Fundamental of Microwave Engineering

Q.No.1. Solve any five

a. *Explain advantages & applications of microwave.*

Ans: **Advantages of microwave:** **[2]**

1] Effects of reflection, polarization, scattering, diffraction and atmospheric absorption usually associated with visible light are of practical significance in the study of microwave propagation.

2] More band width can be available.

3] Microwave signal can travel by line of sight & are not bent by ionosphere.

Applications: **[3]**

1] **Communication:** fiber-optic transmission, most long distance telephone calls were carried via networks of microwave radio relay links.

Wireless LAN protocols, such as Bluetooth and the IEEE 802.11 specifications, also use microwaves in the 2.4 GHz ISM band, although 802.11a uses ISM band and U-NII frequencies in the 5 GHz range.

Mobile phone networks, like GSM, use the low-microwave/high-UHF frequencies around 1.8 and 1.9 GHz in the Americas.

2] **Radar**

Radar uses microwave radiation to detect the range, speed, and other characteristics of remote objects. Development of radar was accelerated during World War II due to its great military utility. Now radar is widely used for applications such as air traffic control, weather forecasting, navigation of ships, and speed limit enforcement.

A Gunn diode oscillator and waveguide are used as a motion detector for automatic door openers.

3] **Radio astronomy**

Most radio astronomy uses microwaves. Usually the naturally-occurring microwave radiation is observed, but active radar experiments have also been done with objects in the solar system, such as determining the distance to the Moon or mapping the invisible surface of Venus through cloud cover.

4] **Navigation**

Global Navigation Satellite Systems (GNSS) including the Chinese Beidou, the American Global Positioning System (GPS) and the Russian GLONASS broadcast navigational signals in various bands between about 1.2 GHz and 1.6 GHz.

5] Microwave heating is used in industrial processes for drying and curing products.

Many semiconductor processing techniques use microwaves to generate plasma for such purposes as reactive ion etching and plasma-enhanced chemical vapor deposition (PECVD).

Microwave frequencies typically ranging from 110 – 140 GHz are used in stellarators and more notably in tokamak experimental fusion reactors to help heat the fuel into a plasma state. The upcoming ITER Thermonuclear Reactor is expected to range from 110–170 GHz and will employ Electron Cyclotron Resonance Heating (ECRH).

Microwaves can be used to transmit power over long distances, and post-World War II research was done to examine possibilities. NASA worked in the 1970s and early 1980s to research the possibilities of using solar power satellite (SPS) systems with large solar arrays that would beam power down to the Earth's surface via microwaves.

Less-than-lethal weaponry exists that uses millimeter waves to heat a thin layer of human skin to an intolerable temperature so as to make the targeted person move away. A two-second burst of the 95 GHz focused beam heats the skin to a temperature of 130 °F (54 °C) at a depth of 1/64th of an inch (0.4 mm). The United States Air Force and Marines are currently using this type of active denial system.

b. A 50Ω transmission line is matched to 10 v source that feeds a load ZL= 100Ω. If the line is 2.3λ long & has an attenuation constant α = 0.5dB/λ ,find the powers that delivered by the source, lost in the line & delivered to the load.

Ans: Since the generator is matched to the line,

$Vo^+ = \frac{Vg}{2} e^{\Gamma l}$ (phase reference at z=0)

$\alpha = 0.5$ dB/ λ = 0.0575 neper/λ

$rl = (\alpha + j\beta)\, l = 0.1325 + j108$ [01]

$|V0^+| = \frac{10}{2} e^{-\alpha l} = 4.38$ v [1/2]

$\Gamma_l = \frac{Zl - Z0}{Zl + Z0} = \frac{100 - 50}{100 + 50} = 0.333$ [1/2]

$\Gamma_{(l)} = \Gamma e^{-2\Gamma l}$ $Pin = \frac{[V0+]^2}{2\,Z0}\,[1 - \Gamma\,(l)^2]\, e^{2\alpha l}$

$= \frac{4.38^2}{100}\,[e^{2(0.1325} - (0.333)^2\, e^{2(0.1325)}$

= 0.2337 Watts (power delivered to line) [01]

$$P_{in} = \frac{[V0+]^2}{2\ Z0}\ [1-\Gamma\ (l)^2]$$

$$= \frac{4.38^2}{100}\ [1-\ (0.333)^2\ ]$$

= 0.1706 Watts (power to load) [01]

Ploss = Pin-PL = 0.2337 – 0.1706 = 0.0631 W [01]

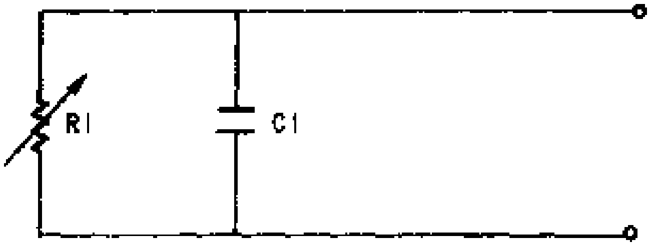
C With neat diagram explain the working of PIN diode.

Ans: PIN Diodes [2]

The pin diode consists of two narrow, but highly doped, semiconductor regions separated by a thicker, lightly-doped material called the intrinsic region. As suggested in the name, pin, one of the heavily doped regions is p-type material and the other is n-type. The same semiconductor material, usually silicon, is used for all three areas. Silicon is used most often for its power-handling capability and because it provides a highly resistive intrinsic (i) region. The pin diode acts as an ordinary diode at frequencies up to about 100 megahertz, but above this frequency the operational characteristics change.

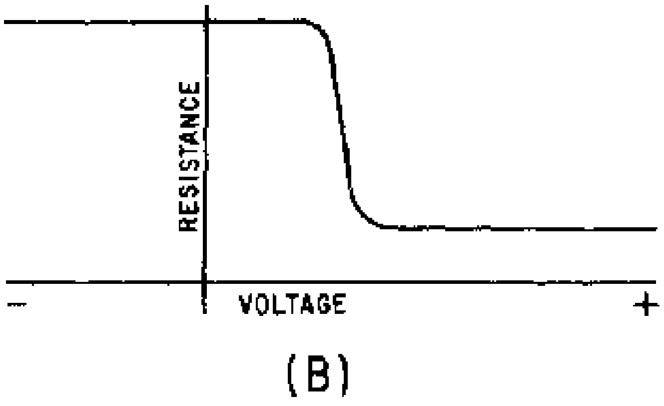
The large intrinsic region increases the transit time of electrons crossing the region. Above 100 megahertz, electrons begin to accumulate in the intrinsic region. The carrier storage in the intrinsic region causes the diode to stop acting as a rectifier and begin acting as a variable resistance. The equivalent circuit of a pin diode at microwave frequencies is shown in figure (A). A resistance versus voltage characteristic curve is shown in view (B).

