Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the Figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any Equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant Values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q1)

A) Attempt any Three: **12M**

(a) Define the terms w.r.t waveguide:
(i) Cut-off frequency
(ii) Cut-off wavelength
Ans: **(each correct definition – 1 marks, formula 1 marks each)**

- **Cut-off frequency of a waveguide:**

It is the frequency of the signal above which propagation of waves occur.

$$f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

Where m & n are integers, a is broader dimension & b is narrower dimension

- **Cut-off wavelength of a waveguide:**

It is defined as the distance travelled by the wave in order to undergo a phase shift of 2π radians.

$$\lambda_g = \frac{\lambda}{\sqrt{1 + \left(\frac{\lambda}{\lambda_c}\right)^2}}$$

where λ = wavelength of the signal, λc= cut off wavelength

(b) Draw labeled sketched diagram of Reflex Klystron. Give any two application.

Ans: **(diagram – 3 marks – each applications – 1/2 mark)**

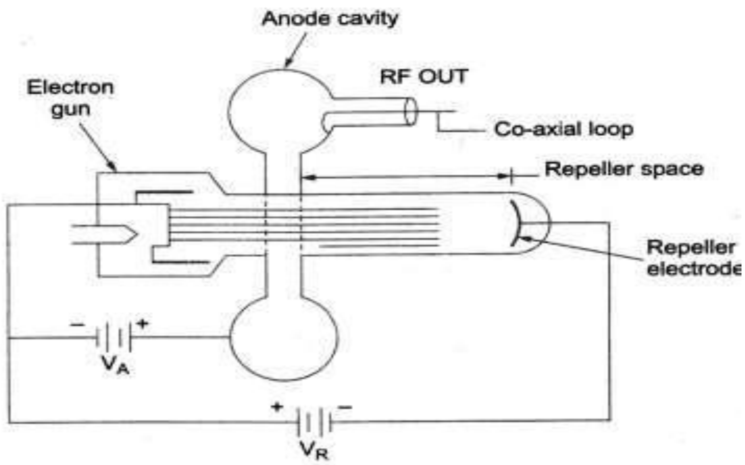


Fig. Constructional details of reflex klystron.

Applications: (any two)

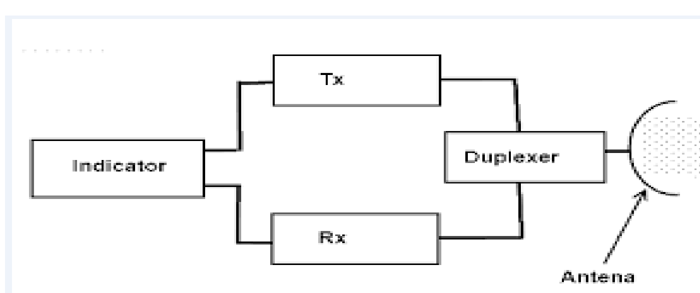
This is the most widely used in applications where variable frequency is desired as

- In radar receivers.
- Local oscillator in microwave receivers.
- Signal source in microwave generator of variable frequency.
- Portable microwave links and
- Pump oscillator in parametric amplifier.

(c) Draw block diagram of Radar system and explain it.

Ans: **(Diagram 2M, Explanation 2M)**

Diagram:



- The diagram shows basic radar system which consist of transmitter receiver and antenna which act as both transmitting and receiving antenna.
- The main function of the duplexer is to connect the transmitter to these antenna, when the pulses are to transmitted and connect the antenna to these receivers, when echo –pulses are received.
- Pulse modulated Magnetrons, Klystrons, and Travelling Wave tubes (TWT) or Crossed-field amplifier (CFA) are used as transmitter output tubes. In the receiver for first stages usually a diode mixer is used. The antenna generally uses a parabolic reflector.

- Antenna can scan continuously the scanning speed of antenna is mechanically is higher part, it is small in comparison with the time taken by pulses to return from.

(d) Define following term w.r.t to satellite:
(i) Footprint
(ii) Station Keeping

Ans: **(2M Each Definition)**

i) Foot print: The geographical representation of a satellite antenna radiation pattern is called foot print. The foot print of a satellite is the earth area that the satellite can receive from and transmitted to.

ii) Station keeping: The process of the firing the rocket underground control to maintain or adjust the orbit is referred to as station keeping. Once the satellite is in the orbit, the forces acting on it tends to keep it in place. If the satellite speed and height, during launch are accurately controlled, the satellite will entered in the proper orbit and remains there.

B) Attempt any ONE: **[6M]**

(a) Describe TE and TM modes in rectangular wave guide.

Ans: **(Describe 2M each, diagram 1 M each)**

TE stands for transverse Electric mode. Here electric Field of the signal is perpendicular to the direction of propagation through waveguide and the magnetic field component can be in the direction of propogation. It is labeled as $TE_{m,n}$ where *m* and *n* are integers denoting the number of half wavelengths of EF intensity variations along the broader and narrower dimension .

$TE_{m,0}$ Modes:

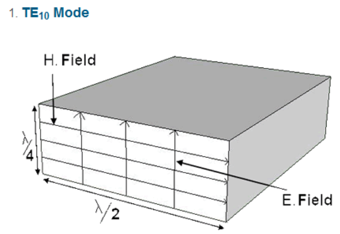
The equation of characteristic wave impedance is given by –

$$Z_0 = \frac{377}{\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}}$$

Where,

Z_0= characteristic wave impedance of the waveguide

It is seen that the different $TE_{m,0}$ modes all have different cutoff wavelengths and therefore encounter different characteristic wave impedances.



TE$_{m,n}$ Modes:

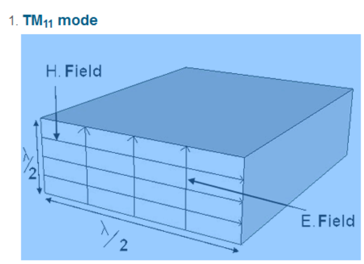
The cut-off wavelength for TE$_{m,n}$ mode is given by-

$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}$$

TM$_{m,n}$ Modes:

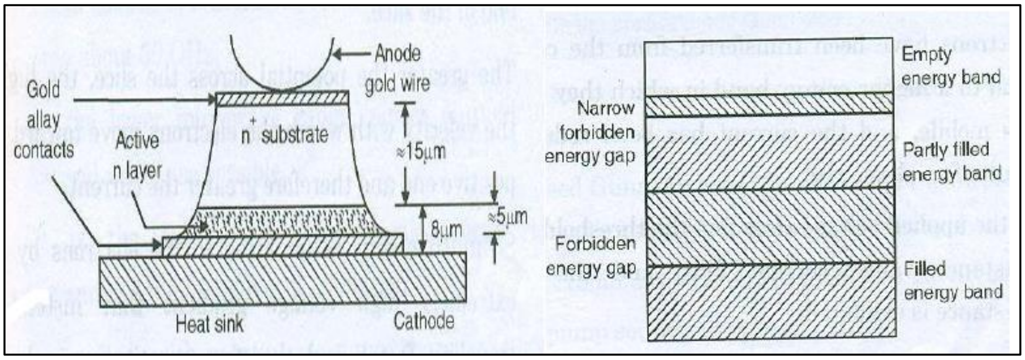
In TM modes, the magnetic field is transverse only, and the electric field has a component in the direction of propagation. Since lines of magnetic force are closed loops, if a magnetic field exists and is changing in the *x* direction, it must also exist and be changing in the *y* direction. Hence TM$_{m,0}$ modes cannot exist in rectangular waveguides. The formula for characteristic wave impedance for TM modes is,

$$Z_0 = 377\sqrt{1 - \left(\frac{\lambda}{\lambda_c}\right)^2}$$



(b) Sketch the construction of Gum diode and give its operation.

Ans: **(Diagram - 3 marks, operation – 3 marks)**



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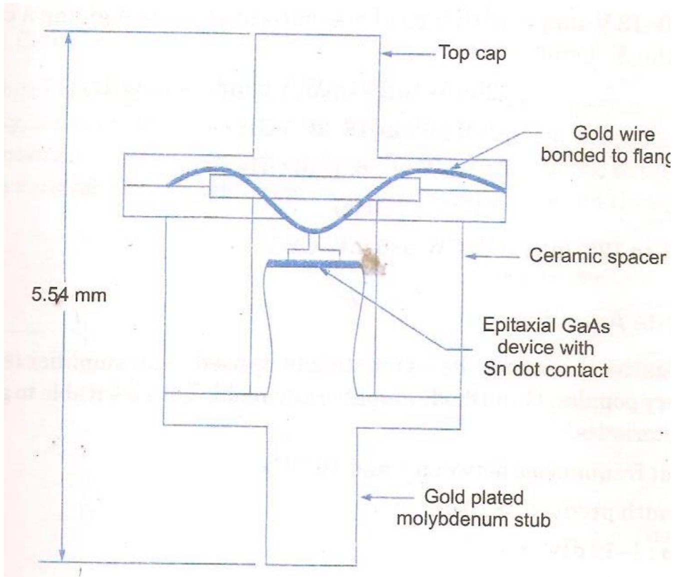


OPERATION:

- When a DC bias of value equal or more than threshold field (of about 3.3KV/cm) is applied to an n-type GaAs sample, the charge density and electric field within the sample become non- uniform creating domains
- that is electron in some region of the sample will be first to experience the inter valley transfer than the rest of the electrons in the sample. The EF inside the dip[ole domain will be greater than the fields on either side of the dipole so the electrons in that region or domain will move to upper- valley and hence with less mobility. This creates a slight deficiency of *e*-1 s in the region immediately ahead. This region of excess and efficient *e*-1 s form a dipole layer.

- As the dipole drifts along more *e*-1 s in the vicinity will be transferred to the U-valley until the electric field outside the dipole region is depress below the threshold EF. This dipole continues towards the anode until it is collected upon collector, the EF in the sample jumps immediately to its original value and next domain formation begins as soon as the field values exceeds the threshold values and this process is repeated cyclically.

