SKDAV GOVT. POLYTECHNIC ROURKELA

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING

LECTURE NOTES

Year & Semester: 3RD Year, VI Semester

Subject Code/Name: ETT-601, ADVANCED COMMUNICATION ENGINEERING

CONTENTS

Intermodal dispersion

3.12 Optical sources
3.13 LED- semiconductor
3.14 Define LASER and its working Principles diagram using laser feedback control circuit
3.15 Explain Optical detectors – PIN and APD diodes
3.16 Connectors, splices and Couplers of fiber cable
3.17 Applications of optical fibers – civil, Industry and Military application
3.18 Explain concept of Wave Length Division Multiplexing (WLDM) principles.

4. TELECOMMUNICATION SYSTEM

4.1 Discuss the operation of Electronic Telephone System. (Telephone Set)
4.2 Discuss the function of switching system.& Call procedures
4.3 Discuss the principle of space and time switching.
4.4 Discuss the numbering plan of telephone networks (National Schemes & International Numbering)
4.6 Describe the operation of a PBX & Digital EPABX.
4.7 Define units of Power Measurement.
4.8 Describe the operation of Internet Protocol Telephone.
4.9 Describe the principal of Internet Telephone

COURSE OUTCOME (CO)

After the completion of course the students are able to:

1. Describe the working principle of different RADAR systems and their advantages, disadvantages and applications.
2. Derive the radar range equation and solve the related problems.
3. Describe the satellite orbital patterns and concept of geostationary satellite.
4. Explain the working of a satellite communication system & its applications in different areas and different multiple access techniques.
5. Demonstrate the understanding of optical fiber communication system, structure of optical fiber and its types.
6. Discuss the channel impairments, optical sources, detectors, connectors, splices and couplers.
7. Explain the operation of telephone set, function of switching system, call procedure and numbering plan.
8. Describe the operation of PBX, EPABX and IP Telephone.

UNIT-1: RADAR & NAVIGATION AIDS

1.1 STATE AND EXPLAIN THE SIMPLE RADAR SYSTEM & ITS CLASSIFICATION:

Radar is a detection system that uses radio waves to determine the range, angle, or velocity of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. A radar system consists of a transmitter producing electromagnetic waves in the radio or microwaves domain, a transmitting antenna, a receiving antenna (often the same antenna is used for transmitting and receiving) and a receiver and processor to determine properties of the object(s). Radio waves (pulsed or continuous) from the transmitter reflect off the object and return to the receiver, giving information about the object's location and speed. Radar was developed secretly for military use by several nations in the period before and during World War II. A key development was the cavity magnetron in the United Kingdom, which allowed the creation of relatively small systems with sub-meter resolution.

RADAR stands for radio detection and ranging.

TYPES OF RADAR-

There are two types of radar system

1-Pulsed radar

2-Continuous wave radar

The pulse radar transmits short rectangular pulses & the continuous wave radar transmits continuous sinusoidal EM waves.

Pulse Radar

The Radar, which operates with pulse signal is called the **Pulse Radar**. Pulse Radars can be classified into the following two types based on the type of the target it detects.

- Basic Pulse Radar
- Moving Target Indication Radar

Continuous Wave Radar

The Radar, which operates with continuous signal or wave is called **Continuous Wave Radar**. They use Doppler Effect for detecting non-stationary targets. Continuous Wave Radars can be classified into the following two types.

- Unmodulated Continuous Wave Radar
- Frequency Modulated Continuous Wave Radar

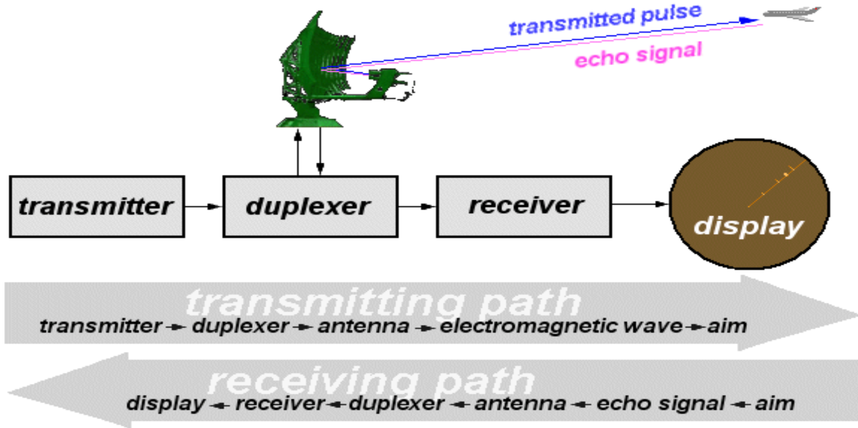
BASIC RADAR SYSTEM-

The following figure shows the operating principle of a primary radar set. The radar antenna illuminates the target with a microwave signal, which is then reflected and picked up by a receiving device. The electrical signal picked up by the receiving antenna is called echo or return. The radar signal is generated by a powerful transmitter and received by a highly sensitive receiver.

All targets produce a diffuse reflection i.e. it is reflected in a wide number of directions. The reflected signal is also-called scattering. **Backscatter** is the term given to reflections in the opposite direction to the incident rays.

Radar signals can be displayed on the traditional plan position indicator (PPI) or other more advanced radar display systems. A PPI has a rotating vector with the radar at the origin, which indicates the pointing direction of the antenna and hence the bearing of targets.

- **Transmitter**
  The radar transmitter produces the short duration high-power rf pulses of energy that are into space by the antenna.
- **Duplexer**
  The duplexer alternately switches the antenna between the transmitter and receiver so that only one antenna need be used. This switching is necessary because the high-power pulses of the transmitter would destroy the receiver if energy were allowed to enter the receiver.
- **Receiver**
  The receivers amplify and demodulate the received RF-signals. The receiver provides video signals on the output.
- **Radar Antenna**
  The Antenna transfers the transmitter energy to signals in space with the required distribution and efficiency. This process is applied in an identical way on reception.
- **Indicator**
  The indicator should present to the observer a continuous, easily understandable, graphic picture of the relative position of radar targets.
  The radar screen (in this case a PPI-scope) displays the output produced from the echo signals. The longer the pulses were delayed by the runtime, the further away from the center of this radar scope they are displayed. The direction of the deflection on this screen is that in which the antenna is currently pointing.



1.2 DERIVE RADAR RANGE EQUATION AND THEIR APPLICATION:

Derivation of Radar Range Equation

The standard form of Radar range equation is also called as simple form of Radar range equation. Now, let us derive the standard form of Radar range equation.

We know that **power density** is nothing but the ratio of power and area. So, the power density (P_{di}) at a distance, R from the Radar can be mathematically represented as –

$$P_{di} = P_t \,/\, 4\pi R^2 \qquad \text{(equation 1)}$$

Where,

Pt is the amount of power transmitted by the Radar transmitter

The above power density is valid for an isotropic Antenna. In general, Radars use directional Antennas. Therefore, the power density, P_{dd} due to directional Antenna will be

$$P_{dd}=P_t\mathrm{G} \,/\, 4\pi R^2 \qquad \text{(equation 2)}$$

Target radiates the power in different directions from the received input power. The amount of power, which is reflected back towards the Radar depends on its cross section. So, the power density P_{de} of echo signal at Radar can be mathematically represented as –

$$P_{de}=P_{dd}(\sigma \,/\, 4\pi R^2) \qquad \text{(equation 3)}$$

Substitute, Equation 2 in Equation 3.

$$P_{de} = (P_t \,/\mathrm{G}4\pi R^2)(\sigma \,/\, 4\pi R^2) \qquad \text{(Equation4)}$$

The amount of **power,** P_r **received** by the Radar depends on the effective aperture, A_e of the receiving Antenna.

$$P_r = P_{de}A_e \qquad \text{(Equation5)}$$

Substitute, Equation 4 in Equation 5.

$$P_r = (P_t\mathrm{G} \,/\, 4\pi R^2)(\sigma \,/\, 4\pi R^2)\, A_e$$

$$\Rightarrow P_r=P_t\mathrm{G}\sigma A_e \,/\, (4\pi)^2 R^4$$

$$\Rightarrow R^4 = P_t\mathrm{G}\sigma A_e \,/\, (4\pi)^2 P_r$$

$$\Rightarrow R = [\frac{P_t G \sigma A_e}{(4\pi)^2 P_r}]^{1/4} \qquad \text{Equation 6}$$

Standard Form of Radar Range Equation

If the echo signal is having the power less than the power of the minimum detectable signal, then Radar cannot detect the target since it is beyond the maximum limit of the Radar's range.

Therefore, we can say that the range of the target is said to be maximum range when the received echo signal is having the power equal to that of minimum detectable signal. We will get the following equation, by substituting R=RMax and Pr = Smin in Equation 6.

$$R_{Max} = [\frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}}]^{1/4} \qquad \text{Equation7}$$

Equation 7 represents the **standard form** of Radar range equation. By using the above equation, we can find the maximum range of the target.

Modified Forms of Radar Range Equation

We know the following relation between the Gain of directional Antenna, G and effective aperture, Ae.

$$G = 4\pi A_e / \lambda^2 \qquad \text{Equation8}$$

Substitute, Equation 8 in Equation 7.

$$R_{Max} = [\frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}} \ (4\pi A_e / \lambda^2)]^{1/4}$$

$$\Rightarrow R_{Max} = [\frac{P_t G \sigma {A_e}^2}{4\pi \lambda^2 S_{min}}]^{1/4} \qquad \text{Equation9}$$

Equation 9 represents the **modified form** of Radar range equation. By using the above equation, we can find the maximum range of the target.

We will get the following relation between effective aperture, Ae and the Gain of directional Antenna, G from Equation 8.

$$Ae = G\lambda^2 / 4\pi \qquad \text{Equation10}$$

Substitute, Equation 10 in Equation 7.

$$R_{Max} = [\frac{P_t G \sigma}{(4\pi)^2 S_{min}} \ (G\lambda^2 / 4\pi)]^{1/4}$$

$$\Rightarrow R_{Max} = [\frac{P_t G^2 \sigma \lambda^2}{(4\pi)^2 S_{min}}]^{1/4} \qquad \text{Equation11}$$

Equation 11 represents **another modified form** of Radar range equation. By using the above equation, we can find the maximum range of the target.

APPLICATION

Applications and uses of Radar are given below:

- Military
- Law Enforcements
- Space
- Remote Sensing of Environment
- Aircraft navigation
- Ship Navigation
- Air Traffic Controller

RADAR are used in Military

Radars have a wide range of usage in military operations. They are used in Naval, Ground as well as Air defense purposes. They are used for detection, tracking and surveillance purposes also. Weapon control and missile guidance often use various types of RADARs.

These are used in Law Enforcements

Law enforcements especially highway police has an extensive uses of RADARs during a pursuit in order to measure the speed of a vehicle. Due to bad weather conditions, when satellite is unable to get a clear image of traffic and barricades, then RADARs is used to get the desired results.

This technology is used in Space

RADARs are used to track and detect satellites and spacecraft. They are also used for safely landing and docking of spacecraft. RADARs in satellites are used for remote sensing.

RADAR is used for Remote Sensing of Environment

Just like various type of waves are received by an antenna. This technology are also used to detect weather condition of atmosphere and are also used for tracking motions of planets, asteroids and other celestial bodies in the solar system.

It is used in Aircraft Navigation

Ground mapping RADARs and weather avoidance RADARs are used in aircraft to navigate it properly. This technology enables an aircraft to ensure the location of obstacles which can be a threat to the flight plan.

Uses of RADAR in Navigating Ships

Ships are guided through high resolutions RADARs situated on the shores. Because of poor visibility in bad weather conditions, RADARs provides safety by warning threats. These ships often use this technology to measure the proximity of other ships and their speed on the water.

RADARs is used in Air Traffic Controller

RADARs are used for safely controlling the traffic in air. It is used to guide aircrafts for proper landing and take-off during bad weather conditions. These type of RADARs also detect the proximity and the altitude of the aircrafts.

1.3 PERFORMANCE FACTOR OF THE RADAR-

The performance of a radar system can be judged by the following:

(1) The maximum range at which it can see a target of a specified size,

(2) The accuracy of its measurement of target location in range and angle,

(3) Its ability to distinguish one target from another,

(4) its ability to detect the desired target echo when masked by large clutter echoes, unintentional interfering signals from other "friendly" transmitters, or intentional radiation from hostile jamming (if a military radar),

(5) Its ability to recognize the type of target,

(6) Its availability (ability to operate when needed), reliability, and maintainability.

Some of the major factors that affect performance are discussed below.

Transmitter power and antenna size

- The maximum range of a radar system depends in large part on the average power of its transmitter and the physical size of its antenna.
- Some radar systems have an average power of roughly one megawatt. Phased-array radars about 100 feet (30 meters) in diameter are not uncommon; some are much larger. There are specialized radars with (fixed) antennas, such as some HF over-the-horizon radars and the U.S. Space Surveillance System (SPASUR), that extend more than one mile (1.6 km).

Receiver noise

- The sensitivity of a radar receiver is determined by the unavoidable noise that appears at its input. At microwave radar frequencies, the noise that limits detectability is usually generated by the receiver itself (i.e., by the random motion of electrons at the input of the receiver) rather than by external noise that enters the receiver via the antenna.
- A radar engineer often employs a transistor amplifier as the first stage of the receiver even though lower noise can be obtained with more sophisticated (and more complex) devices. This is an example of the application of the basic engineering principle that the "best" performance that can be obtained might not necessarily be the solution that best meets the needs of the user.

Target size

- The size of a target as "seen" by radar is not always related to the physical size of the object. The measure of the target size as observed by radar is called the radar cross section and is given in units of area (square meters).
- It is possible for two targets with the same physical cross-sectional area to differ considerably in radar size, or radar cross section. For example, a flat plate 1 square meter in

area will produce a radar cross section of about 1,000 square meters at a frequency of 3 GHz when viewed perpendicular to the surface.

Clutter

- Echoes from land, sea, rain, snow, hail, birds, insects, auroras, and meteors are of interest to those who observe and study the environment, but they are a nuisance to those who want to detect aircraft, ships, missiles, or other similar targets.
- Clutter echoes can seriously limit the capability of a radar system; thus, a significant part of radar design is devoted to minimizing the effects of clutter without reducing the echoes from desired targets.
- The Doppler frequency shift is the usual means by which moving targets are distinguished from the clutter of stationary objects.

Atmospheric effects

- Rain and other forms of precipitation can cause echo signals that mask the desired target echoes.
- The atmosphere can form "ducts" that trap and guide radar energy around the curvature of the Earth and allow detection at ranges beyond the normal horizon.

Interference

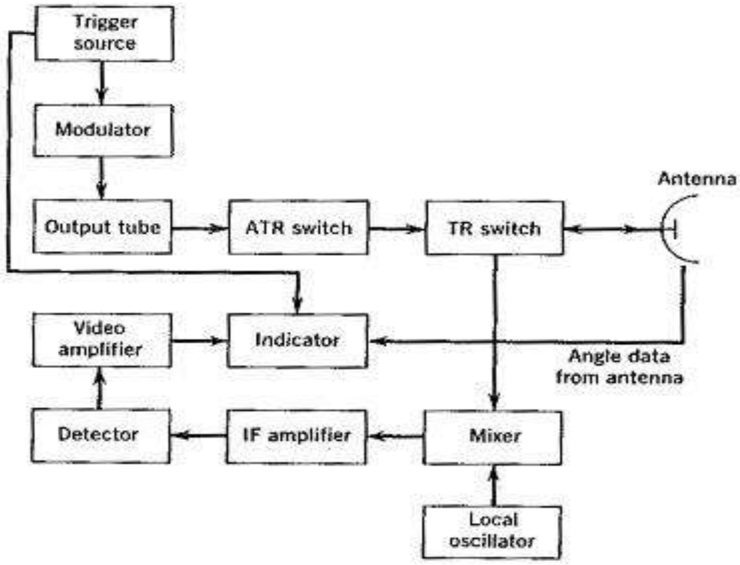
- Signals from nearby radars and other transmitters can be strong enough to enter a radar receiver and produce spurious responses.
- Well-trained operators are not often deceived by interference, though they may find it a nuisance.
- Interference is not as easily ignored by automatic detection and tracking systems, however, and so some method is usually needed to recognize and remove interference pulses before they enter the automatic detector and tracker of a radar.

1.4 PULSE RADAR SYSTEM –

(1) The trigger source provides pulses for the modulator. The modulator provides rectangular voltage pulses used as the supply voltage for the output tube, switching it ON and OFF as required.

(2) This tube may be a magnetron oscillator or an amplifier such as the klystron, traveling-wave tube or crossed-field amplifier, depending on specific requirements. If an amplifier is used, a source of microwaves is also required.

(3) While an amplifier may be modulated at a special grid, the magnetron cannot. If the radar is a low-powered one, it may use IMPATT or Gunn oscillators, or TRAPATT amplifiers. Below C band, power transistor amplifiers or oscillators may also be used. Finally, the transmitter portion of the radar is terminated with the duplexer, which passes the output pulse to the antenna for transmission.



(4) The receiver is connected to the antenna through the duplexer. An RF amplifier can also be used, and this would most likely be a transistor or IC, or perhaps a tunnel diode.

(5) A better noise figure is thus obtained, and the RF amplifier may have the further advantage of saturating for large signals, thus acting as a limiter that prevents mixer diode burnout from strong echoes produced by nearby targets.

(6) The main receiver gain is provided at an intermediate frequency that is typically 30 or 60 MHz. However, it may take two or more down-conversions to reach that IF from the initial microwave RF, to ensure adequate image frequency suppression.

(7) If a diode mixer is the first stage, the (first) IF amplifier must be designed as a low-noise stage to ensure that the overall noise figure of the receiver does not deteriorate.

(8) Another source of noise in the receiver may be the local oscillator, especially for microwave radar receivers. One of the methods of reducing such noise is to use a varactor or step-recovery diode multiplier.

(9) Another method involves the connection of a narrowband filter between the local oscillator and the mixer to reduce the noise bandwidth of the mixer.

(10) The IF amplifier is broadband, to permit the use of fairly narrow pulses. This means that cascaded rather than single-stage amplifiers are used. These can be synchronous, that is, all tuned to the same frequency and having identical bandpass characteristics. If a really large bandwidth is needed, the individual IF amplifiers may be stagger-tuned.

(11) The overall response is achieved by overlapping the responses of the individual amplifiers, which are tuned to nearby frequencies on either side of the center frequency.

(12) The detector is often a Schottky-barrier diode, whose output is amplified by a video amplifier having the same bandwidth as the IF amplifier. Its output is then fed to a display unit, directly or via computer processing and enhancing.

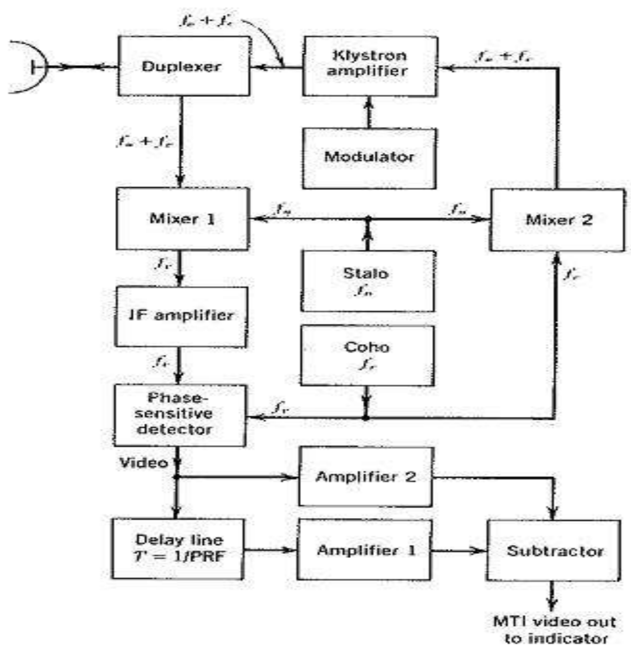
1.5 STATE THE FUNCTION OF RADAR INDICATION AND MOVING TARGET INDICATOR:

MOVING TARGET INDICATION (MTI)-

Moving target indication (**MTI**) is a mode of operation of a radar to discriminate a target against the clutter. It describes a variety of techniques used to find moving objects, like an aircraft, and filter out unmoving ones, like hills or trees. It contrasts with the modern stationary target indication (STI) technique, which uses details of the signal to directly determine the mechanical properties of the reflecting objects and thereby find targets whether they are moving or not.

Early MTI systems generally used an acoustic delay line to store a single pulse of the received signal for exactly the time between broadcasts (the pulse repetition frequency). This stored pulse will be sent to the display along with the next received pulse. The result was that the signal from any objects that did not move mixed with the stored signal and became muted out. Only signals that changed, because they moved, remained on the display. These were subject to a wide variety of noise effects that made them useful only for strong signals, generally for aircraft or ship detection.

MOVING TARGET INDICATION RADAR-



(1) The Moving Target Indicator Radar Block Diagram compares a set of received echoes with those received during the previous sweep. Those echoes whose phase has remained constant are then cancelled out. This applies to echoes due to stationary objects, but those due to moving targets do show a phase change; they are thus not cancelled nor is noise, for obvious reasons.

(2) The fact that clutter due to stationary targets is removed makes it much easier to determine which targets are moving and reduces the time taken by an operator to “take in” the display.

(3) It also allows the detection of moving targets whose echoes are hundreds of times smaller than those of nearby stationary targets and which would otherwise have been completely masked. MTI can be used with a radar using a power oscillator (magnetron) output.

(4) The transmitted frequency in the Moving Target Indicator Radar is the sum of the outputs of two oscillators, produced in mixer 2. The first is the stalo, or stable local oscillator (note that a good case can be made for using a varactor chain here).

(5) The second is the coho, or **coherent oscillator**, operating at the same frequency as the intermediate frequency and providing the **coherent signal**, which is used as will be explained. Mixers 1 and 2 are identical, and both use the same local oscillator (the stalo); thus phase relations existing in their inputs are preserved in their outputs.

(6) This makes it possible to use the Doppler shift at the JF, instead of the less convenient radio frequency $f_0 + f_c$.. The output of the IF amplifier and a reference signal from the coho are fed to the phase-sensitive detector, a circuit very similar to the phase discriminator.

