# Advanced Communication System

**Time : 3 Hrs.]** MSBTE Specimen Question Paper Solution **[Marks : 100**

**Q.1(a) Attempt any THREE of the following : [12]**

**Q.1(a) (i) Define the terms w.r.t waveguide [4]**

**(1) Phase velocity (2) Group Velocity**

**(A) (1) Phase velocity :**

Phase velocity is defined as the rate at which the wave changes its phase in direction parallel to conducting surface in terms of the guide wavelength.

The phase velocity of mode is

$$v_p = \frac{\omega}{\beta}$$

The phase velocity of a mode is a function of frequency.

**(2) Group velocity :**

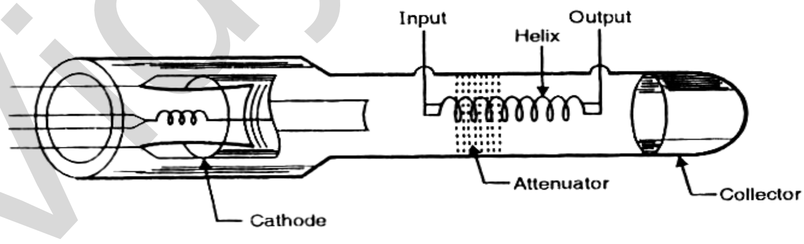
It is defined as the rate at which the wave propagates through the waveguide and is given by $v_g = \frac{d\omega}{d\beta}$

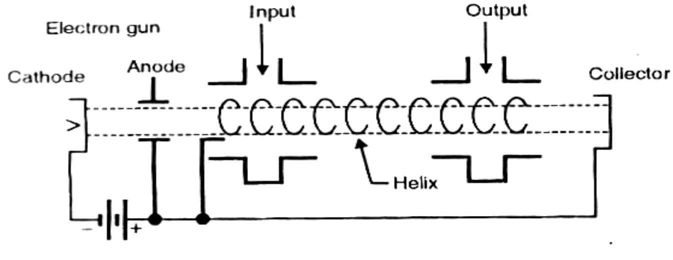
Group velocity is always less than speed of light.

Product of Group velocity and phase velocity is square of light speed. Group velocity in waveguide is speed at which Electromagnetic wave travels in the guide.

**Q.1(a) (ii) Draw labeled sketch of TWT. Give applications. (Any 2) [4]**

**(A) Construction of TWT**



**Q.1(a) (iii) Write RADAR range equation and state the factor affecting maximum range of RADAR.** **[4]**

**(A) Radar Range Equation**

The Radar range equation is given as

$$R_{max} = \left[\frac{P_t \cdot A_e^{\,2} \cdot \sigma}{4\pi \cdot \lambda^2 \cdot S_{min}}\right]^{1/4}$$

Where $R_{max}$ is known as maximum range that radar can measure.
$P_t$ is total power transmitted by radar.
$\sigma$ is radar cross-section.
$A_e$ is area captured by radar antenna.
$\lambda$ is wavelength of signal.
$S_{mnn}$ is minimum acceptable signal by radar.

The following factors affects the range of Radar :

i) Since $R_{max} \propto P_L$ which means that larger the transmitted power of Radar then

ii) Larger is the maximum range of radar.

Since $R_{max} \propto \frac{1}{\sqrt{x}}$

But $\lambda = \frac{1}{f}$

$\therefore \quad R_{max} \propto \sqrt{f}$

which means that increase in transmitted frequency will increase the maximum range of Radar.

iii) Since $R_{max} \propto \sigma^{1/4}$

it means that larger the value of $\sigma$ thin larger is the range. But the Radar cross-section is not a controllable factor it depends upon characteristics of particular target and it depends upon size and shape of the target.

iv) $R_{max} \propto \sqrt{A_e}$ where $A_e$ is antenna aperture area.

Thus larger the size of antenna larger is a radar range.

**Q.1(a) (iv) Define following term w.r.t to satellite.** **[4]**

**(a) Azimuth angle** **(b) Elevation angle**

**(A) Elevation and Azimuth Angles of a Satellite:**

- The exact position of a satellite is determined or designed by considering the height, speed and orbital characteristics etc.
- It is necessary to determine the position of satellite to find whether or not the satellite is within a usable range and to communicate with the satellite earth station needs the azimuth and elevation setting or its antenna.

- Most earth station satellite antennas are highly directional and must be positioned to hit the satellite.
- The azimuth and elevation angles in degrees tell where to point the antenna.

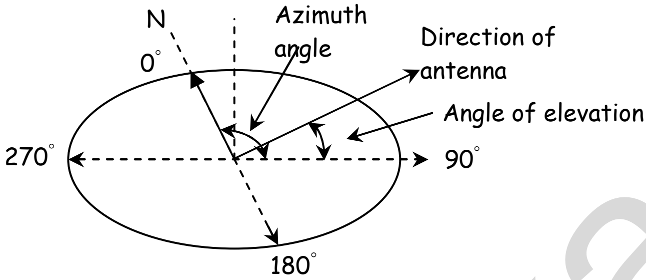



**Fig.**

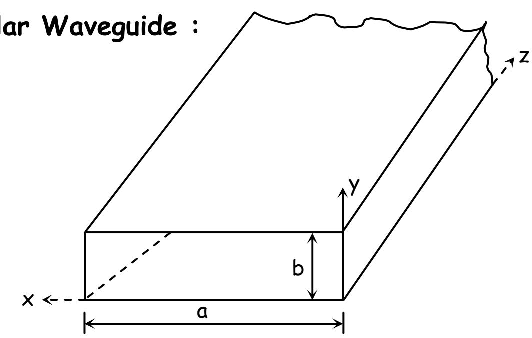
- In above figure, Azimuth angle and angle of elevation is shown.
- Azimuth refers to the direction where north is equal to 0°.
- It is measured clockwise with respect to north.
- Angle of elevation is the angle between the horizontal plane and the direction of antenna.
- Azimuth angle is the angle between the horizontal plane and the direction where north is equal to 0°.
- Once the azimuth and elevation are known the earth station can be pointed in that direction.
- For geosynchronous satellite the azimuth angle and elevation are easy to determine because antenna simply remains in one position.
- For non synchronous satellite it is difficult to find azimuth and elevation angles.
- For that a computer has to set up to calculate orbital calendar, and has to use various graphical devices to trace the ground track and then find the angles.

**Q.1(b) Attempt any ONE of the following : [6]**

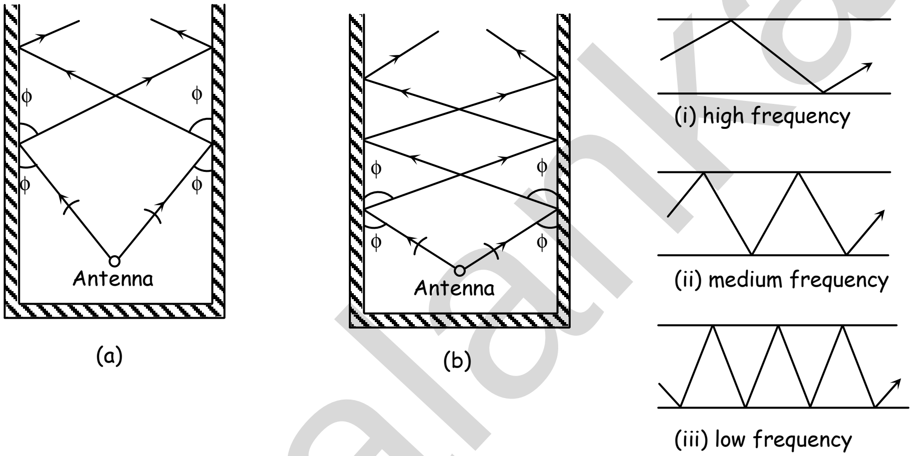
**Q.1(b) (i) With neat diagram describe propogation of microwave through rectangular waveguide. In which condition it becomes dominant mode? [6]**

**(A) Propagation of Waves in Rectangular Waveguide :**

- Rectangular waveguide is a hollow metallic tube with a rectangular cross–section.
- It has width 'a' and height 'b' as shown in figure.

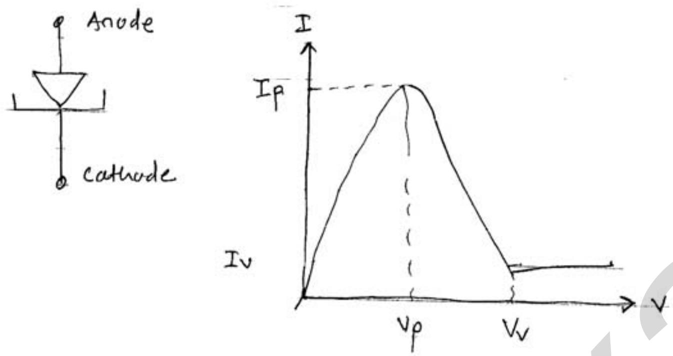


- Commonly used rectangular waveguides have an aspect ratio b/a of approximately 0.5.
- The physical dimensions of a waveguides determine the cut–off frequency for each mode.
- The walls of the waveguide have infinite conductivity and medium is an ideal dielectric having permittivity $\in$, permeability $\mu$ and conductivity $\sigma = 0$.
- The dominant mode in a particular waveguide is the mode having the lowest cut–off frequency or highest cut–off wavelength.
- In rectangular waveguide TEM mode does not exist.
- For rectangular waveguide dominant mode is the $TE_{10}$ mode.




- Above Fig. shows the direction of propagation of two different electromagnetic wavefronts of different frequencies being radiated into a waveguide by a probe.
- Arrowheads shows the direction of propagation
- The angle of incidence and angle of reflection of wavefronts vary in size with frequency of the input energy.
- The angles of reflection are equal to each other in a waveguide.
- The cut-off frequency in a waveguide is a frequency that cause angles of incidents and reflection to be perpendicular to the walls of the guide.
- If the frequency is below the cut–off frequency, the wavefronts will be reflected back and forth across the guide and no energy will be conducted down the waveguide.
- The velocity of propagation of a wave along a waveguide is less than its velocity through free space.
- This lower velocity is caused by the zigzag path taken by the wavefront.

**Q.1(b) (ii) Sketch the construction of Tunnel diode and write its operation. [6]**
**(A)**




The Tunnel diode is a specially made P-N junction diode which exhibits negative Resistance over part of the forward characteristics. It has extremely heavy doping on both sides of junction and abrupt transition from P-side to the n-side. The Tunneling effect is a majority carrier effect and is consequently very fast.

The Tunnel effect controls the current at very low values of forward bias where the normal or injection current is very small. The mechanism of tunneling is purely quantum mechanism phenomenon.

The Tunnel diode is useful for Oscillation or Amplification purpose. Because of the thin junction and short transit time they are also used for fast switching circuits.

**Q.2 Attempt any FOUR of the following : [16]**
**Q.2(a) Differentiate between waveguide and two wire transmission line. [4]**
**(A) Comparison of waveguides with 2–wire transmission lines :**

**Similarities :**

(i) Wave travelling in a waveguide has a phase velocity and will be attenuated as in a transmission line.
(ii) When the wave reaches the end of the waveguide it is reflected unless the load impedance is adjusted to absorb the wave.
(iii) Any irregularity in a waveguide produces reflection just like an irregularity in a transmission line.
(iv) When both incident and reflected waves are present in a waveguide a standing wave pattern results as in a transmission line.

**Dissimilarities :**

(i) There is a cut–off value for the frequency of transmission depending upon the dimensions and shape of the waveguide.

Only waves having frequencies greater than cut–off frequency will be propagated. Hence waveguide acts as high pass filter with $f_c$ cut–off frequency.

In a 2–wire loss less transmission line all frequencies can pass through.

(ii) Waveguide is a one conductor transmission system, the whole body of waveguide acts as ground and wave propagates through multiple reflections from the walls of the waveguide.

(iii) The velocity of propagation of the waves inside the waveguide is quite different from that through free space due to multiple reflections from the walls of the waveguide.

(iv) In waveguide, wave impedance which is analogous to the characteristic impedance $Z_0$ of 2–wire transmission system.

(v) The system of propagation in waveguide is in accordance with field theory while that in transmission line is in accordance with circuit theory.

(vi) If one end of the waveguide is closed using a shorting plate, there will be reflection and hence standing waves will be formed.

If the other end is also closed, then the hollow box so formed can support a signal which can bounce back and forth between two shorting plates resulting in resonance.

**Q.2(b) Justify magnetron as an oscillator. [4]**

**(A) Cavity Magnetron:**

It consists of cylindrical cathode of finite length and radius 'a' at the centre surrounded by a cylindrical anode of radius 'b'. Anode consists of several re–entrant cavities equi–spaced around the circumference and coupled together through the anode cathode space be means of slots. The space between the anode and cathode is the interaction space and to one of the cavities is connected a co–axial line or waveguide for extracting the circuit.

