ADVANCED COMMUNICATION ENGINEERING

[6th SEM ETC -ETT601]

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[CHAPTER-1]

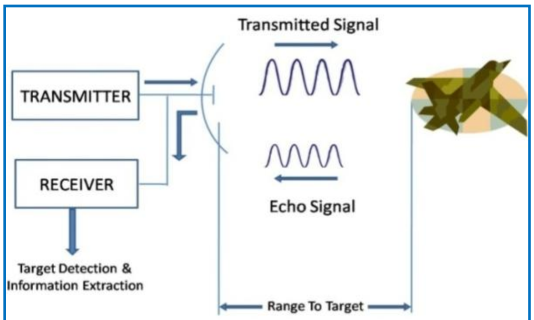
RADAR & NAVIGATION AIDS

1. RADAR & NAVIGATION AIDS.
1.1 State and explain the simple RADAR System & its Classification
1.2 Derive Radar Range Equation, types of Radar and their Application.
1.3 Explain the Performance factor of Radar.
1.4 Describe the block diagram of Pulsed Radar system.
1.5 State the function of Radar indication and Moving Target Indicator.
1.6 Define Doppler Effect & describe the block diagram of C.W RADAR.
1.7 Explain the Radar Aids to Navigator.
1.8 Explain Aircraft Landing System.
1.9 Explain concept of Navigation Satellite System (NAVSAT) & GPS System
1.10 Simple Radar Problems.

❖ INTRODUCTION: -

- RADAR means Radio Detection and Ranging.
- It is a device which can detect the presence of Target and measure its Range.
- Radar is an electromagnetic system for detection and location of reflecting objects such as aircrafts, ships, vehicles, people & natural environment etc.
- It operates by transmitting a particular type of wave form (e.g. pulse modulated sine wave) into space and detects the nature of echo signal reflected form an objects or targets.
- Radar can't recognize colour of objects but it can recognize darkness, fog, smoke, rain, snow etc.

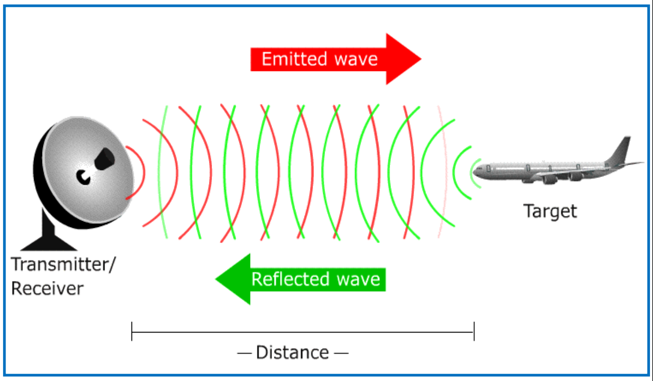
☎ *SIMPLE RADAR SYSTEM:-*



[BLOCK DIAGRAM OF A SIMPLE RADAR SYSTEM]

- A Radar System consists of Transmitter, Receiver & Antenna.
- A Transmitter generates an EM Signal which is radiated into space by Transmitting Antenna.
- A portion of the transmitted energy is intercepted by the target and re-radiated in many directions.
- The radiation directed towards the Radar is collected by the receiving Antenna and delivers into receiver.
- At the receiver the Signal is processed to detect the presence of target and determines its location.
- A Single Antenna is generally used in a time shared basic for both Transmitting and Receiving when the radar waveform is a repetitive series of pulses.
- The range or distance to a target is found by measuring the time it takes for the radar signal to travel to the target and return back to the Radar.
- Radar can also provide information about nature of target being observed.
- If the target is in motion, there is a shift in the frequency of the echo signal due to the Doppler Effect.
- This frequency shift is proportional to the velocity of the target related to the Radar which is known as Radar velocity.

Band	Frequencies	Wavelengths
HF	3–30 MHz	100–10 m
VHF	30–300 MHz	10–1 m
UHF	300 MHz–1 GHz	1–30 cm
L	1–2 GHz	30–15 cm
S	2–4 GHz	15–7.5 cm
C	4–8 GHz	7.5–3.75 cm
X	8–12 GHz	3.75–2.5 cm
K_u	12–18 GHz	2.5–1.67 cm
K	18–27 GHz	1.67–1.11 cm
K_a	27–40 GHz	1.11 cm–7.5 mm
mm	40–300 GHz	7.5–1 mm



☯ **NOTE:** Doppler frequency shift is widely used in Radar as the basic for separating desired moving target from fixed (Unwanted) clutter echoes reflected from natural environments such as see, lake Etc.

- The range of the target is determined by the time T_R;
- It is the time taken by the pulse to travels to the target and returns back to the transmitter (T_R).
- The EM Wave in the free space travel is the speed of light i.e. 3×10^8 m/s. Thus the time taken for the signal to travel to the target located at a Range 'R' and returned back to the Radar can found as: -

$V = S/T \rightarrow T = S/V$ [V ≡ Velocity ≡ **C**; S ≡ Distance ≡ **R**; T ≡ Time ≡ $\mathbf{T_R}$]

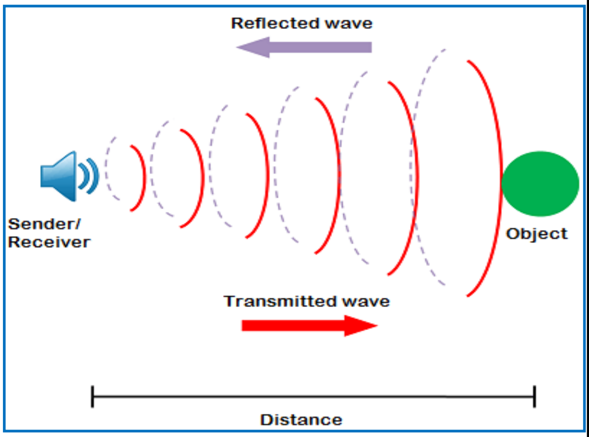
$$T_R = 2R/C \rightarrow \mathbf{R = CT_R/2}$$

NOTE:-

$R_{KM} = 0.15\ T_R\ (\mu s)$ $R_{Mtr} = 150\ T_R\ (\mu s)$ $R_{Yard} = 164\ T_R\ (\mu s)$ $R_{Feet} = 492\ T_R\ (\mu s)$

$R_{nmi} = 0.081\ T_R\ (\mu s)$ [nmi= Nautical Miles] $R_{smi} = 0.081\ T_R\ (\mu s)$ [smi= Statute Miles]

Un-Ambiguous Range:-



- Once the signal is radiated into space by Radar, Sufficient time must elapse to allow all echo signals to return to the Radar before the next pulse is transmitted.
- The rate at which the next pulse transmitted is determined by the longest range at which targets are accepted.
- *If the time between pulses T_P is too short an echo signal from long range target might arrive after the transmission of next pulse and we mistakenly associated with that pulse rather than the actual pulse transmitted earlier.
- This can result an incorrect or ambiguous measurement of Range.
- Echo that arrives after the transmission of next pulse are called second-time around echo.
- Such an echo would appear to be at a closer range than the actual and its range measurement is called misleading, if it were not known to be **Second-time around echo**.
- Hence the range beyond which the target appears as second-time around echo is called **Maximum** Unambiguous Range.

$$R_{Unamb} = CT_P/2 = C/2F_P$$

Where, T_p = Pulse Repetition Period & F_P = Pulse Repetition Frequency.

Certain Terms Associated with RADAR System: -

- Maximum Range
- Transmitted Power
- Operating Frequency
- Pulse Width or Duration
- Pulse Repetiotion Frequency (PRF)
- Duty Cycle
- Average Power

MAXIMUM RANGE

- Maximum distance around the antenna over which target can be detected is called maximum range.
- It depends on power of transmitter, location, directivity of antenna, frequency & sensitivity of receiver.

TRANSMITTED POWER

- The radiated power when the pulse is active is called the peak power of the Radar Transmitter.
- A typical radar cover a range of about 200km then the peak power of transmitter in the order of 1mw.

OPERATING FREQUENCY

- Radar uses Line of Sight (LOS) communication using frequency in range of 1,000MHz to 70,000MHz.
- The advantages of high frequency are: - it require small antenna, greater resolution, it can distinguish two nearby objects etc. where as its disadvantage: - It reduces transmitted power, increases noise figure.

PULSE WIDTH OR PULSE DURATION

- The time interval for which a pulse is active is called pulse width.
- Width of the pulse is used for modulation in a radar transmitter. The range of pulse width used in radar system ranges from 0.2μsec to 30μsec. For better resolution pulse width should be small.

PULSE REPETIOTION FREQUENCY (PRF)

- It is the frequency of pulse applied for modulation. PRF used in radar ranges from 350 to 10.000 PPS.
- Short range radar uses High PRF and Long range radar uses Low PRF.

DUTY CYCLE

- The duty cycle is the total time in sec for which the transmitter is active in sending pulse.
- Duty cycle = PRF x PW, Duty Cycle = P_{avg} / P_{peak},

☎ TYPES Of RADAR: -

- There are basic two types of Radar Detecter
  - Pulse Radar System
  - Contineous Wave (CW) Radar System
- CW Radar System again classified into two categories such as: -
  - CW Doppler Radar
  - Frequency Modulated CW Radar (FM-CW Radar).
- Based on structure basically Radar system are of two types: -
  - **Monostatic**
  - **Bistatic**
- In **bistatic** Radar system the transmitter and receiver antennas are at different location as viewed from the target.
- In **monostatic** radar system the transmitter & receiver uses same antennas are as viewed from the target.

MONOSTATIC RADAR SYSTEM	**BISTATIC** RADAR SYSTEM
✓ It uses a Single Antenna	✓ It uses a Two Antenna
✓ It needs duplexer	✓ It doesn't require duplexer
✓ Less space	✓ More space
✓ Complex system	✓ Simple system
✓ Costly	✓ Low cost

☎ APPLICATIONS Of RADAR: -

- Radar used in Different Fields like: -
  - Highway Safety
  - Remote Sensing
  - Air Traffic Control
  - Aircraft Safety and Navigation
  - Military
  - Ship Safety
  - Space Vehicles Control etc.
  - Law Enforcement

☎ RADAR RANGE EQUATIONS: -

- Radar Equation relates the Range of Radar to the characteristic of Transmitter, Receiver, Antenna, Target, and Environment etc.
- It is used not just as a man for determining the maximum distance from Radar to a Target.
- But it can serve both as a tool for understanding Radar Operation and a Basic form of Radar Design.
- In this section the simple form of Radar Equation is derived.
- For an **Isotropic** antenna; If the Power of Radar Transmitter is denoted by $\mathbf{P_t}$ then the Power Density (watts per unit area) at a distance 'R' is equal to the Transmitted Power Divided by the Surface Area ($4\pi R^2$) of an Imaginary Sphere with Radius 'R'. Where $\mathcal{P}_i$ = Power Density from Isotropic Antenna.

$$\mathcal{P}_i = \frac{Pt}{4\pi R^2} \quad \ldots\ldots\ldots\ldots \textbf{(1)}$$

- Generally Radar uses Directive antennas to channels. In this case the radiated power P_t is in some particular direction. If the gain (**G**) of an antenna is a measure of increased power radiated in the direction of target as compared with power that would have been radiated. And is defined as,

$$G = \frac{\text{Maximum Power Density Radiated by Directive Antenna}}{\text{Power radiated by a loss less Isotropic Antenna with same Power Input}}$$

- So, The Power Density at the target from an Directive Antenna with a transmitting gain 'G' is

$$\mathcal{P}_D = \frac{Pt\ G}{4\pi R^2} \quad \ldots\ldots\ldots\ldots \textbf{(2)}$$

- The target intercepts a portion of radiated power and re-radiated it in the various directions.
- The measure of the amount of incident power intercepted by the target and re-radiated back in the Radar Cross Section (σ) and is defined by the relation.

$$\text{Power Density of the echo signal at Radar} = \frac{Pt\ G}{4\pi R^2} \times \frac{\sigma}{4\pi R^2} = \frac{Pt\ G\ \sigma}{(4\pi R^2)^2} \quad \text{............ (3)}$$

- The Radar cross section (σ) as unit of area, it is the characteristic of a particular target and a measure of its size as seen by the Radar.
- Like target the Receiving Antenna intercepts a portion of the re-radiated power which is proportional to the Cross Sectional Area of the Receiving Antenna (A_e).
- The radar antenna captures a portion of the echo power. If the effective area of the cross sectional area of receiving antenna is denoted as A_e. The power receiving by the Radar is

$$\mathcal{P}_r = \frac{Pt\ G}{4\pi R^2} \times \frac{\sigma}{4\pi R^2} \times Ae \quad \Rightarrow \quad \mathcal{P}_r = \frac{Pt\ G\sigma\ Ae}{(4\pi)^2 R^4} \quad \text{..................... (4)}$$

- The Maximum Radar Range i.e. R_{max} is the distance beyond which the target cannot be detected.
- It occurs when the received echo signal power $\mathcal{P}_r$ just equal to the Minimum Detectable Signal (S_{min}),

$$S_{min} = \frac{Pt\ G\ \sigma\ Ae}{(4\pi)^2 Rmax^4} \Rightarrow (R_{max})^4 = \frac{Pt\ G\ \sigma\ Ae}{(4\pi)^2 S_{min}} \quad \mathbf{R_{max}} = \left[\frac{\mathbf{Pt\ G\ \sigma\ Ae}}{\mathbf{(4\pi)^2 S_{min}}}\right]^{1/4} \quad \text{....(5)}$$

- That is the Fundamental of the Radar Equation.

☎ **NOTE**: - Important antenna parameters are **Transmitting Gain (G) & Receiving Effective Area (**A_e)

- Antenna theory give the relation between Transmitting gain & receiving affective area of antenna i.e.,

$$\mathcal{G} = \frac{4\pi\ Ae}{\lambda^2} \quad \& \quad A_e = \frac{G\ \lambda^2}{4\pi} \quad \text{...................... (6)}$$

- Since the Radar generally use the same antenna both for Transmission and Reception, So we use these values in fundamental equation of Radar.

$$R_{max} = \left[\frac{P_t\ \mathbf{4\pi\ Ae}}{\boldsymbol{\lambda^2}} \times \frac{Ae\ \sigma}{(4\pi)^2 S_{min}}\right]^{1/4} \Rightarrow R_{max} = \left[\frac{P_t\ Ae^2\ \sigma}{4\pi\ \lambda^2 S_{min}}\right]^{1/4} \quad \text{........ (7)}$$

$$\mathbf{R_{max}} = \left[\frac{\mathbf{P_t\left(\frac{G\lambda^2}{4\pi}\right)^2 \sigma}}{\mathbf{4\pi\lambda^2 S_{min}}}\right]^{1/4} \quad \& \quad \mathbf{R_{max}} = \left[\frac{\mathbf{P_t G^2 \lambda^2 \sigma}}{\mathbf{(4\pi)^3 S_{min}}}\right]^{1/4} \quad \text{................ (8)}$$

- These simplified versions of Radar equation don't adequately describe the performance of actual Radars, as many important factors are not included. Also Idealized conditions have been employed i.e. neither the Effect of Ground nor Absorption and Interference is taken into account.
- Hence, the maximum range in practice is often less than that of indicated by the Radar Range Equation.

☎ Important Problems: -

☯ *What is the duty cycle of Radar with a pulse width of 3µsec and a PRT of 6ms?*

As Duty Cycle $= \frac{PW}{PRT} = \frac{\text{Pulse Width (PW)}}{\text{Pulse Repetation Time (PRT)}} \Rightarrow$ Duty cycle $= \frac{PW}{PRT} = \frac{3\times10^{-6}}{6\times10^{-3}} = 0.5\times10^{-3} = 0.0005$

- Duty cycle also is expressed as ratio of average power to that of peak power.

$$\boxed{\text{Average power} = \text{Peak Power} \times \text{Duty Cycle}}$$

- *Calculate the average power when peak power is 100kw with PW of 3µs and PRT of 6ms?*

Duty cycle = $\frac{PW}{PRT} = \frac{3\times10^{-6}}{6\times10^{-3}} = 0.5\times10^{-3} = 0.0005$ ➔ Peak Power = 100kw = 100×10^{3} Watt

- Average Power = Peak Power × Duty Cycle = $100\times10^{3}\times0.5\times10^{-3}$ = 50 watt

- *Calculate the maximum range of a Radar system which operates at 3cm wave length with a peak pulse power of 500kw and its minimum detectable signal S_{min} is 10^{-13}watt, the aperture area of its antenna is $5m^2$ and the Radar cross sectional area of the target is $20m^2$.*

Given: Wave length, λ = 3cm = 0.03m
Peak Power, Pt = 500kw = 500×10^{3}watt
Smin = 10^{-13}W, Aperture Area (Ae) = $5m^2$ & $\sigma = 20m^2$

$$R_{max} = \left[\frac{Pt\ Ae^2\ \sigma}{4\pi\ \lambda^2 S_{min}}\right]^{\frac{1}{4}}$$

⇨ $R_{max} = \left[\frac{500\times10^3\times25\times20}{4\pi\times(0.03)^2\times10^{-13}}\right]^{1/4}$ ➔ R_{max} = 686km = 370nmi

- *A Radar operating at 10GHz with the peak power of 500kW, the power gain of antenna is 5000 and the minimum power at the receiver is 10^{-14}W. Calculate the maximum range of Radar if the affective area of antenna is $10m^2$ and RADAR cross sectional area is $4m^2$?*

Given: f = 10Ghz = 10×10^{9} Hz, P_t = 500kw = 500×10^{3} watt,
G = 5000, $S_{min} = 10^{-14}$W, Aperture Area (A_e) = $10m^2$ & $\sigma = 4m^2$

$$(R_{max}) = \left[\frac{Pt\ G\ \sigma\ Ae}{(4\pi)^2 S_{min}}\right]^{\frac{1}{4}}$$

⇨ $R_{max} = \left[\frac{500\times10^3\times5000\times10\times4}{(4\pi)^2\times10^{-14}}\right]^{1/4}$ = 501643.359m = 501.643km

☎ PERFORMANCE FACTORS OF RADAR : -

TRANSMITING POWER[P_t]

- From the radar range equation it is clear that $\mathbf{R_{max}\ \alpha\ [P_t]^{1/4}}$ for all other parameters to be constant.
- It means that if $P_2 = 16\ P_1$ then $R_2 = 2\ R_1$ i.e. for twice range, transmitted power should be 16 times more

TRANSMITING FREQUENCY [f]

- From the radar range equation, we get $\mathbf{R_{max}\ \alpha} \left\{\left[1/\lambda^2\right]^{1/4} = \left[1/\lambda\right]^{1/2} = \sqrt{1/\lambda} = \sqrt{f/c}\right\}$ ➔ $\mathbf{R_{max}\ \alpha\ \sqrt{f}}$ for all other parameters to be constant. (where $\lambda = c/f$)
- It means that if $f_2 = 4\ f_1$ then $R_2 = 2\ R_1$ i.e. for twice range, transmitted frequency should be 4 times more

TARGET AREA[σ]

- From the radar range equation it is clear that $\mathbf{R_{max}\ \alpha\ [\sigma]^{1/4}}$ for all other parameters to be constant.
- It means that if $\sigma_2 = 16\ \sigma_1$ then $R_2 = 2\ R_1$ i.e. for twice range, transmitted power should be 16 times more
- If the target size is smaller, then the range of radar decreases and vice versa.

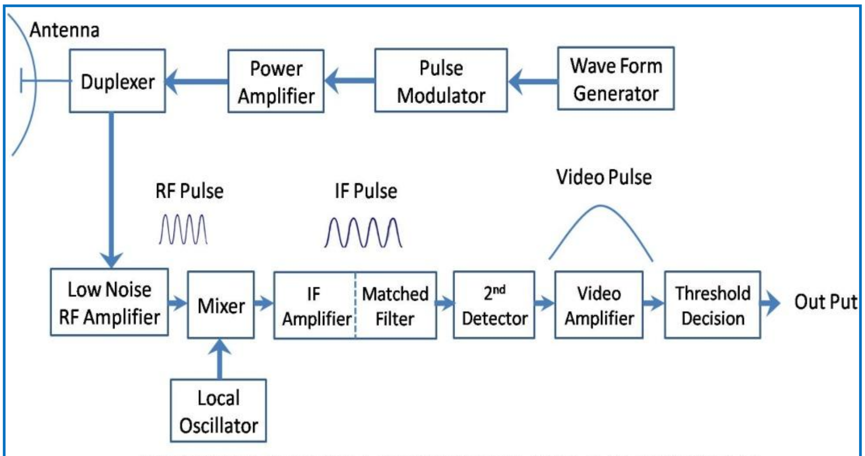
EFFECTIVE AREA OF ANTENNA [A_e]

- From the radar range equation, we get $R_{max}\ \alpha\ [A_e^2]^{1/4}$ → $R_{max}\ \alpha\ [A_e]^{1/2}$ → $\mathbf{R_{ma}\ \alpha\ \sqrt{A_e}}$.
- It means that if $A_{e2} = 4A_{e1}$ → $R_2 = 2R_1$ i.e. for twice range, transmitted frequency should be 4 times more

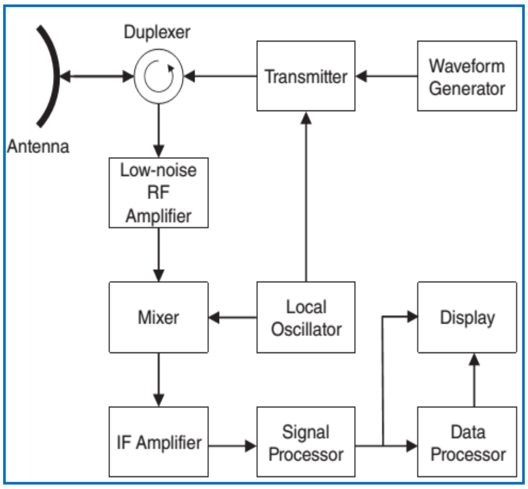
MINIMUM POWER OF THE SIGNAL (Minimum Detectable Signal) [S_{min}]

- From the radar range equation, we get $R_{max}\ \alpha\ \left[1/S_{min}\right]^{1/4}$ for all other parameters to be constant.
- It means that if we decrease the minimum detectable signal power then R_{max} increases and vice versa.
- If the circuit is higher sensitive in receiver part have higher the range of radar system.

☎ PULSE RADAR SYSTEM:-



[BLOCK DIAGRAM OF A **PULSE MODULATED RADAR** SYSTEM]



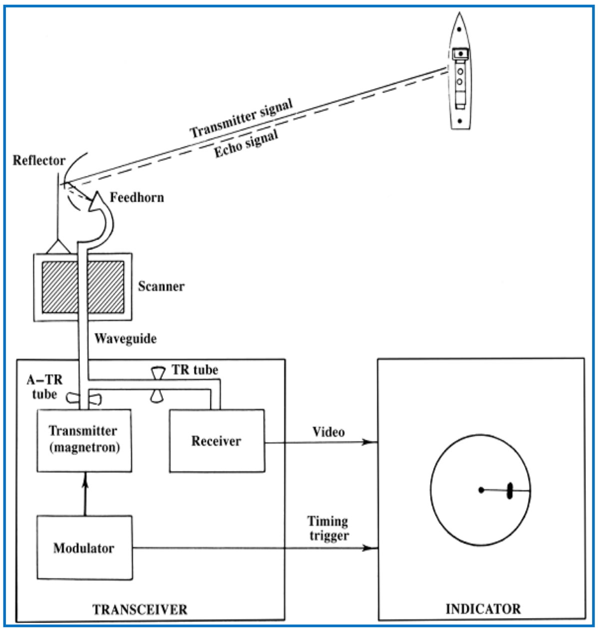
- The operation of a typical Pulse Radar System is described by the help of block diagram.
- Generally it consists of Antenna, Transmitter and Receiver which are explained below.

1. ANTENNA: -

- The function of antenna during transmission is to concentrate the radiated energy into a shaped beam which points in the desired direction in the space.
- On reception the antenna collects energy contained in the echo signal and deliveries it to the receiver.
- The two important input parameters of Antenna i.e. Transmitting Gain (G) and Effective Receiving Area (A_e) are proportional to each other.
- An antenna with large effective receiving aperture implies a large transmitting gain.
- Different type of antenna can be used in Radar such as mechanically steered parabolic reflector, electrically steered planned array antenna or electrically steered phase array antenna etc.

2. TRANSMITTER: -

- The Transmitter may be an oscillator such as a Magnetron i.e. pulsed [turned ON and OFF] by the modulator to generate a repetitive train of pulse.
- The Magnetron most widely used for a various microwave generator for Radar.
- A Typical Radar for the detection of aircraft has the following points: -
  - Ranges nearly equal to 100 to 200nmi.
  - Transmitting power in the order of mega watt & Average power in order of several kilowatt;
  - Pulse Width in the order of micro second.
  - Pulse repetition frequency in the order of several 100 pulses per sec.

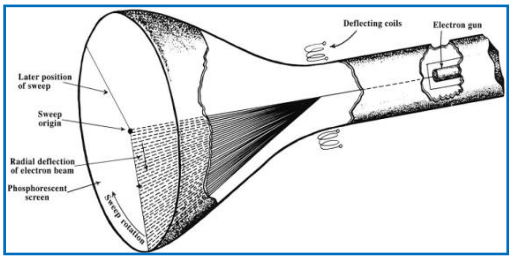


- Transmitting section consists of Waveform Generator, Pulse Modulator, Power Amplifier & Duplexer.
- The waveform generator generates repetitive train of pulse & is fed to pulse modulator for modulation.
- The pulse modulator modulates the train of pulses and gives the pulse modulated signal to the power amplifier for amplification. The power amplifier amplifies the pulse modulated signal and fed to the duplexer. Generally radio frequency amplifier is used for this purpose.
- The duplexer allows a single antenna to be used on a time sharing basis for transmitting and receiving.

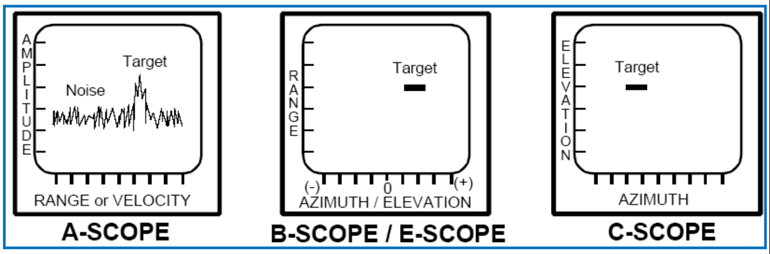
- The duplexer is generally a gaseous device that produces a short circuited at input to the antenna During Transmission. So that the high power is flows to the antenna not to the receiver.
- The duplexer protects from damages caused by the high power of the transmitter.
- It also serves to channel that the returned echo signal to the receiver and not to the transmitter.
- The duplexer might consist of two gassed discharged devices one known as TR (Transmit Receiver) and ATR (Anti-Transmit Receiver).
- The TR protects the receiver during transmitting and the ATR directs the echo signal to the receiver during reception.

3. RECEIVER SECTION: -

- The receiver is usually super heterodyne type. It consists of different part as explained bellow: -
- The 1st stage of the receiver is low noise R.F. transistor amplifier which reduces the noise level.
- The mixer and local oscillator converts the R.F. signal to (I.F.) intermediate frequency where it is amplified by the IF amplifier.
- The signal Bandwidth of a super heterodyne receiver is determined by the bandwidth of the IF stage.
- The IF amplifier is designed as a Matched Filter that is one which maximizes output peak signal-to-mean-noise ratio (SNR).
- Thus the basic function of matched filter is to maximize the detect ability of weak echo signal & attenuates unwanted signal.
- The IF amplifier is followed by a critical diode which is called the second detector or demodulator.



- Its purpose is to assist extracting the modulating signal from the modulated signal.
- The combination of IF amplifier, 2nd detector and video amplifier act as an envelope detector to pass pulse modulation (envelop) and reject the carrier frequency.
- To detect the Doppler shift of the echo signal the enveloped detector replaced by phase detector which is different from the envelope detector.
- The combination of the IF amplifier and video amplifier is designed to provide sufficient amplification or gain to raise the level of the input signal to a magnitude where it can be seen in a display. At the end of the receiver a decision is made whether a target is present or not.

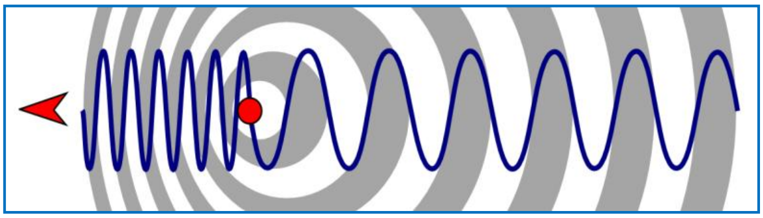


- The decision is based on the magnitude of the receiver output.
- If the output is large enough to exceed a pre-determined threshold, the decision is that target is present.
- If it does not cross the threshold only noise is assumed to present.
- The display unit is usually a Cathode Ray Tube; the most common form of the CRT is Plane Position Indicator (**PPI**) which maps location of the target is in **Azimuth Angle** & **Range** in **polar** co-ordinates.
- **B**-scope display is similar to the PPI except that it utilizes the **rectangular** co-ordinate rather than the polar co-ordinates to display **Range Vs Angle**.
- Another for display is **A**-scope which plots target **Amplitude Vs Range** for some fixed direction.

☎ *CONTINUOUS WAVE RADAR (CW RADAR) :-*

- **Pulse Radar** is used for detection of **Stationary** Objects; whereas Continuous Wave type of Radar is used to detect a **Moving Target**. CW Radar is of Two type: -
  - (1) CW Doppler Radar
  - (2) FM CW Radar
- CW Doppler Radar uses the Doppler Effect for the Target **Speed** Measurement.
- FM CW Radar is used to measure **Range** as well as **Velocity** of the Target.

❖ DOPPLER EFFECT:-



- The apparent frequency of electromagnetic or sound waves depends on the relative radial motion of the source or observer.
- If the source and observer one moving away from each other then the apparent frequency will decrease and when they moving towards each other then the apparent frequency will increase. It was postulated by C. Doppler. So known as **Doppler Effect**.
- If 'R' is the distance from the Radar to target then the total number of wavelength (λ) contained in the two way path between the Radar and target is 2R/λ.
- Each wavelength corresponds to a phase change of 2π radian then the total phase change in the two way propagation path is equal to (2Π x 2R/λ) i.e. **Φ = 4ΠR/λ.**
- If the target is in motion w.r.t. the Radar then R and Φ are continuously changes.
- A change in Φ w.r.t. time is equal to frequency and this is known as **Doppler Angular Frequency** (W_d).

$$W_d = 2\pi f_d = \frac{d\phi}{dt} = \frac{d}{dt}\left(\frac{4\pi R}{\lambda}\right) = \frac{4\pi}{\lambda} x \frac{dR}{dt} \Rightarrow 2\pi f_d = \frac{4\pi}{\lambda} \text{ x } V_r \Rightarrow f_d = \frac{2V_r}{\lambda}$$

Where f_d = Doppler Frequency Shift & V_r = Radial Velocity of the Target w.r.t. Radar

- From the above expression, $f_d = 2V_r/\lambda$. Put $\lambda = C/f_t$, We get $f_d = 2V_rf_t/C$.

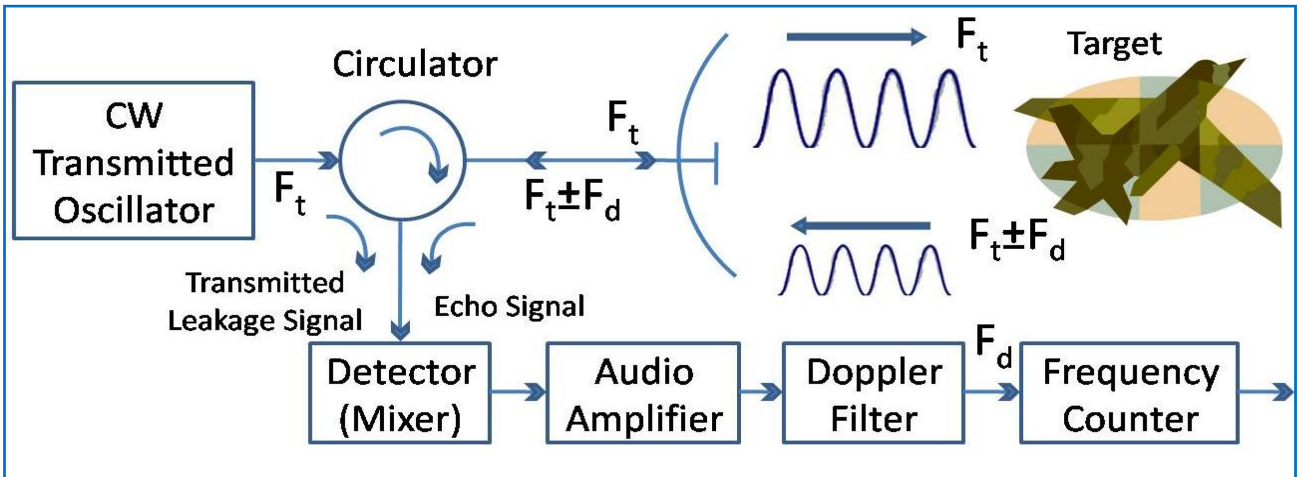
Where f_t=Radar frequency or Transmitted frequency. If f_d in Hz, V_r in nmi & λ in meter → $\mathbf{f_d = 1.03V_r/\lambda}$.

☯ *With a CW Transmit frequency of 5GHz, Calculate the Doppler frequency seen by the Stationary Radar when the Target radial velocity is 100km/hr.*

Given that f_t = 5 GHz = $5x10^9$ Hz **;** V_r =100Km/hr = 100x1000/3600 = 27.8m/s **;** c = $3x10^8$ m/s.

As λ= c/f = $(3x10^8) / (5x10^9)$ = 0.06m ➔ $f_d = 2V_r / \lambda$ = (2x 27.8) / 0.06 = 926 Hz.

☎ 1. CW Doppler RADAR:-

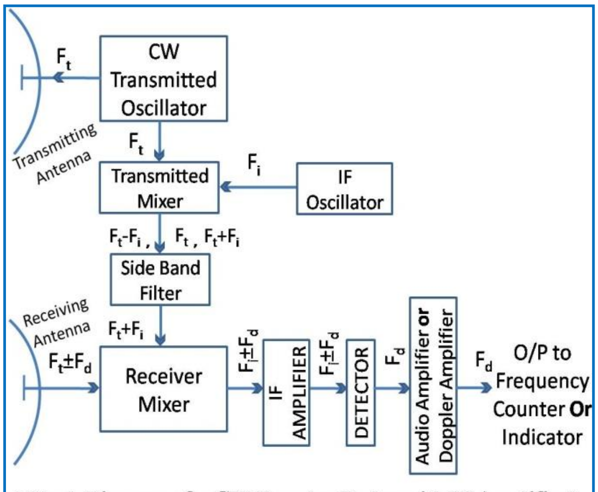


[BLOCK DIAGRAM OF A CW DOPPLER RADAR]

- The CW Transmitter generates a continuous sine wave rather than pulse (Un modulated) of frequency $\mathbf{f_t}$ which is radiated by the antenna.
- Since, here the transmission is continuous the Circulator is used to provide isolation between transmitter and receiver. For continuous wave the use of duplexer is pointless.
- A Portion of radiated energy is intercepted by the target and scattered.
- Some of it in the direction of Radar where it is collected by receiving antenna.
- If the target is in motion with a velocity of V_R relative to the Radar, the received signal will be shifted in frequency from the transmitted frequency $\mathbf{f_t}$ by an amount of $\mathbf{\pm f_d}$.