Q.2. Attempt any Four: [16M]

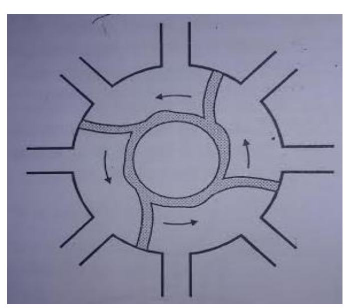
(a) Differentiate between waveguide and two-wire transmission line.

Ans: (any four correct points – 1 mark each)

SR. NO.	WAVEGUIDES	TRANSMISSION LINES
1.	It acts as a High Pass Filter	All frequencies can pass through.
2.	It is one conductor transmission system. The whole body of the waveguide acts as ground. The wave propagates through multiple reflections from the walls of waveguide (WG).	It consists of two conductors. One or both conductors are used to carry the wave.
3.	The system of propagation in waveguide is in accordance with field theory.	The system of propagation in transmission line (TL) is in accordance with circuit theory.
4.	TE and TM modes exist in WG.	TEM mode exists in TL.
5.	Wave impedance (characteristic impedance) is a function of frequency.	Characteristic impedance in TL depends on the physical parameters of TL.
6.	The velocity of propagation of wave in WG is less than the free space velocity.	The velocity of propagation of waves is equal to free space velocity.
7.	WG handles greater power and possesses less resistance.	TL handles less power as compared to WG.
8.	Lower signal attenuation at high frequencies than TL.	Significant signal attenuation at high frequencies due to conductor and dielectric losses.

(b) Describe, how bunching is formed in Magnetron-with neat diagram.
Ans: **(Diagram 2M, description 2M))**

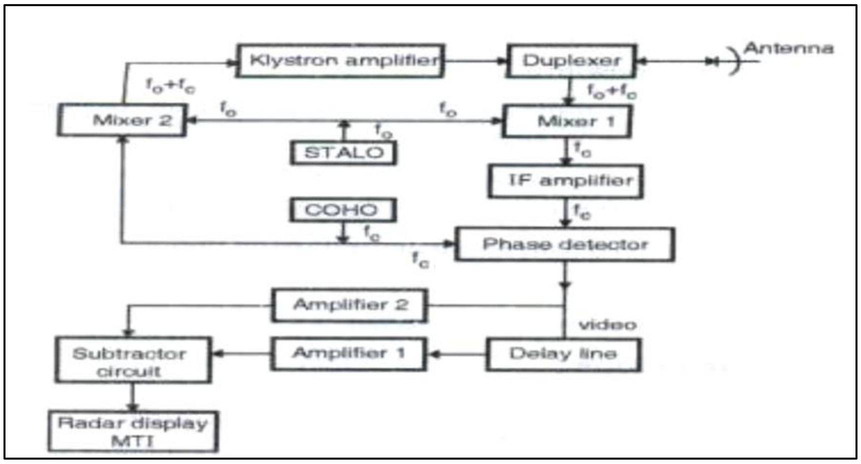
- **Bunching is formed in Magnetron** -Bunching takes place in magnetron like Klystrons which is known as phase focusing effect. This effect is useful for the favored electron to maintain the phase . Since such electron are retarded at each interaction with RF field.
- Diagram shops the wheel spoke bunches in the cavity magnetron. These bunches rotates counter clockwise with the correct velocity to keep up with RF phase changes between adjoining anode poles.



Bunching Process of Magnetron

(c) Describe working of MTI radar with neat block diagram and waveforms.

Ans: **(diagram 2M,working 1M, waveform 1M)**

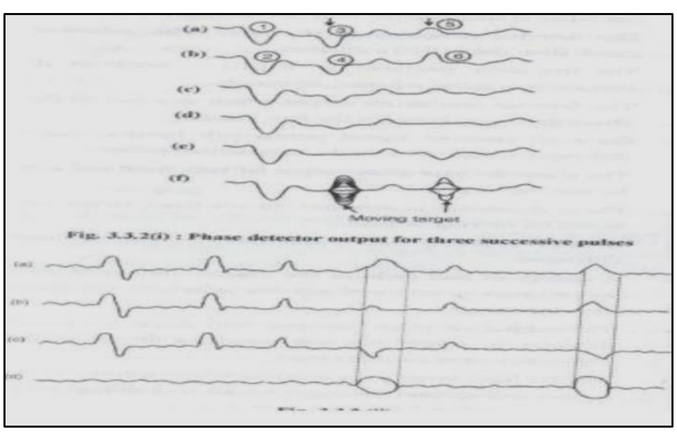


Working principle:

- It compares the present echo with the previous one. If the present and previous echo are same the target is stationary, where as if the present and previous echo are not same the target is moving target.If echo is due to moving target, the echo pulse under goes a Doppler frequency. The received echo pulses than pass through mixer 1 of the receiver. Mixer 1 heterodynes the received signal of frequency (Fo+Fc) with the output of the stalo at Fo. Mixer 1 produces a difference frequency Fc at its output. This difference frequency signal is amplified by an IF amplifier.

- Amplifies output is given to phase detector. The detector compares to IF amplifier with reference signal from the COHO oscillator. The frequency produced by COHO is same as IF frequency so called coherent frequency. The detector provides an output which depends upon the phase difference between the two signals. Since all received signal pulses will have a phase difference compared with the transmitted pulse. The phase detector gives output for both fixed and also moving targets. Phase difference is constant for all fixed targets but varies for moving targets. Doppler frequency shift causes this variation in the phase difference. A change of half cycle in Doppler shift would cause an output of opposite polarity in the phase detector output.

- The output of phase detector will have an output different in magnitude and polarity fro successive pulse in case of moving targets. And fro fixed target magnitude and polarity of output will remain the same as shown in figure.



(d) State reason for difference in uplink and downlink frequency in satellite communications.
Ans: **(2 points-2M each)**
Reasons:
- The uplink and downlink bands are separated in frequency to prevent oscillations within the satellite amplifier while simultaneously transmission and reception.
- Moreover low frequency band is used on the downlink to exploit the lower atmospheric losses thereby minimizing satellite power amplifier requirements

(e) List advantages of fiber optic cable as compare to conventional cables
Ans: **(4 points of Advantages 2M, 4 points of disadvantages 2M)**
Advantages:
- Good information carrying capacity, which depends on bandwidth of the cable and fiber optical cable have much greater bandwidth.
- Lower loss as there is less signal attenuation over long distances.
- Fiber optical cable has lightweight and small size as compared to electrical cable.
- Optical cable does not cause interface because they do not carry the signals, which cause interference.
- Fiber optical cables cannot be tapped as easily as electrical cables.
- Fiber optical cables do not carry electricity. Therefore, there is no shock hazard.
- Fiber Optical cables are stronger than electrical cables.
- Materials required for fiber optical cables are easily available.
- They are simple in construction.

Disadvantages:
1. **Interfacing Costs:**
   To be practical and useful, they must be connected to standard electronic facilities, which often require expensive interfaces.
2. **Strength:**
   Optical fibers by themselves have a significantly lower tensile strength than coaxial cable. This can be improved by coating the fiber with a protective jacket of PVC.
3. **Remote electrical power:**
   Occasionally it is necessary to provide electrical power to remote interface or regenerating equipment. This cannot be accomplished with the optical cable, so additional metallic cables must be included in the cable assembly.
4. **Optical fiber cables are more susceptible to losses introduced by bending the cable:**
   Bending the cable causes irregularities in the cable dimensions, resulting in a loss of signal power.
5. **Specialized tools, equipment and training:**
   Optical fiber cables require special tools to splice and repair cables and special test equipment to make routine measurements. Sometimes it is difficult to locate faults in optical cables because there is no electrical continuity.

(f) Describe absorption loss and scattering loss occurs in optical fiber.
Ans: **(Each loss correct explanation – 2 marks)**

Scattering loss:-
- Basically, scattering losses are caused by the interaction of light with density fluctuations within a fiber. Density changes are produced when optical fibers are manufactured.

- **Linear Scattering Losses:**

Linear scattering occurs when optical energy is transferred from the dominant mode of operation to adjacent modes. It is proportional to the input optical power injected into the dominant mode.
Linear scattering is divided into two categories: **Mie scattering** and **Rayleigh scattering.**

- **Non- Linear Scattering Losses:**

Scattering loss in a fiber also occurs due to fiber non-linearity's i.e. if the optical power at the output of the fiber does not change proportionately with the power change at the input of the fiber, the optical fiber is said to be operating in the non-linear mode. Non-Linear scattering is divided into two categories: **Stimulated Raman Scattering** and **Stimulated Brillouin Scattering.**

Absorption loss:-

Absorption loss in optical fiber is analogous to power dissipation in copper cables. Impurities in the fiber absorb light and convert it to heat. Absorption losses in optical fibers are due to three different mechanisms –

i. Absorption by atomic defects in the glass composition.
ii. Extrinsic absorption by impurities in the glass material.
iii. Intrinsic absorption by the basic constituent atoms of the fiber material.

Q.3 Attempt any Four: **[16M]**

a) State the advantages and application of circular waveguide (2 points each).

Ans: **(Advantages- 2M, Applications-2M)**

***Note:* any other relevant application and advantages can be considered**

Advantages: **(Any 2 application)**

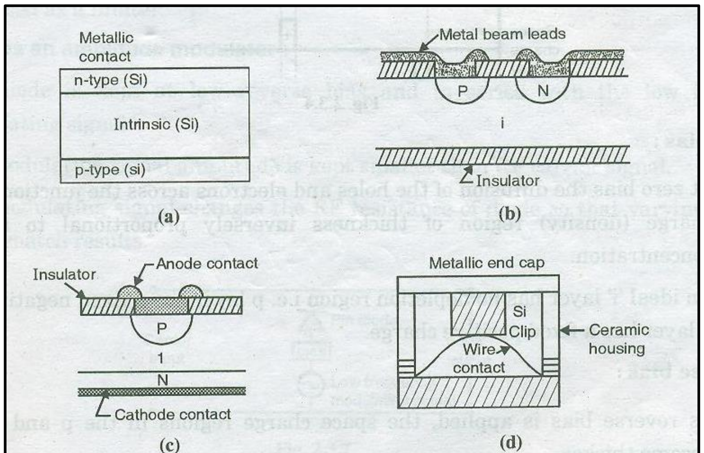
1. The circular waveguide are easier to manufacture than rectangular waveguides and are easier to join.
2. The TM01 modes are rotationally symmetrical and hence rotation of polarization can be overcome.
3. TE01 mode in circular for long distance waveguide transmission.