. - Diode equivalent circuit (pin). [3 marks]



(A)

Fig; characteristics of PIN diode [2 mark]



When the bias on a pin diode is varied, the microwave resistance changes from a typical value of 6 kilohms under negative bias to about 5 ohms when the bias is positive. Thus when the diode is mounted across a transmission line or waveguide, the loading effect is insignificant while the diode is reverse biased, and the diode presents no interference to power flow. When the diode is forward biased, the resistance drops to approximately 5 ohms and most power is reflected. In other words, the diode acts as a switch when mounted in parallel with a transmission line or waveguide. Several diodes in parallel can switch power in excess of 150 kilowatts peak. The upper power limit is determined by the ability of the diode to dissipate power. The upper frequency limit is determined by the shunt capacitance of the pn junction, shown as C1 in figure (A). Pin diodes with upper limit frequencies in excess of 30 gigahertz are available.

***d**. With neat block diagram explain the procedure for measurement of unknown impedance at microwave frequencies.*

Ans: Two methods for measurement of unknown impedance at microwave frequencies.

1] Using slotted line

2] Using reflectometer

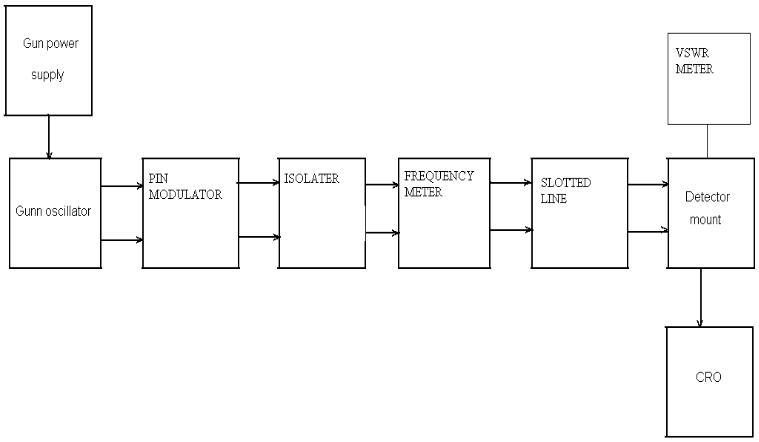
3] using magic tee.

Measurement of unknown impedance at microwave frequencies using slotted line. In first step with load Z_L in the circuit position of Vmax & Vmin can be accurately measured

In the next step load Z_L replaced by short circuit. & the shift in minimum is measured

a] if the minimum is shifted to left then impedance is inductive.

b] if the minimum is shifted to right then impedance is inductive [03]

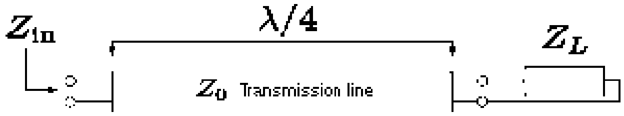


[02]

Q.No 2. a. Using the multiple reflection viewpoint Explain the principle f working of a quarter Wave transformer.

Ans: A **quarter wave impedance transformer**, often written as **λ/4 impedance transformer**, is a component used in electrical engineering consisting of a length of transmission line or waveguide exactly one quarter of a wavelength (λ) long and terminated in some known impedance. The device presents at its input the dual of the impedance with which it is terminated. It is a similar concept to a stub; but whereas a stub is terminated in a short (or open) circuit and the length designed to produce the required impedance, the λ/4 transformer is the other way around; it is a pre-determined length and the termination is designed to produce the required impedance. The relationship between the characteristic, Z_0, input, Z_{in} and load, Z_L, impedances is;

Using a transmission line as an impedance transformer. [03]



$$\frac{Z_{in}}{Z_0} = \frac{Z_0}{Z_L}$$

Theory of operation

[03]

A transmission line that is terminated in some impedance, Z_L, that is different from the characteristic impedance, Z_0, will result in a wave being reflected from the termination back to the source. At the input to the line the reflected voltage adds to the incident voltage and the reflected current subtracts (because the wave is travelling in the opposite direction) from the incident current. The result is that the input impedance of the line (ratio of voltage to current) differs from the characteristic impedance and for a line of length *l* is given by;

$$Z_{\text{in}} = Z_0 \frac{Z_L + Z_0 \tanh(\gamma l)}{Z_0 + Z_L \tanh(\gamma l)}$$

where γ is the line propagation constant.

A very short transmission line, such as those being considered here, in many situations will have no appreciable loss along the length of the line and the propagation constant can be considered to be purely imaginary phase constant, $i\beta$ and the impedance expression reduces to,

$$Z_{\text{in}} = Z_0 \frac{Z_L + iZ_0 \tan(\beta l)}{Z_0 + iZ_L \tan(\beta l)}$$

Since β is the same as the angular wave number,

$$\beta = \frac{2\pi}{\lambda} \ ,$$

for a quarter wavelength line,

$$l = \frac{\lambda}{4} \ , \ \ \beta l = \frac{\pi}{2} \ ,$$

and the impedance becomes,

$$Z_{\text{in}} = Z_0 \frac{Z_L + iZ_0 \tan(\frac{\pi}{2})}{Z_0 + iZ_L \tan(\frac{\pi}{2})} = Z_0 \frac{iZ_0 \tan(\frac{\pi}{2})}{iZ_L \tan(\frac{\pi}{2})} = \frac{{Z_0}^2}{Z_L}$$

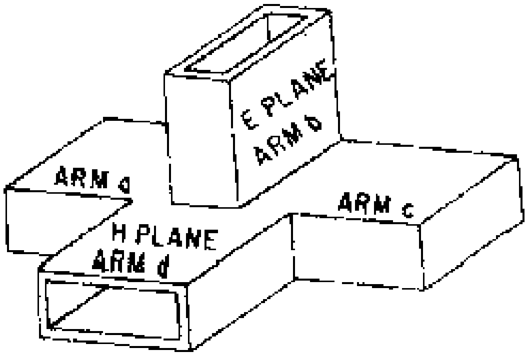
which is the same as the condition for dual impedances;

$$\frac{Z_{\text{in}}}{Z_0} = \frac{Z_0}{Z_L}$$

[04]

Q.No. 2. b. With a neat diaram explain the working of magic tee. Derive its scattering matrix.

Ans: MAGIC TEE:- [2]



If a signal is fed into the b arm of the magic- T, it will divide into two out-of-phase components. As shown in figure 1-67A, these two components will move into the a and c arms. The signal entering the b arm will not enter the d arm because of the zero potential existing at the entrance of the d arm. The potential must be zero at this point to satisfy the boundary conditions of the b arm. This absence of potential is illustrated in figures 1-67B and 1-67C where the magnitude of the E field in the b arm is indicated by the length of the arrows. Since the E lines are at maximum in the center of the b arm and minimum at the edge where the d arm entrance is located, no potential difference exists across the mouth of the d arm.