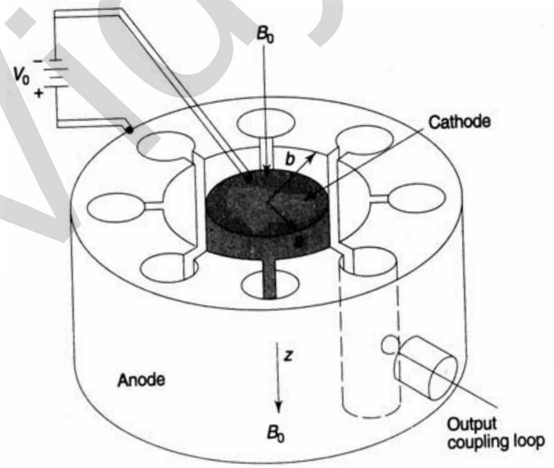



**Fig. (a)** : Cavity Magnetron

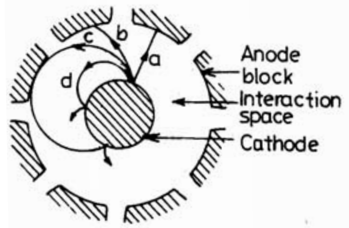



**Fig. (b)**

It is a cross field device as the electric field between anode and cathode is radial whereas the magnetic field produced by a permanent magnet is axial. The permanent magnet is placed such that the magnetic lines are parallel to the vertical cathode and perpendicular to the electric field between cathode and anode.

To understand the operation of cavity magnetron, we must understand how the electrons behave in the presence of closed electric and magnetic fields.

Depending upon the relative strengths of the electric and magnetic fields the electrons emitted from the cathode and moving towards the anode will traverse through the interaction space as shown Figure (b).

**Path a: (travels straight)**
In the absence of magnetic field (B = 0), the electron leaving the cathode travels straight to the anode due to the radial electric field action on it. This is shown by path 'a'. The electric force due to E is

$$\bar{F} = -e\bar{E}$$

Since $\bar{E}$ is radial, the force is also radial.

**Path b: (Application of rotational force)**
If the magnetic field strength is increased slightly (i.e. for moderate value of B) it will exert a lateral force given by,

$$\bar{F} = -e\left(\bar{V} \times \bar{B}\right)$$

Where $\bar{V} \rightarrow$ Velocity vector
$\bar{B} \rightarrow$ Magnetic flux density.

This force will bend the path of the electron as shown by path 'b'. The radius of the path is $R = \frac{mV}{eB}$

**Path c: (grazing the anode surface)**
If B↑, R↓ i.e. the path bends more.
If the strength of the magnetic field is sufficiently high so as to prevent the electrons from reaching the anode, the anode current becomes zero. The magnetic field required to return electrons back to cathode just grazing the surface of the anode is called the critical magnetic field ($B_C$) or the cut off magnetic field. This is shown by path c.

**Path d: (Back heating of the cathode)**
If the magnetic field is made larger than the critical field ($B > B_C$), the electron experiences a greater rotational force and may return back to

cathode quite faster. This is shown by path 'd'. All such electrons may cause back beating of cathode. This can be avoided by switching off the heater supply after commencement of oscillation. This is done to avoid fall in the emitting efficiency of the cathode.

All the above explanation is for a static case in the absence of the RF field in the cavity of magnetron.

The cavity magnetron shown in figure (a) has 8 cavities that are tightly coupled to each other. In general N–cavity tightly coupled system will have N resonant frequencies or modes. Each mode is characterized by resonant frequency of each cavity and phase of oscillation relative to the adjacent cavity. For the sustained oscillations the total phase sift around the ring of the cavity resonator is $2n\pi$ where n is an integer. Thus the phase shift between two adjacent cavities is given by :

$$\phi_n = \frac{2\pi n}{N}$$

where n = 0, ±1, ±2, ±3, …, ± N/2, indicates the $n^{th}$ mode of oscillation.

Due to excitation of the anode cavities by RF noise voltage in biasing circuit, the RF field lines are fringed out of the slot to the space between the anode and cathode. The accelerated electrons in the trajectory, when retarded by this RF field, transfer energy from the electron to the cavities to grow RF oscillations till the system RF losses balance the RF oscillations for stability.

In order for oscillations to be produced in the structure, it requires continuous interaction between the electrons and the RF fields. For this anode dc voltage must be adjusted so that the average rational velocity of the electrons correspond to the phase velocity of the field in the slow wave structure.

**Q.2(c) Write the operation for pulsed radar to detect the object.** **[4]**

**(A) Pulsed Radar:**

- Commonly used pulsed radar
- Signals are transmitted in short pulse

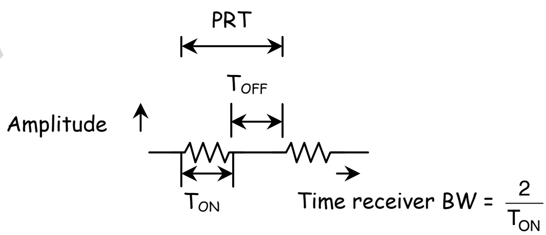



**Fig. 1**

- The time between transmitted pulses is known as pulse repetition time (PRT).

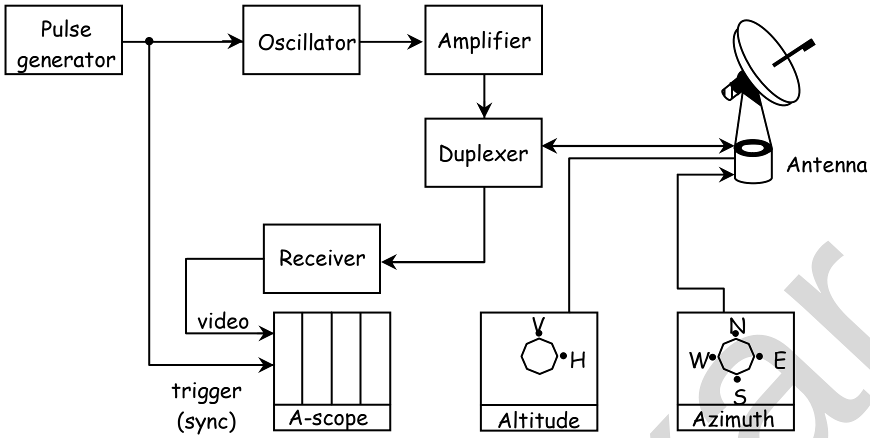



**Fig.2** : Block diagram of pulsed radar

- Block diagram can be divided into 5 sections.
  (i) Transmitter
  (ii) Duplexer
  (iii) Antenna system
  (iv) Display
  (v) Receiver

**1) Transmitter : The transmitter uses an oscillator such as Magnetron**

- Magnetron is most widely used for generating microwave frequencies for radar.
- Magnetron when pulsed, can produce many megawatt of power for the short duration.
- Pulse generator is used to trigger the magnetron.
- Pulse generator sets the pulse duration pulse repetition rate and duty cycle.
- Output of oscillator is passed through amplifier.
- After amplification, the transmitter output is then passed through a duplexer.

**2) Duplexer:**

- A duplexer is a special device that allows the transmitter and receiver to share a single antenna.
- A duplexer contains a device which prevents damage of receiver due to high power transmitted signal.
- A duplexer contains a spark-gap tubes and are referred to as transmit-receive (TR) and anti-transmit-receiver (ATR) tubes.
- TR tube prevents transmitter power from reaching the receiver.

- When RF energy from the transmitter is detected, the spark gap breaks down, creates a short circuit for the RF energy.
- ATR tube disconnect the transmitter from circuit during the receive interval.

**3) Antenna system:**
- Typically horn antenna with a parabolic reflector is used to produce a very narrow beam width.
- A special assembly with rotating joint is used to rotate horn antenna continuously over a 360o angle.
- The same antenna is also for reception.

**4) Receiver:**
- The receiver is standard high gain superheterodyne type.
- During the pulse off time, the received signal passes through the antenna.
- In receiver the mixer and local oscillator convert the RF signal to an intermediate frequency.
- After maximizing signal to noise ratio in the IF amplifier, detector demodulates the signal and video amplifier creates signal that will be displayed.

**5) Display:**
- In radar system display is cathode ray tube.
- Simplest A-scan or A-scope is used to display the transmitted and received pulses.
- Commonly used CRT display is P-type or plan position indicator (PPI).
- PPI display shows both the range and azimuth of the target.
- Center of the display is the location of radar unit.
- Concentric circles indicate the range and azimuth or direction is indicated by the position of the reflected target on the screen.
- The target shows up as lighted blips on the screen.

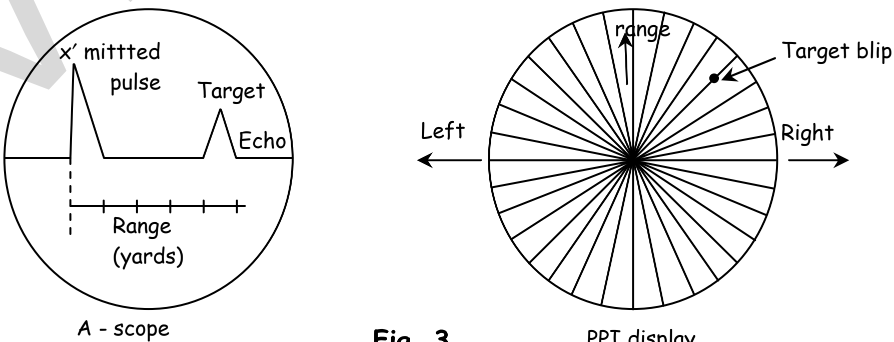



**Fig. 3**

**Q.2(d) State reason for difference in uplink and down link frequency in satellite communication. [4]**

**(A) Uplink and Downlink Frequencies:**

- The range of frequencies used for satellite communication is from 3 to 30 GHz i.e. microwave range.
- Fig. 1(a) shows the uplink and downlink frequencies.
- The uplink frequency can be defined as the frequency used by signal transmitted from transmitting earth station towards the satellite.
- Uplink frequencies are generally higher than downlink.

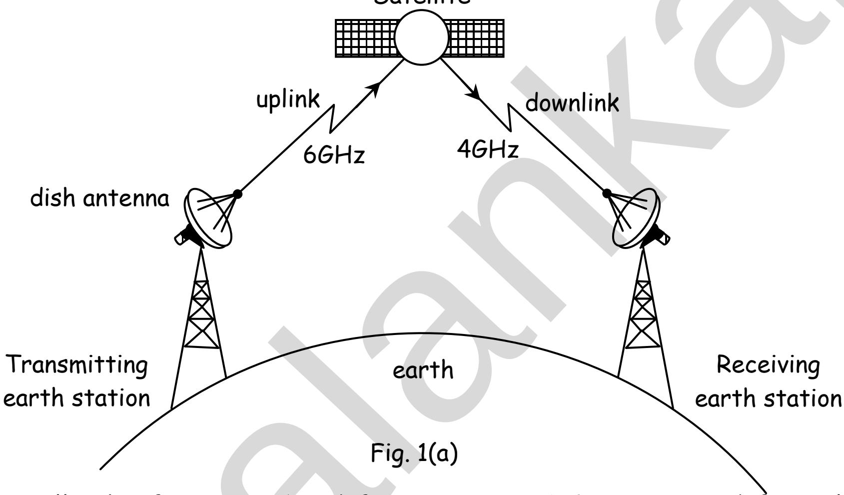



Fig. 1(a)

- Generally the frequency band from 5.9 to 6.4 GHz are used for uplink transmission.
- The downlink frequency can be defined as the frequency of signal which is retransmitted from satellite to earth station (Receiving).
- Generally down link frequency range is between 3.7 to 4.2 GHz.
- In the satellite, the signals are down converted to a frequency of downlink.
- In the satellite, transponder is a combination of transmitter-receiver which down converts the signal as well as receives the signals from earth station.

