1.5 SATELLITE FREQUENCY BANDS (or) FREQUENCY USED IN LINK ESTABLISHMENT.

- Satellite technology is developing fast and the applications for satellite technology are increasing all the time. Not only satellite can be used for radio communications, but they are also used for,
  - Astromy
  - weather forecasting
  - broadcasting
  - Mapping and more applications.
- The higher frequency bands typically give access to wider Bandwidths, but are also more susceptible to signal degradation due to 'rain fade' (the absorption of radio signals by atmospheric rain, snow or ice).
- Because of satellites increased use, number and size, congestion has become a serious issue in the lower frequency bands. New technologies are being investigated so that higher bands can be used.

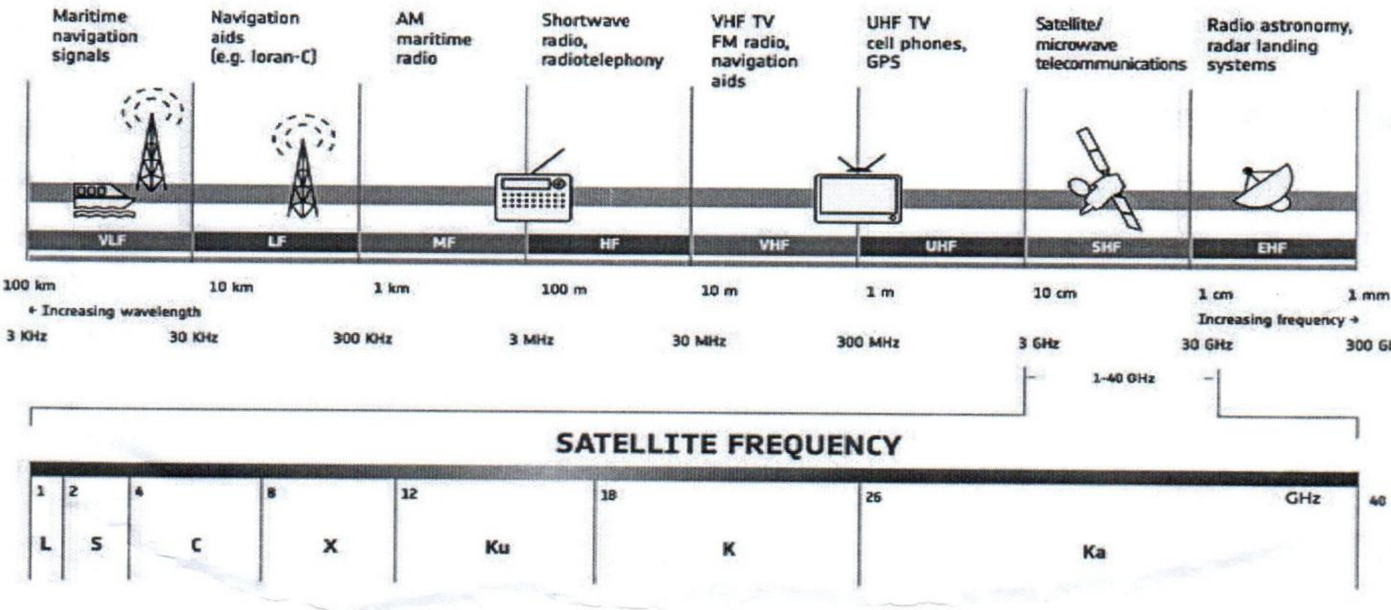


Fig: 5 Satellite Frequency Bands

- L-Band (1-2 GHz): GPS carriers and also satellite mobile phones, such as Iridium, Inmarsat providing communications at sea, land and air; worldspace Satellite Radio.
- S-band (2-4 GHZ): weather radar, surface ship radar and especially those of NASA for communication with ISS and Space Shuttle.
- C-band (4-8 GHZ): used for full time satellite TV networks or raw satellite feeds. Commonly used in areas that are subject to tropical rainfall.

Region 1 - Europe, Africa and Mongolia.

Region 2 - North and South America and Greenland.

Region 3 - Asia (excluding region 1 areas), Australia, and the South west pacific

• For any given frequency allocation for a service, there is an allocation of an uplink band and downlink band, with uplink band always of higher frequency.

Frequency Band	Frequency Range	Applications
VLF	3 - 30KHZ	Guided between earth & inosphere
LF	30 - 300KHZ	Ground waves
MF	30-3000 KHZ	Ground waves during the day
HF	3 - 30 MHZ	Inospheric reflections
VHF	30 - 300MHZ	Line of sight (Messeging)
UHF	300 - 3000MHZ	Military, Navigation Mobile, Digital audio broadcasting (DUB).
L Band	1-2GHZ	Mobile Satellite Service (MSS)
S-Band	2-4 GHZ	MSS, NASA, Deep Space research.
C-Band	4-8 GHZ	Fixed Satellite Service (FSS)
X-band	8 - 12GHZ	FSS for military, Terrestrial earth exploration and Meteorological Satellites.

⊙ X-band (8 - 12 GHz): primarily used by military. used in radar applications including continuous-wave, pulsed, single-polarisation, dual polarisation, synthetic aperture radar and phased arrays.

- X-band radar frequency subbands used in civil, military and government institutions for weather monitoring, air traffic control, maritime vessel traffic control, defence tracking and vehicle speed detection for law enforcement.

⊙ Ku-band (12-18 GHz): used for satellite communications. In Europe, Ku band downlink is used from 10.7 GHz to 12.75 GHz for direct broadcast services, such as Astra.

⊙ Ka-band (26-40 GHz): Communication satellites, uplink in either 27.5 GHz and 31 GHz bands, and high resolution close range targeting radars on military aircraft.

→ Frequency allocations for satellite services requires International coordination and planning. An International union called "International Telecommunication Union (ITU)" plan for this.

- ITU has divided the world into 3-regions for the purpose of frequency allocations. These regions are,

Ku-band	12-18GHz	FSS, Broadcast Satellite Service (BSS)
K-band	18-27GHz	BSS, FSS
Ka-Band	27-40GHz	FSS, Audio broadcasting, Intersatellite.

Table: 1 Frequency Bands for Satellite communication

⊙ The Satellite link can be frequency bands for uplink and downlink in Satellite Communication, given in The table as,

Band	uplink frequency (GHz)	Downlink frequency (GHz)
UHF - military	0.292 - 0.312	0.250 - 0.270
C - commercial	5.925 - 6.425	3.7 - 4.2
X - Military	7.9 - 8.4	7.25 - 7.75
Ku - Broadcast and fixed point Service, Commercial	14.0 - 14.5	11.7 - 12.2
Ka - commercial	27.5 - 31.0	17.7 - 21.2

Table: 2 frequency Bands for uplink and downlink in Satellite communication.

⊙ uplink frequency ranges are greater than downlink frequencies in satellite communication because of the following reason:

1. Ground temperature of the earth which contributes to the thermal Noise is large and so the frequency is increased to increase the Signal to Noise ratio (SNR)

2. To minimize the impact one Microwave Service might have upon another (Satellite on fixed terrestrial, WiMAX on fixed Satellite, fixed terrestrial on satellite).

3. Rain attenuation has related directly to the ~~bigger~~ transmitted frequency, as higher the frequency the bigger rain attenuation is possible.

- Allocation of frequencies to satellite services s a complicated process which requires international coordination and planning. This is done as per the International Telecommunication Union (ITU).
- To implement this frequency planning, the world is divided into three regions:

Region1: Europe, Africa and Mongolia

Region 2: North and South America and Greenland

□Region 3: Asia (excluding region 1 areas), Australia and south-west Pacific.

- Within these regions, he frequency bands are allocated to various satellite services. Some of them are listed below.

Fixed satellite service: Provides Links for existing Telephone Networks Used for transmitting television signals to cable companies

Broadcasting satellite service: Provides Direct Broadcast to homes. E.g. Live Cricket matches etc

Mobile satellite services: This includes services for:
Land Mobile Maritime Mobile Aeronautical mobile

Navigational satellite services : Include Global Positioning systems

Meteorological satellite services: They are often used to perform Search and Rescue service

1.6 Multiple Access Techniques in Satellite Communication

1.6.1 Introduction:

(i) Multiple Access (MA) techniques are used for interconnecting large number of earth station terminals through satellite,
ii) one earth station can communicate with all other ~~satellite~~ stations using the same satellite.
(i) MA techniques provide wide Geography coverage capability.

Multiple Access:

(i) Ability of the satellite to carry many signals at the same time is known as multiple access.

Multiplexing:

(i) It is a process of combining a number of signals into a single, so that it can be processed by a single amplifier or transmitted over a single radio channel,
(i) Multiplexing can be done at a base band or at a radio frequency.

Demultiplexing: The techniques that recovers the individual signals is called demultiplexing.

⊙ Why Multiple Access Techniques ?

1) Allow interconnection among Various earth Stations through Satellite

2) provides wide Geography coverage capability

3) Allow best utilization of Satellite channel.

⊙ Multiple access scheme optimize the following parameters:

1) RF Spectrum

2) Satellite Radiated power

3) connectivity & Ground Station complexity

4) Economics

5) Security

6) Handling of different types of traffic.

1.6.2 Types of Multiple Access Techniques:

- Concept of various multiplexing techniques are used for multiple Access techniques like FDM, TDM hence the various Multiple access techniques used in Satellite Communication are FDMA (frequency Division Multiple Access), TDMA (Time division Multiple Access) and CDMA (code division Multiple Access)

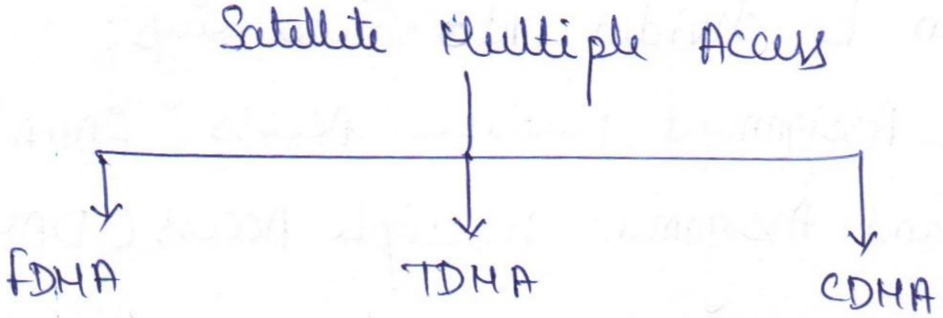


Fig: Types of Multiple Access techniques

FDMA → All user share the satellite at the same time, but each user transmits at a unique allocated frequency.

TDMA → Each user is allocated a unique time slot at the satellite so that signals pass through the transponder sequentially.

CDMA → All user transmit to the satellite on the same frequency and at the same time.

1.6.2.1 FDMA (Frequency Division Multiple Access)

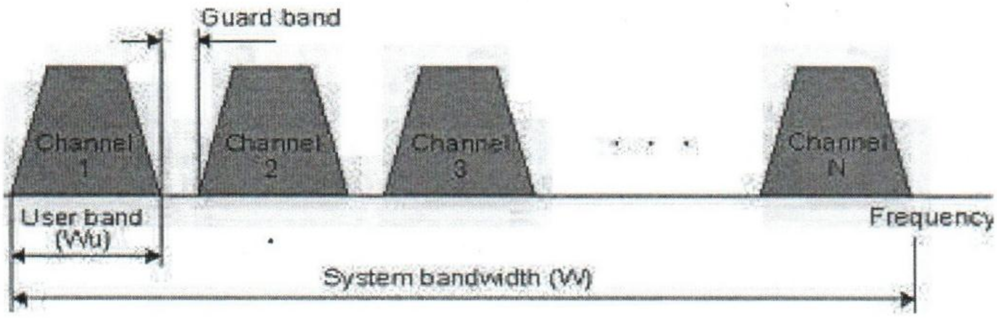
- In FDMA Satellite frequency is divided into bands and hence small channels are made, and one user is allowed to use the band of infinite amount of time this type of multiple access is known as Frequency division Multiple Access (FDMA), since accessing is done on the basics of broken frequency bands.
- FDMA can be divided into two ways:
  - i) Fixed Assignment Multiple Access (FAMA)
  - ii) Demand Assignment Multiple Access (DAMA).