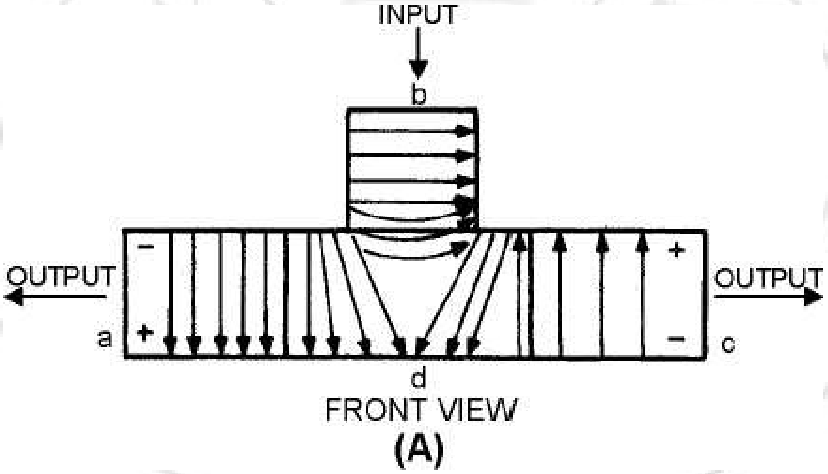
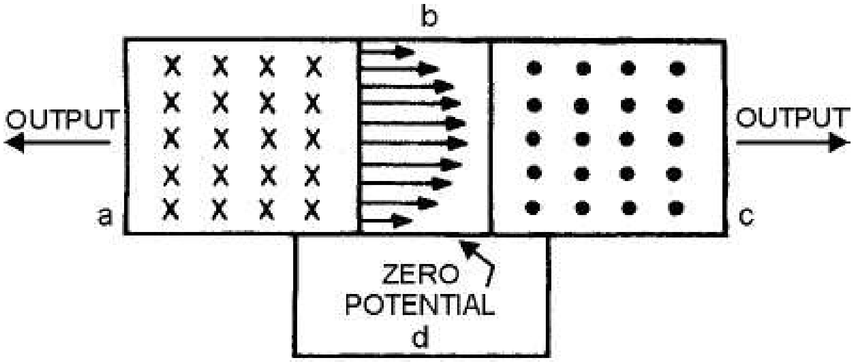
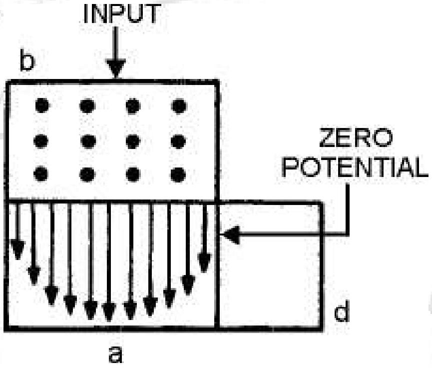


Figure.—Magic-T with input to arm b.

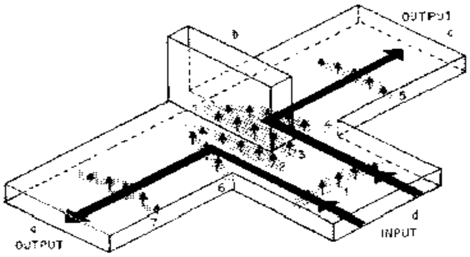


TOP VIEW
(B)

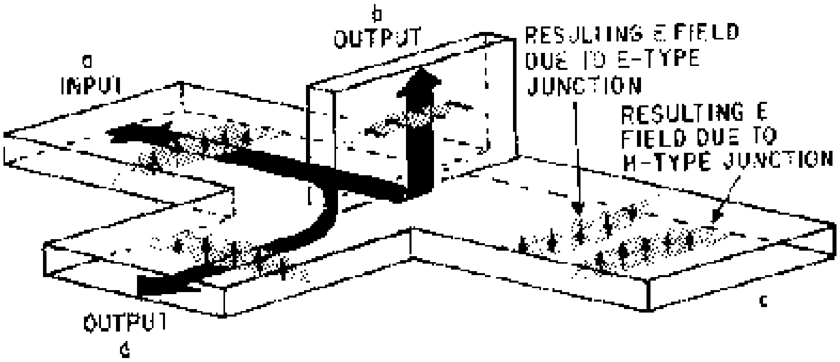


SIDE VIEW
(C)

In summary, when an input is applied to arm b of the magic-T hybrid junction, the output signals from arms a and c are 180 degrees out of phase with each other, and no output occurs at the d arm. The action that occurs when a signal is fed into the d arm of the magic-T is illustrated in figure 1-68. As with the H-type T junction, the signal entering the d arm divides and moves down the a and c arms as outputs which are in phase with each other and with the input. The shape of the E fields in motion is shown by the numbered curved slices. As the E field moves down the d arm, points 2 and 3 are at an equal potential. The energy divides equally into arms a and c, and the E fields in both arms become identical in shape. Since the potentials on both sides of the b arm are equal, no potential difference exists at the entrance to the b arm, resulting in no output.



When an input signal is fed into the a arm as shown in figure 1-69, a portion of the energy is coupled into the b arm as it would be in an E-type T junction. An equal portion of the signal is coupled through the d arm because of the action of the H-type junction. The c arm has two fields across it that are out of phase with each other. Therefore the fields cancel, resulting in no output at the c arm. The reverse of this action takes place if a signal is fed into the c arm, resulting in outputs at the b and d arms and no output at the a arm.



Figure—Magic-T with input to arm a. **[2]**

Unfortunately, when a signal is applied to any arm of a magic-T, the flow of energy in the output arms is affected by reflections. Reflections are caused by impedance mismatching at the junctions. These reflections are the cause of the two major disadvantages of' the magic-T. First, the reflections represent a power loss since all the energy fed into the junction does not reach the load which the arms feed. Second, the reflections produce standing waves that can result in internal arching. Thus the maximum power a magic-T can handle is greatly reduced. Reflections can be reduced by using some means of' impedance matching that does not destroy the shape of' the junctions. One method is shown in figure 1-70. A post is used to match the H plane, and an iris is used to match the E plane. Even though this method reduces reflections, it lowers the power- handling capability even further.