(7) The coho is used for the generation of the RF signal, as well as for reference in the phase detector, and the mixers do not introduce differing phase shifts. The transmitted and reference signals are locked in phase and are said to be coherent; hence the name of the coho. Since the output of this detector is phase-sensitive, an output will be obtained for all fixed or moving targets.

(8) The phase difference between the transmitted and received signals will be constant for fixed targets, whereas it will vary for moving targets. The phase shift is definitely not constant for Moving Target Indicator Radar.

(9) Each pulse that correspond to stationary targets are identical with each pulse, but those portions corresponding to moving targets keep changing in phase. It is thus possible to subtract the output for each pulse from the preceding one, by delaying the earlier output by a time equal to the pulse interval, or 1/PRF.

(10) Since the delay line also attenuates heavily and since signals must be of the same amplitude if permanent echoes are to cancel, an amplifier follows the delay line. To ensure that this does not introduce a spurious phase shift, an amplifier is placed in the un-delayed line, which has exactly the same response characteristics (but a much lower gain) than amplifier 1. The delayed and un-delayed signals are compared in the subtractor and displayed.

1.6 DEFINE DOPPLER EFFECT & DESCRIBE THE BLOCK DIAGRAM OF C.W RADAR:

DOPPLER EFFECT-

- The **Doppler Effect** (or the **Doppler shift**) is the change in frequency of a wave in relation to an observer who is moving relative to the wave source
- A common example of Doppler shift is the change of pitch heard when a vehicle sounding a horn approaches and recedes from an observer. Compared to the emitted frequency, the received frequency is higher during the approach, identical at the instant of passing by, and lower during the recession.
- The reason for the Doppler Effect is that when the source of the waves is moving towards the observer, each successive wave crest is emitted from a position closer to the observer than the crest of the previous wave.
- Therefore, each wave takes slightly less time to reach the observer than the previous wave. Hence, the time between the arrivals of successive wave crests at the observer is reduced, causing an increase in the frequency. While they are traveling, the distance between successive wave fronts is reduced, so the waves "bunch together".

- Conversely, if the source of waves is moving away from the observer, each wave is emitted from a position farther from the observer than the previous wave, so the arrival time between successive waves is increased, reducing the frequency. The distance between successive wave fronts is then increased, so the waves "spread out".

C.W. RADAR-

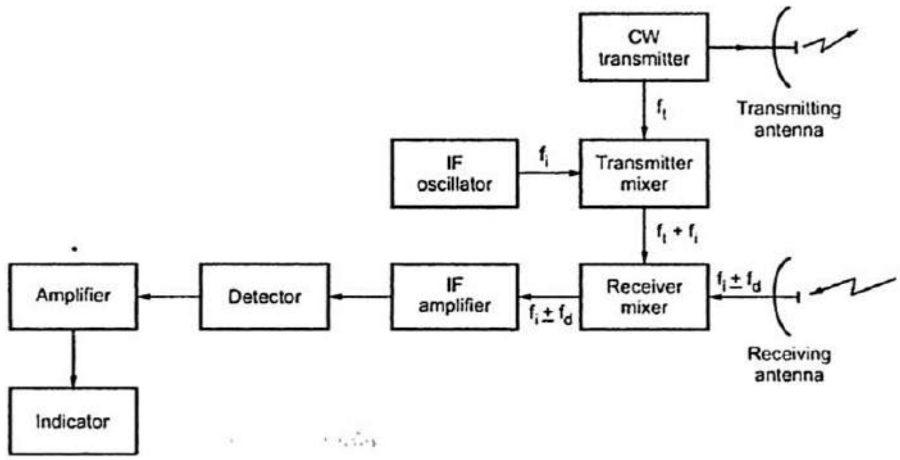


Fig. CW Doppler radar

- It is possible to detect moving targets by radiating unmodulated continuous wave (CW) energy instead of radiating in the form of pulses. Continuous wave (CW) radar makes use of the Doppler Effect for target speed measurements.
- In CW system the carrier frequency f is transmitted and the received signal is at frequency f ± fd. The + or - ve sign is depending upon movement toward the radar or away from it. The frequency modulated CW radar is used for obtaining range as well as the velocity of the target.
- A small portion of transmitted frequency and output of local oscillator are mixed in transmitter mixer and the sum (ft + fi) is fed to receiver mixer. The receiver mixer also receives the Doppler shifted signal from the receiver antenna, this produces an output difference frequency i.e. 30 MHz ± Doppler frequency.
- The output of this receiver is amplified and demodulated again and the signal from the second detector is simply Doppler frequency without a ±sign preceding it so it is not possible to conclude that whether the target is approaching or moving away. For a common transmitting and receiving antenna, the circulator which provides the isolation up to 30-40 dB is used to provide necessary isolation between transmitter and receiver.

Advantages of CW Doppler

1. CW Doppler radar has no blind speed.
2. CW Doppler radar is capable of giving accurate measurements of relative velocities.
3. CW Doppler radars are always on, they need low power and arc compact in size.
4. They can be used for small to large range with high degree of efficiency and accuracy.
5. The performance of radar is not affected by stationary object.

Disadvantages of CW Doppler Radar

1. The maximum range of CW Doppler radar is limited by the power that radar can radiate.
2. The target range cannot be calculated by CW Doppler radar.
3. There is possibility of ambiguous results when number of targets are more.

Applications of CW Doppler Radar

1. CW Doppler radars are used where only velocity information is of interest and actual range is not needed e.g. in police radar for catching cars travelling above the speed limit.
2. Measuring motion of waves on water level.
3. Traffic counters.
4. Intrusion alarm.
5. Runway monitors.
6. Cricket ball speed measurement.

1.7 AIDS TO NAVIGATION-

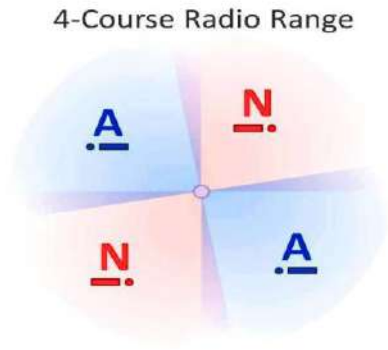
- Navigation is the art of guiding the movement of a craft from one point to another along a desired path. In older days long journeys over sea were accomplished with the knowledge of the movements of sun and various stars.
- These days most of the navigational work is done with electronic navigational aids. Electronic navigational aids are based on the use of EM waves to find the position of the craft.
- A no. of different types of navigational aids are available in the market. One of them is **LORAN.**
- **LORAN** is short form of Long Range Navigational Aid. It is based on the measurement of the difference in the time of arrival of EM waves from two transmitters to the receiver in the craft.
- Another one navigational aid is **radio range navigation.**

There are two types of radio range in operation-

(i) Low frequency or four course radio range
(ii) VHF Omni- directional radio range

Low frequency or four course radio range-

Throughout the 1920s, commercial aviation was hampered by the need to fly only in fair weather, when aircraft could navigate by visual references on the ground (a technique called "pilotage"), or by risky assumptions based upon compass, airspeed and clock indications, and reported winds — combined, calculated and plotted on a map (a technique called "dead reckoning"). Radio navigation technology emerged by the late 1920s, allowing fairly precise navigation without reference to the ground, nor the optimistic and daring trust in dead reckoning.



Initial efforts focused on simple radio beacons, broadcasting a simple Morse Code signal that could be "homed in on" using direction-finding ("DF") antennas. But these were of limited usefulness, and required pilots to have DF equipment, and know how to use it correctly. A simpler, clearer system was desired to ensure easy guidance for all aircraft commercial, military and general aviation — using only a basic radio receiver.

VHF omnidirectional radio range-

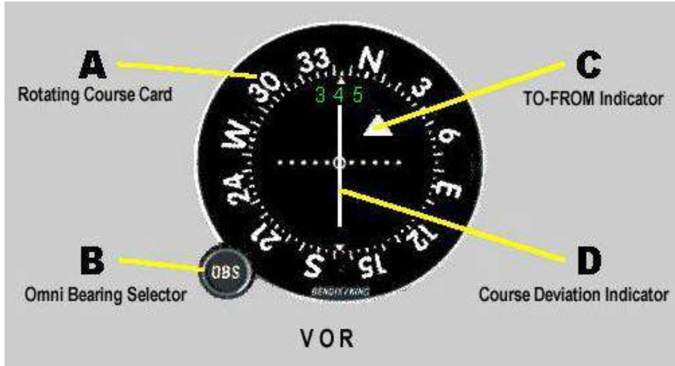
VOR (VHF Omni-Range) is the basic Electronic navigation that in use today. This VHF Omni-Range navigation method relies on the ground based transmitters which emitted signals to VOR receiver. The VOR system operates in the VHF frequency band, from 108.0 to 117.95 MHz. The reception of VHF signals is a line of sight situation. You must be on the minimum altitude of 1000 feet (AGL) above ground level in order to pick up an Omni signals service range.

OPERATION:

The VOR facility at ground base transmits two signals at the same time. One signal is constant in all directions as a reference phase. Another signal, it is variable-phase signal and it rotates through 360 degrees, like the beam from the lighthouse. Both signals are in phase when the variable signal passes 360 degrees (reference to magnetic north) and they are 180 degrees out of phase when the rotating signal passes 180 degrees The aircraft equipment receives both signals. The receiver will calculate the difference between the two signals, and interprets the result as a radial from the station to pilots on the aircraft.

RADIALS: The two signals from VOR transmitter generate 360 lines like spokes in a wheel. Each line is called a Radial. VOR navigation equipment on the airplane will determine which of those 360 radials the airplane is on.

VOR INDICATOR:



A : Rotating Course Card is calibrated from 0 to 360 degrees, which indicates the VOR bearing chosen as the reference to fly by pilot.
B : Omni Bearing Selector or OBS knob , used to manually rotate the course card to where the point to fly to.
C : TO-FROM indicator . The triangle arrow will point UP when flying to the VOR station. The arrow will point DOWN when flying away from the VOR station. A red flag replaces these TO-FROM arrows when the VOR is beyond reception range or the station is out.
D : Course Deviation Indicator (CDI). This needle moves left or right indicating the direction to turn the aircraft to return to course.
DOT : The horizontal dots at center are represent the aircraft away from the course . Each dot represent 2 degrees deviate from desired course.

1.8 AIR CRAFT LANDING SYSTEM-

An *instrument landing system* operates as a ground-based instrument approach system that provides precision lateral and vertical guidance to an aircraft approaching and landing on a runway, using a combination of radio signals and, in many cases, high-intensity lighting arrays to enable a safe landing during instrument meteorological conditions (IMC), such as low ceilings or reduced visibility due to fog, rain, or blowing snow.

An instrument approach procedure chart (or 'approach plate') is published for each ILS approach to provide the information needed to fly an ILS approach during instrument flight rules (IFR) operations. A chart includes the radio frequencies used by the ILS components or navaids and the prescribed minimum visibility requirements.

Radio-navigation aids must provide a certain accuracy (set by international standards of CAST/ICAO); to ensure this is the case, flight inspection organizations periodically check critical parameters with properly equipped aircraft to calibrate and certify ILS precision.

An aircraft approaching a runway is guided by the ILS receivers in the aircraft by performing modulation depth comparisons. Many aircraft can route signals into the autopilot to fly the approach automatically. An ILS consists of two independent sub-systems. The localizer provides lateral guidance; the glide slope provides vertical guidance.

Localizer

The localizer station for runway

A localizer (LOC, or LLZ until ICAO standardization]) is an antenna array normally located beyond the departure end of the runway and generally consists of several pairs of directional antennas.

The localizer will allow the aircraft to turn and match the aircraft with the runway. After that, the pilots will activate approach phase (APP).

Glide slope of ILS (G/S)

Glide slope station for runway

The pilot has to correct to the left and a little upwards.

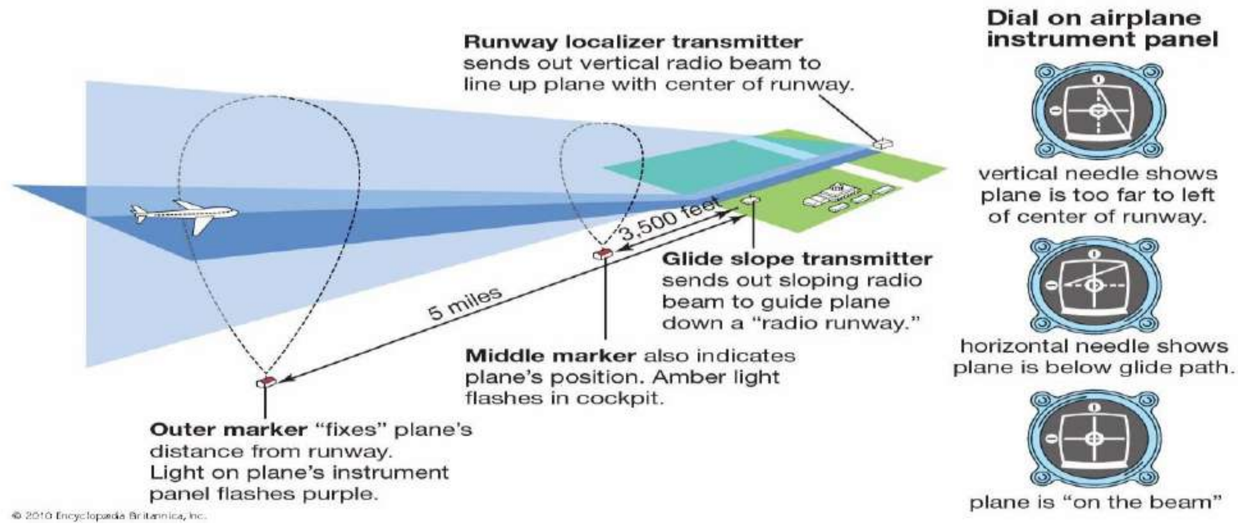
The pilot controls the aircraft so that the glide slope indicator remains centered on the display to ensure the aircraft is following the glide path of approximately 3° above horizontal (ground level) to remain above obstructions and reach the runway at the proper touchdown point (i.e., it provides vertical guidance).

Limitations

Due to the complexity of ILS localizer and glide slope systems, there are some limitations. Localizer systems are sensitive to obstructions in the signal broadcast area, such as large buildings or hangars. Glide slope systems are also limited by the terrain in front of the glide slope antennas. If terrain is sloping or uneven, reflections can create an uneven glide path, causing unwanted needle deflections. Additionally, since the ILS signals are pointed in one direction by the positioning of the arrays, glide slope supports only straight-line approaches with a constant angle of descent. Installation of an ILS can be costly because of siting criteria and the complexity of the antenna system.

Variant

- Instrument guidance system (IGS) is a modified ILS to accommodate a non-straight approach.



1.9 THE CONCEPT OF NAVIGATION SATELLITE SYSTEM.(NAVSAT) & GPS SYSTEM:

NAVSAT-

- The **Transit** system, also known as **NAVSAT** or **NNSS** (for *Navy Navigation Satellite System*), was the first satellite navigation system to be used operationally.
- The system was primarily used by the U.S. Navy to provide accurate location information to its Polaris ballistic missile submarines, and it was also used as a navigation system by the Navy's surface ships, as well as for hydrographic survey and geodetic surveying. Transit provided continuous navigation satellite service from 1964, initially for Polaris submarines and later for civilian use as well.
- The satellites (known as ***OSCAR*** or ***NOVA*** satellites) used in the system were placed in low polar orbits. A *constellation* of five satellites was required to provide reasonable global coverage.

- The orbits of the Transit satellites were chosen to cover the entire Earth; they crossed over the poles and were spread out at the equator. Since only one satellite was usually visible at any given time, fixes could be made only when one of the satellites was above the horizon.
- NAVSAT system is a system that uses satellites to provide autonomous GEO spatial positioning. It allows small electronic receivers to determine their location to high precision using time signals transmitted along a line of sight by radio from satellites.
- The system can be used for providing position, navigation or for tracking the position of something fitted with a receiver.
- The signals also allow the electronic receiver to calculate the current local time to high precision which allows time synchronization.
- A navigational satellite system with global coverage may be termed a global navigation satellite system (GNSS).
- The satellites travelled on well-known paths and broadcast their signals on a well-known radio frequency.
- The received frequency will differ slightly from the broadcast frequency because of the movement of the satellite with respect to the receiver.
- By monitoring this frequency shift over a short time interval the receiver can determine its location.
- Modern systems are more direct. The satellite broadcasts a signal that contains orbital data.

GLOBAL POSITIONING SYSTEM-

The **Global Positioning System** (**GPS**), originally **NAVSTAR GPS** is a satellite-based radio navigation system owned by the United States government and operated by the United States Air Force. It is a global navigation satellite system (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. Obstacles such as mountains and buildings block the relatively weak GPS signals.

The GPS does not require the user to transmit any data, and it operates independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the GPS positioning information. The GPS provides critical positioning capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.

The GPS project was started by the U.S. Department of Defense in 1973, with the first prototype spacecraft launched in 1978 and the full constellation of 24 satellites operational in 1993. Originally limited to use by the United States military, civilian use was allowed from the 1980s.

Working-

- GPS satellites circle the earth twice a day in a precise orbit. Each satellite transmits an unique signal and orbital parameters that allow GPS devices to decode and compute the precise location of the satellite. GPS receiver use this information to calculate a user's exact location.

- The GPS receiver measures the distance to satellite by the amount of time it takes to receive a transmitted signal.
- With distance measurements from a few more satellites the receiver can determine a user's position and display it electronically to measure the running route and find a way to destination.
- To calculate the 2D position (latitude & longitude) and track movement, a GPS receiver must be locked onto the signal of at least 3 satellites.
- With 4 or more satellites, the receiver can determine the 3D position i.e. latitude, longitude and altitude.
- Once our position has been determined, the GPS can calculate other information. The 31 satellites that currently makeup the GPS system are orbiting the earth about 1200miles above us.
- This satellites are constantly moving, making 2 complete orbits in less than 24 hours. They travel at speeds of roughly 7000miles an hours.

1.10 SIMPLE RADAR PROBLEMS-

Problem: - 1

Calculate the maximum range of RADAR for the following specifications:-

- Peak power transmitted by the RADAR, P_t= 250KW
- Gain of transmitting Antenna , G=4000
- Effective aperture of the receiving Antenna, A_e =4m^2
- Radar cross section of the target, σ= 25m^2
- Power of minimum detectable signal, S_{min}= 10^{-12}W

Solution :-

We can use the following standard form of RADAR range equation in order to calculate the maximum range of Radar for given specifications.

$$R_{Max}= \left[\frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}}\right]^{1/4}$$

Substitute all the given parameters in above equation.

$$R_{Max}=\left[\frac{(250\ X\ 10^3)(4000)(25)(4)}{(4\pi)^2(10^{-12})}\right]^{1/4}$$

$$=> R_{Max} =158\ KM$$

Therefore, the maximum range of Radar for given specification is 158KM.

Problem 2

Calculate the maximum range of Radar for the following specifications.

- Operating frequency, f=10GHZ
- Peak power transmitted by the Radar, P_t= 400KW
- Effective aperture of the receiving Antenna, $A_e = 5m^2$
- Radar cross section of the target, σ=30m^2
- Power of minimum detectable signal, $S_{min} = 10^{-10}W$

Solution

We know the following formula for operating wavelength, λ in terms of operating frequency, f.

λ = C/f

Substitute, C=3 X 10^{8}m/sec and f=10GHZ in above equation.

$$\lambda = \frac{3\ X\ 10^8}{10\ X\ 10^9}$$

λ =0.03m

So, the operating wavelength, λ is equal to 0.03m, when the operating frequency, f is 10GHZ

We can use the following modified form of Radar range equation in order to calculate the maximum range of Radar for given specifications.

$$R_{Max}= \left[\frac{P_t G \sigma {A_e}^2}{(4\pi\lambda^2 S_{min}}\right]^{1/4}$$

Substitute, the given parameters in the above equation.

$$R_{Max}=\left[\frac{(400X\ 10^3)(30)(5^2)}{4\pi(0.003)^2(10)^{-10}}\right]^{1/4}$$

=> R_{Max} =128 KM

UNIT-2: SATELLITE COMMUNICATION

2.1 DEFINE & DESCRIBE SATELLITE ORBITAL PATTERNS AND ELEVATION(LEO,MEO & GEO) CATEGORIES

SATELLITE

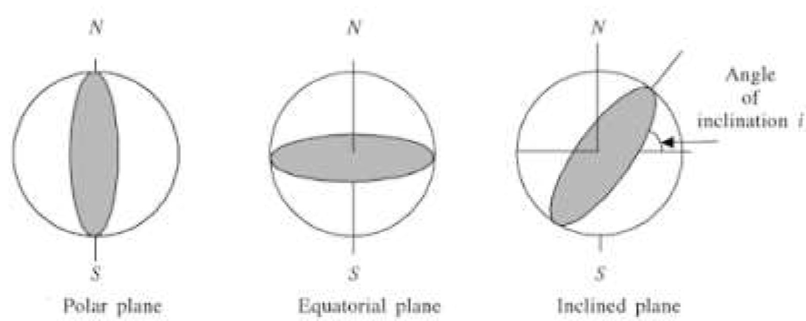
Satellite can be defined as a heavy object acting as a microwave repeater which goes around another object in space due to the effect of mutual gravitational forces. Moon is a natural satellite of earth. Actually in common we use satellite to sense the artificial one which launch to travel around earth or any other planets.

SATELLITE ORBIT

The path in which a satellite travels around the earth in its stable condition is called satellite orbit. The distance from the center of the earth to the satellite is called orbit radius. The height of the satellite from the surface of the earth is called altitude. At any point in the orbit, the angle of the rotation of satellite with horizon is referred as inclination.

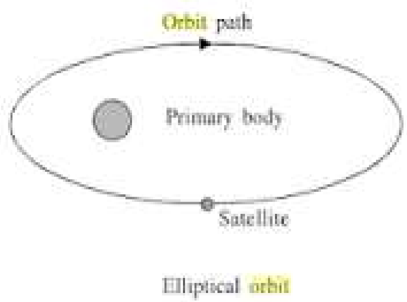
Classification of Satellite orbit: An orbit is characterized by the attributes - radius, altitude and inclination.

