no transmission breaks due to switching times

Disadv

* Require sophisticated and heavy propulsion devices to keep them in a fixed orbit
* Require higher tx'ed power and more sensitive receivers because of longer distance and greater path loss.
* longer propagation delay for high altitude satellite.