- The plus (+) sign associated with the Doppler frequency applied, if the distance between the target and the Radar is decreasing (when they moving towards each other) i.e. when the received signal frequency is greater than the transmitted signal frequency.
- The minus (-) sine applied if the distance is increasing i.e. target is away going from the Radar.
- Hence the received echo signal at the frequency $\mathbf{f_t \pm f_d}$ enters to the Radar via antenna.
- This signal is heterodyne in the detector (mixer) with a portion of transmitted signal $\mathbf{f_t}$ to produce a Doppler bit of frequency $\mathbf{f_d}$. The sign of the $\mathbf{f_d}$ is losses in this process.
- So we cannot predict whether the target is going away from the Radar or coming towards the Radar.
- The purpose of the Doppler amplifier is to eliminate echoes from stationary target and to amplify the Doppler echo signal to a level where it can operate an indicating device like frequency counter.
- The counter is a normal one except that the output is shown as km or miles/hour rather than the actual frequency in Hz. The main disadvantage of simple CW system is its lake of sensitivity.
- The type of diode detector that is used to accommodate the high incoming frequency and is not a good device for the audio output frequency. Thus an increment is in the following ways.

☎ *CW Doppler RADAR With IF Amplifier*:-



[Block Diagram of a CW Doppler Radar with IF Amplifier]

- A small portion of a transmitter output is mixed with output of local oscillator and the sum is fed to the receiver mixer by the help of sideband filter.
- The receiver mixer also receives the Doppler shifted signal from receiving antenna and produces an output difference frequency i.e. typically 30MHz (Generated by the IF oscillator) ± $\mathbf{f_d}$.
- The output of this mixer is amplified by the amplifier and demodulates again by the detector.
- The signal from the 2nd detector is just the Doppler frequency ($\mathbf{f_d}$). This signal is again amplified by the Doppler amplifier so as to raise the signal level such as to meet the frequency counter or indicator.
- Its sine is lost so that it not possible to tell whether the target is approaching or receiving.
- Separate receiving and transmitting antenna have been used.
- A Circulator could be used as shown in simple CW Radar system.
- Separate antenna is used to increase the isolation between transmitter and receiver section of the Radar.

ADVANTAGES: -

- CW Radar is capable of giving accurate measurement of relative velocity using low transmitting power, simple circuitry low power consumption and equipment whose size is much smaller than that of pulsed Radar equipment. It is unaffected by the presence of stationary target.
- With some additional circuitry CW Radar can measure the direction of the target along with its speed.

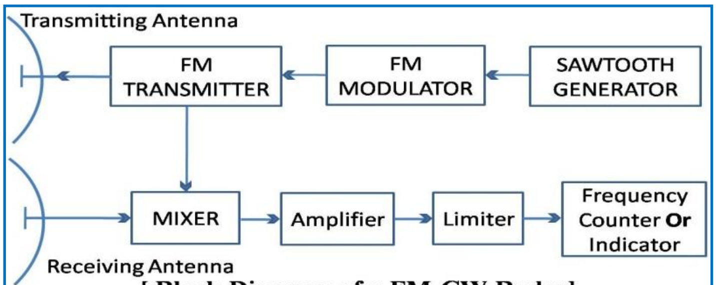
LIMITATIONS: -

- It is limited to the maximum power it transmits and this naturally places a limit on its maximum range.
- It is easily confused by the presence of a large number of targets (Although it is capable of delaying with more than one target if special filters are included) → It is incapable of indicating the range of the target.
- It can only show its velocity because the transmitted signal is Un modulated.
- The receiver cannot sense which particular cycle of oscillation being received at that moment; therefore cannot tell how long ago this particular cycle was transmitted, so that the **range cannot** be measured.

APPLICATIONS:-

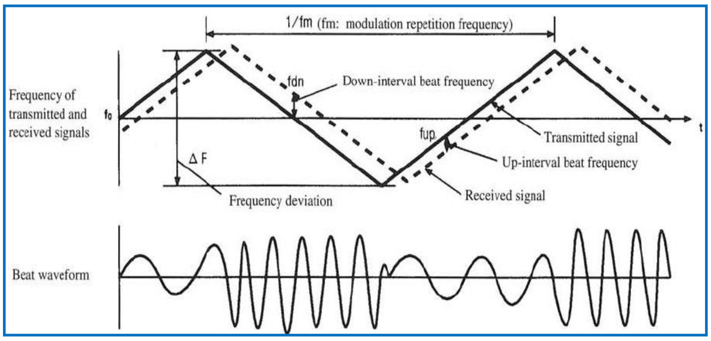
- It is used in aircraft navigation for speed measurement.
- Another application is in a rate of climb meter for vertical take of planes such as Harrier.
- It is most commonly used in Radar speed meter used by police.

☎ 2. *FM CW RADAR*:-



[Block Diagram of a FM-CW Radar]

- The greatest limitation of Doppler radar i.e. it is unable to measure the range is over come if the transmitted carrier is frequency modulate.
- If this is done it would be possible to eliminate difficulty with CW Radar i.e. its inability to distinguish one cycle from other.
- The popular method in CW Radar is to linearly frequency modulated the waveform.
- The modulation is triangular which gives up eventually and comes down.
- The transmitted signal is shown by the solid triangular waveform and the receiver signal is shown by dashed line. Delay time, T=2R/C, Δf = Frequency deviation, F_m = Modulation frequency.
- The target is stationary w.r.t. the plane.
- A frequency difference proportional to height of the plane will exist between the receiver and transmitter signal is now being received was sent at a time when the instantaneous frequency was different.
- The rate of change of frequency with time due to the FM process is known the time difference between the sent and received signal may be calculated.



- The above fig is the block diagram of a common application of FM CW Radar system.
- It is also known as **air borne altimeter** as it is employed for measurement of altitude in aircraft.
- Here we use saw tooth generator to employing saw tooth frequency modulation for simplicity.
- A FM transmitter is used in which frequency modulation of the signal can be done and its output is given to the mixer.
- The output of the mixer which produces the frequency difference (beat frequency) as amplified by amplifier and limited to remove any amplitude fluctuation by limiter.
- This signal is fed to a frequency counter and to an indicator whose output is calibrated in meter or feet.

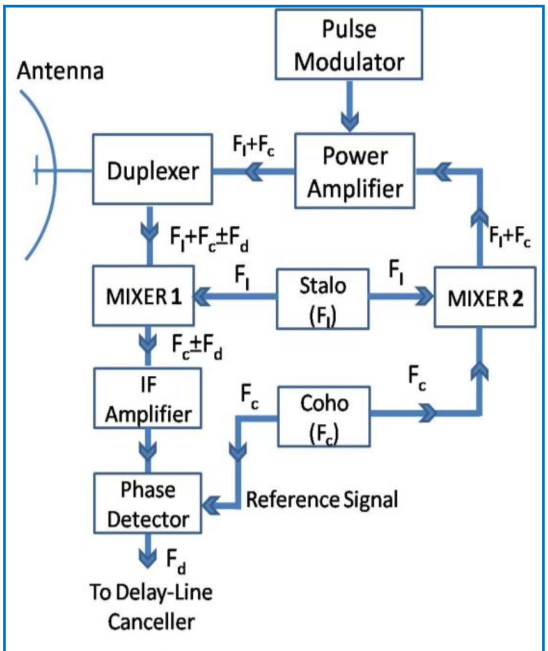
APPLICATION:-

☎ FM CW Radar is mostly used in altimeter in aircraft due to shorter range & lower power requirement as compared to pulse Radar. Smaller size for air craft installation & smaller transmitter power.

☎ *Comparison between Pulse Radar System and CW Radar System*:-

PULSE RADAR SYSTEM	*CW RADAR SYSTEM*
✓ It detects target maximum range, size.	✓ It typically determines target velocity
✓ It generally requires high power	✓ It can be achieved without the high peak power
✓ Pulse modulated signal is used for transmission	✓ Modulated or un-modulated continuous signal is used for transmission.
✓ Duplexer is used to use common antenna for both transmission and reception	✓ Separate antennas are used for transmission and reception.
✓ The performance sometimes affected by the stationary targets.	✓ The performance is not affected by the stationary targets.
✓ The performance is not affected by the presence of large number of targets.	✓ The system gets confused by the presence of large number of targets.
✓ Quite simplex circuit	✓ Simple circuit
✓ Expensive	✓ Less cost
✓ Practically it is mostly used	✓ It is used in some applications.

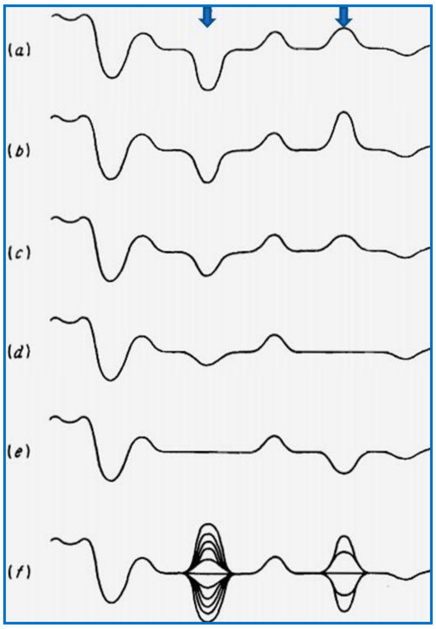
☎ *Moving Target Indicator Radar (MTI):-*



[BLOCK DIAGRAM OF A **MTI RADAR** SYSTEM]

- This Radar uses Doppler Effect for its operation many times it is not possible to distinguish a moving target in the presence of static or permanent echoes of comparable appearance on the Radar screen.
- We have seen that in a PPI display, there is a lot of clutter due to this stationary target echoes.
- When it is desired to remove the clutter due to the stationary target an MTI Radar is employed.
- The basic principle of MTI Radar is to compare a set of received echo with those received during the previous. Sweep and Cancelling out those whose phase has remain unchanged.
- Moving target will give change of phase and are not cancelled thus clutter due to the stationary target are remove from display & this allows easier detection of moving target.
- The side diagram is the simple block diagram of MTI Radar.
- The Transmitter frequency in MTI Radar is the sum of the output of two oscillators produced in mixer 2.
- The First oscillator is the **Stalo** (Stable Oscillator) and the Second one is **Coho** (Coherent Oscillator) which operating same frequency as the intermediate frequency & providing coherent signal.

- The Coho is used for generating the R.F. signal as well as reference signal for the phase detector. The output of the duplexer is the combination of transmitted frequency and Doppler shift frequency.
- At the mixer-1 the Stalo frequency (f_L) cancels out and feeds a signal of frequency $f_c \pm f_d$ to I.F amplifier for amplification.
- The reference signal from the Coho and the I.F echo signal are both feed into the mixer called phase detector.
- The phase detector differs from the normal amplitude detector, since its output is proportional to the phase difference between the two input signals.
- Since the output of this detector is phase sensitive and output will obtain for all fixed or moving target.
- The phase difference between transmitter & receiver signal will be constant for a fixed target where as it will vary for a moving target. This variation of moving target is due to the **Doppler frequency shift**.



- The **delay line canceller** not only eliminate the DC component caused by clutter but also it unfortunately rejects the any moving target whose Doppler frequency happens to be same as the PRF (Pulse Repetition Frequency) or multiple of PRF. (**$f_d = nf_p$**)
- Those related target velocities which result is zero MTI response are called **Blind Speed** and is given by

$$V_n = n\lambda/2T = n\lambda f_p/2$$

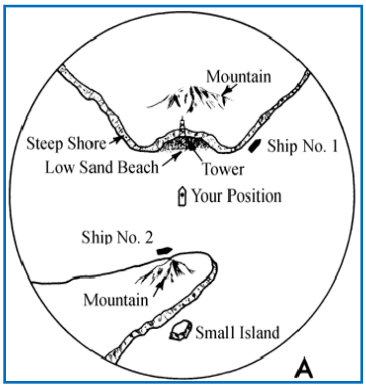
Where n=1, 2, 3…...

☯ An MTI RADAR operates at frequency 5GHz with a PRF of 800pps. Calculate the lowest three blind speeds of this RADAR.

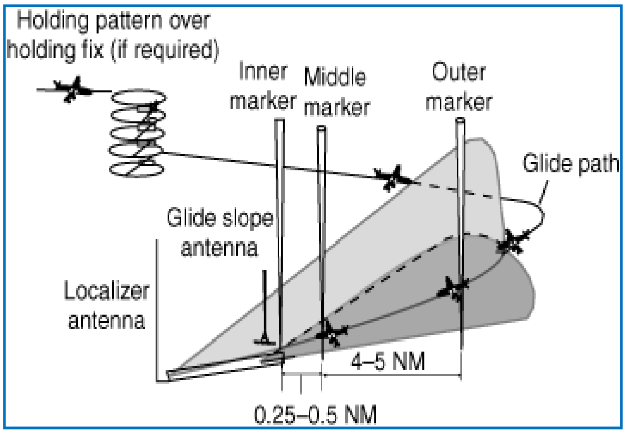
- Given that : f =5GHz = 5×10^9Hz , PRF =800pps
- As λ= c/f = $(3\times10^8) / (5\times10^9)$ = 3/50 = 0.06m
- **V_{n1}** = $n\lambda f_p/2$ = (1x0.06x800)/2=24m/s, **V_{n2}** = (2x0.06x800)/2 = 48m/s & **V_{n3}** = (3x0.06x800)/2 = 72m/s

☎ *Radar Aids to Navigation:-*

- The **position** of air craft or a ship can be found by use of radio navigation aids.
- This is achieved by installation of radio transmitter & receiver at known location on the earth surface as well as at air craft or ship which works in conjunction with those on earth.

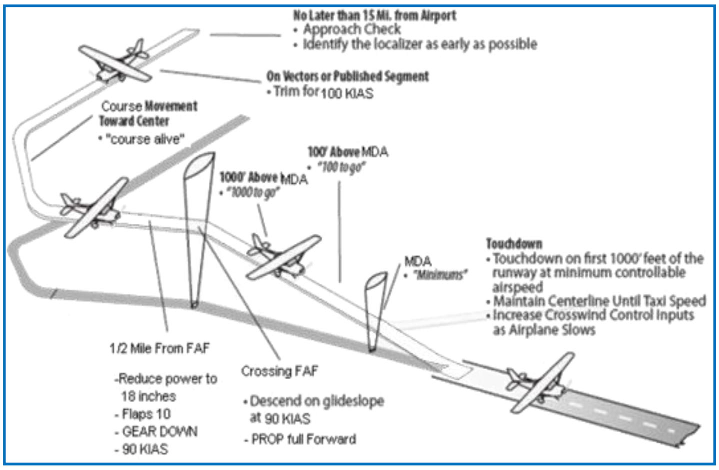


- The rectilinear propagation and constant velocity of electromagnetic waves held this system to provide navigation parameter like distance, direction, etc. by direct and indirect measurement of delay occurring between transmission and reception of these waves.
- The measurement of direction, distance and the difference between two transmitters give an indication of the position of an air craft or ship leading to correct navigation.
- Direction finding through radio is one of the very earliest methods of electronic navigational aids widely used in ship & air craft even today.
- Marine & aviation radar systems can provide very useful navigation information in various situations.
- When a vessel is within radar range of land or special radar aids to navigation, the navigator can take distances and angular bearings to charted objects and use these to establish arcs of position and lines of position on a chart. Parallel indexing is a technique involves creating a line on the screen that is parallel to the ship's course, but offset to the left or right by some distance.
- This parallel line allows the navigator to maintain a given distance away from hazards.
- Some techniques have been developed for special situations.
- Another method is "**Contour Method**," involves marking a transparent plastic template on the radar screen and moving it to the chart to fix a position.



- Another special technique, known as the **Franklin Continuous Radar Plot** Technique, involves drawing the path a radar object should follow on the radar display if the ship stays on its planned course.
- During the transit, the navigator can check that the ship is on track by checking that the pip lies on the drawn line. **The Yeoman Plotter** uses both radar, GPS and traditional charts to plot courses and is one of the most used plotters today.
- After completing the plotting radar technique, image from the radar can either be displayed, captured or recorded to a computer monitor using frame grabber.

☎ *Aircraft Landing System:-*



- Generally two types of landing system are used.
  1. **I.L.S.** (Instrumental Landing System)
  2. M.L.S. (Microwave Landing System)
- Instrument Landing System is used for runway navigation in IFR condition in which by using some specified component landing can be made.
- If this type of system there are two category.
- In first category it guided on aircraft up to 200ft.
- In second category it guided an aircraft up to a level of 100ft below which it cannot guided.

☎ **INSTRUMENT LANDING SYSTEM** contains following Components: -

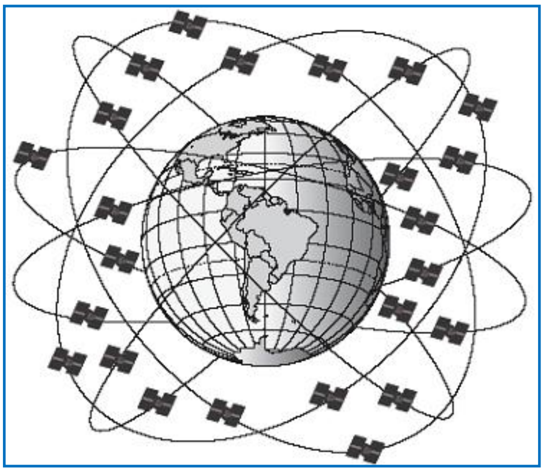
1) **Localizer**: - In front the pilot with aero plane horizontal position w.r.t. runway centre line.
2) **Glide Slope**: - In front the pilot aero plane vertical position w.r.t. ground.

3) **Outer Marker**: - It stands in the same line with localizer and the runway center line four to seven miles before the runway. When the aero plane approaches the runway from the right direction it gives a signal by blinking the outer marker line.
4) **Middle Marker**: - It is positioned 0.8 miles before the runway when the aero plane is above the middle marker the receiver blinks giving a chance to the pilot weather land or not.
5) **Inner Marker**: - It is present in the runway when the aero plane touches the runway and stands over it. The receiver blinks the light of inner marker.
6) **Approach Light**: - It includes medium or high intensity system for both inside & outside the aero plane.

☎ ***NAVSAT:*** - It stands for Navy-Navigation Satellite System. It is developed by USA in 1967 to monitor the military activities and guiding of aero plane & warship. Satellite system means finding out the position of an object from different angles through satellite placed artificially.

Concept & Feature

- NASAT uses the Doppler shift of radio signal transform satellite to measure the relative velocity between the satellite and navigator by knowing the satellite orbit position the navigator position can be determined from the time rate of change of rate to the satellite.
- NAVSAT consists ten orbit satellite and three orbiting space.
- A network of working station continuously monitors the satellite information.
- Each satellite is a circular polar orbit at an altitude of 6a.
- Usually five satellites are operating in the system.
- Generally four satellite can make the constellation and another one is used as a spare to find out the position of a navigator at least information for four satellite taken.
- Each satellite contain receiver to receive the compound from the ground well equipped decoder and memory, control circuit encoder to transmit digital data to phase modulation, ultra stable 5Hz oscillator and a 1.5W transmitter to broadcast the carrier frequency of 150MHz to 400MHz.



☎ ***GPS (Global Positioning System) :-***

- Long before **Global Positioning System (GPS)** arrived, researchers worked hard to arrive at a feasible solution to aid travelers from getting lost.
- Earlier, travelers used to rely on elaborate maps to track and monitor the route to their destination. But today, **GPS technology** has ensured irritate–free trips & increased safety for vehicle owners. Fig shows **GPS satellite.**

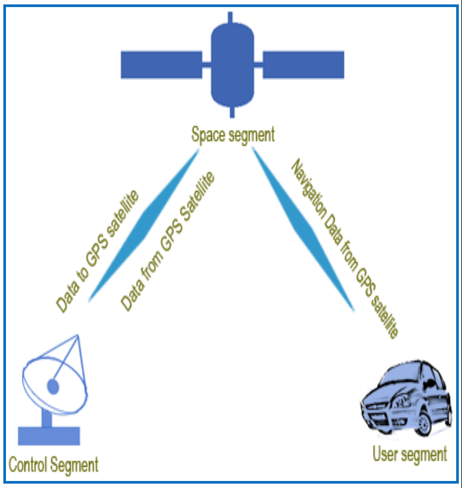
Structure of GPS

- The GPS system comprises of Three parts: - Space segment, User segment and Control segment. The fig of the structure is shown below.

Ψ **Space Segment** – The satellites are the heart of the Global positioning system which helps to locate the position by broadcasting the signal used by the receiver.

- The signals are blocked when they travel through buildings, mountains, and people.
- To calculate position, the signals of four satellites should be locked.
- You need to keep moving around to get clear reception.
- In space segment system it contains 24 operational satellite which are revolving around the earth in 6^{th} different orbit there are used an spare and there are arranged in such a manner at least four satellite are in view to an user at any time on a worldwide base. Out of four satellites **03** are for Dimension **01** for Time.

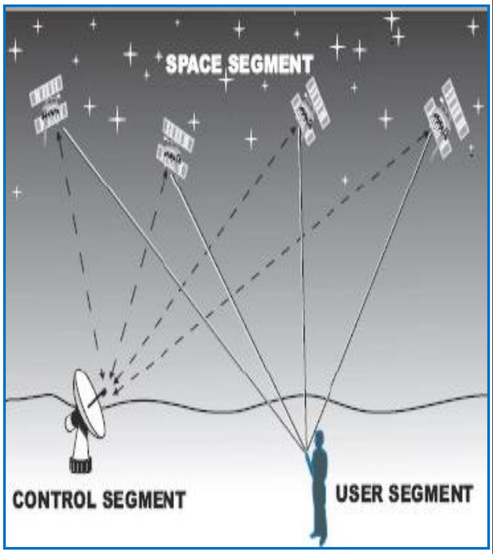
Ψ **Control Segment** – This helps the entire system to work efficiently.



- It is essential that the transmission signals have to be updated and the satellites should be kept in their appropriate orbits.
- It includes a master control station & number of monitory & general antenna allocated throughout world.
- They are all interlinked & all information received is processed by master control system.
- After calculation of accuracy master control system it is transmitted to the antenna by which a position can identify through satellite

Ψ **User Segment** – This segment includes military & civilian users.

- It comprises of a sensitive receiver which can detect signals and a computer to convert the data into useful information.
- GPS receiver helps to locate your own position but disallows you being tracked by someone else.
- User segment contain high, medium and low receiver the user equipment is so designed so that it receives the signal and process all at a time or sequentially then the processer converted signal into three dimensional navigational information.



Working:

- The GPS satellites rotate twice a day around the earth in a specific orbit. These satellites transmit signal information to earth.
- This signal information is received by the GPS receiver in order to measure the user's correct position.
- The GPS receiver compares the time a satellite transmits the signal with the time the signal is received.
- The time difference calculated enables us to know the distance of the satellite. By measuring the distance of few more satellites, the user's position can be verified and displayed on the unit's electronic map.
- To measure 2D position and track movement, the GPS receiver must lock the signal of three satellites.
- The receiver can measure 3D position (latitude, longitude and altitude) if the GPS receiver locks the signal of four or more satellites. On determining the position of the user, the unit of GPS can measure speed, trip distance, bearing, distance to destination, tack, time of sunrise and sunset, etc.

Types of GPS Receivers

- The three types of GPS receivers that offer different level of accuracy, and have different necessity to obtain the accuracies are:

Ψ **Coarse Acquisition (C/A) code receivers** – These receivers offer 1-5 meter GPS position accuracy with differential correction. With an occupation time of 1 second, these receivers offer 1-5 meter GPS position accuracy. The GPS position accuracies can be within 1-3 meters consistently if the occupation time is long.

Ψ **Carrier Phase receivers** – These receivers offer 10-30 meter GPS position accuracy with differential correction. The waves that carry C/A signal are counted to calculate the distance between the satellite and the receiver. High occupation time is required to obtain position accuracy.

Ψ **Dual Frequency receivers** – These receivers offer sub-centimeter GPS position accuracy with differential correction. These receivers accept signals from the satellites on two different frequencies to find out accurate position.

NOTE: Differential correction is a method to compare GPS data collected in the field to the GPS data collected at a known point. GPS is also known as the NAVSTAR (Navigation System for Timing and Ranging).

FOUR STEPS FIND THE POSITION:

- Measuring travel time of satellite signal.
- Measurement of distance from satellite.
- Measurement of position of satellite.
- Trilateration.

APPLICATIONS

- GPS *works* all across the world and in all weather conditions, thus helping users track locations, objects, and even individuals. GPS technology can be used by any person if they have a GPS receiver.
- **Civilian Applications**
  - ✓ **Navigation** – Used by navigators for orientation and precise velocity measurements.
  - ✓ **Surveying** – Surveyors create maps and verify the boundaries of the property.
  - ✓ **Map-making** – Used by civilians and military cartographers.
  - ✓ **Tectonics** – Detect the direct false motion measurement in earthquakes.
  - ✓ **Geofencing** – Vehicle, person or pet can be detected by using GPS vehicle tracking system, person tracking systems, and pet tracking systems.
- **Military Applications**
  - ✓ **Navigation** – Soldiers can find objectives in the dark and unknown regions with the help of GPS.
  - ✓ **Search and Rescue** – Knowing the position of a downed pilot, its location can be traced out easily.
  - ✓ **Reconnaissance** – Patrol movement can be handled.
  - ✓ **Target tracking** – Military weapon systems use GPS to track air targets and potential ground before they are flagged as hostile.
  - ✓ **GPS** carry a set of nuclear detonation detectors (such as optical sensor, dosimeter, electromagnetic pulse sensor, X-ray sensor) which is a part of United States Nuclear Detonation Detection System.
  - ✓ **Missile and projectile guidance** – Targets military weapons such as cruise missiles, precision guided munitions.

LIMITATION OF GPS

- *Line-Of-Sight Essential* - Signal cannot pass through building, it happens in urban area like Sydney city areas. *Long position time* - Around 15 minutes, depends on how accuracy.
- *Battery* - Run out of the battery in GPS receiver, since long calculation time, 4Ah batteries can last for 4 hours only. Need improvement? Cellular Network.

--- ALL THE BEST --- ALL THE BEST ---

[CHAPTER-2]

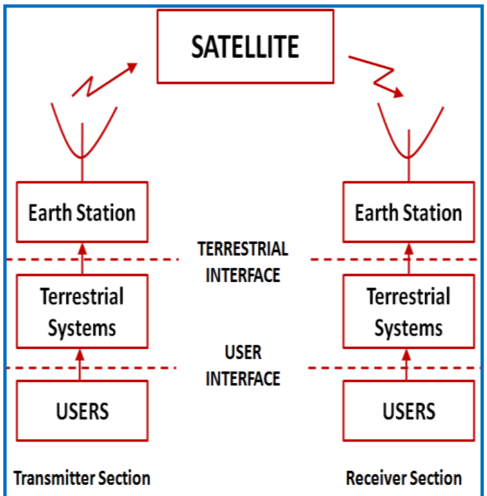
SATELLITE COMMUNICATION

2. SATELLITE COMMUNICATION

2.1 Define & Describe Satellite Orbital patterns and elevation (LEO, MEO & GEO) Categories
2.2 Describe the Concept of Geostationary Satellite , Calculate its height, Velocity & Round trip time delay & their Advantage & Disadvantage over other system.
2.3 State Satellite Frequency Allocation and Frequency Bands.
2.4 Describe General structure of satellite Link system (Uplink, Down link, Transponder, Crosslink)
2.5 Explain the operation of Direct Broadcast System (DBS)
2.6 Explain the operation of VSAT system.
2.7 Define Multiple Accessing & Name Various Types.
2.8 Discuss the Time Division Multiple Accessing (TDMA) & Code Division Multiple Accessing (CDMA) & it's Advantages & Disadvantages.
1.9 Describe Satellite Application- Communication, Satellite, Digital Satellite Radio.
1.10 Explain GPS Receiver & Transmitter.

❖ INTRODUCTION: -

- The basic elements of satellite communication systems are : -
  - ♣ Earth Stations
  - ♣ Terrestrial Systems
  - ♣ Users
- The basic Structure of a Satellite Comm Systems is shown in Fig.
- It consists of many earth stations on the ground and these are linked with a satellite in space.
- The user is connected to the earth station through a terrestrial network and this network may be a telephone switch or dedicated link to earth station.
- The user generates a baseband signal that is preceded through a terrestrial network & transmitted to a satellite at the earth station.
- The satellite consists of a large number of repeaters in space, that receives the modulated RF carrier in its uplink frequency spectrum from all the earth stations in the network, amplifies these carriers and retransmits them back to the earth stations in the down link frequency spectrum.
- To avoid interference download frequency spectrum should be different from uplink frequency spectrum
- The signal at the receiving earth station in processed to get back the base band signal, it is sent to user through a terrestrial network.



[Basic Structure of Satellite Communication System]

- Commercial communication satellites use a frequency band of 500 MHz, bandwidth near **6 GHz** for uplink transmission and another 500 MHz bandwidth near **4GHz** for downlink transmission.
- The 500MHz allocation of frequency is usually divided into 12 channels of approximately 40 MHz each.
- Modern communication satellite also employ frequency reuse concept to increase the number of transponders in the allotted bandwidth. The baseband signal from the terrestrial network is processed through the encoder and modulator, then it is converted to uplink frequency.
- Finally it is amplified by high power amplifier and directed towards the appropriate part of antenna.
- The signal received from satellite is processed through Low Noise Amplifier & then is down converted, demodulated by demodulator and decoded by decoder, thus the original baseband signal is obtained.

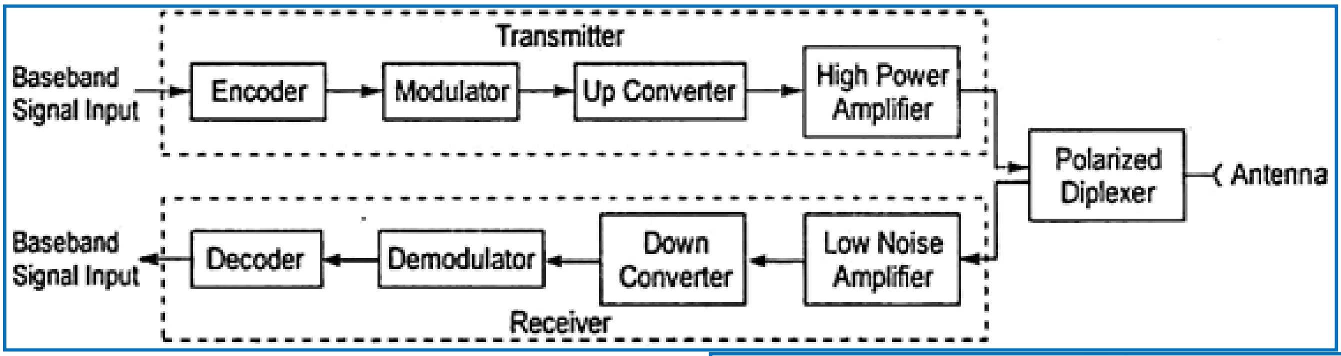
♣ Advantages of 6/4 GHz Band

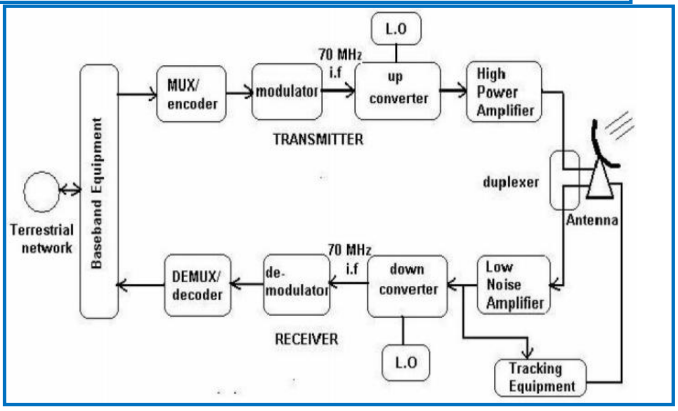
- ✓ No absorption by the rain
- ✓ Less propagation problems
- ✓ Broad beam width
- ✓ Attenuation is low
- ✓ Sky noise is low
- ✓ Null Polarization effect

♣ Disadvantages of 6/4 GHz Band

- ✓ Bandwidth is limited to 500Mhz only
- ✓ Interference from other user is more
- ✓ Direct reception in home TV is not easily possible we need big sized parabolic dish antenna.

- The basic block diagram of an earth station transmitter is shown in figure below.





- Earth station consists of **Three** subsystems
  - Transmitter Subsystem
  - Receiver Subsystem
  - Antenna Subsystem
- The baseband signal from the terrestrial network enters to the earth station at the **Transmitter** & the signal to be transmitted is converted to uplink frequency with proper encoding and modulation.
- It consists of **Encoder**, **Modulator**, **Up-converter**, **High power amplifier** etc as shown in above fig.
- Firstly the input baseband signal fed to the encoder at which the weak baseband signal is encoding to appropriate range and fed to the modulator.
- The **modulator** modulates the signal with proper change of amplitude, phase, frequency of the signal with low noise & destruction and fed to the up converter. **Up converter** converts the normal frequency to a suitable uplink frequency and provides better gain and bandwidth.
- The earth station requires transmission of microwave power so the use high power amplifiers such as travelling wave tube, klystrone amplifier etc.
- Then the **HPAs** output may be combined through band pass filter and fed to the transmitting antenna.
- **Receiver** of an earth station employ mainly low noise amplifier (**LNA**), **down converter**, **demodulator**, **decoder** and baseband signal **processing** unit.
- The signal received from the satellite is amplified in a LNA and then down converted to the downlink frequency. It is then demodulated and decoded and the original base band signal is obtained.
- It is very essential that the receiver should have 1st stage with very low noise and sufficient high gain.

♣ **<u>NOTE</u>: -The Downlink frequency to be Lower than the Uplink Frequency, Why???**

a) Output power amplifier in transponder. **c)** Path loss.
b) Effective area of the receiving antenna. **d)** Beam width.

♣ ADVANTAGES OF SATELLITE COMMUNICATION: -

- Point to multipoint communication is possible whereas terrestrial relay are point to point.
- This is why satellite relays are wide area broadcast.
- Circuits for the satellite can be installed rapidly. Once the satellite is in position, earth stations can be installed and communication may be established within some days or even hours.
- During critical conditions earth stations may be removed relatively quickly from a location and reinstalled somewhere else. The sending and receiving information is independent of distance.
- Mobile communications can be easily achieved by the satellite communication because of its flexibility in interconnecting mobile vehicles.
- Satellite communication has economical advantage i.e. the satellite cost is independent of the distance.
- As compared to fiber optic cable, the satellite communication has the advantage of the quality of transmitted signals and the location of earth stations.

♣ DISADVANTAGES OF SATELLITE COMMUNICATION: -

- With the satellite in position the communication path between the terrestrial transmitter and the receiver is approximately 75000 km long. → There is a delay of ¼ sec between the transmission and reception of a signal because the velocity of electromagnetic wave is 3×10^8 m/sec.
- This delay produces Echo which is actually caused by an imperfect impedance matching.
- The time delay reduces the efficiency of satellite in data transmission and long file transfer, which carried out over the satellites. → Over-crowding of available bandwidths due to low antenna gains.
- High atmospheric losses above 30 GHz limit the carrier frequencies.