Applications of Circular waveguide: **(Any 2 application)**

1. It is used where the transmission or reception is in the range of microwave frequencies.
2. It is also used for handling the high power of energy.
3. It is mostly used in the airborne radar.
4. The circular waveguide is mostly used in the ground radar to transmit or receive the energy from antenna. This revolves in 360 degree bearing continuously.
5. The waveguide is also used in communication system.
6. It can also use in the devices of navigation aids.
7. The circular waveguides are also used with the cavity resonators to carry the input and output signals.

b) With neat sketch describe operation of PIN diode.

Ans: **(Operation - 2 M, Diagram - 2 M)**



: construction of PIN diode

Zero bias:

- At zero bias the diffusion of the holes and electrons across the junction causes space charge 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 charge.

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 carrier will be injected into the I layer and p and n space charge regions will become thinner.
- So the electrons and holes are injected into the i layer from p and n layers respectively.
- This increases the carrier concentration in the I layer above equilibrium.
- Thus resistivity decreases as increase in forward bias.
- Therefore low resistance is offered in the forward direction.

c) Define Radar Beacon. Give its typical usage.

Ans: **(Define- 2 M, Usage- 2M)**

Definition:

- A Radar beacon is a small radar set consisting of a receiver, a separate transmitter and an antenna which is often omnidirectional.
- When radar transmits a coded set of pulses at the beacon i.e it interrogates it, the beacon responds by sending back its specific pulse code.

Usage: **(any 2)**

Racons are used for following purpose:

- To identify aids to navigation both seaborne and land based.
- To indicate navigable spans under the bridges.
- To identify offshore oil platforms.
- To identify and warn of environmentally sensitive areas.
- To identify centers and turning points.

- To mark a uncharted hazards.
- This device is used as navigation aid, identifying landmarks
- beacon may be used to identify itself. The beacon may be installed on a target (aircraft) and will transmit a specific pulse code when interrogated these pulses then appear on the PPI of the interrogating radar and inform it of the identity of the target. The system is used in airport traffic control and also for military purpose, where it is called identification, friend or foe (IFF).

d) Explain the advantages of satellite communication (4 points)

Ans: **(Any 4 advantages 1M each)**

***Note:* Any other relevant advantage can be considered**

Broadcast property – Wide coverage area. Satellites, by virtue of their very nature, are an ideal means of transmitting information over vast geographical areas. This broadcasting property of satellites is fully exploited in point-to-multipoint networks and multipoint interactive networks. The broadcasting property is one of the major plus points of satellites over terrestrial networks, which are not so well suited for broadcasting applications.

Wide bandwidth – high transmission speeds and large transmission capacity. Over the years, satellites have offered greater transmission bandwidths and hence more transmission capacity and speeds as compared to terrestrial networks. However, with the introduction of fiber optic cables into terrestrial cable networks, they are now capable of providing transmission capabilities comparable to those of satellites.

Geographical flexibility – independence of location. Unlike terrestrial networks, satellite networks are not restricted to any particular configuration. Within their coverage area, satellite networks offer an infinite choice of routes and hence they can reach remote location shaving rudimentary or nonexistent terrestrial networks. This feature of satellite networks makes them particularly attractive to Third World countries and countries having difficult geographical terrains and unevenly distributed populations.

Easy installation of ground stations. Once the satellite has been launched, installation and maintenance of satellite Earth stations is much simpler than establishing a terrestrial infrastructure, which requires an extensive ground construction plan. This is particularly helpful in setting up temporary services. Moreover, one fault on the terrestrial communication link can put the entire link out of service, which is not the case with satellite networks.

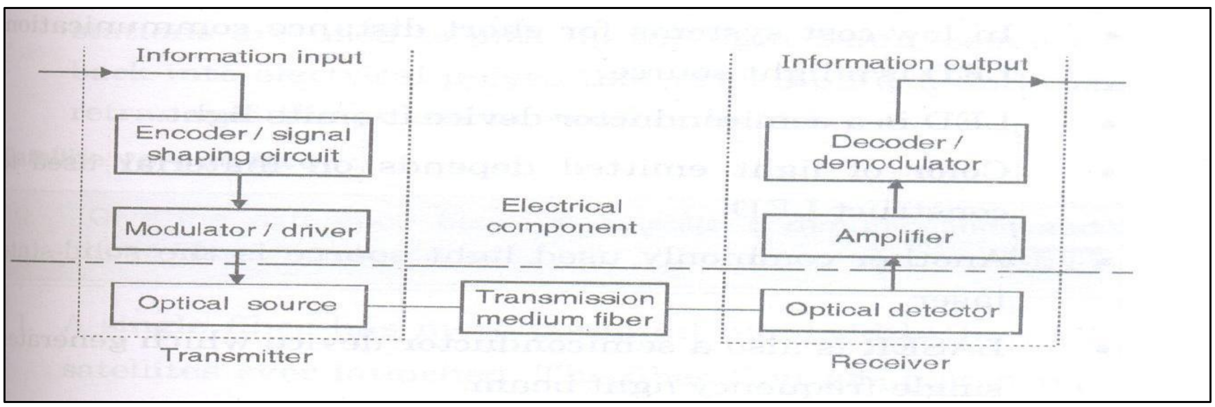
Uniform service characteristics. Satellites provide a more or less uniform service within their coverage area, better known as a 'footprint'. This overcomes some of the problems related to the fragmentation of service that result from connecting network segments from various terrestrial telecommunication operators.
Immunity to natural disaster. Satellites are more immune to natural disaster such as floods, earthquakes, storms, etc., as compared to Earth-based terrestrial networks.

Independence from terrestrial infrastructure. Satellites can render services directly to the users, without requiring a terrestrial interface. Direct-to-home television services, mobile satellite services and certain configurations of VSAT networks are examples of such services. In general, C band satellites usually require terrestrial interfaces, whereas Ku and Ka band systems need little or no terrestrial links.

Cost aspects – low cost per added site and distance insensitive costs. Satellites do not require a complex infrastructure at the ground level; hence the cost of constructing a receiving station is quite modest – more so in case of DTH and mobile receivers. Also, the cost of satellite services is independent of the length of the transmission route, unlike the terrestrial networks where the cost of building and maintaining a communication facility is directly proportional to the distances involved.

e) Draw the block diagram of Fiber Optic Cable Communication System and describe the function of each block.

Ans: **(Diagram -2M, Explanation-2M)**



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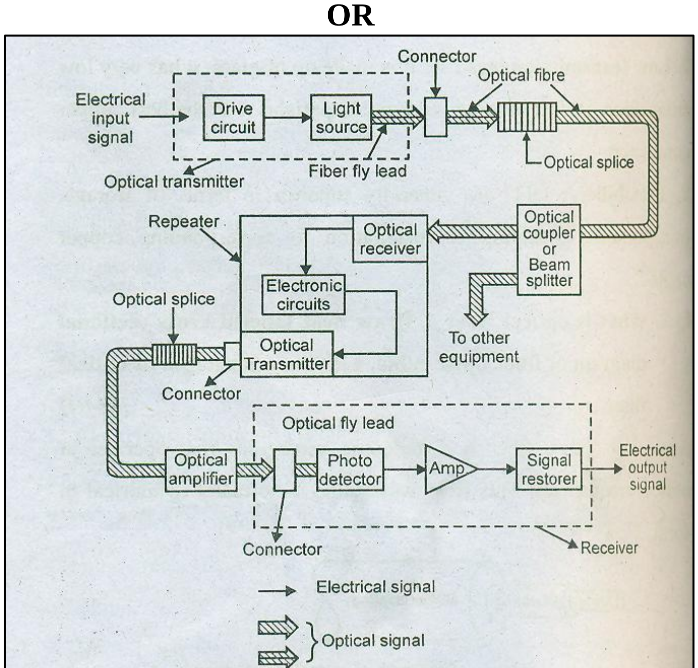


Transmitter:

1. The transmitter first converts the input voltage to current value which is used to drive the light source. Thus it interfaces the input circuit and the light source.
2. The light source is normally an infrared LED or LASER device which is driven by the current value from the V to I convertor. It emits light which is proportional to the drive current. Thus light which is proportional to the input voltage value is generated and given as input to fiber.
3. A source to fiber interface is used for coupling the light source to the fiber optic cable. The light emitted from the source is inserted into the fiber such that maximum light emitted from it is coupled to the fiber.

Optical Splice:

1. For creating long haul communication link, it is necessary to join one fiber to other fibers permanently. For this purpose, optical splicing techniques are used to join different fibers.

Optical Coupler/ Beam splitter:

1. Optical couplers are used to couple the light output from the fiber end to the device which can be receiver or regenerator.
2. Beam splitters are used to split the light beam which can be given to other equipment.

Regenerator/ Repeater:

1. After an optical signal is launched in to a fiber, it will become progressively attenuated and distorted with increasing distance because of scattering, absorption and dispersion mechanisms in the glass material.
2. Therefore repeaters are placed in between to reconstruct the original signal and again retransmit it.
3. The signal is processed in electronics domain and hence optical to electrical conversion and electrical to optical conversions are performed in the repeater.

Optical Amplifier:

1. After an optical signal has travelled a certain distance along a fiber, it becomes greatly weakened due to power loss along the fiber.
2. Therefore, when setting up an optical link, engineers formulate a power loss budget and add amplifiers or repeaters when the path loss exceeds the available power margin.
3. The periodically placed amplifiers merely give the optical signal a power boost, whereas a repeater attempts to restore the signal to its original shape.