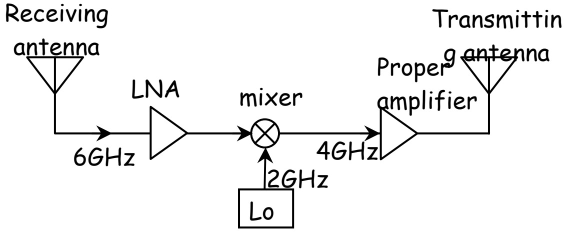


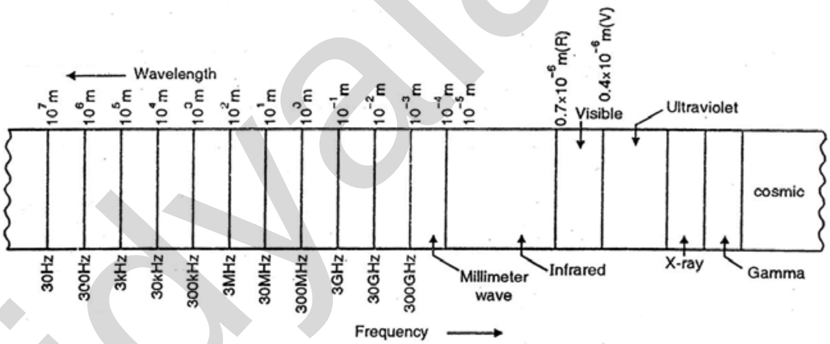

**Fig. 1(b) :** Block diagram

- Above Fig. 1(b) shows the satellite transponder.

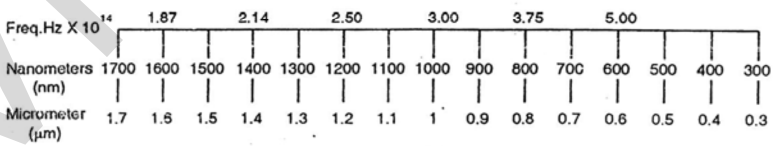
- Mainly the function of transponder is amplification of signal and frequency translation.
- The frequency translation is necessary because transponder cannot transmit and receive on the same frequency.
- A satellite is not a passive relay station.
- It does not just reflect signals, it receives them, processes them, down convert them and retransmits them.
- On-board each satellite has a number of transponders.
- Transponders not only transmit video, also mono and stereo-audio, telephone messages, news reports and data.
- The average operating power of transponder is five watts.
- The number of transponders on a satellite is related to bandwidth requirements.
  e.g. for video use, the band width requirement of a transponder is 40 MHz (36 MHz + 4 MHz band) total bandwidth available 500 MHz (subtracting the LF limit from upper).
- If one uses upto 500/40 i.e. 12 transponders.

**Q.2(e) Draw frequency spectrum for optical communication with band name and its range.** **[4]**

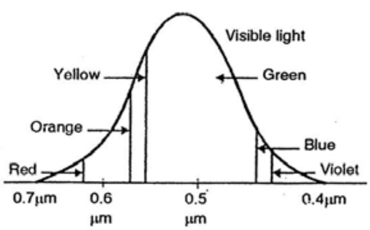
**(A)**




**Electromagnetic spectrum**



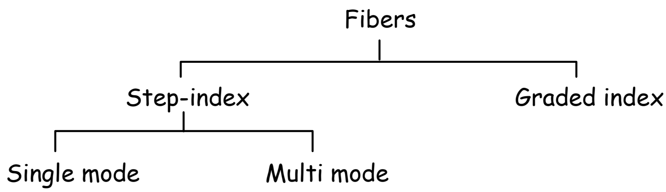

**Light wave spectrum (visible and nonvisible)**



**Q.2 (f) State different types of fiber optic cable on the basis of** **[4]**
**(i) modes** **(ii) refractive index profile**

**(A) Classification of Fiber:**

Optical fibers are classified as follows




**Step Index Fiber:**

- As shown in Fig. 1.
- It is simplest type of fiber.
- It is thin cylindrical structure of transparent glossy material of uniform refractive index $n_1$.
- It is surrounded by cladding of another material of uniform but slightly lower refractive index $n_2$.
- These fibers are referred to steps index due to discontinuity of index profile at the core cladding interface.
- The step index describes an abrupt index change from the core to cladding.

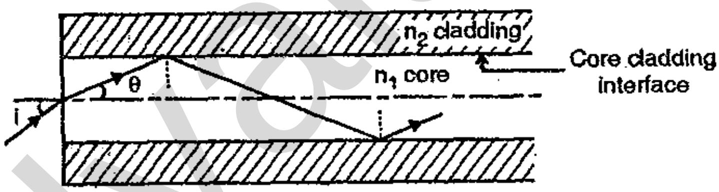



**Fig. 1**

- If the core radius is 'a' and cladding thickness is 'b' then refractive index distribution is,

  $n(r) = n_1 \quad (0 < r < a)$ core

  $\quad\; = n_2 \quad (r > a)$ cladding

  refractive index profile is shown in Figure 2.

**Some of the important characteristics are:**

- Very small core diameter
- Low attenuation
- Low numerical aperture
- Very high bandwidth

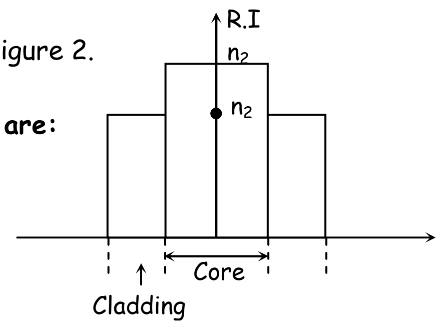



**Fig.2**

**Graded Index Fiber :**

- The core refractive index is function of radial distance from the center of the fiber. i.e. core refractive index gradually decreasing in parabolic manner from a maximum value at the center of the core to a value at the core-cladding interface.
- GRIN fiber is shown in Figure 3.

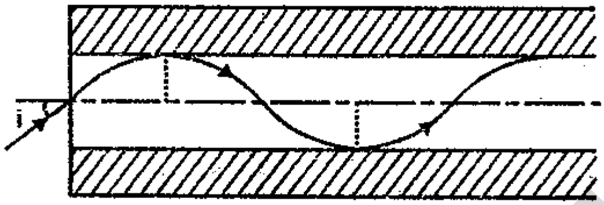


**Fig. 3**

The changes or variations in refractive index is achieved by using concentric layers of different refractive indices.
Refractive index profile is shown in figure below.

**Single Mode Fibers :**

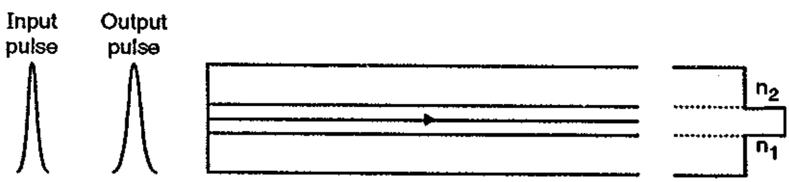
- Can have either a step index or graded index profile.
- Have small core diameters or a narrow core.
- The cladding diameter must be at least ten times the core diameter.
- Light travels parallel to the axis.
- Are fabricated from doped silica to deduce attenuation.
- Used for wideband log-hual transmission.

1. **Single mode step index fiber :**

- Most widely used in today's wide-band communication area.
- With this fiber a light ray can travel on only one path, therefore modal dispersion is zero.
- The core diameter of this fiber range from 5μm to 10 μm standard diameter is 125 μm.

**Specifications of single mode :**

- The bandwidth is from 50 to 100 GHz/km
- Digital communication rate is of 2000 M bytes/sec.




Single mode step index

For diagram refer class notes.

- Carries higher bandwidth.
- Requires a light source with a narrow spectral width.
- Gives higher transmission rate.

**Performance Characteristics of single mode fiber :**

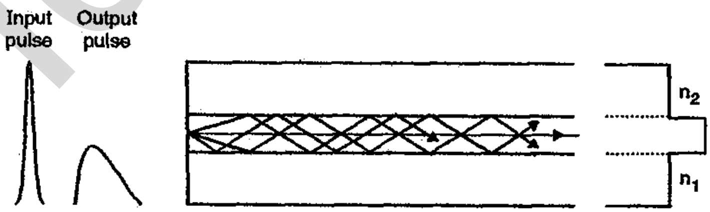
- Attenuation → 2 to 5 dB/km
- Bandwidth → Greater than 500 MHz km.
  40 GHz at wavelength 0.85 μm
  10 GHz at wavelength 1.3 μm
- Application → are suited for high bandwidth
  Very long-haul applications.

**Multimode Fibers :**

- Multimode fibers have step index or graded index profile
- These are fabricated from either multicomponent glass compounds or doped silica.
- These fibers have large core diameters and large Numerical apertures.
- Performance characteristics depends on the materials used and method of preparation.
- Structure for a glass multimode step index fiber.

**Multimode Step Index Fiber :**

- This fiber has core diameter form 100 to 970 μm.
- Due to large core diameter, there are many paths through which light can travel.
- The light ray travelling the straight path through the center reaches the end before the other rays, which follows a zigzag path.
- In this fiber modal dispersion occurs.
- Modal dispersion is a signal distortion which limits the bandwidth of the fiber.




Multimode step index

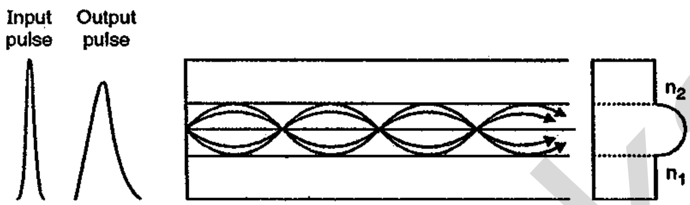
**Performance characteristics of multimode step index :**

- Attenuation : 2.6 to 50 dB/km at a wavelength of 0.85 μm
- Bandwidth : 6 to 50 MHz km

- Applications : Fibers are best suited for short-haul, limited bandwidth and low cost applications.

**Multimode Graded Index :**

- It is an improvement over multimode step index fiber in this fiber, light rays travel faster through the lower index of refraction, the light at the fiber core travels more slowly than the light nearer the surface.




- Figure below shows a structure for a glass multimode graded index fiber.
- Performance characteristics of multimode graded index fibers are better than those for multimode step index fiber, due to index grading and lower attenuation.
- Multimode graded index fibers have smaller core diameter than multimode step index fibers.

**Performance characteristics of multimode graded index :**

- Attenuation : 2 to 10 dB/km at a wavelength of 0.85 μm
  0.4 dB/km at wavelength of 1.3 μm
  0.25 dB/km at wavelength of 1.55 μm
- Bandwidth : 30 MHz km to 3 GHz km
- Applications : best suited for medium-haul, medium to high bandwidth applications.

**Q.3 Attempt any FOUR of the following : [16]**

**Q.3(a) State the advantages of circular waveguide.(Any 4) [4]**

**(A)** i) Circular waveguide are easy to manufacture and easier to join as compare to Rectangular wave guide.

ii) The $TM_{01}$ mode is possible in circular waveguide.

iii) As compare to Rectangular waveguide it gives lowest attenuation.

iv) This can be used in Rotating Antenna like in RADAR Application

**Q.3(b) With neat sketch, describe the operation of the GUNN diode. [4]**

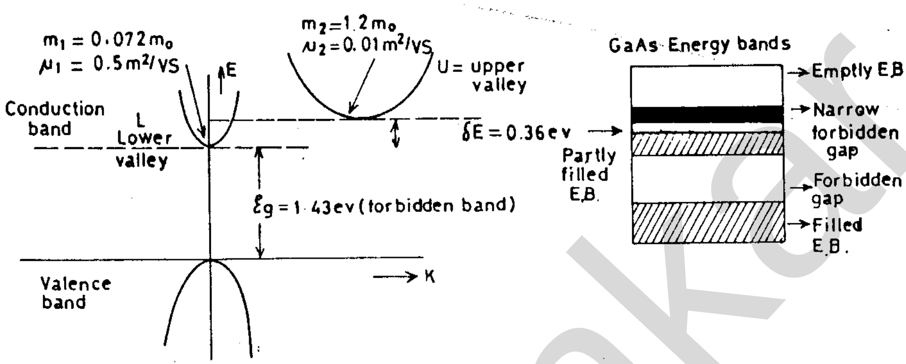
**(A) Gunn Devices**

The microwave devices that operates on the principle of transfer of electrons are called as "gunn diodes".

**Principle of operation :**

Gunn diode works on the principle of Electron transfer which can be explained as follows :

**Electron transfer (Gunn Effect ) :**




Basic mechanism involved in the operation of bulk n–type GaAs device (gunn diode) is the transfer of electrons from lower conduction valley (L–valley), to upper subsidiary valley (U–valley). This concept of Electron transfer is also known as "Gunn effect".

As shown in fig., the curvature of the two valleys in the conduction band are different so that an electron in L–valley has a smaller effective mass ($m_1$) than one in U–valley ($m_2$). The different effective masses mean different mobilities for the L–valley ($\mu_1$) and U–valley ($\mu_2$) respectively.