❖ APPLICATIONS OF SATELLITE COMMUNICATION: -

- The number of operational and planned satellite communications system in growing very rapidly. Some of the satellite applications are:
  - **(A)** Communication Satellite
  - **(B)** Remote sensing Satellite
  - **(C)** Military Satellite
  - **(D)** Weather Satellite
  - **(E)** Positioning Satellite

❖ SATELLITE FREQUENCY ALLOCATION AND BAND SPECTRUM:-

- Allocating frequencies to satellite services is a complicated process which requires international coordination and planning.
- It is carried out under the guidance of the **I**nternational **T**elecommunication **U**nion (ITU).
- To facilitate frequency planning, the world is divided into three regions: -
  - **Region 1**: Europe, Africa, what was formerly the Soviet Union and Mongolia.
  - **Region 2**: North and South America and Greenland.
  - **Region 3**: **ASIA**, Australia and the South West pacific.
- Within these regions frequency bands are allocated to various satellite services, although a given service may be allocated different frequency band in different regions.
- Some of the Services provided by Satellites.
  - **(A)** Fixed Satellite Services (**FSS**)
  - **(B)** Broadcasting Satellite Service (**BSS**)
  - **(C)** Mobile Satellite Service (**MSS**)
  - **(D)** Navigation Satellite Service (**NSS**)
  - **(E)** Metrological Satellite Service (**MLSS**)
- The six frequency bands that have been allocated for the use with satellite communication are given as,

FREQUENCY BAND FOR SATELLITE COMMUNICATION

SN	BAND	DOWNLINK BAND (MHZ)	UPLINK BAND (MHZ)
1	UHF - Military	250 - 270 (Appx.)	292 - 312 (Appx.)
2	**C Band - Commercial**	3700 – 4200 (**4 GHz**)	5925 – 6425 (**6 GHz**)
3	X Band - Military	7250 - 7750	7900 - 8400
4	Ku Band - Commercial	11700 - 12200	14000 - 14500
5	Ka Band - Commercial	17700 - 21200	27500 - 30000
6	Ka Band - Military	20200 - 21200	43500 - 45500

❖ SATELLITE ORBITAL PATTERNS

- Initially, Newton's laws of motion can be summarized into four equations : -
  - ♣ $S = ut + \frac{1}{2} at^2$
  - ♣ $V^2 = u^2 + 2at$
  - ♣ $V = u + at$
  - ♣ $F = m\,a$

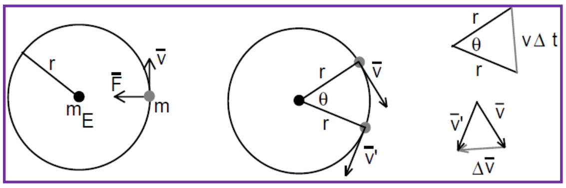
  Where, m → **Mass** of the Object
  a → **Acceleration** of the Object
  F → **Force** acting on the Object
  S → The Distance Travelled from time t =0
  u → **Initial Velocity** of the object at time t = 0
  V → **Final Velocity** of the Object at time t = 0
- In a stable orbit there are **Two Main** forces acting on a satellite
  - ♣ A **Centrifugal Force** due to the kinetic energy of the satellite which attempts to fly the satellite into a higher orbit.
  - ♣ A **Centripetal Force** due to gravitational attraction of the planet about which the satellite is orbiting, which attempts to pull the satellite down towards the planet.
- In order to remain the satellite in stable orbit these two Forces must be equal to each other. (**F = m x a**)
- The acceleration due to gravity at a distance r from the centre of earth is $\mathbf{a = \mu / r^2}$ **km/s²**
- Where **μ**→Product of Universal Gravitational Constant **(G)** & mass of the Earth ($\mathbf{M_E}$). Thus $\mathbf{\mu = G \times M_E}$

- It is called **Kepler Constant** and has the value 3.986004418 x 10^5 km^3/s^2. [G = 6.672 x 10^{-11} Nm^2/Kg^2]
- The **Centripetal Force** acting on the Satellite $\mathbf{F_{IN} = m \times (\mu/r^2)}$ ➔ $\mathbf{F_{IN} = m \times (GM_E/r^2)}$
- The centrifugal acceleration is given by, a = V^2 /r. Thus the Force acting on Satellite $\mathbf{F_{OUT} = m \times V^2/r}$
- If the forces on the satellite are balanced $F_{IN} = F_{OUT}$ ➔ m x (μ/r^2) = m x V^2 /r ➔ $V = (\mu/r)^{1/2}$
- If the orbit is circular the distance travelled by a satellite in one orbit around a planet is 2πr, where r is the radius of the orbit from the satellite to the centre of the planet.
- Since distance divided by velocity equal time to travel that distance, the period of the satellite's orbit T is

  $T = 2\pi r / V = 2\pi r / (\mu/r)^{1/2}$ ➔ $\mathbf{T = (2\pi r^{3/2})/(\mu)^{1/2}}$
- The use of satellites as platforms for remote sounding is based on some very fundamental physics.
- Newton's Laws of Motion and Gravitation.

Ψ **LAWS OF MOTION: -**

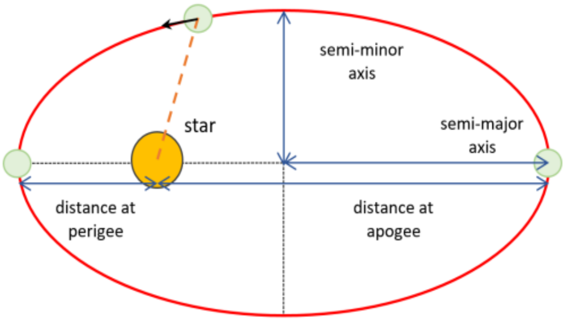
1) Everybody continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by a force impressed upon it.
2) The rate of change of momentum is proportional to the impressed force and is in the same direction as that force. Momentum = Mass × Velocity, so Law (2) becomes $\mathbf{F = \frac{d(mv)}{dt} = m\frac{d(v)}{dt} = m\,a}$



3) For every action, there is an equal & opposite reaction.

Ψ **LAW OF GRAVITATION: -**

1) The force of attraction between any two particles is
   - **a)** Proportional to their masses
   - **b)** Inversely proportional to the square of the distance between them , $\mathbf{F = \frac{Gm_1m_2}{r^2}}$



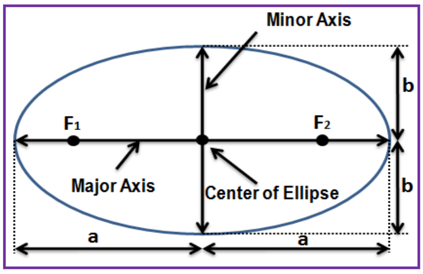
❖ KEPLER'S LAWS FOR ORBITS

- So far, we have assumed that satellites travel in circular orbits, but this is not necessarily true in practice.
- Newton's Laws can be used to derive the exact form of a satellite's orbit.
- However, a simpler approach is to look at Kepler's Laws, which summarize the results of the full derivation. Kepler's Laws were based on observations of the motions of planets.
  - ♣ All planets travel in Elliptical orbits with the Sun at one focus. (→ Defines the shape of orbits)
  - ♣ The radius from the Sun to the planet sweeps out equal areas in equal times.
    → Determines how orbital position varies in time
  - ♣ The square of the period of a planet's revolution is proportional to the cube of its semi-major axis.
    → Suggests that there is some systematic factor at work
- For Satellites Communication, substitute "Satellite" for **Planet** and "Earth" for **Sun**.

❖ **KEPLER'S THREE LAW OF PLANETARY MOTION:-**

(A) The orbit of any smaller body about a larger body is always an ellipse, with centre of mass of larger body as one of two foci. **(B)** The orbit of smaller body sweeps equal areas in equal interval of time.
(C) The square of the period of revolution of the smaller body about the larger body equals a constant multiplied by the third power of the semi major axis of the orbital ellipse. $\mathbf{T^2 = 4\pi^2a^3/\mu}$

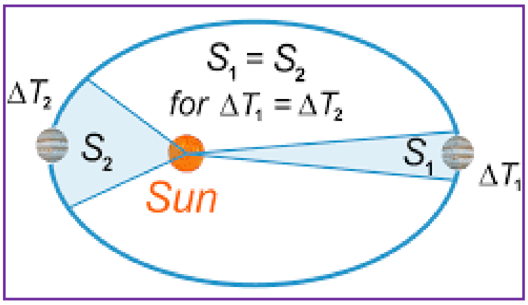
(A) Kepler's First Law: -



- It states that, "The path followed by a satellite around the primary will be an ellipse." An ellipse has two focal points F_1 & F_2 in figure.
- The centre of the mass of the two body system, termed the body centre, is always centered on one of the foci.
- The semi major axis is denoted by '**a**' and semi minor axis is by '**b**'.
- The eccentricity 'e' is given by, $\mathbf{e = \frac{\sqrt{a^2 - b^2}}{a}}$

- The eccentricity and semi major axis are two of the orbital parameters specified for satellite (spacecraft) orbiting the earth. For $0 < e < 1 \rightarrow$ **Elliptical** Orbit **and** If $e = 0 \rightarrow$ **Circular** orbit.

(B) Kepler's Second Law: -



- It states that, "For equal time intervals, a satellite will sweep out equal areas in its orbital plane, focused at body centre".
- Assuming that the satellite travels distances S_1 & S_2 meters in 1 sec, then areas $\mathbf{A_1 = A_2}$
- The average velocity in each case is S_1 and S_2 meters per sec and because of the equal area law, it follows that the velocity at S_2 is less than at S_1.

(C) Kepler's Third Law: -

- It states that, "The Square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies." The mean distance is equal to semi-major axis (a), So, $\mathbf{a^3 = \frac{\mu}{n^2}}$

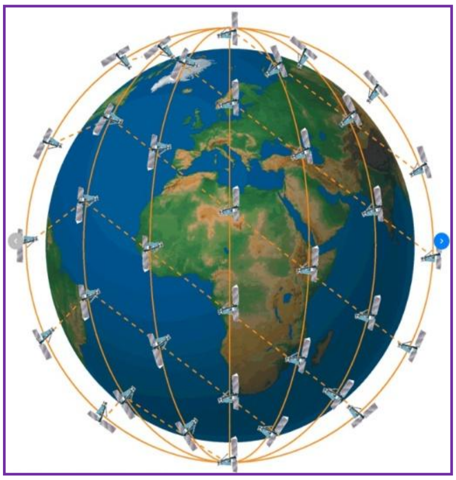
  Where, **n** = Mean motion of the satellite in radians/sec.

  μ = Earth's geocentric gravitational constant = 3.98×10^{14} m^3/sec^2 with n in radians per second.

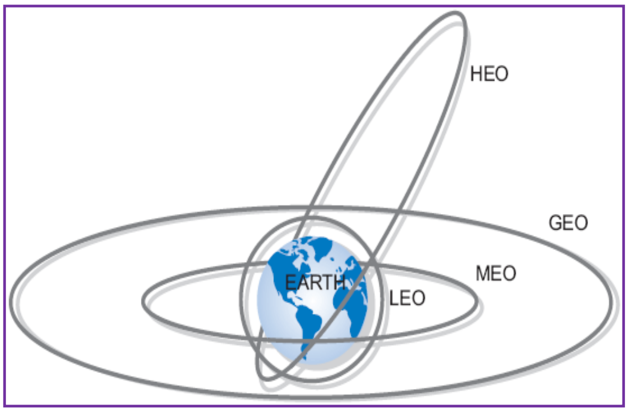
- The orbital period in sec is given by $\mathbf{T = \frac{2\pi}{n}}$ **So,** $\mathbf{T = 2\pi\sqrt{\frac{a^3}{\mu}}}$

❖ ORBITAL ELEVATION (LEO, MEO & GEO) CATEGORIES

Ψ LEO Basics (Lower Earth Orbit)

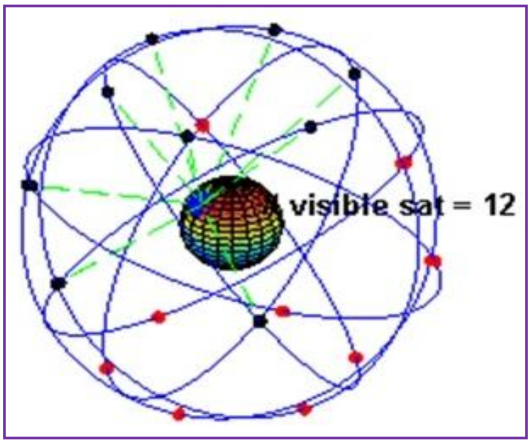


- With LEO extending from 200 km to 1200 km it means that it is relatively low in altitude, although well above anything that a conventional aircraft can reach.
- However LEO is still very close to Earth, especially when compared to other forms of satellite orbit including geostationary orbit.
- The low orbit altitude of leads to a number of characteristics:
  - ♣ Orbit times are much less than many other forms of orbit.
  - ♣ The lower altitude means higher velocities are required to balance the earth's gravitational field.
  - ♣ Typical velocities are very approximately around 8 km/s, with orbit times sometimes of the order of 90 minutes, although these figures vary considerably with the exact details of the orbit.
  - ♣ The lower orbit means the satellite and user are closer together and therefore path losses a less than for other orbits such as GEO. The round trip time, RTT for the radio signals is considerably less than that experienced by geostationary orbit satellites.
  - ♣ The actual time will depend upon factors such as the orbit altitude and the position of the user relative to the satellite. Radiation levels are lower than experienced at higher altitudes.
  - ♣ Less energy is expended placing the satellites in LEO than higher orbits.
  - ♣ Some speed reduction may be experienced as a result of friction from the low, but measurable levels of gasses, especially at lower altitudes.
  - ♣ An altitude of 300 km is normally accepted as the minimum for an orbit as a result of the increasing drag from the presence of gasses at low altitudes.



Ψ Applications for LEO Satellites

- A variety of different types of satellite use the LEO orbit levels. These include different types and applications including:
  - ♣ Communications satellites - Some communications satellites including the Iridium phone system use LEO. Earth monitoring satellites use LEO as they are able to see the surface of the Earth more clearly as they are not so far away.



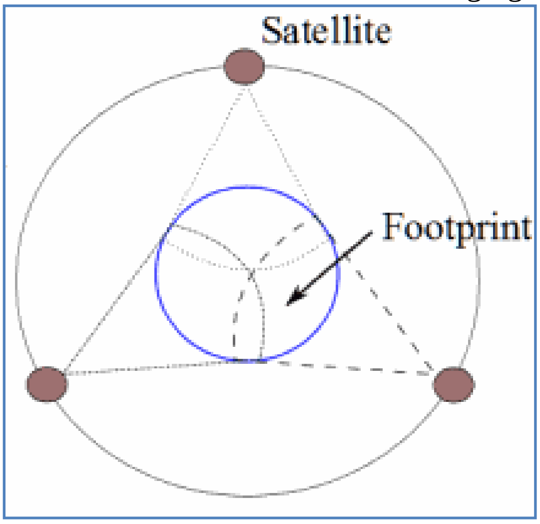
- They are also able to traverse the surface of the Earth.
- The International Space Station is in an LEO that varies between 320 km (199 miles) & 400 km (249 miles) above the Earth's surface. It can often be seen from the Earth's surface with the naked eye.

Ψ MEO Basics (Middle Earth Orbit)

- A Medium Earth Orbit (MEO) satellite is one with an orbit within the range from a few hundred miles to a few thousand miles above the earth's surface.
- Satellites of this type orbit higher than Low Earth orbit Satellites, but lower than Geostationary satellites.
- Orbital periods of MEO satellites range from about 2-12 hours.
- Some MEO satellites orbit in near perfect circles, thus have constant altitude & travel at a constant speed
- Other MEO satellites revolve in elongated orbits.
- The **perigee** of an elliptical-orbit satellite is much less than its **apogee**.
- The orbital speed is much greater near perigee than near apogee.

Ψ **Perigee→** The point in the Orbit where the Satellite is **Closest** to the earth, **Apogee→Farthest** from Earth

- As seen from a point on the surface, a satellite in an elongated orbit crosses the sky in just a few minutes when it is near perigee, as compared to several hours when it is near apogee.
- Elliptical-orbit satellites are easiest to access near apogee, because the earth-based antenna orientation does not have to be changed often, & satellite is above horizon for a fairly long time
- A fleet of several MEO satellites with orbits properly co-ordinated can provide global wireless communication coverage. As MEO satellites are closer to the earth than geostationary satellites, earth based transmitters with relatively low power & medium sized antenna can access system.
- Because MEO satellites orbit at higher altitudes than LEO satellites, the useful footprint (coverage area on the earth's surface) is greater for each satellite.
- Thus a global-coverage fleet of MEO satellites can have fewer members than a global-coverage fleet of LEO satellites. One very popular orbit format is the geostationary satellite orbit.
- The geostationary orbit is used by many applications including direct broadcast as well as communications or relay systems.
- The Geostationary Orbit has the advantage that the satellite remains in the same position throughout the day and antennas can be directed towards the satellite and remains on track.
- This factor is of particular importance for applications such as direct broadcast TV where changing directions for the antenna would not be practicable.
- It is necessary to take care over the use of the abbreviations for geostationary orbit. Both GEO and GSO are seen, and both also used for geosynchronous orbit.

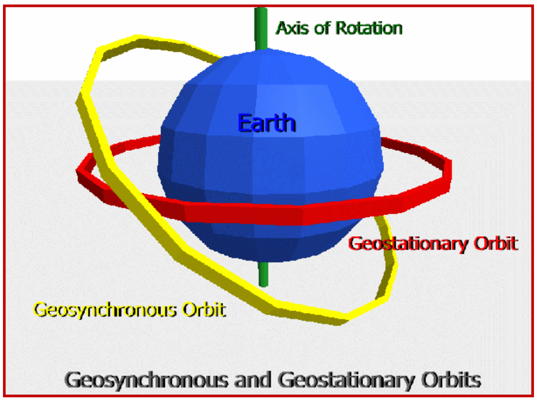


Ψ GEO (Geo Stationary Earth Orbit)

- The idea of a this orbit has been postulated for many years.
- One of the possible originators of the basic idea was a Russian theorist and science fiction writer, Konstantin Tsiolkovsky.
- However it was Herman Oberth and Herman Potocnik who wrote about orbiting stations at an altitude of 35 900 km above the Earth that had a rotational period of 24 hours making it appear to hover over a fixed point on equator.
- The next major step forwards occurred when Arthur C Clarke, the science novel writer, published a serious article in Wireless World, a major UK electronics and radio publication, in October 1945.
- The article was entitled "Extra-Terrestrial Relays: Can Rocket Stations Give World Coverage?" Clarke extrapolated what could be done with the German rocket technology of the day and looked at what might be possible in the future. He postulated that it would be possible to provide complete global coverage with just three geostationary satellites.

❖ GEOSTATIONARY AND GEOSYNCHRONOUS SATELLITE: -

- To be perfectly a **Geostationary** the orbit of a Satellite need to have three features: -
  - It Must be Exactly Circular
  - It must be at the Correct Altitude
  - It must be at the Plane of the Equator



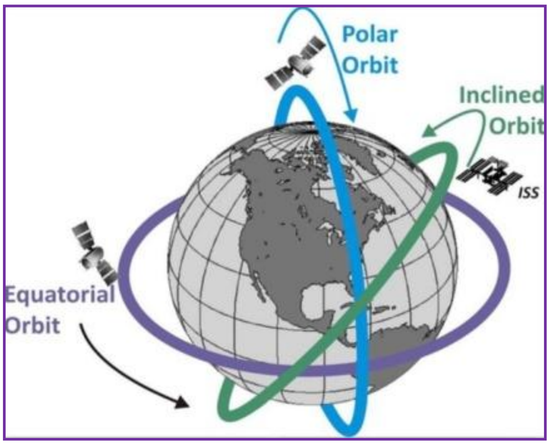
- **Geosynchronous Satellite**
  - If the inclination and eccentricity is not zero (not circular) but the orbital period or altitude is correct than the satellite is Geo Synchronous Orbit.
  - The position of a Geosynchronous Satellite will appear to oscillate about a mean look angle in the sky with respect to a stationary observer on the earth surface.

Ψ SIDEREAL DAY

- The orbital period of a Geo satellite **23 h 56 min 4.1 Sec** is one Sidereal day.
- It is the time between consecutive crossings of particular longitude on earth by any star **other than Sun**.
- **Solar day** is 24 h is the time between any consecutive crossings of any particular longitude by the **Sun**.
- Because of earth moves round the sun once per 365 ¼ days, the solar day is 1440/365.25 = **3.94 min Longer** than that of a Sidereal day.

Ψ GEOSTATIONARY ORBIT BASICS

- As the height of a satellite increases, so the time for the satellite to orbit increases.
- At a height of 35790 km, it takes 24 hours for the satellite to orbit.
- This type of orbit is known as a **Geosynchronous** Orbit, i.e. it is synchronized with the Earth.
- One particular form of geosynchronous orbit is known as a geostationary orbit. In this type of orbit the satellite rotates in the same direction as the rotation of the Earth & has an approximate 24 hour period.



- This means that it revolves at the same angular velocity as the Earth and in the same direction and therefore remains in the same position relative to the Earth.
- In order to ensure that the satellite rotates at exactly the same speed as the Earth, it is necessary to clarify exactly what the time is for the rotation of the Earth.
- For most timekeeping applications, the Earth's rotation is measured relative to the Sun's mean position, and rotations of the earth combined with the rotation around the Sun provide the length of time for a day.
- However this is not the exact rotation that we are interested in to give a geostationary orbit - the time required is just that for one rotation.
- This time period is known as a sidereal day and it is 23 hours 56 minutes and 4 seconds long.
- Geometry dictates that the only way in which an orbit that rotates once per day can remain over exactly the same spot on the Earth's surface is that it moves in the same direction as the earth's rotation.
- Also it must not move north or south for any of its orbit. It can only occur if it remains over the equator.
- Different orbits can be seen from the diagram. As all orbital planes need to pass through the geo-centre of the Earth, the two options available are shown.
- Even if both orbits rotate at the same speed as the Earth, the one labelled geosynchronous will move north of the equator for part of the day, and below for the other half - it will not be stationary.
- For a satellite to be stationary, it must be above the Equator.

Ψ GEOSTATIONARY SATELLITE DRIFT

- Even when satellites are placed into a geostationary orbit, there are several forces that can act on it to change its position slowly over time. Factors including the earth's elliptical shape, the pull of the Sun and Moon and others act to increase the satellite orbital inclination.

- In particular the non-circular shape of the Earth around the Equator tends to draw the satellites towards two stable equilibrium points, one above the Indian Ocean and the other very roughly around the other side of the World. This results in what is termed as an east-west libration or movement back and forth.
- To overcome these movements, fuel is carried by the satellites to enable them to carry out "station-keeping" where the satellite is returned to its desired position.
- The period between station-keeping man oeuvres is determined by the allowable tolerance on the satellite which is mainly determined by the ground antenna beam width.
- This will mean that no re-adjustment of the antennas is required.
- Often the useful life of a satellite is determined by the time for which fuel will allow the station-keeping to be undertaken. Often this will be several years. After this the satellite can drift towards one of the two equilibrium points, and possibly re-enter the Earth's atmosphere.
- The preferred option is for the satellites to utilize some last fuel to lift them into a higher and increasing orbit to prevent them from interfering with other satellites.

Ψ **Geostationary Orbit Coverage**

- A single geostationary satellite obviously cannot provide complete global coverage.
- However, a single geostationary satellite can see approximately 42% of the Earth's surface with coverage falling off towards the satellite is not able to "see" the surface.
- This occurs around the equator and also towards the polar regions.
- For a constellation of three satellites equally spaced around the globe, it is possible to provide complete coverage around the equator and up to latitudes of 81° both north and south.
- The lack of polar coverage is not a problem for most users, although where polar coverage is needed, satellites using other forms of orbit are needed.

Parameter	LEO	MEO	GEO
Satellite Height	500-1500 km	5000-12000 km	35,800 km
Orbital Period	10-40 min.	2-8 hours	24 hours
Number of Satellites	40-80	8-20	3
Satellite Life	Short	Long	Long
Number of Handoffs	High	Low	Least(none)
Gateway Cost	Very expensive	Expensive	Cheap
Propagation Loss	Least	High	Highest

Ψ **HEIGHT, VELOCITY & ROUND TRIP TIME DELAY: -**

- **Height** of GEO satellite can be given as **r** (orbit radius) = $\mathbf{r_e}$ (Radius of the Earth) **+ h** (Height)
- **Round trip time delay** is given as $\mathbf{T = (2\pi r^{3/2})/(\mu)^{1/2}}$ & **Velocity** can be calculated as: - $\mathbf{V = (\mu/r)^{1/2}}$

1. **EXAMPLE: -** A Satellite is at an altitude of 250km above the earth surface. The mean earth's radius is approximately 6378.14km. Find the period of the satellite also fine the linear velocity for a circular path.

Ψ **SOLUTION: -** The radius of the satellite is $r = r_e + h$ = 6378.14 + 250.00 = **6628.14** km

The period of the orbit is $T = \mathbf{(2\pi r^{3/2})/(\mu)^{1/2}}$ **= 5370.30 s = 89 min 30.3 sec**

The velocity, $\mathbf{v = 2\pi a/T}$ = 41,645.83/5370.13 = 7.755 km/s [Where, $2\pi a$ = Circumference]

Alternatively, $\mathbf{V = (\mu/r)^{1/2}}$ **= 7.755km/s** [Where $\mu = 3.986004418 \times 10^5\ km^3/s^2$]

2. **EXAMPLE: -** Determine the orbital velocity of a satellite moving in a circular orbit at a height of 150km above the surface of earth given that gravitation constant, $G = 6.67 \times 10^{-11}\ N\text{-}m^2/kg^2$, mass of earth , $M = 5.98 \times 10^{24}$ kg, radius of earth R_e = 6370 km.

Ψ **SOLUTION: -** The orbital velocity (V) is given by, $V = \sqrt{\mu/(R + H)}$

Where $\mu = GM = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} = 39.8 \times 10^{13}$; R = 6370 km = R_e ; H = 150km

$V = \sqrt{39.8 \times 10^{13} /(6370 + 150) \times 10^{13}}$ = 7.813 Km/S

3. **EXAMPLE: -** A satellite in an elliptical orbit has an apogee of 30,000 km and a perigee of 1000km. determine the semi-major axis of the elliptical orbit.

Ψ **SOLUTION: -** Semi-major axis = $\frac{\text{Apogee} + \text{Perigee}}{2} = \frac{30000 + 1000}{2}$ = 15500Km

4. **EXAMPLE: -** A satellite moving in an elliptical eccentric orbit has the semi major axis of the orbit equal to 16000 km. if the difference between apogee & the perigee is 30,000 km, Find orbit eccentricity.

Ψ **SOLUTION: -** Apogee = a(1+e) ; Perigee = a (1-e)
Where a = semi-major axis of the ellipse; e = orbit eccentricity
Apogee – Perigee = a(1+e) - a(1-e) = 2ae ➔ Or Eccentricity, e = $\frac{\text{Apogee} - \text{Perigee}}{2a}$
Here it is given that difference between apogee and the perigee = 30,000 km.
Semi major axis of the orbit = 16000 km. ➔ e = $\frac{30000}{2x16000} = \frac{30000}{32000}$ = 0.93

5. **EXAMPLE: -** The farthest and the closest points in a satellite's elliptical eccentric orbit from earth's surface are 30,000 km and 200 km respectively. Determine the apogee and the perigee and the orbit eccentricity. Assume radius of earth to be 6370 km.

Ψ **SOLUTION: -** Apogee = 30000 + 6370 = 36370 km (farthest point + R_e)
Perigee = 200 + 6370 m (closest points + R_e) ; Eccentricity, e = $\frac{\text{Apogee} - \text{Perigee}}{2a}$
Also a = $\frac{\text{Apogee} + \text{Perigee}}{2}$ or 2a = Apogee + Perigee; Where a = semi-major axis of the ellipse
Therefore, orbit eccentricity = $\frac{\text{Apogee} - \text{Perigee}}{\text{Apogee} + \text{Perigee}} = \frac{36370 - 6570}{36370 + 6570} = \frac{29800}{42940}$ = 0.693

6. **EXAMPLE: -** Refer to figure showing a satellite moving in an elliptical, eccentric orbit. Determine the apogee and the perigee distances if the orbit eccentricity is 0.5. <From Fig ae =1400 >

Ψ **SOLUTION: -** The distance from centre of ellipse (0) to the centre of earth (c) is given by (a x e). where (a) is the semi-major axis and (e) is the eccentricity. Therefore, a x e = 14000; a = $\frac{14000}{0.5}$ = 28000 km ; Now Apogee = a(1+e) = 28000 (1 + 0.5) = 42000 km. Perigee = a(1-e) = 28000 (1 - 0.5) = 14000 km

7. **EXAMPLE: -** Satellite-1 in an elliptical orbit has the orbit semi-major axis equal to 18000 km and satellite-2 in an elliptical orbit has the semi-major axis equal to 24000 km. Determine the relationship between their orbital periods.

Ψ **SOLUTION: -** The orbital time period (T) is given by, T = $2\pi\sqrt{a^3/\mu}$
Where μ = GM ; G = Earth's gravitational constant; M = mass of earth; a = semi-major axis of ellipse
If (a_1) and (a_2) are the values of the semi-major axis of the ellipse orbits of the satellites 1 and 2, (T_1) & (T_2) are the corresponding orbital periods, then $T_1 = 2\pi\sqrt{a_1{}^3/\mu}$ and $T_2 = 2\pi\sqrt{a_2{}^3/\mu}$
$T_2/T_1 = (a_1/a_2)^{3/2} = \frac{24000}{18000}^{3/2} = (4/3)^{3/2} = 1.54$; so $T_2 = 1.54\, T_1$
Thus orbital period of satellite – 2 is 1.54 times the orbital period of satellite- 1.

8. **EXAMPLE: -** The sum of apogee and perigee distances of a certain elliptical satellite orbit is 50000 km and the difference of apogee and perigee distances is 30000 km. determine the target eccentricity (e).

Ψ **SOLUTION: -** If (r_a) & (r_p) are apogee and perigee distances respectively, then e = $\frac{r_a - r_p}{r_a + r_p} = \frac{30000}{50000}$ = 0.6.

❖ SATELLITE FREQUENCY ALLOCATION AND FREQUENCY BANDS.

Ψ WHAT IS FREQUENCY MANAGEMENT

- **Combination** of administrative, scientific and technical procedures to ensure efficient operation of the various radio-communication services without causing harmful interference.
- It has national and international aspects.
- **Allocation** (of a frequency band):- Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radio-communication services or the radio astronomy service under specified conditions.
- This term shall also be applied to the frequency band concerned.

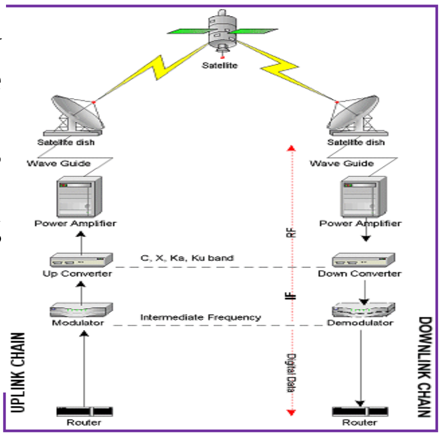
Frequency Allocations For Satellite Services or Fixed Satellite Service (FSS) (Frequency Bands)
✓ 5925-6425 MHz for UP-LINK (C-BAND)

Ψ RADIO FREQUENCY SPECTRUM

- Radio **Frequency** Spectrum (RFS) and associated satellite orbits, including Geostationary-Satellite Orbit (GSO) are limited natural resources.
- Radio waves are defined as electromagnetic waves of frequencies arbitrarily from 3 kHz to 3000 GHz, propagated in space without artificial guide. Radio **frequency** waves do not respect geographical boundary, and these cannot be confined to national boundaries.

- ✓ 3700-4200 MHz for DOWNLINK (C BAND)
- ✓ 6725-7075 MHz for UPLINK (Upper EXT C)
- ✓ 4500-4800 MHz for DOWNLINK (Upper EXT C)
- ✓ 6425-6725 MHz for UPLINK (Lower EXT-C)
- ✓ 3400-3700 MHz for DOWNLINK (Lower EXT-C)
- ✓ 10.95 - 11.2 GHz (Down-links)
- ✓ 11.45 - 11.7 GHz (Down-links)
- ✓ 11.7 - 12.2 GHz (Down-links) (Region 2 only)
- ✓ 12.5 - 12.75 GHz (Down-links) (Region 1 only)
- ✓ 14.0 - 14.5 GHz (Up-links)
- ✓ 17.7 - 21.2 GHz (Down-links)
- ✓ 27.5 - 31.0 GHz (Up-links)

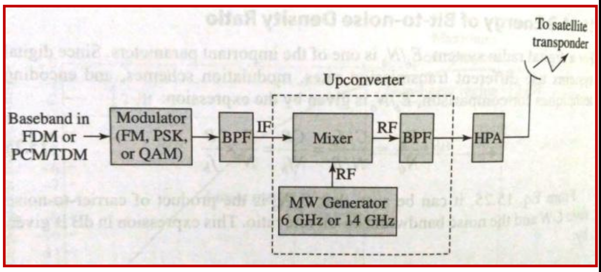
- Radio waves are susceptible to harmful interference and require application of complex engineering tools to ensure interference-free operation of various wireless networks.
- The **Utilization** of radio frequency spectrum is governed by international treaties, namely, the Constitution, the Convention and the Radio
- **Regulations** of the International Telecommunication Union (ITU) as well as by the bilateral agreements between two countries.
- All **frequency** bands are available for use in all countries, including India, in accordance with international table of Frequency allocations and associated radio regulatory provisions.
- National Frequency Allocation Plan forms basis for development, manufacturing and spectrum utilization activities in the country.



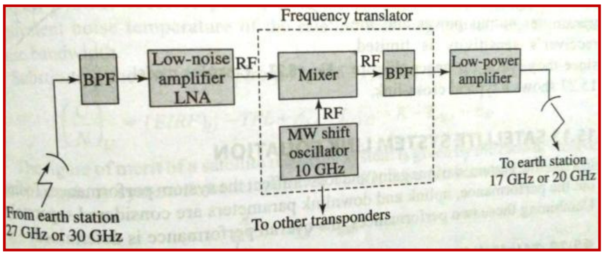
❖ General Structure Of Satellite Link System

- A satellite system consists of an uplink, a satellite transponder, and a downlink.

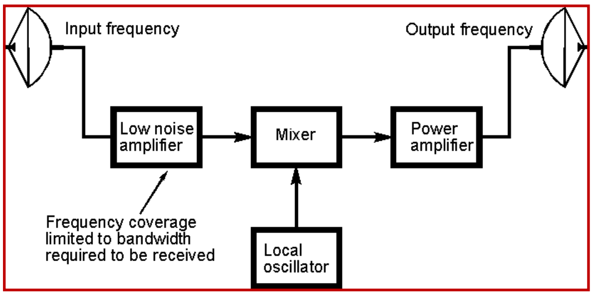
♣ DIGITAL SATELLITE UPLINK CHAIN



- The earth station transmitter is one of the primary components of the uplink station.
- Fig shows a typical satellite uplink model. It consists of an IF modulator, an upconverter used to convert IF to RF, a high-power amplifier HPA & BPF to band limit output.
- The IF modulator is used to convert the input base band signal to an FM, a QAM, or PSK modulated IF.
- Up converter is used to convert the modulated IF to a suitable RF with the help of a mixer.
- Band-pass filter is used to band limit the RF output and the required output power is provided to the transmitting antenna by the HPA (which is normally a klystron or a travelling wave tube).