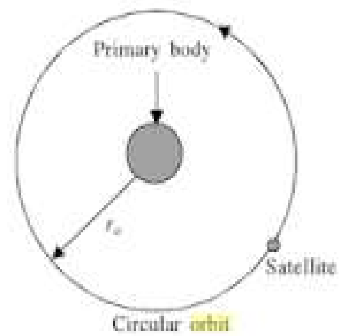
According to the inclination satellite orbits are three types:



i) Equatorial orbit: The orbit which plane coincide with the equator of the earth is known as equatorial orbit. Their inclination angle is zero.
ii) Polar orbit: The orbit which plane coincide with any polar axis of the earth (a line passing the reference points of the north and south poles) is known as polar orbit. Their inclination angle is 90 degree.
iii) Inclined orbit: The orbit which is neither equatorial nor polar is known as inclined orbit. Their inclination angle lies between 0 to 90 degree.

According to radius satellite orbits are two types:





i) **Circular orbit**: The orbit in which the orbital radius is constant, is called circular orbit.

ii) **Elliptical orbit**: The orbit in which the orbital radius is varied is called elliptical orbit.

According to altitude satellite orbits are commonly three types: (details will be included in satellite classification)

1. GEO (Geo-stationary earth orbit)
2. MEO (medium earth orbit)
3. LEO (Low earth orbit)

GEO, MEO AND LEO-

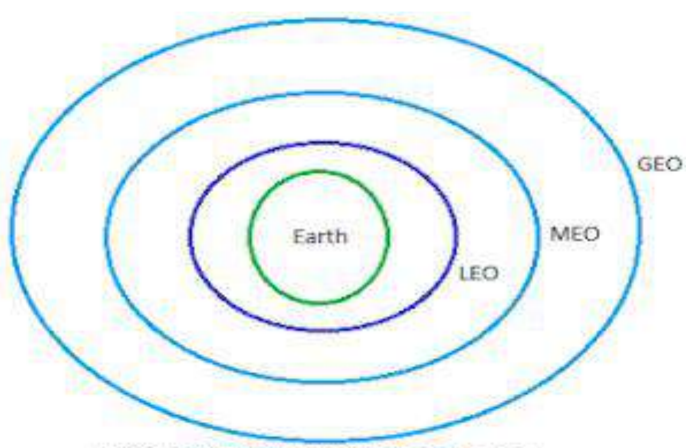


Fig: Satellite orbits according to altitude

Geo-Stationary Earth Orbit (GEO)-

These satellites have almost a distance of 35,786 km to the earth. This orbit has the special characteristic that the apparent position of the satellite in the sky when viewed by a ground observer does not change, the satellite appears to stand still in the sky. This is because the satellite's orbital period is same as the rotation rate of the earth.

E.g. All radio and TV, whether satellite etc, are launched in this orbit.

Advantages of Geo-Stationary Earth Orbit

1. It is possible to cover almost all parts of the earth with just 3 geo satellites.

2. Antennas need not be adjusted every now and then but can be fixed permanently.

3. The life-time of a GEO satellite is quite high usually around 15 years.

Disadvantages of Geo-Stationary Earth Orbit

1. Larger antennas are required for northern/southern regions of the earth.

2. High buildings in a city limit the transmission quality.

3. High transmission power is required.

4. These satellites cannot be used for small mobile phones.

5. Fixing a satellite at Geo stationary orbit is very expensive.

Medium Earth Orbit (MEO)-

The orbital path spreads over 2000km to 35,786km above earth in circular path is called medium earth orbit and the satellite moves around this orbit is called MEO satellite. MEO satellites are visible for much longer periods of time than LEO satellites usually between 2-8 hrs.

These orbits have moderate number of satellites.

Advantages of Medium Earth Orbit

1. Compared to LEO system, MEO requires only a dozen satellites.

2. Simple in design.

3. Requires very few handovers.

4. MEO satellites have a larger coverage area than LEO satellite.

Disadvantages of Medium Earth Orbit

1. Satellites require higher transmission power.

2. Special antennas are required.

3. MEO satellites don't maintain a stationary distance from the earth.

Low Earth Orbit (LEO)-

LEO satellites operate at a distance of about 160-2000 km. Because of their low altitude, these satellites are only visible for few time.

Advantages of Low Earth Orbit

1. The antennas can have low transmission power of about 1 watt.

2. The delay of packets is relatively low.

3. Useful for smaller foot prints.

Disadvantages of Low Earth Orbit

1. If global coverage is required, it requires at least 50-200 satellites in this orbit.

2. Special handover mechanisms are required.

3. These satellites involve complex design.

4. Very short life: Time of 5-8 years. Assuming 48 satellites with a life-time of 8 years each, a new satellite is needed every 2 months.

5. Data packets should be routed from satellite to satellite.

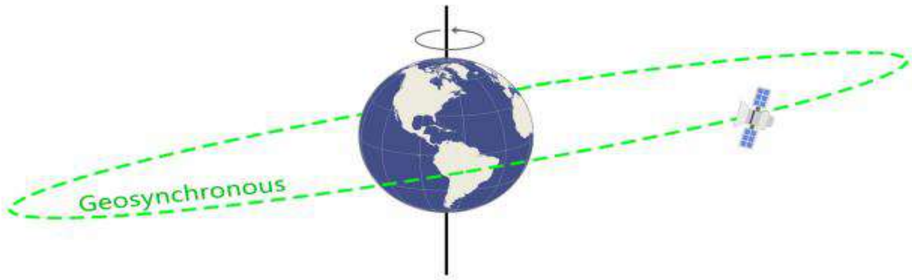
What is the difference between geosynchronous and geostationary orbits?

About 35,786 kilometers above the Earth's surface, satellites are in geostationary orbit. From the center of the Earth, this is approximately 42,164 kilometers. This distance puts it in the **high Earth orbit** category.

At any inclination, a geosynchronous orbit synchronizes with the rotation of the Earth. More specifically, the time it takes for the Earth to rotate on its axis is 23 hours, 56 minutes and 4.09 seconds, which is the same as a satellite in a geosynchronous orbit.

If you are an observer on the ground, you would see the satellite as if it's in a fixed position without movement.

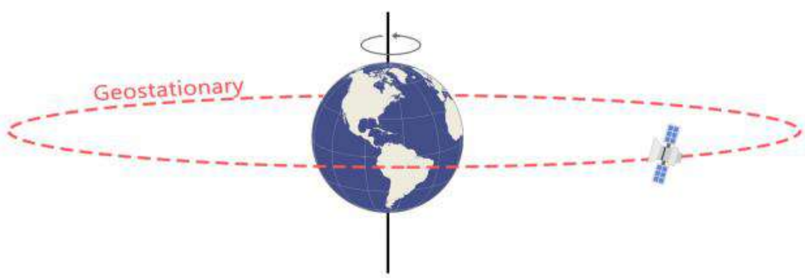
This makes geosynchronous satellites particularly useful for telecommunications and other **remote sensing applications**.



Geostationary Orbits

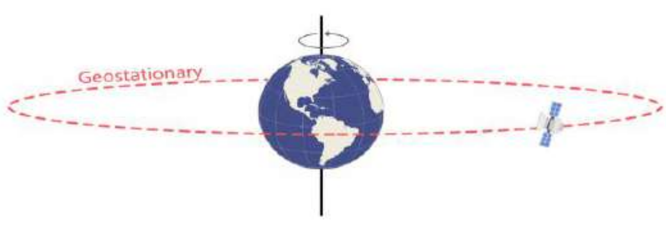
While geosynchronous satellites can have any inclination, the key difference to geostationary orbit is the fact that they lie on the same plane as the equator.

Geostationary orbits fall in the same category as geosynchronous orbits, but it's parked over the equator. This one special quality makes it unique from geosynchronous orbits.



Weather monitoring satellites like GOES are in geostationary orbits because they have a constant view of the same area. In a **high Earth orbit**, it's also useful for search and rescue beacons.

Here's how both orbits compare:



While the geostationary orbit lies on the same plane as the equator, the geosynchronous satellites has a different inclination.

What is a Geo Stationary orbit?

A geo-stationary orbit is an orbit of an Earth's satellite whose period of rotation is exactly equal to the period of rotation of Earth about it's polar axis (which is 23 hours, 56 minutes and 4.1 seconds) and whose trajectory is aligned with the Earth's equator.

Any satellite in this orbit will appear as if it is always in the same place in the sky when observed from the same point on the Earth. This orbit is at a distance of approximately 35,900 km from the surface of the Earth. Communication satellites are usually placed into this orbit, with several satellites in the same orbit, distributed around to provide world wide coverage for relaying the telecommunication signals.

2.2 DESCRIBE THE CONCEPT OF GEOSTATIONARY SATELLITE , CALCULATE ITS HEIGHT, VELOCITY & ROUND TRIP TIME DELAY & THEIR ADVANTAGE & DISADVANTAGE OVEROTHER SYSTEM:

CALCULATION OF HEIGHT OF A GEO STATIONARY SATELLITE-

The gravitational force between the satellite and the Earth is in the radial direction and its magnitude is given by the Newton's equation

$F = GMm/r^2$ (1)

Where G is the gravitational constant, M and m are the masses of the Earth and the satellite respectively and r is the radius of the orbit.

In case of the circular motion the net force equals mass times acceleration, where acceleration can be calculated by $\omega^2 r$, where ω is the angular rate of rotation also known as angular velocity.

Thereby,

$F = ma = m\omega^2 r$. (2)

The angular velocity is given by

$\omega = 2\pi/T$, (3)

where T is the period for one rotation.

We substitute (3) into the equation (2) and we get

$F = m4\pi^2 r/T^2$. (4)

Now we can use the equations (4) and (1) to find the following formula

$m4\pi^2 r/T^2 = GMm/r^2$

or

$r^3 = GMT^2/4\pi^2$.   (5)

We substitute the values and we get

$r^3 = 6.67*10^{-11}*5.972*10^{24}*86400^2/4\pi^2$

and finally,

$r = 4.22*10^7$ m.

The radius of the Earth is $6.37*10^6$ m.

We can calculate the height h above the Earth's surface by subtracting the radius of the Earth from the radius of the orbit.

$h = 4.22*10^7 – 6.37*10^6 = 3.583*10^7$ m.

CALCULATION OF VELOCITY OF A GEO STATIONARY SATELLITE-

A geostationary orbit is a circular orbit directly above the Earth's equator approximately 35,786 km above ground. Any point on the equator plane revolves about the Earth in the same direction and with the same period as the Earth's rotation.
The period of the satellite is one day or approximately 24 hours. To find the speed of the satellite in orbit we use Newton's law of gravity and his second law of motion along with that we know about centripetal acceleration. The inward and outward forces on the satellite must equal each another (by Newton's first law of motion).
$F_{centripetal} = F_{centrifugal}$
By Newton's second law of motion:
F = ma

$$m_{S\,.}\, a_g = m_S \,.\, a_c$$

Where:
m_s – Mass of satellite
a_g – Gravitational acceleration
a_c – Centrifugal acceleration

The centripetal acceleration provided by Earth's gravity:

$a_g = (M_e.\mathrm{G}) / r^2$

Where:
M_e - Mass of Earth in kilograms (5.9742 x10^{24} kg)
G - Gravitational constant (6.6742 x 10-11 N m2 kg-2 = 6.6742 x 10^{-11} m^3 s^{-2} kg^{-1})

Magnitudes of the centrifugal acceleration derived from orbital motion:
$a_c = \omega^2 . r$

Where;
ω - Angular velocity in radians per second.
r - Orbital radius in meters as measured from the Earth's center of mass.

$a_c = (v/r)^2.\mathrm{r}$

$$a_c = \frac{v^2}{r}$$

From the relationship

$m_{S\,.}\ (M_e.\mathrm{G}) / r^2 = m_S . \frac{v^2}{r}$

$F_{centripetal} = F_{centrifugal}$
we note that the mass of the satellite, m_S appears on both sides, geostationary orbit is independent of the mass of the satellite.

$(M_e.\mathrm{G}) / r^2 = \frac{v^2}{r}$

V = $\sqrt{(M_e.\mathrm{G}) / r}$

r (Orbital radius) = Earth's equatorial radius + Height of the satellite above the Earth surface
r = 6,378 km + 35,780 km
r = 42,158 km
r = 4.2158 x 107 m

V = $\sqrt{\frac{(5.9742 \times 10^{24}\mathrm{kg} \times 6.6742 \times 10^{-11}\ \mathrm{N}m^2\ Kg^{-2})}{4.2158 \times 10^7 m}}$

V= $3.0754 \times 10^3\ \mathrm{m}s^{-1}$

Speed of the satellite is 3.0754 x 103 m/s

<u>CALCULATION OF ROUND TRIP TIME DELAY OF GEOSTATIONARY SATELLITE-</u>

Most communications satellites are located in the Geostationary Orbit (GSO) at an altitude of approximately 35,786 km above the equator. At this height the satellites go around the earth in a west to east direction at the same angular speed at the earth's rotation, so they appear to be almost fixed in the sky to an observer on the ground.

The time for one satellite orbit and the time for the earth to rotate is 1 sidereal day or 23 h 56 m 4 seconds.

Radio waves go at the speed of light which is 300,000 km per second.

If you are located on the equator and are communicating with a satellite directly overhead then the total distance, single hop (up and down) is nearly 72,000 km so the time delay is **240 ms**. mS means millisecond or 1 thousandth of a second so 240 mS is just under a quarter of a second.

A geostationary satellite is visible from a little less than one third of the earth's surface and if you are located at the edge of this area the satellite appears to be just above the horizon. The distance to the satellite is greater and for earth stations at the extreme edge of the coverage area, the distance to the satellite is approx 41756 km. If you were to communicate with another similarly located site, the total distance is nearly 84,000 km so the end to end delay is almost **280 mS**, which is a little over quarter of a second.

ADVANTAGES OF GEO OR GEOSYNCHRONOUS EARTH ORBIT

Following are the **advantages of GEO orbit**:

1. As it is at greater height, it covers larger geographical area. Hence only 3 satellites are required to cover the entire Earth.
2. Satellites are visible for 24 hours continuously from single fixed location on the Earth.
3. It is ideal for broadcasting and multi-point distribution applications.
4. Ground station tracking is not required as it is continuously visible from earth all the time from fixed location.
5. Inter-satellite handoff is not needed.
6. Less number of satellites are needed to cover the entire earth. Total three satellites are sufficient for the job.
7. Almost there is no doppler shift and hence less complex receivers can be used for the satellite communication.

DISADVANTAGES OF GEO OR GEOSTATIONARY EARTH ORBIT

Following are the disadvantages of GEO orbit:

1. The signal requires considerable time to travel from Earth to satellite and vice versa. The signal travel delay is about 120ms in one direction. The distance of 35786 Km gives 120 ms latency with $3x10^8$ m/sec speed of the signal. Hence it is not suitable for point to point applications requiring time critical applications such as real time voice, video etc.
2. Since GEO orbit is located above the equator, it is difficult to broadcast near the polar region.
3. Due to longer transmission distance, the received signal is very weak. This requires better LNA (Low Noise Amplifier) and also advanced signal processing algorithms in the satellite modem. This increases cost of the ground station equipment.
4. It provides poor coverage at higher latitude places usually greater than 77 degrees.

2.3 SATELLITE FREQUENCY ALLOCATION & FREQUENCY BANDS-

Frequency allocation (or **spectrum allocation** or spectrum management) is the allocation and regulation of the electromagnetic spectrum into radio frequency bands, which is normally done by governments in most countries. Because radio propagation does not stop at national boundaries, governments have sought to harmonies the allocation of RF bands and their standardization.

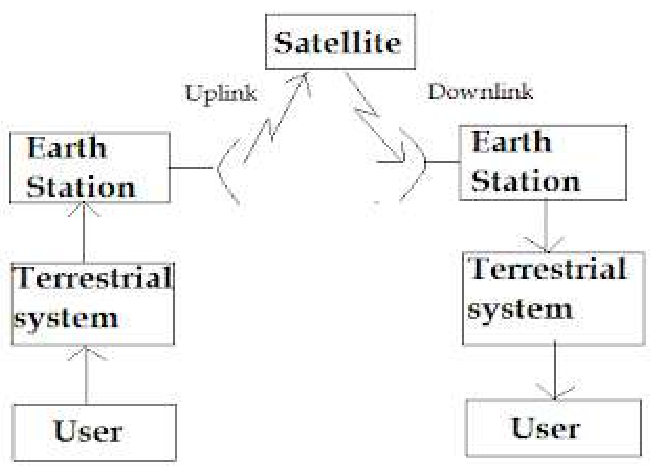
C band **Satellite** will have about 500 MHz of **bandwidth** between upper and lower frequency limits. This 500 MHz bandwidth is divided into 12 channels of 36 MHz bandwidth. 4MHz of guard bands incorporated in between this channels to minimize adjacent channel interference.

Satellite applications include FSS, BSS and MSS. FSS stands for Fixed Service Satellite, BSS stands for Broadcast Service Satellite and MSS stands for Mobile Service Satellite.

Frequency Band	Frequency Range(GHz)	Bandwidth(GHz)	Applications
L band	1-2	1	MSS

S band	2-4	2	MSS,NASA
C band	4-8	4	FSS
X band	8-12.5	4.5	meteorological satellite and FSS military
Ku band	12.5-18	5.5	FSS,BSS
K band	18-26.5	8.5	FSS,BSS
Ka band	26.5-40	13.5	FSS

2.4 GENERAL STRUCTURE OF SATELLITE LINK SYSTEM-



- This consists of a satellite in space that links many earth stations on the ground. The user is connected the earth station through terrestrial network. This terrestrial network may be a telephone switch or a dedicated link to the earth station.
- The user generates the base-band signal that is processed and transmitted to the satellite at the earth station.
- Thus, the satellite may be thought of as a large repeater in space that receives the modulated RF carriers in its up-link (earth to space) frequency spectrum from all the earth stations in the network, amplifies these carriers and re-transmits them back to the earth in the down-

link (space to earth) frequency spectrum which is different from the up-link frequency spectrum in order to avoid the interference.

- The signal at the receiving earth station is processed to get back the baseband signal which is then sent to the user through a terrestrial network.
- On the guidelines of WARC-1979, commercial communication satellite use a frequency band of 500MHz bandwidth near 6GHz for up-link transmission and another 500MHz bandwidth near 4GHz for down-link transmission (i.e. 6/4 GHz band). In fact an up-link of 5.725 to 7.075GHz and a down-link of 3.4 to 4.8GHZ is used.
- The 500MHz allocation is usually divided into 12 channels of approximately 40MHz each and the transmit power per channel is typically of the order of 5 to 10W. This allows each of up to 12 transponders to carry one TV channel or 1500 analog FM voice circuits.

- This 6/4 band have been the most popular because they offer the fewest propagation problems and also RF components for these bands have been readily available.
- Rain attenuation is also not much serious at these bands. Sky noise is also low at 4GHz and so it is possible to build receiving system with low noise at 4GHz.
- With the overcrowding of GEO satellites at 6/4 GHz band, 14/12 GHz band is also being used in commercial communication satellites.

A third band where extremely high capacities are potentially available is the 30/20 GHz band.

Transponder-

A **transponder** receives and transmits radio signals at a prescribed frequency range. After receiving the signal a **transponder** will at the same time broadcast the signal at a different frequency. ... **Transponders** are **used in** satellite communications and in location identification and navigation systems.

Uplink and downlink-

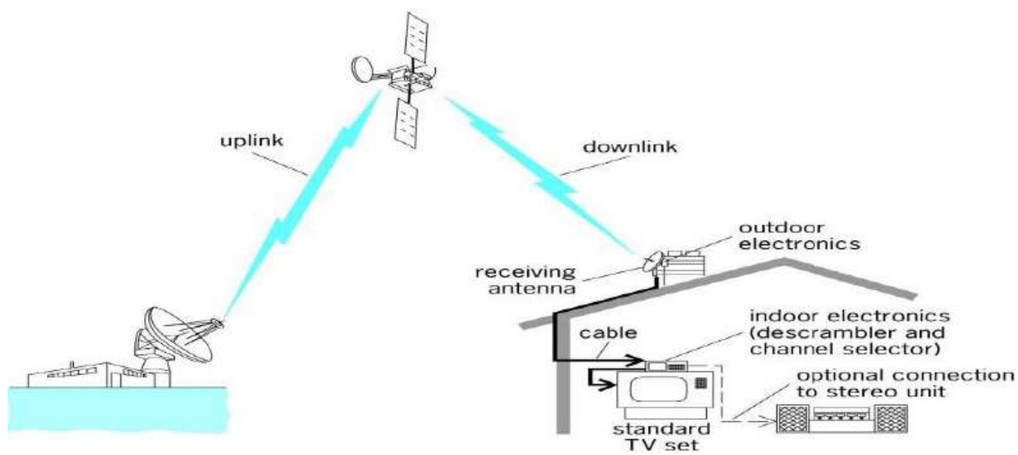
The communication going from a satellite to ground is called downlink, and when it is going from ground to a satellite it is called uplink. When an uplink is being received by the spacecraft at the same time a downlink is being received by Earth, the communication is called two-way. If there is only an uplink happening, this communication is called upload. If there is only a downlink happening, the communication is called one-way.

Crosslink-

A crosslink is a communications link between two satellites, typically serving a relay function in a constellation. For example, in the following illustration, there is a crosslink between Satellite1 and Satellite2, serving to relay communications between two ground stations. The crosslink is needed because the orbits of the satellites in the constellation are too low for a single satellite to have simultaneous access to both ground stations.

2.5 DIRECT BROADCASTING SATELLITE SYSTEMS-

- Systems for transmitting television and other program material via satellite directly to in dividual homes and businesses. Direct broadcasting satellite (DBS) systems operate at mi crowave frequencies, in a portion of the Ku band; in North and South America these syste ms operate in the frequency range 12.2–12.7 GHz.
- DBS systems use a satellite in geostationary orbit to receive television signals sent up fro m the Earth's surface, amplify them, and transmit them back down to the surface.
- The satellite also shifts the signal frequency, so that a signal sent up to the satellite in t he 17.3-17.8GHz uplink band
  is transmitted back down in the 12.212.7GHz downlink band.
- The downlink signal is picked up by a receive antenna located atop an individual home or office; these antennas are usually in the form of a parabolic dish, but flat square Phased array antennas are sometimes used, and may eventually become commonplace.
- The receive antenna may be permanently pointed at the satellite, which is at a fixed point in the sky, in a geostationary orbit.



