RF paper solution / UT-1 /ECE-1 and 2

- Group:- A (MCQ)

Q.1.
The ~~dominant~~ dominant mode of propagation in a rectangular waveguide is ——

TE_{10}

Q.2.
What is the mode of Microstrip line ——

Quasi TEM

Q.3.
What is the approximate bandwidth of radio frequen-cy (RF) electromagnetic waves ——

30 Hz to 300 GHz

Q.4.
The modes of propagation supported by a rectangular waveguide ——

TM and TE

Q.5.
The frequency range of Ku band is ——

300 Hz to 300 GHz

Q.6.
In TM mode, if the direction of wave propagation is in 'z' direction, then ——

$H_z = 0$

Q.7.
For any mode of propagation in a rectangular wave-guide, propagation occurs ——

Above the cut-off frequency

- Group:- B (SAQ)

Q. 1.

What is TE, TM, TEM and Quasi TEM mode?

→ • Transverse electromagnetic (TEM) mode:-
Neither electric nor magnetic field in the direction of propagation.

• Quasi TEM:-
When electric field has fringing effect, then TEM mode is called quasi TEM.

• Transverse Electric (TE) mode:-
No electric field in the direction of propagation. It is also called H mode because there is only magnetic field along the direction of propagation

• Transverse Magnetic (TM) mode:-
No magnetic field in the direction of propagation. It is also called E mode because there is only electric field along the direction of propagation.

Q. 2.

What are the application of RF and microwave.

→ i) Used in wireless communication
(ex:- bluetooth, Wireless LAN etc.)

ii) Used in electronics appliances
(ex:- phase shifter, etc.)

iii) Used in commercial instruments
(ex:- Remote sensing, Garage door openers etc.)

iv) Used in navigation
(ex:- GPS etc.)

vi) Used in military and RADAR
(ex:- RADAR, SONAR, Weather forecast, Minesweepers etc.)

vii) Food industry
(ex:- Microwave ovens, Food processing etc.)

vii) Industrial uses
(ex:- RF lighting, Power transmission etc.)

viii) Semiconductor processing technique
(ex:- Reacting ion etching, Chemical vapor deposition etc.)

ix) Spectroscopy
(ex:- Electron paramagnetic resonance / EPR, Electron spectroscopy resonance / ESR etc.)

x) Medical Application
(ex:- Monitoring heartbeat, etc.)

Q.3.
What are the advantages and disadvantages of RF and microwave?

→ Advantages of RF and microwave:-

i) High ~~frequency~~ energy transfer efficiency.
ii) Short process time.
iii) We can use it in many different ways

Disadvantages:-

i) Uncontrolled radiation of RF affects living creature.
ii) It has limited frequency bandwidth.

Q.4.

What are the different types of waveguides: explain in details.

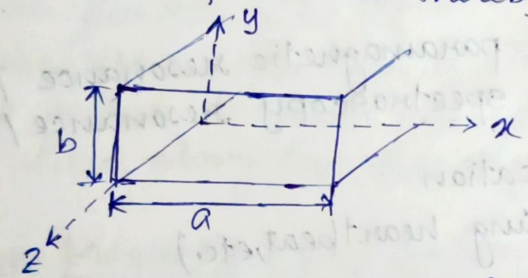
→ **Waveguides:-**

A hollow metalic tube of uniform cross-section for transmitting em waves by successive reflections from the inner walls of the tube.

Types:-

i) **Rectangular:-**

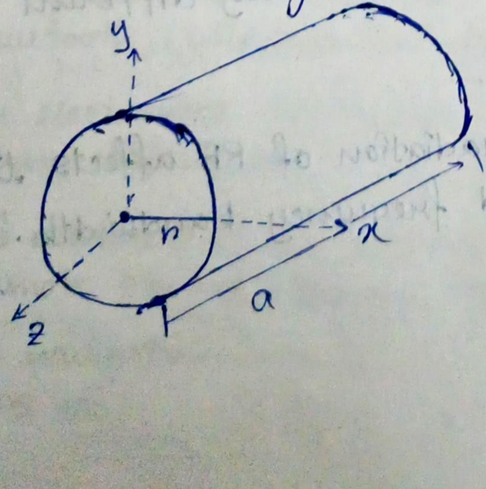
A hollow metallic tube with a rectangular cross section. The conducting walls of the waveguide confine the em fields and thereby guide the em wave.



It supports TE and TM modes of propagation but it doesn't support TEM mode.

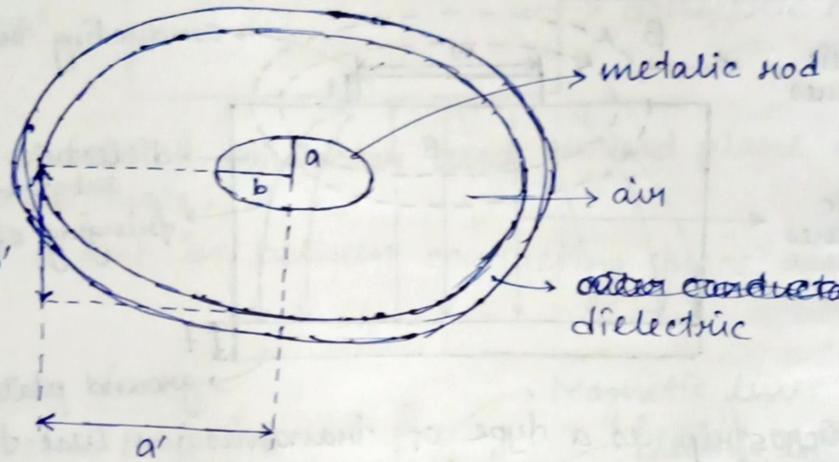
ii) **Circular:-**

A hollow metallic tube with a circular cross-section. It supports TE and TM modes of propagation. The field distribution of each mode varies with the circumferential and radial variations in the circular waveguide.



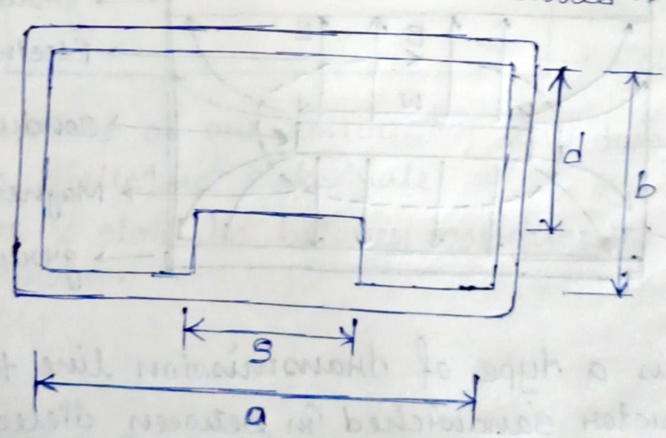
iii) Elliptical:-

A ~~metal~~ hollow metalic tube with a elliptical cross-section. It has the corrugated wall structure that gives the waveguide high-crush strength, lighter weight and better flexibility.