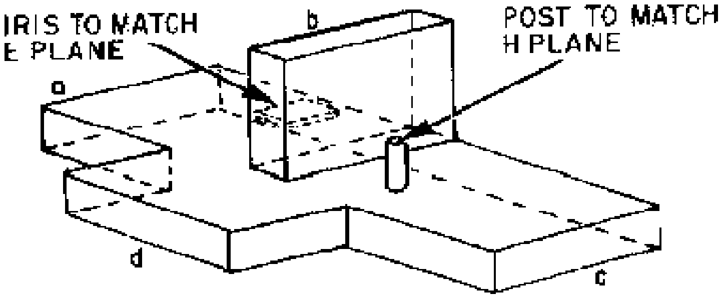
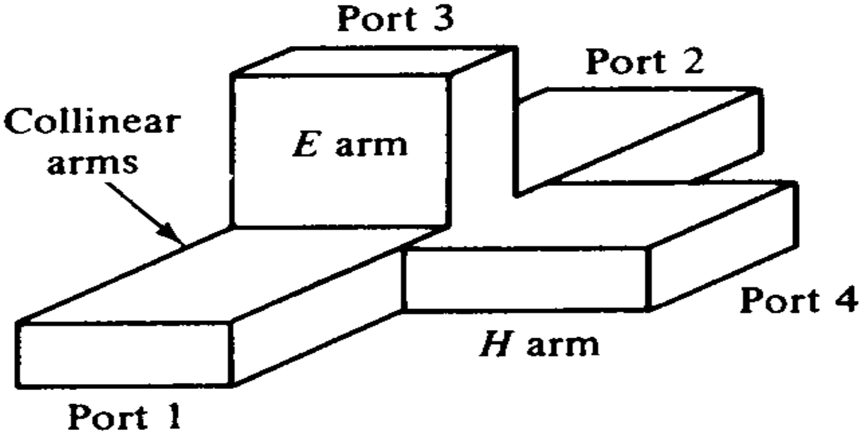


Figure —Magic-T impedance matching.

Scattering matrix:



S matrix of a magic tee can be expressed as

$$\mathbf{S} = \begin{bmatrix} 0 & 0 & S_{13} & S_{14} \\ 0 & 0 & S_{23} & S_{24} \\ S_{31} & S_{32} & 0 & 0 \\ S_{41} & S_{42} & 0 & 0 \end{bmatrix}$$

[06]

Q.No. 3.a.A generator at 150MHZ drives a 10m long, 75Ω coaxial line terminated in a composite Load consisting of parallel connection of two 50Ω lines of lengths 0.5 m & 1.0m,each Terminated in 50Ω resistance. All lines are lossless with €r=2.2 With reference to figure Determine the length ls & connection point d of a parallel connected 75Ω stub that will produce minimum VSWR on the feed line . the stub should be as close as load.

Ans: Phase velocity Vp $=\frac{3*10^8}{\sqrt{2.2}}$ = 2.02 * 10^8 [1/2]

Wavelength = λ = Vp=1.35 m [1/2]

Main 75Ω line is 50Ω II 50Ω

Zl = 25 Ω [02]

Normalised Zl =0.333 [01]

Plot Zl =0.333 n smith chart, draw constant VSWR circle through Zl =0.333 to give

VSWR = 3

To get IrI = 0.5 [02]

Yl = 3+j0

g=1 & VSWR = 3 circles intersect at

y1 = 1+j1.15 at a distance of 0.416 λ from load towards generator [01]

y12= 1-j1.15 at a distance of 0.0835 λ from load towards generator [01]

choose y2 as it closer to load

75 Ω stub is located at

d= 0.0835λ = 11.3 cm [01]

stub length ls for ystub = +j1.5 (shunt circuit condition)

will be (0.25+0.1345)λ = 51.9 cm

VSWR l1 & l2 is 1.0 (Matched load) [01]

Q.No. 3. *b. A lossless air-dielectric waveguide for an S-band RADAR has inside dimension a=7.214 cm & b=3.404 cm .for the TM_{11} mode propagating at an operating that is 1.1 times the cutoff frequency of the mode calculate-(a) critical wave number (b) Cutoff frequency (c) operating frequency (d) propagation constant (e) Cutoff wavelength (f) operating wavelength (g) guide wavelength (h) phase velocity (i)wave impedance*

Ans: $K_{c11} = \sqrt{\Pi/a^2 + \Pi/b^2}$ = 102.05 rad/m [01]

$F_{c11} = \frac{3*10^8}{2\Pi} * 102.05$ = 4.87 GHz [01]

F= 1.1 F_{c11} = 5.36 GHz [01]

$V_{11} = jk_{11} = j\frac{2\Pi}{3*10^8}\left(\sqrt{(5.36)^2 - 4.07^2}\right) 10^9$

$= j\ 46.8\ m^{-1}$ [02]

$\lambda_{c11} = \frac{c}{Fc11}$ = 6.16 cm [01]

$\lambda_0 = \frac{c}{f}$ = 5.6 cm [01]

$\lambda g = \lambda_{11} = \frac{2\Pi}{k11} = \frac{2\Pi}{46.8}$ = 13.4 cm [01]

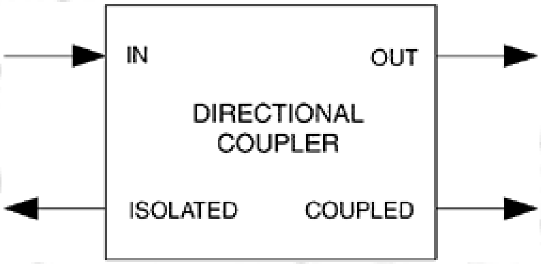
Vg = λgf = 7.18*10^8 m/s [01]

⍰$_{TM\ 11}$ = 120 Π $\sqrt{1-(\frac{fc}{f})^2}$

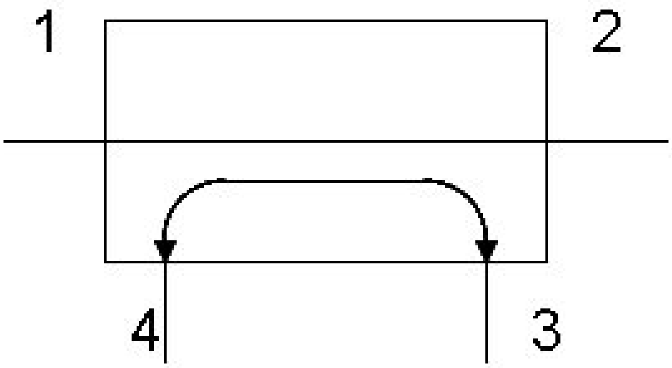
= 157.5 Ω [01]

Q.No. 4. *A] Explain the working & derive the S-matrix for a two hole directional coupler.*

Ans:



[04]



Directional Couplers:-

Directional couplers are used in a wide variety of applications and can satisfy almost any requirement for sampling incident and reflected microwave power conveniently and accurately with minimal disturbance to the transmission line. Some general applications for directional couplers include line monitoring, power measurements and load source isolators. DrawCom offers a wide selection of directional couplers designed to exceed commercial specifications. Standard coupling values of 6, 10, 20, 30 and 40 dB are available from stock.