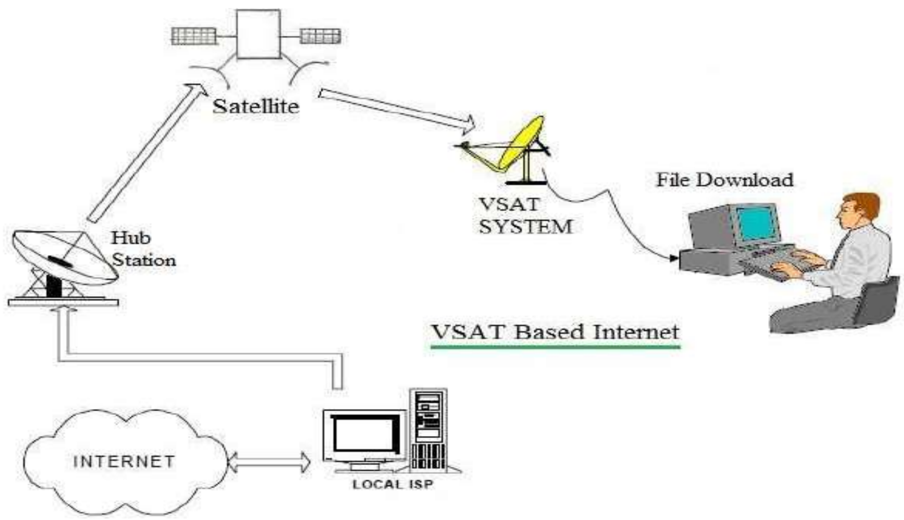
Direct broadcasting satellite system

Operation-

- A direct broadcast satellite system, a satellite broadcast company encodes TV signals that it receives from its partners and transmits them to an orbiting satellite.
- Although a satellite broadcast company may have nos. of satellites in orbit, they may either transmit data directly from multiple transmitters to each satellite or simply use one satellite to share information with another.
- Once the appropriately positioned satellite obtains the data that it needs it retransmits the information to all residences in a specific area. If a residence in that area has paid for services with the satellite broadcast company it will be equipped with a satellite dish and a receiver box that is able to receive the signals and decode them, allowing all users in the residence to access TV services.

2.6 VSAT-

- Low cost business terminals with small antennas (generally less than 2 meters in diameter) are often termed Very Small Aperture Terminals (VSATs).



- These are usually perceived as being two way data terminals, though strictly speaking many of the systems used for data broadcast are really one-way VSATs. Taking the USA as an example, approximately half of all installed VSATs are only used for one way data links.
- ETSI take a different definition for a VSAT as a one or two-way terminal used in a star, mesh or point to point network. Antenna size is restricted to being less than or equal to 3.8 m at Ku band and 7.8 m at C band.
- The majority of VSAT antennas range from 75cm to 1.2cm.
- VSATs access satellites in geosynchronous orbit or geostationary orbit to relay data from small remote earth stations to other terminals or master earth station “hubs”.
- A VSAT end user needs a box that interfaces between the user’s computer and an outside antenna i.e. transceiver.
- The transceiver 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

Advantages of VSAT

1. Installation: VSAT services are deployed in hours or minutes.
2. Coverage: It can be available anywhere with clear line of sight between VSAT antenna disc

and satellite over the earth. It is popular in hilly areas where other mode of communication is either not available or difficult to install.
3. Price: VSAT terminals are cheaper.
4. Upgradation: It is flexible to add a VSAT site and increase the bandwidth as per future requirements.
5. Service charges: It depends on the bandwidth allocated as per user requirements.
6. VSAT provides same quality of service and speed at all the locations across the entire VSAT network.
7. VSAT services are independent of other wired and wireless mediums used as transmission network service provider. Hence it is a great backup system which is available during disaster and emergency situations.
8. VSAT terminals and indoor/outdoor hardware can be installed on truck or van and can be used even in mobility conditions.

Disadvantages of VSAT

1. As mentioned it requires clear Line of Sight between VSAT dish and satellite in the space.
2. The malfunctioning of satellite and Hub station (in case of star topology) will lead to disruption of VSAT services. To avoid this situation, redundant systems and switch over units are needed to have backup systems available for hot switching in faulty situations. But this increases overall cost of the VSAT system as a whole.
3. Latency for packet transmission from source to destination is higher due to distance of satellite from earth is about 36000 Km. Latency further increases in star topology of VSAT, as it requires two hops to reach a final destination.
4. VSAT services get affected in bad weather conditions.
5. As information transmitted by VSAT goes over the air till it reaches destination, it is prone to intrusion by hackers. Hence encryption-decryption units are needed to have secure communication. This increases the overall VSAT terminal cost.

2.7 MULTIPLE ACCESSING & ITS TYPES-

Multiple access is a **technique** that lets **multiple** mobile users share the allotted spectrum in the most effective manner. In computer networks and telecommunications, the **multiple access** method permits various terminals to connect to the same **multi**-point transmission medium to transmit over it and share its capacity.

There are several different ways to allow access to the channel. These includes mainly the following –

- Frequency division multiple-access (FDMA)
- Time division multiple-access (TDMA)
- Code division multiple-access (CDMA)

- Space division multiple access (SDMA)
- Spread Spectrum Multiple Access (SSMA)

Frequency Division Multiple Access (FDMA)

FDMA is the basic technology for advanced mobile phone services. The features of FDMA are as follows.

- FDMA allots a different sub-band of frequency to each different user to access the network.
- If FDMA is not in use, the channel is left idle instead of allotting to the other users.
- FDMA is implemented in Narrowband systems and it is less complex than TDMA.
- Tight filtering is done here to reduce adjacent channel interference.
- The base station BS and mobile station MS, transmit and receive simultaneously and continuously in FDMA.

Time Division Multiple Access (TDMA)

In the cases where continuous transmission is not required, there TDMA is used instead of FDMA. The features of TDMA include the following.

- TDMA shares a single carrier frequency with several users where each users makes use of non-overlapping time slots.
- Data transmission in TDMA is not continuous, but occurs in bursts. Hence handsoff process is simpler.
- TDMA uses different time slots for transmission and reception thus duplexers are not required.
- TDMA has an advantage that is possible to allocate different numbers of time slots per frame to different users.
- Bandwidth can be supplied on demand to different users by concatenating or reassigning time slot based on priority.

Code Division Multiple Access (CDMA)

Code division multiple access technique is an example of multiple access where several transmitters use a single channel to send information simultaneously. Its features are as follows.

- In CDMA every user uses the full available spectrum instead of getting allotted by separate frequency.

- CDMA is much recommended for voice and data communications.
- While multiple codes occupy the same channel in CDMA, the users having same code can communicate with each other.
- CDMA offers more air-space capacity than TDMA.
- The hands-off between base stations is very well handled by CDMA.

Space Division Multiple Access (SDMA)

Space division multiple access or spatial division multiple access is a technique which is MIMO (multiple-input multiple-output) architecture and used mostly in wireless and satellite communication. It has the following features.

- All users can communicate at the same time using the same channel.
- SDMA is completely free from interference.
- A single satellite can communicate with more satellites receivers of the same frequency.
- The directional spot-beam antennas are used and hence the base station in SDMA, can track a moving user.
- Controls the radiated energy for each user in space.

Spread Spectrum Multiple Access (SSMA)

Spread spectrum multiple access (SSMA) uses signals which have a transmission bandwidth whose magnitude is greater than the minimum required RF bandwidth.

There are two main types of spread spectrum multiple access techniques –

- Frequency hopped spread spectrum (FHSS)
- Direct sequence spread spectrum (DSSS)

Frequency Hopped Spread Spectrum (FHSS)

This is a digital multiple access system in which the carrier frequencies of the individual users are varied in a pseudo random fashion within a wideband channel. The digital data is broken into uniform sized bursts which is then transmitted on different carrier frequencies.

Direct Sequence Spread Spectrum (DSSS)

This is the most commonly used technology for CDMA. In DS-SS, the message signal is multiplied by a Pseudo Random Noise Code. Each user is given his own code word which is orthogonal to the codes of other users and in order to detect the user, the receiver must know the code word used by the transmitter.

The combinational sequences called as **hybrid** are also used as another type of spread spectrum. **Time hopping** is also another type which is rarely mentioned.

Since many users can share the same spread spectrum bandwidth without interfering with one another, spread spectrum systems become **bandwidth efficient** in a multiple user environment.

2.8 TIME DIVISION MULTIPLE ACCESS (TDMA)-

TDMA system divide the bandwidth into time slots and in each slot only one user is allowed to either transmit or receive. TDMA systems transmit data in a buffer- and- burst method, thus the transmission for any user in non-continuous.

In a TDMA frame the preamble contains the address and synchronization information that both the base station and the subscribers used to identify each other. Guard times are utilized to allow synchronization of the receivers between different slots and frames. The features of TDMA include the following-

1. TDMA shares a single carrier frequency with several users, where each user makes use of non-overlapping time slots.
2. Data transmission for users of a TDMA system is not continuous, but occurs in bursts. This results in low battery consumption, since the subscriber transmitter can be turned off when not in use.
3. Because of discontinuous transmissions in TDMA the hand off process is much simpler for a subscriber, since it is able to listen for other base stations during ideal time slots.
4. TDMA uses different time slots for transmission and reception thus duplexers are not required.
5. Adaptive equalizer is usually necessary in TDMA systems, since the transmission rates are very high.
6. In TDMA the guard time should be minimized.
7. High synchronization overhead is required in TDMA systems because of burst transmissions. TDMA transmission are slotted and this requires the receiver to be synchronized for each data burst. Guard slots are necessary to separate users and this results in a TDMA system having large overheads.
8. TDMA has an advantage is that it is possible to allocate different numbers of time slots per frame to different users. Thus bandwidth can be supplied on demand to different users.

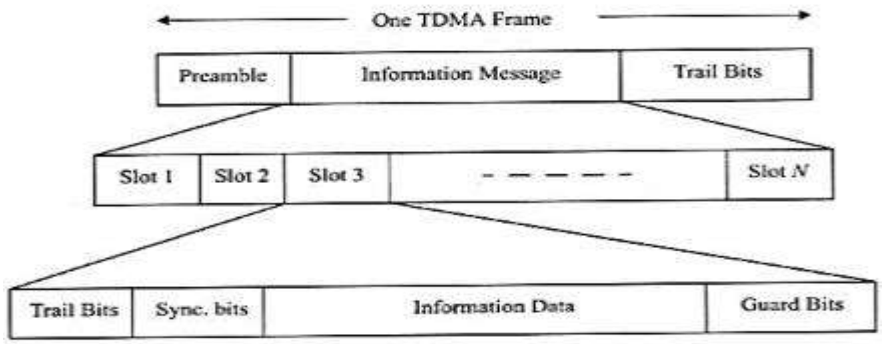


Fig: TDMA frame structure

Advantages of TDMA:

- TDMA can easily adapt to the transmission of data as well as voice communication.
- It has the ability to carry 64 kbps to 120 Mbps of data rates.
- No interference from simultaneous transmission.
- TDMA is the cost-effective technology to convert an analogue system to digital.
- Share a single carrier frequency with multiple users
- Mobile assisted handoff possible
- TDMA provides the user with extended battery life since transmitting the only portion of the time during conversations
- Flexible bit rate
- No frequency guard band required
- No need of a precise narrowband filter
- TDMA separates users according to time ensures that there will be no interference from the simultaneous transmission.
- TDMA allows the operator to do services like fax, voice and data, SMS as well as applications such as multimedia and video conferencing.

Disadvantages of TDMA:

- In TDMA each user has a predefined time slot so that users roaming from one cell to another are not allotted a time slot. Thus, if all the time slots in the next cell are already occupied, a cell might well be disconnected. In the same way, if all the time slots in the cell in which a user happens to be in are already occupied, a user will not receive a dial tone.
- It is subjected to multipath distortion. A signal coming from a tower and receive to handset might come from any one of several directions so on the road signal bounced off several different buildings before arriving which can cause interference.
- Network and spectrum planning is intensive.
- High synchronization overhead.
- Frequency/slot allocation is to be complex in TDMA.
- Equalization was necessary for high data rates.

2.9 CODE DIVISION MULTIPLE ACCESS (CDMA)-

It is cellular technology in which there are two main systems i.e, Base Station (BS) and users. In CDMA systems the narrow band message signal is multiplied by a very large bandwidth signal called the spreading signal. The spreading signal is a pseudo noise or pseudo random code. All users in a CDMA system use the same carrier frequency and may transmit simultaneously. Each user has its own pseudo random code. The receiver performs operation to detect only the specific desired code word. All other code appears as noise. For detection of the message signal, the receiver need to know the code word used by the transmitter.

Advantages-

The use of CDMA offers several advantages that’s why CDMA technology is adopted by many of the 3G cellular telecommunications systems. CDMA technology in mobile communication possesses so many advantages. The following advantages are a few of them:

1. **Security**: It is difficult for hackers to tap the CDMA signals. Hence it is more secure.

2. Improvement in capacity and security: One of the chief claims of CDMA is that it gives significant improvements in network capacity. In CDMA technology data and voice packets are separated using codes, and then transmitted by using a wide range of frequencies. Because more space is allocated for data in CDMA, this standard has become attractive for 3G high-speed mobile internet use.

3. Improvement in hand over/ hand off: By using CDMA technology, it is easy for a terminal to communicate with two base stations at once. In case of this, old link is to be broken when the new one is firmly established. This provides improvement in terms of the reliability of hand over/hand off from one base station to another.

CDMA technology has been used in 3G telecommunication systems in one form or the other. CDMA has become successful in every aspect, and it has enabled improvements need to be gained over the previous technologies used in 2G systems.

Disadvantages-

- In CDMA, orthogonal codes are used by mobile subscriber. Orthogonality between the codes need to be maintained in order to recover the data. The subscribers which are farthest from base station will have more attenuation and hence will lose the orthogonality and hence it will be difficult to recover data.

- CDMA uses soft handoff. In this type of handoff mobile needs to establish connection with the new target cell before disconnecting itself from serving cell. This procedure is more complex compare to the hard handoff type.
- Increase in number of users will decrease the overall quality of service.
- Near far problem is causes in CDMA system. This requires close control of transmit powers of CDMA handsets.
- Self-jamming is observed in CDMA system due to loss of orthogonality of PN codes.

Applications of CDMA technology

- Due to inherent advantages of CDMA over TDMA and FDMA such as user capacity, soft hand offs and security, etc., CDMA emerges as a winner in the battle of wireless technology and services. CDMA allows far greater development and the use of broad band devices such as wireless laptop modems, GPS system units and other innovative devices.
- For business purpose, CDMA supports in providing high speed push to talk and push to email services. Push to talk gives mobile an ability to be used as a walky-talky device. These services are exempted from the service charges imposed by the operators making CDMA cost effective.
- CDMA is considered as the highest mode of wireless communications, and is responsible for gibing fast and safe mode of data exchange such as 3G. Recently, CDMA has merged with the GSM technology to give a high-speed 4G or LTE internet services.

2.10 SATELLITE APPLICATION

COMMUNICATION SATELLITE-

- A communication satellite is an artificial satellite that amplifies radio telecommunication signal using a transponder, it creates a communication channel between a transmitter and receiver at different locations on earth.
- Communication satellites are used for TV, radio, telephone, internet and military applications. There are over 2000 communication satellites in earth orbit used by both private and government organization.
- Wireless communication uses EM waves to carry signals. These waves requires line of sight propagation and are thus obstructed by the curvature of the earth. The purpose of communication satellite is to relay the signal around the curve of the earth allowing communication between widely separated points.

- Communication satellites use a wide range of radio range of radio and microwave frequencies. To avoid signal interference international organizations have regulations for which frequency ranges or bands are allocated to certain organization. This allocation of bands minimizes the risk of signal interference.
- **Advantages-**
  1. Flexibility- Satellites are able to provide communications in a variety of ways.
  2. Mobility- Satellite communications are able to reach all areas of the globe depend upon the type of satellite system in use.
- **Disadvantages-**
  1. Cost- Satellites are very expensive to build, place in orbit and then maintain.
  2. Propagation delay- As distances are very much greater than those involved with terrestrial systems, propagation delay can be an issue, especially for satellites using geostationary orbits.
- **Applications-**
  1. Telecommunication- Satellite systems have been able to provide data communication links over large distances.
  2. Satellite phones- The concept of using mobile phone from anywhere on the globe is one that has many applications. There are still may areas where coverage is not available. In these situations satellite phones are of great use.
  3. Direct Broadcast- Direct broadcast satellite is a type of satellite application that is used to broadcast data directly to a residence or commercial office.

<u>DIGITAL SATELLITE RADIO-</u>

- Satellite Radio is defined by the International Telecommunication Union as a broadcasting satellite service.
- The satellite's signals are broadcast nationwide, across a much wider geographical area than terrestrial radio stations and the service is primarily intended for the motor vehicles.
- It is available by subscription, mostly commercial free and offers subscribers more stations and a wider variety of programming options than terrestrial radio.
- Ground stations transmit signals to the satellites which are 35,786 Km. above the equator.
- The satellites send the signals back down to radio receivers in cars and homes.
- This signal contains scrambled broadcasts, along with Meta data about each specific broadcast.
- The signals are unscrambled by the radio receiver modules, which display the broadcast information.
- Satellite radio uses the 2.3GHz S band in North America for nationwide digital radio broadcasting.
- In other parts of the world, satellite radio uses part of the 1.4GHz L band.

- Satellite radio subscribers purchase a receiver and pay a monthly subscription fee to listen to programming.
- They can listen through built in or portable receivers in automobiles, in the home and office with a portable receiver equipped to connect the receivers to a stereo system.
- There has been three major satellite radio companies: Worldspace, Sirius Satellite radio and XM satellite radio.

2.11 GPS TRANSMITTER AND RECEIVER

The current GPS consists of three major segments. These are the space segment, a control segment, and a user segment. The U.S. Space Force develops, maintains, and operates the space and control segments. GPS satellites broadcast signals from space, and each GPS receiver uses these signals to calculate its three-dimensional location (latitude, longitude, and altitude) and the current time.

Space segment-

The space segment (SS) is composed of 24 to 32 satellites, or Space Vehicles (SV), in medium Earth orbit, and also includes the payload adapters to the boosters required to launch them into orbit. The GPS design originally called for 24 SVs, eight each in three approximately circular orbits, but this was modified to six orbital planes with four satellites each.

The space segment consists of 24 satellites revolving the earth at 1200 miles in altitude. This high altitude allows the signals to cover a greater area. This satellites are arranged in their orbits. So a GPS receiver on earth an always receive a signal from at least 4 satellites at any given time.

Control Segment-

The control segment (CS) is composed of:

1. a master control station (MCS),
2. an alternative master control station,
3. four dedicated ground antennas, and
4. Six dedicated monitor stations.

The control segment tracks the satellites and then provides them with orbital and time information. The control segment consists of 4 un-manned control station and one master control station. The 4 un-manned station receive data from the satellites and then transmit that information to the master control station, where it is corrected and sent back to GPS satellites.

User Segment-

- The user segment consists of the user and their GPS receiver and the no. of simultaneous user is limitless.

- When GPS receiver is turned ON, it first downloads the orbit information of all satellites, this process for the first time can take some time, but once this information is downloaded, it is stored in the receiver memory for future use.
- The GPS receiver can calculate the distance of moving body, by multiplying the velocity of the transmitted signal by the time.
- To determine time part, the receiver matches the satellite's transmitted code to its own code and by comparing them determines how much it needs to delay its code to match the satellite's code. This delay time is multiplied by velocity to get the distance.

UNIT-3: OPTICAL FIBER COMMUNICATION

3.1 DEFINE OPTICAL COMMUNICATION-

Optical communication is any type of communication in which light is used to carry the signal to the remote end, instead of electrical current. Optical communication relies on optical fibers to carry signals to their destinations. A modulator/demodulator, a transmitter/receiver, a light signal and a transparent channel are the building blocks of the optical communications system.

3.2 COMPARE ADVANTAGE AND DISADVANTAGE OF OPTICAL FIBER OVER METALLIC CABLES-

Basic for comparison	Optical Fiber	Metallic Cable
Basic of transmission	Transmission of signal is in optical form.	Transmission of signal is in electrical form.
Composition of the cable	Glass and plastic	Plastic, metal foil and metal wire.
Losses in cable	Dispersion bending, absorption and attenuation	Resistive, radiated and dielectric loss
Efficiency	High	Low
Cost	Highly expensive	Less expensive
Bending effect	Can affect the signal transmission	Bending of wire does not affect the signal transmission
Data transmission rate	2Gbps	44.736 Mbps
Installation of the cable	Difficult	Easy
Bandwidth provided	Very high	Moderately high
External magnetic field	Does not affect the cable	Affects the cable
Noise immunity	High	Intermediate
Diameter of the cable	Smaller	Larger
Weight of the cable	Lighter	Heavier

3.3 DEFINE ELECTROMAGNETIC FREQUENCY AND WAVE LINE SPECTRUM:

ELECTROMAGNETIC FREQUENCY-

Electromagnetic radiation phenomena with wavelengths ranging from as long as one meter to as short as one millimeter are called microwaves; with frequencies between 300 MHz (0.3 GHz) and 300 GHz.

WAVE LINE SPECTRUM-

Spectrum, in optics, the arrangement according to wavelength of visible, ultraviolet, and infrared light. An instrument designed for visual observation of spectra is called a spectroscope; an instrument that photographs or maps spectra is a spectrograph. Spectra may be classified according to the nature of their origin, *i.e.,* emission or absorption. An emission spectrum consists of all the radiations emitted by atoms or molecules, whereas in an absorption spectrum, portions of a continuous spectrum (light containing all wavelengths) are missing because they have been absorbed by the medium through which the light has passed; the missing wavelengths appear as dark lines or gaps.

The spectrum of incandescent solids is said to be continuous because all wavelengths are present. The spectrum of incandescent gases, on the other hand, is called a line spectrum because only a few wavelengths are emitted. These wavelengths appear to be a series of parallel lines because a slit is used as the light-imaging device. Line spectra are characteristic of the elements that emit the radiation. Line spectra are also called atomic spectra because the lines represent wavelengths radiated from atoms when electrons change from one energy level to another. Band spectra is the name given to groups of lines so closely spaced that each group appears to be a band, *e.g.,* nitrogen spectrum. Band spectra, or molecular spectra, are produced by molecules radiating their rotational or vibrational energies, or both simultaneously.