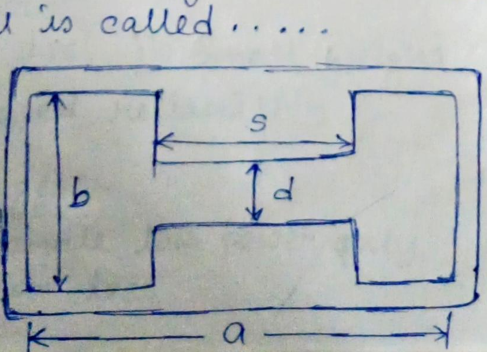
iv) Single Ridged Waveguides:-

A rectangular waveguide with a single protruding ridge from the top or bottom wall is called....



v) Double Ridged Waveguides:-

A rectangular waveguide with a ridge from the top and bottom wall is called....

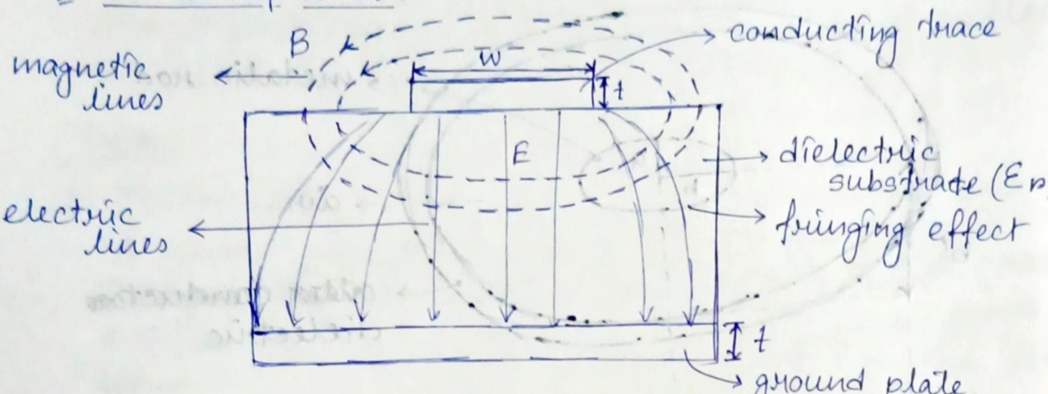


Q.5.

What are the different types of planar transmission line?

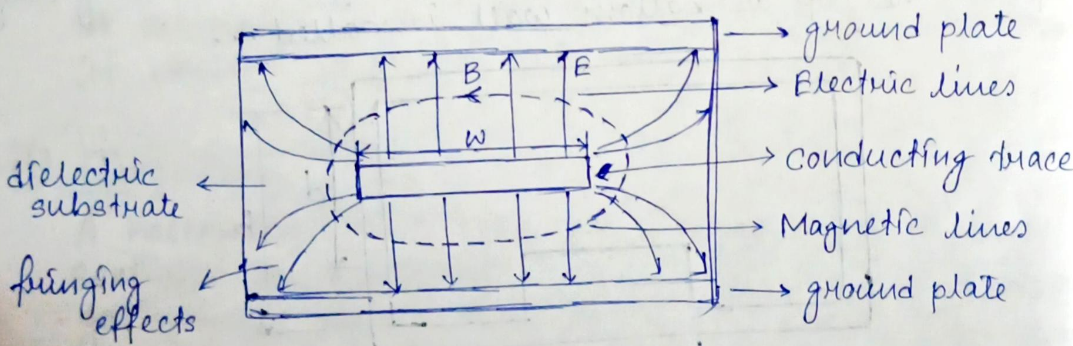
→ Types of planar transmission lines:-

i) Microstrip lines:-



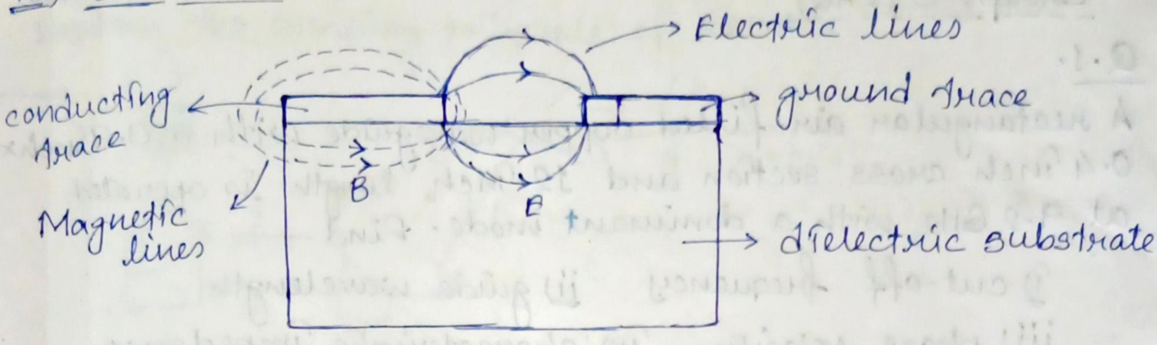
A microstrip is a type of transmission line that consists of a conductor fabricated on dielectric substrate with a grounded plate.

ii) Strip line:-



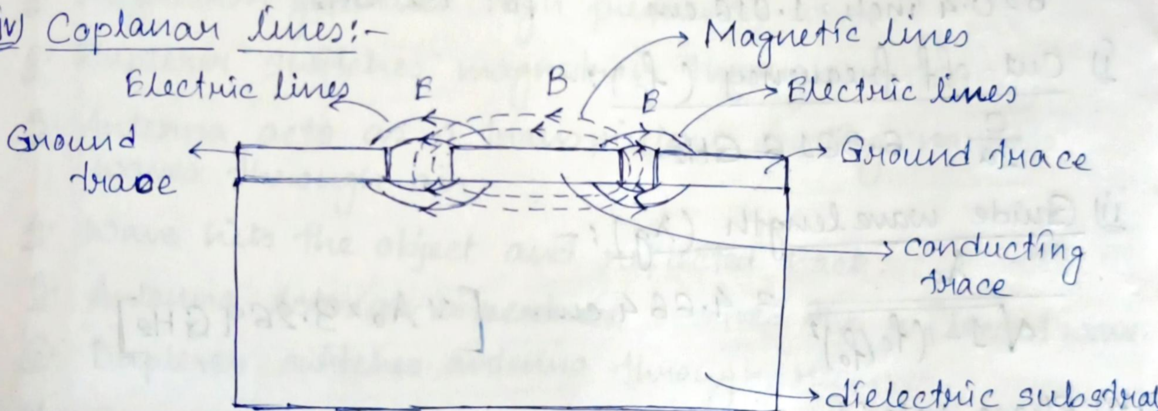
Strip line is a type of transmission line that consists of a conductor sandwiched in between dielectric substrates with two grounded plane.

iii) Slot lines :-



... that consists of conductor and ground plane on dielec-tric substrate.
There's a slot in between conducting trace and ground trace.