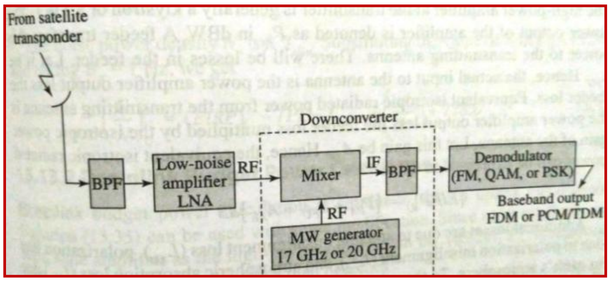


♣ SATELLITE TRANSPONDER:



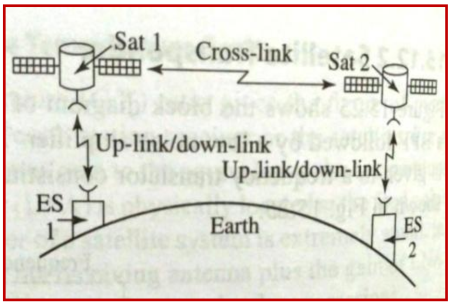
- Fig shows the block diagram of a satellite transponder.
- It consists of a BPF followed by a low-noise amplifier.
- The output of the LNA is given to a frequency translator consisting of a mixer & a local oscillator as shown in fig.
- The incoming uplink transmitted RF frequency is translated to a different RF frequency and is passed through a BPF to band limit the mixer output.
- A low-power amplifier, usually a TWT, amplifies the RF signal to be transmitted back to earth station by the transponder transmitting antenna. Different transponders are required for each RF satellite channel.

♣ DOWNLINK MODEL:



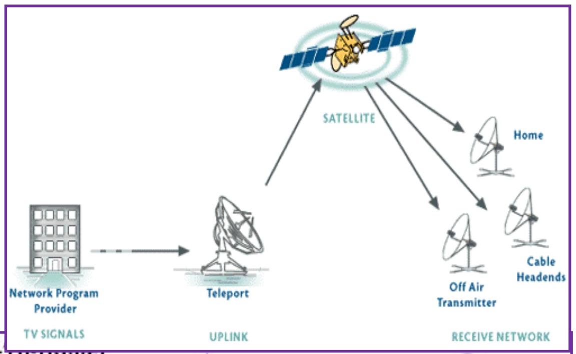
- Figure shows a satellite downlink model. It receives signal from the satellite transponder. The front end consists of a band-pass filter followed by a LNA.
- The received RF frequency is down converted to IF by down converter consisting of a mixer & local oscillator.
- The output of the mixer is band limited by a BPF and passed on to a demodulator.
- This type of demodulator depends on the modulation scheme used.
- The base band signal will be available at the output of the modulator.

♣ CROSSLINK:

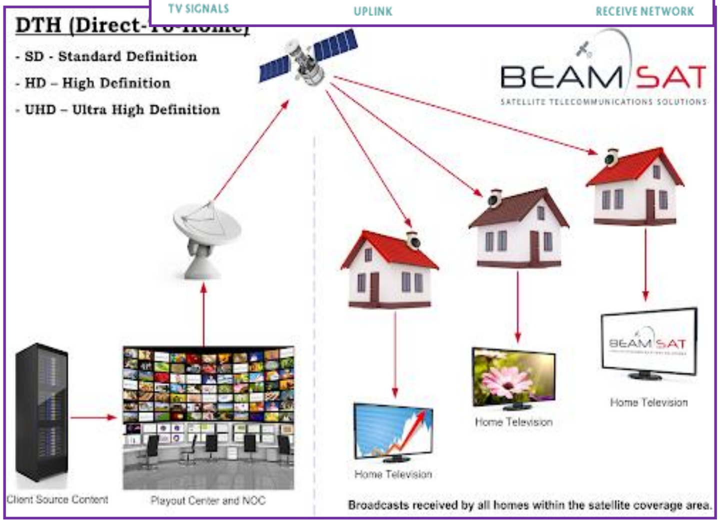


- Sometimes, communication between satellites is required. Satellite cross-links or inters satellite links (ISLs) are used for this purpose.
- The only disadvantages of ISLs are that, the transmitter output power and the receiver's sensitivity is limited, since they are in the space. Figure shows a typical cross-link.

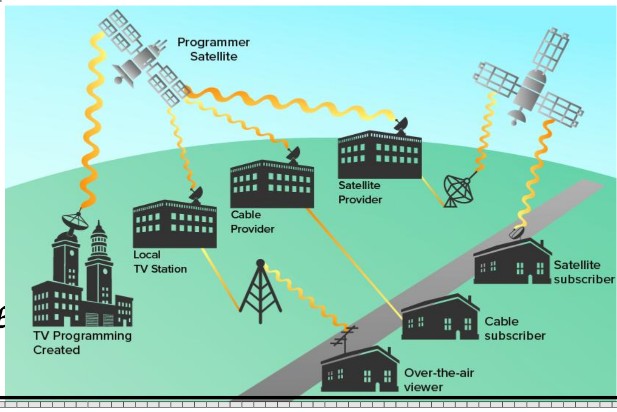
❖ The Operation Of Direct Broadcast System (DBS)



- Systems for transmitting television & other program material via satellite directly to individual homes.
- Direct broadcasting satellite (DBS) systems operate at microwave frequencies, in a portion of the Ku band; in North & South America these systems operate in the frequency 12.2–12.7 GHz.
- DBS systems use a satellite in geostationary orbit to receive television signals sent up from 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 the 17.3–17.8-GHz uplink band is transmitted back down in the 12.2–12.7-GHz 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.
- It is difficult to build receivers to operate at the microwave downlink frequencies, so the signal from the dish antenna is first passed to a down-converter, usually mounted outdoors on the antenna that shifts it to (typically) the 0.95–1.45-GHz band.
- This signal is then conducted by cable to the receiver atop the television set.

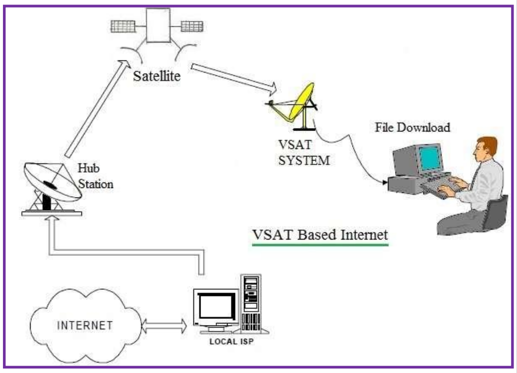


- The receiver contains the channel selector, as well as a decoder to permit the user to view authorized channels.
- The receiver is connected by an additional cable to the television set.
- A typical direct broadcasting satellite contains 16 transponders, or amplifiers, the maximum permitted

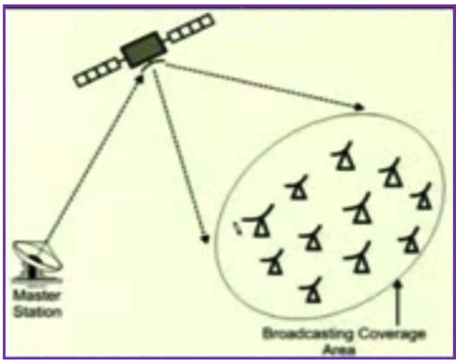
under present regulations, each with a radio-frequency power output in the range 120–240 W.

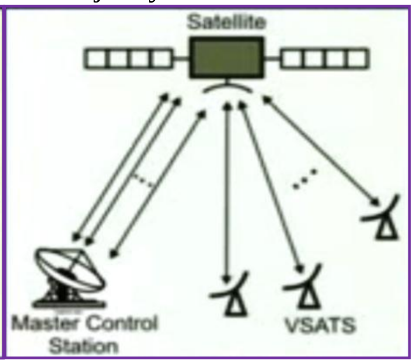
- Two or more direct broadcasting satellites may be located at any of the orbital locations assigned to the United States, for a maximum of 32 transponders.
- DBS satellites in the United States typically use digital signals; a single 24-MHz satellite transponder can carry an error-corrected digital signal of 30 megabits per second or greater.
- A wide variety of communications services can be converted to digital form and carried as part of this digital signal, including television, high-definition television (HDTV), stereo audio, one-way videoconference, information services (such as news retrieval services), and digital data.
- Modern digital signal compression technology greatly increases the capacity of a satellite transponder.
- It is possible to compress up to perhaps 10 television signals into the bandwidth of a DBS transponder, depending on the amount of motion in the picture and the amount of screen resolution required.
- Since some common programming (for example, sports) contains a good deal of motion, the average compression factor for a DBS system will typically be lower than 10. See Data compression
- DBS systems, like all satellite systems operating in the Ku band, are subject to attenuation of their signals by rain. The combination of satellite power and receive-dish antenna size is chosen to enable reception for all but the heaviest rainfall periods of the year, corresponding to an outage period of perhaps 7 h per year at any particular location. The DBS customer can further reduce this expected outage period by purchasing a slightly larger dish antenna.

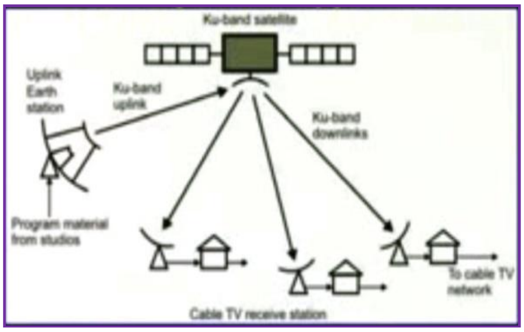
❖ THE OPERATION OF VSAT SYSTEM.



- A Very Small Aperture Terminal (VSAT) is a small telecommunication earth station that receives and transmits real-time data via satellite.
- A VSAT transmits narrow and broadband signals to orbital satellites. The data from the satellites is then transmitted to different hubs in other locations around the globe T.
- VSAT end users have a box that acts as an interface between the computer and the external antenna or satellite dish transceiver.
- The satellite transceiver sends data to and receives data from the geostationary satellite in orbit.
- The satellite sends and receives signals from an earth station, which acts as the hub for the system.
- Each end user is connected to this hub station through the satellite in a star topology.
- For one VSAT user to communicate with another, the data has to be sent to the satellite.
- Then the satellite sends the data to the hub station for further processing. The data is then retransmitted to the other user via a satellite. The majority of VSAT antennas range from 30 inches to 48 inches.







- Data rates typically range from 56 Kbps up to 4 Mbps. VSATs are most commonly used to transmit:
  - **Narrowband** data. This includes point of sale transactions such as credit card, polling or radio-frequency identification (RFID) data, or supervisory control and data acquisition (SCADA) data
  - **Broadband** data, for the provision of satellite Internet access to remote locations, Voice over Internet Protocol (VoIP) or video. VSATs are also used for transportable, on-the-move communications (using phased array antennas) and mobile maritime communications.

Ψ What Is a Very Small Aperture Terminal (VSAT)?

- A very small aperture terminal (VSAT) is a two-way ground station that transmits and receives data from satellites. A VSAT is less than three meters tall and is capable of both narrow and broadband data to satellites in orbit in real-time.
- The data can then redirected to other remote terminals or hubs around the planet.

Ψ KEY TAKEAWAYS

- Very small aperture terminal (VSAT) is a data transmission technology used for many types of data management and in high-frequency trading.
- VSAT can be used in place of a large physical network as it bounces the signal from satellites instead of being transported through physical means like an ethernet connection.
- Because the signal needs to bounce, there can be a latency issue that wouldn't exist with a physical network. However, most users feel this is the price you pay for remote access and less infrastructure, and consider it a fair trade. * Weather can adversely impact the efficacy of a VSAT network.

Ψ How a Very Small Aperture Terminal Works

- VSAT networks have a number of commercial applications, including perhaps most notably, enterprise resource management. The use of VSAT to track inventory was one of the many innovations Walmart pioneered in retail to effectively manage its vast inventory in real-time and reduce delivery costs between the warehouse and stores.
- Combined with the hub system of inventory storage, VSAT allowed Walmart to stock its stores more precisely and reduce how many times a product had to move between locations before being sold.
- Other manufacturers use VSAT to relay orders, check production figures real-time as well as other functions that are otherwise handled over a wired network.
- In fact, the National Stock Exchange (NSE) of India has one of the largest VSAT networks in the world and offers it as one of its connectivity options.
- VSAT offered the NSE a way to offer access in areas where wired options are limited.
- With the exception of the occasional sun outage due to solar radiation distorting signals from the satellite, the VSAT network has held up.

Ψ ADVANTAGES

- VSAT networks have a big advantage when it comes to deployment. Because the ground station is communicating with satellites, there is less infrastructure required to service remote locations.
- This was one of the reasons Walmart chose VSAT as it started out heavily leveraged to rural America where telecommunications infrastructure was less dense than in the cities.
- This has made VSAT networks an ideal choice for providing connectivity to remote work sites like exploratory drilling sites that need to relay daily drill logs back to headquarters.
- VSAT is also independent of local telecommunications networks, making it an ideal system to back up wired systems and reduce business recovery risk.
- If the wired network goes down, a business can still go on using the VSAT network.

Ψ DISADVANTAGES

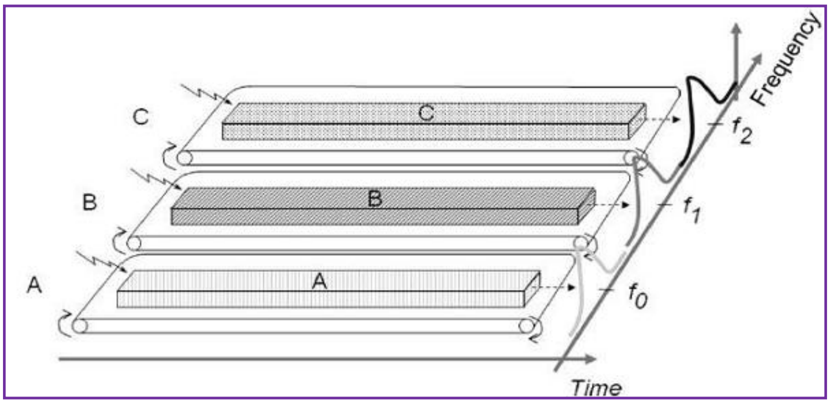
- VSAT does have limitations. The most obvious is latency, as it takes time for information to reach the dish and the station due to one part of the system being way up in geosynchronous orbit above the earth.
- So protocols that require a lot of back & forth communication rather than 1-way data transfer experience lag. The signal quality can also be affected by the weather and other buildings getting in the way.

❖ MULTIPLE ACCESSING & NAME VARIOUS TYPES.

- Sometimes a satellite's service is present at a particular location on the earth station and sometimes it is not present. That means, a satellite may have different service stations of its own located at different places on the earth. They send carrier signal for the satellite.
- In this situation, we do multiple access to enable satellite to take or give signals from different stations at time without any interference between them.
- Following are the three types of multiple access techniques: -
    - ♣ FDMA (Frequency Division Multiple Access)
    - ♣ TDMA (Time Division Multiple Access)

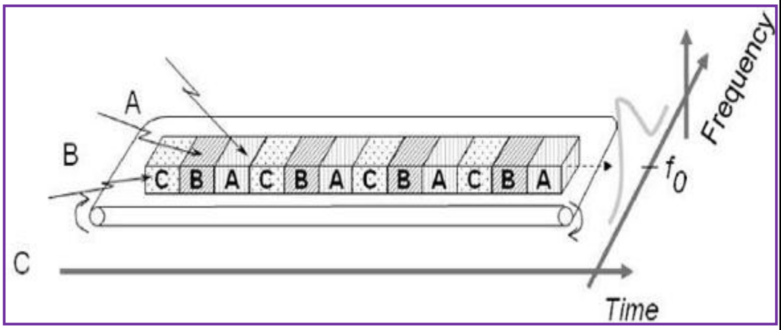
- ♣ CDMA (Code Division Multiple Access)
- ➢ Now, let us discuss each technique one by one.

Ψ FDMA (Frequency Division Multiple Access)



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

Ψ TDMA (Time Division Multiple Access)



- ➢ As the name suggests, TDMA is a time based access. Here, we give certain time frame to each channel.
- ➢ Within that time frame, the channel can access the entire spectrum bandwidth
- ➢ Each station got a fixed length or slot.
- ➢ The slots, which are unused will remain in idle stage.
- ➢ Suppose, we want to send five packets of data to a particular channel in TDMA technique.
- ➢ So, we should assign them certain time slots or time frame within which it can access the entire bandwidth. In above figure, packets 1, 3 and 4 are active, which transmits data.
- ➢ Whereas, packets 2 and 5 are idle because of their non-participation.
- ➢ This format gets repeated every time we assign bandwidth to that particular channel.
- ➢ Although, we have assigned certain time slots to a particular channel but it can also be changed depending upon the load bearing capacity.
- ➢ That means, if a channel is transmitting heavier loads, then it can be assigned a bigger time slot than the channel which is transmitting lighter loads. This is the biggest advantage of TDMA over FDMA.
- ➢ Another advantage of TDMA is that the power consumption will be very low.
- ➢ Note − In some applications, we use the combination of both TDMA and FDMA techniques.
- ➢ In this case, each channel will be operated in a particular frequency band for a particular time frame.
- ➢ In this case, the frequency selection is more robust and it has greater capacity over time compression.
- ➢ The best part of this technique is that each station can use the entire spectrum at all time.

Advantages of TDMA:

- ♣ TDMA can easily adapt to transmission of data as well as voice communication.
- ♣ TDMA has an ability to carry 64 kbps to 120 Mbps of data rates.

- TDMA allows the operator to do services like fax, voice band data, and SMS as well as bandwidth-intensive application such as multimedia and videoconferencing.
- Since TDMA technology separates users according to time, it ensures that there will be no interference from simultaneous transmissions.
- TDMA provides users with an extended battery life, since it transmits only portion of the time during conversations. TDMA is the most cost effective technology to convert an analog system to digital.

Disadvantages of TDMA:

- Disadvantage using TDMA technology is that the users has a predefined time slot. When moving from one cell site to other, if all the time slots in this cell are full the user might be disconnected.

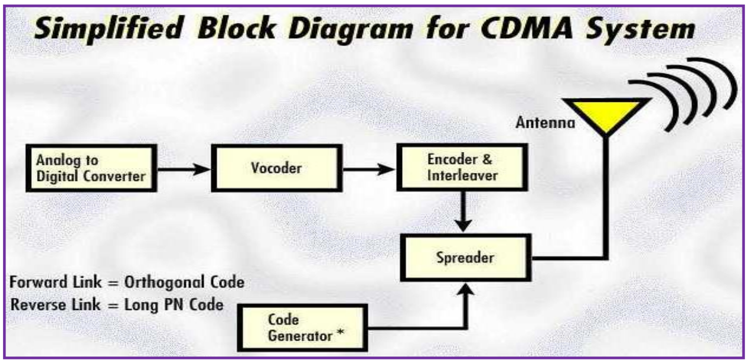
Another problem in TDMA is that it is subjected to multipath distortion. To overcome this distortion, a time limit can be used on the system. Once the time limit is expired the signal is ignored

Ψ CDMA (CODE Division Multiple Access)

- In CDMA technique, a unique code has been assigned to each channel to distinguish from each other.
- A perfect example of this type of multiple access is our cellular system.
- We can see that no two persons' mobile number match with each other although they are same X or Y mobile service providing company's customers using the same bandwidth.
- In CDMA process, we do the decoding of inner product of the encoded signal and chipping sequence. Therefore, mathematically it can be written as **Encoded signal = Orginal data × chipping sequence**
- The basic advantage of this type of multiple access is that it allows all users to coexist and use the entire bandwidth at the same time. Since each user has different code, there won't be any interference.
- In this technique, a number of stations can have number of channels unlike FDMA and TDMA.

Ψ (CDMA) & ITS ADVANTAGES & DIS-ADVANTAGES.

- Code division multiple access (CDMA) is a digital cellular network standard that utilizes spread-spectrum technology.
- This technology does not constrict bandwidth's digital signals or frequencies but spreads it over a fully-available spectrum or across multiple channels via division.
- Thus, there is improved voice and data communication capability & a more secure and private line.



- The CDMA digital standard is a leading communications network standard in North America and parts of Asia. Qualcomm, a US-based wireless communications company, patented CDMA and commercialized this technology.
- CDMA technology was initially used in World War II military operations to thwart enemy attempts to access radio communication signals. In the early 1990s, Qualcomm introduced the possibility of using the same concept with publicly-available cellular network technology.
- During this time, an alternative mobile networking arena digital standard gained traction, proving to be a challenge to CDMA proponents. Despite adamant negativity and discouragement from prominent industry figures, CDMA's supports successfully convinced these leaders to consider, use and eventually accept the newly introduced CDMA standard.
- Essentially, CDMA offers more airspace capacity than the time division multiple access (TDMA) based Global System for Mobile Communications (GSM) standard. Furthermore, CDMA also uses less power.
- Another advantage boasted by CDMA technology is its ability for soft handoffs between base stations, i.e., less likelihood of cut-off calls.
- The usual analogy given in comparing CDMA with other channel access methods like FDMA or TDMA is that of people each carrying out a conversation with a friend in a crowded room.
- TDMA is likened to the method by which communication is carried out by speaking one at a time (hence the name 'Time Division'). FDMA, on the other hand, is likened to the method wherein communication is made by speaking at different pitches (hence, Frequency Division).

- Finally, CDMA is likened to people speaking simultaneously but in different languages.
- Because only those who speak the same language can understand each other, it is possible for multiple conversations to take place in the room at the same time.
- The basic concept in CDMA is that users who wish to communicate through it are given a shared code.
- While multiple codes may occupy the same channel, only those users having the same code can communicate with each other. Because CDMA and GSM standards each have unique pros and cons, the preferred technology standard choice is now in the hands of potential subscribers.

Advantages of CDMA:

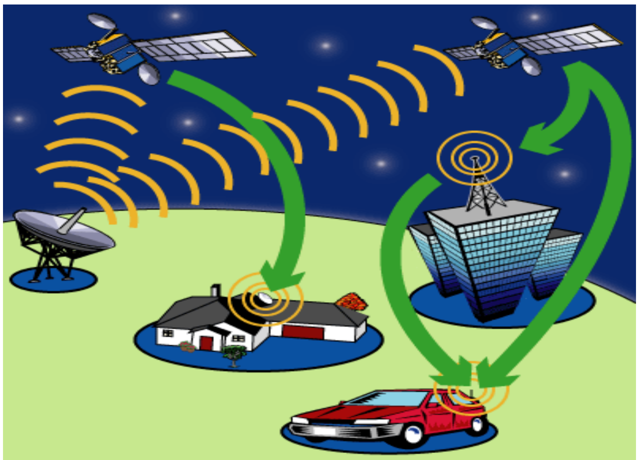
- One of the main advantages of CDMA is that dropouts occur only when the phone is at least twice as far from the base station. Thus, it is used in the rural areas where GSM cannot cover.
- Another advantage is its capacity; it has a very high spectral capacity that it can accommodate more users per MHz of bandwidth.

Disadvantages of CDMA:

- Channel pollution, where signals from too many cell sites are present in the subscriber's phone but none of them is dominant. When this situation arises, the quality of the audio degrades.
- When compared to GSM is the lack of international roaming capabilities.
- The ability to upgrade or change to another handset is not easy with this technology as the network service information for the phone is put in actual phone unlike GSM which uses SIM card for this.
- Limited variety of the handset, because at present the major mobile companies use GSM technology.

Satellite Application- Communication Satellite, Digital Satellite Radio

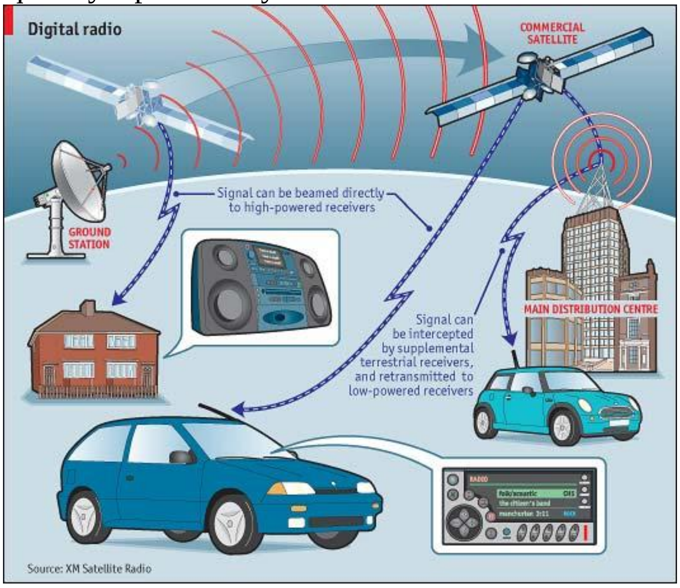
COMMUNICATION SATELLITE



- It is difficult to go through a day without using a communications satellite at least once.
- Do you know when you used a communications satellite today? Did you watch T.V.? Did you make a long distance phone call, use a cellular phone, a fax machine, a pager, or even listen to the radio? Well, if you did, you probably used a communications satellite, either directly or indirectly.
- Communications satellites allow radio, television, and telephone transmissions to be sent live anywhere in the world. Before satellites, transmissions were difficult or impossible at long distances.
- The signals, which travel in straight lines, could not bend around the round Earth to reach a destination far away. Because satellites are in orbit, the signals can be sent instantaneously into space and then redirected to another satellite or directly to their destination.
- The satellite can have a passive role in communications like bouncing signals from the Earth back to another location on the Earth; on the other hand, some satellites carry electronic devices called Transponders for receiving, amplifying, and re-broadcasting signals to the Earth.
- Communications satellites are often in geostationary orbit.
- At the high orbital altitude of 35,800 kilometers, a geostationary satellite orbits the Earth in the same amount of time it takes the Earth to revolve once.
- From Earth, therefore, the satellite appears to be stationary, always above the same area of the Earth.
- The area to which it can transmit is called a satellite's footprint.
- For example, many Canadian communications satellites have a footprint which covers most of Canada.
- Communications satellites can also be in highly elliptical orbits.
- This type of orbit is roughly egg-shaped, with the Earth near the top of the egg.
- In a highly elliptical orbit, the satellite's velocity changes depending on where it is in its orbital path.

- When the satellite is in the part of its orbit that's close to the Earth, it moves faster because the Earth's gravitational pull is stronger. This means that a communications satellite can be over the region of the Earth that it is communicating with for the long part of its orbit.
- It will only be out of contact with that region when it quickly zips close by the Earth.

Ψ DIGITAL SATELLITE RADIO.



- Satellite radio, more formally known as **Satellite Digital Audio Radio Service** (SDARS), is a broadcasting network in which digital high-fidelity (hi-fi) audio entertainment is transmitted from orbiting satellite s to receivers on the surface.
- Signals can be received either directly from a satellite or indirectly by means of earth-based repeater s. Programming can also be received through Internet connections.
- These satellites transmit radio frequency (RF) signals at approximately 2.3 gigahertz (GHz).
- Satellite radio provides programming on a subscription basis. Users pay a nominal monthly fee for the service and in turn receive programming that contains almost no advertising.
- The programming consists mainly of music also includes news, weather, sports and traffic information.
- The services are used primarily by motorists although receivers can be installed in residences and businesses. Portable receivers also exist. Satellite radio is just what its name suggests: a radio service that uses satellites circling Earth to broadcast its programming.
- In 1992, the Federal Communications Commission (FCC) allocated a satellite spectrum ("S" band, 2.3 GHz) for the broadcasting of satellite-based digital audio radio service (DARS).
- It eventually granted two licenses, one to Sirius Satellite Radio (formerly CD Radio) and one to XM Satellite Radio (formerly American Mobile Radio Corporation).
- As the satellites orbit the earth, programs are beamed to them from broadcast stations.
- The satellites then transmit the signal to special antennas on homes, cars and portable radios.
- Terrestrial repeaters throughout the country also receive the signal and help ensure that it's transmitted to receivers, especially in areas with tall buildings that might block the signal
- There are two big pluses for satellite radio listeners.
- **First**, every channel, whether it's on XM or Sirius, is largely commercial-free, which should appeal to radio listeners tired of having advertisements screamed into their ears while they sit in traffic.
- Most music channels have no advertising at all. **Second**, no matter where you are in the continental United States, you get the same reception as long as the skies are relatively clear.
- Unlike traditional radio, which loses reception once you're too far away from a certain station, satellites ensure you receive a signal no matter where you are in America.
- A driver could trek all the way from New York City to Los Angeles & never have to change the channel.
- But there are some notable differences between the two services, too.

❖ GLOBAL POSITIONING SYSTEM

- Global Positioning System (GPS) is a navigation system based on satellite.
- It has created the revolution in navigation and position location.
- It is mainly used in positioning, navigation, monitoring and surveying applications.
- The major advantages of satellite navigation are real time positioning and timing synchronization.
- That’s why satellite navigation systems have become an integral part in most of the applications, where mobility is the key parameter.
- A complete operational GPS space segment contains twenty-four satellites in MEO.
- These satellites are made into six groups so that each group contains four satellites.
- The group of four satellites is called as one constellation.
- Any two adjacent constellations are separated by 60 degrees in longitude.

- The **orbital period** of each satellite is approximately equal to **twelve hours**.
- Hence, all satellites revolve around the earth two times on every day.
- At any time, the GPS receivers will get the signals from at least four satellites.

Ψ GPS Codes and Services

- Each GPS satellite transmits two signals; **L_1 and L_2** are of different frequencies.
- **Trilateration** is a simple method for finding the position (Latitude, Longitude, Elevation) of GPS receiver. By this method, the position of an unknown point can be measured from three known points

Ψ **GPS CODES: -Following** are the two types of GPS codes.

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

- **The** signal, L_1 is modulated with 1.023 Mbps pseudo random bit sequence.
- This code is called as Coarse Acquisition code or **C/A code** and it is used by the public.
- **The** signal, L_2 is modulated with 10.23 Mbps pseudo random bit sequence.
- This code is called as Precise code or **P code** and it is used in military positioning systems.
- Generally, this P code is transmitted in an encrypted format and it is called as **Y code**
- **The** P code gives better measurement accuracy when compared to C/A code, since the bit rate of P code is greater than the bit rate of C/A code.

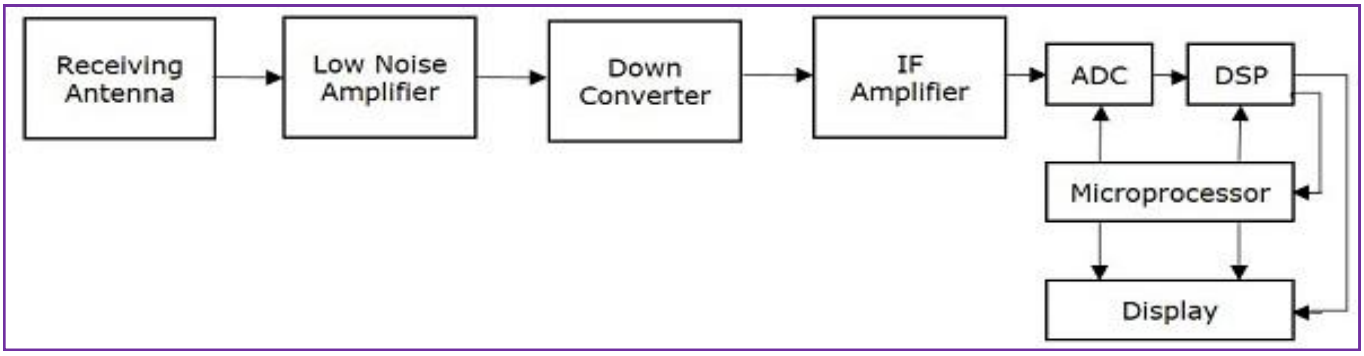
Ψ **GPS Services: - Following** are the two types of services provided by GPS.

- **Precise Positioning Service (PPS)** *** Standard Positioning Service (SPS)**

- **PPS receivers** keep tracking of both C/A code and P code on two signals, L_1 and L_2.
- The Y code is decrypted at the receiver in order to obtain P code.
- **SPS receivers** keep tracking of only C/A code on signal, L_1.

Ψ GPS RECEIVER

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

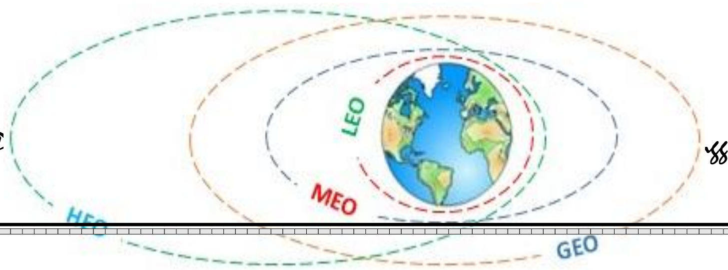


- The function of each block present in GPS receiver is mentioned below: -
  - **Receiving Antenna** receives the satellite signals. It is mainly, a circularly polarized antenna.
  - **Low Noise Amplifier** (LNA) amplifies the weak received signal
  - **Down converter** converts the frequency of received signal to an Intermediate Frequency (IF) signal.
  - **IF Amplifier** amplifies the Intermediate Frequency (IF) signal.
  - **ADC** performs the conversion of analog signal, which is obtained from IF amplifier to digital. Assume, the sampling & quantization blocks are also present in ADC (Analog 2 Digital Converter).
  - **DSP** (Digital Signal Processor) generates the C/A code.
  - **Microprocessor** performs the calculation of position and provides the timing signals in order to control the operation of other digital blocks. It sends the useful information to Display unit in order to display it on the screen.

❖ TYPES OF SATELLITE ORIBITS

- There **are 4 types of orbits, they are: -**

1. GEO (Geo-stationary earth orbit)



2. MEO (medium earth orbit)
3. LEO (Low earth orbit) and
4. HEO (Highly elliptical orbit)

Ψ Geo-Stationary Earth Orbit

- These satellites have almost a distance of 36,000 km to the earth.
- E.g. All radio and TV, whether satellite etc, are launched in this orbit.

♣ Advantages of Geo-Stationary 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.

Ψ Medium Earth Orbit

- Satellite at different orbits operates at different heights.
- The MEO satellite operates at about 5000 to 12000 km away from the earth's surface.
- 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.

♣ Disadvantages of Medium Earth Orbit

1. Satellites require higher transmission power.
2. Special antennas are required.

Ψ Low Earth Orbit

- LEO satellites operate at a distance of about 500-1500 km.

♣ 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.

Ψ Highly Elliptical Orbit

- This orbit is made for satellites that do not revolve in circular orbits, only a very few satellite are operating in this orbit.

---- ALL THE BEST ---- ALL THE BEST ----

[CHAPTER-3]

FIBER OPTICS COMMUNICATION SYSTEM

❖ INTRODUCTION: -

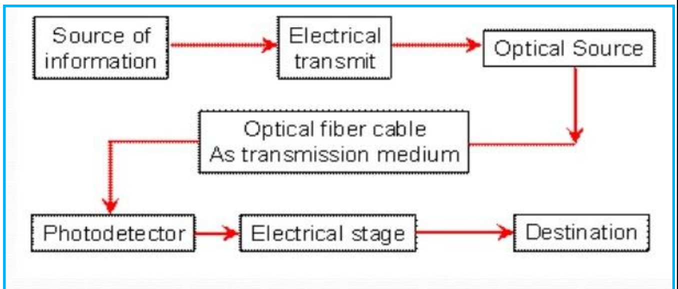


Figure: Basic Block Diagram of Optical Communication System

- Fiber optics is a branch of science which deals with the study of propagation of light through transparent dielectric medium such as optical fibers.
- Fiber optics is a relative new technology that used to transmit television, voice and digital data signal by light waves over flexible hair like threads of glass and plastic.
- Optical fiber is the medium in which the communication signals are transmitted from one location to another in the form of guided light.
- This signal can be voice information, data information, video information and any other information.
- The process of communicating using fiber optics involves the following basic steps.
  1. Creating the optical signal along the fiber.
  2. Relaying the signal along the fiber.
  3. Ensuring that the signal does not become to distort or weak.
  4. Receiving the optical signal.
  5. Converting it in to electrical signal.