Fixed Assignment Multiple Access (FAMA):

The Sub channel assignments are fixed that is allotment for every sub channel is same. This type of multiple access techniques is suitable for broadcast satellite communication.

Demand Assignment Multiple Access (DAMA):

The Sub channel allotment depends and changes with demand, hence according to users demand this allotment changes. This types of multiple access technique is suitable for point to point communication.



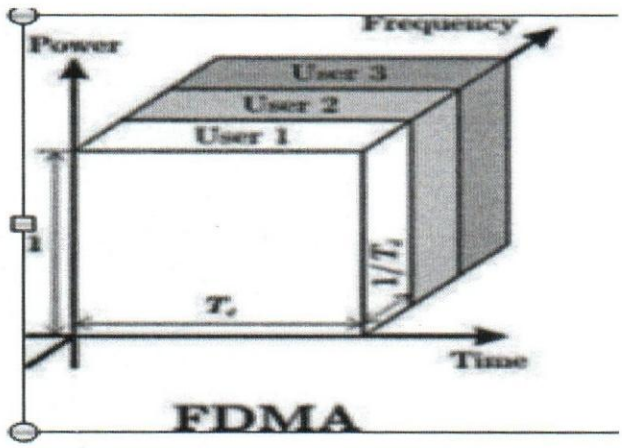


Fig: 6 Principle of FDMA

FDMA is the process of dividing one channel or bandwidth into multiple individual bands, each for use by a single user . Each individual band or channel is wide enough to accommodate the signal spectra of the transmissions to be propagated. The data to be transmitted is modulated on to each subcarrier, and all of them are linearly mixed together.

Principles of FDMA are explained with the help of a communications route between two earth stations A and B.

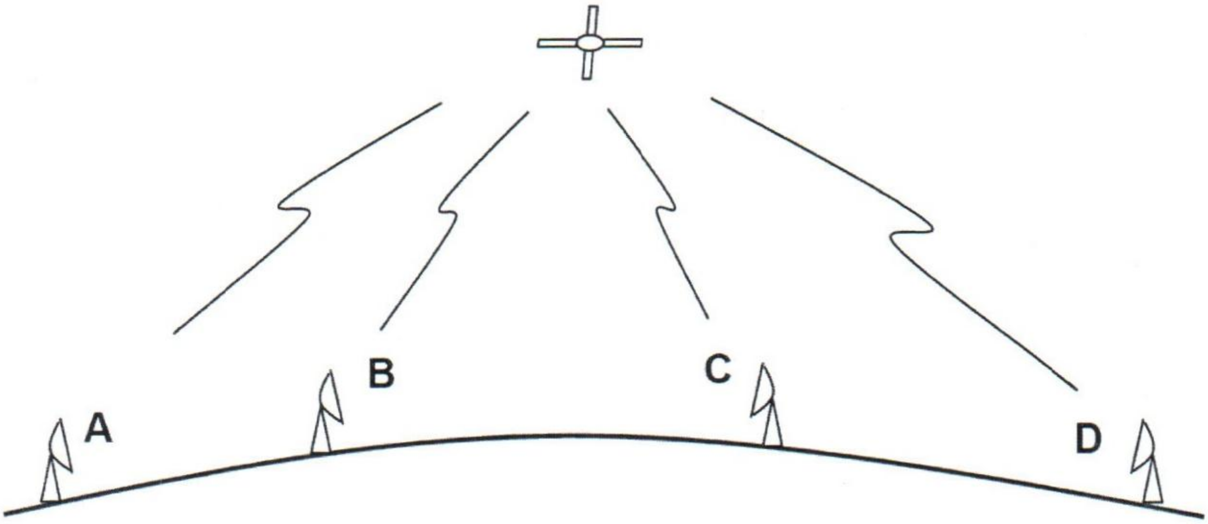


Fig: 7 Communications route between two earth stations A and B Using FDMA

A communication route between two earth stations (A and B) in the network is shown in the following figure.

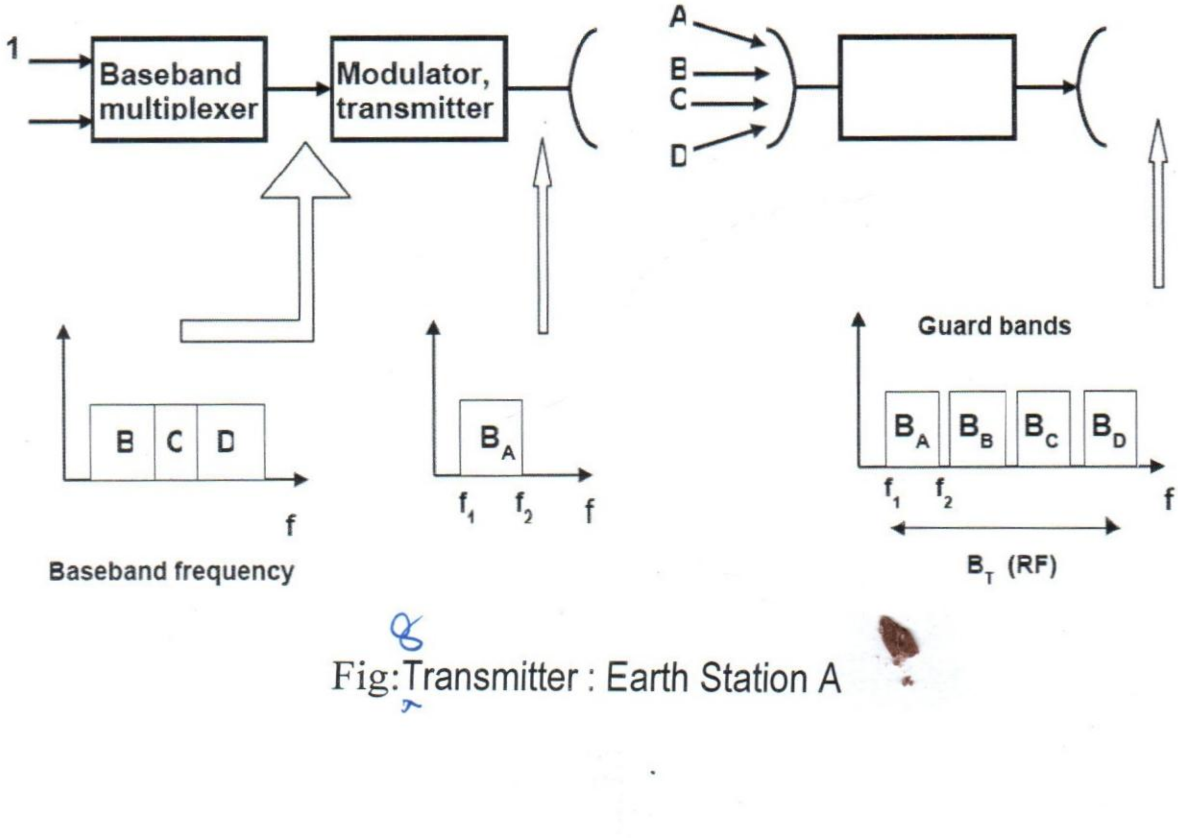


Fig: 8 Transmitter : Earth Station A

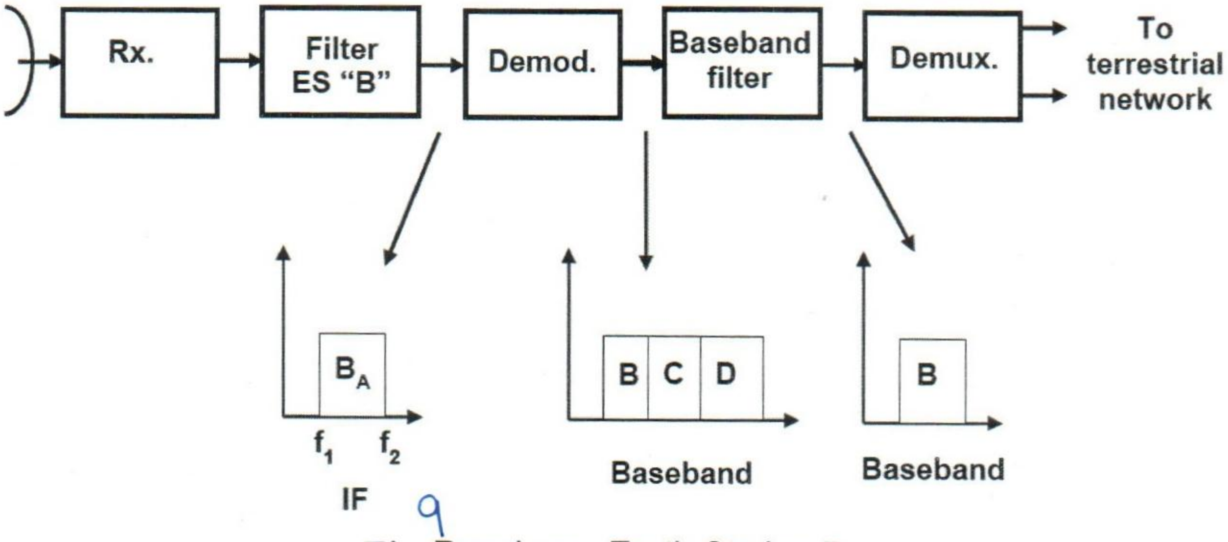


Fig:Receiver : Earth Station B

Types of FDMA:

FDMA may be divided into two main categories based on the traffic demands of earth station

1. Multiple channel per carrier (MCPC)
2. Single channel per carrier (SCPC)

1. MULTIPLE CHANNEL PER CARRIER (MCPC)

- When several voice band channels are frequency division multiplexed together to form a composite base band signal.This is reffered as**MULTIPLE CHANNEL PER CARRIER (MCPC)**
- Analog signals, such as those used by satellite TV and terrestrial microwave-relay communications, depend on subcarriers. MCPC technology modulates analog signals as signals with higher frequencies and bandwidth. Subcarriers are transmitted with video carrier signals on a satellite transponder at frequencies of 5.8 MHz, 6.2 MHz or 6.8 MHz with extra audio at 7 MHz or 8 MHz, as needed. These are the MCPC transmissions, and the satellites involved are known as MCPC satellites.

- By 2011, MCPC technology was largely replaced by digital TV, which multiplexes audio and video data as a single Moving Picture Experts Group (MPEG) transport stream. This process involves streaming multiple video signals from film, sports and news broadcasts, as well as multiplexing data as a single transport stream, which is directed to a large antenna. This antenna broadcasts the stream to a TV with an Advanced Television Systems Committee (ATSC) tuner that receives and decodes signals for screen display.

- Baseband filter in earth station receiver corresponds to a specific transmitting station. Any change in traffic requires the retuning of this filter.

□ Change in traffic are difficult to implement. MCPC is further categorized according to the type of baseband.
e.g FDM / FM / FDMA
or TDM / PSK / FDMA.

2. Single Channel per Carrier (SCPC)

- When the earth station sends one signal on a carrier, then the FDMA access technique is called **Single Channel per Carrier (SCPC)**
- When traffic is low, e.g. service to remote areas, MCPC becomes wasteful of bandwidth because most of the channels remain unutilized for a significant part of the time. SCPC is used in this case.
- In SCPC, each carrier transmits a single channel. SCPC may be preassignedor demand-assigned.

Pre-assigned : e.g. 5 – 10 channels are permanently assigned to an earth station.
Demand-assigned : a pool of frequencies is shared by earth stations. The earth station requests a channel from a pool manager.

