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 judgement 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.

Q.1 Attempt any FIVE. 20 M

(a) List any 4 microwave frequency bands with their frequency range and give two applications of each.

Ans: Listing of any FOUR microwave frequency bands: (1 Mark each)

BAND DESIGNATION	FREQUENCY RANGE	APPLICATIONS
L	1 to 2 GHZ	Military telemetry, GPS, mobile phones (GSM), amateur radio
S	2 to 4 GHZ	Weather radar, surface ship radar, microwave ovens, radio astronomy, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS
C	4 to 8 GHZ	Long distance radio telecommunications
X	8 to 12 GHZ	Satellite communication, astronomical observation, radars
Ku	12 to 18 GHZ	Satellite communication
K	18 to 27 GHZ	Radar, satellite communication
Ka	27 to 40 GHZ	Satellite communication
Q	33 to 50 GHz	Satellite communications, terrestrial microwave communications and for radio astronomy studies, automotive radar, and radar investigating the properties of the Earth's surface
V	40 to 75 GHZ	Millimeter wave radar research, high capacity terrestrial millimeter wave communications systems
W	75 to 110 GHz	Satellite communications, millimeter-wave radar research, military radar targeting and tracking applications, and some non-military applications.

(b) Draw schematic of reflex klystron and describe its function as amplifier.

Ans: **(2 Marks for schematic diagram & 2 Marks for function as a oscillator)**

Diagram:

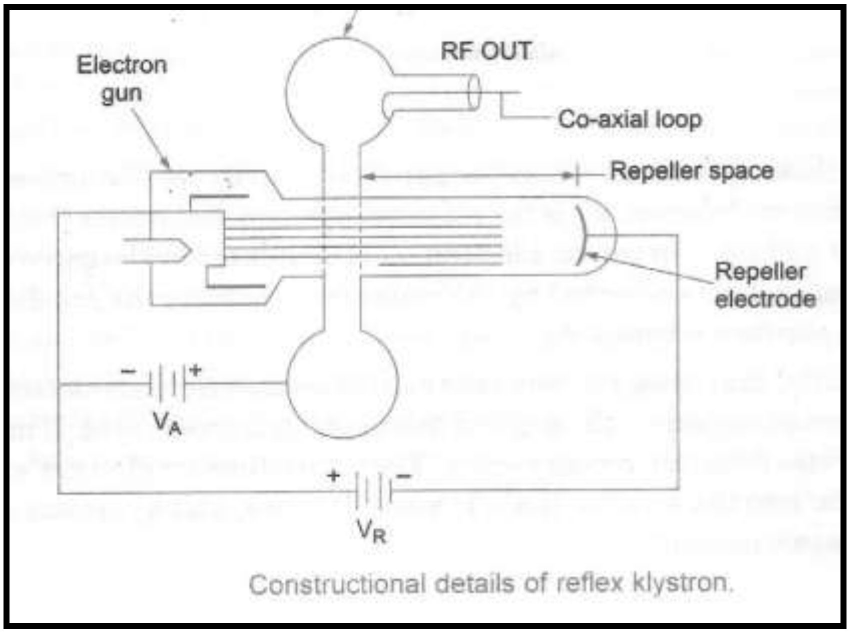


Fig. Reflex klystron

Function:

The reflex klystron is a single cavity variable frequency microwave generator/oscillator.

1. It is assumed that the oscillations are set up in the tube initially due to noise or switching transients and these oscillations are sustained by device operation.
2. The RF voltage that is produced across the gap by the cavity oscillations act on the electron beam to cause velocity modulation. The reference electron e_R is taken as the one that passes the gap on its way to the repeller at the time when the gap voltage is zero and going negative. This electron is unaffected, overshoots the gap and is ultimately returned to it having penetrated some distance into the repeller space.
3. The early electron e_e that passes the gap before the reference electron, experiences a positive voltage at the gap. This electron is accelerated and moves with greater velocity and penetrates deep into repeller space. This electron will take slightly greater time than the reference electron to return to the gap.
4. The late electron e_l that passes through the gap later than reference electron experiences negative voltage at the gap. This electron is retarted and shortens its stay in the repeller space and will return earlier to the gap as compared to the reference electron. So, the late electron will be able to catch up with e_e and e_R electrons forming the bunch.
5. Bunches occur once per cycle centred on the reference electron. These bunches transfer maximum energy to the gap to get sustained oscillations.

(c) With the help of neat sketch, describe construction of GUNN diode.

Ans: (2 Marks for sketch & 2 Marks for construction)

<u>Diagram</u>:

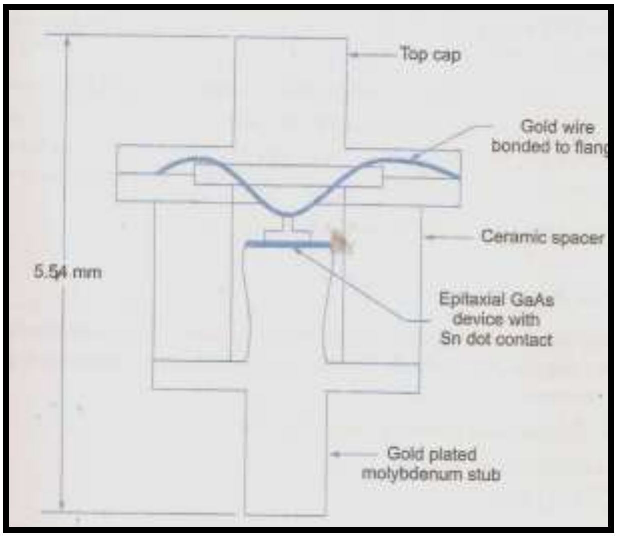


Fig. Construction of GUNN diode

<u>OR</u>

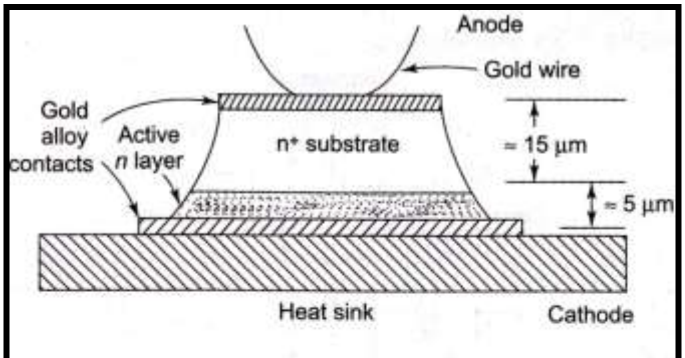


Fig. *Epitaxial GaAs Gunn slice.*

<u>Construction of GUNN diode</u>:

1. The Gunn diode is the transferred electron device. It has the bulk property.
2. The fabrication of the diode requires extremely pure and uniform semiconductor material like Cadmium telluride, Indium arsenide, indium phosphide, gallium arsenide, etc.
3. Gunn diodes are grown epitaxially out of a GaAs or InP doped with Si, tellurium or selenium.
4. The substrate used as an ohmic contact is highly doped for good conductivity. The active layer is this and less heavily doped.
5. The gold alloy contacts are electro-deposited and used for good ohmic contact and heat transfer for subsequent dissipation.

(d) List any 4 factors influencing maximum range of radar.

Ans: <u>Factors influencing maximum range of radar</u>: (1 marks each)

1. Transmitter Power:

In case the radar range is to be doubled, we have to increase the transmitter power 16 times since Rmax α $(P_t)^{1/4}$

2. Minimum Detectable Signal:

Rmax α $(1/S_{min})^{1/4}$; thus redusing S_{min}, the receiver has to be very sensitive and gain of the R_x should be high. But R_x is more susceptible to interference as it now amplifier weak signals rather than amplifying low power received signals.

3. Frequency and Effective Area of Antenna:

Rmax α $1/\sqrt{\lambda}$ or Rmax α $\sqrt{f}$ ($\because \lambda$=c/f).this implies that increase in frequency increases the range. But, in a parabolic antenna, the beamwidth is given by λ/D where D is the diameter of the parabola. If λ is reduced, beamwidth becomes very narrow which reduces the tracking range of the radar. This is particularly is in case of a search radar where the sweep of the antenna that covers a portion of the sky will require a longer time. If the lobe beam width is very narrow. Thus, radar frequency cannot be increased far too much as the radar becomes ineffective although range may increase.

Also, R_{max} α $\sqrt{Ae}$. Hence, range can be increased if effective area of antenna is increased. In order to increase effective area diameter D of parabolic antenna must be increased ,which in turn reduces the beamwidth.

4. Target cross sectional area(σ):

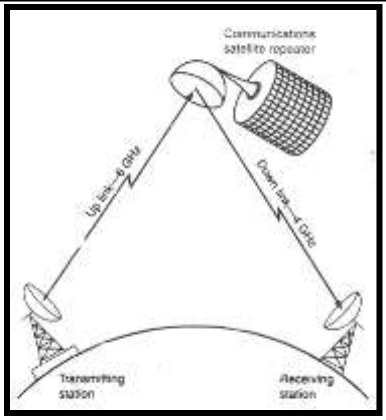
The radar cross section of a target is the area of the target as seen by a radar. The radar cross sectional area of the target is not a controller factor.