ADVANTAGE

- *Attenuation* in a fiber is lower than that of coaxial cable or twisted pair and is constant over a very wide range. So transmission within wide range distance is possible without use of repeaters.
- *Smaller size and lighter weight*. So that it occupy much less space.
- Due to *Electromagnetic Isolation* the system is not risk to interference, impulse noise or cross-talk.
- Fiber optical cable has much *greater band width* than copper wire.
- Fiber optic cable is *less susceptible* to signal degradation that copper wire.
- Data can be transmitted *digitally* and Data rate is much higher. As for example the data rate is 2 Gbps over some kilometers in case of fiber optics where as for coaxial cable it is about 1 Mbps over one Km.
- *Lower power transmitter* can be used instead of high voltage electrical transmitter used in copper wire.
- Because of no electricity is passed through optical fiber it is *nonflammable and immune* to light.
- No cross-talk in optical fibers hence transmission is *more secure* & *private* as it difficult to tap into fiber.

DISADVANTAGE

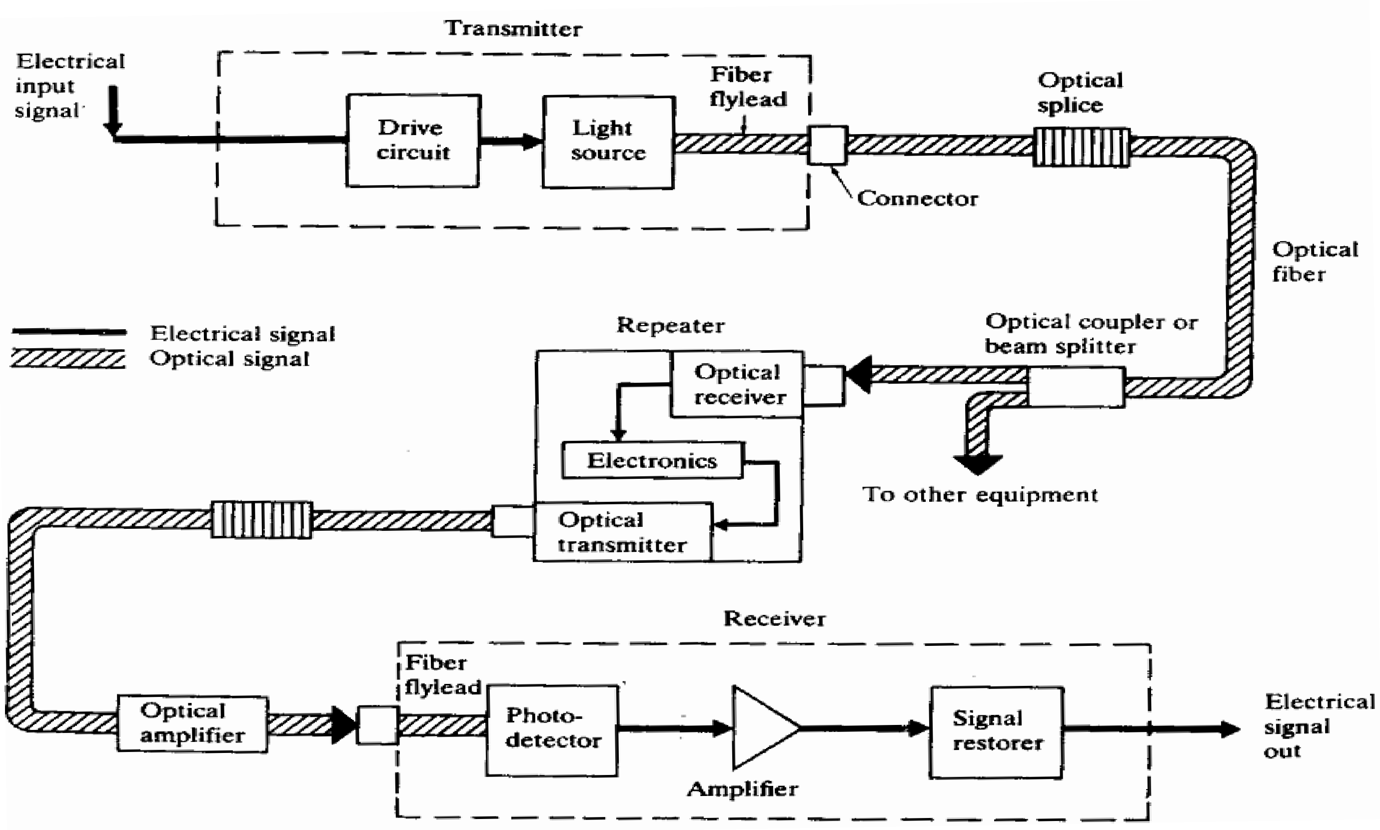
- Fiber optics is the cables which are expensive to installation.
- The termination of fiber cable is complex and requires special tools.
- They are more fragile (easily broken) than co-axial cable.

APPLICATIONS

- Used in Voice Communications. **(**Inter-Office, Intercity, Intercontinental links etc**)**
- Video Communications. **(** TV Broadcast, Cable Television, Remote Monitoring, Wired City**)**
- Data Transfer **(**Inter Office Data Link, Local Area Network, Satellite Ground Stations, Computers etc**)**
- Internet **(**Email, Access to remote information, Video Conferencing etc**)**
- Sensor System **(** Point Sensor, Distributed Sensor, Smart Structure, Robotics etc**)**
- Also it used in other indirect fields like Entertainment (HDTV), Power System, Transportations, Health Care (Endoscope), Military Defense (Guided Missile), Business Developments (CAD/CAM), Educations (CCTV) etc.

❖ BLOCK DIAGRAM OF FIBER OPTIC COMMUNICATION SYSTEM

- In fiber optic communication, visible light (optical) waves represent the signal to be transmitted.
- These visible light waves are transmitted through glass fiber.
- Thus the fiber optic cable transmits light signals from one place to another just like metallic wire carries an electric current. A generalized fiber optic communications system is shown in Fig. below
- The block diagram of FOCS contains following components. Light Signal, Transmitter, Optical Fiber, Photo Detecting Receiver, Cable Splices, Connector, Regenerators, Beam Splitters & Optical Amplifier.



MESSAGE ORIGIN

- Generally message origin is from a transducer that converts a non-electrical message into an electrical signal. Ex- Microphones for converting sound waves into currents & video (TV) cameras for converting images into current. For data transfer between computers, the message is already in electrical form.

TRANSMITTER SECTION

MODULATOR

- The modulator has two main functions.
  1) It converts the electrical message into the proper format.
  2) It impresses this signal onto the wave generated by the carrier source.
- Two distinct categories of modulation are used i.e. analog and digital.

CARRIER SOURCE

- Carrier source generates the wave on which the information is transmitted. This wave is called the carrier. For fiber optic system, a Laser Diode (LD) or a Light Emitting Diode (LED) is used.
- They can be called as optic oscillators; they provide stable, single frequency waves with sufficient power for long distance propagation.

TRANSMITTING CHANNEL SECTION

INFORMATION CHANNEL

- The information channel is the path between the transmitter and receiver. In fiber optic communications, a glass or plastic fiber is the channel.
- Optical fiber cables are the medium for the transmission of signal. It carries data, audio or video information in the form of optical signal.
- Desirable characteristics of the channel include low attenuation and large light acceptance cone angle.
- Optical amplifiers boost the power levels of weak signals. Amplifiers are needed in very long links to provide sufficient power to the receiver.
- Repeaters can be used only for digital systems. They convert weak and distorted optical signals to electrical ones and then regenerate the original digital pulse trains for further transmission.
- Another important property of the channel is the propagation time of the waves traveling along it.
- A signal propagating along a fiber normally contains a range of optic frequencies and divides its power along several ray paths. This results in a distortion of the propagating signal.

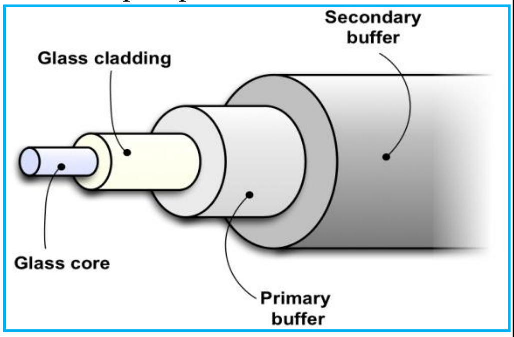
- In a digital system, this distortion appears as a spreading and deforming of the pulses.
- **Cable Splices** are used to joint between the two fiber optical cables.
- **Connectors** are connected just the end of the transmitter and receiver to connect with fiber optics cable. Its construction is more complex than that of splices.
- **Beam Splitter** or Optical Couplers are used to split the optical signal into different parts for different communication system.
- Different type of **Optical Amplifier** is there to amplify the optical signal.
- **Regenerators** are used for restoring the signal shape characteristic. In a long distance transmission the degradation of optical signal takes place so to restore the signal shape characteristic over a long distance regenerators are used. This is mainly used under sea where the longest cables are employed.

RECEIVER SECTION

DETECTOR

- The information being transmitted is detected by detector. An optical receiver is used to recover the signal as an electrical signal. Here the optic wave is converted into electric current by a photo detector.
- The current developed by the detector is proportional to the power in the incident optic wave.
- In the receiver section a photo diode is there which treated the weakened optical signal and convert it to electrical current referred to as photo current.
- This photo current in the form of electrical signal is amplified by the amplifier.
- This detector output is then filtered to remove the constant bias and then amplified.
- The signal restored will produce the required form of the signal at the output.
- The important properties of photo detectors are small size, economy, long life, low power consumption, high sensitivity to optic signals and fast response to quick variations in the optic power.

SIGNAL PROCESSING

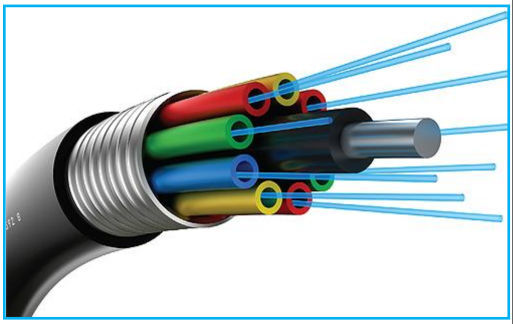


- Signal processing includes filtering, amplification. Proper filtering maximizes the ratio of signal to unwanted power.
- For a digital system decision circuit is an additional block. The bit error rate should be very small for quality communications.

MESSAGE OUTPUT

- The electrical form of the message emerging from the signal processor is transformed into a sound wave or visual image.
- Sometimes these signals are directly usable when computers or other machines are connected through a fiber system.

OPTICAL FIBER CABLE CONSTRUCTION: -



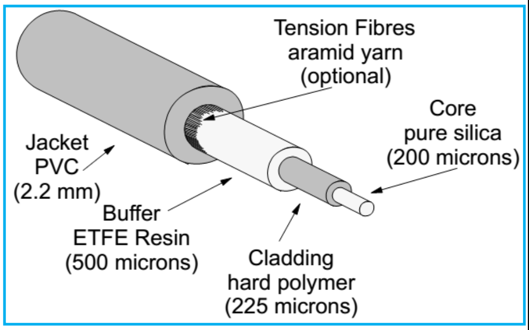
- Optical fiber may be produced with good stable transmission characteristic in long lengths at a minimum cost and with maximum reproducibility.
- The range of optical fiber type with regards to size, refractive indices, operating wave length, material etc is available in order to fulfill many different system applications.
- The fiber may be converted into practical cable which can be handled in a similar manner to a electrical transmission cable without any problem.
- For transmission point of view it is clear that a variation of refractive index inside the optical fiber (Core & Cladding) is the fundamental necessity in fabrication of fiber for transmission.
- Hence at least two difference materials which are transparent to light over the current operating wave length range are required.
- In practice these material must exhibit relatively low practical attenuation and they must therefore have low intrinsic absorption and scattering losses.
- A number of organic and inorganic insulating substances are used to meet these conditions.
- We chose suitable material for the fabrication of optical fibers to either glasses or glass like material & mono crystalline structure.

- It is used full in the case of graded index fiber that the refractive index of the material may be varied by suitable doping with another compactable material.
- This is only achieved in glasses or glass like material & therefore mono crystalline material are not suitable for the fabrication of graded index fiber but may be used for step index fiber.
- Glasses exhibit the best overall low loss optical fiber.
- Therefore it is used almost exclusively in the preparation of fibers for telecommunication application.

❖ <u>STRUCTURE OF OPTICAL FIBER</u>: -

- The working of optical fiber is based on the principal of total internal reflection of light.
- The possible of light being guided through narrow jet of a communication system based on the propagation of light with in a cylindrical wave guided called optical fiber.
- The light entering at one end of the fiber has to travels through the entire length and energy at the other end without much loss.
- Optical fiber consists of three section such as

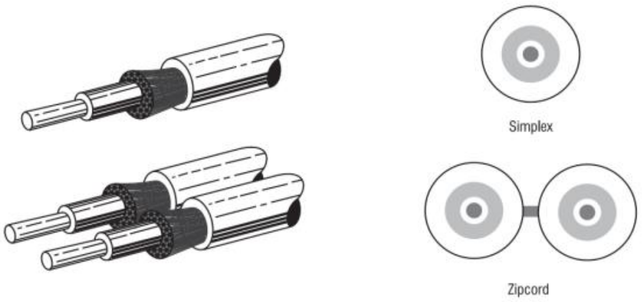
(A) CORE (B) CLADDING (C) JACKET



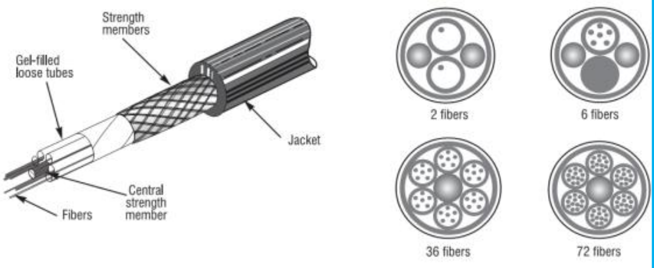
- The **Core** is a hair thin cylindrical fiber of glass any transparent dielectric material like plastic.
- The Core is coated with a layer of material with lower refractive index this layer is called **Cladding**.
- The Core and cladding together guide optical energy along the axis of fiber.
- The core diameter generally 5-100 micron while the cladding diameter is around 125 micron.
- For greater strength and protection of fiber a soft plastic coating or outer cover which is primary which diameter is around 250 micron is used called Jacket or **Primary Jacket**.
- This is often followed by another layer of hard protective material which is known as **Secondary** Jacket.
- The entire unit is remaining flexible for use.

❖ <u>TYPES OF OPTICAL FIBER</u>: -

- In most applications, optical fiber must be protected from the environment using a variety of different cabling types based on the type of environment in which the fiber will be used.
- Cabling provides the fiber with protection from the elements, added tensile strength for pulling, rigidity for bending, and durability.
- In general, fiber optic cable can be separated into two types: - INDOOR & OUTDOOR.



a) Indoor simplex and duplex cable (Courtesy of General Photonics)

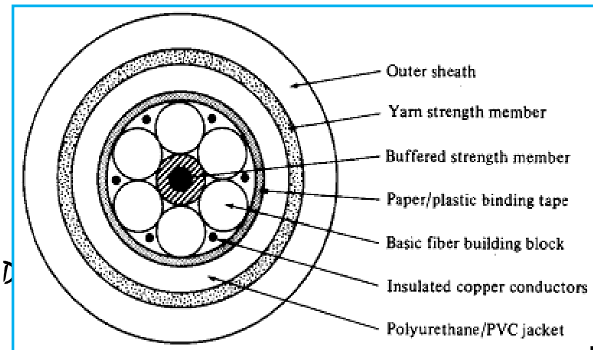


b) Outdoor loose buffer cable (Courtesy of Siecor)

<u>INDOOR CABLES</u>: -

- **Simplex Cable**: - Contains a single fiber for one-way communication.
- **Duplex Cable: -** Contains two fibers for two-way communication.
- **Multi-Fiber Cable -** Contains more than two fibers. Fibers are usually in pairs for duplex operation. A ten-fiber cable permits five duplex circuits.
- **Breakout Cable** - Typically has several individual simplex cables inside an outer jacket. The outer jacket includes a zip cord to allow easy access.
- **Heavy-Duty Cables** have thicker jackets than light-duty cable, for rougher handling.
- **Plenum Cables** are jacketed with low-smoke and fire-retardant materials.
- **Riser Cables** run vertically between floors and must be engineered to prevent fires from spreading between floors.

<u>OUTDOOR CABLES</u>: -



- **Outdoor** cables must withstand harsher environmental conditions than indoor cables.
- Outdoor Cables are used in applications such as: -
  - **Overhead -** Cables strung from telephone lines
  - **Direct Burial -** Cables placed directly in trenches
  - **Indirect Burial -** Cables placed in conduits
  - **Submarine -** Underwater cables, including transoceanic applications
- Sketches of Indoor and Outdoor cables are shown in Figure above.

FIBER OPTIC CONNECTOR: -

- A wide variety of optical fiber connectors has evolved for numerous different applications.
- Some of the principal requirements of a good connector design are as follows: -
  - Low Coupling Losses
  - Interchangeability
  - Ease of assembly
  - Low Environmental sensitivity
  - Low-cost and reliable construction
  - Ease of connection
- A number of Fiber optical connectors have been developed. These are grouped in three categories.
- That are : - **(1)** Butt-Jointed Connectors **(2)** Expanded Beam Connectors **(3)** Multi fiber Connectors

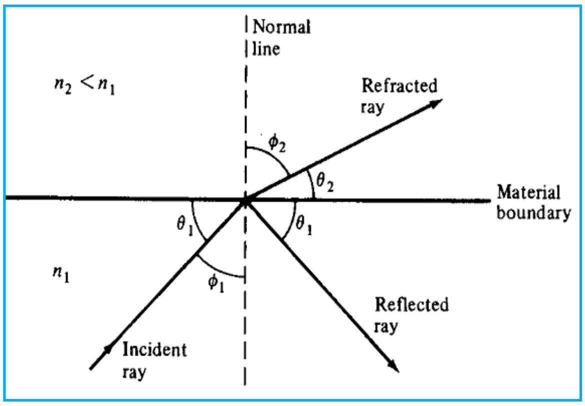
FIBER OPTIC SPLICES: -

- A fiber splices is a permanent joint formed between two optical cables. It is required when length of the system span is more than manufactured cable length **or** when the cable is broken & needs to be repaired.
- The primary objective of splicing is to establish transmission continuity in the fiber-optic link.
- This can be done in two ways, namely, through
  - Fusion splices
  - Mechanical Splices
  - Multiple Splices.

PROPAGATION OF LIGHT IN OPTICAL FIBER:-

- In free space the light wave travels at speed C=3x10^{8}N/s upon entering to a dielectric and non conducting medium the wave now travels at a speed 'V' and is less than that of 'C'.
- The ratio of speed o light in vacuum to that of in a metal is known as **Refractive Index** of the material and is given by

$$n = C/V$$

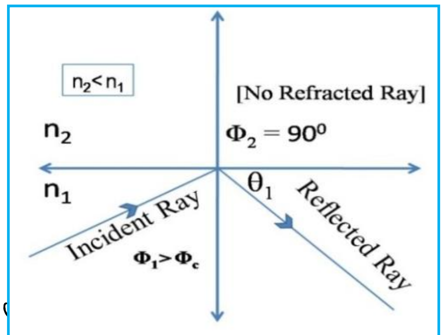


- Typical values of Refractive Index (n) are given by: - Air → 1; Water → **1.33**; Glass → **1.50;** Diamond → **2.42;** SiO_2 → **1.46 ;** Al_2O_3 → **1.8 ;** GaAs → **3.35;** InGaAsP → **3.51 ;** Si → **3.48 and** Ge → **4.0** etc.
- When a light ray encounters a boundary separating two different media, part of the ray has reflected back in to the 1st medium. Then the remainder is bending or refracted as it enters to the second material.
- The bending or refraction of light ray at the interface as a result of difference in the speed of light in two materials that have different refractive indices.
- The relationship at the interface is known as **Snell's Law** and is States that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media, or equivalent to the reciprocal of the ratio of the indices of refraction:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

$$n_1 \sin\Phi_1 = n_2 \sin\Phi_2 \Rightarrow n_1 \sin(90-\theta_1) = n_2 \sin(90-\theta_2) \Rightarrow n_1 \cos\theta_1 = n_2 \cos\theta_2$$

- Where each **Φ** as the angle measured from the normal of the boundary, ***v*** as the velocity of light in the respective medium (SI units are meters per second, or m/s), **λ** as the wavelength of light in the respective medium and **n** as the refractive index (which is unit less) of the respective medium.
- The angle ϕ_1 between the incident ray and the normal to the surface is known as Angle of Incident.



[Total Internal Reflection of Light; When $\Phi_1 > \Phi_c$]

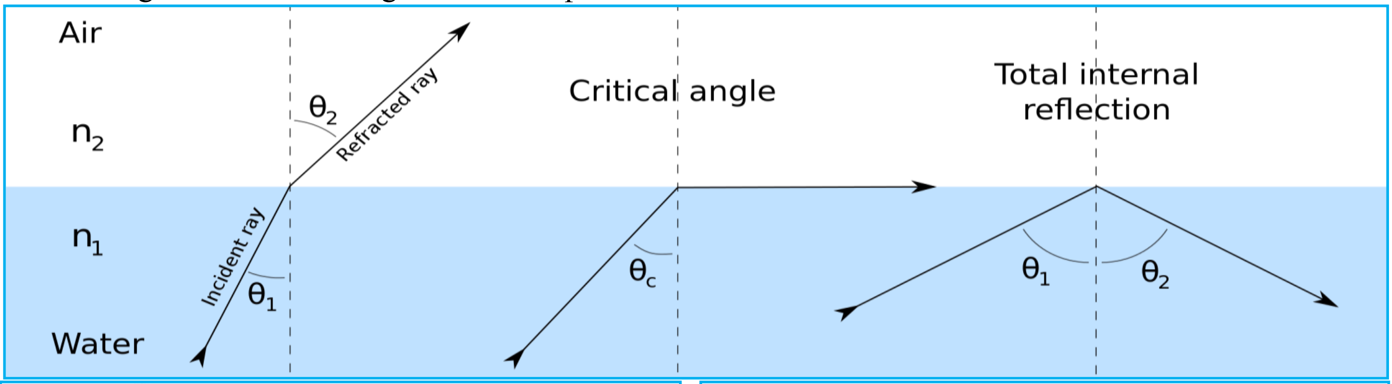
- According to the Laws of Reflection the incident angle **"Φ"** at which the incident ray strikes to the interface is exactly equal to the angle that the reflected ray makes with the same interface.
- In addition the incident rays, the normal to the interface and the reflected ray all lies on the same plane.
- As n_1 is greater than n_2 the angle of refraction is always greater than that of angle of incident.
- If the angle of incident ϕ is increased a point will eventually reached where the light ray in air is parallel to the glass surface. This point is known as **Critical Angle** (**ϕ_c**) of the incident.
- The value of Critical Angle is given by
- When $\theta_c = 90^o$ then $\sin 90^0 = n_2/n_1 = 1 \Rightarrow n_2 = n_1.$

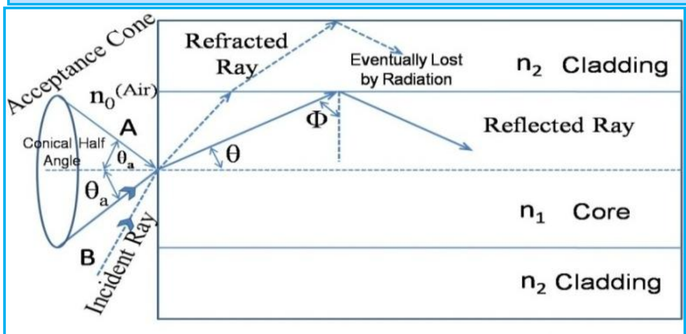
$$\sin \theta_c = n_2 / n_1 \Rightarrow \boldsymbol{\theta_c} = \sin^{-1} (n_2 / n_1)$$

- So we must choose the angle of incidence less than 90˚. When the angle of incidence is greater than that of the critical angle, light is reflected back into the medium and is known as **Total Internal Reflection**.

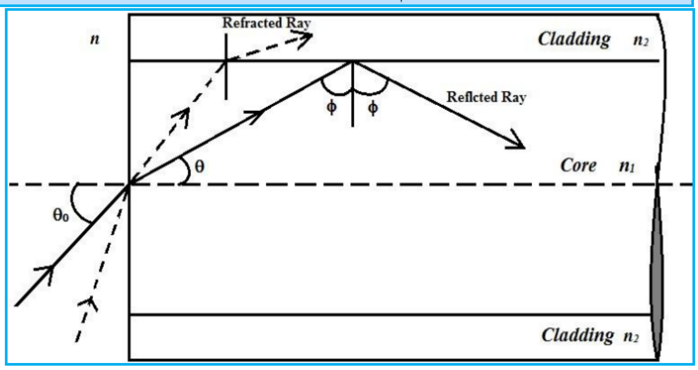
❖ **ACCEPTANCE ANGLE:-**

- Any ray which are incidence into the fiber core at an angle greater than θa will be transmitted to the core cladding interface at an angle less than 'ϕ_c' will not be total internal reflection.

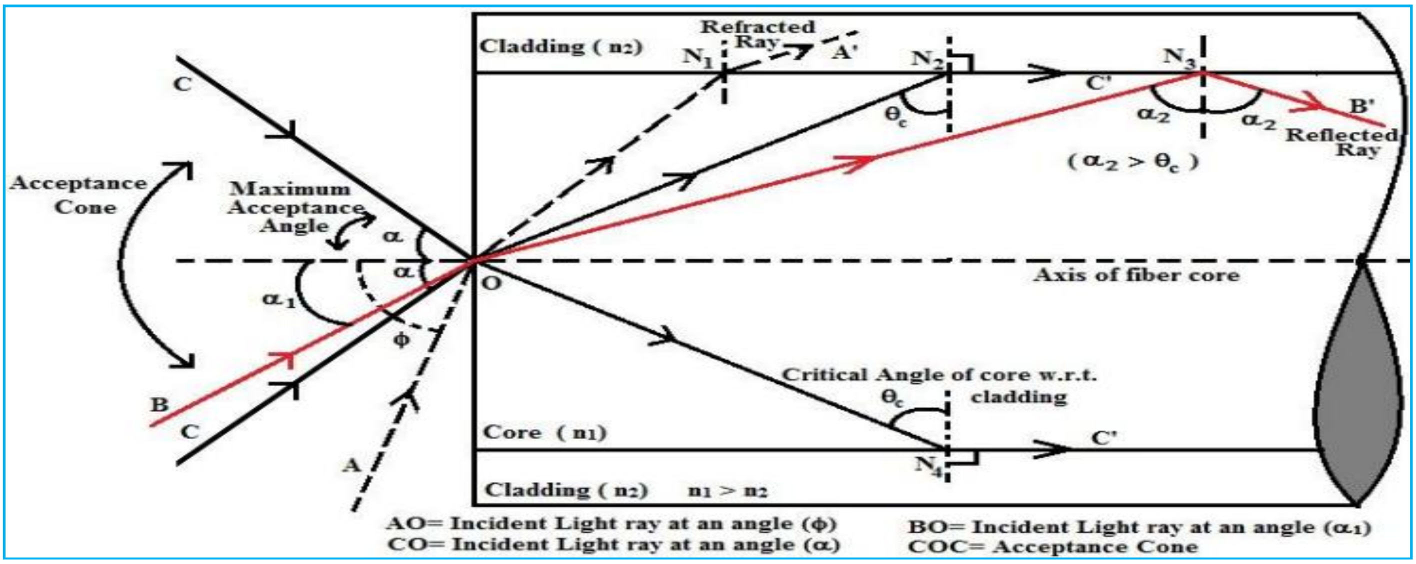




[Propagation Mechanism for in an Ideal Step-Index Fiber]

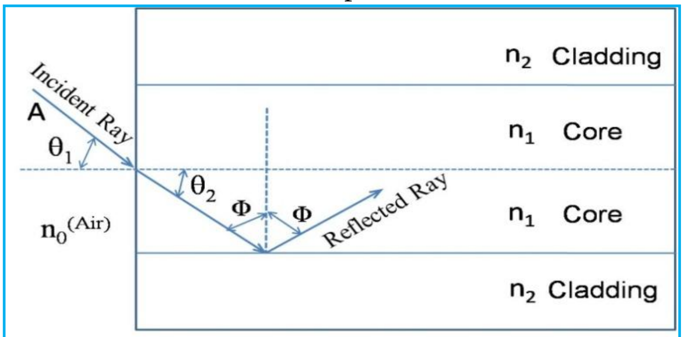


- From the above figure the incident ray 'B' at an angle greater than θ_a is refracted into the cladding and is eventually loosed by the radiation.
- Thus for rays to be transmitted by total internal reflection within the fiber core, they must be incident on the fiber core with in an acceptance angle and is also defined by **Conical Half Angle** (θ_a).
- Hence θ_a is the maximum angle to the axis at which light may enter to the fiber in order to propagate fully and is refer as acceptance angle for the fiber.
- θ is some time refer as **maximum** or **total acceptance angle** .
- It may be noted that the output angle to the axis will be equal to the input angle for the ray assuming the ray emerges in to a medium o the same refractive index from which it was input.



❖ NUMERICAL APERTURE:-

- It is possible to continue the ray theory analysis to obtain a relation between the acceptance angle and the refractive indices of the three medium involve such as core, cladding and air.
- This leads to the definition of a more generally used term that the Numerical Aperture of the fiber.
- The figure of the next page shows a light ray incident on the fiber core at an angle θ_1 to the fiber axis which is less than the acceptance angle for the fiber θ_a.
- The ray enters to the fiber from a medium (Air) that the refractive index 'n_0' and the fiber core refractive index 'n_1' which is slightly greater than the cladding refractive index 'n_2'.
- Now applying Snell's law at the interface, i.e. $\mathbf{n_0 \sin\theta_1 = n_1 \sin\theta_2}$



[Propagation Mechanism for Numerical Aperture]

➔ $\sin\theta_2 = \sin(\pi/2 - \phi) = \cos\phi$ (As $\theta_2 = \pi/2 - \phi$) ➔ So, $n_0 \sin\theta_1 = n_1 \cos\phi$ ------- (1)

➔ $n_0 \sin\theta_1 = n_1 (1 - \sin^2\phi)^{1/2}$ ------- (2)

- When limiting case for the total internal reflection is consider ϕ becomes to the critical angle for the core cladding interface (ϕ_c) also in this limiting θ_1 becomes the acceptance angle (θ_a) for the fiber.
- Combining these limiting case, the above equation becomes, (i.e. By putting $\phi \rightarrow \phi_c$ **&** $\theta_1 \rightarrow \theta_a$)

$n_0 \sin\theta_a = n_1 (1 - \sin^2\phi_c)^{1/2}$ ➔ $n_0 \sin\theta_a = n_1[1 - (n_2/n_1)^2]^{1/2}$ { As $\sin\phi_c = n_2/n_1$ }

$$n_0 \sin\theta_a = (n_1^2 - n_2^2)^{1/2}$$

- This equation relates the acceptance angle to the refractive indices serves for the basic definition of optical fiber parameter i.e. Numerical Aperture.
- Hence the expression of Numerical Aperture is given by → $\mathbf{NA = (n_1^2 - n_2^2)^{1/2}}$
- Since n_0 is often used for air whose value is unity. So the Numerical Aperture is simply equals to $\sin\theta_a$.
- Numerical Aperture may also be given in terms of Relative refractive index difference (Δ) between the core and cladding which is denoted as $\mathbf{\Delta = (n_1^2 - n_2^2)/2n_1^2}$ ➔ $2n_1^2\,\Delta = (n_1^2 - n_2^2)$ ➔ $n_1\sqrt{2\Delta} = (n_1^2 - n_2^2)^{1/2}$
- Thus, NA = $n_1\sqrt{2\Delta}$. This relationship is very use full measure of light collective ability of the fiber.

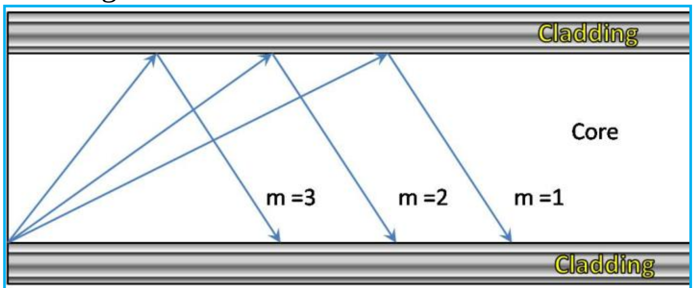
❖ MODES OF PROPAGATION:-

- Propagation of light along an optical fiber can be described in terms of a set of guided electromagnetic waves called the Modes. Each guided mode corresponds to a pattern of electric and magnetic field distribution that is repeated along the fiber at regular intervals.
- Only a certain discrete number of modes or patterns are capable of propagating along the fiber.