- At room temperature, when the applied electric field intensity is low, then almost all electrons are present in the lower valley.
- As the applied field is increased, the electrons gain energy from it and move upward in U–valley. The probability of this intervalley transfer of electrons is good as there are many available states in the U–valley.
- As electrons transfer to this U–valley, their mobility decreases and effective mass increases, thus decreasing the current density J & hence the negative differential conductivity.
- There is a certain threshold field (appr.3.3kv/cm) above which this intervalley transfer (i.e. population inversion) of charges from lower L–valley to U–valley or the "Transfer Electron effect" or "Gunn effect" takes place.
- The current density due to transfer of electrons is given by ,

$$J = \sigma E = \rho(n_1 + n_2)\,\bar{\mu}\,E = e n_0\,\bar{\mu}\,E$$

Where $\bar{\mu} = \dfrac{n_1\mu_1 + n_2\mu_2}{n_0}$ = avg. electron mobility

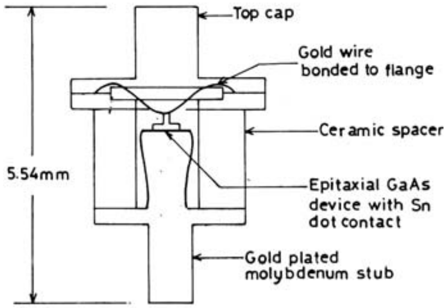
$n_1, n_2$ = carrier concentrations

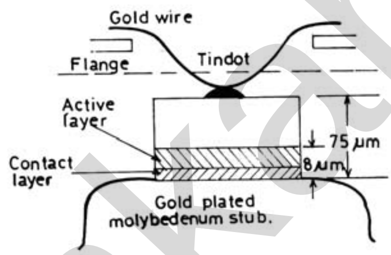
- As the applied field is raised even higher, almost all the electrons in L–valley are transferred to U–valley and current density becomes

$$J = \sigma E = en_2 \mu_2 E$$

**Construction of Gunn diode :**

The schematic of Gunn Diode is shown in the figure (2) while figure (3) shows the constructional details of the Gunn diode.



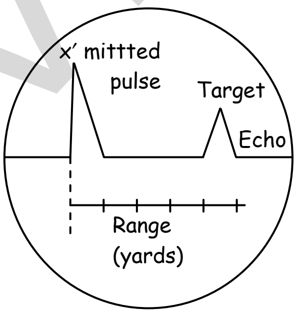




Gunn diodes are grown epitaxially out of GaAs or InP doped with silicon. The substrate, used here is highly doped for good conductivity, while the thin active layer is less heavily doped. The gold alloy contacts are electro deposited and used for good ohmic contact and heat transfer for subsequent dissipation.

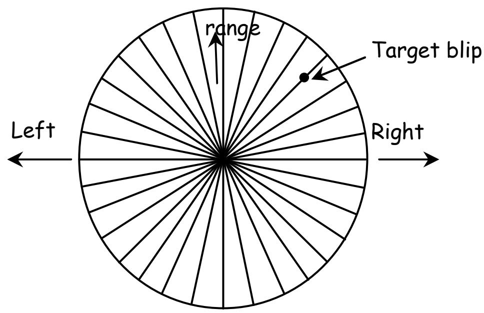
**Q.3(c) Describe A-scope, PPI Display method with its diagram. [4]**

**(A) Display:**

- In radar system display is cathode ray tube.
- Simplest A-scan or A-scope is used to display the transmitted and received pulses.
- Commonly used CRT display is P-type or plan position indicator (PPI).
- PPI display shows both the range and azimuth of the target.
- Center of the display is the location of radar unit.
- Concentric circles indicate the range and azimuth or direction is indicated by the position of the reflected target on the screen.
- The target shows up as lighted blips on the screen.




A - scope




PPI display

**Fig.**

**Q.3(d) Define geostationary orbit and geostationary satellite. [4]**

**(A) Synchronous Orbit:**

- The orbit in which satellite completes one revolution around earth in 24 hours, the orbit is called as synchronous orbit.
- In this orbit satellite angular velocity is same as the earth and so it appear to be stationary.
- A satellite 35800 km away from the earth will complete a revolution in 24 hours.

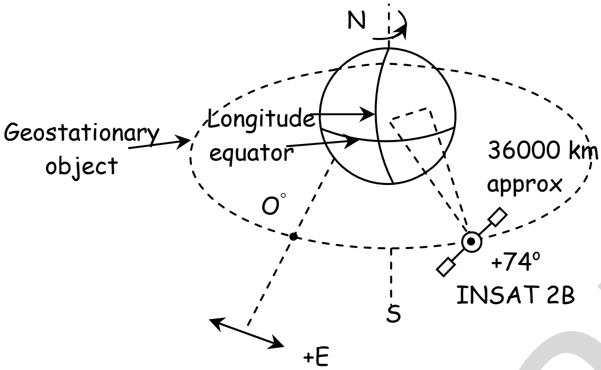



**Fig. 9(a)** : Synchronous orbit

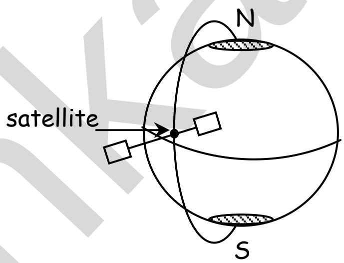



**Fig. 9 (b)** : Polar orbit

- This orbit is parallel to equator.
- It is used for communication satellites. Three geostationary satellites can cover the entire earth.
- It is not necessary to rotated the dish antenna on earth and then track to satellite.
- Antenna pointed at satellite and remain in a fixed position so continuous communications are possible.
- Powerful rockets are required to launch a satellite in the orbit.
- Satellite placed in this orbits cannot establish communication in polar region of the earth.

**Q.3(e) Differentiate satellite communication and fiber optic communication w.r.t [4]**

**(i) Frequency range** **(ii) Electromagnetic interference**

**(iii) Application** **(iv) Limitation**

**(A)**

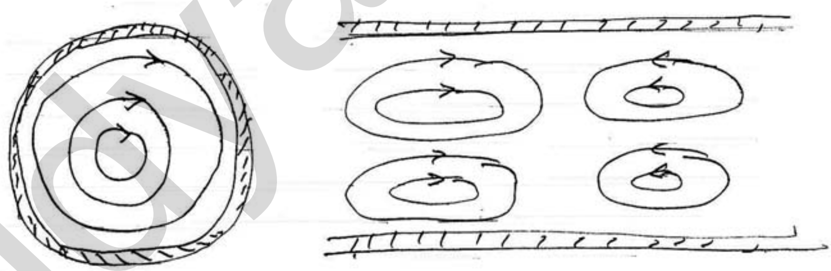
| | Satellite | OFC |
|---|---|---|
| i) | For satellite communication we use frequency from 1 GHz to 100 GHz | For OFC we use the frequency from $10^{14}$ to $10^{15}$ Hz. |
| ii) | In satellite communication via the air therefore we get more amount of noise interference. | We get less noise interference. |

| | | |
|---|---|---|
| iii) | Satellite communication can be used for whether monitoring and GPS system. | OFC can not be used for whether monitoring and GPS system. |
| iv) | The life of one satellite is very less around 15 to 20 years. | The life of OFC is more. |
| v) | In case of satellite communication the satellite is kept in a space and communication takes place via the air, hence it is a wireless communication. | In case of OFC we lay down the fiber optic cable under the ground or in the sear this cables carries the signal from one place to another. |
| vi) | In satellite communication signal is transmitted in the form of emf wave. | In OFC signal is transmitted in the form of light. |
| vii) | The initial installation and manufacturing cost of Satellite Communication is very high. | The initial installation and manufacturing cost of OFC is less. |
| viii) | In Satellite communication we require costlier earth station or ground station at different places. | We do not require such kinds of station in OFC. |

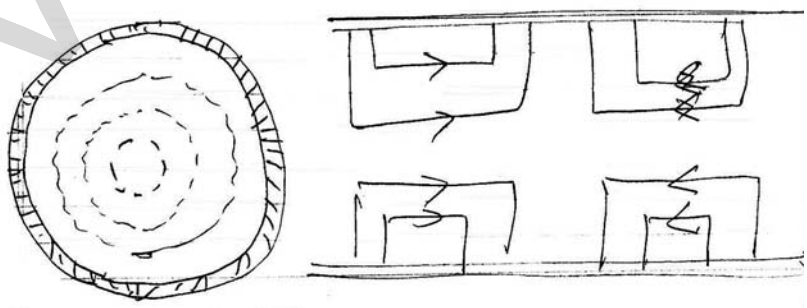
**Q.4(a) Attempt any THREE of the following : [12]**

**Q.4(a) (i) Draw field pattern of circular waveguide. [4]**

**(A) $TE_{01}$ Mode**



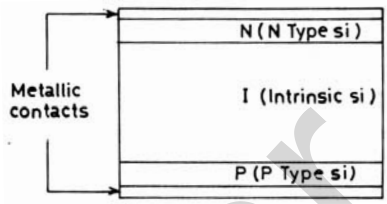
**$TM_{01}$ Mode**



**Q.4(a) (ii) Draw the construction of PIN diode and describe with its working principle. [4]**

**(A) Pin diode**

In a PIN diode, the semiconductor wafer has a heavily doped narrow layer of p–type material separated from an equally heavily doped narrow layer of n–type material by a thicker layer of high resistivity material that is intrinsic.




Generally, silicon is used for PIN diode. Electrical contacts are taken from two heavily doped regions. The PIN diode acts as low frequency rectifier that can rectify more power than ordinary p–n junction diode. At higher frequencies, the rectification ceases & the diode acts like a variable resistance under zero & reverse bias, the diode offers high impedance at microwave frequencies & a very small impedance for small forward currents. In short, for a PIN diode with bias variation its microwave resistance changes from nearly 5 to 10 KΩ under negative bias to 1 to 10Ω for positive bias. Thus it behaves as a microwave switch.

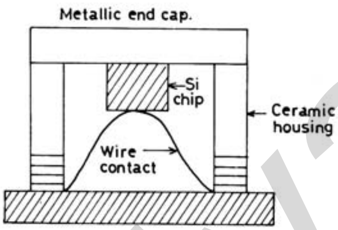



**Fig.** Construction

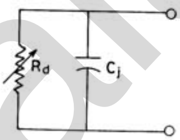



**Fig.** Equivalent Circuit

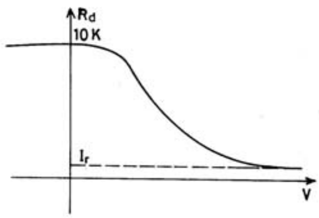
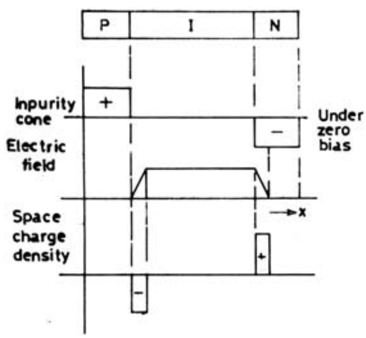



**Fig.** Resistance variation with bias

**Operation of PIN diode:**

The operation can be explained by considering zero bias, reverse and forward bias conditions shown by adjacent Figure.




**Zero bias:** At zero bias the diffusion of the holes and electrons across the junction causes space charge (density) region of thickness inversely proportional to the impurity concentration. An ideal 'i' layer has no depletion region i.e. p layer has a fixed negative charge and n layer has a fixed positive change under zero bias.

**Reverse bias:** As reverse bias is applied, the space charge regions in the p and n layers will become thicker. The reverse resistance will be very high and almost constant.

**Forward bias:** With forward bias carriers will be injected into the i layer and the p and n space charge regions will become thinner i.e. electrons and holes are injected into the 'i' layer from p and n layers respectively. This results in the carrier concentration in the 'i' layer becoming raised above equilibrium levels and the resistivity drops as forward bias is increased. Thus low resistance is offered in the forward direction.

**Q.4(a) (iii) Describe the concept of Doppler Effect. [4]**

**(A) The Doppler Effect:**

- A radar detects the presence of object and locates their position in space by transmitting electromagnetic energy and observing the returned echo.
- Echo indicates the presence of target.
- If the target is moving, the reflected signal undergoes a frequency change.
- Doppler effect states that, In the field of optics and acoustics if either the source of oscillation or observer of the oscillation is in motion, a shift in frequency will results.
- That means the frequency shift that occurs when there is relative motion between the transmitting station and a remote object.

**Q.4(a) (iv) Illustrate how telemetry tracking and command system used in satellite communication. [4]**

**(A) Telemetry tracking and command system :**

- This subsystem is responsible for monitoring on-board conditions like temperature and battery voltage.
- After monitoring it sends data back to earth station for analysis.
- According to results of analysis ground station issues the order to satellite by transmitting a signal to the command subsystem.
- Then command subsystem control the function of satellite like firing and jet thrusters.
- Telemetry typically consists of various electronic sensors for measuring temperature, radiation level, power supply voltage etc.