IV) Coplanar lines :-



... that consists of one conductor and two ground traces on dielectric substrate.
There are 2 slots in between conducting traces and ground traces.

Q.6.
Advantages and disadvantages of Planar transmission lines.

→ Advantages :-
i) Small size, ii) Small weight, iii) Low cost
iv) Increased reliability

Disadvantages :-
i) Can handle low power only
ii) Radiation loss

• Group :- C (LAQ)

Q.1.

A rectangular air-filled copper waveguide with a 0.9 inch × 0.4 inch cross section and 12 inch length is operated at 9.2 GHz with a dominant mode. Find —

i) cut-off frequency ii) guide wavelength

iii) phase velocity iv) characteristic impedance

v) the loss.

→ Given —

$a = 0.9$ inch $= 2.286$ cm

$b = 0.4$ inch $= 1.016$ cm

$f_0 = 9.2$ GHz

i) Cut-off frequency (f_c) :-

$$\frac{c}{2a} = 6.5616 \text{ GHz}.$$

ii) Guide wavelength (λ_g) :-

$$\frac{\lambda_0}{\sqrt{1-(f_c/f_0)^2}} = 4.664 \text{ cm}. \quad [\because \lambda_0 = 3.269 \text{ GHz}]$$

iii) Phase velocity :-

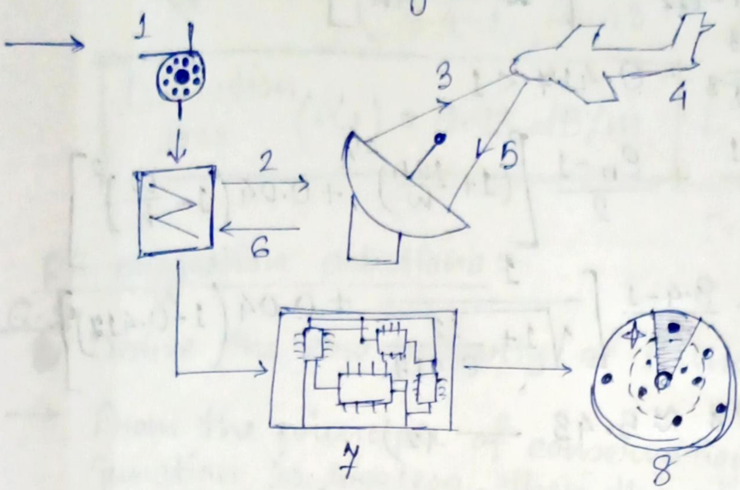
$$\frac{c}{\sqrt{1-(f_c/f_0)^2}} = 4.29 \times 10^8 \text{ m/s}$$

iv) Characteristic impedance :- (Z_0)

$$\frac{376.7}{\sqrt{1-(f_c/f_0)^2}} = 537.419 \, \Omega$$

Q.2.

Explain the working principle of RADAR.



1. Magnetron generates high frequency wave.
2. Duplexer switches magnetron through antenna.
3. Antenna acts as a transmitter, sending narrow waves through air.
4. Wave hits the object and reflected back.
5. Antenna ~~acts as a receiver~~ received the reflected wave.
6. Duplexer switches antenna through receiver.
7. Computer in receiver unit analyse the reflected wave.
8. Enemy plane and other nereby targets are showed on the monitor.

Q.3.

A microstrip line is composed of zero thickness copper conductor on a substrate having $\varepsilon_r = 8.4$, $\tan\delta = 0.0005$ and thickness 2.4 mm. If the line width is 1 mm and operated at 10 GHz. Calculate —

a) the characteristic impedance.

b) the attenuation due to conductor loss and dielectric loss.

i) We know, $Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln\left[\frac{8h}{w} + \frac{w}{4h}\right]$ —— (1)

Here, $\frac{w}{h} = \frac{1\times10^{-3}}{2.4\times10^{-3}} = 0.417 < 1$

$\therefore \varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+\frac{12h}{w}\right)^{-1/2} + 0.04\left(1-\frac{w}{h}\right)^2\right]$

$= \frac{8.4+1}{2} + \frac{8.4-1}{2}\left[\frac{1}{\sqrt{1+\frac{12}{0.417}}} + 0.04\left(1-0.417\right)^2\right]$

$\therefore \varepsilon_{eff} = 5.428 \approx 5.43$ —— (2)

From (1) and (2):-

$Z_0 = \frac{60}{\sqrt{5.43}} \ln\left[\frac{8}{0.417} + \left(\frac{1}{4}\times0.417\right)\right]$

$\therefore \boxed{Z_0 = 76.2\,\Omega}$ [ans (1)]

ii) $8.686\, R_s / Z_0 w$ = Conductor loss (α_c) —— (1)

where, $R_s = \sqrt{\frac{\pi f \mu}{\sigma}} = \sqrt{\frac{3\times10\times10^9\times4\pi\times10^{-7}}{5.8\times10^7}}$

For conductor: —

$\sigma = 5.8\times10^7$ ohm/m^2

$\therefore R_s = 2.6\times10^{-2}$ ohm/m^2 —— (2)

$\therefore$ From (1) and (2): —

$\alpha_c = \frac{8.686\times2.6\times10^{-2}}{76.2\times1\times10^{-3}}$ dB/m

$\boxed{\text{Conduction loss } (\alpha_c) = 2.963 \text{ dB/m}}$ —— (3) [ans (2)]

Again, dielectric loss $(\alpha_d) = 27.3\left(\frac{\varepsilon_{eff}-1}{\varepsilon_r-1}\right)\cdot\frac{\varepsilon_r}{\varepsilon_{eff}}\cdot\frac{\tan\delta}{\lambda_g}$

where, $\lambda = \frac{c}{f} = \frac{3\times10^8}{10\times10^9} \approx 3$ cm —— (4)

and, $\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}} = \frac{3}{\sqrt{5.43}} = 1.287$ cm. —— (5)

$\therefore$ From (4) and (5) —

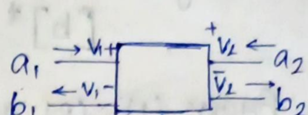
$$\alpha_d = 27.3 \left(\frac{5.43-1}{8.4-1}\right)\frac{8.4}{5.43} \times \frac{0.0005}{1.287\times10^{-2}}$$

$$\boxed{\text{Direction loss } (\alpha_d) = 0.98 \text{ dB/m}}$$ [ans (3)]

RF suggestion solutions :-

Q.1.

Derive the zero property of S matrix.