(e) Define the terms: Uplink and downlink frequencies with respect to satellite communication.

Ans: <u>Definition</u>: (2 Marks each)

Uplink frequency:
The frequency at which the earth station transmitter beams its signal towards the satellite is known **as uplink frequency.**

Downlink frequency:
The frequency at which the satellite transponder beams its signal to the earth station receiver is called **as downlink frequency.**



(f) Explain the term: Cut off frequency with respect to wave guide.

Ans: (2 Marks for definition and 2 Marks for formulae)

Definition:

The cut-off wavelength is the free space wavelength at which signal is just unable to propagate in the waveguide.

OR

The cut-off wavelength is defined as the smallest free-space wavelength that is just unable to propagate in the waveguide.

Mathematically it is given by,

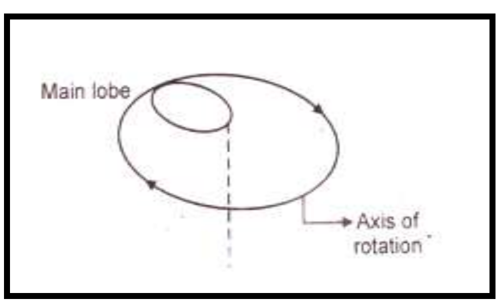
Formulae:

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

(g) Describe any two antenna scanning methods used in radar with neat sketches of scanning patterns.

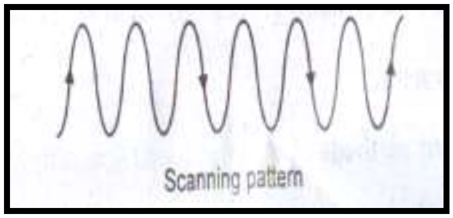
Ans: 1. Horizontal Scan Pattern:

This has the drawback of scanning in the horizontal plane as shown in fig. but, this type of scanning is useful in searching the horizon. E.g. ship to ship radar.



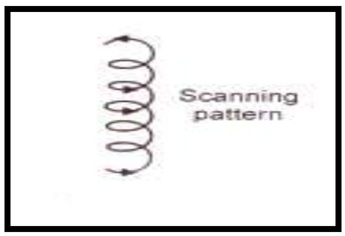
2. **Elevation/Vertical/Nodding scan Pattern:**

Nodding scan is an extension of horizontal scanning. The antenna now moves rapidly in elevation while it rotates more slowly in azimuth as shown in fig. thus scanning in both planes is obtained.



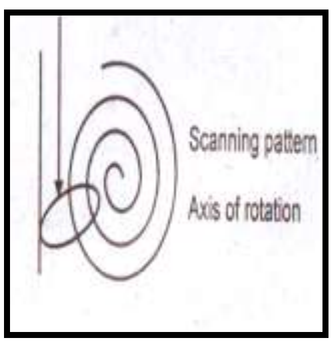
3. **Helical Scanning:**

This scanning helps searching over the complete hemisphere as shown in fig. here the elevation of the antenna is raised slowly while it is rotated more rapidly in azimuth. The antenna is returned to the starting point at the completion of the scanning cycle.



4. **Spiral Scanning:**

If limited area of more or less circular shape is to be covered, spiral scan may be used as shown in fig. the area to be covered may be in horizontal plane or vertical plane. The separation between adjacent sweep does not exceed half the width of the beam. This insures that the search embraces all possible directions in space.



Q.2 Attempt any FOUR: 16 M

(a) Compare wave guide with 2 wire transmission lines.

Ans:

Comparison:- **4M**

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) With neat schematic explain operation of two cavity klystron amplifier.

Ans: (2 Marks for schematic diagram & 2 Marks for operation)

Diagram:

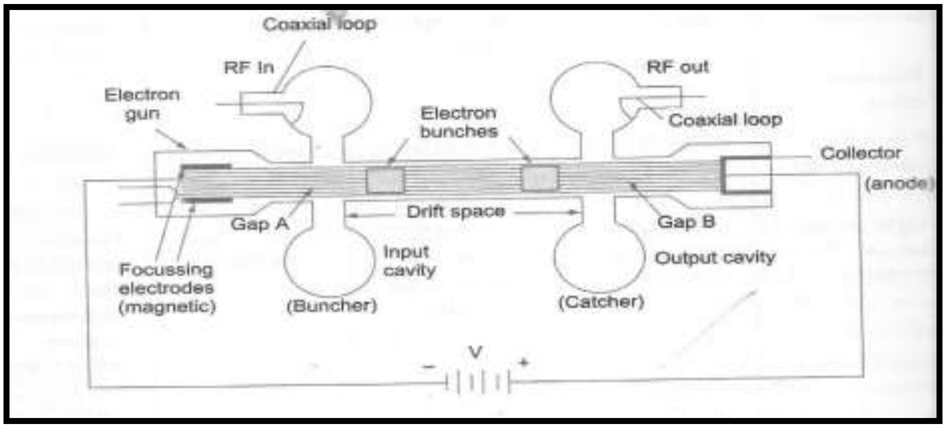


Figure: Two cavity Klystron amplifier

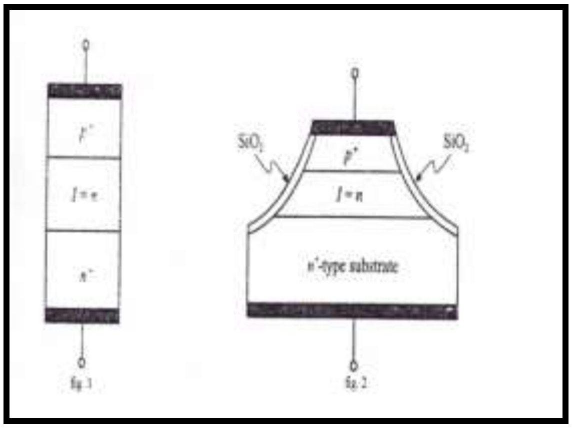
Operation:

1. The RF signal to be amplified is used for exciting the input buncher cavity thereby developing an alternating voltage of signal frequency across gap A.
2. Consider the effect of this gap voltage on the electron beam passing through gap A by means of an Applegate diagram. At point B on the input RF cycle, the alternating voltage is zero and going positive.
3. At this instant, the EF across the gap A is zero and an electron which passes through the gap A at this instant is unaffected by the RF signal.
4. Let us consider this electron be called the reference electron $e_R$which travels with unchanged velocity $v_0 = \sqrt{\frac{2eV}{m}}$ where V is the anode to cathode voltage.
5. At point C of the input RF cycle, an electron which leaves the gap A later than the reference electron called the late electron $e_l$is subjected to maximum positive RF voltage and hence travels towards gap B with an increased velocity ($v>v_0$) and this electron tries to overtake the reference electron e_R.
6. Similarly an early electron e_e that passes the gap A slightly before the reference electron e_R is subjected to a maximum negative voltage field. Hence, this early electron is decelerated and travels with a reduced velocity. This electron falls back and the reference electron catches up with the early electron.
7. Therefore, the velocity of electron varies in accordance with the input RF voltage resulting in velocity modulation of the electron beam. As a result of these actions, the electrons in the bunching limit (between A and C) gradually bunch together as they travel down the drift space from gap A to gap B and excite oscillations in the output cavity (catcher).
8. The density of electrons passing gap B vary cyclically with time i.e. the electron beam contains an ac current and is current modulated.
9. The drift space coverts the velocity modulation into current modulation
10. Bunching occurs only once per cycle, centered on the reference electron.

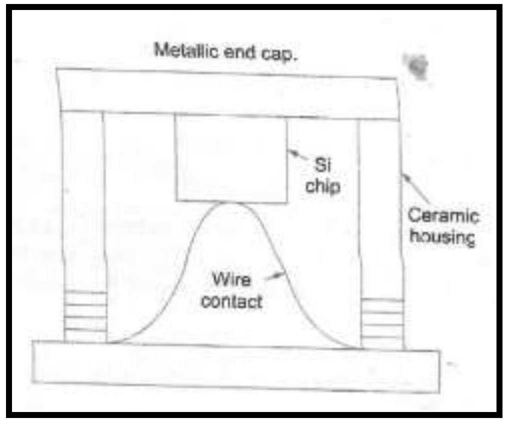
(c) Draw neat sketches & explain working of PIN diode as an microwave component.