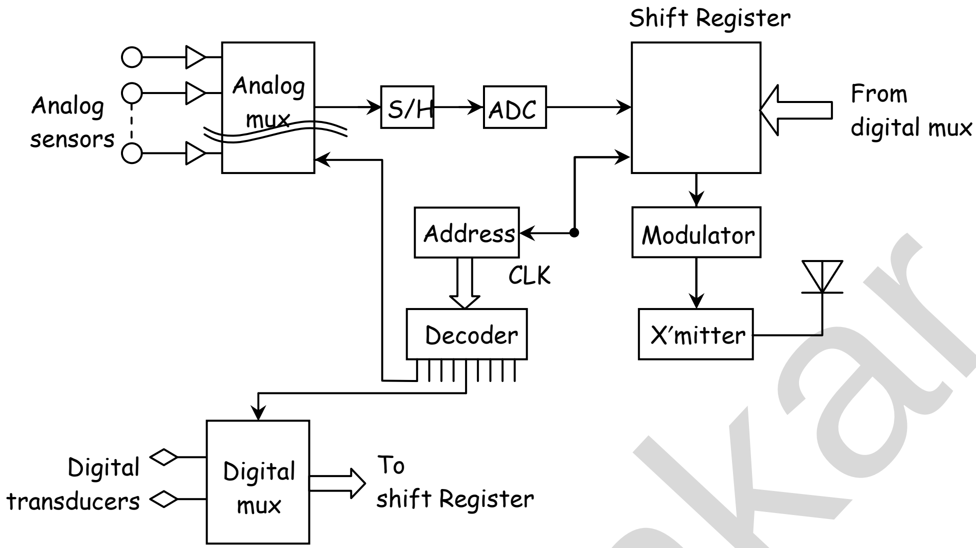



**Fig.1:** Block diagram of telemetry unit

- In above diagram both analog and digital sensors are shown and are selected by multiplexer.
- Sensor output is converted to a digital which modulates the internal transmitter.
- There are two multichannel transponder
  a)Broadband
  b) Narrow band

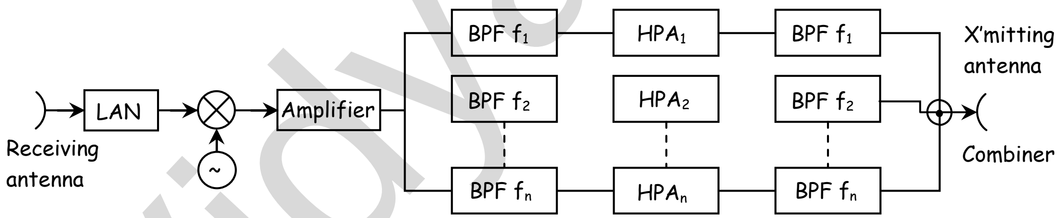



**Fig. 2**

**Q.4 (b) Attempt any ONE of the following : [6]**

**Q.4(b)(i) With neat sketch draw block diagram of fiber optic communication system and list out detectors suitable for it. [6]**

**(A) Block Diagram of Fiber Optic Communication**

Optical fiber is the medium in which communication signals are transmitted from one location to another in the form of light guided through thin fibers of glass or plastic. These signals can be digital pulses or continuously modulated analog streams of light representing information like voice, data etc.

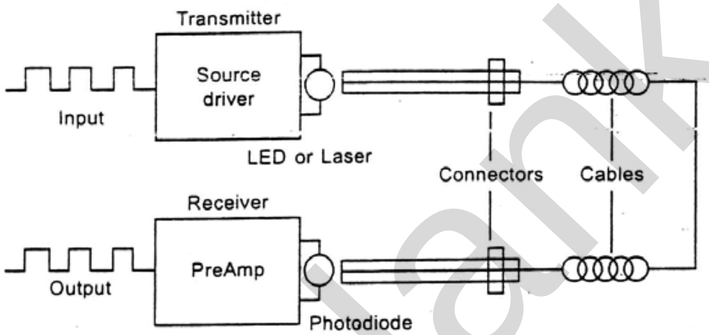
Basically, an optical fiber link is made up of three elements

(i) A light source at one end (LASEER or LED), including a connector to connect the fiber. The light source receives signal from the support electronics and converts the electrical information to optical information.

(ii) The fiber, along with cable connectors and splicers, transports this light to its destination.

(iii) The light detector on the other end, with a connector interface to the fiber. The detector converts the incoming light back to an electrical signal.

The source and detector with their necessary support electronics are called the transmitter and receiver respectively.




A typical fiber optic data link

The above figure shows a basic fiber optic data link. it is clear that fiber optic transmission is basically merging of two technologies i.e.

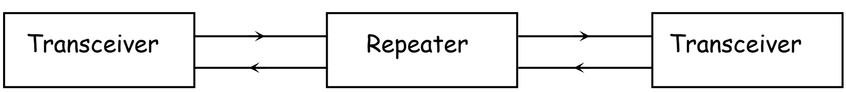
(i) Semiconductor technology. (ii) Optical waveguide technology

Optical waveguide technology relates to the fiber fabrication, transmission characteristics of fibers, fiber connection etc.

Semiconductor technology develops the source and detectors at the required longer wavelengths, that is 1.1-1.6 μm.

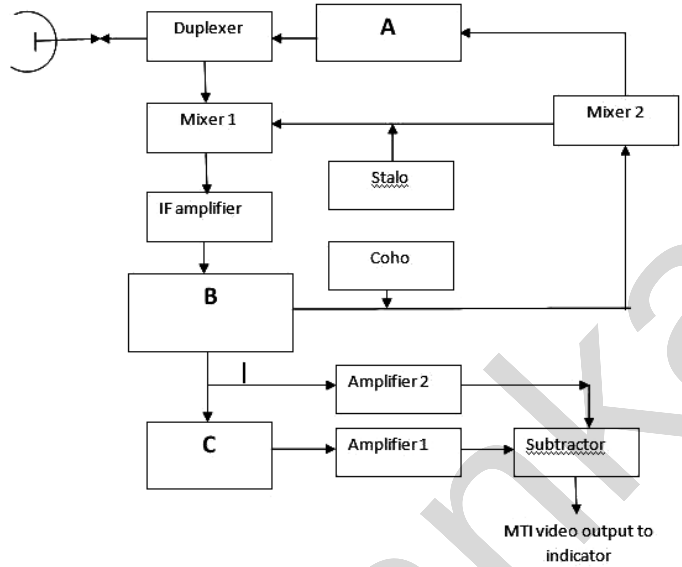
At longer wavelengths, fiber has less dispersion and losses. If a fiber exhibits excellent performance at 1.3 μm, still it will be of no use, if we do not have sources and detectors at that wavelength.

For long distance systems, repeaters are used to compensate for the signal loss over the long run of the fiber. The repeater incorporates a line receiver in order to convert the optical signal back into the electrical regime, where it is amplified before it is retransmitted as an optical signal via a transmitter.

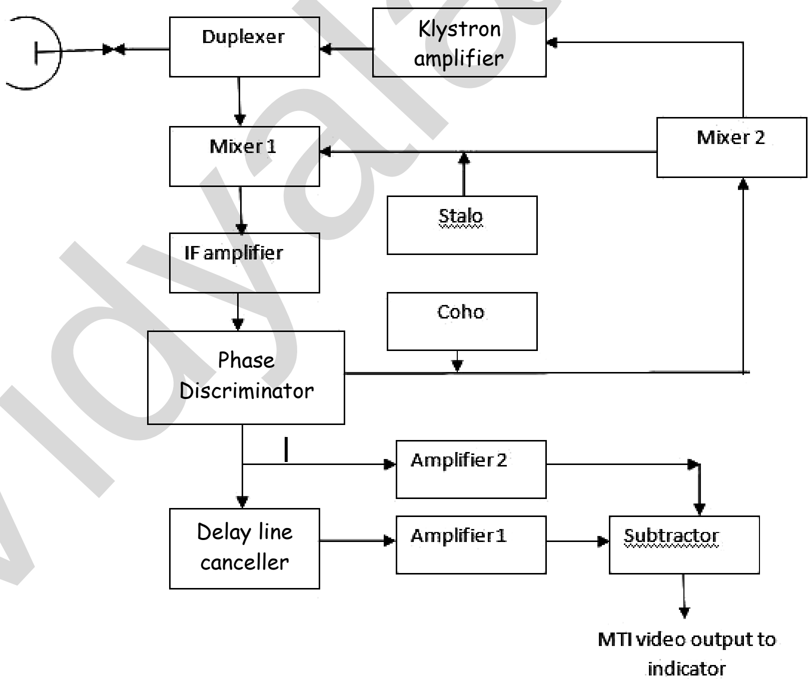



Long distance data links require repeaters

**Q.4(b) (ii) Identify the given diagram, label the block A, B, C and state their function. [6]**




**(A)**



**Q.5 Attempt any FOUR of the following : [16]**

**Q.5(a) Distinguish microwave circulator and isolator with following parameter. [4]**

**i) Function ii) Construction**

**iii) Application iv) Number of ports**

**(A)**

| Parameter | Circulator | Isolator |
|---|---|---|
| Application | It is mainly used as a Duplexer in Radar. | It is used to isolate output from output is in waveguide transmission line. |
| No. of parts | Four | Two |
| Construction | It is made up of circular waveguide with ferrite rod inside and having only four parts. | It is made up of circular waveguide with ferrite rod inside but having two parts. |
| Function | It parses the signal from input port to given output port only. | It provides isolation and avoid stand line wave loss. |

**Q.5 (b) Show how reflex klystron worked as a amplifier. [4]**

**(A) Reflex klystron :**

The reflex klystron is an oscillator tube with a built–in feedback mechanism. It uses the same cavity for bunching and for the output cavity.

If a fraction of the output power is fed back to the input cavity and if the loop gain has a magnitude of unity with a phase shift of multiple $2\pi$, the klystron will oscillate. However, a two cavity klystron oscillator is not constructed because, when the oscillation frequency is varied, the resonant frequency of each cavity and the feedback path phase shift must be readjusted for a positive feedback. The reflex klystron is a single cavity klystron that overcomes the disadvantages of the two cavity klystron oscillator.

It is a low power generator of

Output = 10 to 500 mW at

Frequency range = 1 to 25 GH

Efficiency = 20 to 30%

**Application:**

It is widely used in the laboratory for $\mu$–wave measurements and in microwave receivers as local oscillators in commercial, military, and airborne Doppler radars as well as missiles. The theory of the two cavity Klystron can be applied to the analysis of the reflex klystron with slight modification.

The reflex Klystron tube is as shown in figure, which uses only a single re-entrant microwave cavity as resonator. The electron beam emitted from the cathode is accelerated by the anode and passes through the cavity anode to the repeller space between the cavity anode and the repeller electrode.

We assume an initial ac field in the cavity (due to noise or switching transients). The electrons passing through the cavity gap d experiences this RF field and are velocity modulated in the following manner.

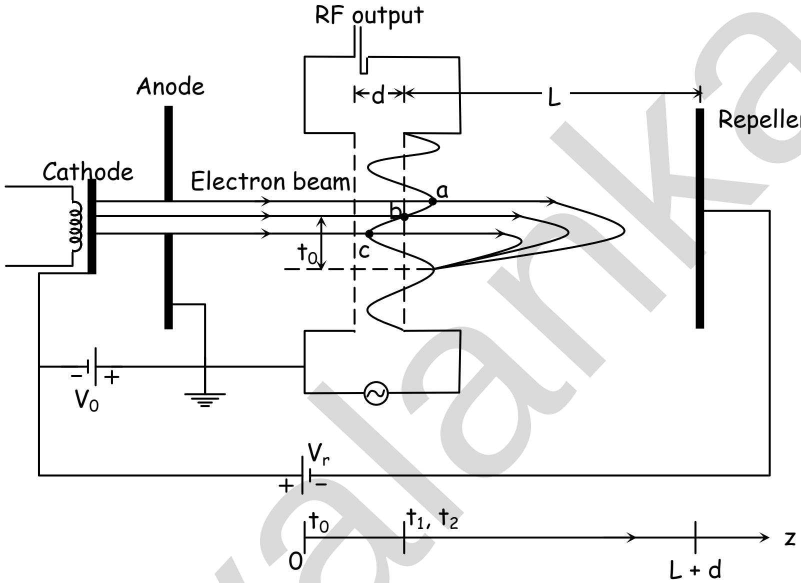



**Fig.** : Reflex Klystron

The electrons a shown in figure which leave the gap at positive half cycle of the RF field in the cavity gap d will be accelerated. While electrons b travel with unchanged original velocity, and the electrons c will be retarded on entering the repeller space.