→ From the principle of conservation of energy, if the junction is lossless, then the power input must be equal to power output. The incident and reflected waves are related to the incident and reflected voltages by —

$$a = \frac{V^+}{\sqrt{Z_0}} \quad \text{and} \quad b = \frac{V^-}{\sqrt{Z_0}}$$

$\therefore$ The incident power $= P^+ = \frac{1}{2} a.a^* = \frac{1}{2}|a|^2$

and the Reflected power $= P^- = \frac{1}{2} b.b^* = \frac{1}{2}|b|^2$

When the junction is lossless, then no real power can be delivered to the network. Thus, if the characteristic impedance of all the ports are identical and assumed to be unity (perfectly normalized), the avg. power delivered to junction is zero.

$$\therefore P_{av} = \frac{1}{2} Re \sum_{i=1}^{n} V_i I_i^* = 0$$

where, I_i^* = complex conjugate of I_i

We know —

$$V_i I_i^* = (a_i+b_i)(a_i-b_i)^*$$

$$\therefore P_{av} = \frac{1}{2} Re \sum_{i=1}^{n} (a_i+b_i)(a_i-b_i)^* = 0$$

$$\Rightarrow \frac{1}{2} Re \sum_{i=1}^{n} (a_i+b_i)(a_i^*-b_i^*) = 0$$

$$\Rightarrow \frac{1}{2} Re \sum_{i=1}^{n} \left[(a_i a_i^* - b_i b_i^*) + (a_i^* b_i - a_i b_i^*)\right] = 0$$

$$\therefore \sum_{i=1}^{n} [(a_i a_i^* - b_i b_i^*)] = 0$$

This eq. can be written in matrix form as —

$$[a][a]^* - [b][b]^* = [0] \quad \text{——— (1)}$$

From the two port n/w, we can write —

$$[b] = [S][a] \quad \text{——— (2)}$$

Taking complex conjugate ~~of~~ on both sides —

$$[b]^* = [S]^*[a]^* \quad \text{——— (3)}$$

From (1), (2) and (3) —

$$[a][a]^* - [S][a][S]^*[a]^* = [0]$$

$$[a][a]^* \{[U] - [S][S]^*\} = 0$$

$[U]$ = unit matrix

Since, $[a][a]^*$ can't be 0, then —

$$[U] - [S][S]^* = 0$$

$$\therefore [S][S]^* = [U] \quad \text{——— (4)}$$

Multiply both sides of equation (4) by $[S]^{-1}$, we get —

$$[S]^{-1}[S][S]^* = [S]^{-1}[U]$$

$$\therefore [S]^* = [S]^{-1} \quad \text{——— (5)}$$

Now, we know —

$$[S] = [S]^T \quad \text{——— (6)}$$

from (5) and (6) —

$$[S]^* = \{[S]^T\}^{-1} \quad \text{——— (7)}$$

Eq. (7) in ~~matrix~~ summation form —

$$\sum_{k=1}^{n} S_{ki} S_{kj}^* = \delta_{ij} \text{ for all } i, j$$

Where,

$$\delta_{ij} = 1 \text{ if } i = j$$

$$\delta_{ij} = 0 \text{ if } i \neq j$$

$\therefore$ if $i = j$:-

$$\sum_{i=1}^{k} S_{ki} S_{kj}^{*} = 1$$ — [unitary property]

if $i \neq j$:-

$$\sum_{i=1}^{k} S_{ki} S_{kj}^{*} = 0$$ — [zero property]

X

Q.2. / Q.2B.

What is meant by π mode operation in a magnetron containing eight cavity resonator?

→ π-mode operation: Pi(π) mode operation of magnetron is a mode of operation for which the phases of the fields of successive anode openings facing the ~~interconnection~~ interaction space differ by π radians.

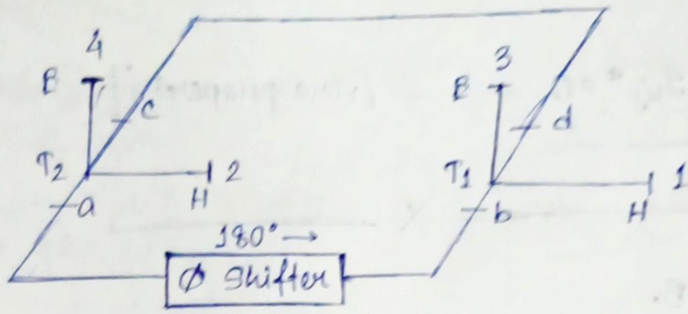
π-mode oscillation: For sustaining the oscillation in a magnetron, the phase difference between two adjacent anode plate should equal $(2\pi n/N)$ where N is the no. of cavities and n is ~~the no.~~ any integer, this gives rise to π mode operation.

Since the magnetron has eight coupled cavity resonators, several different ~~nodes~~ modes of oscillation is possible. The oscillating freq. corresponding to the different modes aren't same. Some are quite close to one another, so that a π-mode oscillation which is normal for magnetron becomes $(3/4)\pi$ mode oscillation.

Q.4.

Describe the operation of four-port microwave circulator.

→



Four port circulator constructed of two magic tees and a phase shifter. An i/p signal at port 1 is split into two in-phase and equal magnitude waves in colinear arms b and d and the additive o/p is obtained at port 2. Similarly, an i/p signal at port 2 is split into two in-phase and equal magnitude waves in colinear arms a and c and appears at b and d out of phase because of phase shifter. So the o/p will appear at port 3. Similarly when an i/p signal is fed at port 3, it will emerge from 4 and i/p at port 4 will appear at port 1.

A perfectly matched, lossless and non reciprocal four port circulator has an S matrix —

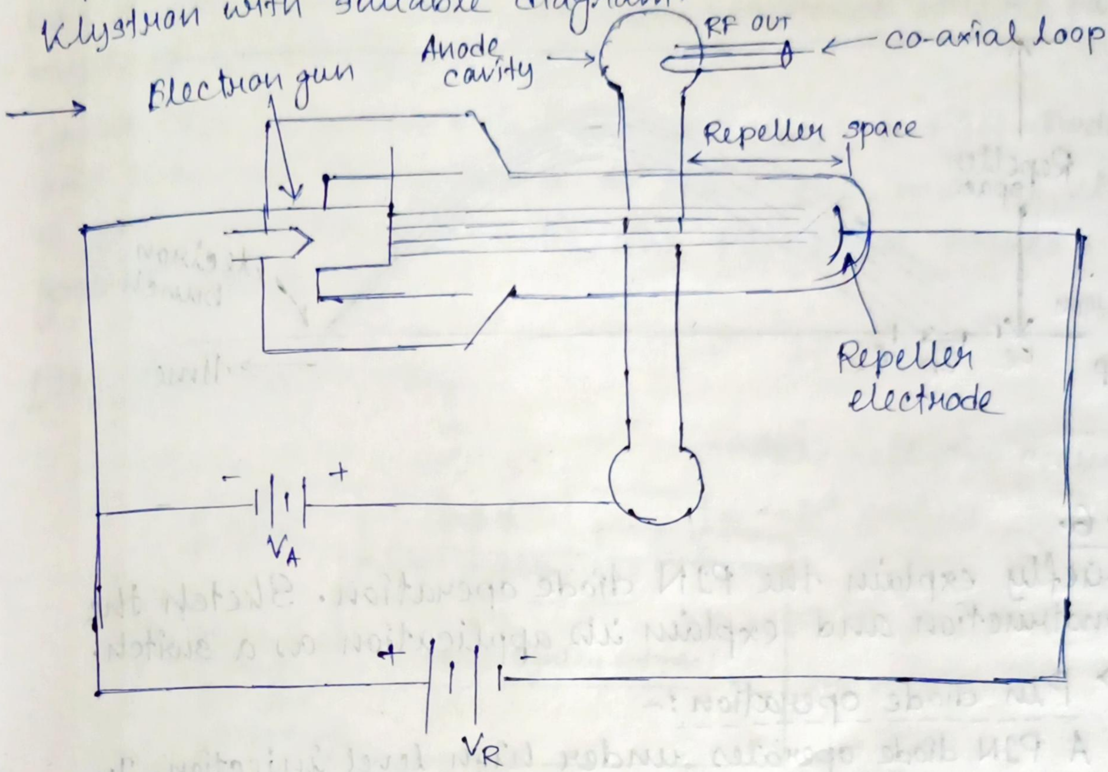
$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & S_{14} \\ S_{21} & 0 & S_{23} & S_{24} \\ S_{31} & S_{32} & 0 & S_{34} \\ S_{41} & S_{42} & S_{43} & 0 \end{bmatrix}$$