3.4 ADVANTAGES AND DISADVANTAGES OF OPTICAL FIBER-

Given the speed and bandwidth advantages optical fiber has over copper cable, it also contains some drawbacks. Here are advantages and disadvantages of optical fiber cable.

Advantages of Optical Fiber

Greater Bandwidth & Faster Speed—Optical fiber cable supports extremely high bandwidth and speed. The amount of information that can be transmitted per unit of optical fiber cable is its most significant advantage.

Cheap—several miles of optical fiber cable can be made cheaper than equivalent lengths of copper wire. With numerous vendors swarm to compete for the market share, optical cable price would sure to drop.

Thinner and Light-weighted—Optical fiber is thinner, and can be drawn to smaller diameters than copper wire. They are of smaller size and light weight than a comparable copper wire cable, offering a better fit for places where space is a concern.

Higher carrying capacity—because optical fibers are much thinner than copper wires, more fibers can be bundled into a given-diameter cable. This allows more phone lines to go over the same cable or more channels to come through the cable into your cable TV box.

Less signal degradation—the loss of signal in optical fiber is less than that in copper wire.

Light signals—unlike electrical signals transmitted in copper wires, light signals from one fiber do not interfere with those of other fibers in the same fiber cable. This means clearer phone conversations or TV reception.

Long Lifespan—Optical fibers usually have a longer life cycle for over 100 years.

Disadvantages of Optical Fiber-

Limited Application—Fiber optic cable can only be used on ground, and it cannot leave the ground or work with the mobile communication.

Low Power—Light emitting sources are limited to low power. Although high power emitters are available to improve power supply, it would add extra cost.

Fragility—Optical fiber is rather fragile and more vulnerable to damage compared to copper wires. You'd better not to twist or bend fiber optic cables.

Distance—the distance between the transmitter and receiver should keep short or repeaters are needed to boost the signal.

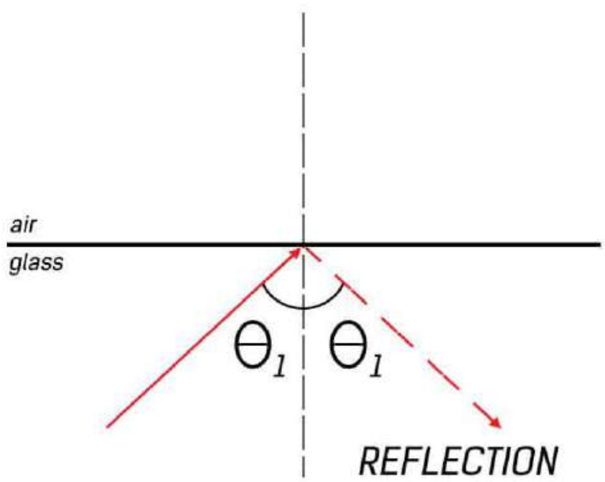
1. Installation and maintenance require expertise.
2. Unidirectional light propagation.
3. Needs for more expensive optical transistors and receivers.
4. Cannot transmit electricity.
5. Slow to make any sort of network.

3.5 PRINCIPLES OF LIGHT TRANSMISSION IN A FIBER USING RAY THEORY-

The basic laws of ray theory are quite self-explanatory

- In a homogeneous medium, light rays are straight lines.
- Light may be absorbed or reflected
- Reflected ray lies in the plane of incidence and angle of incidence will be equal to the angle of reflection.
- At the boundary between two media of different refractive indices, the refracted ray will lie in the plane of incidence. Snell's Law will give the relationship between the angles of incidence and refraction.

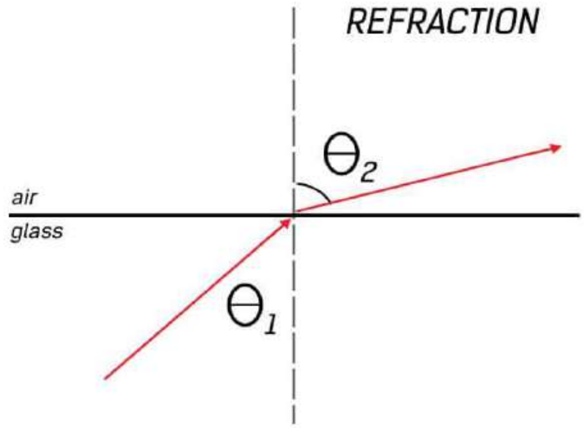
REFLECTION OF LIGHT



The Law of Reflection states that the angle of incidence must be equal to the angle of reflection.

Reflection depends on the type of surface on which light is incident. An essential condition for reflection to occur with glossy surfaces is that the angle made by the incident ray of light with the normal at the point of contact should be equal to the angle of reflection with that normal. The *images* produced from this reflection have different properties according to the shape of the surface. For example, for a flat mirror, the image produced is upright, has the same size as that of the object, and is equally distanced from the surface of the mirror as the real object. However, the properties of a parabolic mirror are different, and so on. Reflection is also possible in one other scenario, even if the surface is not reflective.

REFRACTION OF LIGHT-



Refraction is the bending of light in a particular medium due to the speed of light in that medium. The speed of light in any medium can be given by

$$v = \frac{c}{n}$$

Here n is the **refractive index** of that medium. When a ray of light is incident at the interface of two media with different refractive indices, it will bend either towards or away from the normal depending on the refractive indices of the media. According to **Snell's law**, refraction can be represented as

$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

n_1 = refractive index of first medium

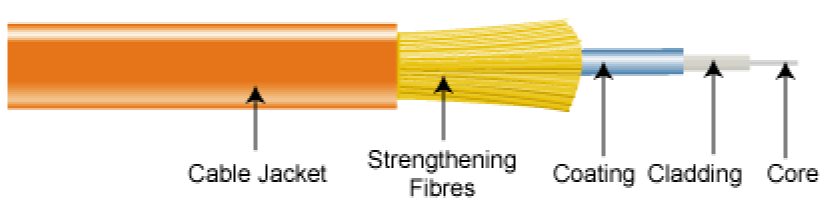
θ_1 = angle of incidence

n_2 = refractive index of second medium

θ_2 = angle of refraction

For $n_1 > n_2$, θ_2 is always greater than θ_1. **Or** to put it in different words, light moving from a medium of high refractive index (glass) to a medium of lower refractive index (air) will move away from the normal.

3.6 FIBRE OPTIC CABLE CONSTRUCTION



Core

This is the physical medium that transports optical data signals from an attached light source to a receiving device. The core is a single continuous strand of glass or plastic that's measured in microns (µ) by the size of its outer diameter. The larger the core, the more light the cable can carry.
All fiber optic cable is sized according to its core's outer diameter. The three multimode sizes most commonly available are 50, 62.5, and 100 microns. Single-mode cores are generally less than 9 microns.

Cladding
This is the thin layer that surrounds the fiber core and serves as a boundary that contains the light waves and causes the refraction, enabling data to travel throughout the length of the fiber segment.

Coating
This is a layer of plastic that surrounds the core and cladding to reinforce and protect the fiber core. Coatings are measured in microns and can range from 250 to 900 microns.

Strengthening fibers
These components help protect the core against crushing forces and excessive tension during installation. The materials can range from Kevlar to wire strands to gel-filled sleeves.

Cable jacket
This is the outer layer of any cable. Most fiber optic cables have an orange jacket, although some types can have black or yellow jackets.

3.7 EXPLAIN THE FOLLOWING TERMS: VELOCITY OF PROPAGATION, CRITICAL ANGLE, ACCEPTANCE ANGLE & NUMERICAL APERTURE:

VELOCITY OF PROPAGATION-

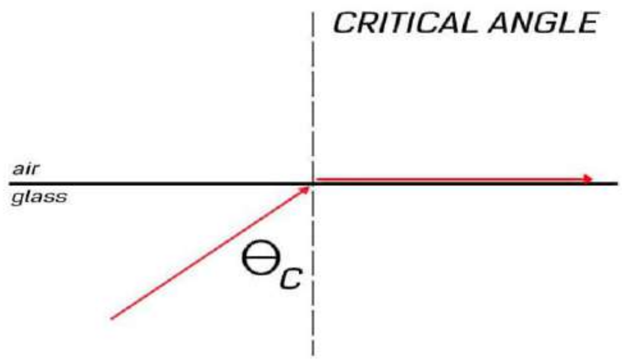
Velocity of propagation is a measure of how fast a signal travels over time, or the speed of the transmitted signal as compared to the speed of light.

In computer technology, the velocity of propagation of an electrical or electromagnetic signal is the speed of transmission through a physical medium such as a coaxial cable or optical fiber. There is also a direct relation between velocity of propagation and wavelength. Velocity of propagation is often stated either as a percentage of the speed of light or as time-to distance.

CRITICAL ANGLE-

When the angle of refraction is 90 degrees to the normal, the refracted ray is parallel to the interface between the two media. In this case, the incident angle is called the critical angle. You can calculate the critical angle using the following formula

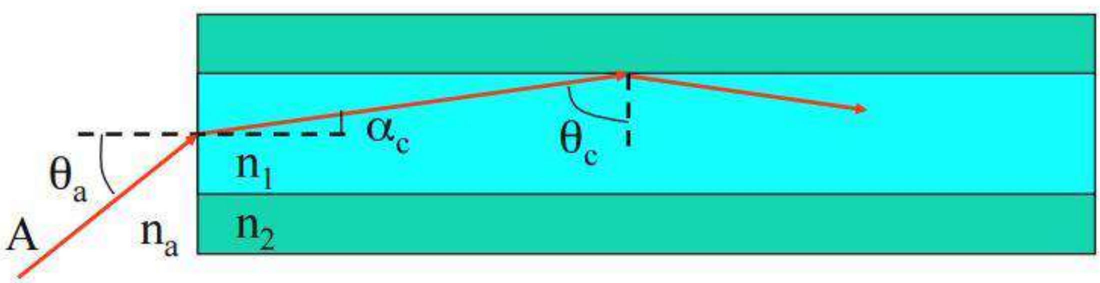
$\theta_c = \sin^{-1} \frac{n_2}{n_1}$



It is important to know about this property because reflection is also possible even if the surfaces are not reflective. If the *angle of incidence is greater than the critical angle* for a given setting, the resulting type of reflection is called **Total Internal Reflection**, and it is the basis of Optical Fiber Communication.

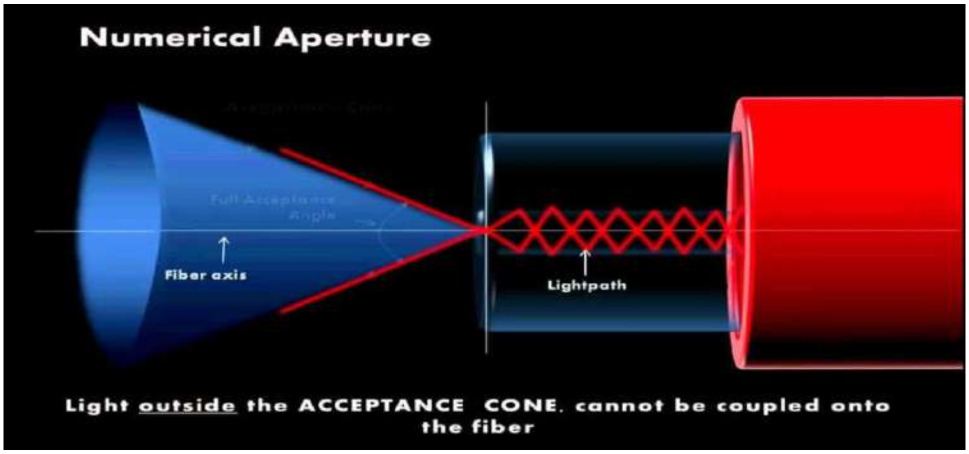
ACCEPTANCE ANGLE

In an optical fiber, a light ray undergoes its *first refraction* at the air-core interface. The angle at which this refraction occurs is crucial because this particular angle will dictate whether the subsequent *internal* reflections will follow the principle of Total Internal Reflection. This angle, at which the light ray first encounters the core of an optical fiber, is called the Acceptance angle.



NUMERICAL APERTURE

Numerical Aperture is a characteristic of any optical system. For example, photo-detector, optical fiber, lenses etc. are all optical systems. Numerical aperture is the ability of the optical system to collect all of the light incident on it, in one area.



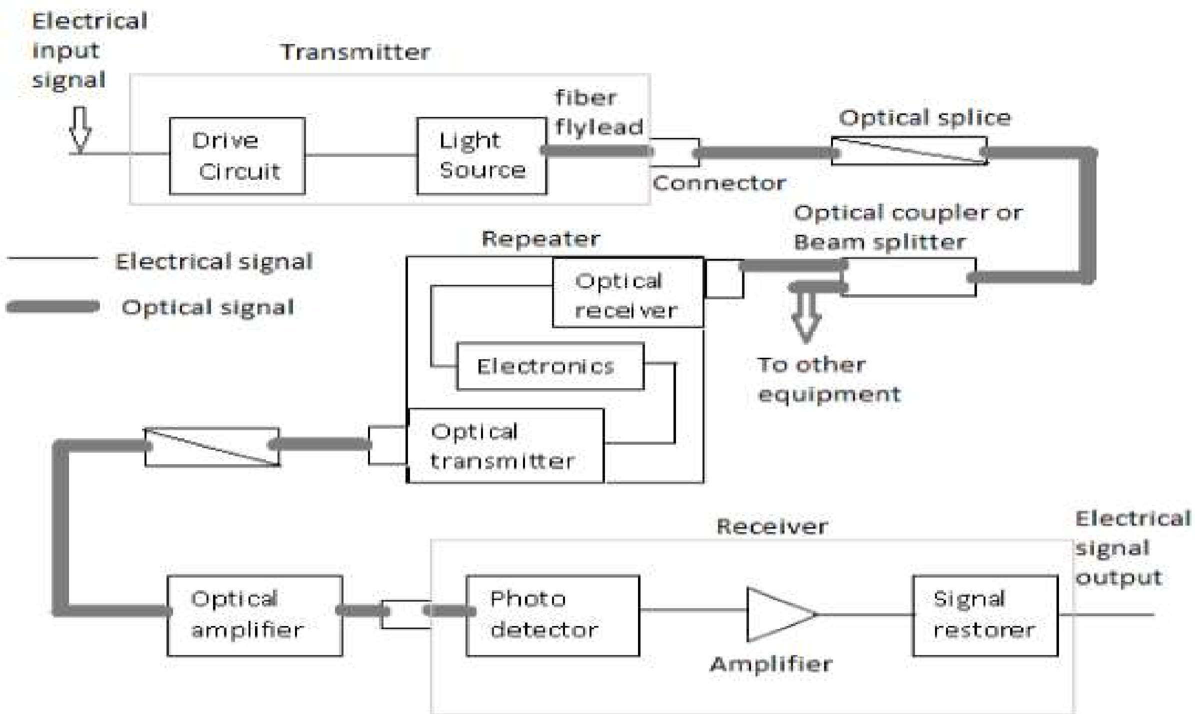
The blue cone is known as the cone of acceptance. As you can see, it is dependent on the Acceptance Angle of the optical fiber. Light waves within the acceptance cone can be collected in a small area which can then be sent into the optical fiber.

The numerical aperture of an optical fiber can be calculated with the following two formulas

$$NA = n_0 \sin \theta_a$$

$$NA = \sqrt{n_1^2 - n_2^2}$$

3.8 BLOCK DIAGRAM OF AN OPTICAL FIBER COMMUNICATION SYSTEM-



- The optical fiber consists of three main elements:

1. **Transmitter**: An electric signal is applied to the optical transmitter. The optical transmitter consists of driver circuit, light source and fiber fly lead.

- Driver circuit drives the light source.
- Light source converts electrical signal to optical signal.
- Fiber fly lead is used to connect optical signal to optical fiber.

2. **Transmission channel**: It consists of a cable that provides mechanical and environmental protection to the optical fibers contained inside. Each optical fiber acts as an individual channel.

- Optical splice is used to permanently join two individual optical fibers.
- Optical connector is for temporary non-fixed joints between two individual optical fibers.
- Optical coupler or splitter provides signal to other devices.
- Repeater converts the optical signal into electrical signal using optical receiver and passes it to electronic circuit where it is reshaped and amplified as it gets attenuated and distorted with increasing distance because of scattering, absorption and dispersion in waveguides, and this signal is then again converted into optical signal by the optical transmitter.

3. **Receiver**: Optical signal is applied to the optical receiver. It consists of photo detector, amplifier and signal restorer.

- Photo detector converts the optical signal to electrical signal.
- Signal restorers and amplifiers are used to improve signal to noise ratio of the signal as there are chances of noise to be introduced in the signal due to the use of photo detectors.

- For short distance communication only main elements are required.

  Source- LED

  Fiber- Multimode step index fiber

  Detector- PIN detector

- For long distance communication along with the main elements there is need for couplers, beam splitters, repeaters, optical amplifiers.

  Source- LASER diode

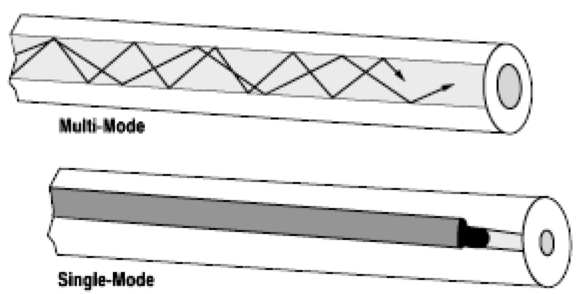
  Fiber- single mode fiber

  Detector- Avalanche photo diode (APD)

3.9 MODES OF PROPAGATION AND INDEX PROFILE OF OPTICAL FIBER

MODES OF PROPAGATION OF OPTICAL FIBER-

There are 2 types of propagation mode in fiber optics cable which are multi-mode and single-mode. These provide different performance with respect to both attenuation and time dispersion. The single-mode fiber optic cable provides the better performance at a higher cost.



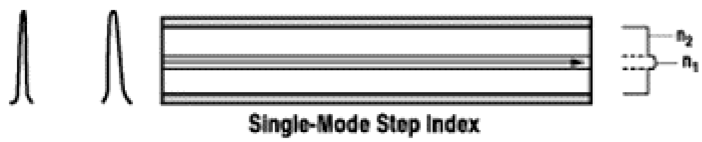
The number of modes in a fiber optic cable depends upon the dimensions of the cable and the variation of the indices of refraction of both core and cladding across the cross section. There are three principal possibilities which are multi-mode step index, single-mode step index and multi-mode graded index.

INDEX PROFILE OF OPTICAL FIBER-

A **refractive index profile** is the distribution of refractive indices of materials within an optical fiber. Some optical fiber has a step-index profile, in which the core has one uniformly-distributed index and the cladding has a lower uniformly-distributed index. Other optical fiber has a graded-index profile, in which the refractive index varies gradually as a function of radial distance from the fiber center. Graded-index profiles include power-law index profiles and parabolic index profiles.

3.10 TYPES OF OPTICAL FIBER CONFIGURATION-

Single-mode Step Index

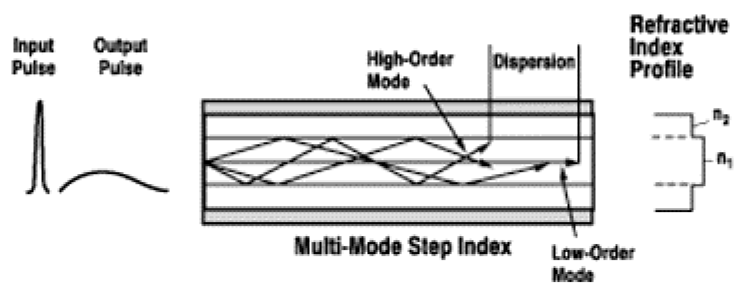


The diameter of the core is fairly small relative to the cladding. Typically, the cladding is ten times thicker than the core. Comparing the output pulse and the input pulse note that there is little attenuation and time dispersion.

Single mode propagation exists only above a certain specific wavelength called the cutoff wavelength. Single-mode fiber optic cable is fabricated from glass. Because of the thickness of the core, plastic cannot be used to fabricate single-mode fiber optic cable.

Less time dispersion of course means higher bandwidth and this is in the 50 to 100 GHz/ km range. However, single mode fiber optic cable is also the most costly in the premises environment. For this reason, it has been used more with Wide Area Networks than with premises data communications. It is attractive more for link lengths go all the way up to 100 km. Nonetheless, single-mode fiber optic cable has been getting increased attention as Local Area Networks have been extended to greater distances over corporate campuses.

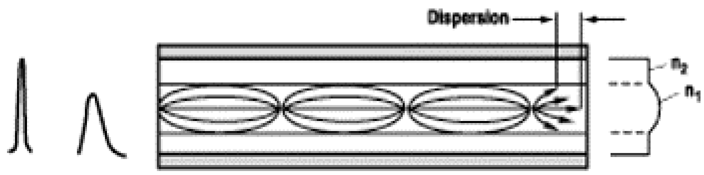
Multi-mode Step Index



The diameter of the core is fairly large relative to the cladding. Note that the output pulse is significantly attenuated relative to the input pulse. It also suffers significant time dispersion. The higher order modes, the bouncing rays, tend to leak into the cladding as they propagate down the fiber optic cable. They lose some of their energy into heat. This results in an attenuated output signal. Consequently, they do not all reach the right end of the fiber optic cable at the same time. When the output pulse is constructed from these separate ray components the result is time dispersion.

Fiber optic cable that exhibits multi-mode propagation with a step index profile is thereby characterized as having higher attenuation and more time dispersion than the other propagation candidates have. However, it is also the least costly and in the premises environment the most widely used. It is especially attractive for link lengths up to 5 km. usually, it has a core diameter that ranges from 100 microns to 970 microns. It can be fabricated either from glass, plastic or PCS.

Multi-mode Graded Index



Multi-Mode Graded Index

There is no sharp discontinuity in the indices of refraction between core and cladding. The core here is much larger than in the single-mode step index. When comparing the output pulse and the input pulse, note that there is some attenuation and time dispersion, but not nearly as great as with multi-mode step index fiber optic cable.

