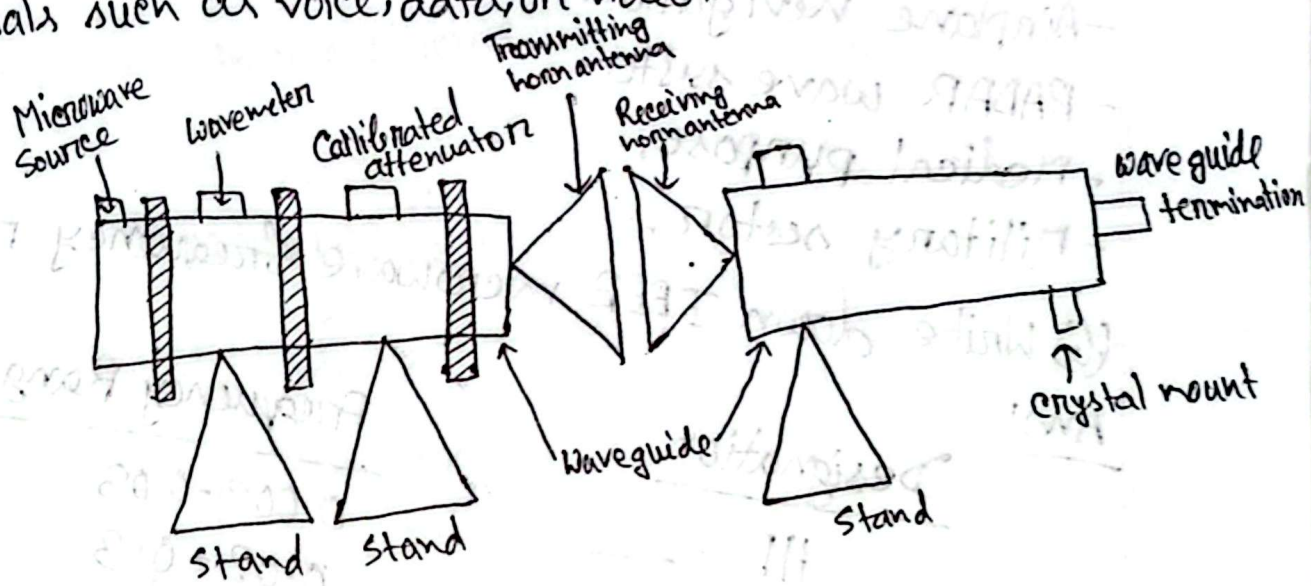
Preparation Test

1. (a) What is microwave system? Write down the advantages and applications of a microwave.

Ans:-

Microwave system:- A microwave system is a communication or transmission system that uses microwave frequencies to transmit signals such as voice, data, or video.



Advantages of Microwave:-

- Microwave do not cause harmful burning.
- Microwave have shorter wavelengths.
- Microwave have high frequencies.
- Microwave have very large bandwidth.
- Microwave can send higher data.
- Consume very less power.
- Suitable for RADAR wave systems.

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Application of microwave:-

- heating and cooking.
- Cellular communication.
- Field of astronomy.
- Remote sensing.
- Airplane nevigation.
- RADAR wave system.
- Medical purposes.
- Military sector.

(6) Write down IEEE microwave frequency ranges.

Ans:

Designation	Frequency Range (in GHz)
HF	0.003-0.03
VHF	0.03-0.3
UHF	0.3 - 1
L-band	1 - 2
S-band	2-4
C-band	4-8
X-band	8-12
Kv-band	12-18
K-band	18-27
Ka-band	27-40
Millimeter	40-300
Submillimeter	>300

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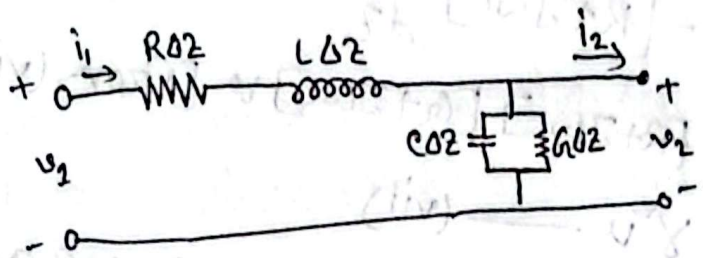
(c) Derive basic transmission line equations.

Ans:-



G = transconductive Component.