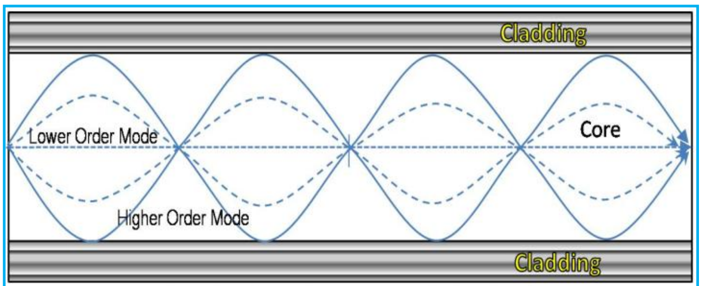
- For monochromic light the amplitude of a mode traveling along the fiber axis (say the +ve z-direction) is represented as $\boldsymbol{\Psi (z, t) = Ae^{j(wt-\beta z)}}$

  Where w=2πv and β is the z-component of propagation vector, k=2π/λ in z-direction.
- For guided modes, β can have only certain discrete values that satisfy the Maxwell's equation and the boundary conditions.
- These modes are identified by solving Maxwell's EM wave equation under the boundary condition of the wave guide surface. The modes can also be visualized by ray tracing method.
- A guided mode travelling along the fiber can be regarded to be assembly of a group of plane waves along the axis with a common wave front.
- Since with any plane wave can associate a light ray that is normal to the wave front of the wave, group of waves corresponding to a particular mode from a set of ray called a **Ray Congruence**.
- Each ray of this particular group is incident at the core cladding interface at the same angle.
- Note as any ray that satisfies the condition ($\theta \geq \theta_c$) can be transmitted in the fiber yet the constant phase condition is satisfied only in limited cases. i.e. there will be limited number of ray congruence or modes.
- The order of the mode m, is linked to the angle that the ray congruence makes with the fiber axis at the point of incidence. In order that the mode rays satisfy the condition, $\theta > \theta_c$ and also converge is in the same phase, the path difference $\Delta P = m\lambda$. Where m is an integer called the **Mode Number**.
- Note that the phase change on reflection should be included in compating ΔP.
- Through the path difference between meridional ray and skew rays is large yet the phase should be the same for transmission to be possible.
- The angle ϕ which a mode ray makes with the wall of the fiber is given by

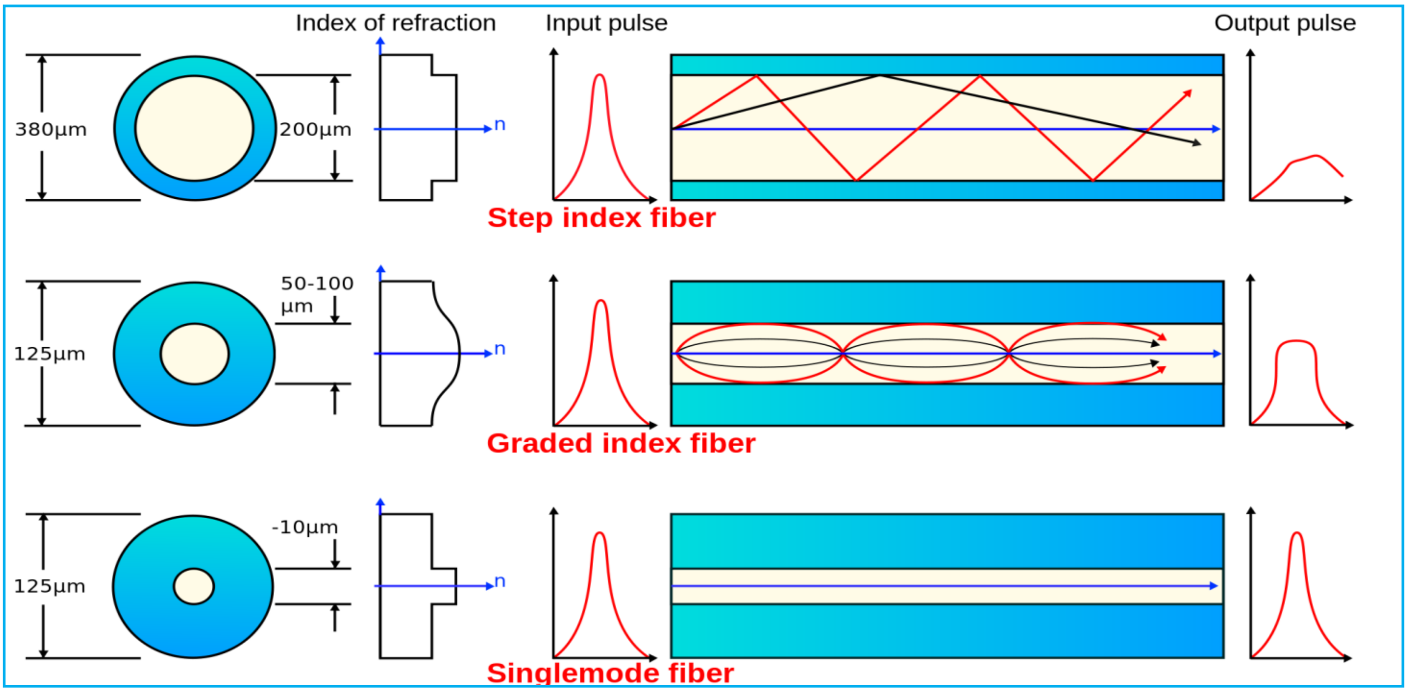
  $\boldsymbol{\sin \phi = (\frac{m}{2} \lambda/d) < 1}$, where $(\theta + \phi) = 90^0$, λ = Wavelength of light used & d = Fiber Diameter.
- Through a distinct mode is available with any integer value of m, number of modes are limited as Sin θ cannot exceed unity for low value of m, value of ϕ is low.
- On the other hand the value of ϕ is more for higher order modes are due to steeper incident ray.
- What happens for ϕ = 90˚ the wave front bounles back and forth from both the walls without advancing along the axis.



[Mode Information in Step Index Fiber]



[Mode Information in Graded Index Fiber]



- When the fiber is very thin, the ray with a single low value of ϕ i.e. grazing incidence can enter into the fiber the steeper ray with high value of ϕ will not enter into the fiber.
- This is a mono mode transmission if the core diameter is large, angle of incidence can change over a range and as such multimode transmission is possible as shown in figure above.

❖ MERIDIONAL RAYS AND SKEW RAYS:-

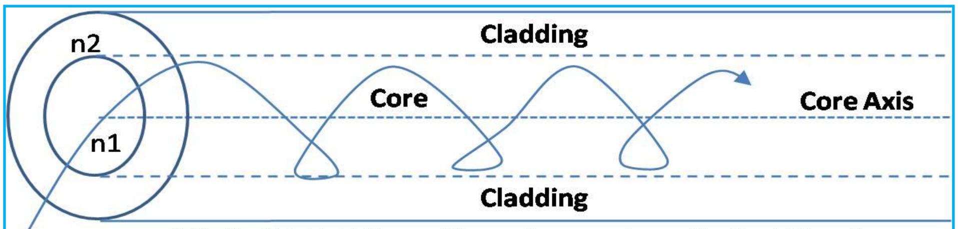
- The rays propagating through an optical fiber can be divided into two groups. They are
  - ♣ Meridinal Rays
  - ♣ Skew Rays

Ψ MERIDINOL RAYS: -

- The rays said to be Meridinal if all of them comprising a mode pass through the longitudinal of z-axis o the fiber core, they are confined to a *single plane* which contain the axis of symmetry in below figure and therefore it is easy to trace its path in the fiber.

Ψ SKEW RAYS: -

- The skew rays can propagate without passing through the axis of the fiber they are not contained to a *single plane* but fallow a spiral or helical path due to reflection in different segment down to the fiber core in figure below. It is difficult to track the path of skew rays in the fiber.

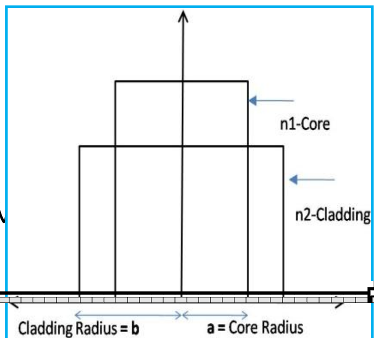


[Helical Path Followed by a skew ray in an Optical Fiber]

- The point of emergency of the skew rays from the fiber in air depends on the number of reflection they undergo rather than the input condition of the optical fiber.
- Some mode of propagation involving skew rays produces loss due to leakage and radiation. But it has certain advantage too.
- Even when the light input to the fiber is not uniform the output will be quite uniform because the skew rays will have a smoothing effect on the distribution of transmitted light.
- Another advantage feature of the transmission of the skew ray in that the effect numerical aperture will be greater than that for Meridinal rays.

❖ CLASSIFICATION OF OPTICAL FIBER : -

- There are two methods of classification
  1. According to Mode Capacity



[Refractive Index of a Step Index Fiber]

2. According to Core Refractive Index

❖ **CLASSIFICATION ON THE BASIS OF MODE : -**

Ψ **MONO MODE FIBER**: - The Mono mode fiber allows only one mode to propagate and hence this name fiber of this type have very small core diameter ~ 2 to 10 micron.

Ψ **MULTI MODE FIBER**: - The core diameter is more than 50micron. Because of large diameter, it allows many modes to transmit through the fiber.

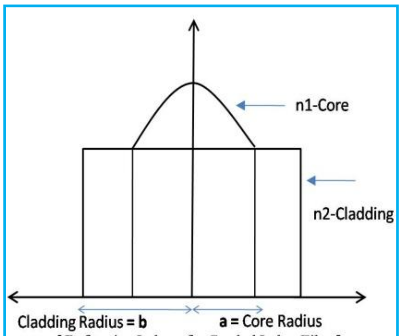
❖ **CLASSIFICATION ON THE BASIS OF CORE REFRACTIVE INDEX:-**

Ψ **STEP INDEX FIBER: -**

- In step index fiber the core has uniform refractive index n_1, through its core section and the cladding also has slightly less but uniform refractive index n_2 through its cross section.
- The refractive index profile, the figure shows a step like structure.

Ψ **GRADED INDEX FIBER: -**

- Refractive index of the core is non-uniform being maximum along the axial and gradually decreases towards the core-cladding interface.
- The cladding refractive index n_2, however is uniform the variation of refractive index of the core n with distance 'x' measure from the axis.



[Refractive Index of a Graded Index Fiber]

❖ ADVANTAGE AND DISADVANTAGE OF OPTICAL FIBER:-

- Communication through plastic fiber or glass fiber has several Advantages over metallic conductor.

Ψ **ADVANTAGES**: -

- It has wider band width (10000 – 40000 GHz).
- It has higher information capacity.
- It can transmit several G byte/sec.
- It eliminates cross falk.
- It eliminates static interference.
- It eliminates environmental resistance and it is not effect of weather changes.
- It can be operated at thin temperature.
- Optical fiber cables are safer & easier to install.
- It is easy to storage due to flexibility in nature.
- It is lower transmission loss.
- It is more secure then metallic cable.
- It has higher durability.
- These are economic in nature.
- It is easy to transport.
- These are compact in size.

Ψ **DISADVANTAGES**: -

- Optical fiber cable requires specialize tool and test equipment.
- The repairing cost of optical fiber is higher than metallic cable.

❖ **ELECTROMAGNETIC FREQUENCY AND SPECTRUM:-**

- The electromagnetic frequency spectrum contains subsonic frequency to cosmic ray frequency (10^{22}).
- The light frequency spectrum is divided into three bands: -

1) **Intra Red**: - These are the light which to have length in between Optical fiber system generally operated in the entire range or band.
2) **Visible Light**: - The wave length between $390\text{x}10^{-9}$ m **to** $770\text{x}10^{9}$ m is known as visible light which is visible to human being.
3) **Ultra Violet:** - Wave length 10nmi **to** 390nmi which are not visible human being. When detailing with high frequency the calculation are mode by the equation → $\lambda = \frac{c}{f}$.

❖ SIGNAL DEGRADATION IN OPTICAL FIBERS: -

- Signal attenuation (fiber loss or Signal loss) is one of the most important properties of an optical fiber.
- As it largely determines the maximum unamplified or repeater less between a transmitter and a receiver.
- Since amplifiers and repeaters are expensive to fabricate, install and maintain, the degree of attenuation in a fiber has a large influences on system cost.
- If these pulses travel sufficiently far, they will eventually overlap with neighboring pulses, thereby creating errors in the receiver output.
- The basic attenuation mechanisms in a fiber are **Absorption**, **Scattering** & **Radiation** of optical energy.
- Signal attenuation is defined as the ratio of the optical output power P_{out} from a fiber length L to the optical input Power P_{in}.

- The symbol **α** is commonly used to express attenuation in Decibels per kilometer and is expressed as : -

$$\alpha = \frac{10}{L} \log \left(\frac{P_{Out}}{P_{In}}\right)$$

Ψ ABSORPTION LOSS: -

- Absorption is caused by three different mechanisms: -
  - ♣ Absorption by atomic defects in the glass composition.
  - ♣ Intrinsic absorption by the basic constituent atoms of the fiber material.
  - ♣ Extrinsic absorption by the impurities atoms in the glass material.
- Atomic defects are imperfections of the atomic structure of the fiber materials such as missing molecules, high density clusters of atom groups or oxygen defects in the glass structure.
- Usually absorption losses arising from these defects are negligible as compared to intrinsic and impurity absorption effects. However, they can be significant if the fiber is exposed to intense nuclear radiation levels as might occurs in a nuclear reactor during a nuclear explosion or in the earth's Van Allen belts.

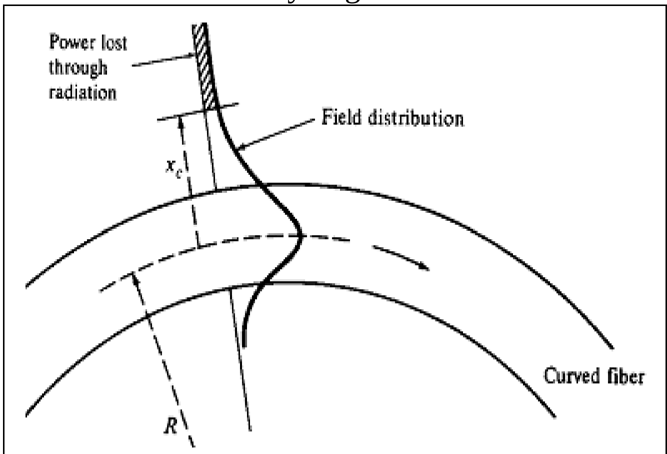
Ψ SCATTERING LOSS: -

- Scattering losses in glass arises from microscopic variations in the material density from compositional fluctuations and from structural in homogeneities or defects occurring during fiber manufactures.
- As glass is composed of a randomly connected network of molecules. Such a structure naturally contains regions in which the molecular density is either higher or lower than the average density in the glass.
- In addition this, since glass is made glass is made up of several oxides, such as SiO_2, GeO_2 and P_2O_5, compositional fluctuations can occurs. These two effects give rise to refractive index variations which occur within the glass over distance that are small compared to the wavelength.
- Theses index variation causes a Rayleigh type scattering of light. Rayleigh scattering in glass is the same phenomenon that scatters light from the Sun in the atmosphere, thereby giving rise to a blue sky.
- The expression for scattering-induced attenuation is fairly complex due to the random molecular nature and the various oxide constituents of glass.
- For single component glass the scattering loss at a wavelength λ resulting from density fluctuations can be approximated by →

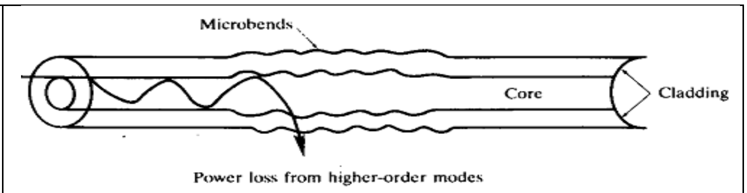
$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4}\left(n^2 - 1\right)^2 k_B T_f \beta_T$$

Ψ BENDING LOSS: -

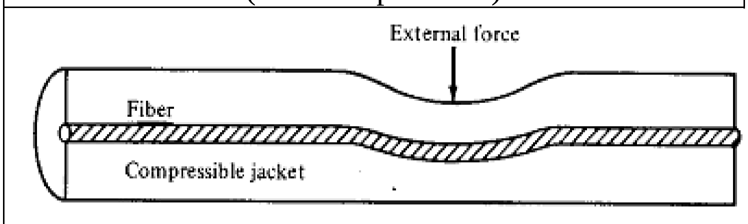
- Radiation losses occur whenever an optical fiber undergoes a bend of finite radius of curvature.
- Fiber can be subjected to two types of bends: -
  - ♣ Macroscopic bends having radii that re large compared to the fiber diameter and
  - ♣ Random microscopic bends of the fiber axis that arises when the fibers are incorporated into cables.
- Let us first examine large curvature radiation losses, which are known as Macro bending Losses or simply Bending Losses.
- For slight bends the excess loss is extremely small & is essentially unobservable
- As radius of curvature decreases, the loss increases exponentially until at a certain critical radius the curvature loss becomes observable.
- If the bend radius is made a bit smaller once this threshold point has been reached, the losses suddenly becomes extremely large.



(Macroscopic Bend)



(Microscopic Bend)



(Compressible Jacket over the fiber)

- Another form of radiation loss is optical waveguides caused by random micro bends of the optical fiber.

- Micro bends are repetitive small-scale fluctuations in the radius of curvature of the fiber axis.
- An increase in attenuation results from micro bending because of the fiber curvature.
- One method of minimizing, micro bending losses is by covering a compressible jacket over the fiber.
- When external forces are applied to this configuration, the jacket will be deformed but the fiber will tend to stay relatively straight as show in figure above.

Ψ CORE AND CLADDING LOSS

- Upon measuring the propagation losses in an actual fiber, all the dissipative and scattering losses will be manifested simultaneously.
- Since the core and cladding have different indices of refraction and therefore differ in composition, the core and cladding generally have different attenuation coefficients denoted α_1 and α_1, respectively.
- If the influence of modal coupling is ignored, the loss for mode of order (*v*, *m*) for a step-index waveguide is $\boldsymbol{\alpha_{vm}} = \boldsymbol{\alpha_1}\frac{P_{core}}{P} + \boldsymbol{\alpha_2}\frac{P_{clad}}{P}$. But $\mathbf{P_{Core}} + \mathbf{P_{Clad}} = \mathbf{1}$ ➔ $\boldsymbol{\alpha_{vm}} = \boldsymbol{\alpha_1} + (\boldsymbol{\alpha_2} - \boldsymbol{\alpha_1})\frac{P_{clad}}{P}$
- The total loss of the wave guide is sum of overall model weighted by the fractional power in that mode.

Ψ SIGNAL DISTORTION IN OPTICAL WAVEGUIDES

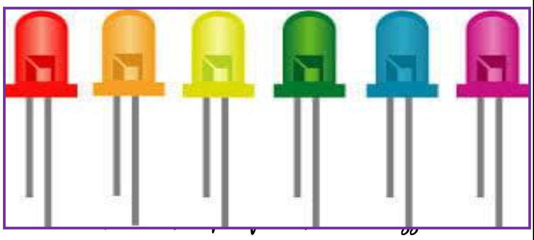
- An optical signal becomes increasingly distorted as it travels along a fiber.
- This distortion is a consequence of intramodal dispersion and intermodal delay effect.
- These distortion effects can be explained by examining the behavior of group velocities of guided modes
- Where the group velocity is the speed at which energy in a particular mode travels along the fiber.
- Intramodal dispersion is pulse spreading that occurs within a single mode.
- It is a result of the group velocity being a function of the wavelength λ.
- Since intramodal dispersion on the wavelength, its effect on signal distortion increase with the spectral width of the optical source.
- This spectral width is the band of wavelengths over which the source emits light.
- It is normally characterized by the root-mean-square (rms) spectral width σ_λ.
- For light-emitting diodes (LEDs) the rms spectral width would be 40nm; that is, the source emits most of its optical power in the 830- to 870-nm wavelength band.
- Laser diode optical sources have much narrow spectral widths, typical values being 1 to 2 nm.
- The two main causes of intramodal dispersion are:
  1) **<u>Material Dispersion</u>**: - It arises from the variation of the refractive index of the core material as a function of wavelength. This causes a wavelength dependence of the group velocity of any given mode; that is, pulse spreading occurs even when different wavelength follow the same path. It is also referred as **Chromatic Dispersion** as this is the same effect by which a prism spreads out a spectrum
  2) **<u>Waveguide Dispersion</u>**: - It occurs because a single-mode fiber only confines about 80 percent of the optical power to the core. Dispersion thus arises,
- Since the 20 percent of the light propagating in the cladding travels faster than light confined to the core.
- The amount of waveguide dispersion depends on the fiber design, since the modal propagation constant β is a function of a/λ (the optical fiber dimension relative to the wavelength λ; here a is the core radius).
- The other factor giving rise to pulse spreading is intermodal delay, which is a result of each having a different value of the group velocity at a single frequency.
- The Losses due to Material Dispersion and Waveguide Dispersion is given below: -

$$\boldsymbol{\tau_{mat}} = \frac{L}{c}\left(n - \lambda\frac{dn}{d\lambda}\right)$$

$$\boldsymbol{\tau_{wg}} = \frac{L}{c}\frac{d\beta}{dk} = \frac{L}{c}\left[n_2 + n_2\Delta\frac{d(kb)}{dk}\right]$$

❖ OPTICAL SOURCES

- In fiber optic system, electrical signals (Current or Voltage) at the transmitter end have to be converted into optical signals as efficiently as possible. This function is performed by an Optoelectronics Sources.
- There are two types of sources which to a large extents, fulfill these requirements, these are
  - ♣ Incoherent Optoelectronics Sources (Ex - LED)
  - ♣ Coherent Optoelectronics Sources (Ex - LASER)



❖ LED <Light Emitting Diode (LED>

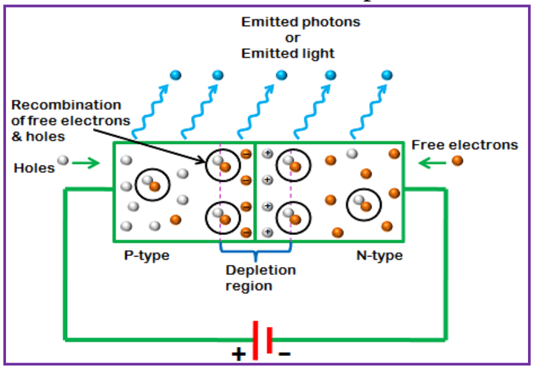
- LEDs are the most widely used semiconductor diodes among all the different types of semiconductor diodes available today.
- LEDs emit either visible light or invisible infrared light when forward biased. The LEDs which emit invisible infrared light are used for remote controls.
- A LED is an optical semiconductor device that emits light when voltage is applied.
- In other words, LED is an optical semiconductor device that converts electrical energy into light energy.
- When LED is forward biased, free electrons in the conduction band recombines with the holes in the valence band and releases energy in the form of light. The process of emitting light in response to the strong electric field or flow of electric current is called **electroluminescence**.
- A normal p-n junction diode allows electric current only in one direction.
- It allows electric current when forward biased and does not allow electric current when reverse biased.
- Thus, normal p-n junction diode operates only in forward bias condition.
- Like the normal p-n junction diodes, LEDs also operates only in forward bias condition.
- To create an LED, the n-type material should be connected to the negative terminal of the battery and p-type material should be connected to the positive terminal of the battery.
- The construction of LED is similar to the normal p-n junction diode except that **gallium**, **phosphorus** and **arsenic** materials are used for construction **instead** of **silicon** or **germanium** materials.
- In normal p-n junction diodes, silicon is most widely used as it is less sensitive to the temperature. Also, it allows electric current efficiently without any damage. In some cases, germanium is also used.
- However, silicon or germanium diodes do not emit energy in the form of light. Instead, they emit energy in the form of heat. Thus, silicon or germanium is not used for constructing LEDs.

Ψ Layers of LED

- A LED consists of three layers: p-type semiconductor, n-type semiconductor and depletion layer.
- P-type semiconductor & N-type semiconductor are separated by a depletion region or depletion layer.
- **P-type semiconductor: -** When trivalent impurities are added to the intrinsic or pure semiconductor, a p-type semiconductor is formed. In p-type semiconductor, holes are majority charge carriers & electrons are minority charge carriers. Thus, holes carry most of electric current in p-type semiconductor.
- **N-type semiconductor: -**When pentavalent impurities are added to the intrinsic semiconductor, an n-type semiconductor is formed. In n-type semiconductor, free electrons are the majority & holes are minority charge carriers. Thus, free electrons carry most of electric current in n-type semiconductor.
- **Depletion layer or region: -** Depletion region is present between p-type & n-type semiconductor where no mobile charge carriers are present. This region acts as barrier to electric current. It opposes flow of electrons from n-type semiconductor & flow of holes from p-type semiconductor. To overcome barrier of depletion layer, we need to apply voltage which is greater than barrier potential of depletion layer. If applied voltage is greater than barrier potential of the depletion layer, the electric current starts flowing.

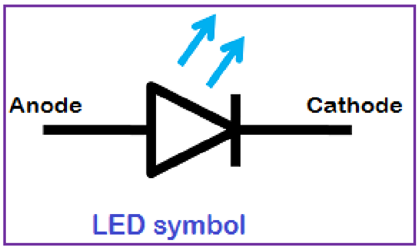
Ψ How Light Emitting Diode (LED) works?

- LED works only in forward bias condition. When LED is forward biased, free electrons from n-side & holes from p-side are pushed towards junction.
- When free electrons reach the junction or depletion region, some of the free electrons recombine with the holes in the positive ions. We know that positive ions have less number of electrons than protons.



- Therefore, they are ready to accept electrons.
- Thus, free electrons recombine with holes in depletion region.
- In the similar way, holes from p-side recombine with electrons in the depletion region.
- Because of the recombination of free electrons and holes in the depletion region, the width of depletion region decreases. As a result, more charge carriers will cross the p-n junction.
- Some of the charge carriers from p-side and n-side will cross the p-n junction before they recombine in the depletion region. For example, some free electrons from n-type semiconductor cross the p-n junction and recombines with holes in p-type semiconductor.
- In the similar way, holes from p-type semiconductor cross the p-n junction and recombines with free electrons in the n-type semiconductor.

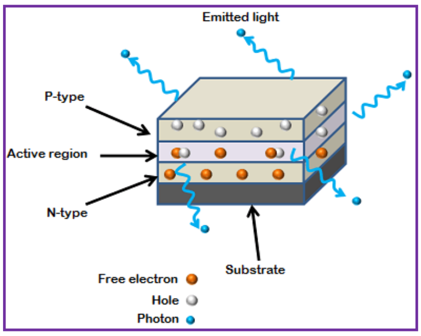
- Thus, recombination takes place in depletion region as well as in p-type and n-type semiconductor.
- The free electrons in the conduction band releases energy in the form of light before they recombine with holes in the valence band.
- In silicon and germanium diodes, most of the energy is released in the form of heat and emitted light is too small.
- However, in materials like gallium arsenide & gallium phosphide emitted photons have sufficient energy to produce intense visible light.



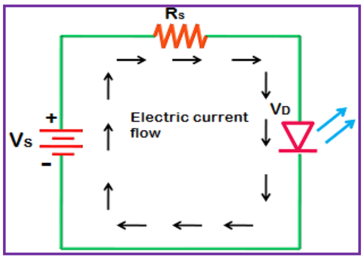
Ψ Light Emitting Diode (LED) symbol

- The symbol of LED is similar to the normal p-n junction diode except that it contains arrows pointing away from the diode indicating that light is being emitted by the diode.
- LEDs are available in different colors. Most common colors of LEDs are Orange, Yellow, Green & Red.
- The schematic symbol of LED does not represent the color of light. The schematic symbol is same for all colors of LEDs. Hence, it is not possible to identify the color of LED by seeing its symbol.

Ψ LED Construction

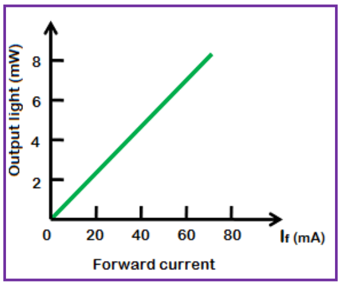


- One of the methods used to construct LED is to deposit three semiconductor layers on the substrate.
- The three semiconductor layers deposited on substrate are n-type semiconductor, p-type semiconductor and active region.
- Active region is present in between the n-type & p-type layers.
- When LED is forward biased, free electrons from n-type and holes from p-type semiconductor are pushed towards the active region.
- When free electrons from n-side and holes from p-side recombine with the opposite charge carriers in active region, an invisible or visible light is emitted.
- In LED, most of the charge carriers recombine at active region.
- Thus, most of the light is emitted by active region. The active region is also called as depletion region.



Ψ Biasing of LED

- The safe forward **voltage** ratings of most LEDs are 1V to 3 V and **current** ratings is 200 mA to 100 mA.
- If the voltage applied to LED is in between 1V to 3V, LED works perfectly, if the applied voltage greater than 3 volts, depletion region in the LED breaks down and the electric current suddenly rises.
- This sudden rise in current may destroy the device.
- To avoid this we need to place a resistor (R_s) in series with the LED.
- Resistor (R_s) must be placed in between voltage source (Vs) & LED.
- The resistor placed between LED and voltage source is called current limiting resistor. This resistor restricts extra current which may destroy the LED.
- Current limiting resistor protects LED from damage.

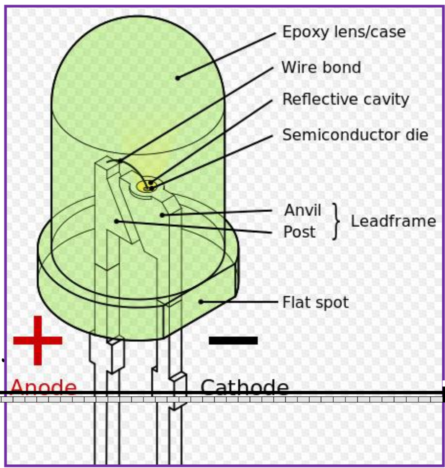


Ψ Output characteristics of LED

- The amount of output light emitted by the LED is directly proportional to the amount of forward current flowing through the LED.
- More the forward current, the greater is the emitted output light.
- The graph of forward current vs output light is shown in the figure.

Ψ Visible LEDs and invisible LEDs

- LEDs are mainly classified into two types: **Visible** & **Invisible** LEDs.
- Visible LED is a type of LED that emits visible light. These LEDs are mainly used for display or illumination where LEDs are used individually without photosensors.
- Invisible LED is a type of LED that emits invisible light (infrared light).
- These LEDs are mainly used with photosensors such as photodiodes.



Ψ What determines the color of an LED?

- The material used for constructing LED determines its color.
- In other words, the wavelength or color of the emitted light depends on the forbidden gap or energy gap of the material.
- Different materials emit different colors of light.
  - ✓ Gallium Arsenide LEDs emit **Red** and **Infrared** light.
  - ✓ Gallium Nitride LEDs emit **Bright Blue** light.
  - ✓ Yttrium Aluminium Garnet LEDs emit **White** light.
  - ✓ Gallium Phosphide LEDs emit **Red**, **Yellow** and **Green** light.
  - ✓ Aluminium Gallium Nitride LEDs emit **Ultraviolet** light.
  - ✓ Aluminum Gallium Phosphide LEDs emit **Green** light.

Ψ Advantages of LED

1. The brightness of light emitted by LED is depends on the current flowing through the LED. Hence, the brightness of LED can be easily controlled by varying the current.
2. Light emitting diodes consume low energy.
3. LEDs are very cheap and readily available.
4. LEDs are light in weight.
5. Smaller size.
6. LEDs have longer lifetime.
7. LEDs can emit different colors of light.
8. LEDs operate very fast. They can be turned on and off in very less time.
9. LEDs do not contain toxic material like mercury which is used in fluorescent lamps.

Ψ Disadvantages of LED

1. LEDs need more power to operate than normal p-n junction diodes.
2. Luminous efficiency of LEDs is low.

Ψ Applications of LED: - The various applications of LEDs are as follows

1. Burglar alarms systems
2. Calculators
3. Picture phones
4. Traffic signals
5. Digital computers
6. Multimeters
7. Microprocessors
8. Digital watches
9. Automotive heat lamps
10. Camera flashes
11. Aviation lighting

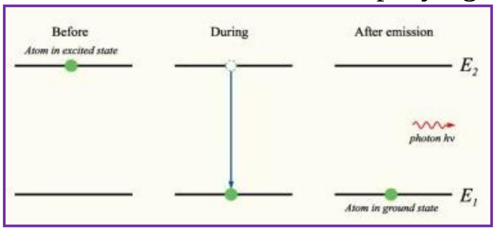
❖ LASER:-

- Laser is the abbreviation of **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation.
- It is a device that creates a narrow and low-divergent beam of coherent light, while most other light sources emit incoherent light, which has a phase that varies randomly with time and position.
- Most lasers emit nearly "monochromatic" light with a narrow wavelength spectrum.

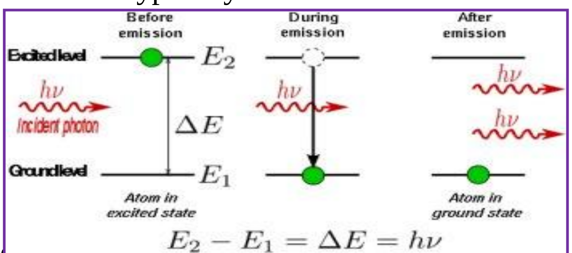
Ψ Principle of Lasers

- The principle of a laser is based on three separate features: (a) Stimulated Emission within an amplifying medium, b) Population Inversion and c) an Optical Resonator.

♣ Spontaneous Emission and Stimulated Emission



- According to the quantum mechanics, an electron within an atom or lattice can have only certain values of energy, or energy levels.
- There are many energy levels that an electron can occupy, but here we will only consider two. **Spontaneous Emission →**
- If an electron is in the excited state with the energy E_2 it may spontaneously decay to the ground state, with energy E_1, releasing the difference in energy between the two states as a photon.
- This process is called **spontaneous emission**, producing fluorescent light.
- The phase & direction of photon in spontaneous emission are completely random due to Uncertainty Principle. The electron remains in this excited state for a period of time typically less than 10^{-6} second.
- Then it returns to the lower state spontaneously by a photon or a phonon. [**Fig. Stimulated Emission→**]
- These common processes of absorption & spontaneous emission can't give rise to amplification of light.
- The best that can be achieved is that for every photon absorbed, another is emitted. Alternatively, if the excited-

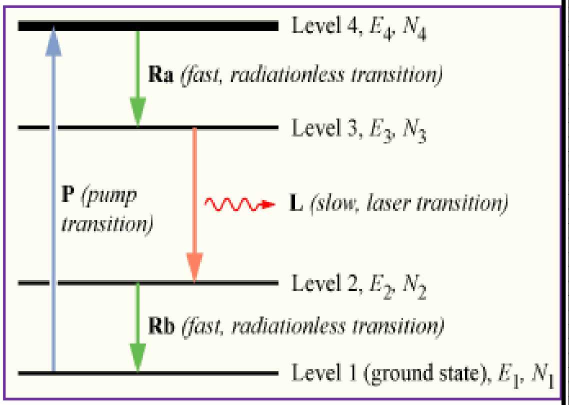


state atom is perturbed by the electric field of a photon with frequency ω, it may release a second photon of the same frequency, in phase with the first photon.

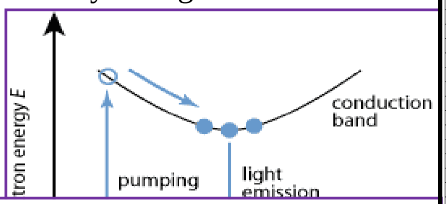
- The atom will again decay into the ground state. This process is known as stimulated emission.
- The emitted photon is identical to the stimulating photon with same frequency, polarization, & direction of propagation. And there is a fixed phase relationship between light radiated from different atoms.
- The photons, as a result, are totally coherent. This is critical property that allows optical amplification to take place. All the three processes occur simultaneously within a medium. However, in thermal equilibrium, stimulated emission does not account to a significant extent.
- The reason is there are far more electrons in the ground state than in the excited states.
- And the rates of absorption and emission is proportional the number of electrons in ground state and excited states, respectively. So absorption process dominates.

♣ Population Inversion of the Gain Medium

- If the higher energy state has a greater population than the lower energy state, then the light in the system undergoes a net increase in intensity. And this is called **population** inversion.
- But this process cannot be achieved by only two states, because the electrons will eventually reach equilibrium with the de-exciting processes of spontaneous and stimulated emission.
- Instead, an indirect way is adopted, with three energy levels ($E_1 < E_2 < E_3$) and energy population N_1, N_2 and N_3 respectively. Initially, the system is at thermal equilibrium, and the majority of electrons stay in the ground state. Then external energy is provided to excite them to level 3, referred as pumping.
- The source of pumping energy varies with different laser medium, such as electrical discharge and chemical reaction, etc.



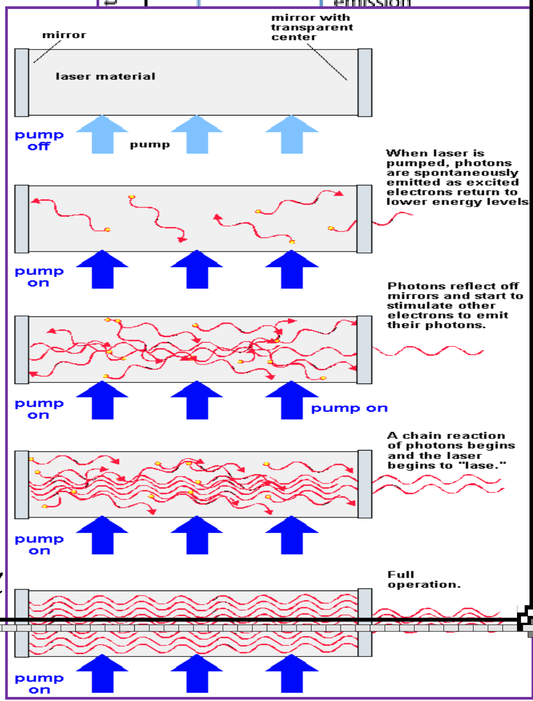
- In a medium suitable for laser operation, we require these excited atoms to quickly decay to level 2, transferring the energy to the phonons of the lattice of the host material.
- This wouldn't generate a photon, and labeled as R, meaning radiation less.
- Then electrons on level 2 will decay by spontaneous emission to level 1, labeled as L, meaning laser.
- If the life time of L is much longer than that of R, the population of the E_3 will be essentially zero and a population of excited state atoms will accumulate in level 2.
- When level 2 hosts over half of the total electrons, a population inversion be achieved.
- Because half of the electrons must be excited, the pump system needs to be very strong.
- This makes three-level lasers rather inefficient.
- Most of the present lasers are 4-level lasers, see
- The population of level 2 and 4 are 0 and electrons just accumulate in level 3. Laser transition takes place between level 3 and 2, so the population is easily inverted.