Custom configurations with special coupling values, external high power terminations and alternate connector styles or plating are also readily available in quantity. All models may be specified without an internal termination for bi-directional coupling. Passive intermodulation (PIM) compliant and weather resistant models are also available.

A wide range of directional or transmitter couplers are available from miniature low power to broadband, high power versions. Directional couplers are available to sample power/frequency at a pre-set coupling level with a sampling/coupling range 6dB to 30dB. Single or dual outputs can be provided. The broadband transmitter coupler design allows operation across the range from 800 –2500MHz making it particularly suitable for use in the distribution of multiple operators into buildings and tunnels. All units are manufactured to IP65 standard.

-High directivity

- Good VSWR

- High power

-Broadband 800 to 2500MHz

A directional coupler has four ports which we can draw diagrammatically as

1 2
4 3

taken in clockwise order around the device. For illustration we consider a directional coupler where port 1 couples to ports 2 and 3 only but not to port 4, and where port 2 couples to ports 1 and 4 only, but not to port 3.

The absence of coupling between ports 1 and 4, and between ports 2 and 3, means that $s14 = 0$ and $s23 = 0$.

Applying these properties to our general matched 4-port relationships above, we find that

$$s12s12^* + s13s13^* = 1$$
$$s12s12^* + s24s24^* = 1$$

so that

$$s13s13^* = s24s24^*$$

and similarly

$$s12s12^* + s24s24^* = 1$$
$$s34s34^* + s24s24^* = 1$$

so that

$$s12s12^* = s34s34^*$$

> Let us call the size or complex modulus of s13 the coupling strength k. Then we see that the size of s12 is sqrt(1-k^2). The sizes of s24 and s34 are then k and sqrt(1-k^2)respectively. The coupling strength k is the first of our two arbitrary adjustable parameters.

We now have only one remaining parameter that we can choose; and it has to be a phase angle. Now, since the S-matrix is only determined to within a complex multiplicative factor of modulus unity, as explained above, we can choose the phase angle of s12 to be zero degrees, so that s12 is the real number sqrt(1-k^2). This does not use up one of the constraints imposed by the unitary nature of the S-matrix. Then the relationships above allow us to determine the S-matrix for our directional coupler and we will find that we have a single phase angle which we can specify.

Looking again at our relationships for the off-diagonal (zero) elements of [U] and substituting our values above for the directional coupler we find that since s14=s23=0 there are only two remaining complex constraints..

s12s13* + s24s34* = 0
s12s24* + s13s34* = 0

the size of each of the terms in these two equations is k*sqrt(1-k^2). If we call the phase angle of s13 theta, the phase angle of s24 phi, and the phase angle of s34 psi then the equations reduce to (since the phase of s12 is 0)

In a directional coupler all four ports are completely matched. Thus the diagonal elements of the **S** matrix are zeros and

$$S_{11} = S_{22} = S_{33} = S_{44} = 0$$

As noted, there is no coupling between port 1 and port 3 and between port 2 and port 4. Thus

$$S_{13} = S_{31} = S_{24} = S_{42} = 0$$

Consequently, the **S** matrix of a directional coupler becomes

$$\mathbf{S} = \begin{bmatrix} 0 & S_{12} & 0 & S_{14} \\ S_{21} & 0 & S_{23} & 0 \\ 0 & S_{32} & 0 & S_{34} \\ S_{41} & 0 & S_{43} & 0 \end{bmatrix}$$

$$S_{12}S_{14}^* + S_{32}S_{34}^* = 0$$

$$S_{21}S_{23}^* + S_{41}S_{43}^* = 0$$

Also from the unity property of the **S** matrix, we can write

$$S_{12}S_{12}^* + S_{14}S_{14}^* = 1$$

$$|S_{12}||S_{14}| = |S_{32}||S_{34}|$$

$$|S_{21}||S_{23}| = |S_{41}||S_{43}|$$

The S matrix of a directional coupler is reduced to

$$\mathbf{S} = \begin{bmatrix} 0 & p & 0 & jq \\ p & 0 & jq & 0 \\ 0 & jq & 0 & p \\ jq & 0 & p & 0 \end{bmatrix}$$

[06]

Q.No. 4. b. With neat diagrams explain the working of a Gunn diode. [04]

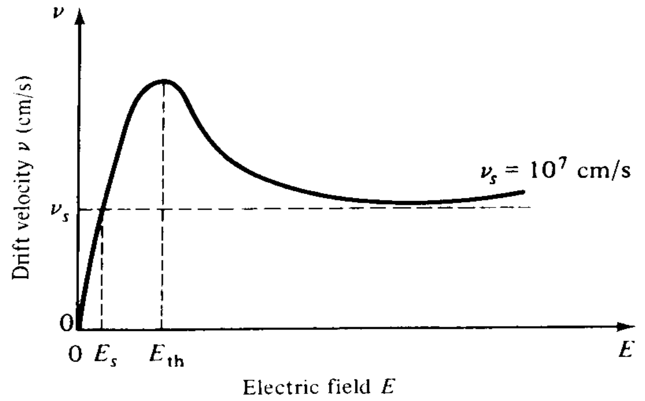
Ans: A Gunn diode, also known as a transferred electron device (TED), is a form of diode used in high-frequency electronics. It is somewhat unusual in that it consists only of N-doped semiconductor material, whereas most diodes consist of both P and N-doped regions. In the Gunn diode, three regions exist: two of them are heavily N-doped on each terminal, with a thin layer of lightly doped material in between. When a voltage is applied to the device, the electrical gradient will be largest across the thin middle layer. Conduction will take place as in any conductive material with current being proportional to the applied voltage. Eventually, at higher field values, the conductive properties of the middle layer will be altered, increasing its resistivity and reducing the gradient across it, preventing further conduction and current actually starts to fall down. In practice, this means a Gunn diode has a region of negative differential resistance.

The negative differential resistance, combined with the timing properties of the intermediate layer, allows construction of an RF relaxation oscillator simply by applying a suitable direct current through the device. In effect, the negative differential resistance created by the diode will negate the real and positive resistance of an actual load and thus create a "zero" resistance circuit which will sustain oscillations indefinitely. The oscillation frequency is determined partly by the properties of the thin middle layer, but can be tuned by external factors. Gunn diodes are therefore used to build oscillators in the 10 GHz and higher (THz) frequency range, where a resonator is usually added to control frequency. This resonator can take the form of a waveguide, microwave cavity or YIG sphere. Tuning is done mechanically, by adjusting the parameters of the resonator, or in case of YIG spheres by changing the magnetic field

Gallium arsenide Gunn diodes are made for frequencies up to 200 GHz, gallium nitride materials can reach up to 3 terahertz.