The electrons never reach the repeller because of the negative field and are returned back towards the gap.

It is obvious that the electrons a moving with greater velocity towards repeller penetrates deep into repeller space before they are repelled. The return time of these electrons is long. The electrons 'a' are also called as early electrons ($e_e$), since they leave the gap early before electrons b & c.

The electrons 'b' is called reference ($e_R$) electrons. They travel with velocity less than that of $e_e$ and are returned back.

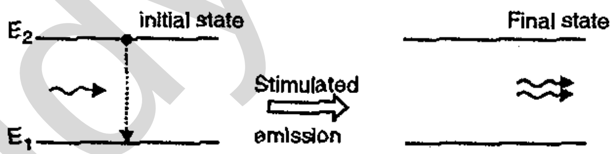
The electrons 'c' is called late electrons ($e_l$). They travel less than that by $e_e$ and $e_R$ in the repeller space before they are repelled.

Thus electrons $e_l$ catches up with $e_R$ and $e_e$ electrons forming a bunch.
The repeller distance L and the voltages can be adjusted to receive all the velocity modulated electrons at a same time on the positive peak of the cavity RF voltage cycle. Thus the velocity modulated electrons are bunched together and lose their kinetic energy when they encounter the positive half cycle of the cavity RF field. This loss of energy is thus transferred to the cavity to conserve the total power. If the power delivered by the bunched electrons to the cavity is greater than power loss in the cavity, the electromagnetic field amplitude at the resonant frequency of the cavity will increase to produce microwave oscillations. The RF power is coupled to the output load by means of a small loop which forms the centre conductor of the co–axial line. When the power delivered by the electrons become equal to the total power loss in the cavity system, a steady microwave oscillation is generated at resonant frequency of the cavity.

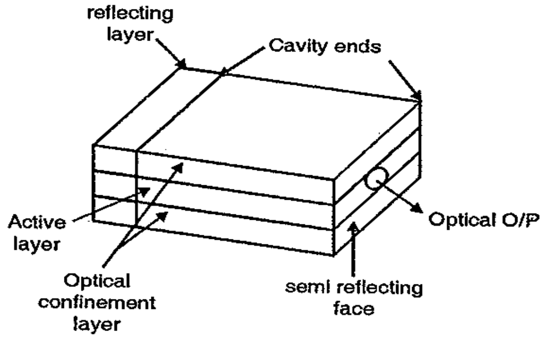
**Q.5(c) Draw schematic of LASER and describe it's working principle with transition process involved in LASER process.** **[4]**

**(A) LASER (Light Amplification by Stimulated Emission of Radiation):**

- LASER operates on the principle of stimulated emission.
- Stimulated emission is a emission or creation of a second photon when a photon having an energy equal to the energy difference between the two states interacts with the atom in the upper energy state causing it to return to the lower state.




- The photon produced by stimulated emission is of identical energy to the one which caused it and hence the light associated with them is of the same frequency.
- The light associated with the stimulating and stimulated photon is in phase and has the same polarization. Therefore coherent radiation is obtained.
- This means that when an atom is stimulated to emit light energy by an incident wave, the liberated energy can add to the wave in a constructive manner, providing amplification.



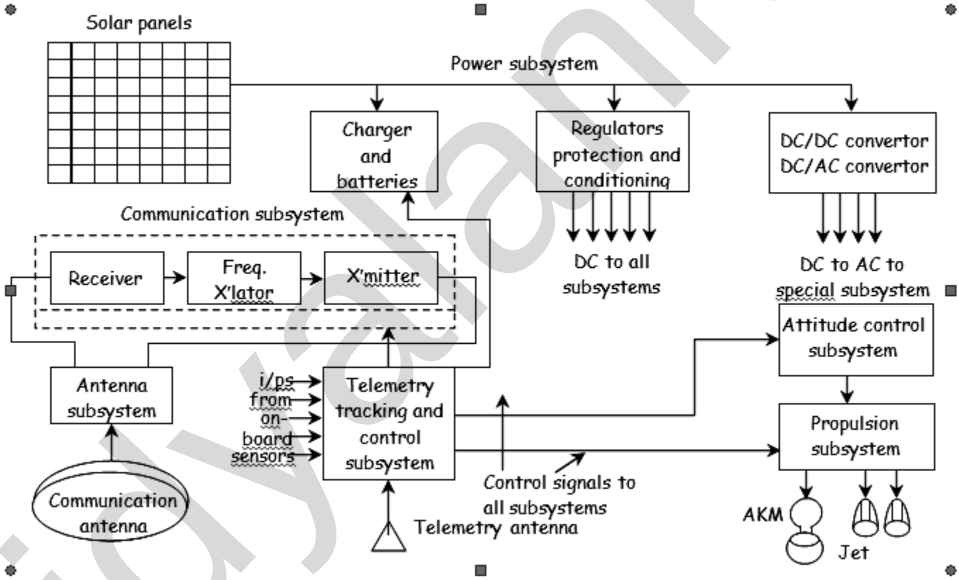

- Figure above, shows the structure of laser diode.
- Light amplification in the laser occurs when a photon colliding with an atom in the excited energy state causes the stimulated emission of a second photon then both these, photons release two more.
- Continuation of this process effectively creates avalanche multiplication, and when the electromagnetic waves associated with these photons are in phase amplified coherent emission is obtained.
- To achieve this laser action it is necessary to contain photons within the laser medium, and maintain the conditions for coherence.
- This is accomplished by placing or forming mirrors at either end of the amplifying medium.
- The optical cavity formed to provide positive feedback of the photons by reflection at the mirror at either end of cavity.
- Hence the optical signal is feedback many times whilst receiving amplification as it passes through the medium.
- A stable output is obtained at saturation when the optical gain is exactly matched by the losses incurred in the amplifying medium.
- The device is not a perfectly monochromatic source but emits over a narrow spectral band.
- The central frequency of this spectral band is determined by the mean energy level difference of the stimulated emission transition.
- For optical communication systems, bandwidth requirement is grater than 200 MHz, the injection laser diode is preferred over the LED.
- Laser diodes typically have response time less than 1 ns.
- Optical bandwidth is of 2 nm or less.
- It is capable of coupling several milliwatts of useful luminescent power in to optical fibers with small cores and small numerical apertures.

**Q.5(d) Illustrate block diagram of sallelite subsystem. [4]**

**(A) Satellite Substystems:**

- Satellite communication system consists of two main parts.
  (i) Satellite or space craft (ii) One or more earth stations.

- Satellite can be used to as radio repeater or relay station.
- Two or more earth stations communicate with each other through satellite.
- The important parts of communication satellite are their subsystems.
- Transponder is a main part of satellite and transponder supports a variety of subsystems.
- The different subsystem are as follows:
  (i) Power subsystem
  (ii) Communication subsystem
  (iii) Telemetry tracking and command subsystems.
  (iv) Attitude control subsystem.
  (v) Propulsion subsystem
  (vi) Antenna subsystem




In above figure different subsystem of communication satellite are shown.

**Q.5(e) Calculate critical angle of incidence between two substances with different refractive indices $n_1$ = 1.4 and $n_2$ = 1.36** **[4]**

**(A)** **Given :** $n_1 = 1.4$

$n_2 = 1.36$

Critical Angle $Q_C = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

$= \sin^{-1}\left(\frac{1.36}{1.4}\right)$

$Q_C = 76.27^\circ$

**Q.5 (f) When the optical power launched into an 8 km length of fiber is 120μw the mean optical power at the fiber output is 3 μw. Determine:** **[4]**

**(i) The overall signal attenuation or loss in decibels through the fiber assuming there are no connector or splicer.**

**(ii) The signal attenuation per kilometer for the fibers.**

**(A)** ***Given :*** $L = 8$ Km $\quad P_S = 120\ \mu w \quad P_R = 3\ \mu w$

(i) The overall loss is given as

$$\text{Loss} = P_S - P_R = 120 - 3 = 117\ \mu w = 20.14\ \text{dBm}$$

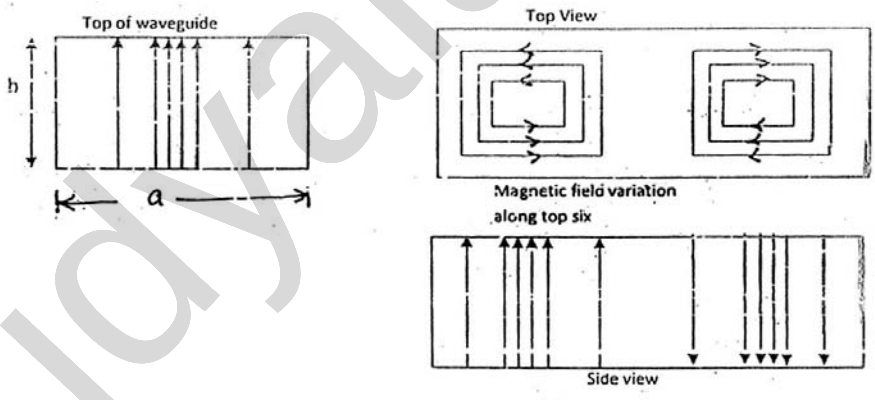
(ii) Signal attenuation per Kilometer

$$= \frac{117}{8} = 11.65\ \text{dBm}$$

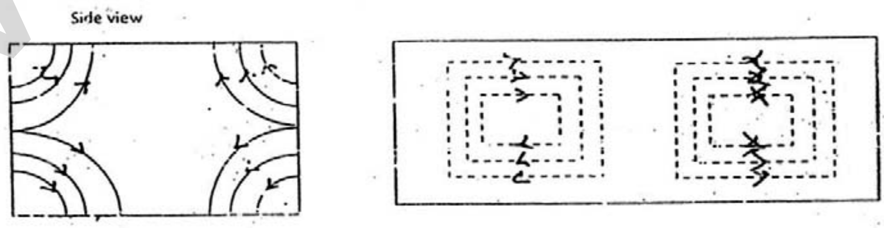
**Q.6 Attempt any FOUR of the following :** **[16]**

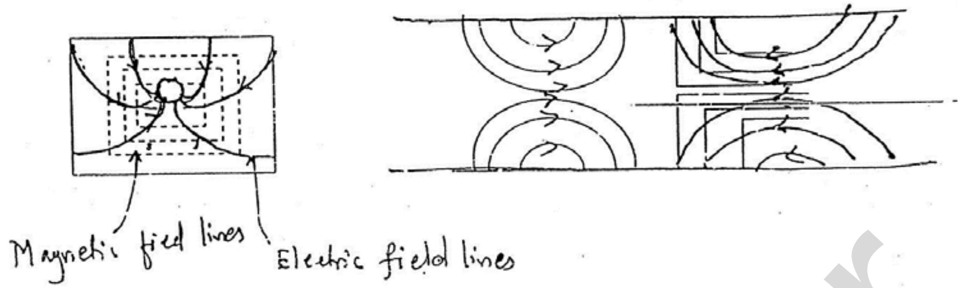
**Q.6(a) Draw field pattern of TE10 and TE11 mode.** **[4]**

**(A) (i) TE10**




**(ii) TE 11**






**Q.6(b) Describe Scattering and dispersion losses in optical fiber. [4]**

**(A) Dispersion :**

- Dispersion of transmitted optical signal causes distortion for both digital analog transmission along optical fibers.
- Dispersion mechanisms within the fiber cause broadening of the transmit pulses as they travel along the channel.
- As shown in Fig. 1, each pulse broadens and overlaps with its neighbours eventually becoming in distinguishable at the receiver inputs the effect is known as intersymbol interference.