Fiber optic cable that exhibits multi-mode propagation with a graded index profile is thereby characterized as having attenuation and time dispersion properties somewhere between the other two candidates. Likewise its cost is somewhere between the other two candidates. This type of fiber optic cable is extremely popular in premise data communications applications.

ATTENUATION IN OPTICAL FIBERS-

ATTENUATION -

- Attenuation is the loss of optical energy as it travels through the fiber, this loss of optical energy as it travels through the fiber, this loss is measured in dB.
- Attenuation is a transmission loss that can be measured as a difference between the output signal power and the input signal power.

Attenuation loss= α = 10 log_{10} (P_{input}/P_{out}) dB

- Attenuation depends on-
    1) Attenuation depends on wavelength used.
    2) Attenuation depends on light intensity i.e. input light power.
    3) It depends on diameter of optical fiber.
    4) It depends on distance. Distance between optical source and repeater/detector.

Different types of losses in optical fiber.

1. ABSORPTION-

It is the way by which the energy of a photon is taken up by matter. Thus the light energy is transformed to other forms of energy i.e, to heat. The absorption of light during wave propagation is called attenuation.

Absorption of light in optical fibers may be intrinsic or extrinsic.

Intrinsic Absorption-

Intrinsic absorption is caused by basic fiber material properties. Intrinsic absorption is due to material and electron absorption.

Material absorption is a loss mechanism which results in the dissipation of some of the transmitted optical power into heat in the optical fiber.

Intrinsic absorption in the ultraviolet region is caused by electronic absorption. Basically, absorption occurs when a light particle interacts with an electron and excites it to higher energy level.

Extrinsic Absorption-

Extrinsic absorption is caused by impurities introduced into the fiber material. Metal impurities such as, iron, nickel and chromium are introduced into the fiber during fabrication.

2. SCATTERING LOSS-

Scattering loss occurs when light strikes a substance which emits light of its own at the same wavelength as the incident light. The propagation of light through the core of an optical fiber is based on total internal reflection of the light wave. Rough and irregular surfaces can cause light rays to be reflected in random directions. This is called scattering.

3. BENDING LOSSES-

The loss which exists when an optical fiber undergoes bending is called bending losses. There are two types of bending-

(b) Macroscopic Bending-

Bending in which complete fiber under goes bends which causes certain modes not to be reflected and therefore causes loss to the cladding.

(c) Microscopic Bending-

Either the core or cladding undergoes slight bends at its surface. It causes light to be reflected at angles when there is no further reflection

4. DISPERSION-

Dispersion is the spreading out of a light pulse in time as it propagates down the fiber. Dispersion is of 2 types.

- Intermodal Dispersion
- Intra modal Dispersion

Intermodal Dispersion-

Multimode fibers can guide many different light modes since they have much larger core size. Each mode enters the fiber at a different angle and thus travels at different paths in the fiber. Since each mode ray travels at different distance as it propagates, the ray arrive at different times at the fiber output.

So, the light pulse spreads out in time which can cause signal overlapping. Intermodal dispersion is not a problem in single mode fibers since there is only one mode.

Intra modal Dispersion-

There are two types of intra modal Dispersion.

- Material Dispersion
- Waveguide Dispersion

Material Dispersion-

Material dispersion is a type of chromatic dispersion. Chromatic dispersion is the pulse spreading that arises because the velocity of light through a fiber depends on its wavelength.

Waveguide Dispersion-

It is caused by the fact that some light travels in the fiber cladding compared to most light travels in the fiber core. Since fiber cladding has lower index than fiber core, light ray that travels in the cladding travels faster than that in the core.

3.12 OPTICAL SOURCES AND ITS TYPE

Like other communication system, fiber optic communication has also a transmitter at one end of the system, which injects information on to the fiber cables. The transmitter processes and translates coded electronic pulse information coming from copper wire into equivalently coded light pulses. The basic concept behind the optical transmitter is that it converts electrical input signals into modulated light for transmission over an optical fiber. The input signal determines the characteristics of the resulting modulated light, which may be turned on and off or may be linearly varied in intensity between two predetermined levels.

Here are two commonly· used optical sources for generating the light pulses. These are light emitting diode (LED) and Laser Diode (LD). Laser diode with its version as injection-laser diode (ILD) is commonly employed. Both the sources funnel the light pulses into the fiber-optic medium where they transmit themselves down the fiber cable and are placed in very close proximity to the light emitting region to couple as much light as possible into the fiber. To accomplish the same, they are mounted in a package that enables an optical fiber to couple as .much light as possible into the fiber.

CONCEPT OF LED-

An LED or a Light Emitting Diode is semiconductor device that emits light due to Electroluminescence effect. An LED is basically a PN Junction Diode, which emits light when forward biased. Light Emitting Diodes are almost everywhere. You can find LEDs in Cars, Bikes, Street Lights, Home Lighting, Office Lighting, Mobile Phones, Televisions and many more.

The reason for such wide range of implementation of LEDs is its advantages over traditional incandescent bulbs and the recent compact fluorescent lamps (CFL). Few advantages of LEDs over incandescent and CFL light sources are mentioned below:

- Low Power Consumption
- Small Size
- Fast Switching
- Physically Robust
- Long Lasting

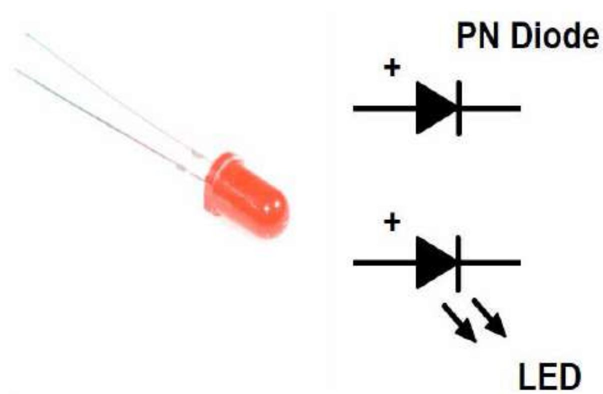
Because of these advantages, LEDs have become quite popular among a large set of people. Electronics Engineers, Electronic Hobbyists and Electronics Enthusiasts often work with LEDs for various projects.

It consists of a PN Junction Diode and when voltage is applied to the LED, electrons and holes recombine in the PN Junction and release energy in the form of light (Photons).

The light emitted by an LED is usually monochromatic i.e. of single color and the color is dependent on the energy band gap of the semiconductor.

Light Emitting Diodes can be manufactured to emit all the wavelengths of visible spectrum i.e. from Red (620nm to 750nm) to blue – violet (380nm to 490nm).

The electrical symbol of an LED is similar to that of a PN Junction Diode. The following image shows a Red LED along with symbols of PN Junction Diode and LED.



Types of LED-

There are two basic types of LED structures:

1. Surface Emitting LED

2. Edge Emitting LED

Surface Emitting LED-

• It is modified form of DH LED (Double Heterojunction LED). In this LED type, optical fiber is butt-coupled with itself.

• The surface emitting LED structure consists of thin central active layer of p type GaAs.

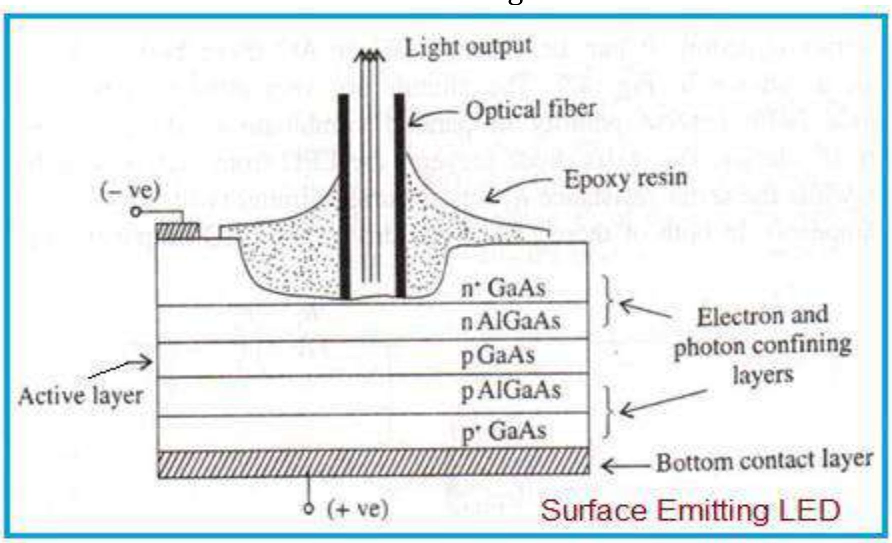
• This central layer is bounded by n-type AlGaAs/n^+-type GaAs at the top side.

• This central layer is bounded by p-type AlGaAs/p^+-type GaAs at the bottom side.

• The extreme top n^+ type GaAs and bottom p^+-type GaAs layers are used to provide low resistive ohmic contacts only.

• The external optical fiber is butt connected by etching the top layers and by shielding with epoxy resin.

• When refractive indices of both p-type and n-type materials are same, light is free to come out from all the sides of the semiconductor device due to no confinement. However only active region near the surface will emit the significant amount of light while absorbing from the other parts. Hence it is known as surface emitting LED.



• Output radiation is originated from central thin layer i.e. p-type GaAs layer.

Advantages of Surface Emitting LED:

1) Optical coupling coefficient of LED with external fiber system is relatively higher. Hence this LED offers high optical coupling efficiency.

2) Optical loss (due to internal absorption) is very low. This is because of carrier recombination near its top heterojunction.

3) InP/InGaAsP based LED is used for long wavelength applications.

4) It offers higher efficiency with low to high radiance.

5) The top n-GaAs contact layer ensures low thermal resistance and contact resistance. This allows high current densities and high radiation intensity.

6) The internal absorption in the device is very low due to larger bandgap confining layers. Moreover reflection coefficient at the back crystal face is high which gives good forward radiance.

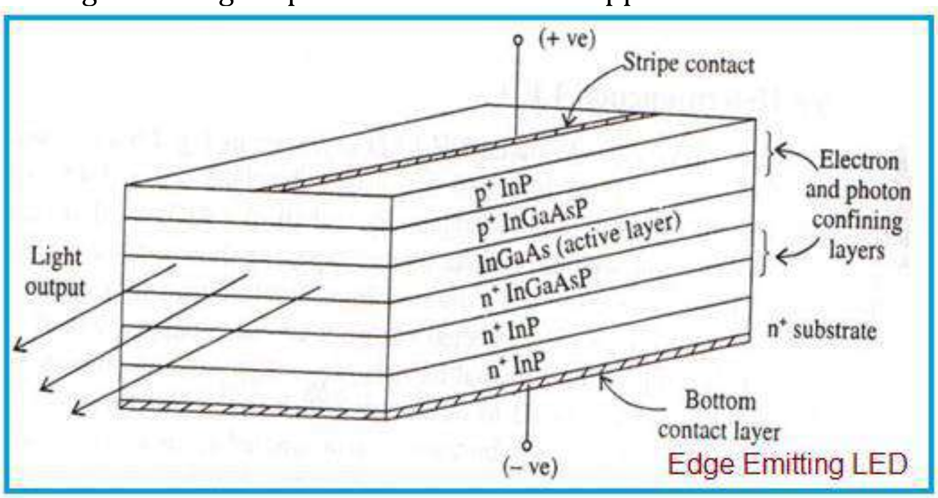
Disadvantages of Surface Emitting LED:

1) The surface emitting LED can transmit data rate less than 20 Mbps than edge emitting LED.

2) It contains short optical link with large NA (Numerical Aperture).

Edge Emitting LED-

- It is widely used in optical fiber communication system. Here collimated light from LED is required to be fed into the fiber with high coupling efficiency.
- It is used for long wavelength optical communication approx. between 1.33 to 1.55 μm.



- Modern epitaxial growth techniques such as MBE, MOCVD etc. are used in order to design such complex LED structures.

• Central active layer is made using InGaAs having narrow bandgap. It is bounded by wide bandgap layers such as p+ InGaAsP and n+ InP cladding layers.

• These two cladding layers help in confining injected electrons and holes into the middle layer. It also helps emitted photons to travel along LED axis as per optical properties.

• Due to above, light is emitted from the edge of the LED. Hence it is known by the name edge emitting LED.

Advantages of Edge Emitting LED:

1) It has superior beam collimation property which offers greater coupling efficiency with fiber optic cable compare to surface emitting LED.
2) It offers higher efficiency with low to high radiance. It fulfills high brightness LED requirements of the lighting industry.
3) It radiates less power to the air compare to surface emitting LED due to reabsorption and interfacial recombination.
4) It offers better modulation bandwidth and more directional emission pattern.
5) It offers 5-6 times more coupled power into NA (Numerical Aperture) of step/graded index fibers. This is due to small beam divergence.
6) It offers high data rates (> 20 Mbps) than surface emitting LED.

Disadvantages of Edge Emitting LED:

1) Its structure is complex.
2) It is difficult to design heat sink.
3) It is expensive compare to other LED types.
4) There are many issues to be handled during mechanical mounting and installation.

3.14 DEFINE LASER AND ITS WORKING PRINCIPLE-

A LASER diode is an optoelectronic device, which converts electrical energy to produce high intensity coherent light. In a Laser diode, the P-N junction of the semiconductor diode acts as the active medium.

Construction-

The Laser diode is made of two doped gallium arsenide layers. One doped gallium arsenide layer will produce an n-type semiconductor whereas another doped gallium arsenide layer will produce a p-type semiconductor. In Laser diodes, selenium, aluminium and silicon are used as doping agents.

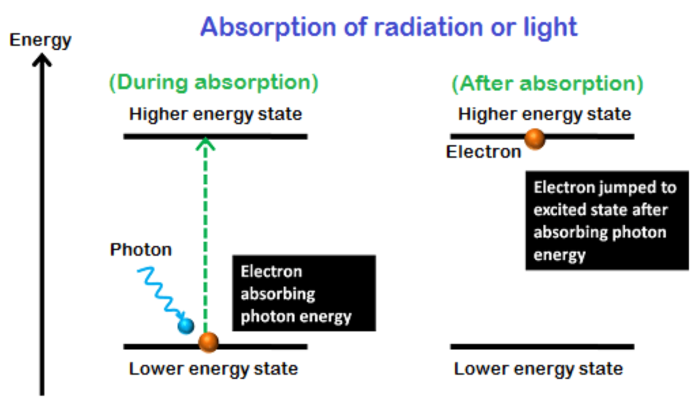
Working-

In lasers, photons are interacted in three ways with the atoms:

- Absorption of radiation
- Spontaneous emission
- Stimulated emission

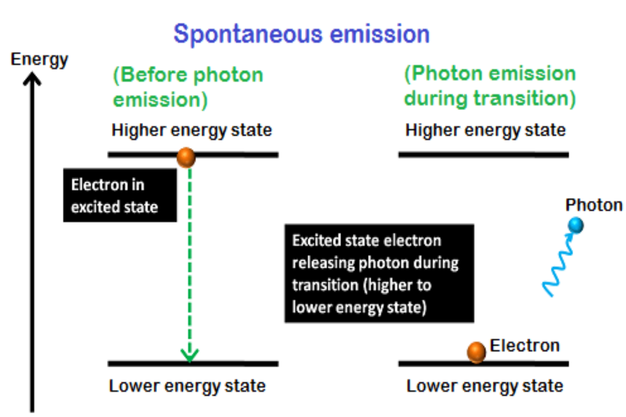
Absorption of radiation

Absorption of energy is the process of absorbing energy from the external energy sources.



Spontaneous emission

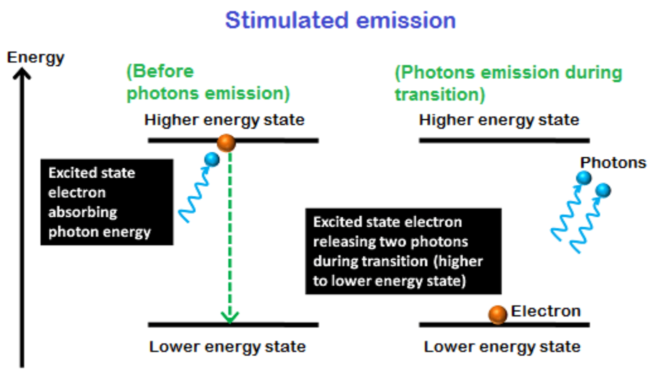
Spontaneous emission is the process of emitting light or photons naturally while electrons falling to the lower energy state.



Stimulated emission

Stimulated emission is the process by which excited electrons are stimulated to fall into the lower energy state by releasing energy in the form of light. The stimulated emission is an artificial process.

In spontaneous emission, the electrons in the excited state will remain there until its lifetime is over. After completing their lifetime, they return to the ground state by releasing energy in the form of light.



- When DC voltage is applied across the laser diode, the free electrons move across the junction region from N-type material to the P-type material.
- In this process some electron will directly interact with the valence electrons and excites them to the higher energy level whereas some other electrons will recombine with the holes in the P-type semiconductor and releases energy in the form of light. This process of emission is called spontaneous emission.
- The photons generated due to spontaneous emission will travel through the junction region and stimulate the excited electrons.
- As a result, more photons are released. This process of light or photons emission is called stimulated emission will moves parallel to the junction.
- The two ends of the laser diode structure are optically reflective. One end is fully reflective end will reflect the light completely whereas the partially reflective end will reflect most part of the light but allows a small amount of light.
- The light generated due to the stimulated emission is escaped through the partially reflective end of the laser to produce a narrow beam laser light.

Advantages-

1) Simple in construction.
2) Light weight.
3) Small in size.
4) High efficiency.
5) Low power consumption.

Disadvantages-

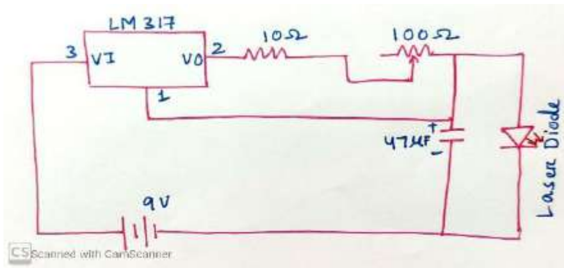
1) Not suitable for the applications where high powers are required.
2) Semiconductor lasers are highly dependent on temperature.

Application-

1) Laser diodes are used in laser pointer.
2) It is used in fiber optic cable.
3) It is used in laser scanning.

LASER FEEDBACK CONTROL CIRCUIT-

- LASER diodes require complex drive circuit that involve feedback loops by measuring output optical power, temperature voltage and input current.
- But for controlling a laser diode used in applications where high accuracy is not required, a simple LASER diode driver circuit can be constructed using LM 317 voltage regulator IC.



- The LM 317 is configured to function as a constant current source. The output current depends on the value of resistance between V_{out} and V_{adj} of LM 317.
- So adjusting the 100 `Ω potentiometer will change the output current that flows into the LASER diode. The 10`Ω resistor is used to prevent large currents from flowing when the value of potentiometer is at zero. The 47μF capacitor is used to absorb any battery voltage spikes.

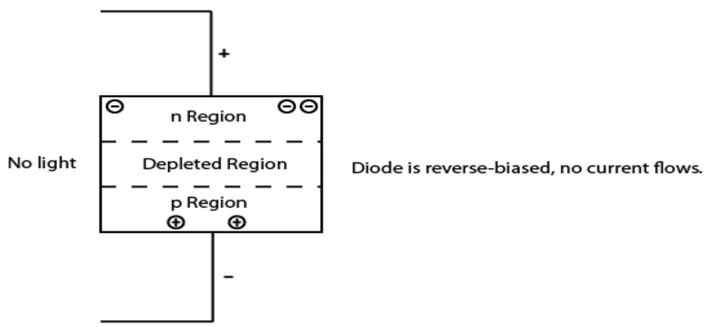
3.15 OPTICAL DETECTOR-

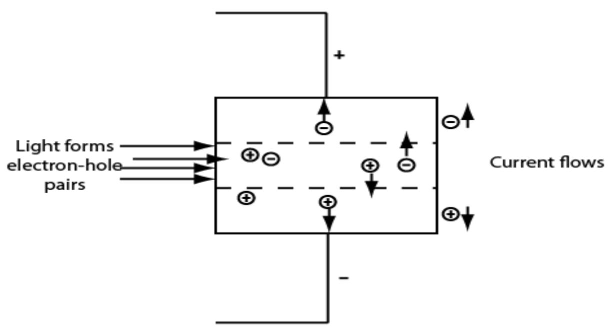
An optical detector is a device that converts light signals into electrical signals, which can then be amplified and processed. The photodetector is as essential an element of any fiber optic system as the optical fiber or the light source. Photodetectors can dictate the performance of a fiber optic communication link.

WORKING OF PIN DIODE-

PIN photodetector has an intrinsic semiconductor region sandwiched between a P-doped and an n-doped region. Since the intrinsic region has no free charges, its resistance is high, so that most of the reverse biased voltage is applied to this i region. The i region is usually wide so that incoming photons have a greater probability of absorption in the i region rather than in the p or n regions. Since the electric field is high in the i region, any electron hole pairs generated in this region are immediately swept away by the field.

The detector is electrically reverse-biased. (In contrary, LEDs and Lasers are forward-biased to emit light).





In the first illustration when there is no light, the reverse bias draws current-carrying electrons and holes out of the p-n junction region, creating a depleted region, which stops current from passing through the diode.

In the second illustration when there are lights on the detector, photons with the proper energy (wavelength) can create electron-hole pairs in this region by raising an electron from the valence band to the conduction band, leaving a hole behind. The bias voltage causes these current carriers to drift quickly away from the junction region, so a current flows proportional to the light hitting the detector.

AVALANCHE PHOTODIODE-

- An avalanche photodiode is a semiconductor-based **photodetector** (**photodiode**) which is operated with a relatively high reverse voltage (typically tens or even hundreds of volts), sometimes just below breakdown.
- In this region, carriers (electrons and holes) excited by absorbed **photons** are strongly accelerated in the strong internal electric field, so that they can generate secondary carriers.