- In semiconductor lasers, where there are no discrete energy levels, a pump beam with energy slightly above the band gap energy can excite electrons into a higher state in the conduction band, from where they quickly decay to states near the bottom of the conduction band.
- At the same time, the holes generated in the valence band move to the top of the valence band.
- Electrons in conduction band can then recombine with these holes, emitting photons with an energy near band gap energy.

♣ Summary of Principles and Modes of Operation

- As a summary, refer diagram of the working process of lasers.
- The output of a laser may be a continuous constant-amplitude output (CW or continuous wave); or pulsed, by using the techniques of Q-switching, model-locking, or gain-switching.



- In many fields of pulsed lasers, one aims to deposit as much energy as possible at a given place in as short time as possible.
- Some dye lasers and vibronic solid-state lasers can produce light over a broad range of wavelengths; this property makes them suitable for generating extremely short pulses of light, on the order of a few femtoseconds (10^{-15} s).
- The peak power of pulsed laser can achieve 10^{12} Watts.

♣ TYPES OF LASERS AND APPLICATIONS

- According to the gain material, lasers can be divided into the following types.
- Several common used lasers are listed in each type.

Ψ GAS LASERS:

Laser Medium	Wavelength(s)	Pump Source	Applications and Notes
Helium-neon laser	632.8nm	Electrical discharge	Interferometry, holography, spectroscopy, barcode scanning, alignment, optical demonstrations
Argon laser	454.6 nm, 488.0 nm, 514.5 nm	Electrical discharge	Retinal phototherapy (for diabetes), lithography, confocal microscopy, spectroscopy pumping other lasers
Carbon dioxide laser	10.6 μm, (9.4 μm)	Electrical discharge	Material processing (cutting, welding, etc.), surgery
Excimer laser	193 nm (ArF), 248 nm (KrF), 308 nm (XeCl), 353 nm (XeF)	Excimer recombination via electrical discharge	Ultraviolet lithography for semiconductor manufacturing, laser surgery

Ψ SOLID STATE LASERS:

Laser Medium	Wavelength(s)	Pump Source	Applications and Notes
Ruby laser	694.3nm	Flash Lamp	Holography, tattoo removal. The first type of visible light laser invented; May 1960.
Nd:YAG laser	1.064 μm, (1.32 μm)	Flash Lamp, Laser Diode	Material processing, laser target designation, surgery, research, pumping other lasers. One of the most common high power lasers.
Erbium doped glass lasers	1.53-1.56 μm	Laser diode	um doped fibers are commonly used as optical amplifiers for telecommunications.
F-center laser	Mid infrared to far infrared	Electrical current	Research

Ψ METAL-VAPOR LASERS:

Laser Medium	Wavelength(s)	Pump Source	Applications and Notes
Helium-cadmium (HeCd) metal-vapor laser	441.563 nm, 325 nm	Electrical discharge in metal vapor mixed with helium buffer gas.	Printing and typesetting applications, fluorescence excitation examination (ie. in U.S. paper currency printing)
Copper vapor laser	510.6 nm, 578.2 nm	Electrical discharge	Dermatological uses, high speed photography, pump for dye lasers

Ψ OTHER TYPES OF LASERS:

Laser Medium	Wavelength(s)	Pump Source	Applications and Notes
Dye lasers	Depending on materials, usually a broad spectrum	Other laser, flashlamp	Research, spectroscopy, birthmark removal, isotope

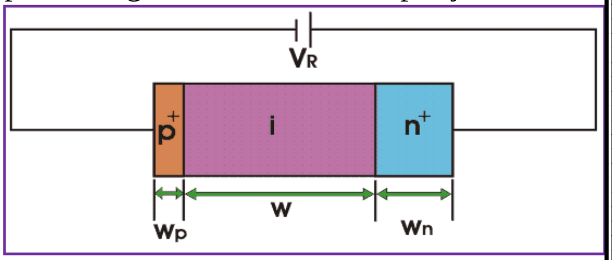
			separation.
Free electron laser	A broad wavelength range (about 100 nm - several mm)	Relativistic electron beam	Atmospheric research, material science, medical applications

❖ PIN DIODE

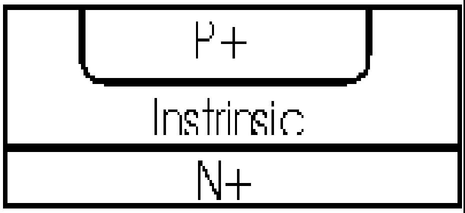
Table 8-4 LED Versus Laser

Characteristic	LED	Laser
Output power	Lower	Higher
Spectral width	Wider	Narrower
Numerical aperture	Larger	Smaller
Speed	Slower	Faster
Cost	Less	More
Ease of operation	Easier	More difficult

- **PIN photodiode** is a kind of photo detector, it can convert optical signals into electrical signals.
- This technology was invented in the latest of 1950's. There are three regions in this type of diode.
- Those are **p-region, intrinsic region** and **n-region.**
- The p-region and n-region are comparatively heavily doped than the p-region and n-region of usual p-n diodes.
- The width of the intrinsic region should be larger than the space charge width of a normal p-n junction.
- The **PIN photo diode** operates with an applied reverse bias voltage and when the reverse bias is applied, space charge region must cover intrinsic region completely.



- Electron hole pairs are generated in the space charge region by photon absorption.
- The switching speed of frequency response of photo diode is inversely proportional to life time.
- The switching speed can be enhanced by a small minority carrier lifetime.
- For photo detector applications where speed of response is important, the depletion region width should be made as large as possible for small minority carrier lifetime as a result switch speed also increases.
- This can be achieved PIN photo diode as the insertion of intrinsic region the space charge width larger.
- The PIN diode, p-i-n diode is essentially a refinement of the ordinary PN junction diode.
- Its development arose from the original PN diode development activities and applications for the new diode were soon found. The PIN diode differs from the basic PN junction diode in that the PIN diode includes a layer of intrinsic material between the P and N layers.

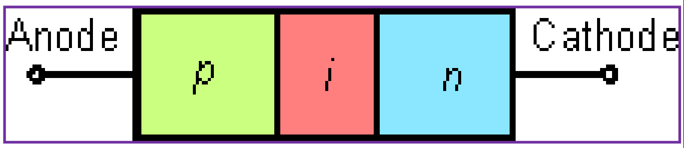


- As a result of the intrinsic layer, PIN diodes have a high breakdown voltage and they also exhibit a low level of junction capacitance.
- In addition to this the larger deletion region of the PIN diode is ideal for applications as a photodiode.

Ψ PIN DIODE STRUCTURE

- The PIN diode consists of a semiconductor diode with three layers. The usual P and N regions are present, but between them is a layer of intrinsic material a very low level of doping.
- This may be either N-type or P-type, but with a concentration of the order of 13^13 cm^-3 which gives it a resistivity of the order of one k-ohm cm. The thickness of the intrinsic layer is normally very narrow, typically ranging from 10 to 200 microns. The outer P and N-type regions are then heavily doped.
- There are two ways in which the PIN diode can be realised.
- One is to fabricate the p-i-n diode in a planar structure, and the other is to use a mesa structure.
- When the planar structure is fabricated an epitaxial film is grown onto substrate material and P+ region is introduced either by diffusion or ion implantation.
- The mesa structure has layers grown onto the substrate. These layers have the dopants incorporated.
- In this way it is possible to control the thickness of the layers and the level of dopants more accurately and a very thin intrinsic layer can be fabricated if required. This is ideal for high frequency operation.
- A further advantage of the mesa structure is that it provides a reduced level of fringing capacitance and inductance as well as an improved level of surface breakdown.
- PIN diodes are widely made of silicon, and this was the semiconductor material that was used exclusively until the 1980s when gallium arsenide was introduced.

Ψ PIN DIODE BASICS AND OPERATION



- The PIN diode can be shown diagrammatically as being a PN junction, but with an intrinsic layer between the PN and layers.
- The intrinsic layer of the PIN diode is a layer without doping, and as a result this increases the size of the depletion region - the region between the P and N layers where there are no majority carriers.
- This change in the structure gives the PIN diode its unique properties.
- The PIN diode operates in exactly the same way as a normal diode.
- The only real difference is that the depletion region that normally exists between the P and N regions in an unbiased or reverse biased diode is larger.
- In any PN junction, the P region contains holes as it has been doped to ensure that it has a predominance of holes. Similarly the N region has been doped to contain excess electrons.
- The region between the P and N regions contains no charge carriers as any holes or electrons combine As the depletion region has no charge carriers it acts as an insulator.
- Within a PIN diode the depletion region exists, but if the diode is forward biased, the carriers enter the depletion region (including the intrinsic region) and as the two carrier types meet, current starts to flow.
- When the diode is forward biased, the carrier concentration, i.e. holes and electrons is very much higher than the intrinsic level carrier concentration.
- Due to this high level injection level, electric field extends deeply (almost entire length) into the region.
- This electric field helps in speeding up of the transport of charge carriers from p to n region, which results in faster operation of the diode, making it a suitable device for high frequency operations.

Ψ **PIN DIODE USES AND ADVANTAGES**

- The PIN diode is used in a number of areas as a result of its structure proving some properties which are of particular use.
  - **HIGH VOLTAGE RECTIFIER*:*** The PIN diode can be used as a high voltage rectifier. The intrinsic region provides a greater separation between the PN and N regions, allowing higher reverse voltages to be tolerated.
  - **RF SWITCH*:*** The PIN diode makes an ideal RF switch. The intrinsic layer between the P and N regions increases the distance between them. This also decreases the capacitance between them, thereby increasing the level of isolation when the diode is reverse biased.
  - **PHOTODETECTOR*:*** As the conversion of light into current takes place within the depletion region of a photodiode, increasing the depletion region by adding the intrinsic layer improves the performance by increasing he volume in which light conversion occurs.
- These are three main applications for PIN diodes, although they can also be used in some other area also.
- The PIN diode is an ideal component to provide electronics switching in many areas of electronics.
- It is particularly useful for RF design applications and for providing the switching, or attenuating element in RF switches and RF attenuators.
- The PIN diode is able to provide much higher levels of reliability than RF relays.
- The PIN diode is widely used in a number of areas where the properties and characteristics it has as a result of its intrinsic region make it uniquely applicable for a number of applications.
- While the PIN diode characteristics mean that it is not suitable for many standard rectifier applications, they provide some properties that can be used in a number of specific areas.

Ψ **Key PIN Diode Characteristics**

- There are a number of PIN diode characteristics that set this diode apart from other forms of diode.
- These key PIN diode characteristics include the following:
  - **High breakdown voltage*:*** The wide depletion layer provided by the intrinsic layer ensures that PIN diodes have a high reverse breakdown characteristic.
  - **Low capacitance*:*** Again the intrinsic layer increases the depletion region width. As the capacitance of a capacitor reduces with increasing separation, this means that a PIN diode will have a lower capacitance as the depletion region will be wider than a conventional diode. This PIN diode characteristic can have significant advantages in a number of RF applications - for example when a PIN diode is used as an RF switch.
  - **Carrier storage*:*** Carrier storage gives a most useful PIN diode characteristic. For small signals at high frequencies the stored carriers within the intrinsic layer are not completely swept by the RF signal or recombination. At these frequencies there is no rectification or distortion and the PIN diode

characteristic is that of a linear resistor which introduces no distortion or rectification. The PIN diode resistance is governed by the DC bias applied. In this way it is possible to use the device as an effective RF switch or variable resistor for an attenuator producing far less distortion than ordinary PN junction diodes.

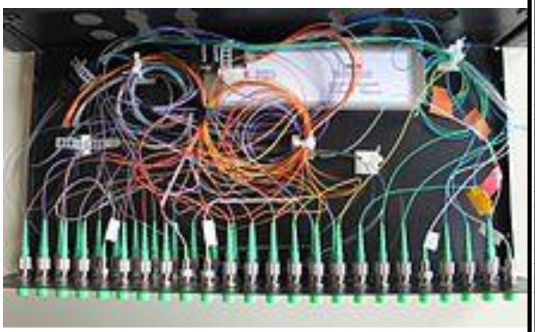
- **Sensitive photo detection***:* The sensitive area of a photodiode is the depletion region. Light striking the crystal lattice can release holes and electrons which are drawn away out of the depletion region by the reverse bias on the diode. By having a larger depletion region - as in the case of a PIN diode - the volume for light reception is increased. This makes PIN diodes ideal for use as photo detectors.

❖ AVALANCHE PHOTODIODE BASICS

- ➢ The avalanche photodiode possesses a similar structure to that of the PIN or PN photodiode.
- ➢ A structure similar to that of a Schottky photodiode can also be used but this is less common.
- ➢ However the structure is optimised for avalanche operation.
- ➢ The main difference of the avalanche photodiode operates under a slightly different scenario to that of the more standard photodiodes.
- ➢ It operates under a high reverse bias condition to enable avalanche multiplication of the holes and electrons created by the initial hole electron pairs created by the photon / light impact.
- ➢ The avalanche action enables the gain of the diode to be increased many times, providing a much greater level of sensitivity.

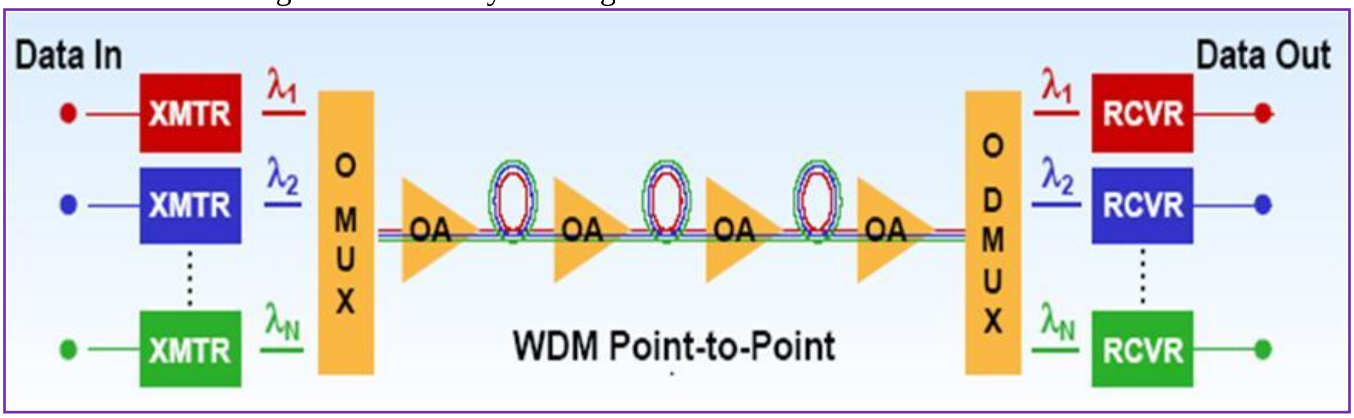
Ψ AVALANCHE PHOTODIODE ADVANTAGES AND DISADVANTAGES

- ➢ The avalanche photodiode has a number of different characteristics to the normal p-n or p-i-n photodiodes, making them more suitable for use in some applications.
- ➢ In view of this it is worth summarizing their advantages and disadvantages.
- ➢ The main **advantages** of the avalanche photodiode include:
  - Greater level of sensitivity
- ➢ The **disadvantages** of the avalanche photodiode include:
  - Much higher operating voltage may be required.
  - Avalanche photodiode produces a much higher level of noise than a p-n photodiode
  - Avalanche process means that the output is not linear



❖ Wave Length Division Multiplexing (WLDM):-

- ➢ In FOCS, wavelength-division multiplexing (WDM) is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelength (i.e. colors) of laser light.
- ➢ This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity. A WDM system uses a multiplexer at the transmitter to join the signals together and a demultiplexer at the receiver to split them apart.
- ➢ With the right type of fiber it is possible to have a device that does both simultaneously, and can function as an optical add-drop multiplexer.
- ➢ This is often done by use of optical-to-electrical-to-optical (O/E/O) translation at the very edge of the transport network, thus permitting interoperation with existing equipment with optical interfaces.
- ➢ The basic block diagram of WDM system is given below.



- WDM systems are divided into different wavelength patterns, conventional/coarse (CWDM) and dense (DWDM). WDM, DWDM and CWDM are based on the same concept of using multiple wavelengths of light on a single fiber, but differ in the spacing of the wavelengths, number of channels, and the ability to amplify the multiplexed signals in the optical space.
- Conventional WDM systems provide up to 8 channels in the 3rd transmission window (C-band) of silica fibers around 1550 nm. Dense wavelength division multiplexing (DWDM) uses the same transmission window but with denser channel spacing.
- Channel plans vary, but a typical system would use 40 channels at 100 GHz spacing or 80 channels with 50 GHz spacing. Some technologies are capable of 12.5 GHz spacing (sometimes called ultra dense WDM). Such spacings are today only achieved by free space optics technology.
- Coarse Wavelength Division Multiplexing (CWDM) in contrast to conventional WDM and DWDM uses increased channel spacing to allow less sophisticated and thus cheaper transceiver designs.
- To provide 8 channels on a single fiber CWDM uses the entire frequency band between second and third transmission window (1310/1550 nm respectively) including both windows (minimum dispersion window and minimum attenuation window) but also the critical area where OH scattering may occur, recommending the use of OH-free silica fibers in case the wavelengths between second and third transmission window should also be used
- In this type of technology transmission of multiple digital signals can be made in difference wave length without any interference. Using W.D.M a number of optical signals can be transmitted at a time by a signal fiber cable at the same time with different wave length or frequencies.
- ***Transmitted** in the same medium in different paths only and at the receiving section.
- They are reached at different time interval.
- The wave lengths are created depending upon the color and combination of these can be transmitted by multimode step index profile creating paths for individual colour.
- In wavelength-division multiplexing, each data channel is transmitted using a slightly different wavelength (different color). With use of a different wavelength for each channel, many channels can be transmitted through the same fiber without interference.
- This method is used to increase the capacity of existing fiber optic systems many times.
- Each WDM data channel may consist of a single data source or may be a combination of a single data source and a TDM (time-division multiplexing) and/or FDM (frequency-division multiplexing) signal.
- Dense wavelength-division multiplexing (DWDM) refers to the transmission of multiple closely spaced wavelengths through the same fiber.

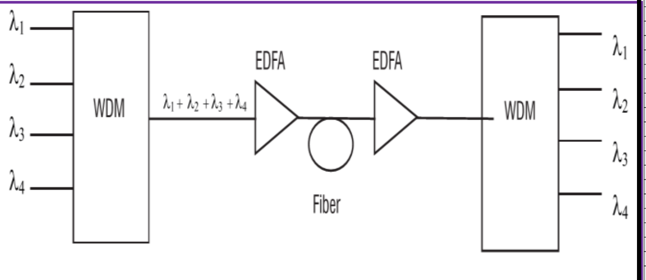


Figure 8-17 *Wavelength-division multiplexing*

- For any given wavelength λ and corresponding frequency f, the International Telecommunications Union (ITU) defines standard frequency spacing Δf as 100 GHz, which translates into a $\Delta\lambda$ of 0.8-nm wavelength spacing.
- This follows from the relationship $\Delta\lambda = \lambda \Delta f$
- DWDM systems operate in the 1550-nm window because of the low attenuation characteristics of glass at 1550 nm & the fact that Erbium-Doped Fiber Amplifiers (EDFA) operate in 1530nm -1570nm range.
- Commercially available systems today can multiplex up to 128 individual wavelengths at 2.5 Gb/s or 32 individual wavelengths at 10 Gb/s. Although the ITU grid specifies that each transmitted wavelength in a DWDM system is separated by 100 GHz, systems currently under development have been demonstrated that reduce the channel spacing to 50 GHz and below (< 0.4 nm).
- As the channel spacing decreases, the number of channels that can be transmitted increases, thus further increasing the transmission capacity of the system.

❖ CONNECTORS & SPLICES

- Electronic devices are often interconnected, either to form a larger system or to exchange information or data. An example of this is the local telephone system, which has electronic devices (such as a telephone) connected with copper wires to large switching networks.
- The wire carries power and signals from the phone to the switching office, and electrical connectors are used to link the wire to various devices in the system.

- In the previous module, we mentioned optical fiber, networks, transmitters and receivers, but we have not described in detail how these elements are connected to each other.
- Fiber optic cable performs a function similar to that of copper wire, and connectors are similarly used to attach fiber to the many devices in a fiber optic system.
- Fiber optic cables need to be connected and disconnected just like their copper counterparts.
- In this section we will discuss several connection methods and tools used with optical fiber components.
- **Linking Optical Fibers and Devices** In electronic systems, electrical current or energy is used either to transfer power or carry information among components and subsystems.
- Fiber optic systems use optical energy primarily to carry information or data. Regardless of the data format or transmission rate within a fiber optic system, three fundamental actions are performed among the various components and subsystems.
- A component is either emitting optical energy (LEDs and LASERS), transferring optical energy (Fiber optic Cables and Couplers), or receiving optical energy (Phototransistors and Photodiodes).
- To link these fiber optic components so optical energy can be transferred within the system, two primary methods are used:- **(1) CONNECTORS (2) SPLICES**
- Connectors most often are used to link fiber optic cable to photo detectors or LEDs.
- The devices are packaged in a housing which accepts a connectorized fiber optic cable, permitting efficient transfer of optical energy between the cable and optoelectronic component.
- Splices most often are used to permanently connect two fiber optic cables. While connectors can also be used to attach two fibers, splices generally offer less light loss and are more permanent.
- Connectors are removable and therefore more flexible when interchanging components within a system.
- Table shows a comparison between connectors and splices.

CONNECTORS	SPLICES
Removable	Permanent
Can be factory-installed	Can be field-installed
Can be field-installed	Lower attenuation/reflection than connectors
Easy to reconfigure	Strong, compact junction
Provide standard interface	Lower cost per connection
	Easier to fit inside conduit

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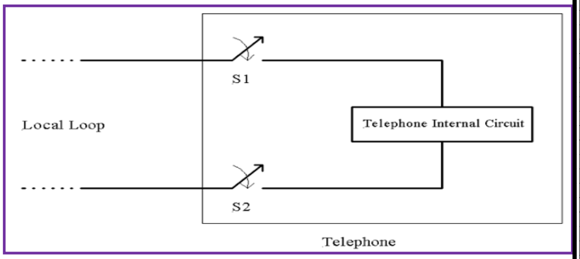
TELECOMMUNICATION SYSTEM

❖ The Operation of Electronic Telephone System. (Basic Telephone Set)

4. TELECOMMUNICATION SYSTEM **10**

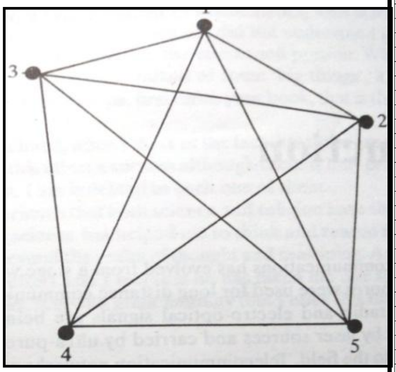
- 4.1 Discuss the operation of Electronic Telephone System. (Telephone Set)
- 4.2 Discuss the function of switching system.& Call procedures
- 4.3 Discuss the principle of space and time switching.
- 4.4 Discuss the numbering plan of telephone networks (National Schemes & International Numbering)
- 4.6 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

- ♣ To provide a signal to the telephone company that a call is to be made or a call is complete.
- ♣ To provide the telephone company with the number the caller wishes to call.
- ♣ To provide a way for the telephone company to indicate that a call is coming in or ringing.
- ♣ To convert voice frequencies to electrical signals that can be transmitted at the transmitter and convert those electrical signals back to voice frequencies at the receiver.
- ☯ The Federal Communications Commission (FCC) has set standards for the above features and all manufacturers selling telephones in this country must match these standards or the phone will not work properly.



- ☯ In addition many modern telephones also come with features like speed dial, redial, memory, caller ID, voice mail, etc. These are all additional features that are not necessary to make or receive calls.
- ☯ Let's look at Telephone Set Function 1: To provide a signal to the telephone company that a call is to be made (off-hook) or a call is complete (on-hook).
- ☯ The switch hook gets its name from the old telephones that had a hook on the side. On modern phones the switch hook is a button that is depressed when the handset is put on the cradle of the telephone.
- ☯ According to Telephone Company specifications individual telephone set DC resistance should be 200 Ω but in reality most telephones range between 150 and 1000 Ω of DC resistance.
- ☯ When a user picks up a connected telephone handset to make a call the switch hooks in the figure above (S_1 and S_2) close (off-hook condition) and the local loop circuit is complete.
- ☯ When a handset is picked up, a DC current ranging between 20 and 120 mA flows on the pair of wires connecting the telephone to CO. This current flow causes a relay coil to magnetize & it's contacts close.
- ☯ In the CO current flows through a relay coil attached to the local loop wire pair.
- ☯ The coil energizes, its contacts close and the CO switch knows a phone is off hook somewhere.
- ☯ A line feeder in the CO switch looks for the off-hook signal, finds it and sets up a connection. In the CO switch a dial-tone generator is connected to the line so the caller knows they can dial a number.

❖ The Function of Switching System & Call Procedures: -



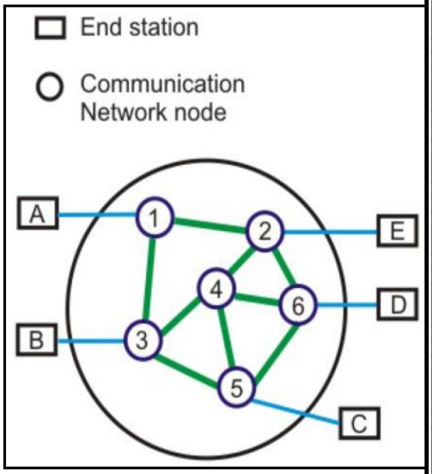
SWITCHING SYSTEM

- ☯ When there are many devices, it is necessary to develop suitable mechanism for communication between any two devices.
- ☯ One alternative is to establish point-to-point communication between each pair of devices using **Mesh Topology.**
- ☯ However, mesh topology is impractical for large number of devices, because the number of links increases exponentially [n(n-1)/2], where n is the number of devices) with the number of devices. A better alternative is to use switching techniques leading to switched communication network.
- ☯ In the **switched network** methodology, the network consists of a set of interconnected nodes, among which information is transmitted from source to destination via different routes, which is controlled by the switching mechanism. A basic model of a switched communication is shown in Fig.
- ☯ The end devices that wish to communicate with each other are called ***stations***. The switching devices are called ***nodes***. Some nodes connect to other nodes and some are connected to some stations.
- ☯ Key features of a switched communication network are given below:
  - Network Topology is not regular.

- Uses FDM or TDM for node-to-node communication.
- There exist multiple paths between a source-destination pair for better network reliability.
- The switching nodes are not concerned with the contents of data.
- Their purpose is to provide a switching facility that will move data from node to node until they reach the destination.

☯ The switching performed by different nodes can be categorized into the following three types: -

♣ Circuit Switching
♣ Packet Switching
♣ Message Switching



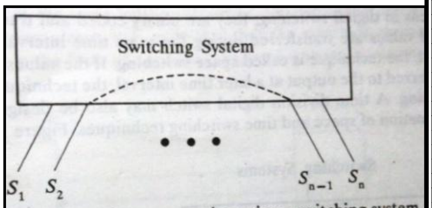
Ψ **BASIC CALL PROCEDURE**: -

☯ Fig. Shows a simplification diagram illustrating how two telephone sets (subscribers) are interconnected through central office dial switch.

☯ Each subscriber is connected to the switch through a local loop.

☯ The switch is most likely some sort of an electronic switching system.

☯ The local loop are terminated at the calling and called station **s** in telephone sets and at the central office ends to switching machines.



Subscriber interconnection using a switching system.

☯ When the calling party's telephone set goes off hook (i.e., lifting the handset off the cradle), the switch hook in the telephone set is released, completing a dc path between the tip & the ring of the loop trough the microphone .

☯ The ESS machine senses a dc current in the loop & recognizes this as an off-hook condition.

☯ Completing a local telephone call between two subscribers connected to the same telephone switch is accomplished through a standard set of procedure that includes the 10 steps listed next.

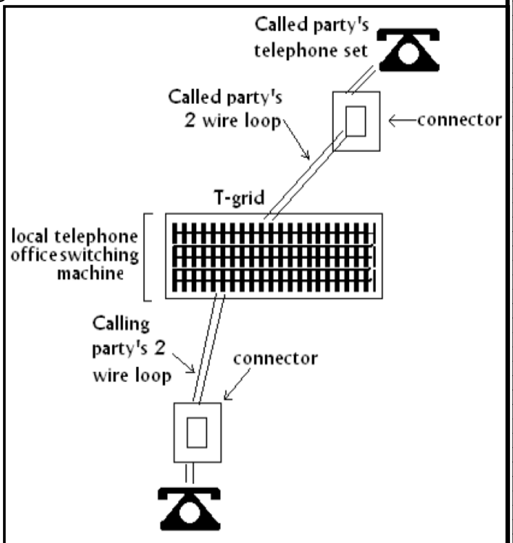


FIG - Telephone Call Procedure

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 the 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 dialled number, it removes the dial tone from the loop.

Step-5 The switch interprets the telephone number & then locates the loop for destination telephone no.

Step-6 Before ringing the destination telephone , the switching machine tests the destination loop for dc current to see if tt 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-7 (**A**) If the destination telephone is off hook, the switching machine sends a station busy signal back to the calling station. (**B**) If the destination telephone is on hook, the switching machine sends a ringing signal to the destination telephone on the local loop and the same time sends a ring back signal to the calling station to give the caller some assurance that something is happening.

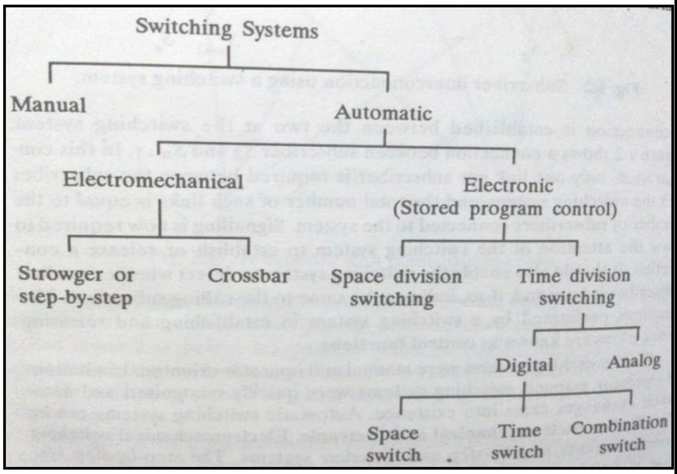
Step-8 When the destination answers the telephone, it completes the loop, causing dc current to flow.

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 to begin conversation.

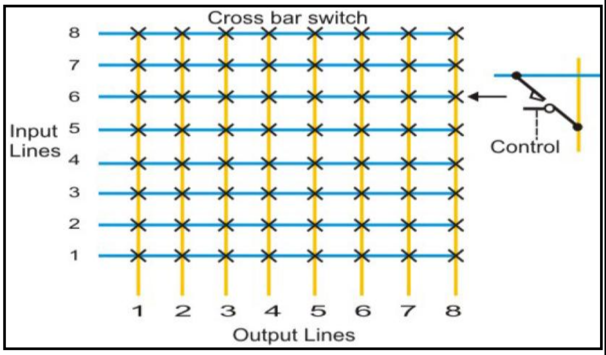
Step-10 When either end goes on hook, the switching machine detects an open circuit on that loop and then drops the connections through the switch

❖ THE PRINCIPLE OF SPACE AND TIME SWITCHING: -

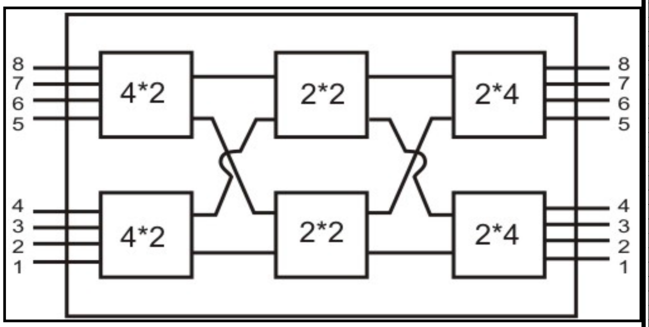
Ψ SPACE SWITCHING



- Circuit switching uses any of the three technologies: **Space-division** switches, **Time-division** switches or a **combination of both**.
- 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, which are separated spatially.
- This was originally developed for the analog environment, and has been carried over to the digital domain.
- Some of the space switches are crossbar switches; Multi-stage switches (e.g. Omega Switches).
- A **Crossbar** switch is shown in Fig. Basic building block of the switch is a metallic cross-point or semiconductor gate that can be enabled or disabled by a control unit.
- **Limitations** of crossbar switches are as follows:



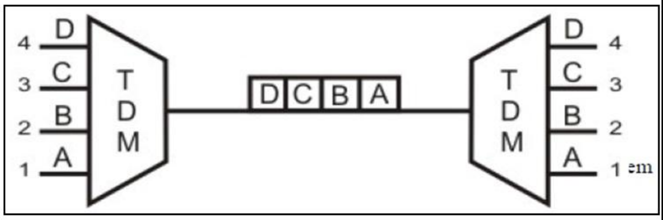
♣ The number of cross points grows with the square of the number of attached stations.
♣ Costly for a large switch.
♣ The failure of a cross point prevents connection between the two devices whose lines intersect at that cross point.
♣ The cross points are inefficiently utilized.
♣ Only small fractions of cross points are engaged even if all of the attached devices are active.
♣ Some of the above problems can be overcome with the help of *multistage space division* switches.
♣ By splitting the crossbar switch into smaller units and interconnecting them, it is possible to build multistage switches with fewer cross points.



- Figure in next page shows a three-stage space division switch. In this case the number of cross points needed goes down from 64 to 40.
- There is more than one path through the network to connect two endpoints, thereby increasing reliability.

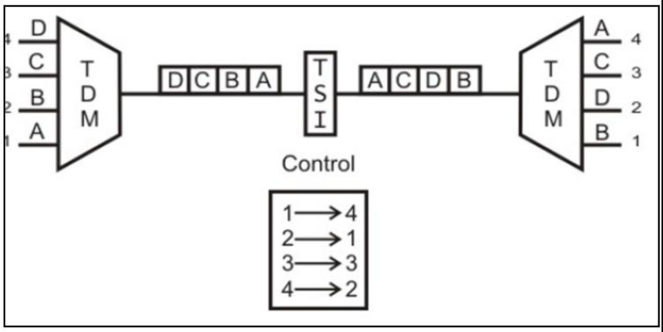
[Fig- A Three-Stage Space Division Switch]

- Multistage switches may lead to *blocking*. The problem may be tackled by increasing the number or size of the intermediate switches, which also increases the cost.
- As shown in Fig. after setting up connections for 1-to-3 and 2-to-4, the switch cannot establish connections for 3-to-6 and 4-to-5.