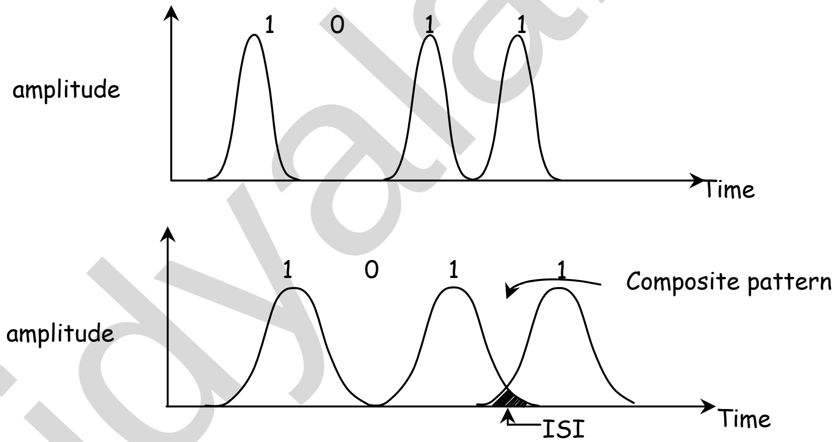



**Fig. 1:** Pulse broadening

- Signal dispersion alone limits the maximum possible bandwidth attainable with a particular optical fiber to the point where individual symbols can no longer be distinguished.
- It is necessary to consider the dispersive mechanisms to determine the reasons for the different amounts to pulse broadening within various types of optical fiber.
  - Intramodal dispersion
  - Intermodal dispersion

**Intramodal dispersion:**

- Intramodal dispersion is also called chromatic dispersion.
- It occurs in all types of optical fibers.
- It results from the finite spectral linewidth of the optical source.
- We know that optical sources do not emit just a single frequency but band of frequencies.
- There may be propagation delay differences between the different spectral components of the transmitted signal.
- Delay in propagation causes broadening of each transmitted mode and so called intramodal dispersion.
- Delay in propagation causes broadening of each transmitted mode and so called intramodal dispersion.
- This delay may be caused by the dispersive properties of wavegiode material and the fiber structure.
  Delay due to waveguide material is called material dispersion.
  Delay due to fiber structure is called wavegude dispersion.

**Material dispersion :**

- It results from the different group velocities of the various spectral components launched into the fiber from optical source.
- It occurs when the phase velocity of a plane wave propagating in the dielectric medium varies nonlinearly with wavelength.
- A material is said to exhibit material dispersion when the second differential of the refractive index with respect to wavelength is not zero.

$$\frac{d^2n}{d\lambda^2} \neq 0$$

**Waveguide dispersion :**

- It results from the variation in group velocity with wavelength for a particular mode.
- According to ray theory the angle between the ray and the fiber axis varying with wavelength.
- These variations leads to a variation in the transmission times for the rays and so dispersion.
- For a single mode propagation constant is $\beta$,
- When $\frac{d^2\beta}{d\lambda^2} \neq 0$, single mode fiber exhibits waveguide dispersion.
- In multimode fiber, majority of modes propagate far from cutoff, are almost free of waveguide dispersion.

**Intermodal dispersion :**

- It results from the propagation delay difference between modes within a multimode fiber travel along the channel with different group velocities.
- The pulse width at output is dependent upon the transmission times of the slowest and fastest modes.
- Multimode step index fibers exhibit a large amount of intermodal dispersion.
- It may be reduced by adapting an optimum refractive index profile.
- In purse single mode there is no intermodal dispersion.
- In multimode graded index fibers is far less than that obtained in multimode step index fibers.
- In multimode step index, the fastest and slowest modes propagating are represented by axial by axial ray and the extreme meridional ray respectively.
- The delay difference between these two rays when travelling in the fiber core allows estimation of the pulse broadening i.e. intermodal dispersion.

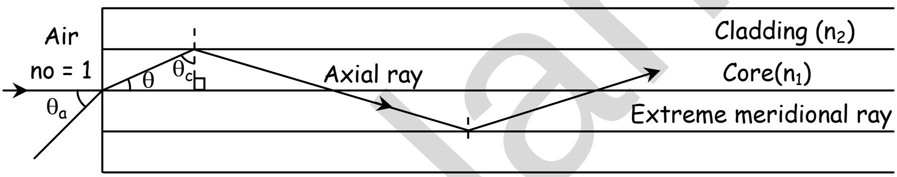



**Fig. 2:** Multimode step index fiber

- It may be reduced by propagation mechanisms within practical fibers.
- The differential attenuation of modes reduces intermodal dispersion.
- Mode coupling or mixing reduces the intermodal dispersion.
- The coupling between guided modes transfers optical power from the slower to fastest modes and vice versa.
- Strongly coupled, optical power transmit at an average speed i.e. mean of various propagating modes.
- It reduces intermodal dispersion.
- International dispersion in multimode fiber is minimized by using graded index fiber.

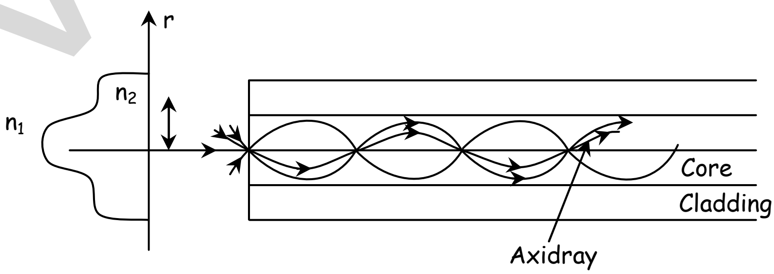



**Fig. 3:** Multimedia graded index fiber

- In above figure 3 merimodional rays follow sinusoidal trajectories of different path lengths which results from the index grading.
- The group velocity is inversely proportional to the refractive index.
- The longer sinusoidal paths are compensated for by higher speed in the lower index medium away from axis.

Rays travels in the high index region at core axis at the slowest speed.
Various ray paths represent the different modes propagating in the fiber.

**Bend loss:**

- Whenver an optical fiber undergoes a bend of finite radius of curvature, radiative losses occurs.
- These are two types of bends:
  1) Macroscopic bend
  2) Microscopic bend

**1) Macrobending losses :**

- Macroscopic bends have radii large compared to fiber diameter e.g. it occurs when fiber turns a corner.
- For slight bends the excess loss in extremely small.
- As the radius of curvature decreases, the loss increases exponentially.

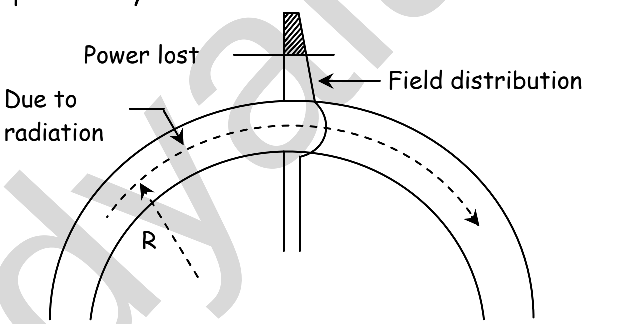


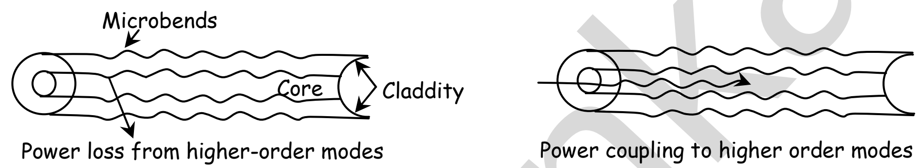

**Fig.: 4**

- At a certain critical radius curvature loss becomes observable.
- Fig. 2 shows relationship between radiation from a bent and field strength.
- Any bound core mode has field tail in the cladding which decays exponentially as a function of distance from the core.
- This fields tail moves long with the field in the core, part of the energy of propagating mode travels in the fiber cladding.
- When a fiber is bent, the field fail on the far side of the center of curvature must move faster to keepup with the field in the core, for lowest order mode.

- The amount of optical radiation from a bent fiber depends on the field strength and on the radius of curvature.
- Higher-order modes are bund less tightly to the fiber core than lower-order modes, the higher-order modes will radiate out of the fiber first.

**Microbend loss :**

- Microbends are respective small-scale fluctuations in the radius of curvature of the fiber axis as shown in figure.
- They are caused either by nonuniformities in the manufacturing of the fiber, or by nonuniform lateral pressures created during cabling of the fiber.




**(a) Power loss from higher-order modes** **(b) Power coupling to higher order modes**

**Fig. 5**

- In microbending the fiber curvature causes modes and leaky or non guided modes in the fiber.
- To minimize this loss, extrude a compressible jacket over the fiber.
- When external forces are applied, the jacket will be deformed but the fiber will tends to stay straight.

**Scattering loss:**

- It occurs in glass to microscopic variations in the material density, compositional fluctuations, structural in homogeneities, defects during fiber manufacturing.
- Two types of scattering losses;
  (1) Linear scattering
  (2) Nonlinear scattering

**1) Linear scattering:**

- This mechanism causes the transfer of some or all optical power contained within one propagating mode linearly into a different mode.
- This results in attenuation of transmitted light as leaky or radiation mode without continue propagation.

  Linear scattering categorized into two major types:

  1) Ray leigh scattering    2) Mie scattering

**Rayleigh scattering:**

- It is the dominant intrinsic loss mechanism in the low absorption window between the ultraviolet and infrared absorption tails.
- It results from inhomogeneities of a random nature occurring on a small scale compared with the wavelength of the light these inhomigeneities manifest themselves as refractive index fluctuations and arise from density and compositional variations which are frozen into glass lattice on cooling.
- The compositional variations may be reduced by improved fabrication.
- The index fluctuations caused by the freezing of density inhomogeneities are fundamental and cannot be avoided.
- The scattering due to density fluctuations, in all direction produces an attenuation proportional to $1/\lambda^4$.
- For a single component glass rayleigh scattering is given by

$$\gamma_R = \frac{8\pi^3}{3\lambda^4} n^3 p^2 \beta_c k T_F$$

$\gamma_R$ → Rayleigh scattering coefficient
$\lambda$ → optical wavelength
$n$ → refractive index of medium
$p$ → average photo elastic coefficient
$\beta_c$ → Isothermal compressibility at $T_F$
$T_F$ → Fictive temperature
$k$ → Boltzmann's constant

**Fictive temperature:**

- It is defined as the temperature at which the glass can reach a state of thermal equilibrium.

**Mie scattering :**

- Results from the nonperfect cylindrical structures of the waveguide and due to fiber imperfections such as irregularities in the core cladding interface, core-cladding refractive index differences along the fiber length, diameter fluctuations, strains and bubbles.
- Scattering by inhomogeneities is mainly in forward direction and so called Mie scattering.
- This scattering loss depends upon the fiber material, design and manufacture.
- The inhomogeneities may be reduced by removing imperfections due to the glass manufacturing process, increasing the fiber guidance by increasing the relative refractive index difference.
- Carefully controlled coating of the fiber.

**2) Nonlinear scattering losses:**

- In optical waveguide output optical power do not always proportional to input optical power.
- At high optical power levels, due to non linear effects, scattering causes disproportionate attenuation.
- Nonlinear scattering causes the optical power from one mode to be transferred in either the forward or backward direction to the same or other modes at different frequency.
- It depends upon the optical power density within the fiber, so becomes significant above threshold power levels.
- Important types of nonlinear scattering are:
  (i) Stimulated Brillouin Scattering
  (ii) Raman scattering

**(i) Stimulated Brillouin scattering**

- It observed at high optical power densities in long single-mode fibers.
- It may be regarded as the modulation of light through thermal molecular vibrations within the fiber.
- The scattered light appears as upper and lower sideband separated from incident light by modulation frequency.
- The incidents photon produces a phonon of acoustic frequency and a scattered photon.
- This produces an optical frequency shift varies with the scattering angle.
- The frequency shift is a maximum in backward direction and reduces to zero in forward direction.
- The threshold power is given by

$$p_B = 4.4 \times 10^{-3}\, d^2 \lambda^2\, \alpha_{dB}\, v \text{ watts}$$

where $d \rightarrow$ fiber core diameter μm
$\lambda \rightarrow$ Operating wavelength μm
$\alpha_{dB} \rightarrow$ fiber attenuation in dB/km
$v \rightarrow$ Source bandwidth GHz.

**(ii) Raman scattering:**

- It is similar to Brillouin scattering only the differences is as below
- Here the incident photon in scattering produces a high frequency optical phonon and a scattered photon.
- It occurs in both forward and backward direction.
- It have an optical power threshold upto three orders of magnitude higher than Brillouin threshold in particular fiber.

- The threshold optical power for a long single mode fiber is given by,

$$p_R = 5.9 \times 10^{-2}\, d^2 \lambda\, \alpha_{dB} \text{ watts}$$

where $d$ = fiber core diameter in μm

$\lambda$ = operating wavelength in μm

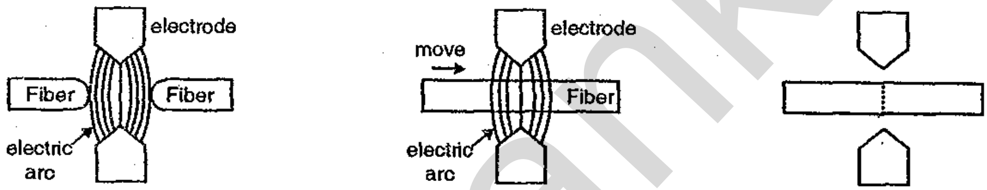
$\alpha_{dB}$ = fiber attenuation in decibel per km

**Q.6(c) Draw the diagram of fusion splicing and V-Groove splicing technique.**

(A) (i) Prefusion : It is a technique, which involves the rounding of the fiber ends with a low energy discharge before pressing the fibers together, as in Figure (a).