Using the properties of S-parameter —

$$[S] = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

Q.B.

Explain Transit Time and Mode Number of a Reflex Klystron with suitable diagram.



Let's assume that a reference electron e_r crosses the anode cavity but has no extra velocity and it repels back after reaching the repeller electrode, with the same velocity. Another electron, let's say e_e which has started earlier than this reference electron, reaches the Repeller first, but returns slowly, reaching at the same time as the reference electron.

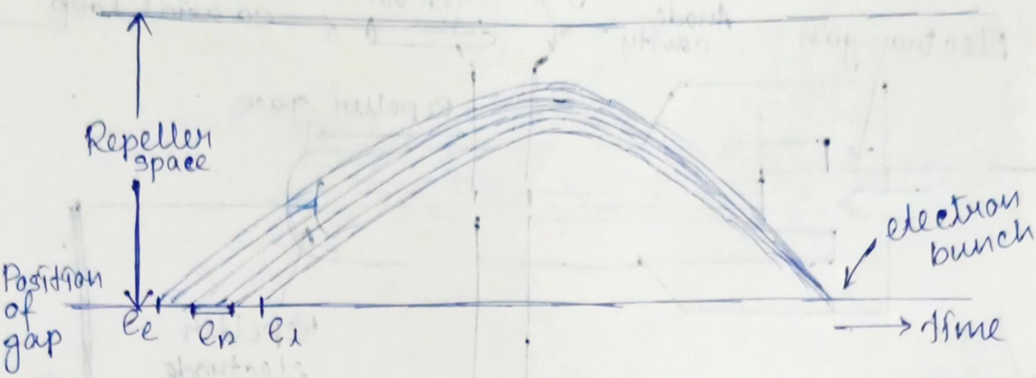
We've another electron, late electron (e_l), which starts later than both e_r and e_e. however, it moves with greater velocity while returning back, reaching at the same time as e_r and e_e.

Now these electrons e_r, e_e and e_l reach the gap at the same time, forming an electron bunch. This travel time is called as transit time.

Mode number:-

There are several combinations of repeller volt. and anode volt. that provide favourable conditions for bunching. Accordingly there may exist several modes of operation expressed by $N+3/4$ where N is an integer.

$1\frac{3}{4}$ and $2\frac{3}{4}$ are the commonly used in a practi-cal reflex klystron.



Q.6.

Briefly explain the PIN diode operation. Sketch the construction and explain its application as a switch.

→ Pin diode operation :-

A PIN diode operates under high level injection. In other words, the intrinsic "i" region is flooded with charge carries from the "p" and "n" regions. The diode will conduct current when the no. of flooded electrons and holes are both equals in intrinsic region.

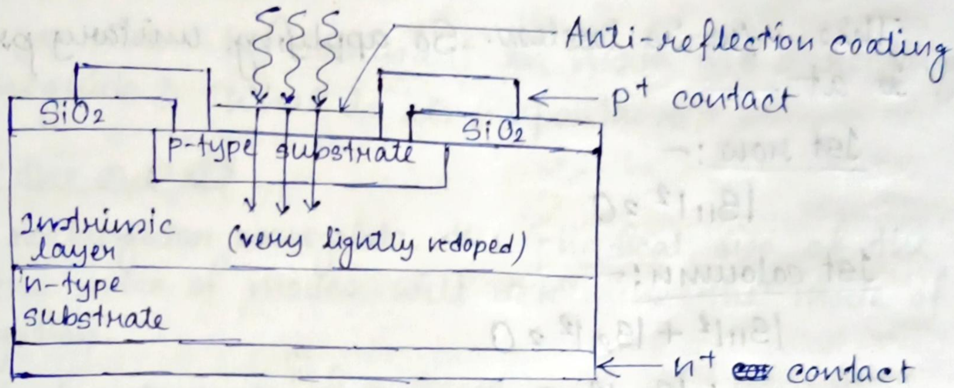
When the diode is forward biased, the injected concentration is typically very much higher than intrinsic carrier concentration. Due to this level injection, which in turn is due to depletion process, the electric field extends almost the entire length into the region. This electric field helps in speeding up the charge carrier transportation from the P to N region which results in faster operation of diode making it a suitable device for high frequency operation.

Application as a switch:-

Under zero or reverse bias (the "off" state), a PIN diode has a low capacitance. The low capacitance willn't pass much of an RF signal.

Under the forward bias (the "on" state), a PIN diode will have an RF resistance of about 1Ω, making it a good conductor of RF. So, the PIN diode makes a good RF switch.

PIN diode construction:-



Q.8.

Consider a loss-less ~~transmission~~ two port network —

i) If the network is reciprocal, show that —

$$|S_{21}|^2 = 1 - |S_{11}|^2$$

ii) If the network is non-reciprocal, show that it's impossible to have unidirectional transmission, where $S_{12} = 0$ and $S_{21} \neq 0$.

$\longrightarrow$ S-matrix of a two port n/w:—

$$[S]_2 = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

i) ~~Bec~~ We can apply unitary property because the n/w is lossless:—

$\therefore$ Applying unitary property at 1st Row:—

$$|S_{11}|^2 + |S_{12}|^2 = 1$$

Applying reciprocal property —

~~$|S_{11}|^2 = 1 - |S_{21}|^2$ [proved]~~

$|S_{21}|^2 = 1 - |S_{11}|^2$ [proved]

Reciprocal property —

$S_{ij} = S_{ji}$

ii) Now, S_{12} is said to be 0, then —

$$[S] = \begin{bmatrix} S_{11} & 0 \\ S_{21} & S_{22} \end{bmatrix}$$

This n/w is lossless. So applying unitary property at —

1st row :—

$$|S_{11}|^2 = 0$$

1st coloumn :—

$$|S_{11}|^2 + |S_{21}|^2 = 0$$

$$\therefore |S_{21}|^2 = 0$$

But, according to the question, $S_{21} \neq 0$. So, it is ~~impos~~ impossible to have unidirectional transmission where $S_{12} = 0$ and $S_{21} \neq 0$. [proved].