Advantages:

1. Using well established technology.

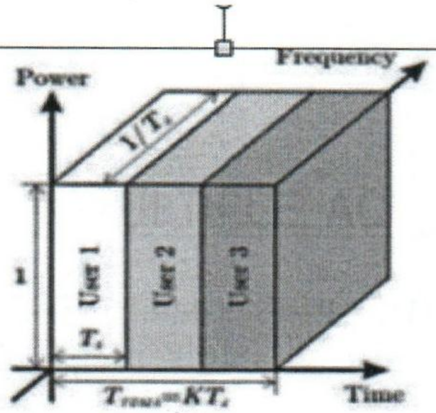
2. No need for network timing.
3. No restriction regarding the type of baseband or the type of Modulation

Disadvantages:

1. Inter-modulation noise in the transponder leads to interference with other links – satellite capacity reduction.
2. Lack of flexibility in channel allocation.
3. Requires up-link power control to maintain quality.
4. Weak carrier tend to be suppressed.

1.6.2.2 TIME DIVISION MULTIPLE ACCESS (TDMA)

According to this multiple earth stations transmits at the same frequency but in different time slots, that is entire frequency band is divided on the basis of time that is, one user will use the complete frequency band for a given time slot and another user will use the same frequency band for some other time slot hence like this TDMA is done.



TDMA

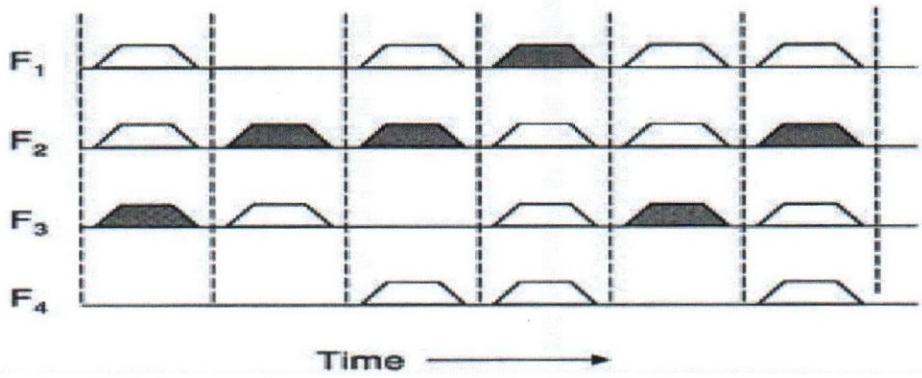


Fig: 10 **Principle of TDMA**

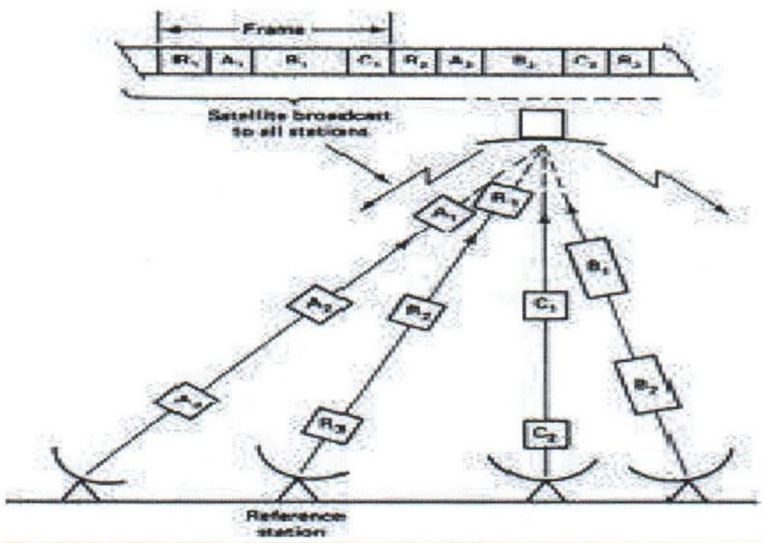


Fig: 11 TDMA Burst synchronization

Hence there are several earth stations as shown in the above diagram, these transmit traffic bursts in a period time frame well known as TDMA frame, hence the earth stations can access the entire bandwidth of the transponder but during their time slot. There is a time termed as guard time between transmitting times of individual bursts such that bursts may not overlap.

TDMA can be of two ways :

1) Fixed Assignment TDMA: In Fixed Assignment TDMA frame is divided into time slots of fixed duration.

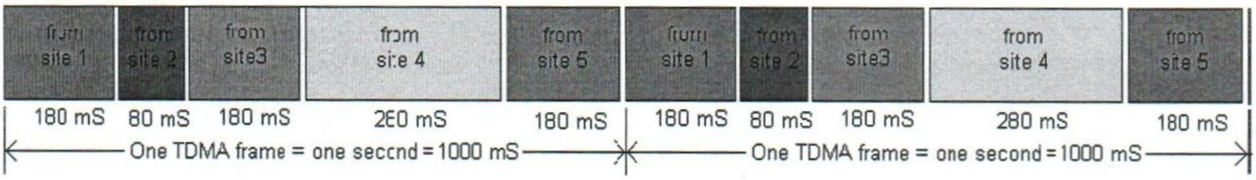
2) Demand Assignment TDMA: In Demand Assignment TDMA, the transmission time are demand based.

Number of voice channels n in a TDMA system is given by the expression:

n= (1/r) (R-NP/T)

r: Voice channel bit rate
T: Frame period
P: Number of digits in the preamble
R: Satellite channel bit rate (power or band limited)
N: Number of bursts in a frame.

TDMA frame structure:



TDMA burst structure:

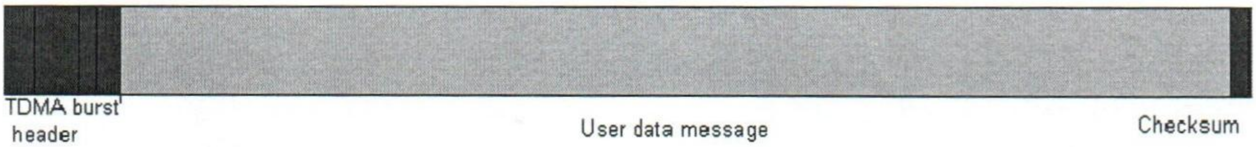


Fig: 12 Fram Structure (TDMA)

TDMA frame efficiency:

TDMA frame efficiency is defined as the ratio of time devoted foe usefull transmission to the total frame length

$$\eta = 1 - \sum t / T_F$$

Where t=sum of all guard times and preamble

T_F = Total frame time

TDMA Frame Acquisition and Synchronisation:

- It is very essential that the traffic stations while transmitting must transmit in the given time slot and similar goes with receiving, the aim is that the burst should not overlap with each other , this accuracy is achieved by using Fame acquisition and Frame Synchronisation.
- Various tuimings in TDMA are Transmit Frame timing, Transmit burst timing, Receive frame timing and Receiving burst timing, and the processes of acquisition and synchronisation are receive frame acquisition, transmit frame acquisition, transmit frame synchroniosation and receive frame synchronisation.
- Doppler shift is used in various timings , this shift is used in various timings, on the basis of techniques for determining D_N , there are two kinds of synchronisation processes:

1) **Open Loop control Method** : D_N is determined by earth station directly from monitoring its own transmission.

2) **Closed Loop control Method**: In this bursts aren't received directly by transmitting stations but some other methods are used.

Advantages of TDMA

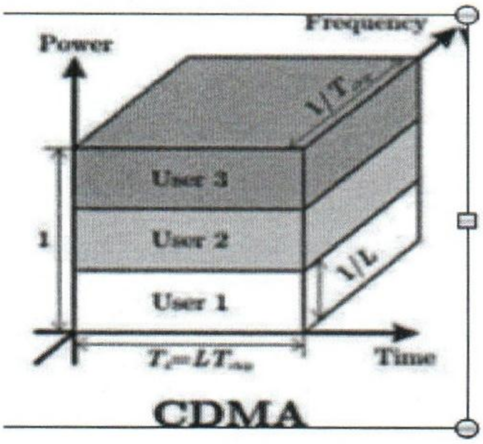
1. Uplink power control is required
2. Transmission plans are easier to construct and modify
3. Capacity management is simply and flexible
4. Maximum use can be made of the available satellite power since intermodulation noise is minimal

Dis-Advantages of TDMA

1. Analog system must be converted to digital form
2. Interference with analog terrestrial plant is expensive
3. It requires network wide timing synchronization hence it is relatively complex

1.6.2.3 CODE DIVISION MULTIPLE ACCESS(CDMA)

- Code division multiple Access is a scheme in which a number of users can use entire transponder bandwidth at all of the time.
- CDMA uses digital format, in this several transmissions takes place simultaneously on the same frequency bandwidth.



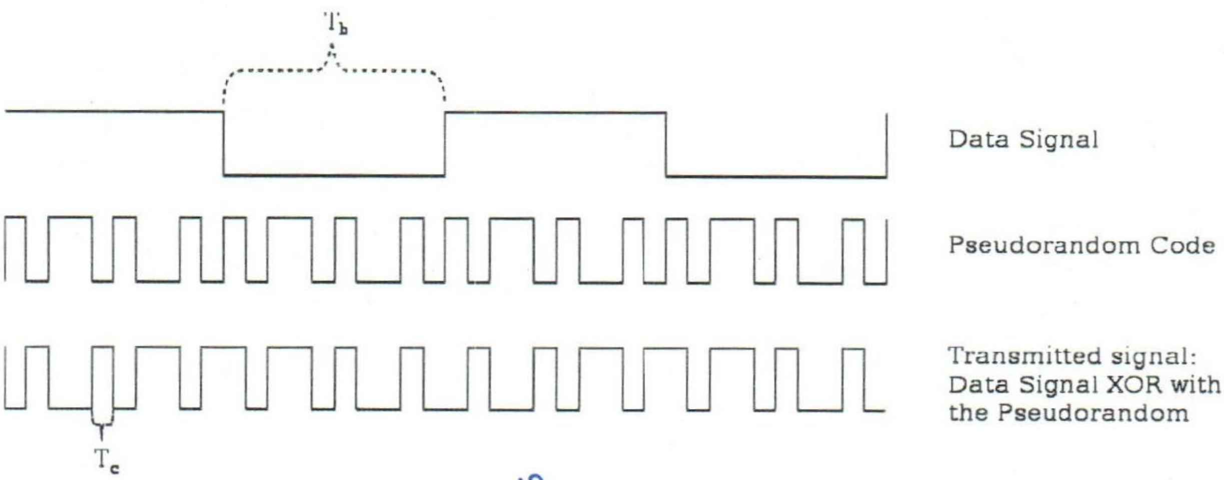


Fig: 13 principle of CDMA

- The user data at the transmitter side is combined with a code and is then transmitted and everything gets mixed in air and at the receiver's side the same code is used.