Ans: (2 Marks for schematic diagram & 2 Marks for working)

Diagram:



OR

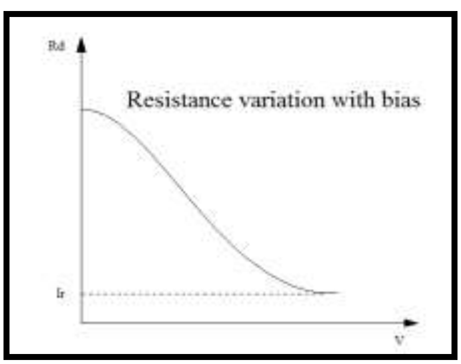


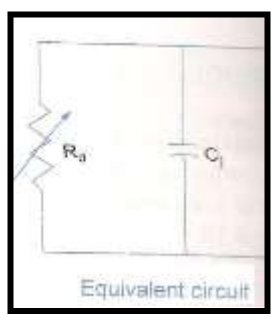
Working:

The PIN diode has following modes of operation:

1. Forward biased:

1. When the diode is forward biased, it behaves as if it possesses a variable resistance controlled by the applied current.
2. When a PIN diode is forward biased, holes and electrons are injected from the P and N regions into the I-region.
3. This results in the carrier concentration in the I layer becoming raised above equilibrium levels and the resistivity drops as forward bias is increased. Thu low resistance is offered in the forward direction.





4. The high-frequency resistance is inversely proportional to the DC bias voltage applied to the diode. A PIN diode, suitably biased, therefore acts as a variable resistor. This high-frequency resistance may vary over a wide range from 0.1Ω to 10 kΩ.

2. Reverse biased:

When the diode is reversed biased the space charge regions in the p and n layers will become thicker. The reverse resistance will be very high and almost constant.

3. 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. The diode has high impedance.

(d) Define radar beacons. Describe their typical usage.

Ans: (2Marks Definition & 2 Marks for Typical usage)

Definition:

A radar beacon is small radar consisting of a receiver, a separate transmitter and an antenna which is often Omni-directional.

Typical usage of radar beacons:

i) One of the functions of a beacon may be 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).

ii) Another use is similar to that of lighthouses, except that radar beacons can operate over much larger distances.

(e) Describe station keeping in satellite communication system.

Ans:

Explanation: **4M**

i. Once a satellite is in orbit, the forces acting on it tend to keep it in place. If the satellite's height and speed during launch are accurately controlled, the satellite will enter the proper orbit and remain there. However, even with a very good launch, the satellite will drift somewhat in its orbit. This drift is particularly undesirable in a geosynchronous satellite whose position is supposed to remain fixed for reliable continuous communications.

ii. Because of this drift, the orbits of the satellite contain small rockets or thruster jets for that purpose. These rockets placed at various positions on the satellite, can be used to speed up or slow down the satellite for the purpose of compensating for orbital drift.

iii. The process of firing the rockets underground control to maintain or adjust the orbit is referred to as station keeping.

(f) Describe the function of isolator with neat schematic diagram. Give any 2 application of isolator.

(2 Marks for schematic diagram,1 Marks for function & 1 Marks for application)

Ans:

Function:

An isolator is a 2 port device which provides very small amount of attenuation for transmission from port 1 to port 2 but provides maximum attenuation for transmission from port 2 to port 1. This is very desirable when we want to match a source with a variable load.

When an isolator is inserted between the microwave generator and the load, generator is coupled to the load with zero attenuation and reflections if any from the load side are completely absorbed by the isolator without affecting generator output.

Diagram :

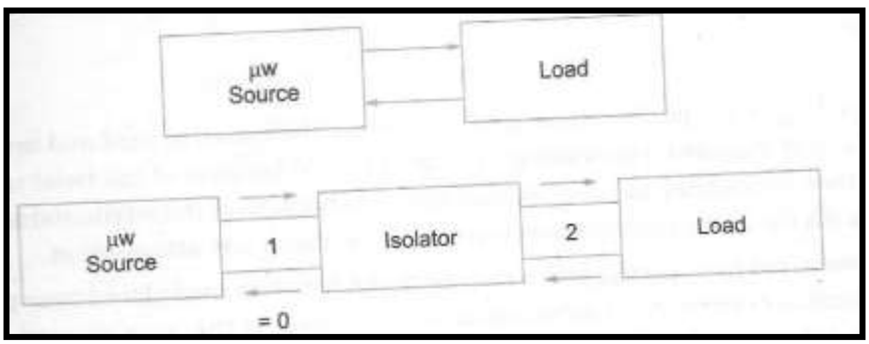


Figure: Isolator

Application of isolator:

1. It is used between the microwave generator and the load to control SWR.
2. It is used in Microwave Test Bench.

Q3. Attempt any TWO: 16M

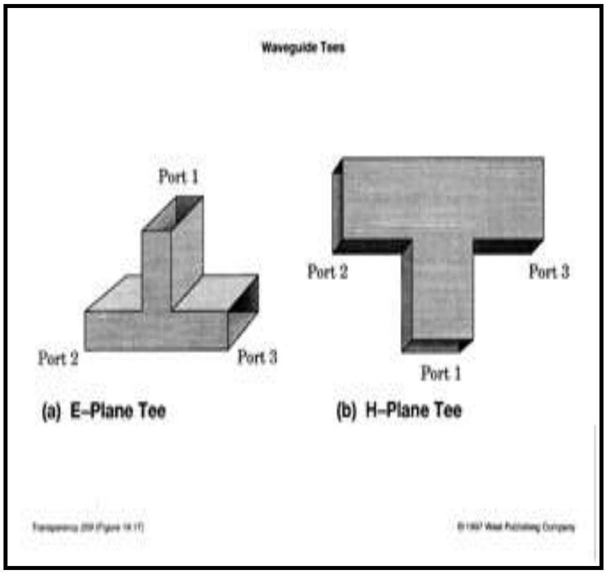
(a) (i) Describe the Function of E and H plane junction with diagram.

Ans: (Diagram 2Marks, Explanation 2 Marks any other sketches taken in consideration)

E PLANE TEE

E - Plane tee are series type T - junction and consists of three section of wave guide joined together in order to divide or compare power levels. The signal entering the first port of this T - junction will be equally dividing at second and third ports of the same magnitude but in opp. phase

Diagram:



OR

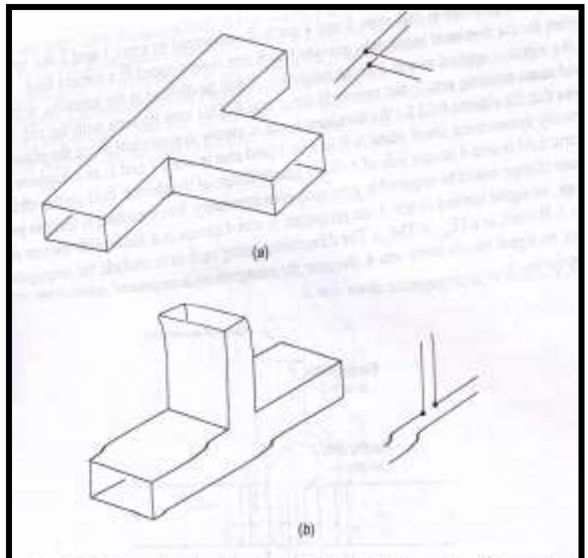


Fig. T junctions (tees) and their equivalent circuits, (a) H-plane tee; (b) E- plane tee.

Fig.(a)E-Plane Tee (b)H-Plane Tee

H - PLANT TEE

H - Plane Tee is shunt type T - junction for use in conjunction with VSWR meters, frequency - meters and other detector devices. Like in E-plane tee, the signal fed through first port of H - plane Tee will be equally divided in magnitude at second and third ports but in same phase

E - H Tee

This consists of a section of wave guide in both series and shunt wave guide arms, mounted at the exact midpoint of main arm. Both ends of the section of wave guide and both arms are flanged on their ends. These Tees are employed in balanced mixers, AFC circuits and impedance measurement circuits etc. This becomes a four terminal device where one terminal is isolated from the input terminal.

ii)Describe working of Cavity Resonator with the help of neat diagram.

Ans:

(Diagram 2Marks, Explanation 2 Marks)

Explanation:

A **resonator** is a device or system that exhibits resonance or resonant behavior, that is, it naturally oscillates at some frequencies, called its resonant frequencies, with greater amplitude than at other.

A cavity resonator, usually used in reference to electromagnetic resonators, is one in which waves exist in a hollow space inside the device. A cavity resonator is a hollow closed conductor such as a metal box or a cavity within a metal block, containing electromagnetic waves (radio waves) reflecting back and forth between the cavity's walls. When a source of radio waves at one of the cavity's resonant frequencies is applied, the oppositely-moving waves form standing waves, and the cavity stores electromagnetic energy.