(ii) By moving movable block, with proper pressure two fibers are pressed together as in Figure (b).

(iii) Then there will be accomplishment of splice figure (c).



(a) (b) (c)

**Drawbacks of Fusion Splicing :**

(i) Heat necessary to fuse the fibers may weaken the fiber.

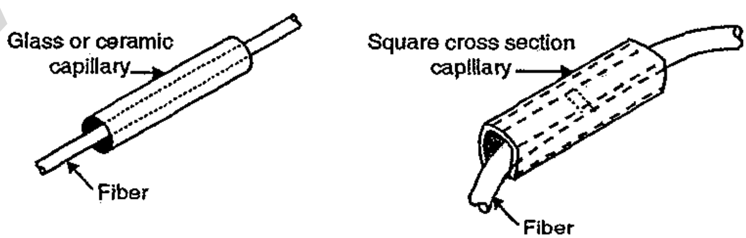
(ii) Possibility of fiber fracture in fused joint.

**Mechanical Splicing :**

- There are number of mechanical splicing techniques.
- The common methods are
  (1) Using rigid alignment tube. (2) Using V-grooves.

**(1) Using rigid alignment tube:**

- In this method accurately produced rigid alignment tube is used to bond the prepared fiber ends permanently.
- Figure shows the snug tube splice and loose tube splice.

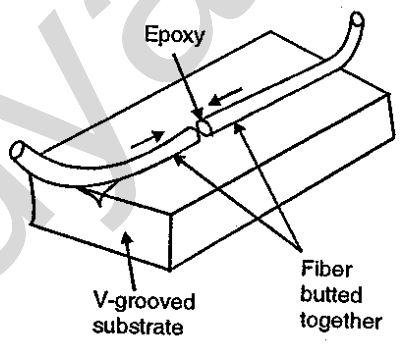


(a) (b)

- In snug tube splicing technique uses a glass or ceramic capillary tube with an inner diameter just large enough to accept the optical fibers.
- Transparent adhesive is injected through a transverse bore in capillary to give mechanical sealing and index matching of the splice.
- Average insertion losses as low as 0.1 dB have been obtained.
- In Figure above loose tube splice is used.
- In this splice an oversized square section metal tube is used to accept the prepared fiber ends.
- Transparent adhesive is first inserted into the tube followed by the fibers. The splice is self aligned, when fibers are curved in same plane. Mean splice insertion losses of 0.073 dB have been achieved.

**(2) Using V-grooves:**

- In this techniques V-grooves are used to secure the fibers to be jointed.
- This method utilizes a V-groove into which the two prepared fiber ends are pressed.
- The V-groove splice gives alignment of the prepared fiber ends through insertion in the groove.
- The splice is made permanent by securing the fibers in the V-groove with epoxy resin.
- For single mode fiber splice insertion losses of less than 0.01 dB.
- The figure below is shown for this technique as below :




**Q.6(d) How power is generated in satellite? Describe how it is distributed to other subsystem of satellite. [4]**

**(A) i) Power subsystem:**

- Fig. 1 shows the power subsystem.
- Solar panels supply the electrical power for the satellite.
- They drive regulators and distribute d.c. power to all other subsystems.
- The main component of the satellite is power subsystem.

- Every thing on board operates electrically.
- Solar cells are large arrays of photocells connected in various series and parallel circuits as d.c. source.
- Solar panels are capable of generating many kilowatts.

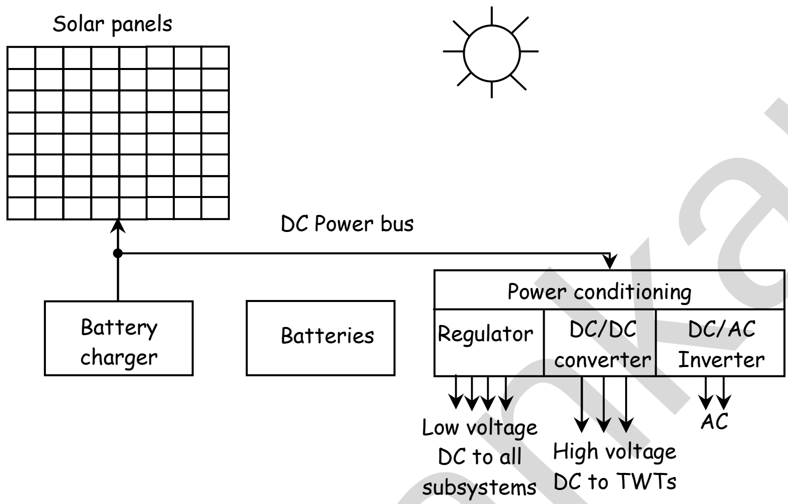



**Fig. 1**

- All solar panels always be pointed towards the sun, Solar panels generate a direct current that is used to operate the various components of satellite.
- D.C. power is used to charge the batteries which provides d.c. current to component of satellite when solar panels are not properly positioned.
- Voltage regulators are used to power individual electronic circuits.
- Some components like TWT amplifier in transponder requires very high d.c. voltage to operate, so d.c. to d.c. converter is used to raise the level of low voltages to high voltage.

**ii) Communication subsystem:**

- It consists of multiple transponders.
- Transponder receives the up-link frequency.
- It amplify them and translate them in frequency.
- Again amplify them and retransmit as down-link frequency.
- Transponder share a common antenna subsystem for both reception and transmission.
- As we know transponder consist transmitter and receiver and are designed to operate at separate frequencies.
- Therefore they will no interfere with one another.

There are three basic transponder configuration used in communication satellite.

a) Single – conversion transponder.
b) Double – conversion transponder
c) Regenerative transponder

**a) Single – conversion transponder:**

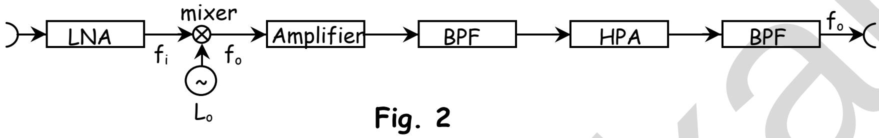



**Fig. 2**

- Above Fig. 2 shows the block diagram of single conversion transponder.
- In this transponder only a single-frequency translation process takes place.
- First uplink frequency signal is picked up by the receiving antenna and is routed to LNA (Low Noise Amplifier).
- The signal is very weak at this point, so LNA amplifies the signal.
- Once the signal is amplified, it is translated in frequency, by mixer.
- The output of mixer is then amplified again and fed to band pass filter (BPF1).
- BPF1 allows only desired down-link signal of 4 GHz.
- At last, the downlink signal is amplified by high-power amplifier (HPA) usually TWT (traveling wave tube).
- Again output of BPF2 is fed to the down-link antenna.
- If common antenna is used for transmission or reception then displexer is used to share the antenna.

**b) Double – Conversion transponder:**

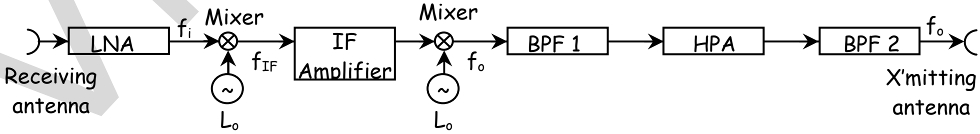



**Fig. 3**

- In above Fig. 3 two frequency conversions are carried out therefore named as double-conversion transponder.
- First uplink signal is received by receiving antenna.
- LNA amplified the received signal.

- Amplified signal then fed to first mixer (I).
- The mixer I translates the received signal frequency into intermediate frequency (typically 70 and 150 MHz).
- If output is fed to an IF amplifier.
- The output of IF amplifier is fed to another mixer II.
- The mixer II translates the signal to the output frequency.
- BPFI filters the output signal and eliminates the unwanted output.
- HPA increases the output signal level.
- Again output signal is passed through BPF2 to filter out the harmonics etc.
- At last, transmitting antenna sends the signal over the down link.
- This transponder provides greater flexibility in filtering and amplification.

**c) Regenerative transponder:**

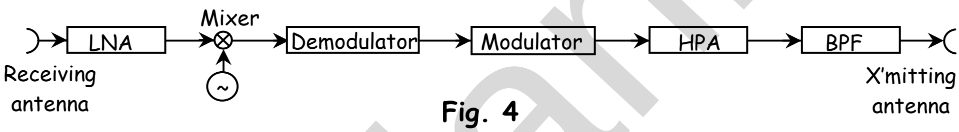


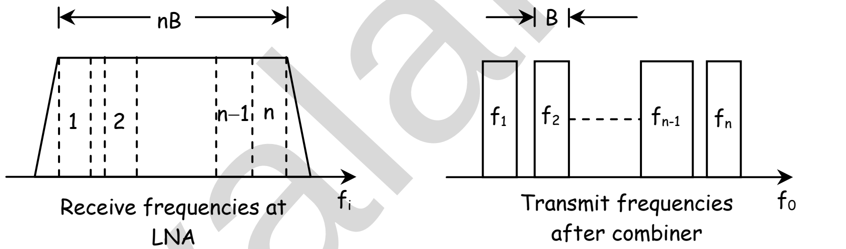

**Fig. 4**

- Above Fig. 4 shows a block diagram for regenerative transponder.
- Receiving antenna first receives uplink signal transmitted by earth station.
- This uplink frequency signal is amplified and fed to mixer to translate the frequency of signal.
- After translation of frequency, signal is demodulated.
- Demodulated output again modulated along with carrier at the down link frequency.
- Then the signal is amplified, filtered and transmitted over the downlink.
- Because of demodulation modulation technique overall signal/noise ratio of transponder can be improved.
- Communication satellite contain multiple transponders.
- So it permits more signal to be received and transmitted.
- Typically commercial communication satellite contains 12 transponders.
- Each transponder operates on a separate frequency and has wide bandwidth to carry multiple channels.

**iii) Telemetry tracking and command system :**
(Refer Q.4(a-iv) solution of May '14)

**a) Broadband multichannel:**

- Modern communication satellites contain multiple transponder.
- Typically commercial communication satellite contains 12 transponders.
- Each transponder operators on a separate frequency.
- Each having wider bandwidth to carry multiple channels.
- Fig. broadband multichannel system is shown.
- The receiving antenna is connected to LNA.
- A mixer translates all incoming signals into their equivalent lower downlink frequencies.
- A wideband amplifier amplifies the entire spectrum.
- Each bandpass filter passes only the frequency for which it is designed.



(a) Receive frequency at LNA (b) Transmit frequencies after combiner

**Fig. 5**

- Transmitter sends the telemetry information back to earth station where it is monitored and recorded for analysis.
- In this way earth station determines the status of satellite at all times.
- A command and control subsystem receives control signal from earth station transmitter.
- Control signals are made up of various digital codes that tells the satellite what to do.
- Now a days, most satellite contain a small digital computer.
- That acts a central control unit for entire satellite.
- The computer contains a built – in ROM with a master control program.
- Master control program operates the computer and operates all other subsystem as required.

- The computer may also be used to make necessary computations and decisions.

**4) Attitude control subsystem:**
- It provides stabilization in orbit and senses the changes in orientation of satellite.
- With built-in-jet thruster it makes the necessary corrections to the attitude of satellite.
- When this subsystem senses the change in position of satellite from the desired.
- It receives signal from command and control system and that fires the appropriate thruster at proper time.

**5) Propulsion subsystem:**
- Most satellite contains propulsion subsystem in addition with attitude control subsystem.
- It is used AKM (Apogee Kick Motor) to put the satellite into final orbit.
- By using rockets that could be change the orbit of a satellite, or remove the satellite from orbit.
- This subsystem is also operated by command control subsystem.

**6) Antenna subsystem:**
- It consists one or more antennas used for receiving signals from ground station and for transmitting information back to earth.
- Most of the antennas have highly directional gain and must be accurately pointed.
- Mostly satellite contains an omnidirectional antenna.

**Q.6(e) Distinguish LED & LASER on the basis of**
**i) operating principle** **ii) Switching time**
**iii) Power consumption** **iv) Spectral width**

**(A)**

| Parameter | LED | LASER |
|---|---|---|
| Operating principle | Works on principle of spontaneous emission. | Works on principle of stimulated emission. |
| Switching time | Slow | Fast |
| Power Consumption | Less | More |
| Spectral width | Wider | Narrow |

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