- The avalanche process, which may take place over a distance of only a few micrometers, for example, effectively amplifies the **photocurrent** by a significant factor, although not as much as in a **photomultiplier**.
- Therefore, avalanche photodiodes can be used for very sensitive detectors, which need less electronic signal amplification and are thus less susceptible to electronic noise.
- However, the avalanche process itself is subject to **quantum noise** and amplification noise, which can offset the mentioned advantage. The excess noise is quantified with the excess noise factor *F*, which is the factor by which the electronic noise power is increased compared with that of an ideal photodetector.
- Note that the amplification factor and thus the effective **responsivity** of an APD depends strongly on the reverse voltage, and may also substantially vary from device to device.

- Generally, the noise performance of photodetectors with APDs can be better than that of devices with ordinary **p–i–n photodiodes** when electronic noise is a limiting factor: the internal amplification in an APD reduces the influences of electronic noise. However, the above mentioned excess noise factor increases with increasing amplification factor, as obtained for increasing reverse voltage.
- Therefore, the reverse voltage is often chosen such that the multiplication noise approximately equals the noise of the electronic amplifier, because this minimizes the overall noise. The amount of excess noise depends on many factors: the magnitude of the reverse voltage, material properties (in particular, the ionization coefficient ratio), and the device design.
- **Advantages-**
  1. High level of sensitivity as a result of avalanche gain.
- **Disadvantages-**
  1. Much higher operating voltage may be required.
  2. Avalanche photodiode produces a much higher level of noise than a PIN photodiode.
  3. Avalanche process means that the output is not linear.

- The avalanche photodiodes are not as widely used as their PIN counterparts. They are used primarily where the level of gain is of paramount importance, because the high voltages required, combined with a lower reliability means that they are often less convenient to use.

3.16 CONNECTORS, SPLICES AND COUPLERS OF FIBER CABLE:

OPTICAL CONNECTORS-

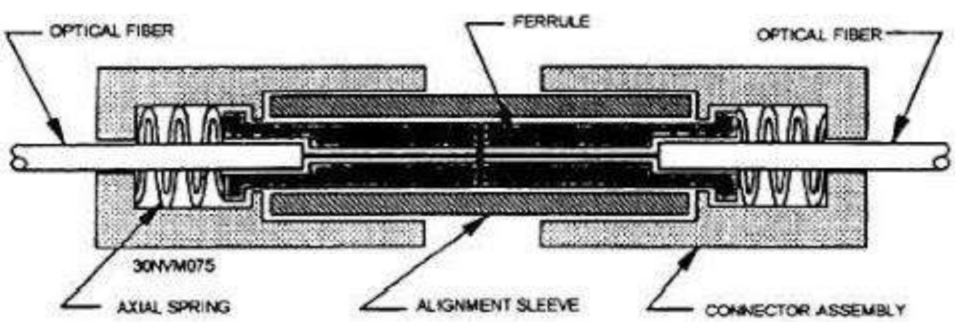
An optical fiber connector is a flexible device that connects fiber cables requiring a quick connection and disconnection.

Types of connector-

1. Butt- joint connector
2. Expanded beam connector

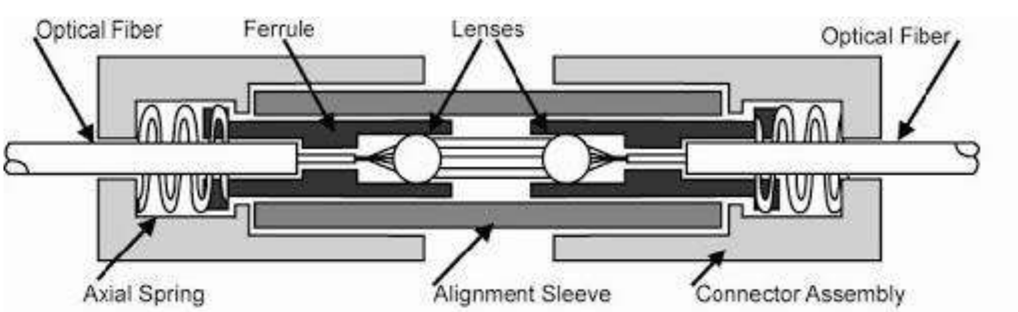
Butt-joint connector-

Butt joint connectors employ a metal, ceramic or molded plastic ferrule for each fiber and a precision sleeve into which the ferrule fit. The fiber is epoxied into a precision hole which has been drilled into the ferrule.



Expanded beam connector-

Expanded beam connector, employs lenses on the ends of the fibers. These lenses either collimate the light emerging from the transmitting fiber, or focus the expanded beam onto the core of the receiving fiber. The fiber to lens distance is equal to the focal length of the lens.



SPLICING-

A fiber optic splice is defined by the fact that it gives a permanent or relatively permanent connection between two fiber optic cables.

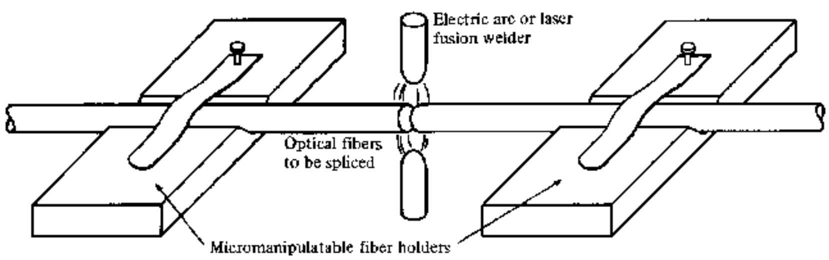
Types of Splicing

There are two main types of splicing

i) Fusion splicing.
ii) Mechanical splicing / V groove

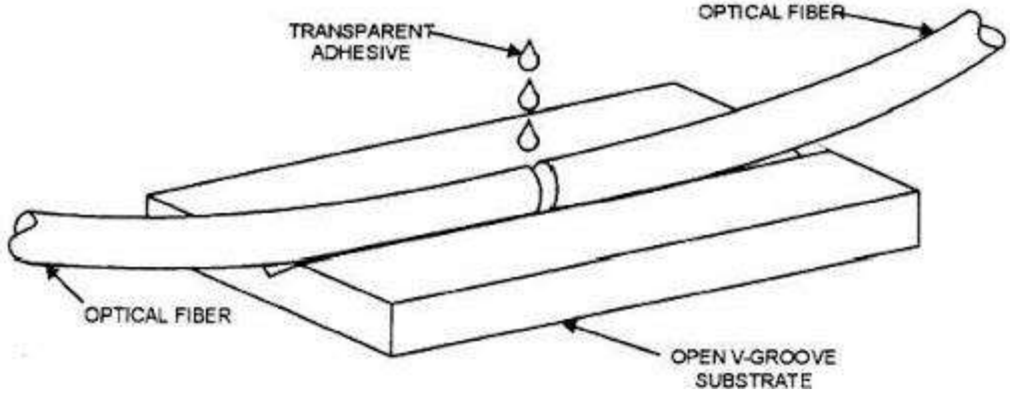
Fusion Splicing

Fusion splicing involves butting two cleaned fiber end faces and heating them until they melt together or fuse. Fusion splicing is normally done with a fusion splicer that controls the alignment of the two fibers to keep losses as low as 0.05 dB. Fiber ends are first pre aligned and butted together under a microscope with micromanipulators. The butted joint is heated with electric arc or laser pulse to melt the fiber ends so can be bonded together.



Mechanical Splicing / V Groove

Mechanical splices join two fibers together by clamping them with a structure or by epoxying the fibers together. Mechanical splices may have a slightly higher loss and back reflection. These can be reduced by inserting index matching gel. V groove mechanical splicing provides a temporary joint i.e fibers can be disassembled if required. The fiber ends are butted together in a V – shaped groove.



OPTICAL COUPLER-

A fiber optic coupler is an optical device capable of connecting one or more fiber ends in order to allow the transmission of light waves in multiple paths. The device is capable of combining two or more inputs into a single output and also dividing a single input into two or more outputs. Compared to a splice or connector, the signal can be more attenuated by fiber optic couplers, as the input signal can be divided amongst the output ports.

Passive and Active Couplers

Fiber optic couplers can either be passive or active devices.

Passive fiber optic couplers are said to be passive as no power is required for operation. They are simple fiber optic components that are used to redirect light waves. Passive couplers either use micro-lenses, graded-refractive-index (GRIN) rods and beam splitters, optical mixers, or splice and fuse the core of the optical fibers together.

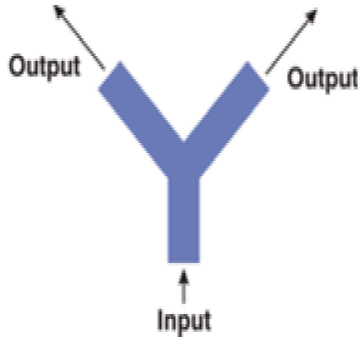
Active fiber optic couplers require an external power source. They receive input signal(s), and then use a combination of fiber optic detectors, optical-to-electrical converters, and light sources to transmit fiber optic signals.

TYPES

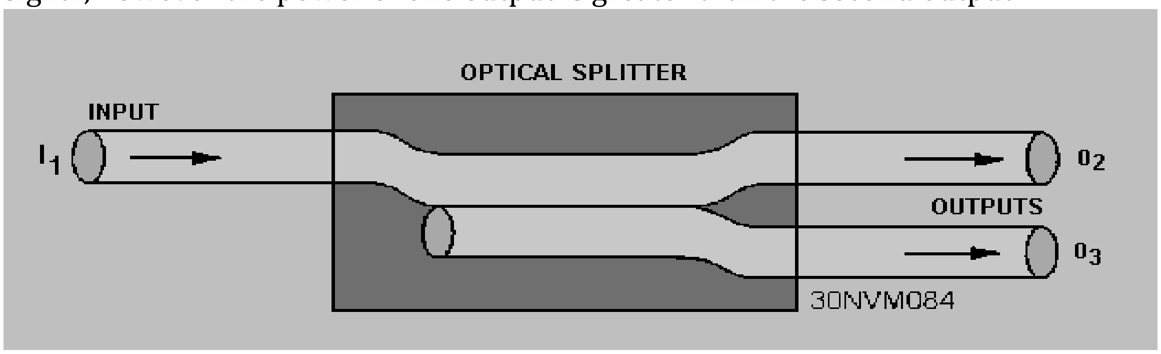
Types of fiber optic couplers include splitters, combiners, X-couplers, trees, and stars, which all include single window, dual window, or wideband transmissions.

Fiber optic splitters take an optical signal and supply two outputs. They can further be described as either Y-couplers or T-couplers.

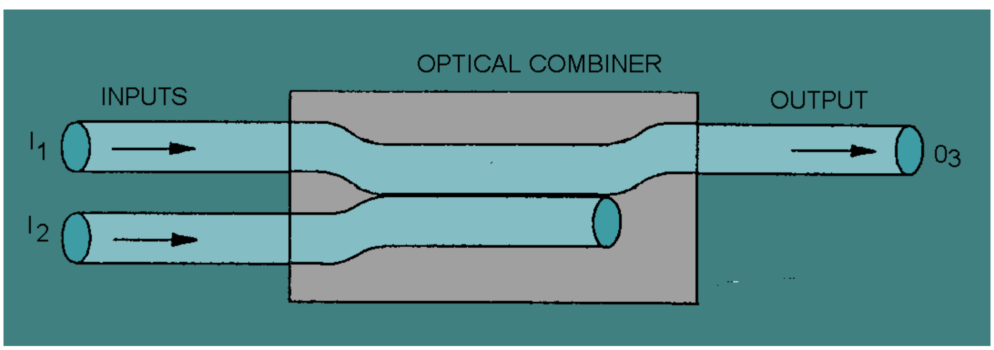
- **Y-couplers** have equal power distribution, meaning that the two output signal each receive half of the transmitted power.



- **T-couplers** have an uneven power distribution. The signal outputs still carrier the same signal, however the power of one output is greater than the second output.

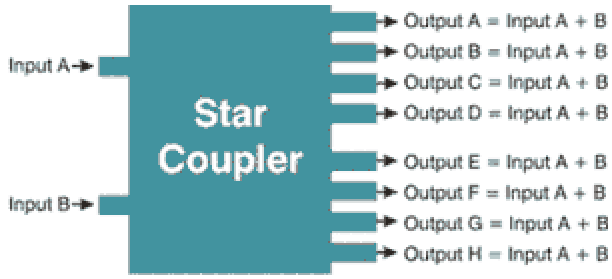


Fiber optic combiners receive two signals and provide a single output. The output signal is typically comprised of multiple wavelengths, due to the amount of interference that occurs when attempting to combine two signals that share the same wavelength.

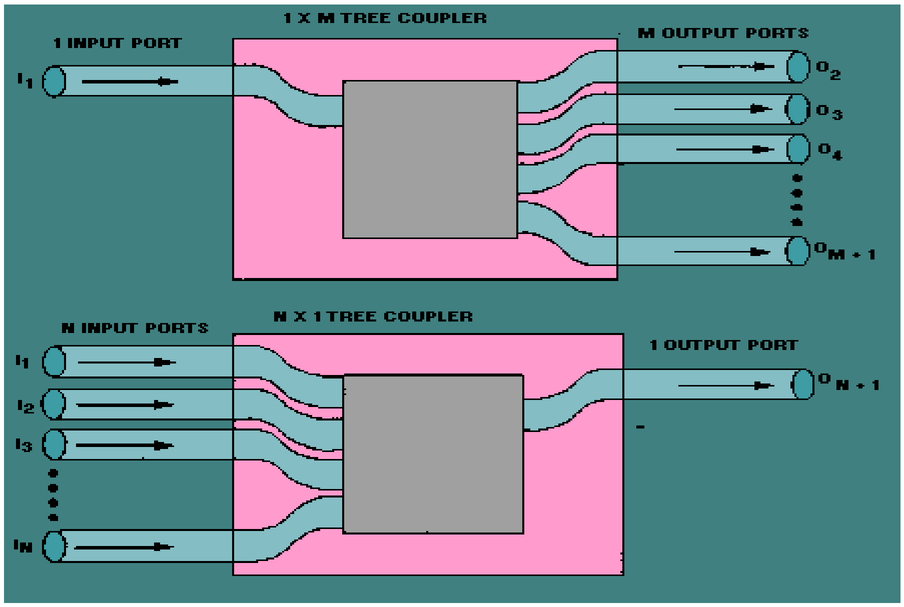


X-couplers carry out the function of a splitter and combiner in one package. They are a 2x2 coupler that combines the power of two signals and then divides the signal between two outputs.

Star couplers have M inputs and N outputs (MxN). They are used to distribute the power from all of the inputs to all outputs.



Tree couplers either have 1 input and M outputs (1xM) or N inputs and 1 output (Nx1).



3.17 APPLICATION OF OPTICAL FIBER-

The application and uses of optical fiber can be seen in:

- Medical Industry
- Communication
- Defense
- Industries
- Broadcasting
- Lighting and Decorations
- Mechanical Inspections

The application of optical fibers in various fields are given below:

1. **Optical Fibers uses in Medical industry**

Because of the extremely thin and flexible nature, it used in various instruments to view internal body parts by inserting into hollow spaces in the body. It is used as lasers during surgeries, endoscopy, microscopy and biomedical research.

2**. Optical Fibers used in Communication**

In the communication system, telecommunication has major uses of optical fiber cables for transmitting and receiving purposes. It is used in various networking fields and even increases the speed and accuracy of the transmitted data. Compared to copper wires, fiber optics cables are lighter, more flexible and carry more data.

3. **Optical Fibers used in Defense Purpose**

Fiber optics are used for data transmission in high level data security fields of military and aerospace applications. These are used in wirings in aircrafts, hydrophones for SONARs and Seismic applications.

4. **Optical Fibers are used in Industries**

These fibers are used for imaging in hard to reach places such as they are used for safety measures and lighting purposes in automobiles both in the interior and exterior. They transmit information in lightning speed and are used in airbags and traction control. They are also used for research and testing purposes in industries.

5**. Optical Fibers used for Broadcasting**

These cables are used to transmit high definition television signals which has a greater bandwidth and speed. Optical Fiber is cheaper compared to same quantity of copper wires. Broadcasting companies use optical fibers for wiring HDTV, CATV, video-on demand and many applications.

6**. Uses of Optical Fiber for Lightening and Decorations**

It also gives an attractive, economical and easy way to illuminate the area and that is why, it is widely used in decorations and Christmas trees.

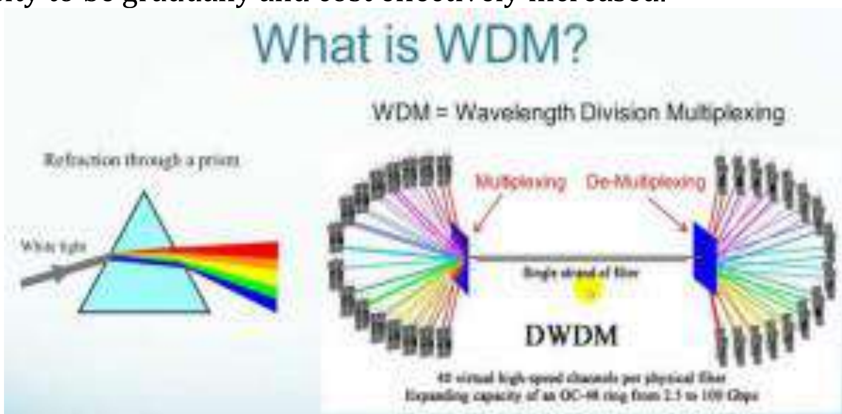
7**. Optical Fibers used in Mechanical Inspections**

On-site inspection engineers use optical fibers to detect damages and faults which are at hard to reach places. Even plumbers use optical fibers for inspection of pipes.

3.18 WAVELENGTH DIVISION MULTIPLEXING (WDM)-

Wavelength division multiplexing (WDM) is a technique modulating various data streams, i.e. optical carrier signals of varying wavelengths in terms of colors of laser light onto a single optical fiber. Wavelength division multiplexing WDM is similar to frequency-division multiplexing (FDM) but referencing the wavelength of light to the frequency of light.

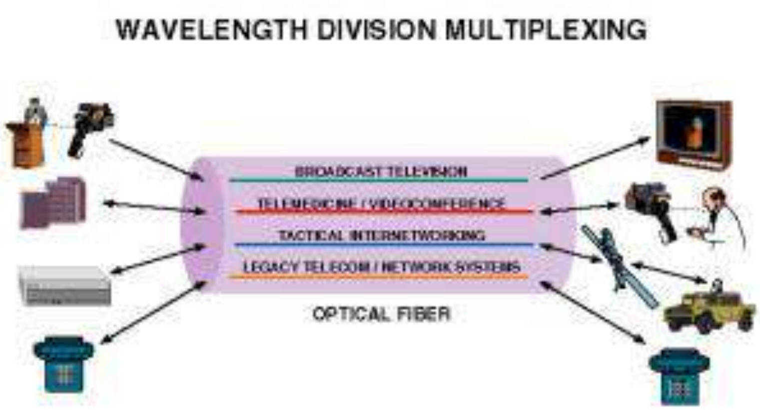
WDM is done in the IR portion of the electromagnetic spectrum instead of taking place at radio frequencies (RF). Each IR channel carries several RF signals combined with frequency-division multiplexing (FDM) or time-division multiplexing (TDM). Each multiplexed infrared channel is separated or de-multiplexed into the original signals at final point. Data in different formats and at different speeds can be transmitted simultaneously on a single fiber by using FDM or TDM in each IR channel in combination with WDM. It allows network capacity to be gradually and cost effectively increased.



Wavelength Division Multiplexing (WDM)

What is Wavelength Division Multiplexing?

- WDM enables bi-directional communication and multiplies signal capacity. Each laser beam is modulated by separate set of signals. Since wavelength and frequency have an inverse relationship (shorter wavelength means higher frequency), the WDM and FDM both contains the same technology in them.
- At the receiving end, Wavelength-sensitive filters, IR analog of visible-light color filters are used.
- The first WDM systems were two-channel systems that used 1310nm and 1550nm wavelengths.



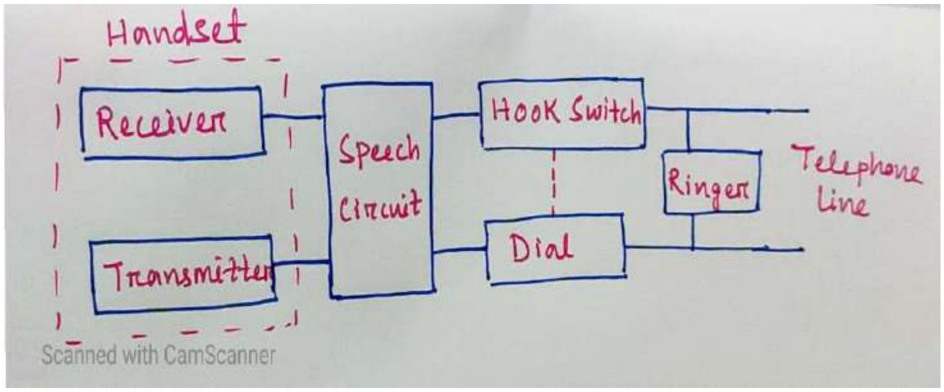
- Wavelength division multiplexing systems can combine signals with multiplexing and split them apart with a de-multiplexer. WDM systems are popular with telecommunications companies because they allow them to expand the capacity of the network without laying more fiber by using WDM and optical amplifiers.
- These two devices work as drop multiplexer (ADM), i.e. simultaneously adding light beams while dropping other light beams and rerouting them to other destinations and devices and this type of filtering of light beams were made possible with e talons, devices called Fabry-Perot interferometers using thin-film-coated optical glass.
- Present modern systems can handle up to128 signals and can expand a basic 9.6 Gbps fibre system to a capacity of over 1000 Gbps. It is mostly used for optical fiber communications to transmit data in several channels with slight variation in wavelengths. WDM can increase the total bit rate of point-to-point systems.

Uses of Wavelength Division Multiplexing:

- WDM multiply the effective bandwidth of a fiber optic communications system
- A fiber optic repeater device called the erbium amplifier can make WDM a cost-effective and it is the long-term solution.
- This reduces the cost and increases the capacity of the cable to carry data.
- Wavelength Division Multiplexing (WDM) uses multiple wavelengths (colors of light) to transport signals over a single fiber.
- It uses light of different colours to create a number of signal paths.
- It uses Optical prisms to separate the different colours at the receiving end and optical prisms does not require power source.
- These systems used temperature stabilized lasers to provide the needed channels count.