Diagram:

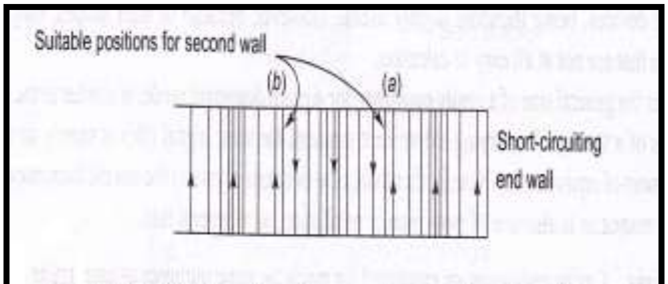


Fig. *Transformation from rectangular waveguide propagating $TE_{1,0}$ mode to cavity resonator oscillating in (a) $TE_{1,0,1}$ mode; (b) $TE_{1,0,2}$ mode.*

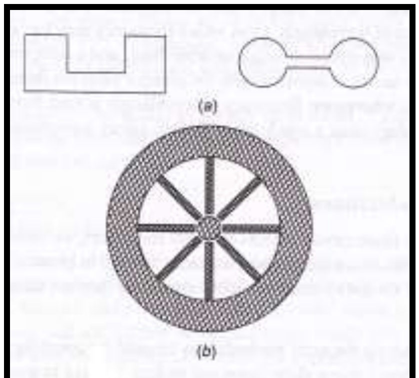


Fig. *Reentrant cavity resonators.*

Since the cavity's lowest resonant frequency, the fundamental frequency, is that at which the width of the cavity is equal to a half-wavelength ($\lambda/2$), cavity resonators are only used at microwave frequencies and above, where wavelengths are short enough that the cavity is conveniently small in size.

Due to the low resistance of their conductive walls, cavity resonators have very high Q factors; that is their bandwidth, the range of frequencies around the resonant frequency at which they will resonate, is very narrow. Thus they can act as narrow band pass filters. Cavity resonators are widely used as the frequency determining element in microwave oscillators. Their resonant frequency can be tuned by moving one of the walls of the cavity in or out, changing its size.
Examples Acoustic cavity resonators, in which sound is produced by air vibrating in a cavity with one opening

b) Describe working of Magnetron with neat diagrams. List any two applications.
Ans:

(Working4 Marks, Diagram 2 Marks, Applications 2 Marks)

Working of Magnetron:

1. Now assume RF oscillations are initiated due to some noise transient within the magnetron, the oscillations will be sustained by device operation.

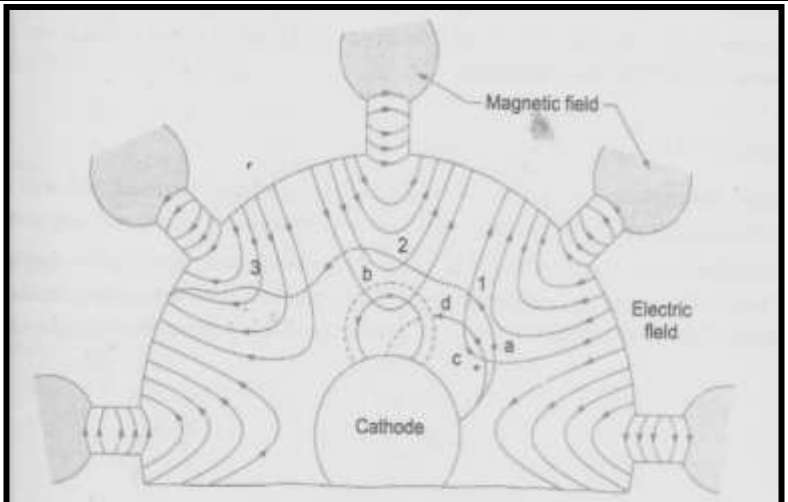


Fig. 8.33 π-mode of magnetron

2. Self-oscillations will be obtained if the phase difference between adjacent anode poles is nπ/4 (N=8), where n is an integer. n=4 results in π mode. Here the anode poles are π radians apart.
3. The dotted lines refer to the path of electrons in case of static field. The solid lines refer to the electron trajectories in the presence of RF oscillations in the interaction space.
4. The electron 'a' is seen to be slowed down in the presence of oscillations thus transferring energy to the oscillations during its longer journey from cathode to anode. Such electrons which participate in transferring energy to the RF field are called as favored electrons and these electrons are responsible for bunching effect.
5. An electron 'b' is accelerated by the RF field. Instead of imparting energy to the oscillations, it takes energy from the oscillations resulting in increased velocity. Hence bends more sharply, spends very little time in the interaction space and is returned back to the cathode. Such electrons are called un-favored electrons which do not participate in the bunching process; rather they are harmful as they cause back heating.
6. Similarly electron 'c' which is emitted little later to be in correct position moves faster and tries to catch up with electron 'a' and an electron emitted at d will be slowed down to fall back in step with the electron 'a'.
7. This result in all favored electrons like a, c, d to form a bunch and are confined to electron clouds or spokes as shown in fig below. This process is called **phase focusing effect** corresponding to the bunch of favored electrons around the reference electron 'a'. The spokes so formed in the π-mode rotate with an angular velocity corresponding to 2 poles/cycle.

Applications:
Magnetron is used in Microwave oven, Radar Transmitter, Induction heating

[Note: Can consider any other application other application]

c) Describe operation Of impatt diode with the help of well labeled sketches.

Ans: Note: [Or any other sketches with same operation can be consider]

(Operation 6 Marks, Diagram 2Marks)

Diagram:

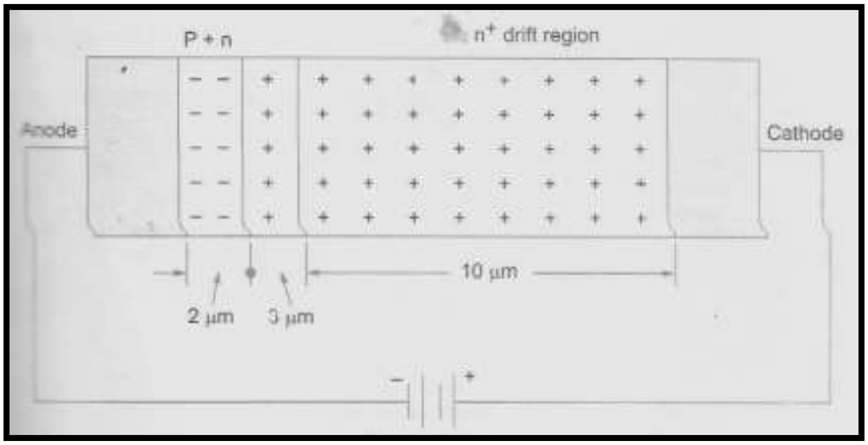


Figure: IMPATT diode

Operation Of impatt diode :

1. Any device which exhibits negative resistance for dc will also exhibit for ac i.e. if an ac voltage is applied current will rise when voltage falls at an ac rate.
2. Hence negative resistance can also be defined as that property of a device which causes the current through it to be 180° out of phase with the voltage across it.
3. This kind of negative resistance is exhibited by IMPATT diode.
4. A combination of delay involved in generating avalanche current multiplication together with delay due to transit time through drift space provides the necessary 180° phase difference between applied voltage and resulting current in an IMPATT diode.
5. The cross section of the active region of this device is shown in figure above. It is a diode with the junction between the p^+ and *n* layers.
6. An extremely high-voltage gradient is applied to the IMPATT diode, of the order of 400kV/cm, eventually resulting in a very high current. A normal diode would very quickly breakdown under such conditions, but the IMPATT diode is constructed so as to be able to withstand such conditions repeatedly.
7. Let us consider application of a RF ac voltage superimposed on top of the high dc voltage. Increased velocity of electrons and holes result in additional electrons and holes by knocking them out of the crystal structure by so called impact ionization.
8. These additional carriers continue the process at the junction and it now snowballs into an avalanche.
9. If the original dc field was just at the threshold of allowing this situation to develop, his voltage will be exceeded during the whole of the RF positive cycle and the avalanche current multiplication will be taking place during this entire time.

10. Since it is a multiplication process avalanche is not instantaneous. This process in fact takes a time such that current pulse maximum at the junction occurs at the instant when RF voltage across the diode is zero and going negative.
11. A 90° phase shift or phase difference between voltage and current has then been achieved.
12. The current pulse as shown in figure below is situated at the junction. It does not stay there but moves towards the cathode due to applied reverse bias at a drift velocity dependent upon the presence of high dc field.

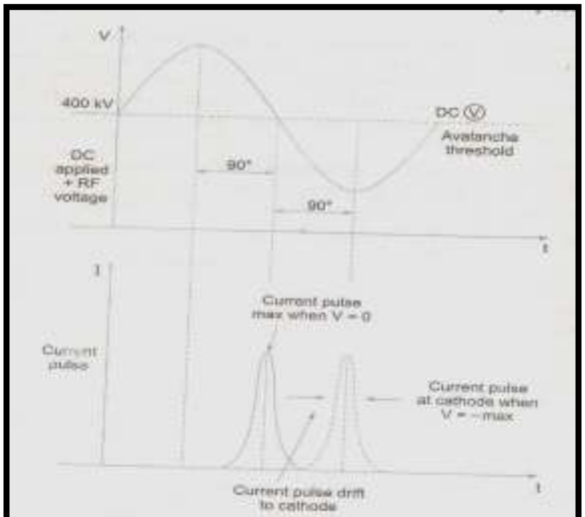


Fig. 9.54 V and I vs t characteristics

13. The time taken by the pulse to reach the cathode depends on this velocity and on the thickness of the highly doped 'n^+'layer. The thickness is adjusted such that time taken for current pulse to move from V=0 position to V=negative maximum RF cycle is exactly 90°.
14. Hence voltage and current are 180° out of phase and a dynamic RF negative resistance has been proved to exist. Hence IMPATT diode is useful both as an oscillator and as an amplifier.
15. The resonant frequency of IMATT diode is given by: $f = \frac{V_d}{2L}$; where, V_d = carrier drift velocity and L = length of drift space charge region.