Q.9.

A waveguide termination having VSWR = 1.1 is used to dissipate 100 W of power. Find the reflected power.

→ Given,

VSWR = 1.1

$P_{fwd} = 100W$

$$VSWR = \frac{1 + \sqrt{P_{ref}/P_{fwd}}}{1 - \sqrt{P_{ref}/P_{fwd}}}$$

[formula]

Putting the given values in formula —

$$1.1 = \left(1+\sqrt{\frac{P_{ref}}{100}}\right) \Big/ \left(1-\sqrt{\frac{P_{ref}}{100}}\right)$$

$$= \left(10+\sqrt{P_{ref}}\right) \Big/ \left(10-\sqrt{P_{ref}}\right)$$

$$\Rightarrow 11 - \left[(1.1)\times\sqrt{P_{ref}}\right] = 10+\sqrt{P_{ref}}$$

$$\Rightarrow 1 = (2.1)\sqrt{P_{ref}} \quad \therefore P_{ref} \approx 0.2268\ W \text{ [ans]}$$

Q.10.

What do you mean by dominant ~~m~~ mode in a rectangular waveguide? What is its importance?

→ ~~Hence the cut off~~

In a rectangular waveguide, the physical size of the and the index of modes will determine the mode of propagation.

The dominant mode in ~~of~~ a particular waveguide is the mode having the lowest cutoff frequency.

In a rectangular waveguide, lowest cut-off frequency can be obtained when ~~axis~~ ~~too dimensions~~ length is greater than width and mode indexes are $m=1$ and $n=0$.

~~[illegible] so we can't find lowest cut off frequency.~~

The dominant modes in rectangular waveguide are — TE_{10} and TM_{11}

Importance :-

The criterion for the wave propagation through the waveguide ~~th~~ is that the operating frequency should be greater than the dominant mode cut-off frequency. There will be minimum degradation of the signal in the dominant mode.

Q. 11.

Explain the principle of operation of a multi-hole waveguide directional coupler.
Define directivity and coupling.

→ Multihole directional coupler is a four port waveguide junction consisting of primary main waveguide and a secondary auxiliary waveguide.

The first port is named as i/p, second port is named as o/p or transmitted, third port is named as sampling or coupled and fourth port is named as isolated or terminated. By using a special design, the i/p power is divided between o/p and coupled port in a certain ratio called coupling factor. The performance of the directional coupler is usually evaluated by its directivity between port 3 and 4.

The multi hole waveguide directional couplers have a good directivity compared to other couplers.

Directivity :-

The directivity is a calculated parameter from isolation and coupling factor and shows how the two components of wave cancel each other at port 4.

Q. 12.

A reflex klystron is operated at 10 GHz, with dc beam vlt. 280V, dc beam current 20 mA, repeller space 1 mm for $1\frac{3}{4}$ th mode. Calculate maximum RF power o/p and corresponding repeller volt. V_R.

→ Given,

$f = 10\ GHz = 10 \times 10^{9}\ Hz$

$V_0 = 280V$, $I_0 = 20mA = 20 \times 10^{-3}\ A$

$L = 1mm = 1 \times 10^{-3}\ m$, $\frac{e}{m} = 1.75 \times 10^{11}$

$1\frac{3}{4} = 1.75$

$\therefore \omega = 2\pi f = 2\times\pi\times 10\times 10^9$

$n = 2$

We know —

$$\frac{V_0}{(V_0+V_R)^2} = \frac{(2\pi n - \frac{\pi}{2})^2}{8\omega^2 L^2}\,\frac{e}{m}$$

$$\Rightarrow \frac{280}{(280+V_R)^2} = \frac{(4n-1)^2 \cdot \frac{\pi^2}{4}}{8\times(2\pi\times 10\times 10^9)^2\times(1\times 10^{-3})^2}\times 1.75\times 10^{11}$$

$$= \frac{49\pi^2/4}{8\times 4\pi^2\times 10^{20}\times 10^{-6}}\times 1.75\times 10^{11}$$

$$\Rightarrow \frac{280}{(280+V_R)^2} = \frac{21.44}{32\times 10^{14}}\times 10^{11}$$

$$\Rightarrow 280\times 32\times 10^{3} = 21.44\,(280+V_R)^2$$

$$\Rightarrow \frac{8960\times 10^3}{21.44} = (280+V_R)^2$$

$\therefore$ Repeller volt. $(V_R) = 366.45\ V$ [ans ①]

Power output $(P_{ac}) = \dfrac{2I_0 V_0 X' J_1(X')}{2\pi n - \pi/2}$ | where, $X' = 0.582$, $J_1(X') = 2.048$

$$= \frac{2\times 20\times 10^{-3}\times 280\times 0.582\times 2.048}{(7\pi/2)}$$

$= 1.214\ W$ [ans ②]

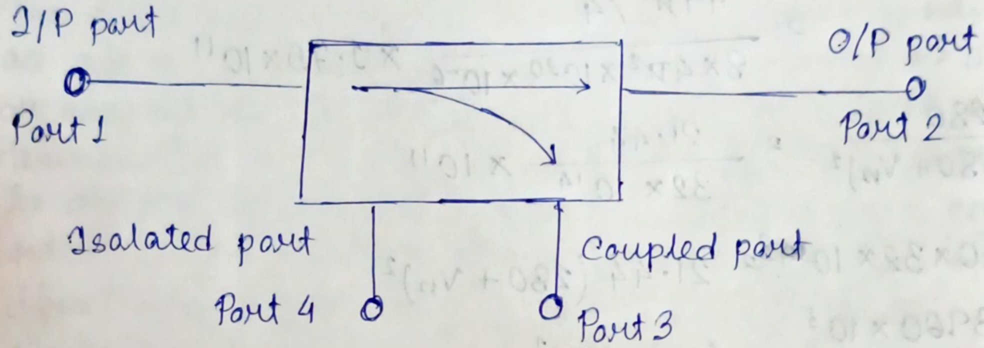
Q. 13.

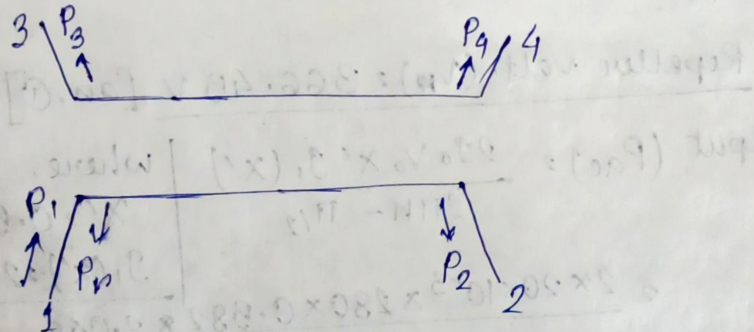
Describe an Ideal directional coupler with the help of a suitable diagram. Define 'Coupling factor' and 'Directi-vity' in the context of a coupler.