Receiver:

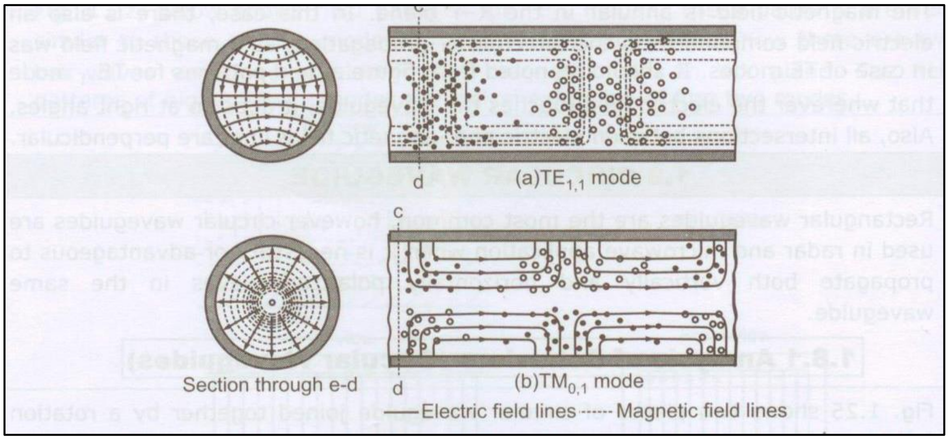
1. At the destination of an optical fiber transmission line there is a coupling device (connector) which couples the light signal to the detector.
2. Inside the receiver is a photodiode that detects the weakened and distorted optical signal emerging from the end of an optical fiber and converts it to an electrical signal. (Referred to as photo current).
3. I to V convertor produce an output voltage proportional to the current generated by the light detector. Thus, we obtain output value which was given to the system as data input.

Q4.

A) Attempt any THREE : [12 M]

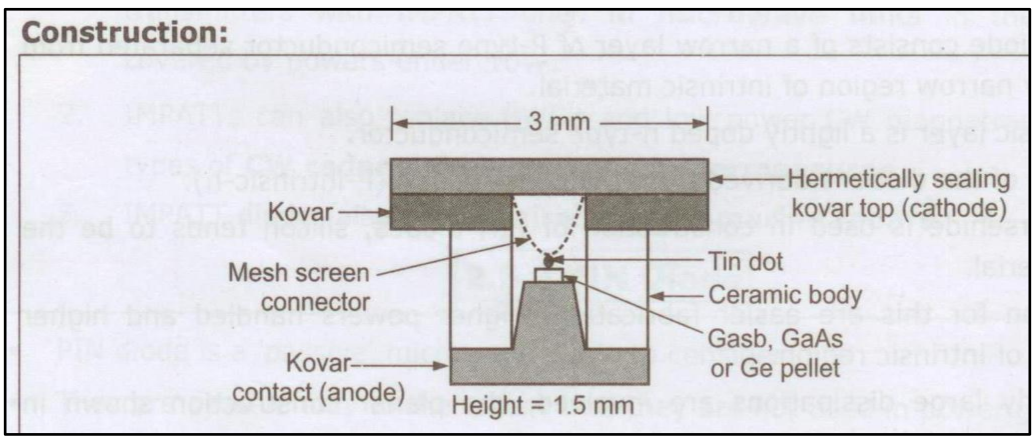
(a) Draw field pattern of circular waveguide.

Ans:



(b) Draw the construction of Tunnel diode and give its Working as microwave component.

Ans: **(Diagram- 2M, Working- 2M)**

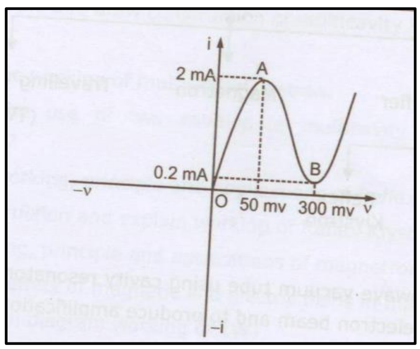


Tunnel diode

Working:

- Tunnel diode is a thin junction diode which under low forward bias conditions exhibits negative resistance useful for oscillation or amplification.
- The junction capacitance of the tunnel diode is highly dependent on the bias voltage and temperature.
- A very small tin dot about 50µm in diameter is soldered or alloyed to a heavily doped pellet of n- type Ge, GaSb or GaAs.
- The pellet is then soldered to a kovar pedestal, used for heat dissipation, which forms the anode contact.
- The cathode contact is also kovar being connected to the tin dot via a mesh screen used to reduce inductance.

- The diode has a ceramic body and hermetically sealing lid on top.
- In tunnel diode semiconductor material are very heavily doped, as much as 1000 times more than in ordinary diodes.
- This heavy doping result in a junction which has a depletion layer that is so thin (0.01μm) as to prevent tunneling to occur.
- In addition, the thinness of the junction allows microwave operation of the diode because it considerably shortens the time taken by the carriers to cross the junction.
- A current-voltage characteristics for a typical Germanium tunnel diode is shown in figure.
- Forward current rises sharply as voltage is applied.
- At point A, peak voltage occurs.
- As forward bias is increased past this point, the forward current drops and continues to drop until point B is reached, this is the valley voltage.
- At point B current starts to increase once again and does so very rapidly as bias is increases further.
- Diode exhibits dynamic negative resistance between A and B therefore, useful for oscillator applications.



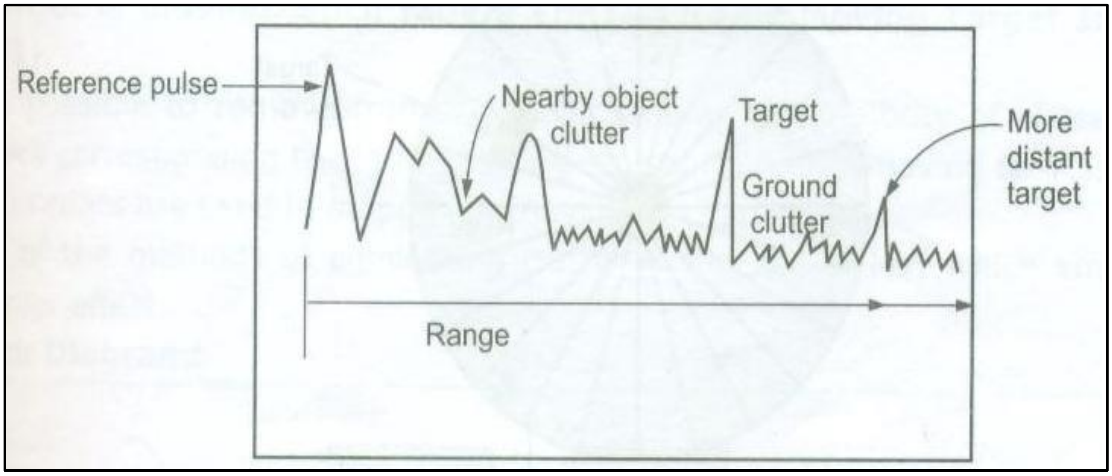
(c) Describe A scope, PPI display method with its diagram.

Ans: **(A-scope 2M and PPI- 2M)**

<u>A-scope Display:</u>

- A beam is made to scan the CRT screen horizontally by applying a linear saw tooth voltage to the horizontal deflection plates in synchronism with the transmitted pulses.
- The demodulated echo signals from the receiver is applied to the vertical deflection plates so as to cause vertical deflections from the horizontal lines.
- In the absence of any echo signal, the display is simply a horizontal line(as in a ordinary CRO)
- As indicated in the diagram, A-scope displays range v/s amplitude of the received echo signals.
- The first ‘blip’ is due to the transmitted pulse, part of which is deliberately applied to the CRT for reference. In addition to this there are blips corresponding to:

i. Ground clutter i.e., echoes from various fixed objects near the transmitter and from the ground.
ii. Grass noise i.e., an almost constant amplitude and continuous receiver noise.
iii. Actual targets. These blips are usually large.



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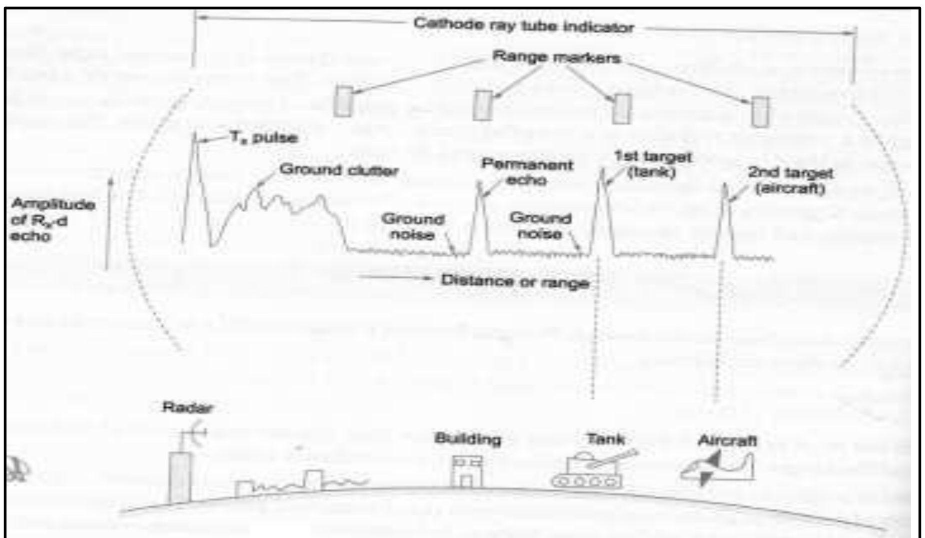


Fig. A-scope display format

Plan-Position indicator (PPI):

- This is an intensity- modulation type displays system which indicates both range and azimuth angle of the target simultaneously in polar co-ordinate as shown in figure.
- The Demodulated echo signals from the receivers is applied to the grid of the CRT which is biased slightly beyond cut-off.
- Only when Blips corresponding to the targets occur, a saw tooth current applied to a pair of coils(on opposite side of the neck of the tube) flows.
- Thus, a beam is made to deflect radially outward from the center and also continuously around the tube(mechanically) at the same angular velocity as that of the antenna.