Applying KVL in the circuit,

$$\Delta V = V_2 - V_1$$

$$\Rightarrow \Delta V = -\left(R\Delta z\, i_1 + L\Delta z \frac{di_1}{dt}\right)$$

$$\Rightarrow \frac{\Delta V}{\Delta z} = -\left(R + L\frac{d}{dt}\right) i_1 \quad \text{——(i)}$$

Applying KCL in the circuit,

$$\Delta i = i_2 - i_1$$

$$\Rightarrow \Delta i = -\left(G\Delta z V_2 + C\Delta z \frac{dv_2}{dt}\right)$$

$$\Rightarrow \frac{\Delta i}{\Delta z} = -\left(G + C\frac{d}{dt}\right) V_2 \quad \text{——(ii)}$$

Now writing the equation (i) and (ii) in form of v and i.

$$\frac{dv}{dz} = -\left[R + L\frac{d}{dt}\right] i \quad \text{——(iii)}$$

$$\frac{di}{dz} = -\left[G + C\frac{d}{dt}\right] v \quad \text{——(iv)}$$

Considering $\frac{d}{dt} = j\omega$

$$\frac{dv}{dz} = -\left[R + j\omega L\right] i \quad \text{——(v)}$$

$$\frac{di}{dz} = -\left[G + j\omega C\right] v \quad \text{——(vi)}$$

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Now, differentiating (v) w.r.to z, we get,

$$\frac{d^2v}{dz^2} = -[R+j\omega L]\frac{di}{dz}$$

$$= [R+j\omega L][G+j\omega C]v \quad [\text{from (vi)}]$$

$$= \gamma^2 v \quad \text{—— (vii)}$$

Again, differentiating (vi) w.r.to z, we get,

$$\frac{d^2i}{dz^2} = -[G+j\omega C]\frac{dv}{dz}$$

$$= [G+j\omega C][R+j\omega L]i$$

$$= \gamma^2 i \quad \text{—— (viii)}$$

Here, equation (vii)(viii) are the transmission line equation, where γ is the propagation constant.

2. (a) Find propagation constant and characteristics impedence from the solution of transmission line equations.

Sol^n

Consider, general wave equation for transmission line in term of instantenous voltage, $v(z,t)$ and current $i(z,t)$.

Voltage form,

$$\frac{dv}{dz} = -\left[R + L\frac{d}{dt}\right]i \quad \text{—(i)}$$

$$\frac{di}{dz} = -\left[G + C\frac{d}{dt}\right]v \quad \text{—(ii)}$$

When $\frac{d}{dt}$ operator applied to the complex form, its equivalent to the $j\omega$.

Now from (i) $\Rightarrow$

$$\frac{dv}{dz} = -[R + j\omega L]i$$

Now, from (ii)

$$\frac{di}{dz} = -[G + j\omega C]v$$

Differentiate w.r.to z, we get:

$$\frac{d^2v}{dz^2} = -[R + j\omega L]\frac{di}{dz}$$

$$= [R + j\omega L][G + j\omega C]v \quad \text{—(iii)}$$

$$\Rightarrow \frac{d^2v}{dz^2} = \gamma^2 v \quad \text{—(iv)} \rightarrow \text{Tran}$$

It's transmission line wave equation, where,

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \text{Propagation constant}.$$

Solution of equation (iv) we get.

$$v = (v_+ e^{-\gamma z} + v_- e^{+\gamma z}) \quad \text{—(v)}$$

v_+: Incident Signal

v_-: Reflected Signal.

Characteristics impedence.

$$Z_0 = \frac{(V_+ e^{-\gamma z} + V_- e^{+\gamma z})}{i}$$

$$= \frac{(V_+ e^{-\gamma z} + V_- e^{+\gamma z})}{\sqrt{\frac{G+J\omega C}{R+J\omega L}}\,(V_+ e^{-\gamma z} + V_- e^{+\gamma z})}$$

$$\therefore Z_0 = \sqrt{\frac{R+J\omega L}{G+J\omega C}} = \text{characteristics impedence}$$

Phase velocity,

$$v_p = \frac{\omega}{\beta} = \frac{\omega}{\omega\sqrt{LC}} = \frac{1}{\sqrt{LC}}$$

Similar to current,

$$I = (\underbrace{I_+ e^{-\gamma z}}_{\text{Incident Signal}} + \underbrace{I_- e^{\gamma z}}_{\text{Reflected Signal}})$$

from equation (iv) $\Rightarrow$

$$\frac{d^2 v}{dz^2} = \gamma^2 v$$

$$\therefore \gamma = \sqrt{(R+J\omega L)(G+J\omega C)} = \underbrace{\alpha}_{\text{Attenuation Constant}} + J\underbrace{\beta}_{\text{Phase constant}}$$