Q4. Attempt any FOUR. 16M

a) Define the terms : Group velocity and phase velocity with respect to wave guide.

Ans: **Definition: (2Marks each)**

i) Group Velocity : It is the velocity of electromagnetic waves in the waveguide. Group velocity is denoted by the symbol Vg. Group velocity is less than velocity of electromagnetic waves in free space.

OR

The velocity at which energy is transported down the length of the waveguide is defined as the group velocity.

ii) Phase Velocity : It is the velocity which the electromagnetic waves changes it phase in the waveguide during propagation. Its symbol is Vph. Group velocity and phase velocity of the electromagnetic waves is the same in free space.

OR

The velocity of propagation for a TEM wave (plane wave or transmission line wave) is referred to as the phase velocity (the velocity at which a point of constant phase moves). The phase velocity of a TEM wave is equal to the velocity of energy transport.

b) Describe function of following microwave components with the help of neat sketch:

i) Flanges

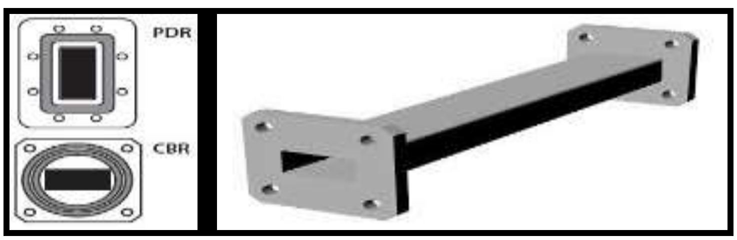
ii)Taper& Twist

Ans: (1mark for sketch and 1mark for function 2mark each)

Functions:

i) Flanges:

A waveguide flange is a connector for joining sections of waveguide.



i) Taper and Twist:

Taper is used to couple the WGs having different dimensions or cross sectional shapes.

The twist section is used to change between horizontal and vertical polarization.

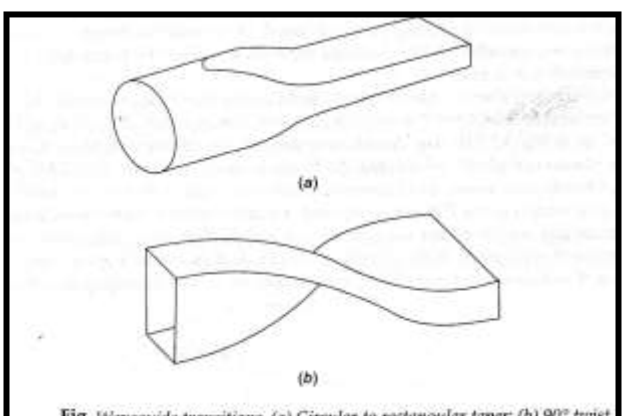


Fig. Waveguide transitions, (a) Circular to rectangular taper; (b) 90° twist.

c) List advantage of microwave Tubes over conventional vacuum tube.

Ans: Advantages :(Any four ,1mark each)

1) Conventional tubes such as triodes, tetrodes and pentodes are useful only at low microwave frequencies.

2) These tubes cannot operate at high frequencies due to their limitations at those frequencies The conventional tubes become less effective at microwave frequency range when these are used as an amplifier and oscillator. The limitations of conventional tubes at high frequencies is due to :

- Inter-electrode capacitance effect
- Lead Inductance effect
- Transit Time effects.

3) Large life span

4) Large transit time

5) This loading is due to the dissipation of the power at the grid. The effect of loading is such that the noise in the circuit increases

6) RF loses effect.

7) Gain bandwidth limitations.

d) Draw well labeled schematic of TWT and describe its working as amplifier. List any 2 applications of TWT.

Ans: (Diagram: 2 Marks , working 1mark, application 1mark)

Diagram:

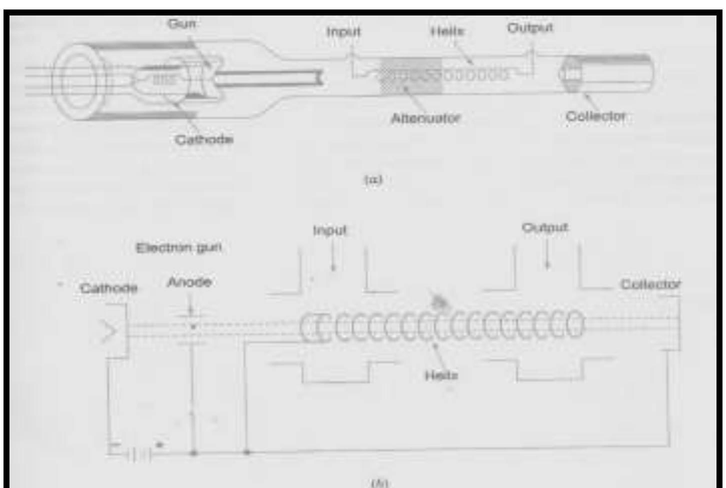


Fig. 8.22 (a) Physical construction of TWT (b) schematic electrode arrangement.

Fig. Schematic of TWT

OPERATION:

1. The RF signal to be amplified is applied to the input end of the helix structure. When the applied RF signal propagates around the turns of the helix, it produces an electric field at the center of the helix called as axial EF.
2. The RF field propagates with the velocity of light. The axial RF field travels with the velocity of light multiplied by the ratio of helix pitch to that of helix circumference. The axial phase velocity v_p is given by - $v_p = v_c\left(\frac{pitch}{2\pi r}\right)$; where r = radius of the helix and it essentially remains constant over a range of frequencies and this characteristic of helix slow wave structure enables TWT to have broadband operation.

How bunching takes place in TWT:

1. The TWT can be thought of a large number of closely spaced gaps with the phase change that propagates from left to right at approximately the same velocity as the electron beam.
2. When the axial field is zero, electron velocity is unaffected. This happens at the point of node of the axial electric field.
3. At a point where the axial field is positive antinode, the electron coming against it is accelerated and tries to catch up with the later electron which encounters the nodal RF axial field.
4. At a later point where the axial RF field is negative antinode, the electrons referred before tend to overtake.
5. This leads to bunching of electrons because of velocity modulation.
6. Bunching continues to take place as it travels. The electrons in the bunch encounter retarding field and delivers energy to the wave on the helix. The output becomes larger than the input and hence amplification results.

Application: [any 2, list is enough]

1. TWTAs are commonly used as amplifiers in satellite transponders
2. TWTA transmitters are used extensively in radar, particularly in airborne fire-control radar systems,
3. In electronic warfare and self-protection systems
4. TWTAs is use for the electromagnetic compatibility (EMC) testing industry for immunity testing of electronic devices.

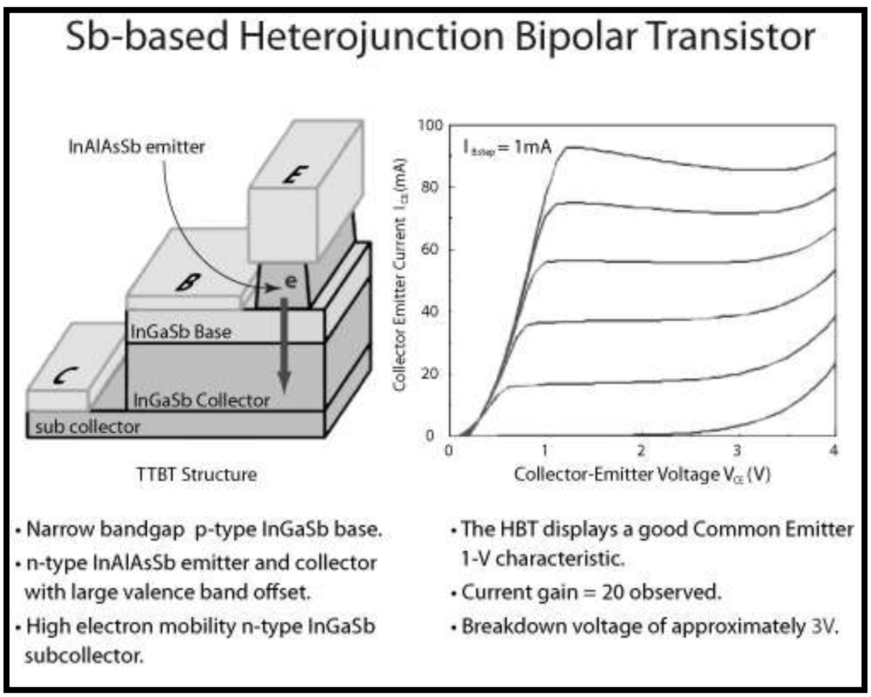
e) Describe working of Microwave bipolar transistor with characteristics curve.