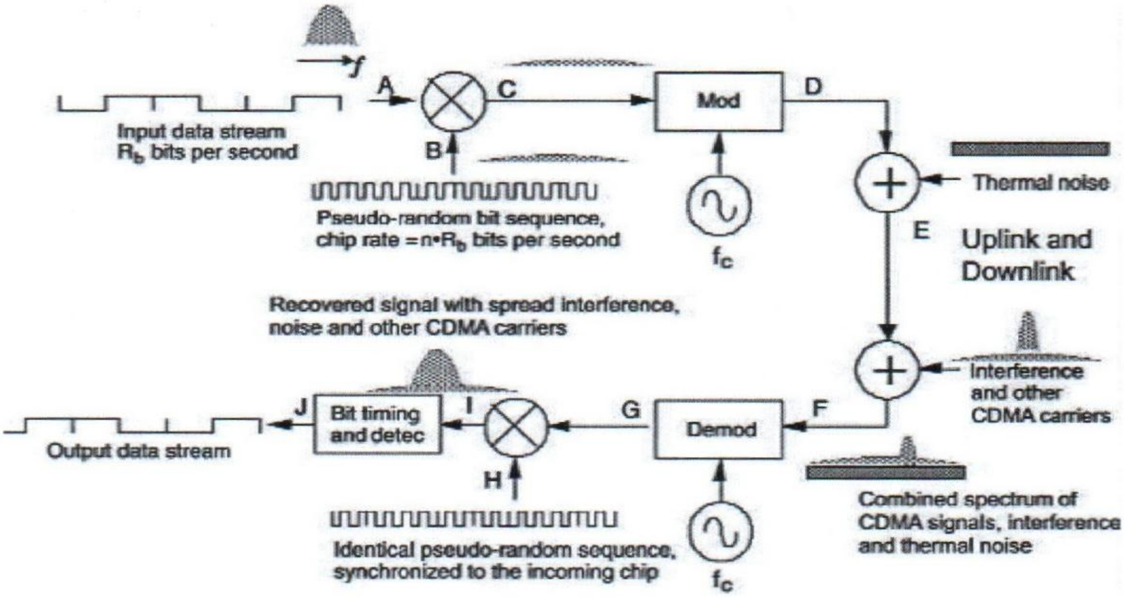


Fig: 14 Block Diagram of CDMA System

- CDMA combines modulation and multiple accesses to achieve a certain degree of information efficiency and protection through the technique of spread spectrum communications.
- The message signal is spread over a wide band by multiplying it with a noise like or pseudo random spreading signal.so CDMA is also known as **spread spectrum (SS).**
- To apply an SS technique, simply inject the corresponding SS code somewhere in the transmitting chain before the antenna. (That injection is called the spreading operation.) The effect is to diffuse the information in a larger bandwidth. The SS code (despreading operation) at a point in the receive chain before data retrieval. The effect of a despreading operation is to reconstitute the information in its original bandwidth. Obviously, the same code must be known in advance at both end of the transmission channel.

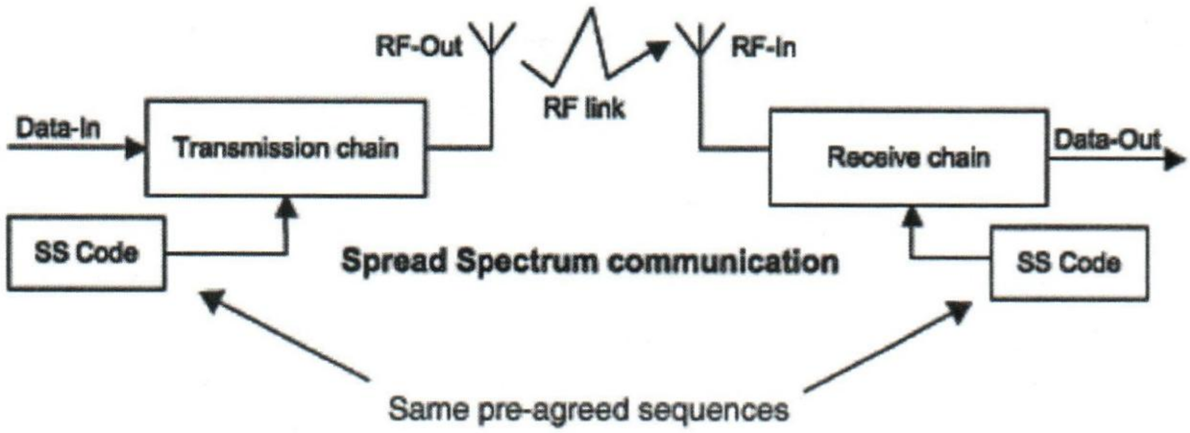


Fig: 15 A Basic spread spectrum System

- CDMA system is divided into two ways:
  1. Direct Sequence Spread Spectrum(DSSS)
  2. Frequency Hopped Spread Spectrum(FHSS)

Direct Sequence Spread Spectrum(DSSS):

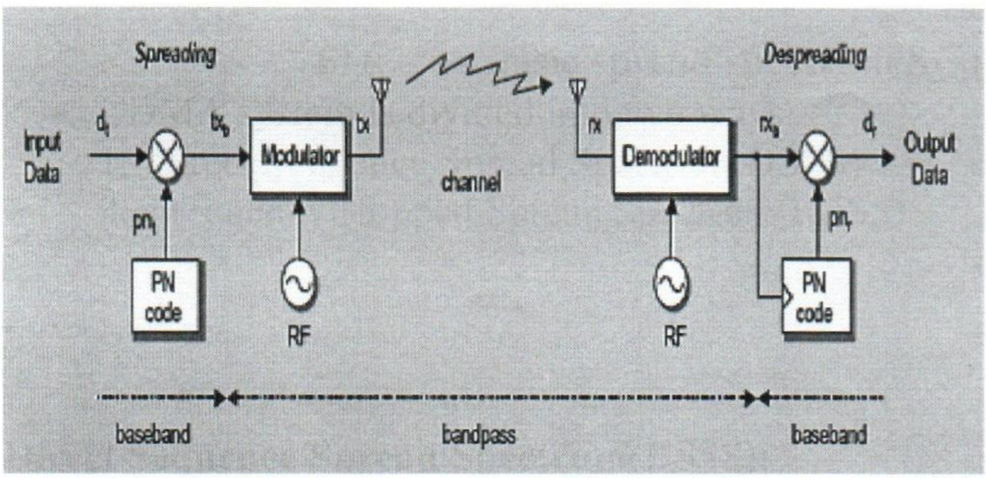


Fig: 16 DSSS Block Diagram

In Direct Sequence-Spread Spectrum the baseband waveform is XOR by the PN sequence in order to spread the signal. After spreading, the signal is modulated and transmitted. The most widely modulation scheme is BPSK (Binary Phase Shift Keying).

Advantages of CDMA:

1. Small antennas can be employed without any problem of interference from adjacent satellite
2. Spread spectrum systems are resistant to multipath noise which is commonly experiences by mobile terminals
3. CDMA is highly resistant to interference and therefore satellite spacing can be reduced considerable without causing unacceptable degradation in received signal quality.

1.7 SATELLITE EARTH STATION (ES)
(OR) SATELLITE COMMUNICATION SYSTEM:—

⊙ The earth-based communications station providing the communication link to a communication satellite. The earth station itself is usually an antenna that includes a low-Noise amplifier, a down-converter, as well as an electronics Receiver.

⊙ It also provide and maintain the necessary command and control links with spacecraft.

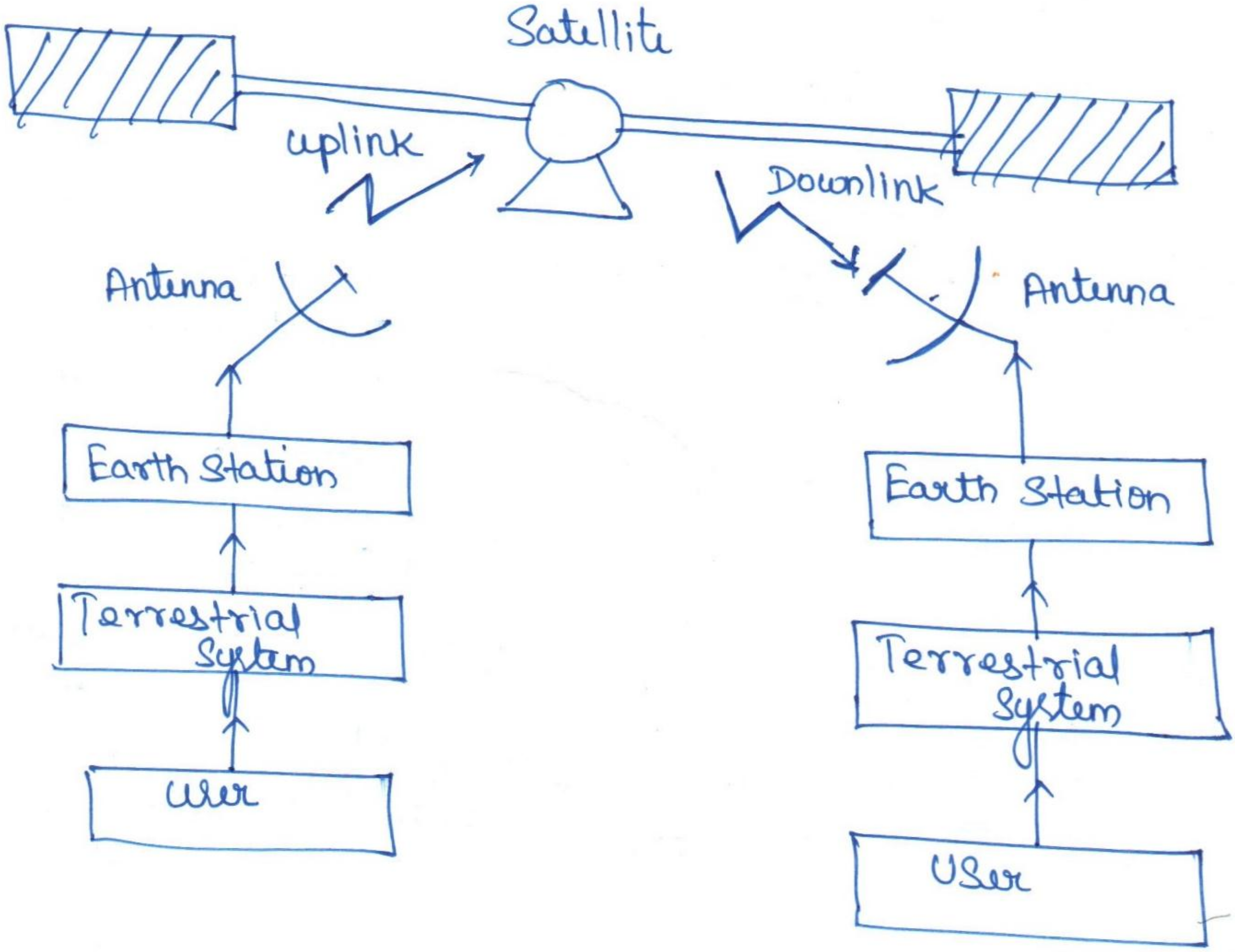


Fig: 17 Satellite communication system

Satellite Earth Station or Satellite Subsystem :-

- Earth Station provides the communication pathway between the Geo-Stationary Satellite and local networks. Signals from the all the local networks are send to the Satellite for long distance communication and Signal Received from the Satellite are send to desired location within a network is done by the Earth Station.
- Major Subsystems of earth stations are Receiver, antenna, transmitter and tracking equipment.
- Example of Special earth stations are,
  - (i) TVRO (DTH)
  - (ii) Tracking and control of Satellite