For lossless transmission line $R = G = 0$

$$\gamma = \sqrt{(0+J\omega L)(0+J\omega C)}$$

$$\Rightarrow \gamma = J\omega\sqrt{LC}$$

$$\Rightarrow \alpha + J\beta = J\omega\sqrt{LC}$$

$$\Rightarrow J\beta = J\omega\sqrt{LC} \quad ; \text{where } \alpha = 0$$

$$\therefore \beta = \omega\sqrt{LC} = \text{phase constant}$$

$$\Rightarrow \alpha = \frac{1}{2}\left(R\sqrt{\frac{L}{C}} + G\sqrt{\frac{L}{C}}\right) = \text{Attenuation constant.}$$

from equation (vi) $\Rightarrow$

$$\frac{dv}{dz} = -(R+J\omega L)\,i$$

$$\Rightarrow i = -\frac{1}{(R+J\omega L)}\left(\frac{dv}{dz}\right)$$

$$= \frac{-1}{R+J\omega L}\,\frac{d}{dz}\left(V_+ e^{-\gamma z} + V_- e^{+\gamma z}\right)$$

$$\Rightarrow i = \frac{-1}{R+J\omega L}\left(V_+(-\gamma)e^{-\gamma z} + V_-(\gamma)e^{+\gamma z}\right)$$

$$\Rightarrow i = \frac{\gamma(V_+ e^{-\gamma z} + V_- e^{+\gamma z})}{(R+J\omega L)}$$

$$\Rightarrow i = \frac{\sqrt{(R+J\omega L)(G+J\omega C)}}{(R+J\omega L)}\,(V_+ e^{-\gamma z} + V_- e^{+\gamma z}) \quad \therefore i = \sqrt{\frac{G+J\omega C}{R+J\omega L}}\,(V_+ e^{-\gamma z} + V_- e^{+\gamma z})$$

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(b) Transmission line has following parameters, $R = 2\,\Omega/m$; $G = 0.5$ mho/m; $f = 1$ GHz; $L = 8$ nH/m and $C = 0.23$ pF. Find (i) characteristics impedence and (ii) propogation constant.

Ans.

(i) Characteristic impedence,

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$= \sqrt{\frac{2 + j2\pi \times 1\times10^9 \times 8\times10^{-9}}{0.5\times10^{-3} + j2\pi\times10^9\times0.23\times10^{-12}}}$$

$$= \sqrt{\frac{50.31\angle 87.72^\circ}{15.20\times10^{-4}\angle 76.91^\circ}}$$

$$= 181.39\angle 8.40^\circ$$

$$= 179.44 + j26.5$$

(b) Propogation constant,

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

$$= \sqrt{(50.31\angle 87.72^\circ)\times(15.20\times10^{-4})\angle 76.91^\circ}$$

$$= \sqrt{76.24\times10^{-4}\angle 158.63^\circ}$$

$$= 0.2774\angle 79.31^\circ$$

$$= 0.051 + j0.273$$

(c) Explain microwave system with necessary diagram.

⇒ Microwave System:- A microwave system is a communication system that uses microwave frequency range (1 GHz to 300 GHz) for transmitting information such as voice, data, and video over long distances.

It is widely used in radar, satellite communication, television broadcast and wireless communication.

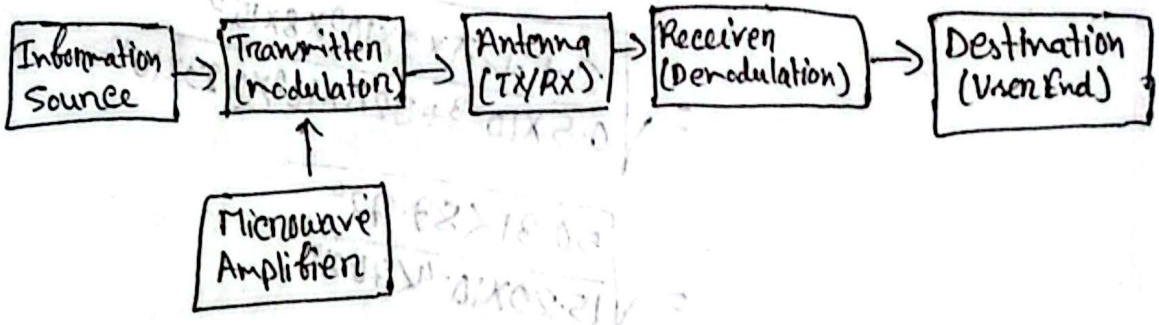

Fig: Block Diagram of microwave system.