Ans:(Explanation 2 Marks , Characteristics 2Marks ,Dia. Not Expected)

Working:

AlGaAs/GaAs hetero junction bipolar transistors (HBTs) are used for digital and analog microwave applications with frequencies as high as Ku band. HBTs can provide faster switching speeds than silicon bipolar transistors mainly because of reduced base resistance and collector-to-substrate capacitance. HBT processing requires less demanding lithography than GaAs FETs, therefore, HBTs can cost less to fabricate and can provide improved lithographic yield. This technology can also provide higher breakdown voltages and easier broad-band impedance matching than GaAs FETs. In comparison with Si bipolar junction transistors (BJTs), HBTs show better performance in terms of emitter injection efficiency, base resistance, base-emitter capacitance, and cutoff frequency. They also offer good linearity, low phase noise and high power-added efficiency.

characteristics between AlGaAs/GaAs HBTs and Si BJTs. HBTs are used in both commercial and high-reliability applications, such as power amplifiers in mobile telephones and laser drivers



f) Describe A-scope display in Radar System.

Ans:

Explanation: **2M**

A-scope Display :

- 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.

Diagram: **2M**

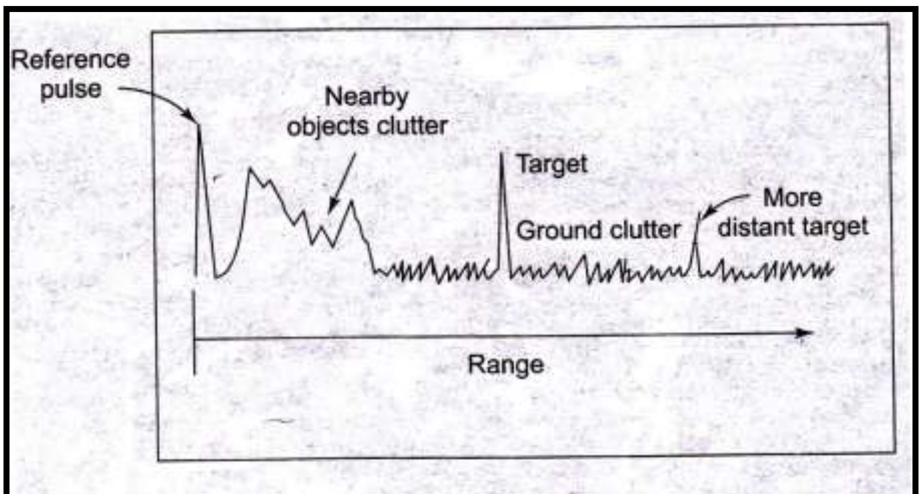


Fig. *A scope display.*

Fig. A-scope display in Radar System

Q.5 Attempt any FOUR: 16M

(a) List two application of two cavity klystron & four specifications of same.

Ans:

Application: (Any Two) 2M

- Used in satellite earth station transmitter as power amplifier.
- Used in UHF TV amplifier.
- It is used as a medium, high and very high power amplifier in the UHF and microwave ranges.
- Used as radar transmitter.

Specification:(Any Four) 2M

- Frequency: 250 MHz to 100 GHz. (60 GHz nominal).
- Power: 10KW-500KW (CW) 30MW (pulsed).
- Power gain: 15 dB-70 dB (60dB nominal).
- Bandwidths: Limited (because cavity resonators are being used) 10-60 MHz- generally used in fixed frequency applications.
- Noise figure: 15-20dB (Sometimes greater than 25dB).
- Theoretical efficiency: 50% (30-40% nominal).

(b) Give specification and application of Trapatt diode.

Ans:

Specification:(Any four) 2M

- CW power: 1-3 W between 8GHz to 0.5GHz.
- Pulse power: 1.2kW at 1.1 GHz (More suitable for pubed operation).
- Operating Voltage: 60-150 V
- Efficiency: 15 to 40% (8GHz) (0.5GHz).
- Noise figure: >30dB.
- Frequency: 3 to 50 GHz.

Application: **2M**

- In low power Doppler radars or as local oscillators for radar system.
- Microwave beacon landing system.
- Radio altimeter.
- Phased array radar system.

(c) Draw block diagram of basic pulse radar system and describe the function of each block.

Ans: **Diagram**: **2M**

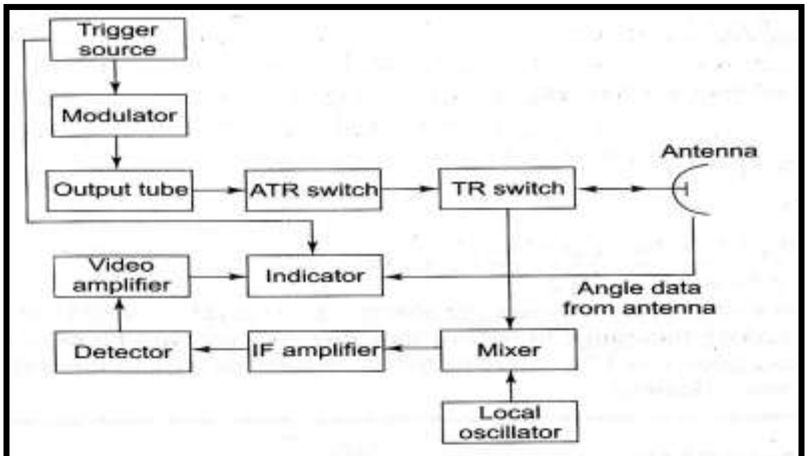


Fig. *Pulsed radar block diagram.*

Explanation:- **2M**

- **Triggering Source**: It provides pulses for the modulator which establishes the rate at which the pulses are to be transmitted.
- **Modulator**: The modulator provides rectangular voltage pulses which are used as the supply voltage for the output tube, thus switching it ON and OFF as required. The modulation process is at high power level, because the peak transmitted power is generally of the order of 500KW, although the average power over a cycle is less than 500 watts. The modulator should therefore be capable of supplying three to four times the carrier power to the power tube.
- **Output tube**: Magnetron is commonly used output tube because it can develop large power.
- **ATR & TR switch**: It acts as duplexer is a circuit designed to allow the same antenna for radar transmission and echo reception, such that it will neither allow the transmitter output into the receiver nor the echo input into the transmitter
- **Video amplifier**: The video amplifier has the same band width as that of IF amplifier. It amplifies the detector output.

- **Indicator**: The output of the radar receiver is presented to the operator in the form of visual indication, using a cathode ray tube. Presentation may be deflection modulated or intensity modulated, depending on whether the trace is deflected or brightened by the presence of an echo. Since a radar is rang measuring instrument, one-coordinate displays range.

- **Detector:** Since vaccume tubes or transistors do not function at microwave frequency due to transmit time, the detector is often a schottky – barrier diode or crystal diode.

- **IF amplifier**: The IF amplifier section usually consists of five or six amplifiers to ensure high gain and approximately 10MHz bandwidth. In addition, all the amplifiers are also synchronous, that is, all stagger tuned to the same frequency to obtain a pass band within the broad selectively.

- **Local Oscillator**: Local oscillator in radar receiver is reflex klystron with a narrow band filter at the output to reduce its noise.

- **Mixer**: Mixer is fed a signal from RF amplifier as well as local oscillator signal. The local oscillator operates at frequency higher than the RF signal and required a special high frequency tube. The output from the mixer is selected as the difference frequency at about 30 MHz.

(d) Draw block diagram of MTI radar system and give function of COHO and Stalo.