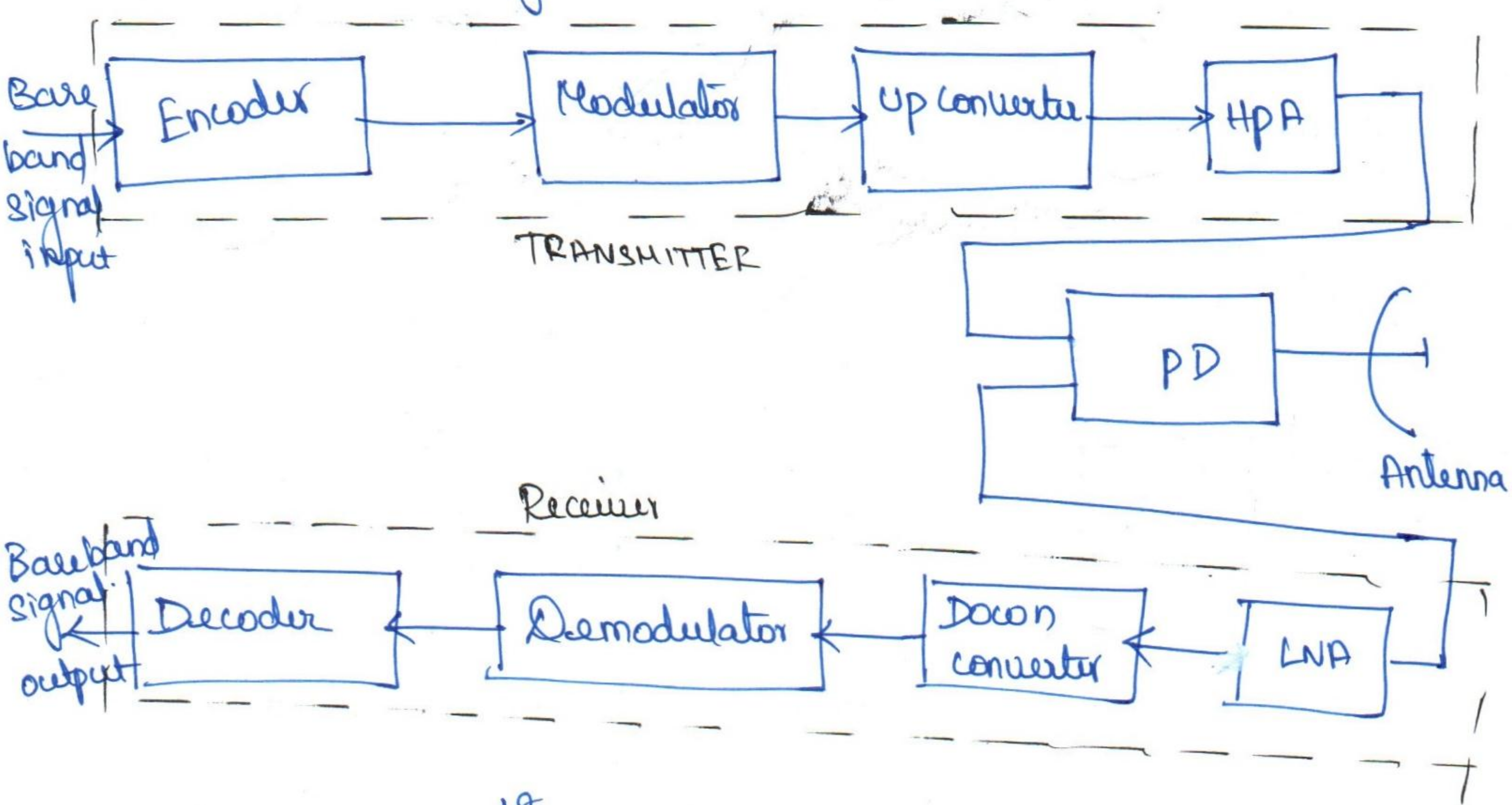


Fig: Block diagram of Earth Station Communication

where HPA - High power Amplifier
LNA - Low Noise Amplifier
PD - polarized Duplexer.

- Base band signal is applied to the encoder, which converts the format ready for modulation.
- Modulated signal is upconverted to a uplink frequency by the upconverter.
- Amplifier Amplifies this signal to high power level ready for transmission, then the signal is passed through the polarization feed of the antenna.
- Received signal is of different frequency (Downlink frequency) and is very small in amplitude.
- This signal is amplified by Low Noise amplifier, then down converted to intermediate frequency by down converter, then demodulated & decoded to get baseband signal.

(X) (Insert Fig: 19 Earth station)

(i) Earth Station Transmitter:-

- Earth Station transmitter consists of IF modulator, IF to RF up converter, HPA and Band pass filter.
- Modulator techniques used in transmitter side are FM, PSK or QAM which are modulated Intermediate

frequency (IF).

• The IF from Modulator and RF from oscillators are mixed to provide Radio frequency as uplink frequency range as 6 GHZ or 14 GHZ for c band or ku band respectively.

• HPA provides adequate input sensitivity and output power to propagate the signal to the satellite transponder.

• HPA are used commonly as klystron and Traveling wave Tube Amplifiers (TWTA).

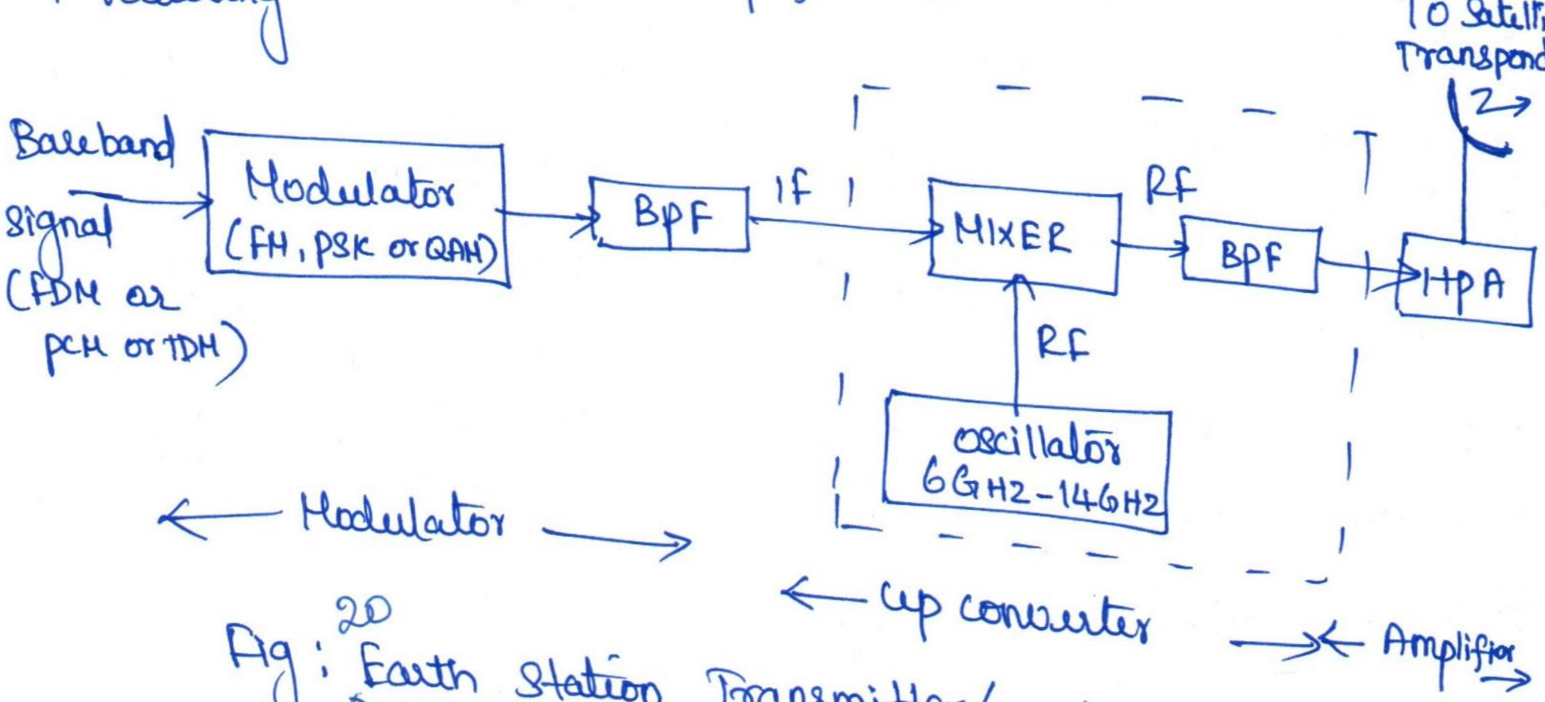


Fig 20: Earth Station Transmitter (uplink Model).

(ii) Satellite Transponder:-

Transponder can receives the uplink transmission from earth station Transmitter and transmits the signal to Receiver as downlink.

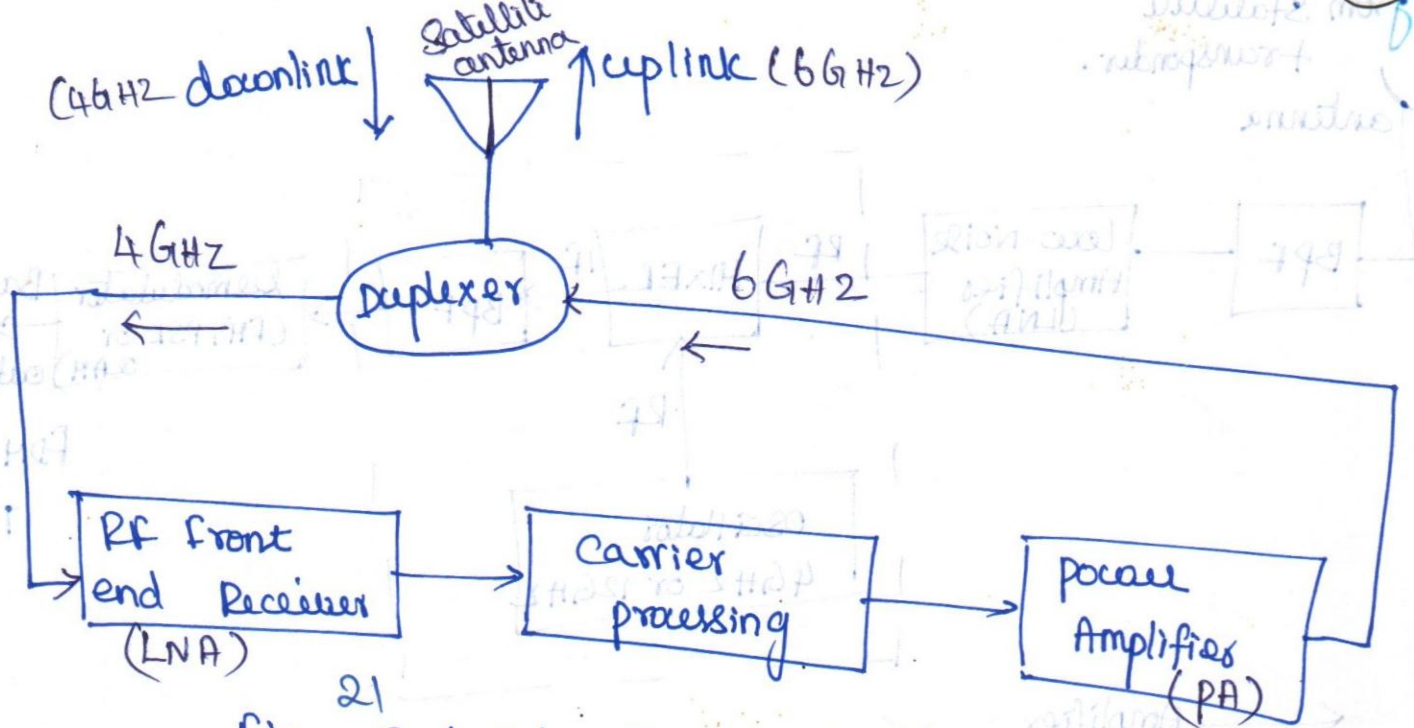


Fig: 21 Satellite Transponder

- Front end Receiver Increase SNR of Received signal and provides amplification.
- Carrier processing involves modulation of uplink carrier frequency and demodulation of downlink frequency.
- Duplexer can Seperate uplink & downlink frequencies and done Simultaneous transmission & Reception of Signals.
- power amplifier used to increase power level of downlink carrier, Gain of transponder is 80-100dB.

(iii) Earth Station Receiver:

- The Receiver section of satellite earth station performs exact opposite function of transmitter.