Components:-

Transmitter: Converts the original data into a microwave signal.

Antenna:- Focuses the microwave signal and transmits it through the air, usually with a parabolic dish.

Transmission medium: Free space through which the microwave signal travels.

Receiver:- An antenna that capture the signal.

Receiver Components:- Includes a bandpass filter, mixer, IF amplifier and detector to process the signal.

How it works:-

The transmitter creates the microwave signal. The antenna

3. (a) Why double stud matching is used instead of single stub matching? Explain with figures.
=> NOT Done

focuses and sends the signal to the receiving antenna. The receiver antenna collects the signal. The signal is filtered, dow-converted to a lower frequency, amplified, and then demodulated to extract the original data. The baseband signal is sent to the destination.

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(b) Define and explain Smith chart.

Ans:

Smith Chart:- The Smith chart is a graphical tool used in microwave engineering and RF (radio frequency) circuits to represent complex impedence and reflection coefficients.

It is essentially a polar plot of the reflection coefficient that allows engineers to analyze and design matching network easily.

The Smith chart consists of a plot of the normalized impedence or admittance with the angle and magnitude of a generalized complex reflection coefficient in a unity circle.

Any load impedance (Z_L) can be normalized with respect to the characteristic impedence (Z_0)

$$\text{Normalized impedence}, Z = \frac{Z_L}{Z_0} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

The reflection coefficient is,

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

The Smith Chart is basically a plot of Γ in the complex plane.

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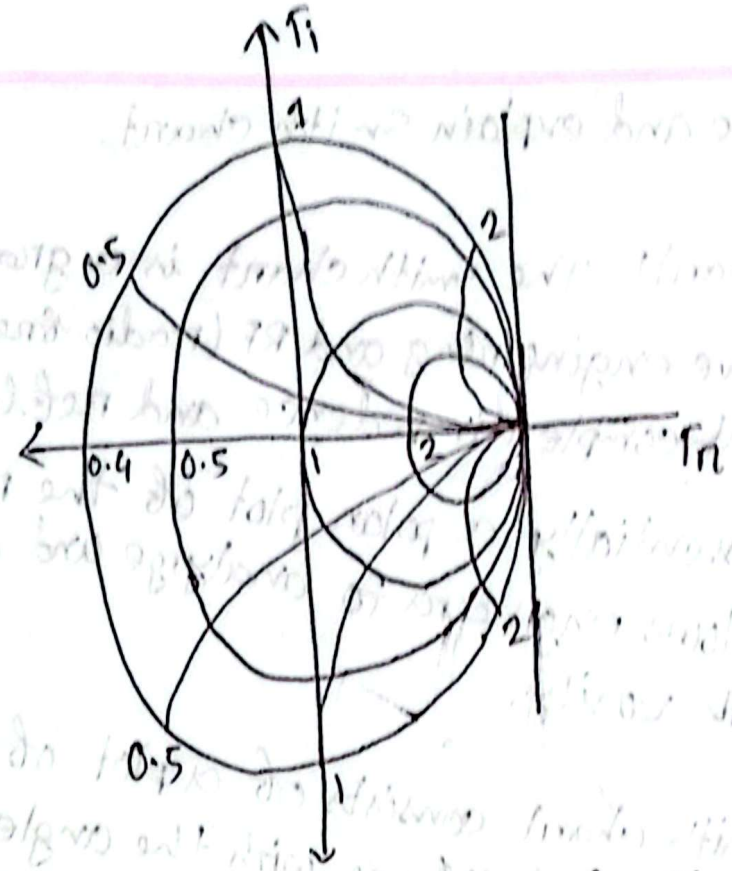


(c) Establish the relationship between reflection and transmission coefficient.

Ans:

Reflection coefficient:

Where, Γ is reflection coefficient;

$$\Gamma = \frac{\text{reflected voltage or current}}{\text{incident voltage or current}}$$

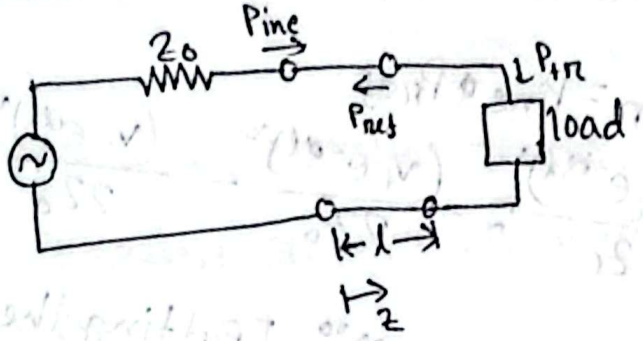
$$= \frac{V_{ref}}{V_{in}}$$

$$= \frac{V_- e^{\gamma L}}{V_+ e^{\gamma L}}$$

$$\therefore \Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$$

; Z_L = load impedence
Z_0 = characteristics impedence of the line.