Ans: **Diagram**: **2M**

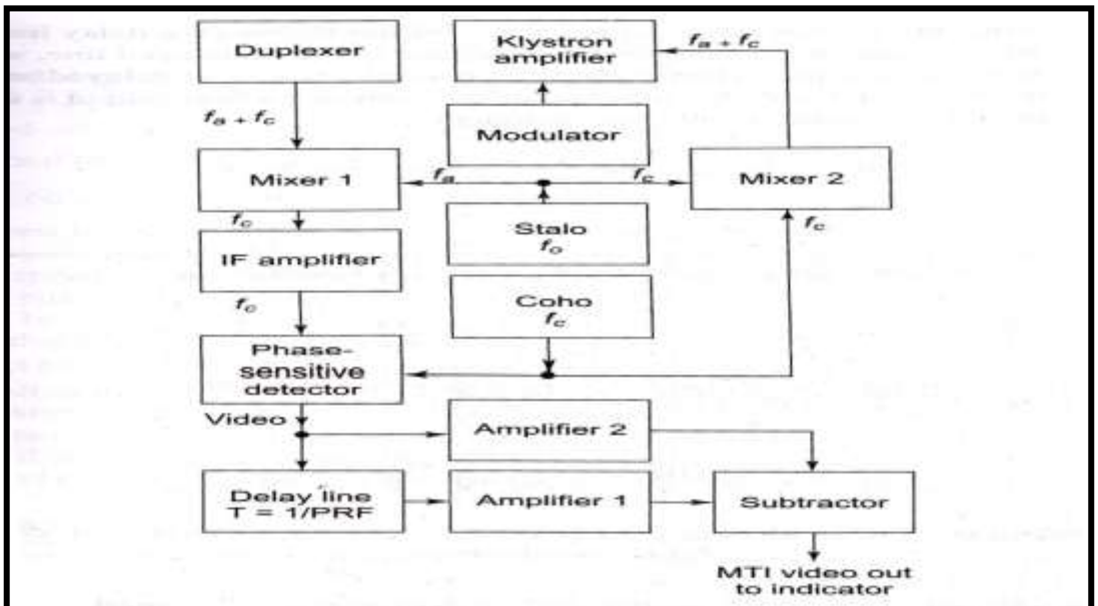


Fig. *Block diagram of MTI radar using power amplifier output.*

Function:

COHO: **1M**

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

STALO: **1M**

The same local oscillator (stalo),Thus the phase relations existing in their inputs are preserved in their inputs are preserved in their outputs. This makes it possible to use the Doppler shift at the intermediate frequency (IF) instead of less convenient radio frequency ($f_0 + f_1$). The output of the IF amplifier and the reference signal from the coho are fed to phase sensitive detector.

(e) Define the term: look angles, footprint in satellite communication system.

Ans:

Definition:

Look angles: **2M**

The look angles are the angles (coordinates) to which an earth station antenna must be pointed to communicate with the geosynchronous satellite. These angles are

- Azimuth(A)
- Elevation angle (E)

Footprint in satellite: **2M**

The geographical representation of a satellite antenna's radiation pattern is called a footprint or sometimes a footprint map.

(f) Draw the block diagram of communication subsystem of satellite.

Ans: **Diagram :(Any one 4 M)**

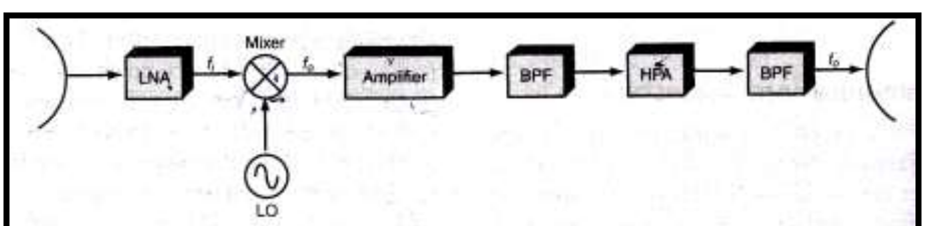


Fig. A single-conversion transponder.

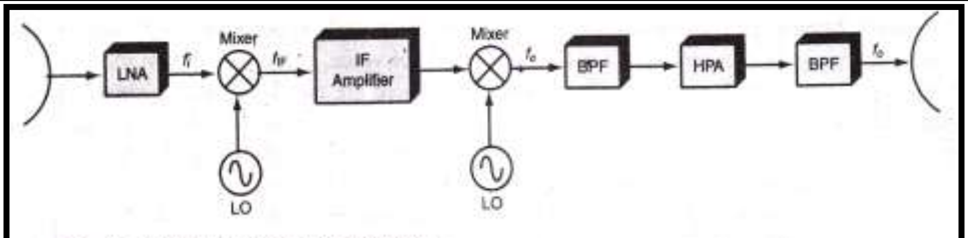


Fig. A double-conversion transponder.

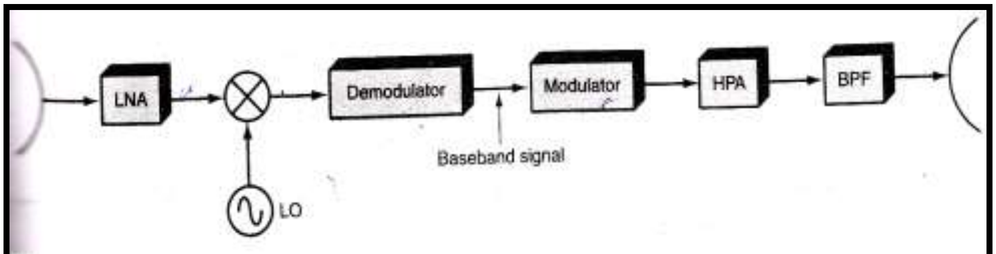


Fig: A regenerative transponder.

Q.6 Attempt any FOUR: 16M

(a) Describe the working of CW Doppler radar system with the help of block diagram.

Ans:

Diagram: **2M**

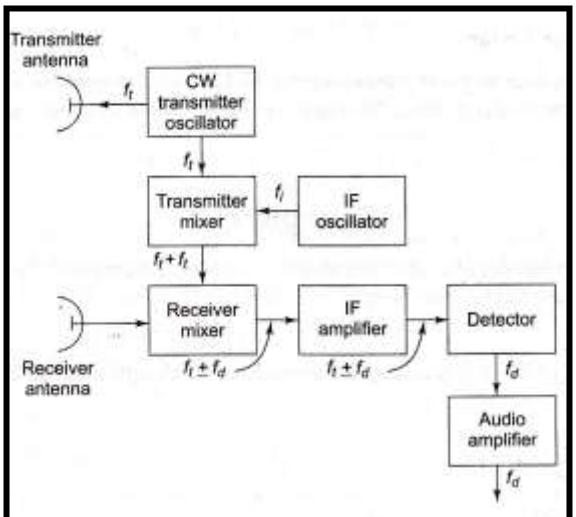


Fig. *CW Doppler radar with IF amplification.*

Explanation: **2M**

- CW Doppler radar makes use of Doppler effect for target speed measurement. It transmit continuous sine wave rather than pulses.
- As CW radar transmission is continuous, there is no point to use duplexer, Instead od duplexer circulator is used to provide isolation between the transmitter and the receiver.
- The isolation provided by typical circulator is of the order of 30 dB, so that some of the transmitted signal leaks into receiver.
- This signal is mixed in the detector with echo signal from the target and the difference is doppler frequency .This doppler frequency is usually in the audio range, hence it is amplified by audio amplifier.
- The output of the audio amplifier is then applied to the frequency counter, whose output is displayed in terms of Km/hr or miles/hr, rather than actual frequency in hertz.
- The main dis-advantage of this system is its low sensitivity. The type of diode detector that is used to accommodate the high incoming frequency is not a very good device at the audio output frequency, because of the modulation noise which it exhibits at low frequencies. The figure shows the block diagram of CW doppler radar with IF amplifier, which is improved version in that regard.

(b) List various tracking methods used in radar system. Describe mono pulse tracking method.

Ans:

Types: **2M**

- Lobe switching
- Conical scanning
- Mono pulse tracking

Mono pulse:

Diagram: **2M**

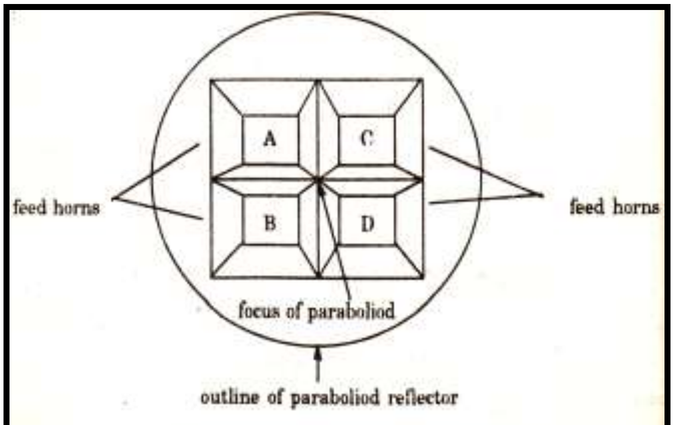


Fig. Feed arrangement for monopulse tracking.

Explanation: **2M**

- Each of the four feeds produces a slightly different beam from the one reflector, so that in transmission four individual beams "stab out" into space, being centered on the direction, a bam would have had from a signal feed placed at the focus of the reflector.
- As in conical scanning and sequential lobing, no differences will be recorded if the target is precisely in the axial direction of the antenna.
- However, once the target has been acquired, any deviation from the central position will be shown by the presence of a vertical difference signal, a horizontal difference signal or both.
- The receiver has three separate input channels(one for each of the three signals) consisting of three mixers with a common local oscillator, three IF amplifiers.
- The output of the sum channel is used to provide the data generally obtained from a radar receiver, driving the antenna so as to keep it pointed exactly at the target.

(c) With the help of block diagram, describe the working of TTC subsystem of satellite.