UNIT-4: TELECOMMUNICATION SYSTEM

4.1 THE OPERATION OF ELECTRONIC TELEPHONE SYSTEM:



The telephone set consists of the following parts:

1. Microphone
2. Receiver
3. Switch connections to the telephone system
4. Ringing circuitry
5. Dial network

- The instrument, which contains the microphone and the receiver, is called handset.
- The handset is placed on the cradle when the telephone is not in use.
- In this position it opens the switches and disconnects the handset from the telephone system.
- An electromagnet, called the ringer is connected to the telephone line on the exchange side, so that a ring can be received from the exchange when it is called.
- The exchange determines that whether the telephone is idle or busy or initiating a call by monitoring the dc current.
- Microphone in telephone is regarded as transmitter. It is a transducer, which converts sound energy into electrical energy. There are different types of transmitter is the most widely used in the handset.
- The sound reproducer in telephone is called receiver. The receiver does the reverse function of the transmitter. It is a device, which converts electrical energy into sound energy.

4.2 DISCUSS THE FUNCTION OF SWITCHING SYSTEM.& CALL PROCEDURES:

FUNCTION OF SWITCHING SYSTEM-

- A switching system can be understand as a collection of switching elements arranged and controlled in such a way as to set up a common path between any two distant points.
- Switching systems reduced the complexity of wiring and made the telephony hassle free.
- The network connection cannot be simply made with telephone sets and bunch of wires, but a good system is required to make or break a connection. This system is known as the switching system or the switching office or the exchange.
- The subscribers instead of getting connected directly to one another, are connected to a switching office and then to the required subscriber.
- With the introduction of switching systems, the need for traditional connections between the subscribers reduced. All the subscribers need to have a connection with the switching system, which makes or breaks any connection, requested by the calling subscriber.
- The switching system, which is also called the telephone exchange, takes care of establishing the calls. Hence the total number of such links is equal to the number of subscribers connected to the system.
- Signaling is required for the switching system to establish or release a connection. It should also enable the switching system to detect whether a called subscriber is busy or not.
- The functions performed by a switching system in establishing and releasing connections are known as control function.
- The early systems required manual operations to establish telephone calls. An operator used to receive a call from the calling subscriber and then connect the call to the called subscriber. Later on, the system was automated.

STEPS OF CALL PROCEDURE-

Step 1:- Calling station goes off hook.

Step 2:- After detecting a dc current flow on the loop, the switching machine returns an audible dial tone to the calling station, acknowledging that the caller has access to the switching machine.

Step 3:- The caller dials the destination telephone number using one of two methods: mechanical dial pulsing or, more likely, electronic dual-tone multi frequency (Touch-Tone) signals.

Step 4:-When the switching machine detects the first dialed number, it removes the dial tone from the loop.

Step 5:-The switch interprets the telephone number and then locates the local loop for the destination telephone number.

Step 6:- Before ringing the destination telephone, the switching machine tests the destination loop for dc current to see if it is idle (on hook) or in use (off hook). At the same time, the switching machine locates a signal path through the switch between the two local loops.

Step 7a:- if the destination telephone is off hook, the switching machine sends a station busy signal back to the calling station.

Step7b:- If the destination telephone is on hook, the switching machine sends a ringing signal to the destination telephone on the local loop and at the same time sends a ring-back signal to the calling station to give the caller some assurance that something is happening.

Step 8:- When the destination answers the telephone, it completes the loop, causing dc current to flow.

Step 9:- The switch recognizes the dc current as the station answering the telephone. At this time, the switch removes the ringing and ring-back signals and completes the path through the switch, allowing the calling and called parties begin their conversation.

Step 10:- When either end goes on hook, the switching machine detects an open circuit on that loop and then drops the connections through the switch.

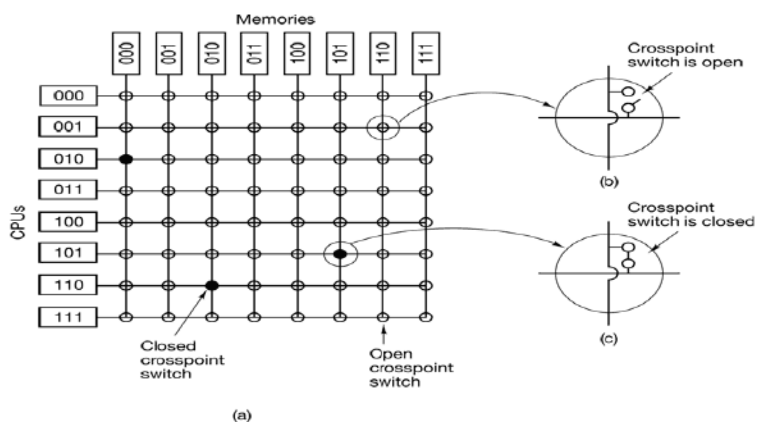
4.3 PRINCIPLE OF SPACE AND TIME SWITCHING-

The switching scheme used by the electronic switching systems may be either **Space Division Switching** or **Time Division Switching.** In space division switching, a dedicated path is established between the calling and the called subscribers for the entire duration of the call. In time division switching, sampled values of speech signals are transferred at fixed intervals.

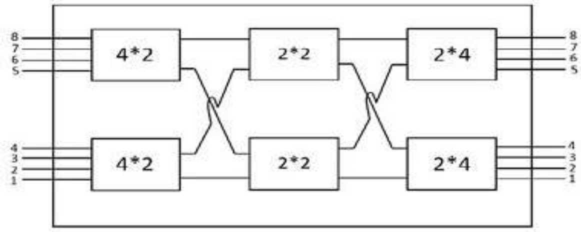
The time division switching may be analog or digital. In analog switching, the sampled voltage levels are transmitted as they are whereas in binary switching, they are binary coded and transmitted. If the coded values are transferred during the same time interval from input to output, the technique is called **Space Switching**. If the values are stored and transferred to the output at a late time interval, the technique is called as **Time Switching**. A time division digital switch may also be designed by using a combination of space and time switching techniques.

SPACE DIVISION SWITCHING

- In space division switching, the paths in the circuit are separated with each other spatially, i.e. different ongoing connections at a same instant of time, uses different switching paths.
- This was originally developed for the analog environment and has been carried over to the digital domain. The space switches are crossbar switches and multi stage switches.
- **Crossbar switch-**
  1. Basic building block of the switch is a metallic cross points or semiconductor gate that can be enabled or disabled by a control unit.
  2. The number of cross points grows with the square of the number of attached stations.
  3. Costly for a large switch.
  4. The failure of a cross point prevents connection between the two devices whose lines intersect at that cross point.
  5. The cross points are inefficiently utilized.
  6. Only a small fraction of cross points are engaged even if all of the attached devices are active.

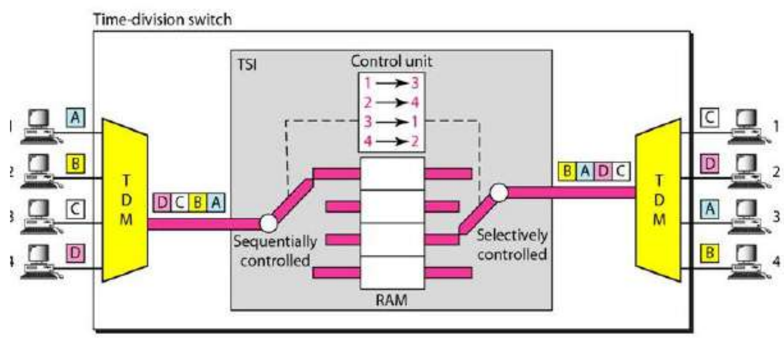


- Multistage space division switch-
  1. Some of the problem in crossbar switch can be overcome with the help of multistage space division switches.
  2. By splitting the crossbar switch into smaller units and interconnecting them it is possible to build multistage switches with fewer cross points.
  3. There is more than one path through the network to connect two endpoints, thereby increasing reliability.
  4. Multistage switches may lead to blocking.
  5. The problem may be tackled by increasing the number or size of the intermediate switches, which also increases the cost.

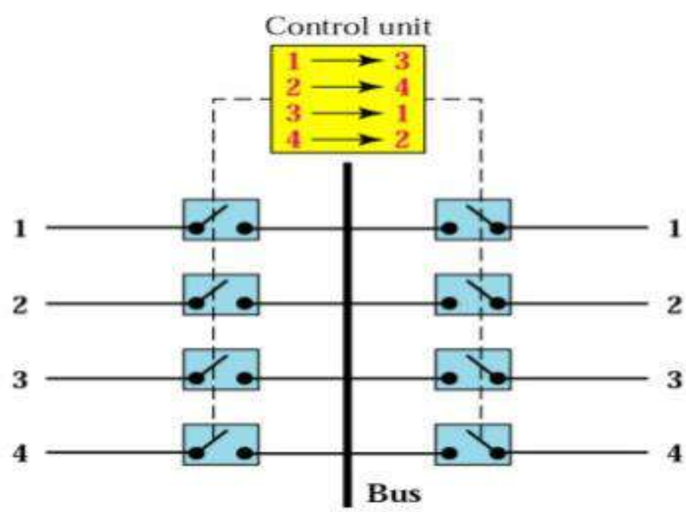


<u>**TIME DIVISION SWITCHING**</u>

- Both voice and data can be transmitted using digital signals.
- All modern circuit switches use digital time division multiplexing technique for establishing and maintaining circuits.
- Time division switching uses TDM to achieve switching i.e. different ongoing connections can use same switching path.
- There are two popular methods of time division switching i.e. **Time Slot Interchange (TSI)** and the **TDM Bus** .
- **TSI** changes the ordering of the slots based on desired connection and it has a random access memory to store data and flip the time slots.



- In **TDM bus** there are several input and outputs connected to a high speed bus.
- During a time slot only one particular output switch is closed, so only one connection at a particular instant of time.



4.4 NUMBERING PLAN OF TELEPHONE NETWORKS (NATIONAL AND INTERNATIONAL NUMBERING)-

Telephone Numbering Plan is a type of numbering scheme used in telecommunication to assign Phone Numbers to subscriber telephones or other telephony endpoints.

Telephone Numbering Plan defines the pattern of digits for a country phone number. Telephone Numbering Plan defines the **specific** components of phone numbers, display format styles, and codes.

Phone Numbers are the addresses of participants in a Telecommunications network, reachable by a system of destination code routing.

Telephone Numbering Plans are defined in each of administrative regions of the Public Switched Telephone Network (PSTN) and they are also present in private telephone networks. For public number systems, geographic location plays a role in the sequence of numbers assigned to each telephone subscriber.

Telephone Numbering Plan Components

Telephone Numbering Plan generally consists of the following Components: The E.164 recommendation provides the telephone number structure and functionality for three categories of telephone numbers used in international public telecommunication:

- Country Calling Code
- National Destination Code (Area Code)
- Subscriber Number

Country Calling Code-

Country Calling Code are a component of the international Telephone Numbering Plan and are prefixes for the member countries or regions of the International Telecommunication Union (ITU) and are defined by the ITU-T in standards E.123 and E.164. Country Calling Code are typically are necessary only when dialing a Phone Number to establish a call to another country and are dialed before the National Significant Number.

Country Calling Code prefixes enable International Direct Dialing (IDD), and are also referred to as International Subscriber Dialing (ISD) codes.

Country Calling Code, by convention, International Telephone Numbers are represented by prefixing the Country Calling Code with a plus sign (+), which also indicates to the subscriber that the local international call prefix must first be dialed.

Ordered by code

Each Country Calling Code's first digit directs to these broad areas:

- +1: North American Numbering Plan
- +2: mostly Africa
- +3–4: Europe

- +5: Americas outside the NANP
- +6: Southeast Asia and Oceania
- +7: Parts of the former Soviet Union
- +8: East Asia and special services
- +9: mostly southern Asia

Example-

Country Calling Code prefix in all countries belonging to the North American Numbering Plan is 011, while it is 00 in most European, Asian and African countries. On GSM (Mobile Networks), the prefix may automatically be inserted when the user prefixes a dialed number with the plus sign.

National Destination Code-

National Destination Code (NDC or NXX), commonly referred to as an International City Code or Number Plan Area or Area Code or significant leading digits of National Significant Number, is specified in ITU-T E.164.
National Destination Code identifies the Number Plan Area that is to be used.

National Destination Code optional code field which determined by each specific Telephone Numbering Plan.

National Destination Code when combined with the Subscriber Number (SN) - will constitute the National Significant Number within the international E.164-number for geographic areas.

National Destination Code North American Numbering Plan (NANP)

North American Numbering Plan (NANP) National Destination Code values are available.[2]
The following 555-XXXX National Destination Code line numbers remain in use:

- 555-1212 Directory Assistance National use
- 555-4334 Assigned National use
- 555-0100 through 555-0199 are **fictitious non-working numbers** reserved for entertainment/advertising.

Subscriber Number-

Subscriber Number is typically End-User unique Phone Number which may be in many different formats.
Subscriber Number is defined in the ITU E.164.

4.6 OPERATION OF A PBX & DIGITAL EPABX

PRIVATE BRANCH EXCHANGE (PBX)-

- PBX is a privately owned telephone switching system for handling multiple telephone lines without having to pay the phone company to lease each line separately.
- Normally a telephone line is connected to the phone company's local central office through "a trunk". The central office is responsible for routing incoming and outgoing calls. It provides other services like voice mail, call forwarding, caller ID and other features.
- Companies use a PBX for connecting all their internal phones to an external line. This way they can lease only one line and have many people using it, with each one having a phone at the desk with different number.
- The number is not in the same format as a phone number though, as it depends on the internal numbering. Inside a PBX, we only need to dial three digit or four digit numbers to make a call to another phone in the network.

Types of PBX-

TRADITIONAL PBX-

- A PBX is a privately owned phone system for handling multiple phone lines and routing calls.
- Depending on the services we need, it can be costly or rather cheap.
- These systems are being used less because they are harder to install and need to be connected to a land line.

HOSTED/ VIRTUAL PBX PHONE SYSTEM-

A hosted PBX is a virtual telephone system where, instead of having all our telephone hardware in the office, hardware is provided by a system hosting company and connect to the system via a network connection.

IP PBX-

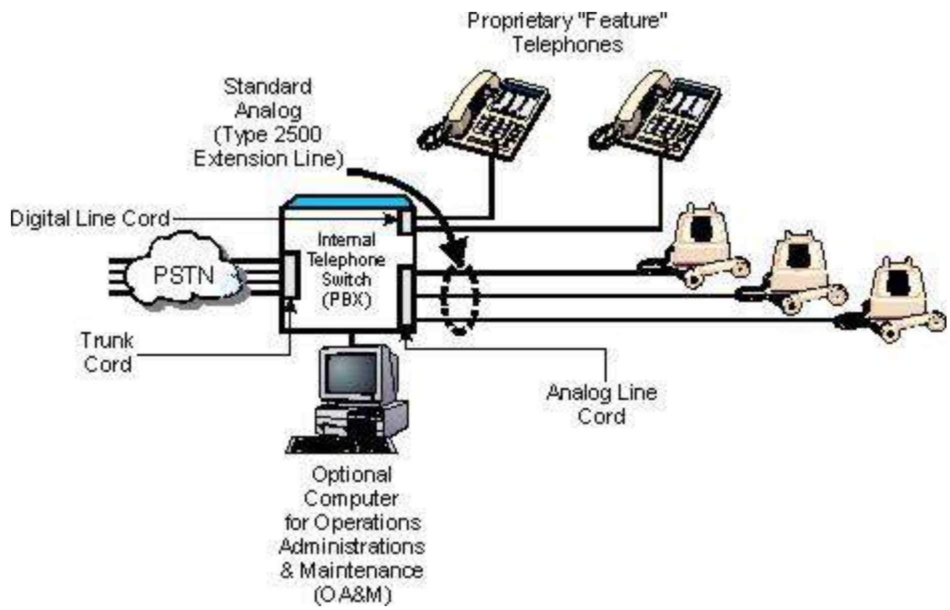
- In this method costs are greatly reduced since there is no extra hardware to install.
- Phones can be connected to a computer port, rather than deals with wires.
- Like virtual PBX, we can manage the system online.
- Just install software and we are ready to start taking calls.
- Computer software allows for more features to be added.
- Low costs means its affordable for small and large companies.

DIAGRAM-

. PBX systems contain **small switches** and advanced call processing features such as speed dialing, call transfer, and voice mail. PBX systems **connect local telephones** ("stations") with each other and **to the public switched telephone network (PSTN)**.

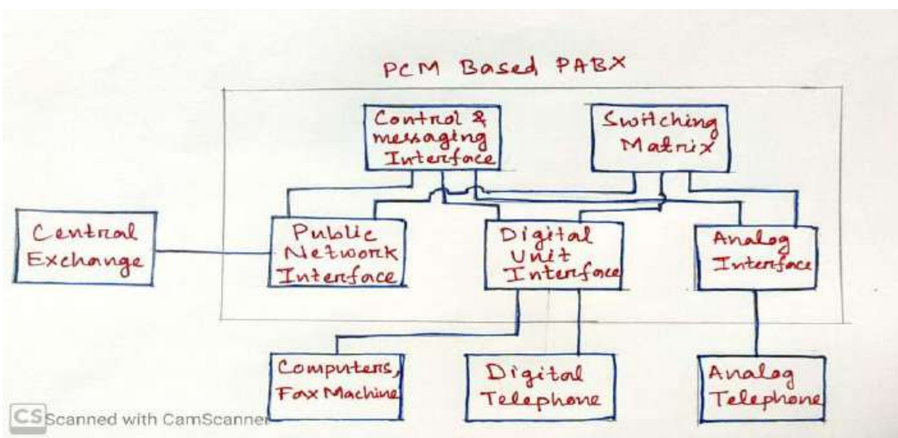
This diagram shows a private branch exchange (PBX) system. This diagram shows a PBX with telephone sets, voice mail system, and trunk connections to PSTN. The PBX switches calls between telephone sets and also provides them switched access to the PSTN.

The voice mail depends on the PBX to switch all calls needing access to it along with the appropriate information to process the call.



ELECTRONIC PRIVATE AUTOMATIC BRANCH EXCHANGE (EPABX)-

- EPABX provides telephone switching in an office or hospital.
- A PCM Based EPABX provides all the facilities like a Public Telephone Exchange.



Public Network Interface-

This section connects the EPABX with the local telephone Exchange and the no. of extensions connected with each line depends upon the design of the EPABX.

Control Message Interface-

This section checks the status of the subscriber's line and provides different tone.

Switching Matrix-

The function of switching matrix is to interconnect any two lines along with any internal signaling.

Digital Unit Interface-

The digital telephone sets, fax machines and other data base equipment are connected to this section.

Analog Unit Interface-

The analog telephone lines are connected with this section. The digital to analog and analog to digital conversion is done with the help of codes. The no. of extension point depends on the design of EPABX.

4.7 UNITS OF POWER MEASUREMENT

The **decibel** (symbol: **dB**) is a relative unit of measurement corresponding to one tenth of bel. It is used to express the ratio of one value of a power or field quantity to another, on a logarithmic scale, the logarithmic quantity being called the power level or field level, respectively.

4.8 INTERNET PROTOCOL TELEPHONY-

- Internet Protocol Telephony (IP Telephony) is the use of IP-based networks to build, provide and access voice, data or other forms of telephonic communications. IP telephony provides traditional telephonic communication over an IP-based network, the Internet - via an Internet service provider (ISP) - or directly from a telecommunications service provider.
- IP telephony is designed to replace the telecommunications' infrastructure of circuit switched public data networks (CSPDN) and public switched telephone networks (PSTN) with packet switched IP communication networks.
- In a consumer IP telephony solution, a soft IP phone application and backend Internet connection enable voice and data communication, such as calling and faxing. A user may call other softphone users, send or receive faxes and even communicate with circuit switched and cellular communication services.
- In an enterprise environment, IP telephony is implemented through physical IP phones that work on top of an IP network infrastructure. An IP phone's built-in firmware provides the complete functionality for initiating and managing telephonic communications. Moreover, IP telephony also supports video communication between two or more users.

Voice over Internet Protocol (VoIP), a popular IP telephony implementation, only supports voice communication over IP.

Advantages-

- IP telephony systems tend to be much less expensive than traditional systems for both local and long distance calling.
- Benefits of IP telephony systems to small businesses and organizations is that fact that they can be very flexible and have the ability to expand or contract with organization. If the business is growing rapidly or if the business is seasonal in nature.
- Internal communication is vital to organizations of every size and IP telephony systems make internal communication easier.

4.9 INTERNET TELEPHONY-

Internet Telephony is divided into three main categories consisting of –

(1) PC to PC telephony/ Calling

(2) PC to Phone telephony / Calling

(3) Phone to Phone telephony / Calling

PC to PC telephony / Calling-

- PC to PC telephony enables us to call another person who is online at the same time we are using the same telephony client.
- To use PC to PC calling, we will need compatible software, a microphone and speakers and internet access.
- PC to PC telephony is free. This makes it a popular choice for family and friends who live outside of each other's local telephone calling access.
- The client software converts transmitted speech into data packets and routes it over the internet. The receiving client turns the data packets back into voice signal. Example- Skype

PC to Phone Calling-

- PC to Phone telephony allows you to make calls from your computer to regular telephones. The technology is similar to PC to PC Calling.
- While this is a service we pay for, its usually cheaper than using a long distance telephone provider.
- To use PC to Phone services, we need to have the same equipment used for PC to PC calling, a microphone, speakers and internet access.
- The PC phone user's PC acts as the originating gateway, which converts the voice transmission into data packets onto the internet.
- At the end gateway provided by the software distributor, the data packets are converted to voice signals and routed to the Public Switched Telephone Network (PSTN)

Phone to Phone Calling-

- A relatively new type of Internet Telephony service, which is quickly gaining popularity.
- Phone to Phone telephony allow telephone calls to be placed over the internet, but if differs from the other types of internet telephony.
- Phone to Phone telephony does not require users to have special software, or even a computer to use it.
- Phone to Phone uses traditional telephones on both ends.
- Users with Phone to Phone calling place a call from their landline phone. The voice signals are digitized, compressed and converted to data packets.
- When the data packets arrive at the gateway, they are converted back into voice signals.
- Once converted, the voice signals are then transmitted through the local PSTN to the receiver.