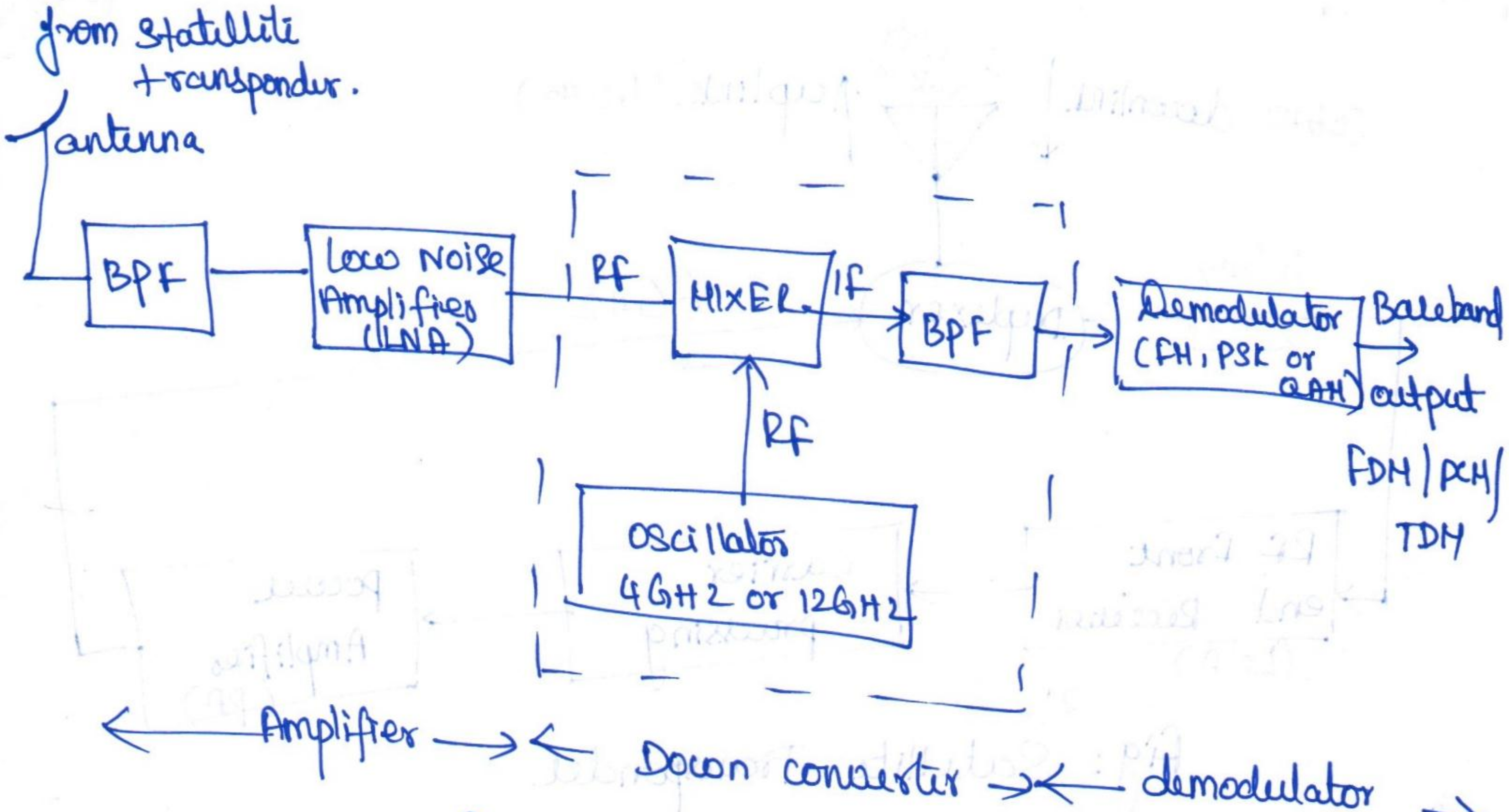


Fig: 22 Earth Station Receiver (down-link).

⊙ Here Low Noise Amplifier can be tunnel diode amplifier (or) parametric amplifier.

⊙ BPF limits the input Noise power to LNA.

1.8 SATELLITE APERTURE ACTUATORS

- Actuators in space are broadly used to operate satellites' platform and payload devices.
- Actuators still represent critical subsystems as their failure might often lead to severe, when not catastrophic, effects on the spacecraft operations.
- Environmental conditions to which actuators are exposed in space are generally not favourable: operating temperature ranges and deep vacuum are certainly the most critical ones

Very Small Aperture Terminal(VSAT):

- VSAT (Very Small Aperture Terminal) is a satellite communications system that serves home and business users. A VSAT end user needs a box that interfaces between the user's computer and an outside antenna with a transceiver.
- The tranceiver receives or sends a signal to a satellite transponder in the sky. The satellite sends and receives signals from an earth station computer that acts as a hub for the system. Each end user is interconnected with the hub station via the satellite in a star topology.
- For one end user to communicate with another, each transmission has to first go to the hub station which retransmits it via the satellite to the other end user's VSAT. VSAT handles data, voice, and video signals.
- A very small aperture terminal (VSAT) is a two-way satelliteground station with a dish antenna that is smaller than 3 meters. The majority of VSAT antennas range from 75 cm to 1.2 m. Data rates range from 4 kbit/s up to 16 Mbit/s. VSATs access satellites in geosynchronous orbit to relay data from small remote Earth stations (terminals) to other terminals (in meshtopology) or master Earth station "hubs" (in star topology)
- VSATs are used to transmit narrowband data (e.g., point-of-sale transactions using credit cards, polling or RFID data, or SCADA), or broadband data (for the provision of satellite Internet access to remote locations, VoIP or video). VSATs are also used for transportable, on-the-move (utilisingphased array antennas) or mobile maritime communications.

1.9 INTERNATIONAL TELECOMMUNICATION SATELLITE (INTELSAT):

- INTELSAT provides telecommunication services to its member countries throughout the world by means of satellite systems owned by it.
- The organisation was created in 1964 and currently has over 140 member countries and more than 40 investing entities.
- July 2001 INTELSAT become private company and in May 2002 the company began providing end-to-end solutions through a network of teleports, leased fiber, and points of presence (pops) around the globe.
- provides Applications TOOLKIT to guide us through design, planning, budgeting and deployment of satellite network.
- The ~~telecommunication~~ services includes,
  1) TV & telephone services
  2) Digital transmissions services
  3) Telegraphy
  4) Telex.
  5) computer to computer
  6) Video conferencing, Videotext etc.

- Every Satellite network is unique & determines which Services to use
- Each telecommunication Services by means of Satellite Systems.
- organisation founded in 1964 Aug 20.
- Design of network depends on,
  - Specific application
  - Geography of network
  - Volume of traffic.
- There are 10 INTELSAT Satellite System, they are categorized as,

Intelsat 1 - 1 Satellites	Intelsat 7 - 6 Satellite
Intelsat 2 - 4 Satellites	Intelsat 7A - 3 "
Intelsat 3 - 8 "	Intelsat 8 - 4 "
Intelsat 4 - 8 "	Intelsat 8A - 2 "
Intelsat 4A - 6 "	Intelsat 9 - 7 "
Intelsat 5 - 9 "	Intelsat 10 - 1 "
Intelsat 5A - 6 "	
Intelsat 6 - 5 "	

- INTELSAT 10 - Satellites are the latest series. They provide wider range of services like
  - Internet
  - Direct to Home (DHT)
  - Telemedicine, tele-education
  - Interactive video and multimedia.
- International traffic - INTELSAT coverage
  - Atlantic Ocean Region (AOR)
  - Indian ocean Region (IOR) and
  - pacific ocean Region (POR)
- For each region, the satellites are positioned in Geostationary orbit above the particular ocean, when they provide a transoceanic telecommunications route.

1.10 INDIAN NATIONAL SATELLITE SYSYTEM (INSAT):

- INSAT is one of the largest domestic satellite system in the world
- INSAT is a series of multipurpose geo-stationary satellites launched by ISRO to satisfy the telecommunications, broadcasting, meteorology, and search and rescue operations.
- Commissioned in 1983, INSAT is the largest domestic communication system in the Asia Pacific Region. It is a joint venture of the Department of Space, Department of Telecommunications, India MeteorologicalDepartment, All India Radio and Doordarshan.
- The overall coordination and management of INSAT system rests with the Secretary-level INSAT Coordination Committee.
- INSAT satellites provide transponders in various bands (C, S, Extended C and Ku) to serve the television and communication needs of India. Some of the satellites also have the Very High Resolution Radiometer (VHRR), CCD cameras for metrological imaging. The satellites also incorporate transponder(s) for receiving distress alert signals for search and rescue missions in the South Asian and Indian Ocean Region, as ISRO is a member of the Cospas-Sarsatprogramme.

2 FIBER OPTIC COMMUNICATION

2.1 Introduction:

- Communication is a transfer of information from one place to another, in which the communication medium is the most electronic communication systems that can be either guided ~~channel~~ medium (wire conductor cable) or unguided medium (free space).

- The wired network has been of great success with the emergence of optical communication network.

DEFITION:

~~The communication in which electromagnetic signal i.e) light signal is selected from the optical range of frequencies are transmitted~~

The communication in which light signal is selected from the optical range of frequencies as a electromagnetic carrier are transmitted over a fiber optic cable is called called fiber optic communication.

- In optical system the specified band of interest is represented interms of wavelength (λ), instead of interms of frequency (f) in Radio region.

• optical Spectrum ranges from 10nm to 390nm as ultraviolet (uv), 390mm to 770nm as Visible and 770mm to 10^6 nm as Infrared (IR). optical fiber communication which operate in the range of 800 to 1600nm wavelength band.

2.1.1 OPTICAL FIBER COMMONICATION SYSTEM:

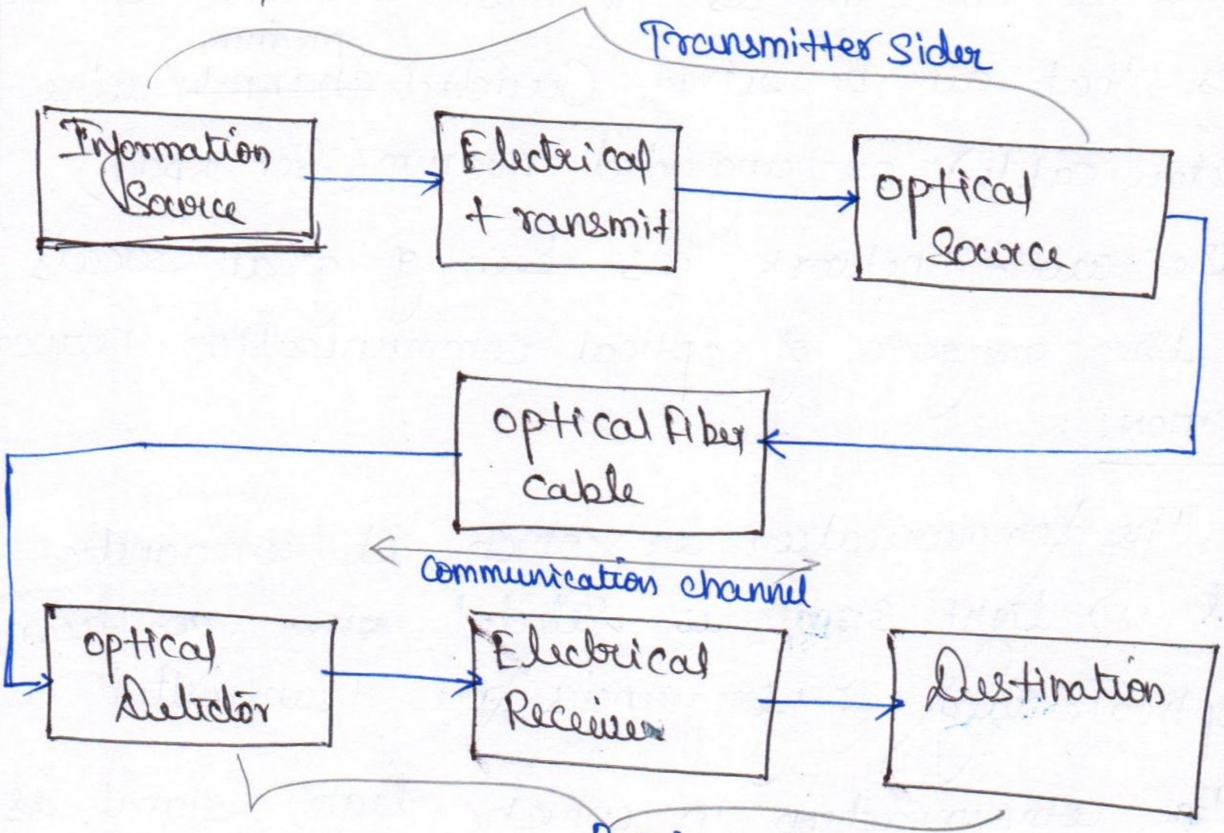


Fig: 1 Block diagram of optical fiber communication System

⊙ The Information Source (Voice, Video or computer data) are non electrical messages are converted into electrical Signals using transducer in the Electrical transmit. Example: microphone is used to convert Voice Signal into electrical Signal.