- The brightness spot at any point on the screen indicates the presence of an objet there.
- Normally PPI screens are circular with a diameter of 30cm or 40cm. Long persistence phosphors are used to ensure that the PPI screen dose not flicker.

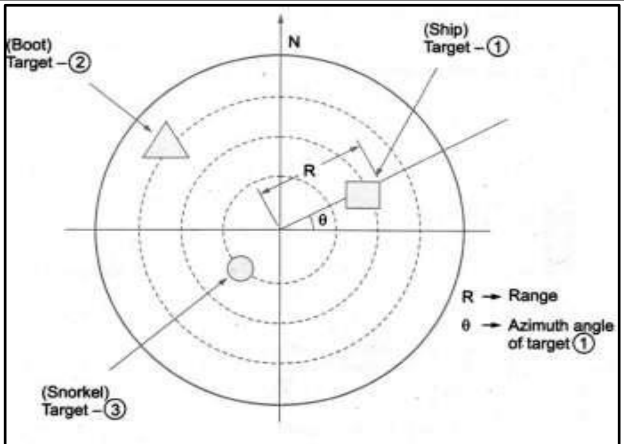


Fig. PPI display

(d) Draw block diagram of satellite subsystem and explain working of any one subsystem.
Ans: **(Diagram 3M, Any one subsystem 2M)**

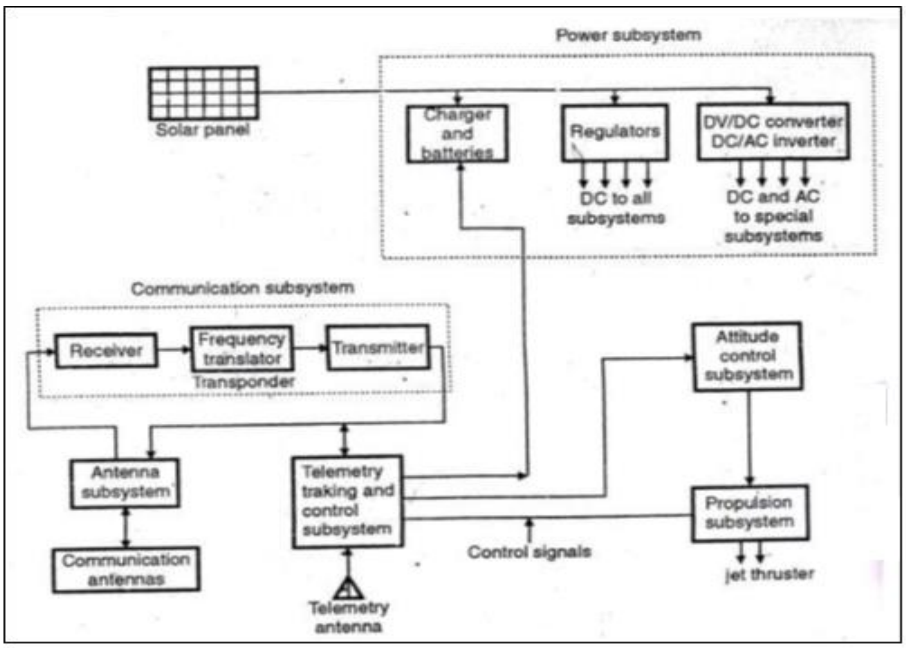


Fig. Block diagram of satellite subsystem

(1) Telemetry, Tracking and Command (TT&C) Subsystem:

- These systems are partly on the satellite and partly at the control earth station. They support the functions of the spacecraft management. The main functions of a TTC system are
- To monitor the performance of all satellite subsystems and transmit the monitored data to the satellite control center via a separate Telemetry link.
- To support the determination of orbital parameters.
- To provide a source to earth station for tracking.
- To receive commands from the control center for performing various functions of the satellite.
- Typical functions include:
- To correct the position and attitude of the satellite.
- To control the antenna pointing and communication system configuration to suit current traffic requirements.

- To operate switches on the spacecraft.

Telemetry:

- It collects data from all sensors on the satellite and send to the controlling earth station.
- The sighting device is used to maintain space craft altitudes are also monitored by telemetry.
- At a controlling earth station using computer telemetry data can be monitored and decode.
- And status of any system on satellite can be determined and can be controlled from earth station

Tracking:

- By using velocity and acceleration sensors, on spacecraft the orbital position of satellite can be detect from earth station.
- For accurate and precise result number of earth stations can be used.

OR

(2) Propulsion sub-system:

- Propulsion sub-system is the reaction control sub-system carried by the satellite in the geostationary orbit so as to generate forces on it whenever needed.
- It moves satellite to its assigned position in orbit, to maintain in that position (station keeping) and to maintain the direction of spin axis and attitude control.
- Usually propulsion subsystem has three units.
  i) Low thrust (10^{-3} to 20N) actuators (Reaction control system, RCS)
  ii) High thrust (400 to 50,000 N) motor (Apogee kick motor: AKM or Apogee Boost Motor (ABM) which provides velocity increment) to inject satellite into geostationary orbit from transfer orbit apogee.
  iii) Perigee kick motor (PKM) which provides velocity increments required to inject the satellite into the transfer orbit.
- Low thrust actuators (RCS) are of much importance as these are responsible for keeping the satellite in orbit with its perfect attitude till its life end. They are either chemical or electrical thrusters.

OR

(3) Antenna Sub-system:

- Antenna on board serves as an interface between the earth on the ground and various satellite subsystems

OR

(4) Power Subsystem:

- This system provides the necessary DC power to the satellite. All communication satellites derive their electrical power from solar cells. There is also a battery backup facility used during launch and eclipses. The batteries are of sealed Nickel Cadmium type and have good reliability and long life.

OR

(5) Communication Subsystems

- It is a major component of the communication satellite, and the remainder of the spacecraft is there solely to support it. It consists of:
  i. Microwave antennas and
  ii. As set of receiver and transmitter units referred to as Transponders
- The antenna system is used to receive signals from and transmit signals to the ground stations in the coverage area. The antenna used range from dipole type antennas where Omni directional characteristics are required to the highly directional antennas (the paraboloidal reflector being the most common) required for telecommunication purposes and TV relay and broadcast.
- The transponders amplify and retransmit the incoming signals

OR

(6) Attitude and Orbit Control System (ACOS)

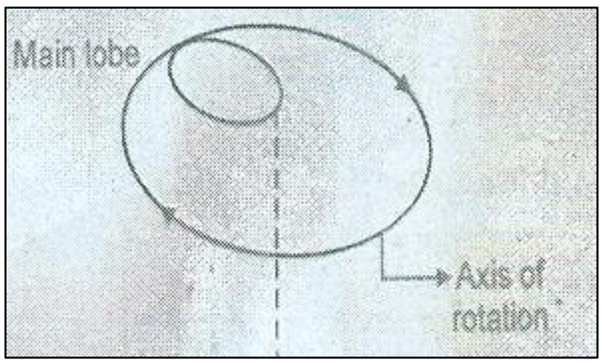
- This subsystem provides stabilization of the satellite and controls its orbit. It fires jet thrusters to perform attitude adjustments and station keeping man oeuvres that keep the satellite in its original orbital position with correct orientation.

(B) Attempt any ONE: [6 M]

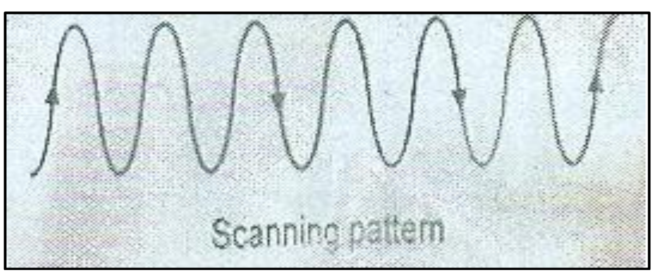
a) Explain horizontal, vertical, helical and spiral antenna scanning in radar system.

Ans: (Each Scanning 1.5M)

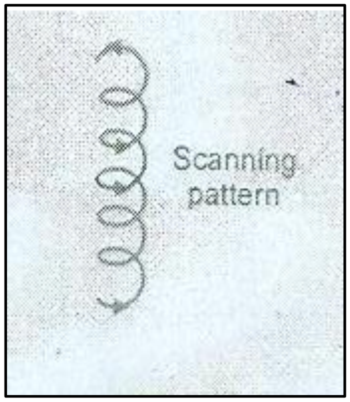
Horizontal scanning: If scanning is required in only plane is called horizontal scanning.
e.g. Ship to ship communication, navigation.



Vertical/Nodding/Elevation:
In this scanning, antenna is moved rapidly assuming in slowly in elevation. It covers limited area or complete hemisphere. Thus scanning in both the planes is obtained. Its is used to scan a limited sector.

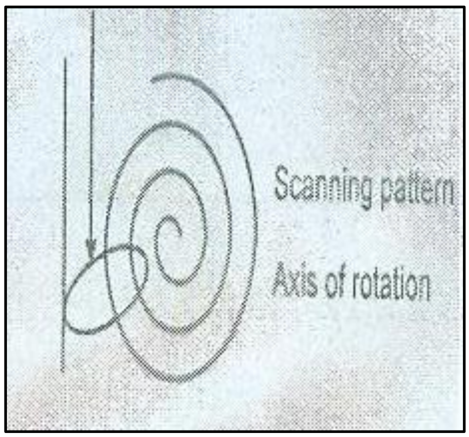


Helical:
Elevation is slowly raised while it rotates more rapidly in assuming. Covers complete hemisphere and it takes place in both plane e.g. tracking of satellite. This Scanning helps searching over the complete hemisphere. The antenna is returned to the starting point at the completion of the scanning.