The Gunn diode is based on the Gunn effect, and both are named for the physicist J. B. Gunn who, at IBM in 1962, discovered the effect because he refused to accept inconsistent experimental results in Gallium arsenide as "noise", and tracked down the cause. Alan Chynoweth, of Bell Telephone Laboratories, showed in June 1965 that only a transferred-electron mechanism could explain the experimental results The interpretation refers to the Ridley-Watkins-Hilsum theory.

The Gunn effect, and its relation to the Watkins-Ridley-Hilsum effect entered the monograph literature in the early 1970s, e.g. in books on transferred electron devices and, more recently on nonlinear wave methods for charge transport.[5] Several other books that provided the same coverage were published in the intervening years, and can be found by searching library and bookseller catalogues on Gunn effect.



[02]

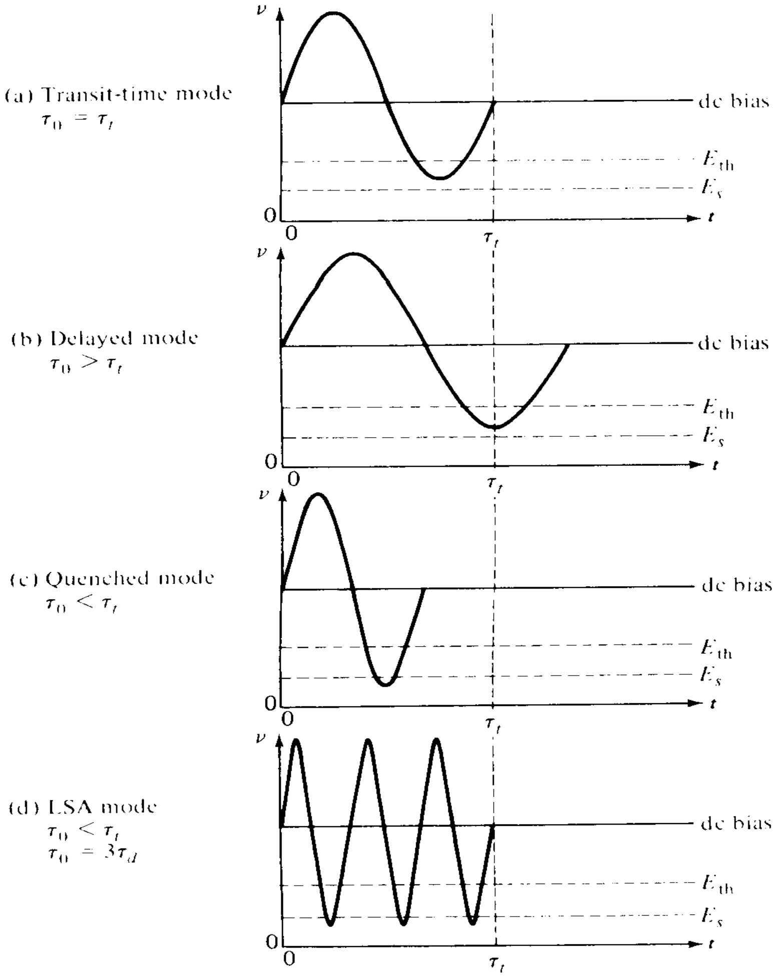


Figure 7-3-4 Gunn domain modes.

[04]

Q.No. 5. *A. Design a composite low pass filter by the image parameter method with the following specifications: R_0=500 MHz, fc = 50MHz f =52MHz*

Ans: Constant k section:

$L = \frac{2R0}{wc} = 3.18 * 10^{-7}$

$\frac{L}{2} = 159$ mH $\quad C = \frac{2}{w0R0} = 127$ pF [02]

m derived section :

m= $\sqrt{1-(\frac{fc}{f})^2}$ = 0.275

$\frac{ml}{2}$ = 43.7nH mc = 34.9 pF (1-m^2)L = 2.67 nH [03]

Diagram [05]

Q.No. 5. *b. With suitable diagrams, explain th working of reflex klystron.*

Ans: Another tube based on velocity modulation, and used to generate microwave energy, is the REFLEX KLYSTRON (figure 2-9). The reflex klystron contains a REFLECTOR PLATE, referred to as the REPELLER, instead of the output cavity used in other types of klystrons. The electron beam is modulated as it was in the other types of klystrons by passing it through an oscillating resonant cavity, but here the similarity ends. The feedback required to maintain oscillations within the cavity is obtained by reversing the beam and sending it back through the cavity. The electrons in the beam are velocity-modulated before the beam passes through the cavity the second time and will give up the energy required to maintain oscillations. The electron beam is turned around by a negatively charged electrode that repels the beam. This negative element is the repeller mentioned earlier. This type of klystron oscillator is called a reflex klystron because of the reflex action of the electron beam.

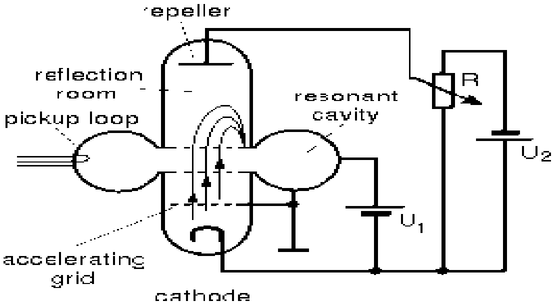
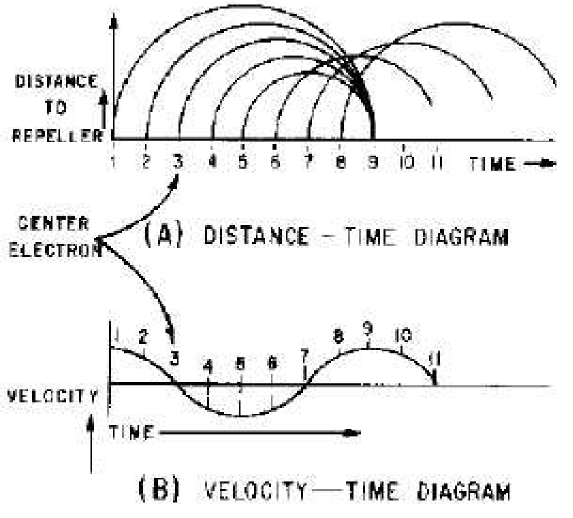


Figure Functional diagram of a reflex klystron. [03]

Three power sources are required for reflex klystron operation: (1) filament power, (2) positive resonator voltage (often referred to as beam voltage) used to accelerate the electrons through the grid gap of the resonant cavity, and (3) negative repeller voltage used to turn the electron beam around. The electrons are focused into a beam by the electrostatic fields set up by the resonator potential (B+) in the body of the tube. Note in figure 2-9 that the resonator potential is common to the resonator cavity, the accelerating grid, and the entire body of the tube.