→ A directional coupler is a four port passive device commonly used for coupling a known fraction of a microwave power to a port in the auxiliary line while flowing from the i/p port to o/p port in the main line.

The remaining port is an ideally isolated port and matched port.

In an ideal directional coupler, no signal should appear at the isolated port, however practically, a small amount of power called back power is obtained at port 4. The directional coupler operates in a single direction i.e. it's parts can't be interchanged.





Coupling factor:-

Measure of the ratio of the power levels in the main and auxiliary line

$$C(dB) = 10 \log \frac{P_1}{P_4}$$

Directivity:-

Measure how well the forward travelling wave in the main waveguide couples only to a specific port of the auxiliary waveguide.

$$D(dB) = 10 \log \frac{P_4}{P_3}$$

Q. 14.

From the properties of directional coupler, derive the S-matrix of ideal directional coupler.

→ For a four port network:–

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}$$

In ideal directional coupler, all ports are perfectly matched to the junc. Hence, the diagonal elements are 0.

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

From the symmetric property –

$S_{23} = S_{32}$; $S_{13} = S_{31}$; $S_{24} = S_{42}$; $S_{34} = S_{43}$;
$S_{41} = S_{14}$;

There are no coupling in between port (1 and 3) and (2 and 4). So –

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

Substituting all these values –

$$[S] = \begin{bmatrix} 0 & S_{12} & 0 & S_{14} \\ S_{12} & 0 & S_{23} & 0 \\ 0 & S_{23} & 0 & S_{34} \\ S_{14} & 0 & S_{34} & 0 \end{bmatrix}$$

Applying unitary property –

$|S_{12}|^2 + |S_{14}|^2 = 1$ —— (1)

$|S_{12}|^2 + |S_{23}|^2 = 1$ —— (2)

$|S_{23}|^2 + |S_{34}|^2 = 1$ —— (3)

$|S_{14}|^2 + |S_{34}|^2 = 1$ —— (4)

Comparing eq (1) and (2) :–

$|S_{14}| = |S_{23}|$

Comparing eq (2) and (3) :–

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

Let, $S_{12} = S_{34} = p$ —— (5)

According to zero property of [S]:-

[2nd and 4th row] —— $S_{12} S_{14}^* + S_{23} S_{34}^* = 0$ —— (6)

[1st and 3rd row] —— $S_{12} S_{23}^* + S_{14} S_{34}^* = 0$ —— (7)

Substituting (5) in (7):-

$$p\left(S_{23}^* + S_{14}\right) = 0$$

Let, $S_{23} = S_{14} = jq$ —— (8) [where, $j = \sqrt{-1}$]

$\therefore p^2 + q^2 = 1$

$$\therefore [S] = \begin{bmatrix} 0 & p & 0 & jq \\ p & 0 & jq & 0 \\ 0 & jq & 0 & p \\ jq & 0 & p & 0 \end{bmatrix}$$ [ans]

Q. 15.

Describe the working principle of a Faraday rotation isolation with the help of a suitable diagram.

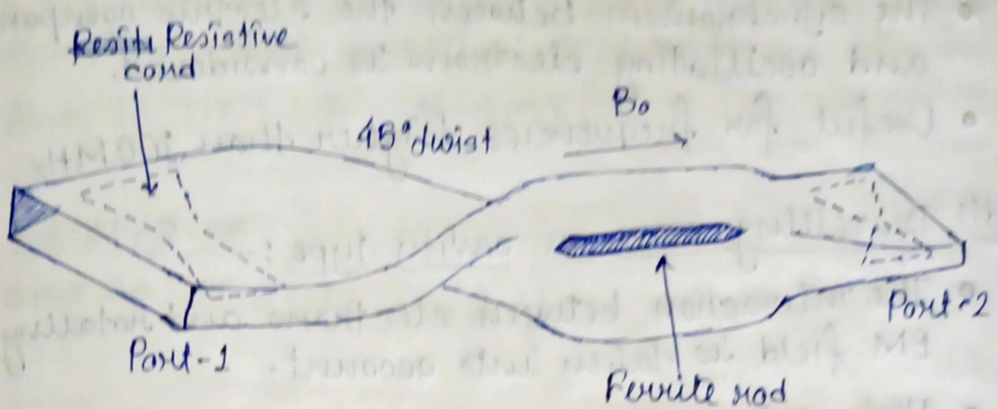
→ When an electromagnetic wave passes through ferrites, plane of polarization continuious to rotate to angle θ in one particular direction (either clock-wise or anticlockwise). This plane of polarization changes in the same direction whatever may be the direction of propagation of wave. This is called as Faraday's rotation isolator comprises of four components ——

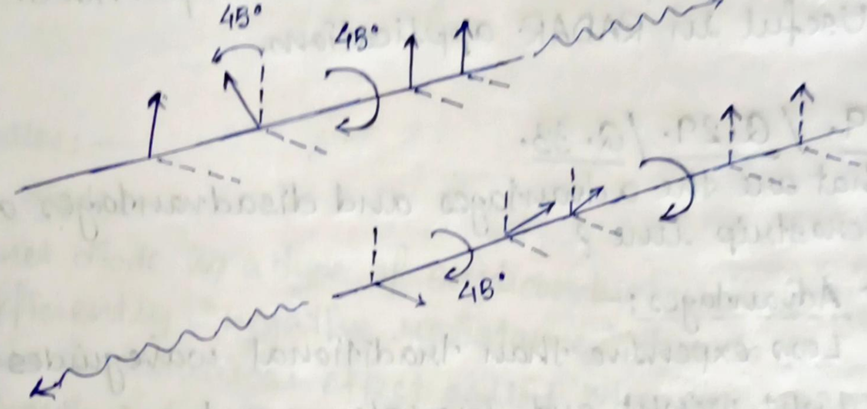
i) Rectangular waveguide with planer resistive cord

ii) Mechanical bend of 45° in anticlockwise direction. It is reciprocal device.

iii) Circular waveguide with ferrite rod to give a polarization rotation of 45° in clockwise direction. It is non-reciprocal device.

iv) Rectangular waveguide with resistive cord.





Q·16.

Make a classification of different types of magnetron.

→ Magnetrons are the cross field tubes in which the electric and magnetic field cross (i.e. run perpendi-cular) to each other.

There are three types of magnetron —

1) Negative Resistance type :-

- In this type, the negative resistance between two anode segment is used.
- They have low frequency.
- They are used at low frequencies (< 500 MHz)

ii) Cyclotron Frequency magnetrons :-

- The synchronism between the electric component and oscillating electrons is considered.
- Useful for frequencies higher than 100 MHz.

iii) Travelling wave or cavity type :-

- The interaction between electrons and rotating EM field is taken into account.
- High peak power oscillations are provided.
- Useful in RADAR applications.

Q. 19. / Q. 29. / Q. 33.
What are the advantages and disadvantages of microstrip line ?

→ **Advantages :-**

i) Less expensive than traditional waveguides.
ii) Light weight and low volume and more compact.
iii) It is easy to fabricate.
iv) It is easy to troubleshoot.