Ans:

Diagram: **2M**

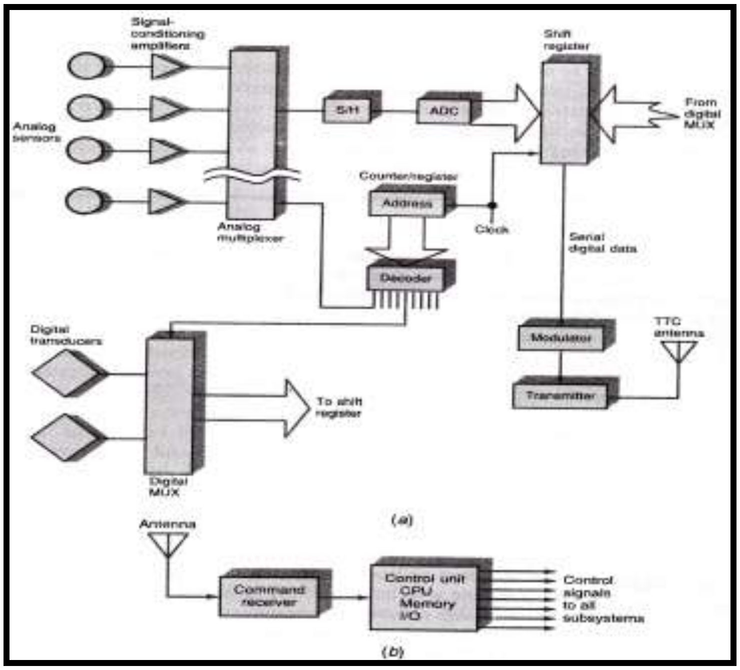


Figure:- Block diagram of TTC subsystem satellite

Explanation:- **2M**

- TTC sub-system allows ground station to monitor and control conditions in the satellite.
- The telemetry system is used to report the status of the ON board sub-system to the ground station.
- The telemetry system typically consist of various electronic sensors(Analog & Digital) to measure temperature, radiation level, power supply voltage & other key operating characteristics.
- The output of sensor converted to digital signal which then modulates by internal transmitter and sense to ground station where is recorded and monitor.
- The command and control system permits the ground station to control the satellite.
- The satellite contains command receiver, which receives command signal from earth station & tells the satellite what to do.
- Various command may initiate telemetry sequence, activate thrusters for attitude correction, and reorient an antenna or perform other operations as required by the special equipment specific to the mission.

(d) Draw well labeled block diagram of satellite subsystem.

Ans:

Diagram: **4M**

:

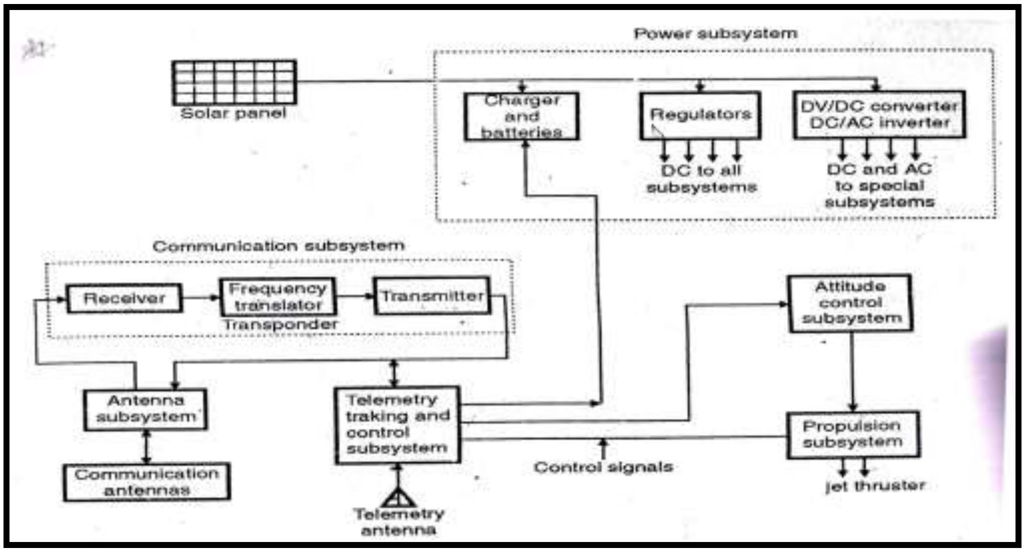
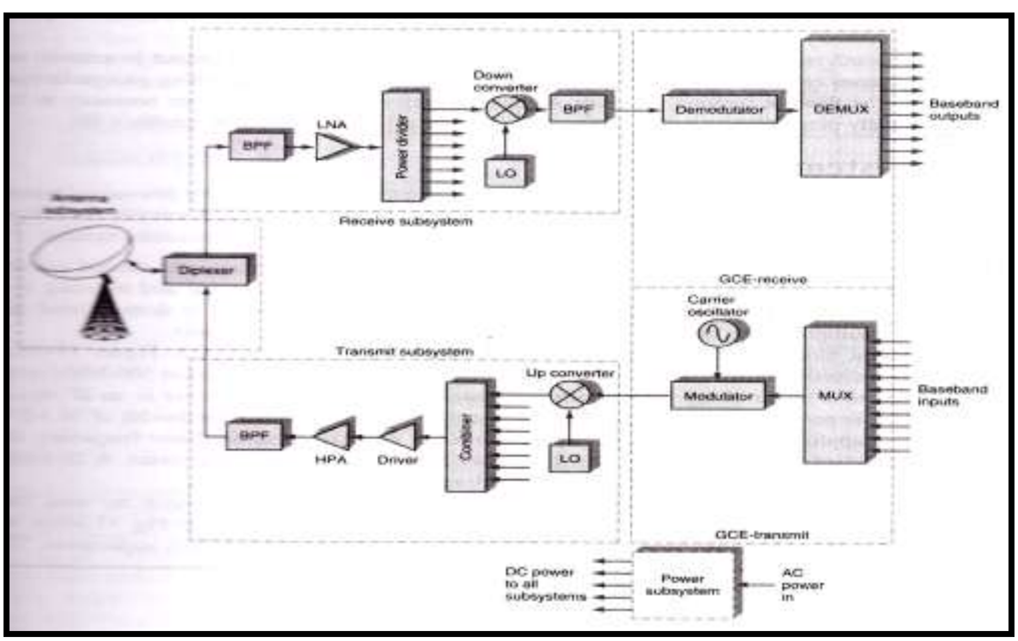


Fig. Block diagram of satellite subsystem

(e) Draw block diagram of satellite earth station transmitter and state function of each block.

Ans:

Diagram: **2M**



NOTE: (or any other relevant Diagram)

Explanation: **2M**

1. **Transmitter:**
There may be one or many transmit chains depending on the number of separate carrier frequencies and satellites with which the station must operate simultaneously. It consists of MUX, modulators and filters, HPA. Microwave transmitters are expensive devices that employ costly HPA's such as TWTA and multi-cavity klystrons.

2. **Receiver:**
There may be many receiver chains depending on the number of separate frequencies and satellites to be received and various operating conditions. The receiver subsystem consists of LNA and filters, down convertors, filters, demodulators and DEMUX equipment.

3. **Antenna:**
Usually one antenna is used for both transmission and reception but not necessarily. Within the antenna subsystem are the antenna reflector and feed, separate feed systems to permit automatic tracking and a duplexer and MUX arrangement to permit simultaneous connection of many transmitters and receiver chains to the same antenna.
4. **Tracking System:**
This comprises of control circuit and drive which are necessary to keep the antenna pointed at the satellite. Tracking system keeps antenna pointing in the direction of the satellite in spite of relative movement of the satellite and the station.
5. **Terrestrial Interface:**
This is the interconnection with whatever terrestrial system if any is involved. In case of small receive only and transmit only stations, the user may be at the earth station itself.
6. **Power Subsystem:**
This system includes the primary sources (the standard AC lines) for running the earth station. The subsystem operates power supplies which distribute a variety of dc voltages to the other equipment. The power subsystem also consists of emergency power sources such as diesel generators, batteries and inverters to ensure continuous operation during power failures. It often includes provision for no break changeover from one source to another.
7. **Test Equipment:**
This includes the equipment necessary for routine checking of the earth station and terrestrial interface, possible monitoring of satellite characteristics and occasionally for the measurement of special characteristics.

(f) Describe the function of propulsion subsystem and antenna subsystem in satellite.

Ans:

Function:

Propulsion sub-system: **2M**

(a) 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.

(b) 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.

(c) 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.

Antenna Sub-system: **2M**

Antenna on board serves as an interface between the earth on the ground and various satellite subsystems during operations.

(a) Receive uplink signals.

(b) Transmit downlink signals.

(c) Provides signal link for satellite telemetry, command and ranging systems.

(d) Provide signal link for attitude control subsystem.

(e) Provide becon tracking signals for precise pointing of the antenna towards the earth area.