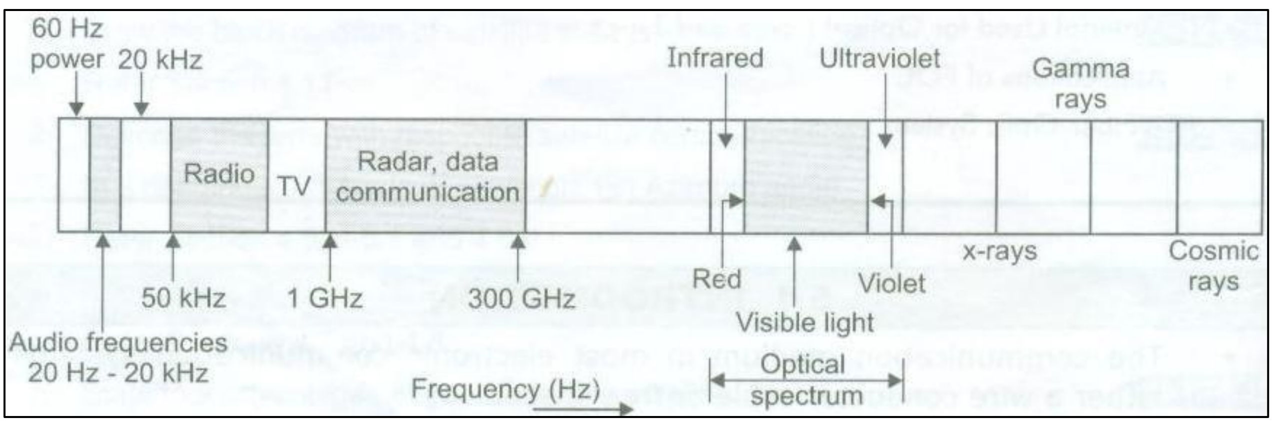
Spiral:

It is required to scan limited area. When target is to be detected, scanning take place first with somewhat wide because of width. Whereas tracking is locate at exact position of target which take place with narrow phase shift beam width.



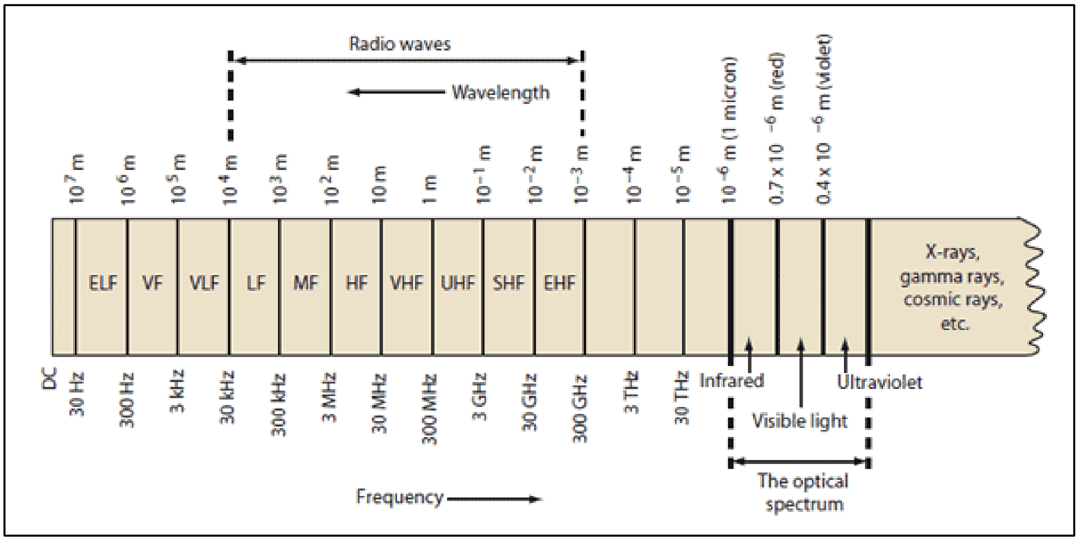
b) Draw Frequency spectrum for optical communication with band name and its range.

Ans: **[Any Relevant Correct Diagram – 6 M]**

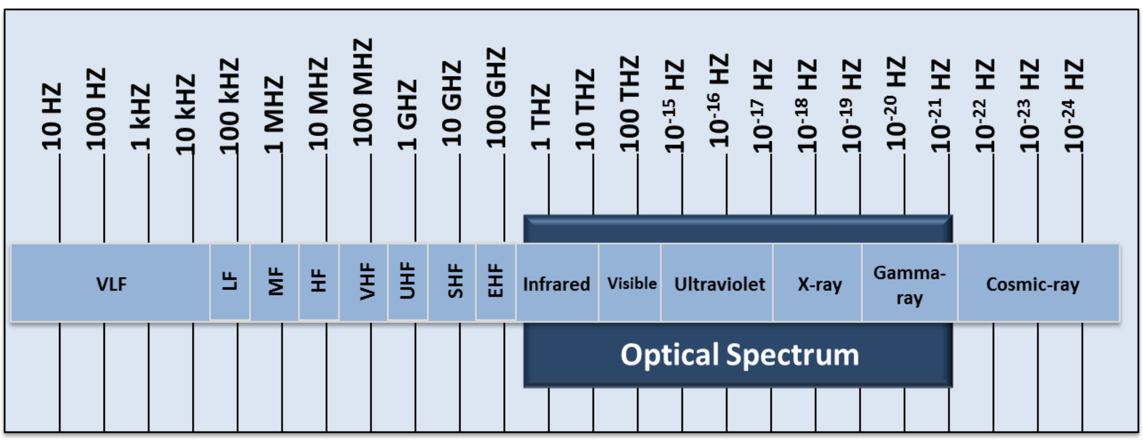


Frequency spectrum for optical communication

OR



OR



Band Name	Wavelengths
O-band	1260 – 1360 nm
E-band	1360 – 1460 nm
S-band	1460 – 1530 nm
C-band	1530 – 1565 nm
L-band	1565 – 1625 nm
U-band	1625 – 1675 nm

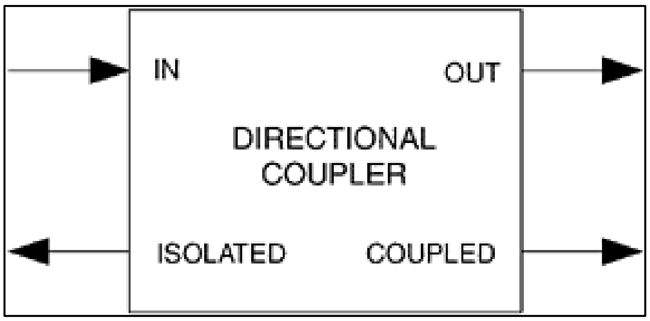
Q. 5 Attempt any FOUR: [16M]

a) Describe working of directional coupler with neat diagram.

Ans: (Diagram -2M, Working -2 M)

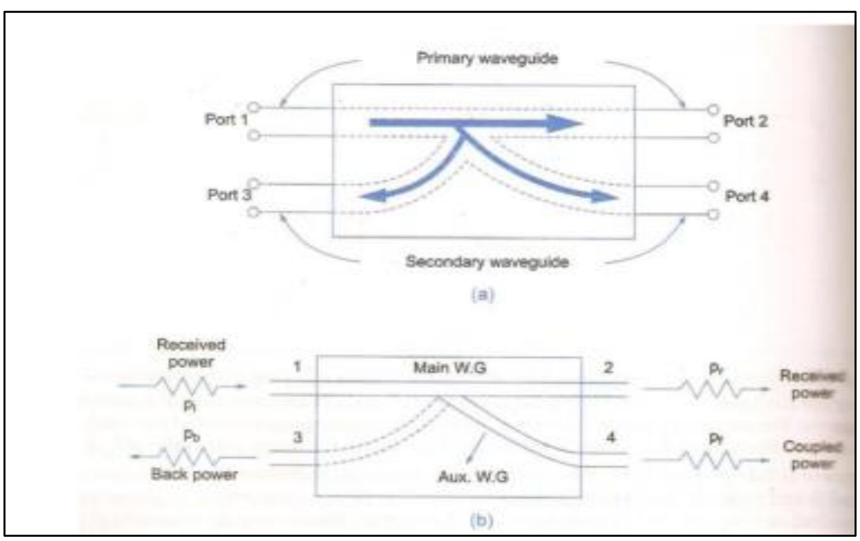
Note: any other relevant diagram can be considered

- Directional couplers are devices that will pass signal across one path while passing a much smaller signal along another path.
- One of the most common uses of the directional coupler is to sample a RF power signal either for controlling transmitter output power level or for measurement.
- An example of the latter use is to connect a digital frequency counter to the low-level port and the transmitter and antenna to the straight-through (high-power) ports.
- The circuit symbol for a directional coupler is shown in Fig. below. Note that there are three outputs and one input.
- The IN OUT path is low-loss and is the principal path between the signal source and the load. The coupled output is a sample of the forward path while the isolated showed very low signal. If the IN and OUT are reversed then the roles of the coupled and isolated ports also reversed.



OR

Directional couplers are flanged built in waveguide assemblies which can sample a small amount of microwave power for measurement purposes. They can be designed to measure incident and/or reflected powers, SWR values, provide a signal path to a Rx or perform other desirable operations. In its most common form, the directional coupler is a four port waveguide junction consisting of a primary main waveguide and a secondary auxiliary waveguide as shown below.



i. The principle of operation of a two-hole directional coupler is shown in figure above. It consists of two guides; the main and the auxiliary with two tiny holes common between them as shown.

ii. The two holes are at a distance of $\lambda_g 4$ where λ_g is the guide wavelength.