Disadvantages :-

i) Lower power handling capacity and higher losses comparing with waveguide.
ii) Poor isolation among adjacent lines.
iii) Unwanted radiation in uncovered configuration.
iv) Higher losses.

Q. 20. / Q. 30. / Q. 34.

Show the electric and magnetic field line configurations in microstrip lines for Quasi TEM mode.

⟶ Ans. in UT-1 (Gr.:- B/Q.5)

Q. 21. / Q. 31. / Q. 35

Same as UT-1 (Gr.:- C/Q.3)

Q. 32.

Same as UT-1 (Gr.:- C/Q.1)

Q. 36.

Short notes:—

i) Tunnel diode:—

A tunnel diode is a type of semiconductor diode that has efficiently "negative resistance" due to the quantam mechanical effect called "tunneling". Tunnel diodes have a heavily doped pn junction. The heavy doping results in a broken band gap, where conducti-on band electron states on the N-side and more or less aligned with valanced band hole states on the p-side.

ii) Gunn diode:—

A gunn diode is a passive semiconductor device with two terminals, which composes of only an n-doped semiconductor material, unlike other diodes which consists of a p-n junction. Gunn diodes can be made from the materials which consist of multiple, initially-empty, closely-spaced energy valleys in their conduction band like GaAs

IV) TWT amplifier:-

A TWT or traveling-wave tube amplifier is a specialized vaccum tube is used in electronics to amplify radio frequency (RF) signals in the microwave range. The TWT belongs to a category of "linear beam tubes, such as the klystron, in which the radio wave is amplified by absorbing ~~prom~~ power from a beam of electrons as it passes down the tube. Although there are various types of TWT, two major categories are ———

i) Helix TWT　　　ii) Coupled cavity TWT

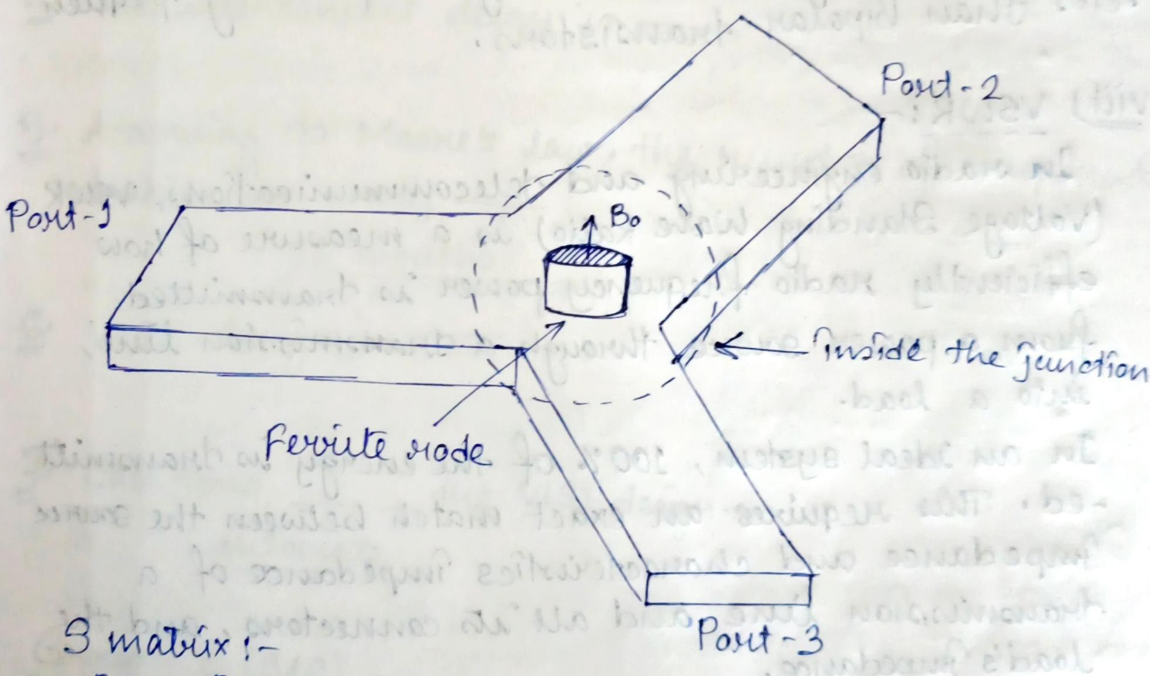
V) Precision waveguide phase shifter:-

The pricision phase shifter can be realized by a rotary phase shifter, which is useful in microwave measurement. The essential parts of this phase shifter are three guide sections: two fixed and one rotary. The fixed sections consists of quarter-wave plates, and the rotary section consists of half-wave plates and all plates are dielectric type. The center section is rotable to provide the required phase shift. The two fixed quarter wave sections are identical in all respects, and the rotable half-wave section is just the double of a quarter wave section. Each of the two fixed sections, attached to a transition, consists of a piece of a circular waveguide with a dielectric plate, making an angle of 45° with the horizontal. The output remains polarized, which means that the phase shifter is lossless and reflection less for any position of the rotary section.

It is used as a calibration standard due to its high accuracy.

vi) 3-port circulator:-

A 3 port circulator is an asymmetrical Y-type junction of three identical waveguides with an axially magnetized ferrite post placed at the center. The ferrite post is magnetized by a static B field along the axis. It provides the necessary non reciprocal property. The junction can be matched by placing a suitable tuning element in each arm. It is an essential element used to isolate the i/p and o/p in a -ve resistance amplifier. Three port circulator are also used to couple a transmitter to various receiver.



S matrix:-

$$[S] = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

The diagram represents 3 port RF circulator. The signal that is to be transmitted travels from port-1 to port-2 and signal received at antenna travels from port-2 to port-3 as shown.

vii) MESFET:-

The Metal-Semiconductor-Field-Effect-Transistor (MESFET) is a unipolar device, because its conduction process involves predominantly only one kind of carrier. The MESFET offers many attractive features for applications in both analog and digital circuits. It is particularly useful for microwave amplification and high speed integrated circuits, since it can be made from semiconductors with high mobilities. Because MESFET is a unipolar device, it doesn't suffer from minority-carrier effects and so has higher switching speeds and higher operating frequencies than bipolar transistors.

viii) VSWR:-

In radio engineering and telecommunications, VSWR (Voltage Standing Wave Ratio) is a measure of how efficiently radio frequency power is transmitted from a power source through a transmission line, into a load.

In an ideal system, 100% of the energy is transmitted. This requires an exact match between the source impedance and characteristics impedance of a transmission line and all its connectors, and the load's impedance.

But in real system, mismatched impedances cause some of the power to be reflected towards the source. Reflections cause destructive interference.

VSWR measures these voltage variances. It is the ratio of the highest volt. anywhere along transmission line to the lowest.

$$VSWR = \frac{|V_{max}|}{|V_{min}|}$$