The resonator potential also causes the resonant cavity to begin oscillating at its natural frequency when the tube is energized. These oscillations cause an electrostatic field across the grid gap of the cavity that changes direction at the frequency of the cavity. The changing electrostatic field affects the electrons in the beam as they pass through the grid gap. Some are accelerated and some are decelerated, depending upon the polarity of the electrostatic field as they pass through the gap. Figure 2-10, view (A), illustrates the three possible ways an electron can be affected as it passes through the gap (velocity increasing, decreasing, or remaining constant). Since the resonant cavity is oscillating, the grid potential is an alternating voltage that causes the electrostatic field between the grids to follow a sine-wave curve as shown in figure 2-10, view (B). As a result, the velocity of the electrons passing through the gap is affected uniformly as a function of that sine wave. The amount of velocity change is dependent on the strength and polarity of the grid voltage. [02]

Figure Electron bunching diagram.

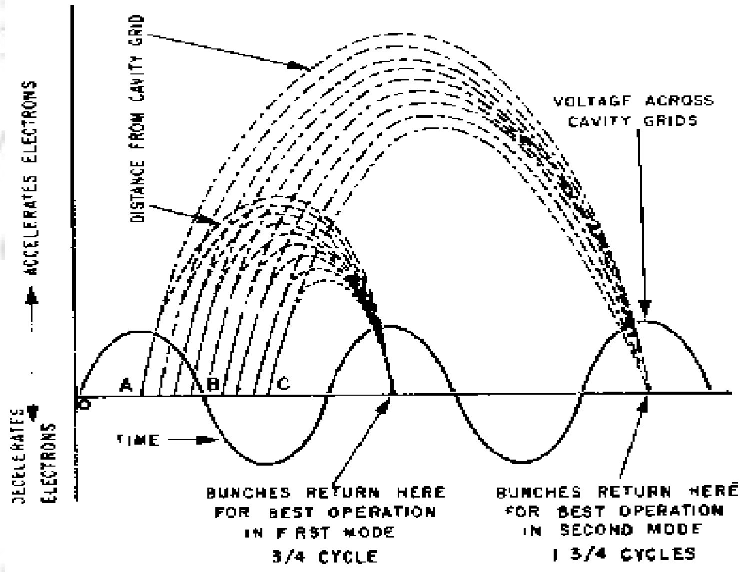


The variation in grid voltage causes the electrons to enter the space between the grid and the repeller at various velocities. For example, in figure 2-10, views (A) and (B), the electrons at times 1 and 2 are speeded up as they pass through the grid. At time 3, the field is passing through zero and the electron is unaffected. At times 4 and 5, the grid field is reversed; the electrons give up energy because their velocity is reduced as they pass through the grids.

The distance the electrons travel in the space separating the grid and the repeller depends upon their velocity. Those moving at slower velocities, such as the electron at time 4, move only a short distance from the grid before being affected by the repeller voltage. When this happens, the electron is forced by the repeller voltage to stop, reverse direction, and return toward the grid. The electrons moving at higher velocities travel further beyond the grid before reversing direction because they have greater momentum. If the repeller voltage is set at the correct value, the electrons will form a bunch around the constant-speed electrons. The electrons will then return to the grid gap at the instant the electrostatic field is at the correct polarity to cause maximum deceleration of the bunch. This action is also illustrated in figure 2-10, view (A). When the grid field provides maximum deceleration, the returning electrons release maximum energy to the grid field which is in phase with cavity current. Thus, the returning electrons supply the regenerative feedback required to maintain cavity oscillations.

The constant-speed electrons must remain in the reflecting field space for a minimum time of 3/4 cycle of the grid field for maximum energy transfer. The period of time the electrons remain in the repeller field is determined by the amount of negative repeller voltage. The reflex klystron will continue to oscillate if the electrons remain in the repeller field longer than 3/4 cycle (as long as the electrons return to the grid gap when the field is of the proper polarity to decelerate the electrons). Figure 2-11 shows the effect of the repeller field on the electron bunch for 3/4 cycle and for 1 3/4 cycles. Although not shown in the figure, the constant-velocity electrons may remain in the repeller field for any number of cycles over the minimum 3/4 cycle. If the electrons remain in the field for longer than 3/4 cycle, the difference in electron transit time causes the tube performance characteristics to change. The differences in operating characteristics are identified by MODES OF OPERATION.

Figure Bunching action of a reflex klystron. [03]



The reflex klystron operates in a different mode for each additional cycle that the electrons remain in the repeller field. Mode 1 is obtained when the repeller voltage produces an electron transit time of 3/4 cycle. Additional modes follow in sequence. Mode 2 has an electron transit time of 1 3/4 cycles; mode 3 has an electron transit time of 2 3/4 cycles; etc. The physical design of the tube limits the number of modes possible in practical applications. A range of four modes of operation are normally available. The actual mode used (1 3/4 cycles through 4 3/4 cycles, 2 3/4 cycles through 6 3/4 cycles, etc.) depends upon the application. The choice of mode is determined by the difference in power available from each mode and the band of frequencies over which the circuit can be tuned. [02]

Q.No. 6. *A] Design a low pass fourth order maximally flat filter using only shunt stubs. The Cutoff frequency is 8GHz and the impedance is 500Ω*

Ans: f_0 = 8 GHz N = 4 Low pass maximally flat Z0=50 Ω from table

applying Richard transform & adding unit element

use kuorda's identity from first identity

$Z_1 = 0.433$

$Z_2 = 1$

$n_2 = 3.309$ [04]

Q.No. 6. *B] A travelling wave tube operates under the following parameters*

Beam voltage =V_0 =3kv Beam current = I_0=30mA circuit length = N=50

Characteristics impedance of helix=Z_0=10Ω Frequncy = 10 GHz

Determine (1)gain parameter C (b) o/p power gain A_p in dB

(c) four propagation constant

Ans: **$C = \left(\frac{I0Z0}{4V0}\right)^{\frac{1}{3}}$ = 2.92 * 10^{-2}** **[01]**

Ap = -9.54+47.3 Nc = 59.52 dB **[01]**

$\beta = \frac{w}{v0}$ V0 = 0.593 * $10^6 \sqrt{Vo}$ [01]

β_e = 1.93 * 10^2 rad/m [01]