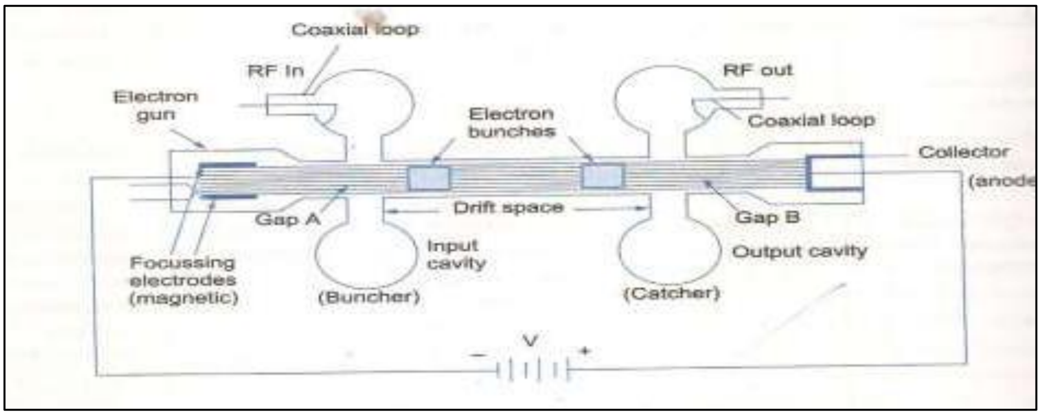
iii. The two leakages out of holes 1 and 2 both in phase at position of 2nd hole and hence they add up contributing to P_f. But the two leakages are out of phase by 180° at the position of the 1st hole and therefore they cancel each other making $P_b = 0$ (ideally).

iv. The magnitude of power coming out of the two holes depends on the dimension of the holes.

v. Although a high degree of directivity can be achieved at a fixed frequency, it is quite difficult over a band of frequencies. The frequency determines the separation of the two holes as a fraction of the wavelength.

b) Describe working of two cavity klystron Amplifier

Ans: **(Explanation-2M, Diagram 2M)**



- In the two-chamber klystron, the electron beam is injected into a resonant cavity. The electron beam, accelerated by a positive potential, is constrained to travel through a cylindrical drift tube in a straight path by an axial magnetic field.
- While passing through the first cavity, the electron beam is velocity modulated by the weak RF signal. In the moving frame of the electron beam, the velocity modulation is equivalent to a plasma oscillation.
- Plasma oscillations are rapid oscillations of the electron density in conducting media such as plasmas or metals.(The frequency only depends weakly on the wavelength). So in a quarter of one period of the plasma frequency, the velocity modulation is converted to density modulation, i.e. bunches of electrons.
- As the bunched electrons enter the second chamber they induce standing waves at the same frequency as the input signal. The signal induced in the second chamber is much stronger than that in the first. When the tube is energized, the cathode emits electrons which are focused into a beam by a low positive voltage on the control grid.
- The beam is then accelerated by a very high positive dc potential that is applied in equal amplitude to both the accelerator grid and the buncher grids. The buncher grids are connected to a cavity resonator that superimposes an ac potential on the dc voltage.
- Ac potentials are produced by oscillations within the cavity that begin spontaneously when the tube is energized. The initial oscillations are caused by random fields and circuit imbalances that are present when the circuit is energized.
- The oscillations within the cavity produce an oscillating electrostatic field between the buncher grids that is at the same frequency as the natural frequency of the cavity. The direction of the field changes with the frequency of the cavity.
- These changes alternately accelerate and decelerate the electrons of the beam passing through the

grids. The area beyond the buncher grids is called the drift space. The electrons form bunches in this area when the accelerated electrons overtake the decelerated electrons. The function of the catcher grids is to absorb energy from the electron beam.

- The catcher grids are placed along the beam at a point where the bunches are fully formed. The location is determined by the transit time of the bunches at the natural resonant frequency of the cavities (the resonant frequency of the catcher cavity is the same as the buncher cavity).
- The location is chosen because maximum energy transfer to the output (catcher) cavity occurs when the electrostatic field is of the correct polarity to slow down the electron bunches.
- The feedback path provides energy of the proper delay and phase relationship to sustain oscillations. A signal applied at the buncher grids will be amplified if the feedback path is removed.

c) Differentiate between LED and LASER.

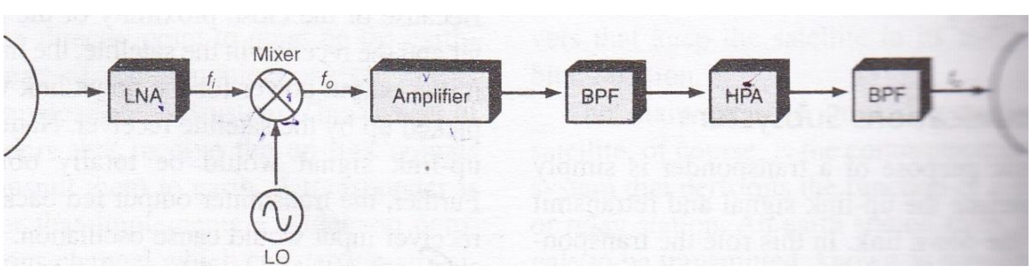
Ans: (Note: any other relevant point can be considered) (Any 4 points, 1M each)

Parameter	LED	LASER
Principle of operation	Spontaneous emission	Stimulated emission
Output Beam	Non-coherent	Coherent
Data rate	Low(max. 400Mbps)	High(several Gbps)
Coupling efficiency	Very low	High
Spectral width	20 to 100nm	1 to 5nm
Transmission distance	Smaller	Greater
Compatible with	Multimode SI/GI fiber	Single mode fiber
Circuit complexity	Simple	Complex

d) Describe the working of communication subsystem in satellite.

Ans: (Diagram -2M, Working -2 M)

1. The block diagram of single conversion transponder is shown in figure below. The term single conversion refers to the fact that only a single frequency translation process from the received signal to the transmitted signal takes place within the satellite.



2. Signals from the antenna and feed systems are first routed to the Low Noise Amplifiers (LNA).
3. The signal is very weak at this point even though it has been multiplied somewhat by the gain of the receiver antenna. The LNA should have sufficiently high gain with low noise figure.
4. After amplification, the LNA output is given to the mixer where it is mixed with a stable reference signal generated locally band output the mixer consists of sum and difference frequencies.
5. The mixer output is amplified again and fed to the band pass filter (BPF). The BPF is used to pass the difference frequency (downlink signal) and reject all others. The other function of BPF is to channelize the output i.e. only input signals on a specific frequency will be accepted by the band pass filter.
6. The output of the BPF carries the information as the input but the center frequency of the carrier is shifted to the downlink frequency.
7. Finally the downlink signal is amplified by high power amplifier (HPA) usually TWT. Each HPA is preceded by an attenuator. This is necessary to provide an input drive to each power amplifier for adjusting the desired level.
8. The final stage of HPA inherently possesses relatively high non-linearities. The non-linearities increase with the increased drive level. Therefore in multicarrier environment the final stage of the amplifier leads to inter-modulation products and harmonics.
9. Hence the output is further filtered at the channel frequencies to eliminate harmonics and inter-modulation products.
10. The resulting signal is fed to the downlink antenna. In some cases, both the receive and transmit antennas are one and the same. A duplexer is used to keep the signals separate.

e) Define w.r.t Optical fiber a) Numerical aperture b) Acceptance angle.

Ans: **[Definition with formula- 2M each]**

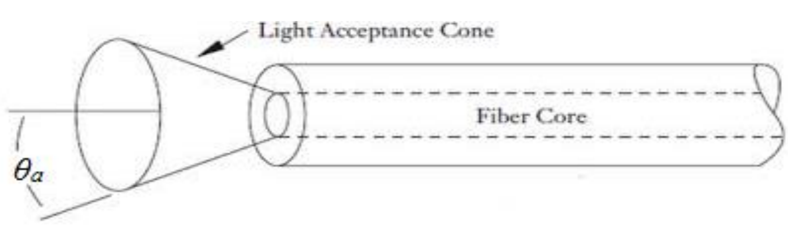
1. It is defined as the light gathering ability of an optical fiber and is given by the sine of the maximum angle a ray entering the fiber can have with the axis of the fiber and still propagate by internal reflection.

   For step index; $= sin\theta_{in} = \sqrt{\eta_1^2 - \eta_2^2}$; θ_{in} = *acceptance cone half angle*

   For graded index; $= sin\theta_c$; θ_c = *critical angle*

1. It defines the maximum angle in which external light rays may strike the air fiber interface and still propagate down the fiber.

$$\theta_a = sin^{-1}(Numerical\ Aperture)$$



f) Describe Fusion splicing, Vgroove splice, and elastic tube splice w.r.t. Fiber optic cable

Ans: **(Fusion splicing-1M, Vgroove splice-1M, elastic tube splice- 2M)**

***Note:* if diagram is drawn marks can be given**

Fusion Splice:

It is accomplished by applying localized heating i.e by a flame or an electrical arc at interference between two butted, pre aligned fiber ends.

This technique involves heating of two prepared fiber ends to their fusing point by applying sufficient axial pressure between the two optical fibers. For heating most widely source is electric arc. Following are steps for fusion process

1. PERFUSION: It is a technique, which involves the rounding of the fiber ends with a low energy discharge before pressing the fibers together.
2. By moving movable block, with proper pressure two fibers are pressed together.
3. Then there will be accomplishment of splice.

V-groove Splice:

In this technique V-grooves are used to secure the fibers to be joined. This method utilizes a V-groove into which the two prepared fiber ends are pressed. The V-groove splice ends through insertion in the groove. The splice is made permanent by securing the fibers in the V-grooves with epoxy resin.

Elastic tube splice:

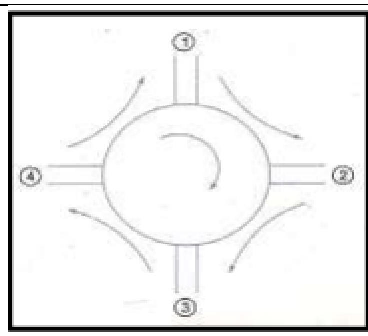
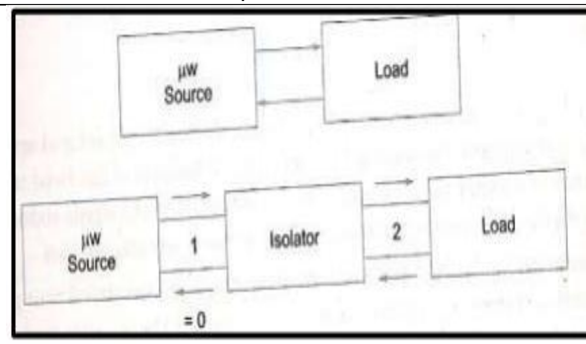
1. The elastic tube splice shown cross sectionally in the figure below is a unique device that automatically performs lateral, longitudinal and angular alignment.
2. It splices multimode fibers with losses in the same range as commercial fusion splices, but much less equipment and skill are needed.
3. The splice mechanism is basically a tube made of elastic material. The central hole diameter is slightly smaller than that of the fiber to be spliced and is tapered on each end for easy fiber insertion.
4. When the fiber is inserted, it expands the hole diameter so that the elastic material exerts a symmetrical force on the fiber.
5. This symmetry feature allows an accurate and automatic alignment of the axes of the two joined fibers.
6. A wide range of diameters can be inserted into the elastic tube. Thus the fibers to be spliced do not have to be equal in diameter, since each fiber moves into position independently relative to the tube axis.