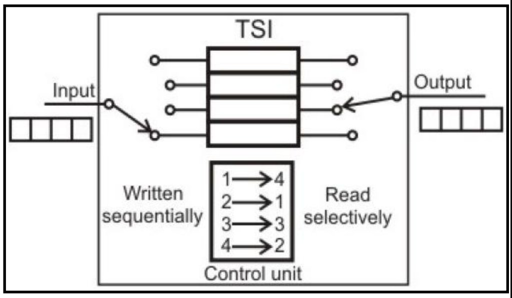


Ψ TIME DIVISION SWITCHING

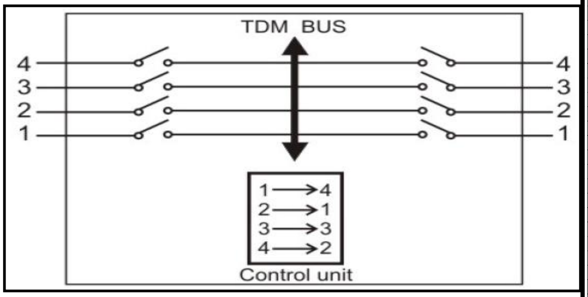
- Both voice and data can be transmitted using digital signals through the same switches.
- All modern circuit switches use digital time-division multiplexing (TDM) technique for establishing and maintaining circuits.



- Synchronous TDM allows multiple low-speed bit streams to share a high-speed line.
- A set of inputs is sampled in a round robin manner.
- The samples are organized serially into slots (channels) to form a recurring frame of slots.
- During successive time slots, different I/O pairings are enabled, allowing a number of connections to be carried over the shared bus.



- To keep up with the input lines, the data rate on the bus must be high enough so that the slots recur sufficiently frequently.
- For 100 full-duplex lines at 19.200 Kbps, the data rate on the bus must be greater than 1.92 Mbps.
- The source-destination pairs corresponding to all active connections are stored in the control memory.
- Thus slots need not specify the source & destination addresses.
- Schematic diagram of time division switching shown in fig.
- Time-division switching uses time-division multiplexing to achieve switching, i.e. different ongoing connections can use same switching path but at different interleaved time intervals.



- There are two popular methods of time-division switching namely, 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 as shown in Fig.
- The operation of a TSI is depicted in Fig.1 As shown in the fig., writing can be performed in the memory sequentially, but data is read selectively.
- 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 as shown in Fig.2

❖ The Numbering Plan Of Telephone Networks

- The National Numbering Plan was last reviewed during 1993. The plan covered basic as well as other services like cellular mobile, paging etc. Though the 1993 Numbering Plan could cater to the needs of existing and new services for another few years, yet it was felt to rationalize and review the existing National Numbering Plan because of introduction of a large number of new telecom services and opening up of the entire telecom sector for private participation.
- The existing Numbering Plan was formulated at a time when there was no competition in the basic telecom services and the competition in cellular mobile services had just started, paging services were in a stage of infancy and Internet services were not available in the country.

Ψ THE MAIN OBJECTIVES OF THE PLAN ARE: –

- ♣ To plan in conformity with relevant and applicable ITU standards to the extent possible.
- ♣ To meet the challenges of the changing telecom environment.
- ♣ To reserve numbering capacity to meet the undefined future needs.
- ♣ To support effective competition by fair access to numbering resources.
- ♣ To meet subscriber needs for a meaningful and user-friendly scheme.

- Only the decimal character set 0-9 has been used for all number allocations.
- Letters and other non-decimal characters shall not form part of the National Number.
- Dialing procedure as per ITU Recommendation E.164 has been followed.
- The Short Distance Charging Area (SDCA) based linked numbering scheme with 10-digit N(S)N has been followed. This would expand the existing numbering capacity to ten times.

Ψ NATIONAL NUMBERING SCHEME

- **Level '0': Sub level '000':**
- The prefix '000' shall be used for home country direct service (Bilateral) and international toll free service (Bilateral). The format used is: '000 + Country Code + Operator Code' except '000800' which is used for bilateral international toll free service.
- **Sub level '0010' - International Carrier Access (Prefix) Code**: The prefix '0010' shall be used for selection of international carrier. It will be followed by International Carrier Identification Code (ICIC), Country Code (CC) and N(S)N. The format shall be as under: -

Prefix	International Carrier Identification Code	Country Code	National(Significant)Number
0010	ICIC	CC	N(S)N

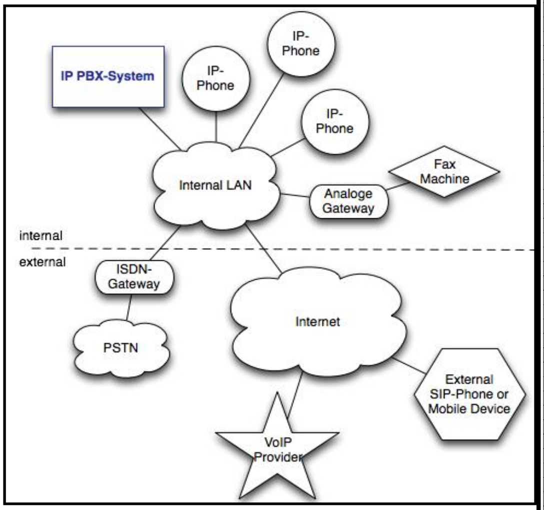
- Initially ICIC shall be a two-digit code. This will be sufficient for allotment to 50 international long distance service providers considering that maximum of two codes may be allotted to each service provider depending upon toll quality and non-toll quality network.
- However, to take care of all possible future requirements, length of ICIC may be reviewed and changed to 3- digit code as and when required.
- The allotment of ICIC may start from '10' and codes '00' to '09' may be kept reserved.
- **Sub level '00' - International Prefix:**
- The prefix '00' shall be used for International dialing. It will be followed by country code and the N(S) N of the country to which that call is attempted. The format is as per ITU Recommendation E.164:

Prefix	Country Code	National(Significant)Number
00	CC	N(S)N

- **Sub level '010' - National Carrier Access (Prefix) Code:**
- The prefix '010' shall be used for selection of national long distance carrier. It will be followed by (National) Carrier Identification Code (CIC) and N(S) N. The format shall be as under:

Prefix	Carrier Identification Code	National(Significant)Number
010	CIC	N(S)N

- Initially CIC shall be a two-digit code.
- This will be sufficient for allotment to 40 NLDOs (including NLDOs licensed for basic services) and 10 BSOs licensed only for basic services, considering that maximum of two codes may be allotted to each service provider depending upon toll quality and non-toll quality network.
- However to take care of all possible future requirements, length of CIC may be reviewed and changed to 3-digit code in future.
- The allotment of CIC may start from '10' and codes '00' to '09' may be kept reserved. For intra circle long distance service, the carrier access code shall be the same as applicable for NLD service.
- The CIC from '10' to '79' shall be allotted to NLD service providers. For the NLD service providers, who are also Basic Service Operators (BSOs), same CIC shall be applicable for intra circle (service area) calls. CIC from '80' to '99' shall be allocated to the BSOs who are not licensed to provide NLD service



❖ OPERATION PBX & DIGITAL EPABX.

- **PBX** stands for **Private Branch Exchange**, which is a private telephone network used within a company or organization.
- The users of the PBX phone system can communicate within their organization & the outside world, using different communication channels like Voice over IP, ISDN or analog.
- A PBX also allows you to have more phones than physical phone lines (PTSN) and allows free calls between users.
- It also provides features like transfers, voicemail, call recording, interactive voice menus (IVRs) and ACD call queues. PBX phone systems are available as Hosted or Virtual solutions (sometimes also called Centrix), and as in-house solutions to be used on your own hardware.
- PBX phone systems are usually much more flexible than proprietary systems, as they are using open standards and interfaces. Modern PBX phone systems are based on standard hardware, which is cheaper and can easier be replaced than a closed systems.

Ψ **Switching to an IP PBX offers many benefits**

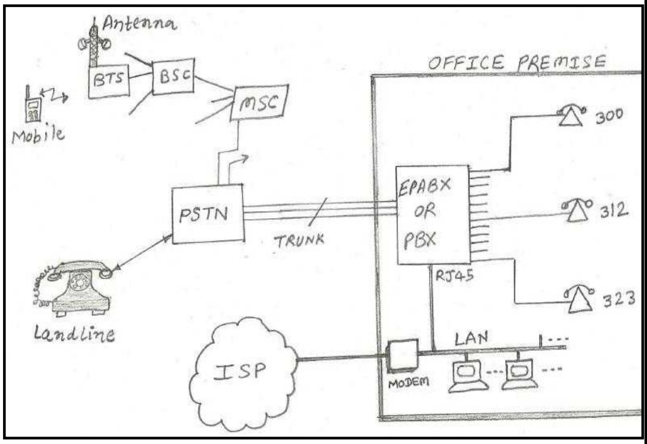
- With an IP phone system all your internal telephony is routed through the existing LAN (local computer network). This way a separate network for telephony is not required.
- Even though the internal telephony is routed through the LAN, it is also possible to connect your IP-PBX via gateways to the PSTN. Of course, VoIP, telephony via the internet is also possible.
- Since IP telephony is mostly using the open SIP standard, an IP phone system gives you a lot more freedom in your choice of phones.

- Basically any SIP compatible phone (VoIP phone) will work with an IP PBX. Furthermore an IP PBX doesn't limit the growth of a company.
- Since VoIP phones don't have to be connected physically to the phone system, it doesn't require a free port in the phone system like it used to be with traditional phone systems.
- IP phones can not only be connected via the LAN but also via the internet, using for example a VPN connection. Because of this, multiple locations and offices can easily be connected.
- There is a huge variety of VoIP providers on the internet which provide SIP trunking (telephony services) for cheaper call rates than traditional telephony providers. Internal calls via an IP phone system are free general.

Ψ Practical advantages of IP telephony

- Interconnecting teams and mobile working is one of the huge advantages of IP phone systems. No matter if team members are on the road, are located in a different country or work from home, they can connect via IP desk phone, smart phone or laptop to the PBX in the office.
- This way all calls within the company are free and clients will not realize if an employee is in the office or somewhere else around the world. The same also applies for conferences, these can be hosted directly on the own IP PBX with as many participants as required. These safes traveling time and money.

Ψ DIGITAL EPABX



- As shown in the figure EPABX/PBX facilitates use of one external telephone line by many internal users in the office premises.
- In the office each employee is provided one telephone set and all the telephones are connected with PBX.
- All the employees within the office premises can communicate using 3-digit or 4-digit number programmed in EPABX/PBX without any charge.
- EPABX/PBX is connected to PSTN (Public switched Telephone network) via trunk lines; hence all can use one external voice line in time shared basis.
- PSTN is connected with MSC (Mobile switching centre) of cellular networks such as GSM/CDMA/UMTS. By this mobile cell phone user can connect to any telephone set in the office premises using extension number. Similar to voice line EPABX/PBX can be used for Data applications.
- As shown in fig Data port of PBX is connected to LAN where so many PCs are connected and are using same external internet connection line from ISP via Modem/router.
- The same facility of PBX can extended for WLAN users too.

❖ UNITS OF POWER MEASUREMENT.

$$W = \frac{J}{s} = \frac{N \cdot m}{s} = \frac{kg \cdot m^2}{s^3}$$

- The watt (symbol: W) is a derived unit of power in the International System of Units (SI), named after the Scottish Engineer **James Watt** (1736-1819).
- The unit is defined as **joule per second** and can be used to express the rate of energy conversion or transfer with respect to time. It has dimensions of $\mathbf{L^2MT^{-3}}$. When an object's velocity is held constant at one meter per sec against constant opposing force of one newton the rate at which work is done is 1 watt.
- In terms of electromagnetism, one watt is the rate at which work is done when one ampere (A) of current flows through an electrical potential difference of one volt (V).
- Two additional unit conversions for watt can be found using **W = V. I** above equation & Ohm's Law.
- $W = V^2/\Omega = I^2\,\Omega$, Where ohm (Ω) is the SI derived unit of electrical resistance.

♣ FEMTO WATT

- The Femto watt is equal to one quadrillionth (10^{-15}) of a watt. Technologically important powers that are measured in Femto watts are typically found in reference (s) to radio and radar receivers.
- For example, meaningful FM tuner performance figures for sensitivity, quieting and signal-to-noise require that the RF energy applied to the antenna input be specified.

♣ PICOWATT

- The Pico watt is equal to one trillionth (10^{-12}) of a watt. Technologically important powers that are measured in Pico watts are typically used in radio, radar receivers, acoustics & radio astronomy.

♣ **NANOWATT**

- The nano watt is equal to one billionth (10^{-9}) of a watt. Important powers that are measured in nano watts are also typically used in reference to radio and radar receivers.

♣ **MICROWATT**

- The Micro watt is equal to one millionth (10^{-6}) of a watt. Important powers that are measured in microwatts are typically stated in medical instrumentation systems such as the EEG and the ECG, in a wide variety of scientific and engineering instruments and also in reference to radio and radar receivers.
- Compact solar cells for devices such as calculators and watches are typically measured in microwatts.

♣ **MILLIWATT**

- The milli watt is equal to one thousandth (10^{-3}) of a watt. A typical laser pointer outputs about five milli watts of light power, whereas a typical hearing aid for people uses less than one milli watt.

♣ **KILOWATT**

- The Kilo watt is equal to one thousand (10^{3}) watts. This unit is typically used to express the output power of engines and the power of electric motors, tools, machines, and heaters.
- It is also a common unit used to express the electromagnetic power output of broadcast radio and television transmitters. One kilowatt is approximately equal to 1.34 **horsepower**.
- Also, kilowatts of light power can be measured in the output pulses of some lasers.
- A surface area of one square meter on Earth receives typically about one kilowatt of sunlight from the sun (the solar irradiance) (on a clear day at mid day, close to the equator).

♣ **MEGAWATT**

- The Mega watt is equal to one million (10^{6}) watts. Many events or machines produce or sustain the conversion of energy on this scale, including lightning strikes; large electric motors; large warships such as aircraft carriers, cruisers, and submarines; large server farms or data centers; and some scientific research equipment, such as super colliders, and the output pulses of very large lasers.
- A large residential or commercial building may use several megawatts in electric power and heat.
- On railways, modern high-powered electric locomotives typically have a peak power output of 5 or 6 MW or more. Nuclear Power Plants have net summer capacities between about 500 and 1300 MW.

♣ **GIGAWATT**

- The Giga watt is equal to one billion (10^{9}) watts or 1 Giga watt = 1000 mega watts.
- This unit is often used for large power plants or power grids.
- The largest unit (out of four) of the Belgian Nuclear Plant Doel has a peak output of 1.04 GW.
- HVDC converters have been built with power ratings of up to 2 GW.
- The London Array, the world's largest offshore wind farm, is designed to produce a Giga watt of power

♣ **TERAWATT**

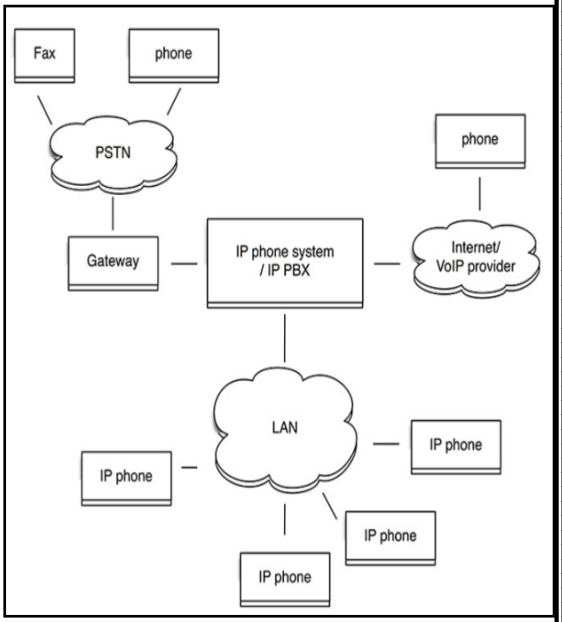
- The terawatt is equal to one trillion (10^{12}) watts.
- The total power used by humans worldwide (about 16 TW in 2006) is commonly measured in this unit.
- The most powerful lasers produced power in terawatts, but only for nanosecond time frames.
- The average lightning strike peaks at 1 terawatt, but these strikes only last for 30 microseconds.

♣ **PETAWATT**

- The petawatt is equal to one quadrillion (10^{15}) watts and can be produced by the current generation of lasers for time-scales on the order of picoseconds (10^{-12} s).
- One such laser is the Lawrence Livermore's Nova laser, which achieved a power output of 1.25 PW (1.25×10^{15} W) by a process called chirped pulse amplification.
- The duration of the pulse was about 0.5 ps (5×10^{-13} s), giving a total energy of 600 J, or enough energy to power a 100 W light bulb for six seconds

❖ Operation And Principle Of Internet Protocol Telephony (IP 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 for telecommunications infrastructure of Circuit Switched Public Data Networks (CSPDN) & 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 soft phone 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.

♣ How do IP Phone Systems Work?

- The "IP" in IP phone system refers to Voice over IP, or having your phone calls routed over the internet or your local network (LAN). This is great for many reasons.
- First of all, you don't have to use the telephone network of your telephony service provider for making calls, which will reduce your costs for phone calls.
- At the same time you are gaining many technical advantages by using IP technology for your telephony.
- Users of an VoIP phone system simply plug their IP phone into the nearest LAN port.
- Then, the IP phone registers automatically at the VoIP phone system.
- The IP phone always keeps its number, and behaves exactly the same way, no matter where you plug it in - on your desk, in the office next door or on a tropical island. All of this works because of the SIP protocol. It is a standard widely used by ISPs, VoIP phone systems and VoIP phones world-wide.
- It makes expensive proprietary phones obsolete, and helps that all devices can talk to each other.
- IP phone systems are usually built on standard PC or embedded hardware which is more cost-effective and powerful than the hardware of the traditional phone manufacturers.
- At the same time, IP phone systems are scalable, as they are not limited to a certain number of physical phone ports. That means you don't need to replace your phone system when your company grows.

---- ALL THE BEST ---- ---- ALL THE BEST ----

VI-SEM/ETC/2017(S) <APR-17, REG>

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

1. (a) Define Doppler Effect. [2]
(b) Explain working of CW Radar with a neat block diagram. [5]
(c) With neat block diagram describe the operation of MTI Radar. [7]

2. (a) What is Radar? [2]
(b) Derive the Radar Range Equation. [5]
(c) Explain the operation of VSAT System with a neat diagram. [7]

3. (a) What is transponder and downlink frequency? [2]
(b) Discuss the Code Division Multiple Accessing with a neat diagram. [5]
(c) Describe the operation o GPS system with neat diagram. [7]

4. (a) Define multiple accessing. [2]
(b) List the applications of optical fiber cables. [5]
(c) Discuss Satellite orbital pattern LEO, MEO and GEO. [7]

5. (a) What is numerical aperture? [2]
(b) Write short notes on modes of propagation and index profile of optical fiber. [5]
(c) Explain the operation of Direct Broadcast System with a neat diagram. [7]

6. (a) Name the types of Dispersion. [2]
(b) Explain different types of source and detector used for optical fiber system. [5]
(c) With a neat block diagram discuss about the optical fiber communication system. [7]

7. (a) Define Acceptance Angle. [2]
(b) Discuss the principle of space and time switching. [5]
(c) Describe the operation of Internet Protocol Telephone. [7]

---ALL THE BEST --- ALL THE BEST ---

Collected By:-
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VI-SEM/ETC/2016(W) **<DEC, BACK>**

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

1. (a) Define Doppler effect. [2]
(b) Describe the block diagram of pulsed radar system. [5]
(c) Derive Radar range equation, types of radar system. [7]

2. (a) State radar aids to navigator. [2]
(b) Describe the block diagram of C.W radar. [5]
(c) Explain the concept of Navigation Satellite System. (NAVSAT) and GPS System. [7]

3. (a) State Satellite frequency bands. [2]
(b) Describe concept of Geostationary Satellite, calculate its height, velocity and round trip time.
(c) Explain the operation of VAST system with diagram. State its application. [7]

4. (a) Define multi accessing. [2]
(b) Describe Satellite Orbital patterns and elevation (LEO, MEO and GEO) categories. [5]
(c) Explain GPS Recieiver4 and Transmitter with block diagram. [7]

5. (a) State types of optical fiber configuration. [2]
(b) Explain Velocity of propagation, Critical angle, Acceptance angle & numerical aperture. [5]
(c) Explain difference types of Losses and Dispersions in Optical Fiber. [7]

6. (a) Define optical communication. [2]
(b) Define the modes of propagation and index profile of optical fiber. [5]
(c) Explain wave length division multiplexing (WLDM) with diagram & state its application. [7]

7. (a) Define space and time switching. [2]
(b) Discuss the function of switching system and call procedures. [5]
(c) Describe the operation of a PBX and Digital EPABX. [7]

--- ALL THE BEST --- ALL THE BEST ---

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VI / SEM / ETC / 2018 (S) **[01-05-2018, REG]**

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

1.

- **a)** What are the different components of a simple radar system? [2]
- **b)** What is an optical fiber? What are its different configurations? Explain structure of optical fiber. [5]
- **c)** What is Doppler Effect? Draw the block diagram of a CW radar system. Explain its operation. [7]

2.

- **a)** What is the difference between a geostationary satellite and a low altitude satellite? Can a low altitude satellite be also used for communication purpose? [2]
- **b)** With the aid of a suitable sketch, describe the construction of a PIN diode. What does PIN stands for? Briefly explain the operation of this diode. [5]
- **c)** What is CDMA? How does it employ spread spectrum technique during the multiple access of the signals? Also explain the relative merits and demerits of CDMA and TDMA. [7]

3.

- **a)** What is a multimode step index fiber and what is its bandwidth range. [2]
- **b)** A silica optical fiber with a ore diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and a cladding refractive index of 1.47. determine,
  - **(i)** The critical angle at the core-cladding interface;
  - **(ii)** The NA for the fiber;
  - **(iii)** The acceptance angle in air for the fiber. [5]
- **c)** What does RADAR stands for? Derive the expression of the radar range equation. Also mention some of its applications. [7]

4.

- **a)** What are some of the ways of Jamming of confusing, enemy radar? [2]
- **b)** What are elements of satellite communication system? Explain each with block diagram? [5]
- **c)** Discuss the following (any one): [7]
  - **(i)** Internet protocol telephone **(ii)** Digital EPABX **(iii)** Aircraft landing system.

5.

- **a)** Draw schematic diagram only of ray transmission mechanism in a multimode graded index fiber. [2]
- **b)** Describe the optical fiber communication. [5]
- **c)** Discuss function of switching system & call procedures in a telecommunication system. [7]

6.

- **a)** What is LASER? What is the threshold condition for laser oscillation? [2]
- **b)** Give the reasons as to why the uplink frequency is different than the down link frequency. Also mention the reasons for keeping uplink frequency higher than downlink frequency. [5]
- **c)** With the aid of a block diagram, explain fully the operation of an MTI system using a power amplifier in the transmitter. [7]

7.

- **a)** Define the following terms in connection with optical fiber communication: [2]
  - **(i)** Critical angle **(ii)** Acceptance angle.
- **b)** Explain the construction & operation of avalanche photodiode (APD) with a neat diagram. [5]
- **c)** Explain the concept of Wavelength Division Multiplexing (WLDM) Principle with a neat diagram.[7

ALL THE BEST — **ALL THE BEST**

VI-SEM/ETC/2017(W) **[06-12-2017, BACK]**

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

1. (a) What is the function of duplexer? [2]
(b) Derive the Radar Range Equation. [5]
(c) Explain Briefly Working of Simple Pulsed Radar System with a neat diagram. [7]

2. (a) What is Geostationary satellite? [2]
(b) Explain satellite frequency allocation and frequency bands. [5]
(c) Explain different types of satellites (GEO, MEO and LEO). [7]

3. (a) What is an Optical Fiber? [2]
(b) Explain basic principle of PIN Photodiode. [5]
(c) Explain the principle of Optical Fiber Communication System with neat block diagram. [7]

4. (a) Define units of Power Measurement. [2]
(b) Describe the operation of EPABX with a neat block diagram. [5]
(c) Describe operation of Internet Protocol Telephone. [7]

5. (a) Write the different Application of RADAR. [2]
(b) State and explain the simple Radar system with a neat block diagram. [5]
(c) State the function of Radar Indicators. [7]

6. (a) What is satellite orbit? [2]
(b) Write short notes on Geosynchronous Orbit. [5]
(c) Describe general structure of Satellite Communication System. [7]

7. (a) Define Acceptance Angle. [2]
(b) Explain the basic principle of avalanched photodiode. [5]
(c) Describe the basic principle of propagation of light in an optical fiber. [7]

--- ALL THE BEST --- ALL THE BEST ---

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VI-SEM/ETC/2017(S) <APR-17, REG>

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

8. (a) Define Doppler Effect. [2]
(b) Explain working of CW Radar with a neat block diagram. [5]
(c) With neat block diagram describe the operation of MTI Radar. [7]

9. (a) What is Radar? [2]
(b) Derive the Radar Range Equation. [5]
(c) Explain the operation of VSAT System with a neat diagram. [7]

10. (a) What is transponder and downlink frequency? [2]
(b) Discuss the Code Division Multiple Accessing with a neat diagram. [5]
(c) Describe the operation o GPS system with neat diagram. [7]

11. (a) Define multiple accessing. [2]
(b) List the applications of optical fiber cables. [5]
(c) Discuss Satellite orbital pattern LEO, MEO and GEO. [7]

12. (a) What is numerical aperture? [2]
(b) Write short notes on modes of propagation and index profile of optical fiber. [5]
(c) Explain the operation of Direct Broadcast System with a neat diagram. [7]

13. (a) Name the types of Dispersion. [2]
(b) Explain different types of source and detector used for optical fiber system. [5]
(c) With a neat block diagram discuss about the optical fiber communication system. [7]

14. (a) Define Acceptance Angle. [2]
(b) Discuss the principle of space and time switching. [5]
(c) Describe the operation of Internet Protocol Telephone. [7]

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VI-SEM/ETC/2016(W) **<DEC, BACK>**

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

8. (a) Define Doppler effect. [2]
(b) Describe the block diagram of pulsed radar system. [5]
(c) Derive Radar range equation, types of radar system. [7]

9. (a) State radar aids to navigator. [2]
(b) Describe the block diagram of C.W radar. [5]
(c) Explain the concept of Navigation Satellite System. (NAVSAT) and GPS System. [7]

10. (a) State Satellite frequency bands. [2]
(b) Describe concept of Geostationary Satellite, calculate its height, velocity and round trip time.
(c) Explain the operation of VAST system with diagram. State its application. [7]

11. (a) Define multi accessing. [2]
(b) Describe Satellite Orbital patterns and elevation (LEO, MEO and GEO) categories. [5]
(c) Explain GPS Recieiver4 and Transmitter with block diagram. [7]

12. (a) State types of optical fiber configuration. [2]
(b) Explain Velocity of propagation, Critical angle, Acceptance angle & numerical aperture. [5]
(c) Explain difference types of Losses and Dispersions in Optical Fiber. [7]

13. (a) Define optical communication. [2]
(b) Define the modes of propagation and index profile of optical fiber. [5]
(c) Explain wave length division multiplexing (WLDM) with diagram & state its application. [7]

14. (a) Define space and time switching. [2]
(b) Discuss the function of switching system and call procedures. [5]
(c) Describe the operation of a PBX and Digital EPABX. [7]

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VI-SEM/ETC/2016(S) <APR, REG>

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

1. (a) What is Radar and its classification? [2]
(b) Derive the Radar Range equation. [5]
(c) Draw the block diagram of CW Radar and explain the function of each block. [7]

2. (a) Define Doppler Effect and where it is used. [2]
(b) Explain the block diagram of Pulse Radar system with a neat block diagram. [5]
(c) Describe satellite orbital patterns (GEO, LEO, MEO) and distinguish between them. [7]

3. (a)What is the meaning of Geostationary? [2]
(b) Explain the operation of DBS. [5]
(c) Describe the general structure of satellite link system with a neat diagram. [7]

4. (a) Define optical communication. [2]
(b) Compare the advantage and disadvantage of optical fiber cables. [5]
(c) Discuss the code division Multiple Accessing and its advantages and disadvantages. [7]

5. (a) What is Numerical Aperture? [2]
(b) Write a short note on PIN diode. [5]
(c) Discuss the block diagram of an optical fiber communication system with neat diagram. [7]

6. (a) Write down any two applications of optical fibers. [2]
(b) Describe the three types of optical fiber configuration. (Single mode step Index, Multimode step Index and Multimode graded Index). [5]
(c) Explain the working principle of LED. [7]

7. (a) Define Multi Accessing and name various types. [2]
(b) Discuss the operation of Electronic Telephone system. [5]
(c) Describe the operation of Digital EPABX with a neat diagram. [7]

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VI / SEM / E & TC / 2013 (S)

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions

The figures in the right-hand margin indicate marks

1.

a) What is Doppler Effect? [2]

b) Describe the function of radar indicator and moving target indicator. [6]

c) Derive Radar range equation & performance factor of radar and also give its importance. [8]

2.

a) What do you understand by uplink and down link frequency? Why the uplink frequency is always higher than downlink frequency? [2]

b) Discuss different types of satellite and explain briefly the function of earth station. [6]

c) Explain the operation of Code Division Multiple Access (CDMA) spread spectrum system. [8]

3. (a) Define Acceptance angle and numerical aperture. [2]

(b) Describe the working principle of LASER. [6]

(c) Describe the working principle of optical fiber communication system with neat diagram. [8]

4. (a) What is the difference between connector and splices? [2]

(b) Describe the principle of light wave propagate through optical fiber. [6]

(c) What is optical fiber and explain different types of optical fiber. [8]

5. (a) Define space and time switching. [2]

(b) Discuss the operation of a PBX and Digital EPABX. [6]

(c) Discuss the operation of ATM and ISDN network. [8]

6. (a) Write the units of power measurement. [2]

(b) Discuss the numbering plan of telephone network (National & International Schemes). [6]

(c) Describe the operation of GPS receiver and transmitter. [8]

7. (a) Name different types of bands available in Radar system. [2]

(b) Explain Aircraft landing system. [6]

(c) Explain the concept of NAVSAT. [8]

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VI / SEM / E & TC / 2012 (S)

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions including Q. No. 1 & 2

The figures in the right-hand margin indicate marks

[GROUP – A]

1. Answer **ALL** question: [2x10]

a) What is MTI Radar and where it is used?
b) What do you mean by GPS system?
c) What do you mean by up-link and down-link frequency of a satellite communication system?
d) Define Geostationary orbit.
e) Define critical angle of a optical fiber communication system.
f) What is the function of repeater?
g) Define space and time switching.
h) What is ISDN?
i) Write any two advantages of optical fiber as compared to co-axial cable.
j) State the units of power measurement.

[GROUP – B]

2. Answer any **FIVE** question: [5x6]

a) Discuss the factors affect the range of RADAR.
b) Explain MEO and LEO satellites.
c) Describe the operation of VAST system.
d) Name the different types of optical fiber configurations and explain them.
e) Explain the concept of wavelength division multiplexing.
f) Describe the function of switching system and call procedure in Tele-communication system.
g) Discuss the principle of PDH and SDH modes of transmission.

[GROUP – C]

3. What is Doppler's effect? With a neat diagram, describe operation of CW Doppler RADAR [10]
4. Discuss CDMA Technology in communication system & write its advantages & disadvantages.
5. Explain principle of working of Optical Fiber Communication system with neat diagram. [10]
6. Describe the operation of ATM and ISDN network. [10]
7. Write short notes on any TWO [5x2]

(i) NAVSAT
(ii) Digital EPABX
(iii) Internet Protocol Telephone

--- ALL THE BEST --- ALL THE BEST ---

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VI / SEM / E & TC / 2011 (S)

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions including Q. No. 1 & 2

The figures in the right-hand margin indicate marks

[GROUP – A]

1. Answer ALL Question: [2x10]

(a) What is MTI Radar and where it is used?

(b) Why isolators are used in microwave?

(c) What are the applications of travelling wave tube?

(d) What are the factors influencing the maximum range of a radar?

(e) Classify satellites according to the location in orbit.

(f) What do you mean by uplink and downlink frequency?

(g) What are the advantages of optical fiber cable in communication?

(h) State the essential features of wireless communication system.

(i) Name various types of spread spectrum system.

(j) Why a cell structure is hexagonal.

[GROUP – B]

2. Answer any **FIVE** Question: [5x6]

(a) Discuss the basic principle of Messer.

(b) Explain with neat block diagram the working of pulsed radar system.

(c) Describe the operation of PIN diode.

(d) Explain the operation of earth station with a block diagram.

(e) Discuss optical fiber communication system and explain its need.

(f) State the importance of national and international standardization.

(g) State and explain the meaning of WLL communication system.

[GROUP – C]

3. What is the difference between TE and TM modes in rectangular waveguide? Why TE_{10} mode is considered to be dominant mode in rectangular waveguide? Explain the operation of TWT with neat diagram. Discuss its application. [10]

4. Explain the principle of RADAR system and derive range equation and performance factor. [10]

5. Explain CDMA Technology with a block diagram. [10]

6. Discuss optical fiber communication system and explain the basic principle of propagation of light in the optical fiber. [10]

7. Write short notes on any two [5x2]

(i) The operation of magnetron with block diagram

(ii) Aircraft Landing system

(iii) Mobile Personal Communication System

(iv) TDMA

---- ALL THE BEST ---- ALL THE BEST ----

VI / SEM / E & TC / 2010 (S)

ADVANCED COMMUNICATION ENGINEERING

Sub Code – **ETT-601**

Full Marks: 70

Time: 3 hours

Answer any **FIVE** Questions including Q. No. 1 and 2

The figures in the right-hand margin indicate marks

[GROUP – A]

1. Answer **ALL** question: [2x10]

(a) What is microwave circulator and why it is essential?

(b) Define phase velocity and cut-off wavelength.

(c) Define Doppler Effect and how this principle is utilized in radar.

(d) What is second-time around echo and maximum unambiguous range?

(e) What are the advantages of satellite communication? (any four)

(f) What is refractive index and Snell law?

(g) Define spontaneous emission and where it is used.

(h) What is CDMA and where it is used?

(i) What is spread spectrum and what are the condition for spread spectrum?

[GROUP – B]

2. Answer any **FIVE** question: [5x6]

(a) Explain working principle of rectangular waveguide briefly..

(b) Explain the principle of working of PIN diode and its application.

(c) What are the factors affecting range of radar and what radar beacons are?

(d) Explain the working of CW Doppler radar with help of block diagram.

(e) Explain the operation of Earth Station with the help of a block diagram.

(f) Describe the structure of fiber and how propagation of light took place in fiber.

(g) What is multiple point to multiple point mobile communication and explain briefly, about personal communication system?

[GROUP – C]

3. Explain the principle & operation of 2 cavity klystron with the help of neat circuit diagram. [10]

4. Explain the principle working of pulsed radar system with the help of block diagram. [10]

5. What are the optical fiber and explain the need of optical fiber and distinguish between copper cable and optical fiber cable. [10]

6. (a) Describe concept of geostationary satellite & distinguish between GEO, LEO and MEO. [6]

(b) Describe briefly about INSAT satellite system. [4]

7. Explain the working of direct sequence spread spectrum techniques with the help of block diagram & mention its advantages and disadvantages over other spread spectrum techniques.[10]

--- ALL THE BEST --- ALL THE BEST ---

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