Transmission Coefficient:-



We know that,

Transmission coefficient, $T = \frac{V_{tr}}{V_{inc}}$

$$T = \frac{\text{Transmitted voltage or current}}{\text{Incident voltage or current}}$$

$$= \frac{V_{tr}}{V_{inc}}$$

$$= \frac{I_{tr}}{I_{inc}}$$

$$= \frac{V_+ e^{-\gamma l} + V_- e^{+\gamma l}}{V_+ e^{-\gamma l}}$$

$$= \frac{V_+ + V_-}{V_+}$$

$$= 1 + \frac{V_-}{V_+}$$

$$= 1 + \Gamma_l$$

$$= 1 + \frac{Z_l - Z_0}{Z_l + Z_0} \quad \left[\text{Since, } \Gamma_l = \frac{Z_l - Z_0}{Z_l + Z_0}\right]$$

$$= \frac{2Z_l}{Z_l + Z_0}$$

Power transmitted,

$$P_{tr} = P_{inc} - P_{ref}$$

$$\Rightarrow \frac{(V_{tr} e^{-\alpha l})^2}{2Z_l} = \frac{(V_+ e^{-\alpha l})^2}{2Z_0} - \frac{(V_- e^{\alpha l})^2}{2Z_0}$$

$$\therefore T^2 = \frac{Z_l}{Z_0}(1-\Gamma_l)^2$$ [Putting the value of T and Γ_l]

(4)(a) What do you mean by waveguides? What are the advantages?

Ans:-

Waveguide:- A wave guide consist of a hollow metallic table of a rectangular or circular shape used to guide an electromagnetic wave.

In waveguides the electric and magnetic field is confined to the space within the guides. Thus no power is lost through the radiation and even dielectric loss is negliable. There is some heat loss in the walls. However the loss is very small.

Advantages:-

1. Waveguide have lower transmission losses at high frequencies compared to coaxial cables or parallel wire lines.
2. They can handle very high power levels without breakdown, which is essential in radar and microwave systems.
3. Electromagnetic waves remain confined within the waveguide walls, minimizing radiation loss.
4. Well-suited for microwave and millimeter-wave frequencies, where ordinary cables become inefficient.
5. Being metallic and hollow, waveguides are mechanically strong and durable.
6. Specific modes of propagation (TE, TM) can be selected, which allows controlled signal transmission.

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(6) An RG/U waveguide has outside dimensions of ~~1.78cm x 0.~~ 1.78 cm X 0.993 cm and wall thickness of 0.102 cm. Find the cut off frequencies at TE_{10} and TE_{12} mode.

Ans:

Width (a) = Width - 2 (wall thickness)

$= 1.78 - 2(0.102)$

$= 1.576$ cm

$= 1.576 \times 10^{-2}$ m.

Height (b) = $0.993 - 2(0.102) = 0.789$ cm $= 0.789 \times 10^{-2}$ m.

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

For, TE_{10} here, $m = 1$; $n = 0$

$$f_{c_{TE_{10}}} = \frac{c}{2}\sqrt{\left(\frac{1}{1.576\times10^{-2}}\right)^2 + 0}$$

$$= \frac{3\times10^8}{2\times(1.576\times10^{-2})} = 9.52\times10^9 \text{ Hz} = 9.52 \text{ GHz}$$

For, TE_{21}, where $m = 2$, $n = 1$

$$f_{c_{TE_{21}}} = \frac{3\times10^8}{2}\sqrt{\left(\frac{2}{1.576\times10^{-2}}\right)^2 + \left(\frac{1}{0.789\times10^{-2}}\right)^2}$$

$= 2.690 \times 10^{10}$ Hz.

$= 26.9$ GHz.

(c) What is attenuator? Describe different types of attenuators?

Ans:

Attenuator:- An attenuator is an electronic device or network that reduces the power level of a signal without distoring its waveform.

Types of attenuator:-

(i) Fixed attenuators.
(ii) Step attenuators.
(iii) variable attenuators.

(i) Fixed attenuators:-

Fixed attenuators often called pads, reduce the power through them by a fixed ammount. They are designed as a 3dB, 10dB etc. Fixed attenuators are constructed using film resistors around a center conductor and no disk.