- optical Source may be either a Semiconductor laser or light emitting diode (LED), which are used to convert the electrical signal into optical Signal.
- The transmission medium consists of an optical fiber cable and Receiver consists of an optical ~~Receiver~~ detector which converts ~~electrical~~ optical signal into electrical signal.
- The optical detectors are photodiodes (p-n, PIN (or) avalanche) and phototransistors and photo conductors.

2.1.2 Advantages of optical fiber communication:

- Low cost ~~and low loss~~ of information
- High data rate
- Small Size and weight
- Low transmission loss ($\approx 0.2 dB/Km$).
- Ruggedness and flexiblity is high.
- High degree of Signal Security.
- Immunity to Interference and crosstalk.
- Enormous potential Bandwidth.
- Increase the Speed of transmission.

2.1.3 RAY Theory transmission / characteristics of Light.

- Ray is a narrow beam of light travel in a Straight line. Ray tracing uses Maxwell's equations that are valid as long as the light waves propagated through and around objects.
- Generally speed of light is 3×10^8 m/s or 186×10^3 miles/sec in free space.

2.1.3.1 Law of Reflection:

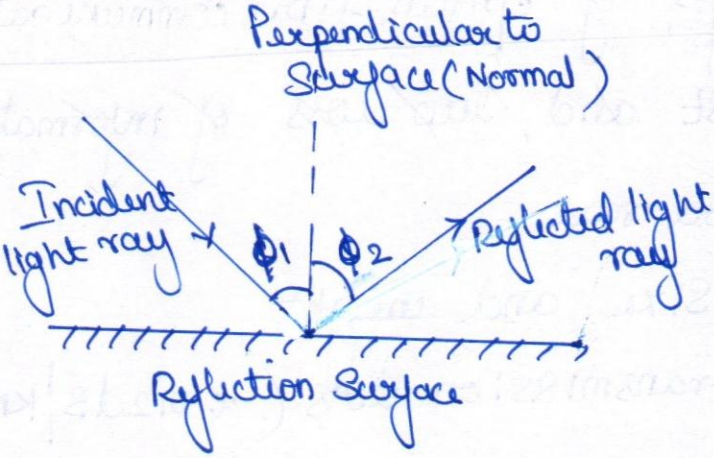


Fig: 2 Reflection

The law of reflection states that the angle of incidence is equal to the angle of reflection

$$\angle \phi_1 = \angle \phi_2$$

2.1.3.2 Law of Refraction:

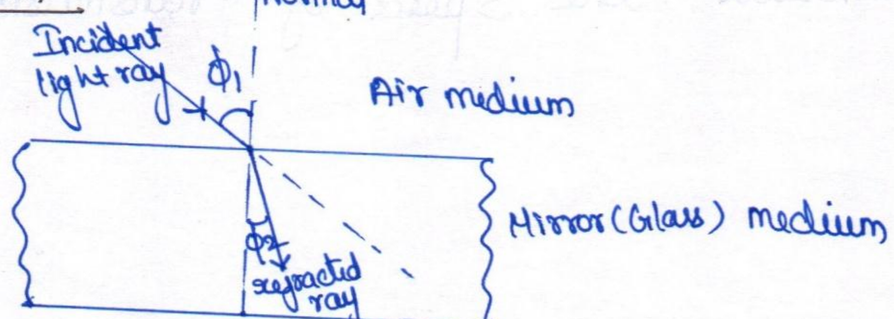


Fig: 3 Refraction

when light ray travels from one medium (air) to another medium (glass), bending of light ray may occur. This is called Refraction.

2.1.3.3 Refractive index :

The index of refraction (n) is defined as the ratio of the velocity of light in a vaccum to the velocity of light in the medium.

(Refractive index) $n = \frac{\text{Speed of light in air (free space) (C)}}{\text{Speed of light in a given material (V)}}$

$$\boxed{n = \frac{C}{V}} \longrightarrow (1)$$

where, n = Refractive index
(n = 1 for air, 1.33 for water, 1.50 for glass and 2.42 for diamond)
C = Speed of light in free space (3×10^8 m/s)
V = Speed of light in a given material (m/s).

2.1.3.4 SNELL'S LAW:

- The angle of incidence ϕ_1 and refraction ϕ_2 are related to each other. The Snell's law is given by,

$$\boxed{n_1 \sin\phi_1 = n_2 \sin\phi_2} \longrightarrow (2)$$

- The refractive indexes of two medias have n_1 and n_2, $[n_1 >> n_2]$

$$\boxed{\frac{\sin\phi_1}{\sin\phi_2} = \frac{n_2}{n_1}} \longrightarrow (3)$$

2.1.3.5 Critical Angle (ϕ_c):

The angle of incident for which the angle of refraction becomes 90° is called as critical angle.

$$n_1 \sin\phi_1 = n_2 \sin\phi_2$$

when $\phi_2 = 90°$, ϕ_1 becomes critical angle ϕ_c.

$$\sin\phi_c = \frac{n_2}{n_1} \sin 90°$$

$$\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) \rightarrow (4)$$

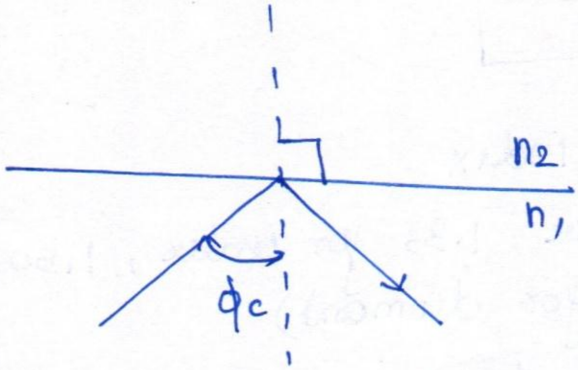


Fig: 4 critical angle ϕ_c.

2.1.3.6 Total Internal Reflection (TIR):

When the incident angle (ϕ_1) is greater than the critical angle (ϕ_c), the light ray is reflected back to medium 1 with high efficiency (99.9%). There will be no light transmission or reflection in medium 2. This is called Total Internal Reflection.

2.1.37 Acceptance Angle - (ϕa):—

Acceptance angle is the maximum angle to the axis at which light may enter the fiber in order to be propagated. This is called as acceptance angle (ϕa).

$$\text{Acceptance angle } \phi a = \sin^{-1}(NA) \longrightarrow (5)$$

where NA = Numerical Aperture.

2.1.3.8 Numerical Aperture (NA):-

- Ability of an optical fiber to gathering or collecting light capacity of the fiber.
- Its values ranges from 0 to 1 and dimensionless.
- Numerical Aperture of the fiber is used to obtain a relationship between the Acceptance angle and the refractive indixes of the core, cladding and air.

$$NA = \sqrt{n_1^2 - n_2^2} \longrightarrow (6)$$

where,

n_1 = refractive index of medium 1

n_2 = refractive index of medium 2

$$N.A = \sin \phi_a \longleftrightarrow (7)$$

where ϕa = Acceptance angle in degrees.

$$N.A = n_1\sqrt{2\Delta} \longrightarrow (8)$$

22 BASIC STRUCTURE OF OPTICAL FIBER:—

• optical fiber is a cylindrical dielectric waveguide that guides the light in a direction parallel to its axis.

⊙ optical fiber has three regions.

(i) Core - inner region (ii) cladding - outer region.

(iii) Buffer Coating

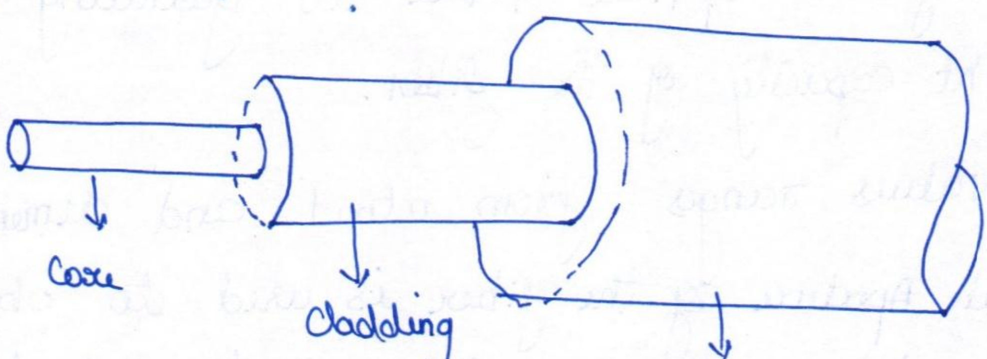


Fig: 5 optical fiber structure.

Core:

⊙ Core is a inner region of fiber in which the light rays travel through the core layer.

⊙ Refractive index of core is n_1.

cladding:

⊙ The core is surrounded by a dielectric Solid Surface called as cladding.

⊙ Refractive index of cladding is n_2.

where ($n_1 > n_2$).

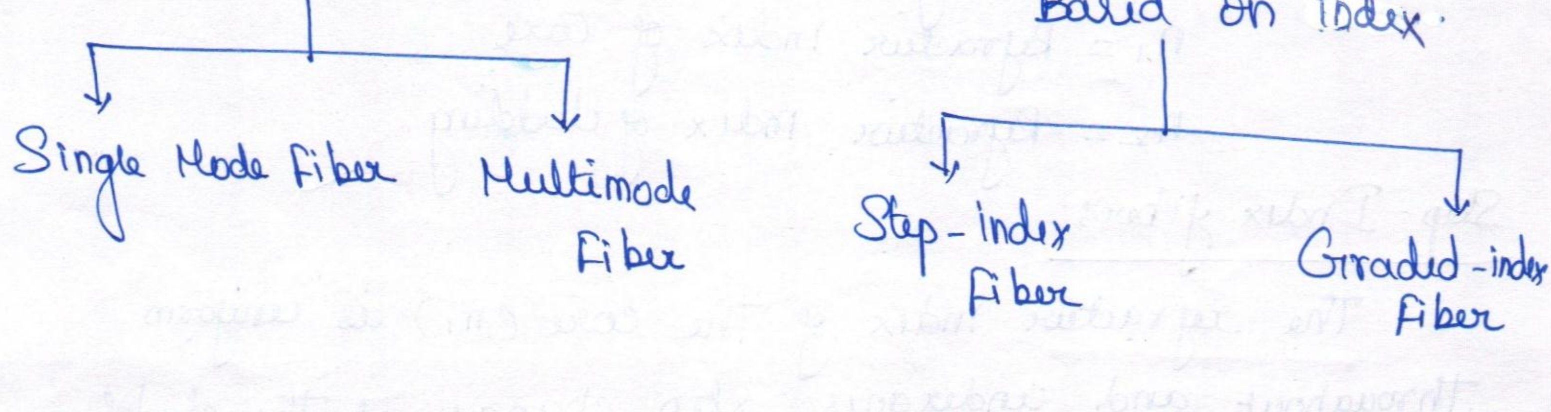
• Cladding reduces Scattering loss and it adds mechanical strength to the fiber, it protects the core from absorbing Surface contaminants which it could come in contact.