V1 = - $\beta_e C \frac{\sqrt{3}}{2} + j \beta_e (1+\frac{C}{2})$

= -49.03+j195.2 $[1\frac{1}{2}]$

V2 = $\beta e\, C \frac{\sqrt{3}}{2} + j \beta_e (1+\frac{C}{2})$

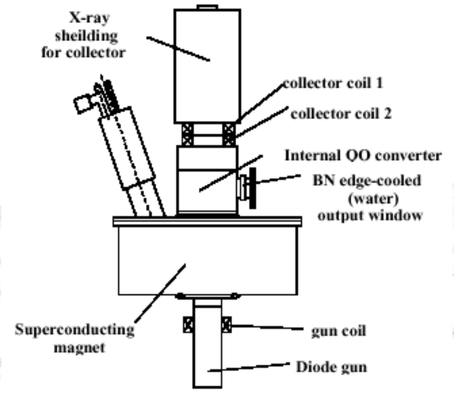
= 49.03+j195.2 $[1\frac{1}{2}]$

V3 = j βe (1-c) = j1872.25 $[1\frac{1}{2}]$

V4 = - j βe $(1-\frac{c^3}{4})$ = -j 1930

Q.No. 7. a. Explain principle of operation of a gyrotron.

Ans:



[02]

Gyrotrons are high powered vacuum tubes which emit millimeter-wave beams by bunching electrons with cyclotron motion in a strong magnetic field. Output frequencies range from about 20 to 250 GHz, covering wavelengths from microwave to the edge of the terahertz gap. Typical output powers range from tens of kilowatts to 1-2 megawatts. Gyrotrons can be designed for pulsed or continuous operation.

Principle of operation

The gyrotron is a type of free electron maser (microwave amplification by stimulated emission of radiation). It has high power at millimeter wavelengths because its dimensions can be much larger than the wavelength, unlike conventional vacuum tubes, and it is not dependent on material properties, as are conventional masers. The bunching depends on a relativistic effect called the Cyclotron Resonance Maser instability. The electron speed in a gyrotron is slightly relativistic (comparable to but not close to the speed of light). This contrasts to the free electron laser (and xaser) that work on different principles and which electrons are highly relativistic.

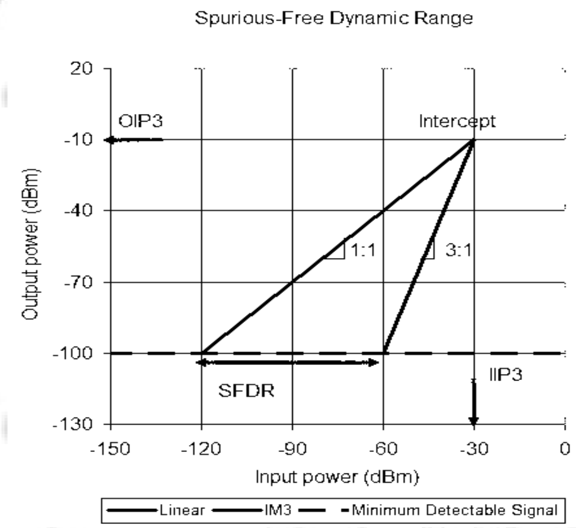
Applications

Gyrotrons are used for many industrial and high technology heating applications. For example, gyrotrons are used in nuclear fusion research experiments to heat plasmas, and also in manufacturing industry as a rapid heating tool in processing glass, composites, and ceramics, as well as for annealing (solar and semiconductors). Additionally, years of testing by the U.S. military has led to the development of a weapon system intended for non-lethal crowd control called the Active Denial System, which heats the skin of the crowd it is directed at to unpleasant levels. [03]

Q.No. 7. *b. Briefly explain the concept of Dynamic range.*

Ans: Dynamic range has the same meaning in audio. In orchestras there are passages of nearsilence, along with passages of booming cannons, in the case of the 1812 Overture. Recording and reproducing wide dynamic range is a challenge. Sometimes a wide dynamic range is an annoyance. Did you ever try listening to a "book on tape" in a car on the highway? If the speaker's voice goes up and down in volume, you find yourself adjusting the speaker volume in order to boost the quiet passages above the wind, motor and tire noise, and reducing it when shouting starts in order to spare your ears. In this manner, you have have become a compander, mitigating the effects of a signal that has too much dynamic range for the channel (your ears). The word "compansion" is a portmanteau, a contraction of compression/expansion.

Spurious-free dynamic rangeThis is equal to 2/3 of the range between the minimum detectable signal, and the third order intercept. Defined this way, the dynamic range is the area between the minimum detectable signal, and the point where the third-order product exceeds minimum detection level.



[02]

Linear dynamic range

The linear dynamic range of a receiver is a measurement of the minimum detectable signal, to the maximum signal that will start to compress the receiver.

Extending dynamic range

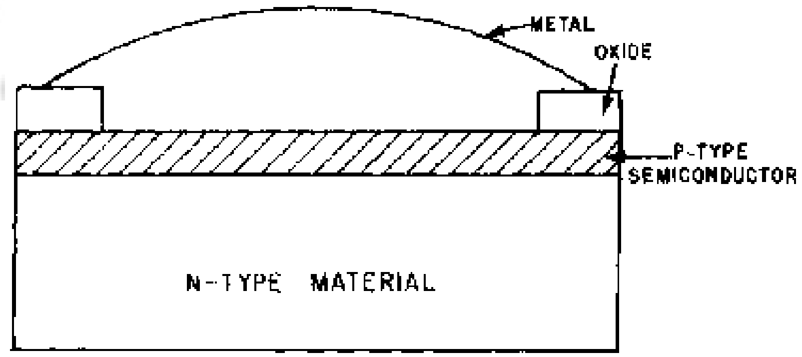
Switchable attenuators can be used in front of the receiver to extend the dynamic range. However, this is at a cost of higher noise figure in the low gain state. [03]

Q.No. 7.C] Explain the working of a schottky diode.

Ans :- The SCHOTTKY BARRIER DIODE is actually a variation of the point-contact diode in which the metal semiconductor junction is a surface rather than a point contact. The large contact area, or barrier, between the metal and the semiconductor in the Schottky barrier diode provides some advantages over the point-contact diode. Lower forward resistance and lower noise generation are the most important advantages of the Schottky barrier diode. The applications of the Schottky barrier diode are the same as those of the point-contact diode. The low noise level generated by Schottky diodes makes them especially suitable as microwave receiver detectors and mixers.

The Schottky barrier diode is sometimes called the HOT-ELECTRON or HOT-CARRIER DIODE because the electrons flowing from the semiconductor to the metal have a higher energy level than the electrons in the metal. The effect is the same as it would be if the metal were heated to a higher temperature than normal. Figure is an illustration of the construction of a Schottky barrier diode. [02]

Figure Schottky-barrier diode.



[03]