Q6. Attempt any FOUR : [16M]

(a) Distinguish microwave circulator and isolator with the following parameters.:

i) Function
ii) Construction
iii) Application
iv) Number of ports

Ans:

Sr. No.	Parameter	Circulator	Isolator
1	Function	It has peculiar property that each terminal is connected to next clockwise terminals. That means port 1 is connected to port 2 only and not to port 3 and port4.	It uses property of faradays rotation in the ferrite material. It provides very small attenuation for transmission from port 1 to 2. But provides very high attenuation for transmission from port 2 to 1.
2	Construction		
3	Application	Circulators are used in parametric amplifiers, tunnel diode amplifiers and duplexers in radars.	Isolators are used in the output of an amplifier that is sensitive to its load conditions. In UHF or VHF transmitters. In Radio Transmitters.
4	Number of ports	Circulator is usually (more than 2) 4 port microwave device.	Isolator is a 2 port microwave device.

(b) Describe scattering and dispersion losses in optical fiber.

Ans: **(Each Loss Correct Explanation 2M)**

Scattering loss:-

Basically, scattering losses are caused by the interaction of light with density fluctuations within a fiber. Density changes are produced when optical fibers are manufactured.

- **Linear Scattering Losses:**
  - Linear scattering occurs when optical energy is transferred from the dominant mode of operation to adjacent modes. It is proportional to the input optical power injected into the dominant mode.
  - Linear scattering is divided into two categories: **Mie scattering** and **Rayleigh scattering.**

- **Non- Linear Scattering Losses:**
  - Scattering loss in a fiber also occurs due to fiber non-linearity's i.e. if the optical power at the output of the fiber does not change proportionately with the power change at the input of the fiber, the optical fiber is said to be operating in the non-linear mode. Non-Linear scattering is divided into two categories: **Stimulated Raman Scattering** and **Stimulated Brillouin Scattering.**

Dispersion loss:

- Dispersion is a measure of the temporal spreading that occurs when a light pulse propagates through an optical fiber. Dispersion is sometimes referred to as delay distortion in the sense that the propagation time delay causes the pulse to broaden.

- The broadened pulse overlaps with its neighbors eventually becoming indistinguishable at the receiver input. This effect is known as inter-symbol interference (ISI).
- The signal dispersion alone limits the maximum possible bandwidth or the data rate attainable with a particular optical fiber.
- Three mechanisms are responsible for the pulse broadening in fibers:
- modal (or mode) dispersion, material dispersion and waveguide dispersion. Modal dispersion is referred to as intermodal dispersion. The combination of material and waveguide dispersion is often called as intra-modal or chromatic dispersion because both are dependent on wavelength.

(c) Distinguish between splicing and connectors of fiber optic cable.

Ans: **(Any 4 Relevant Point– 1M each)**

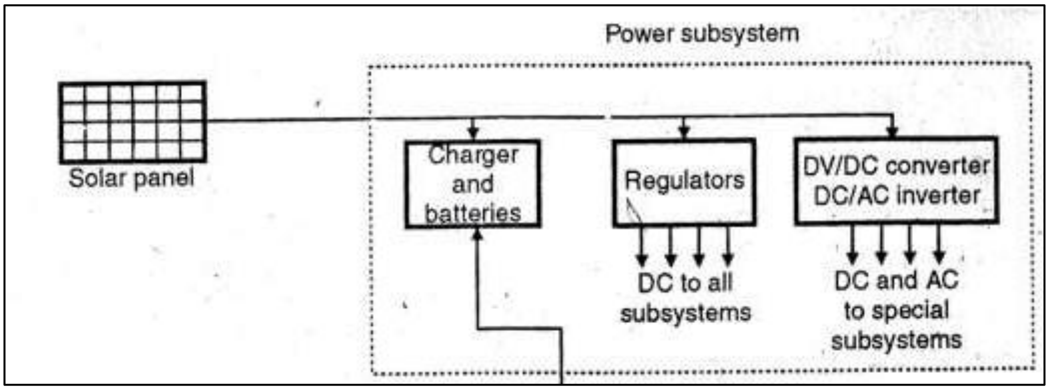
Sr.No.	Parameter	Splicing	Connector
1.	Connection	Splicing provide permanent connections.	Connector provide temporary connections.
2.	Losses	Lower loss & these losses depend on parameters such as input power distribution at the joint, the geometrical and waveguide characteristics of the two fiber ends at the joint and the fiber end face qualities.	Higher loss depends on type of connector.
3.	Size	Smaller size	Larger size
4.	Immune	Immune to environmental effects.	Conditions such as temperature, dust and moisture should have a small effect on connector loss variations.
5.	Interfacing	Between fibre and fibre.	Between Light source and fibre & fibre and Photodiodes.
6	Ease of connection	Skilled person is required	Easily handled.
7.	Types	Few Types e.g. Fusion splicing, Mechanical splicing	Many Types e.g. ST, SC FDDI, MTP, SFF, LC, RJ-45 etc.

(d) How power is generated in satellite? Describe how it is distributed to other subsystem of satellite.
Ans:

How power is generated in satellite **1 M**

- Today every satellite uses solar panels for its basic power source. Individual solar cells can generate only small amount of DC power (by converting incident sunlight into electrical energy). So these solar panels are large arrays of photocells connected in various series and parallel circuits to create a powerful source of direct current. The key requirement of the solar panels is to always point towards the sun.

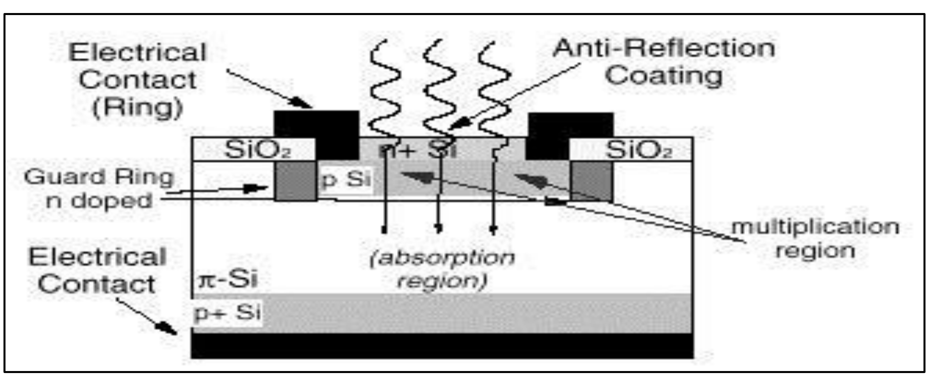
A key component of the satellite is its power subsystem for power distribution to all subsystem. The figure shows the block diagram of power subsystem with its power distribution. **3 M**



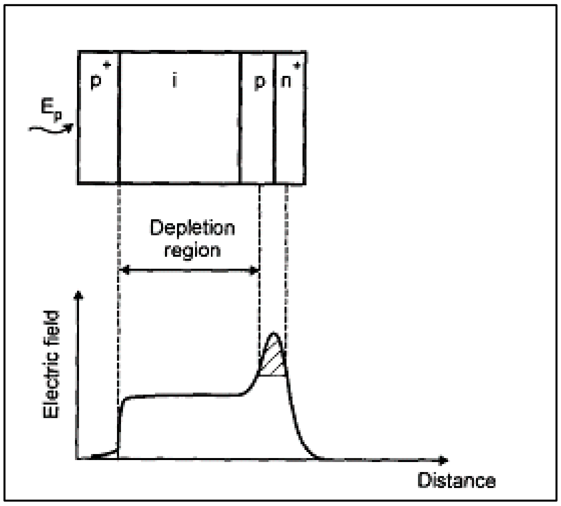
- Everything on board operates electrically. Most satellites therefore depend entirely upon their power supplies for success. The function of the power subsystem is to provide DC power to all subsystems throughout the life of the spacecraft.
- The basic DC voltage from the solar panels is then conditioned in various ways –
  It is typically passed through voltage regulators before being used to power individual electronic circuits. Most electronic equipment works best with fixed stable voltages and therefore regulators are incorporated in most satellite systems.
- Some parts of the satellite require higher voltage than those produced by the solar panels. The TWT amplifiers in most communication transponders require thousands of volts for proper operation. Special DC to DC converters are used to translate the lower DC voltage of the solar panels to the higher DC voltage required by the TWTs.
- Some circuits of the satellite require Ac voltage so inverters (DC to AC) are used to generate AC voltage.

(e) Describe working and principle of avalanche photodiode with a neat sketch.

Ans: **(Diagram-2M, Explanation-2M)**



OR



Working Principle:

- The RAPD is operated in the fully depleted mode. Photons enter the device through the p^+ region and are mostly absorbed by the high resistivity intrinsic p type layer where electron hole pairs are created.
- The relatively weak electric field in this region forces or separates the carriers causing the electrons and holes to drift into the high electric field region.
- The electrons are drifted towards the $p\text{-}n^+$ layer. Because of the high field intensity, electrons are imparted with high kinetic energy.
- The kinetic energy of electrons is greater than bandgap energy of the valence electrons, so the collision can free a bound electron.
- The free electron and hole so created acquire enough kinetic energy to cause further ionization. It results in avalanche with the number of carriers growing exponentially as the process continues.