Buffer coating:

It is outer most layer of fiber which adds further strength to the fiber and mechanically isolates or buffers the fibers from small geometrical irregularities or distortions.

→ optical fiber cables are made from glass and plastic and its looks like human hair structure.

2.3 TYPES OF optical fiber



~~Based~~

Single Mode Fiber:- Single Mode fibers are capable of carrying the light signal through a single path at a specific wavelength. ie) only one half cycle of standing waves across the fiber core diameter

- Single Mode fiber, core diameter ranges from 8-12 μm and its index difference of core and cladding is very small.

Multimode fiber: Multimode fibers are capable of carrying the light singnal through many paths, ie) many half cycle of standing waves across the fiber core diameter

- In Multimode fiber, the number of paths depends on frequency (wavelength) of the light.
- Number modes in multimode fiber is given by,

$$N \approx \left(\frac{\pi d}{\lambda} \sqrt{n_1^2 - n_2^2} \right)^2 \longrightarrow (9)$$

where,

N - Number of propagation modes

d - core diameter (meters)

λ - wavelength (meters)

n_1 = Refractive Index of core

n_2 = Refractive Index of cladding.

Step-Index fiber:

The refractive index of the core (n_1) is uniform throughout and undergoes step changes at the cladding.

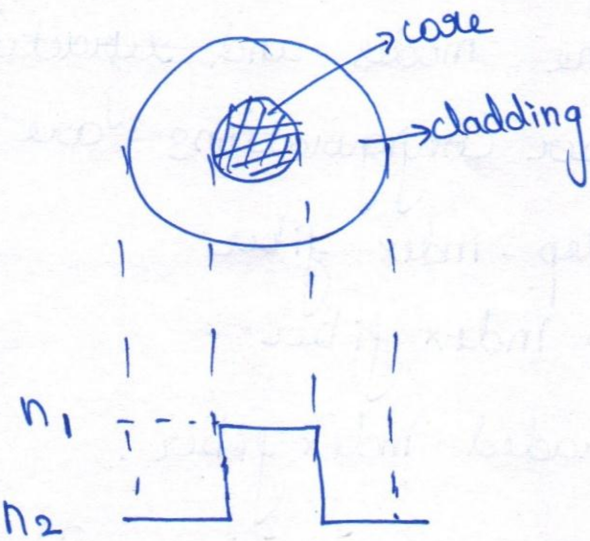


fig: 6 Step index fiber cross section

Graded Index fiber:

• Refractive index of core is varing smoothly and continuously over the diameter of the core.

Fig: 7 Graded index fiber cross section.

2.4 Optical fiber Configurations:-

Depends on the modes and refractive index of the fiber, optical fiber configurations are classified as,

(i) Single Mode Step-index fiber

(ii) Multimode Step index fiber

(iii) Multimode Graded index fiber.

2.4.1 Single Mode (or) Mono mode Step-index Fiber (SMSI):

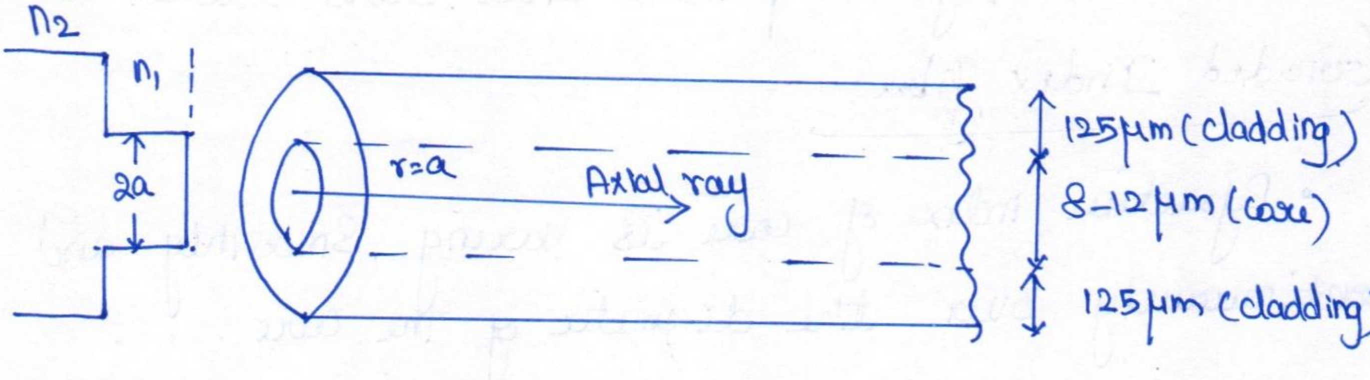


Fig: 8 Single Mode Step index Fiber.

- Single Mode Step Index Fiber, has only the central ray that can propagate in the core as shown in figure: 6.
- It provides high transmission Bandwidth, which makes it ideal for long distant communication.
- Single mode step-index fibers are the dominant fibers used in Telecommunications and data networking industries.
- Typical core size is 8-12μm
- with minimum refraction no pulse stretching occurs.
- The output pulse has essentially the same duration as the input pulse.

⊙ The refractive index profile is defined as,

$$n(r) = \begin{cases} n_1 & r < a \quad \text{for core} \\ n_2 & r > a \quad \text{for cladding} \end{cases} \longrightarrow (10)$$

2.4.12

Multimode Step-index fiber (MMSI):-

~~⊙ The center core is much larger than SMSI.~~

⊙ Multimode fiber is preferred over a single mode fiber as it has a much larger core diameter and it is therefore easier to splice and to couple segment together with lower loss.

⊙ It is easy to manufacture.

⊙ Its core diameter is 50-200μm.

⊙ The light rays are propagated down the core in zigzag manner (meridoinal ray). There are many paths that a light ray may follow during the propagation.

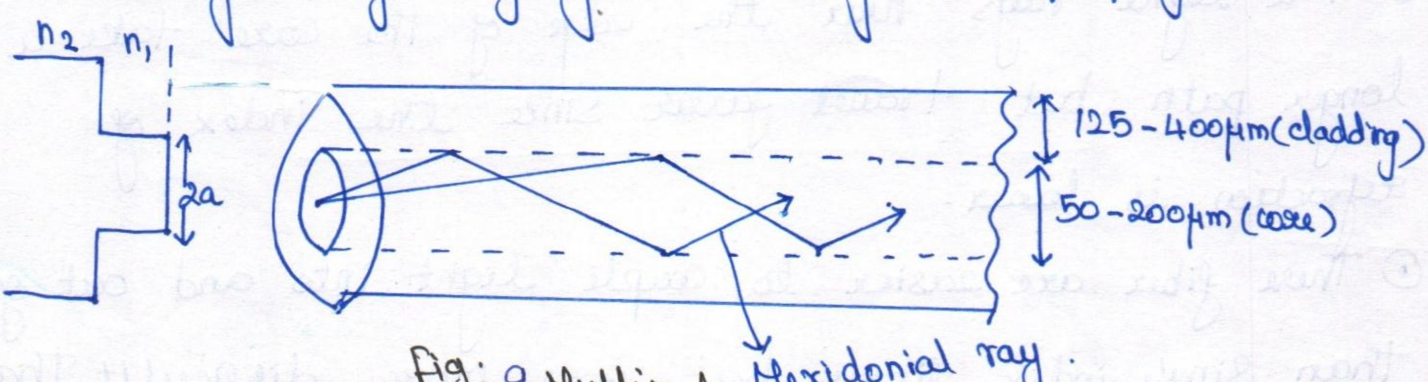


Fig: 9 Multimode Step index fiber

⊙ Light can be launched into multimode fiber using a Light Emitting Diode (LED) Source.

⊙ The refractive index profile is defined as

$$n(r) = \begin{cases} n_1 & r < a \quad \text{for core} \\ n_2 & r > a \quad \text{for cladding} \end{cases} \longrightarrow (11)$$

2.4.3 Multimode Graded index fiber (MMGI):

- Graded index fiber are characterized by a central core with non-uniform refractive index.
- Core refractive index decreases continuously with increasing radial distance 'r' from the center of the fiber.
- Multimode Gradex index fiber have large core diameter 50–100 μm and coupled with Bandwidths suitable for long distance communication.

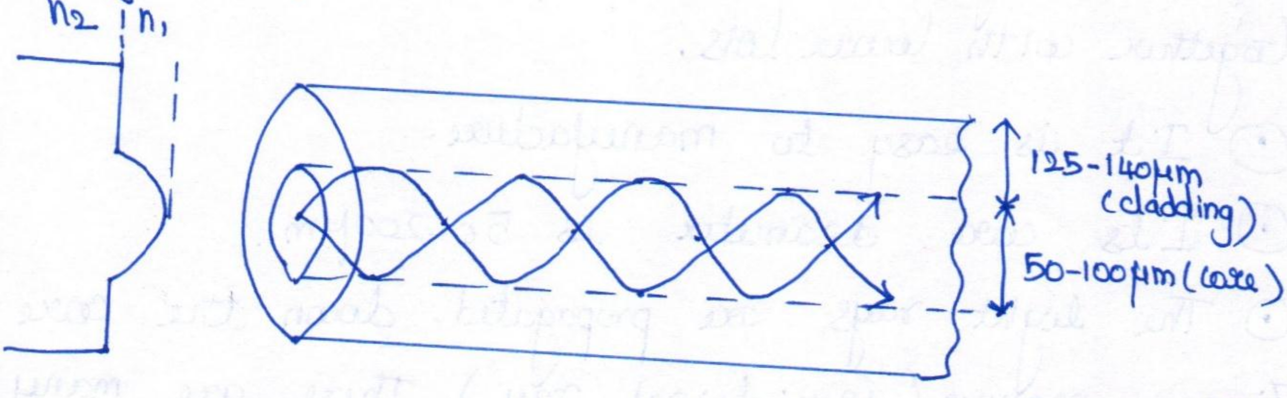


Fig: 10 Multimode Graded Index fiber.

- The light rays near the edge of the core take a longer path but travel faster since the index of refraction is lower.
- These fiber are easier to couple light into and out of than single-index fibers but are more difficult than multimode step-index fiber.
- The refractive index profile is,

$$n(r) = \begin{cases} n_1\left[1 - 2\Delta\left(\frac{r}{a}\right)^{\alpha}\right]^{1/2} & 0 < r < a \text{ (core)} \\ n_1(1-2\Delta)^{1/2} \approx n_1(1-\Delta) \approx n_2 & 0 < r < b \text{ (cladding)} \end{cases}$$

Advantages:

- It reduces Intermodal dispersion
- large core diameter, so large Bandwidth
- easy to couple light when compared to Single mode Step index.

Intermodal dispersion:-

In Multimode fiber, many modes are propagating along fiber at a time. Different modes are taking different ray path and they reach at different time at the output end of the fiber. So, a time delay is experienced between modes. This is called Intermodal delay and pulse broadening occurs due to this intermodal delay is called intermodal dispersion.

2.5 OPTICAL FIBER SOURCES:-

The optical Source is consider as an active component in an optical fiber Communication system.

DEFINITION:

Source that convert electrical energy in form of a current into optical energy (light) which allows the light output to be launched effectively or coupled into the optical fiber.

Types of optical Sources:

There are 3-types of optical Sources

1. wideband continuous optical Sources, Example: Incandescent Lamp.
2. Monochromatic incoherent Sources, Example: LED
3. Monochromatic coherent Sources, Example: LASER.

LASER diode and LED(Light Emitting Diode) are the most commonly used optical Sources.

Light Emitting Diode

- SLED
- ELED
- SLD

where, SLED - Surface ~~Emitters~~ LED

ELED - Edge emitters LED

SLD - Super Luminescent diode

Laser Diode

- Single Mode Laser diode
  - DFB
  - DBR
  - Vertical Cavity Laser.
- Multimode Laser diode
  - Index Guided
  - Gain Guided