(ii) Step Attenuators:-

These attenuators reduces the power through them by fixed amount. It is made of a number of fixed attenuators that can be selected for use one at a time.

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(iii) Variable Attenuators.

Continuously variable attenuators have the ability to vary the amount of power loss through the device.

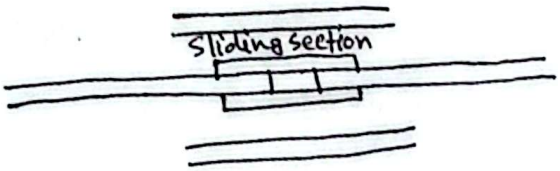


fig1:- Variable Slide attenuator

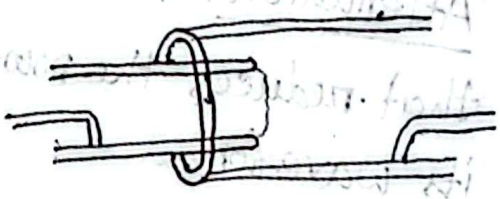


fig2: variable piston attenuators.

⑤ ⓐ What is directional Coupler? Derive the equation of coupling factor of a directional coupler.

Ans:

Directional Coupler:-

A directional coupler is used ~~to~~ in the calculation of the power reflection coefficient in a waveguide in which both incident and reflected power values must be found.

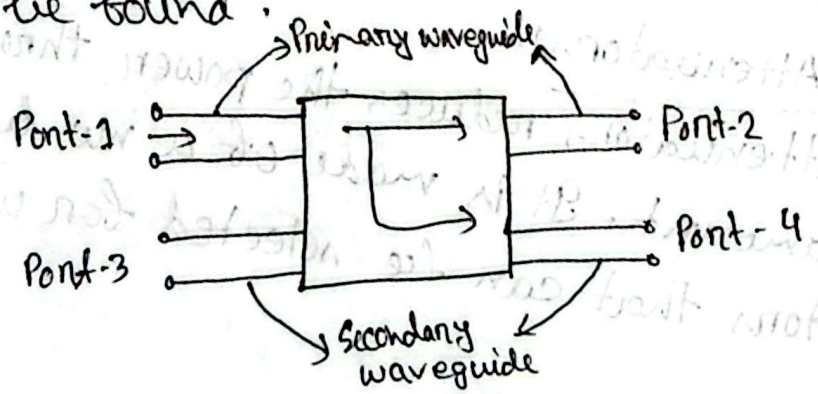
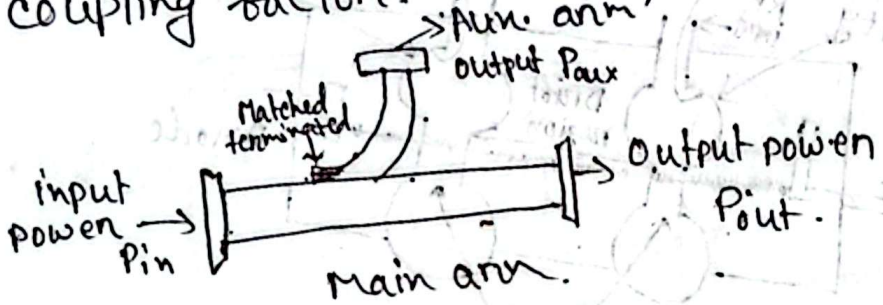


Fig: Directional Coupler.

Coupling factor (C):- is the ration of power input to the coupler to power output of an auxilary arm is called the coupling factor.



Coupler factor, $C = 10 \log_{10} \frac{P_{in}}{P_{aux}}$ [dB] $[P_{in} = P_{out} + P_{aux}]$

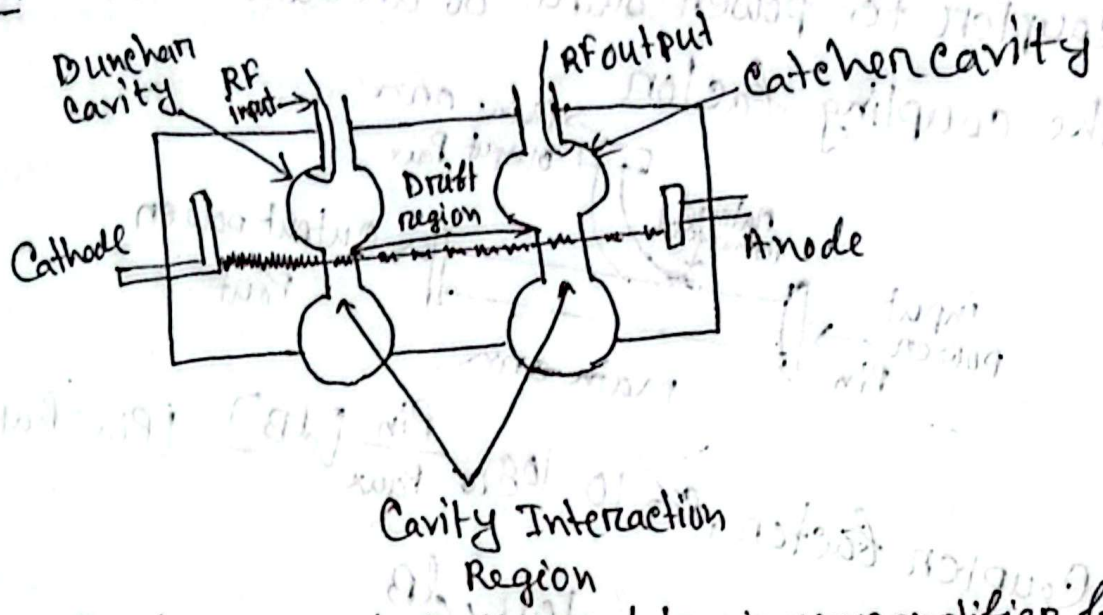
where, C = Coupling factor, dB

P_{in} = input power to the coupler, W

P_{aux} = Power out of the auxilary arms, W.

(6) Draw and explain Two cavity Klystron.

Ans:



Two cavity klystron is a device that used to microwave amplifier by the principle of velocity an current modulation.

- When voltage is applied the electron gun produces electrons.
- When RF input signal is applied all the producing electrons move uniform velocities to catcher cavity and get collected by the collector called reference electrons.
- When RF signal is applied at the buncher cavity,

for (+ve) cycle:

- It creates E-field towards to motion of electron. So electron velocity increased called enlyer electrons.

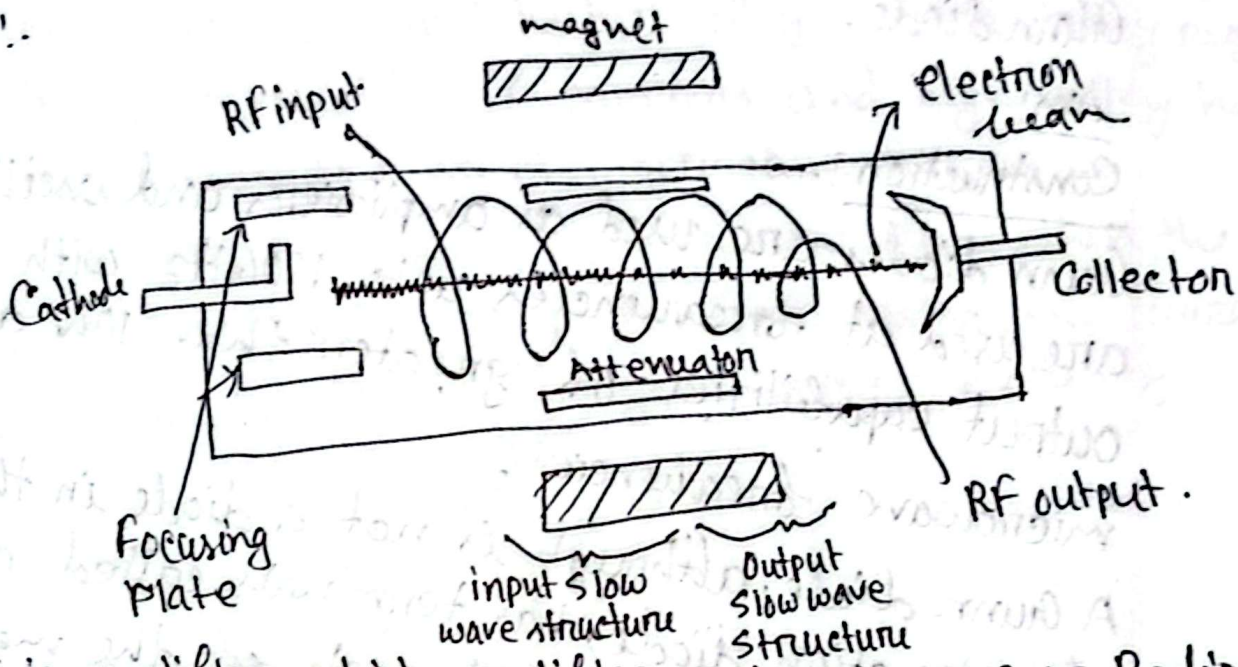
- RF signal with (-ve) cycle:

- It creates E-field opposite to motion of ē so ē velocity get reduced. called later electrons.

- Then both electrons Later, enlier, Reference get bunched into drift velocity region.
- The catcher cavity collected the bunched electrons.
- Then the RF input is amplified produces at RF output at the catcher cavity.

(c) Draw TWT and explain briefly.

Ans:-



TWT is amplifier which amplifier amply microwave or Radio waves. It amplifies broadband microwave.

- The electron gun produces electrons.
- When (+ve) cycle of RF signal is applied due (+ve) polarity the electrons (e^-) get attracted and increases velocity.
- When (-ve) cycle of RF signal is applied due to (-ve) polarity the electrons (e^-) get repelled reduced the velocity.
- Then RF signal gets energy from e^- bunch in helix structure and amplified, which is received at the O/P.
- The remaining electrons received at the collector due to positive terminal of the cavity.

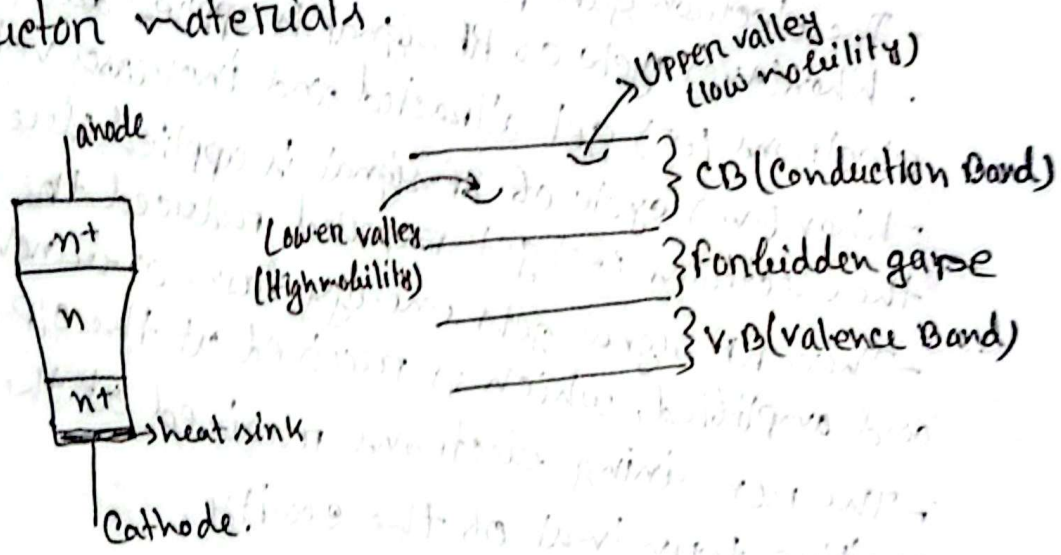
⑥(a) Describe the construction and working principle of Gunn diode.

Ans:

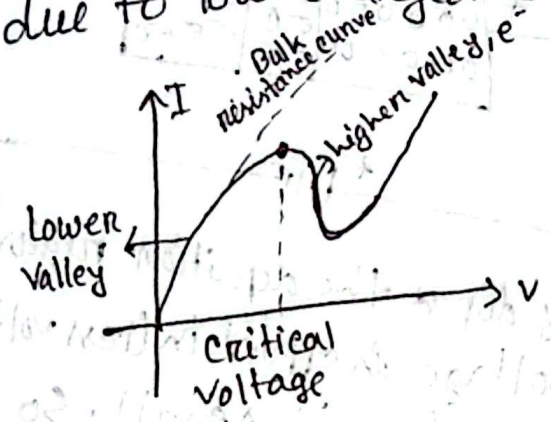
Construction:-

Gunn diodes are used as amplifiers and oscillators. They are used at frequencies upto 100GHz with power output capabilities of greater than 10W at lower microwave frequencies.

A Gunn diode, although is not a diode in the sense of a junction diode, has terminals called cathode and anode connections at each of the material. The bulk region is an n-type gallium arsenide semiconductor materials.



Working Principle:- With GaAs material, there are two energy regions, Lower valley and higher valley. Lower valley region has the high mobility of carriers and high valley has the lower mobility of changer carriers.
Thus, at first it shows high current flow when the changed carriers (e^-) jump to upper valley the current reduced ~~to~~ due to low charged carrier mobility.

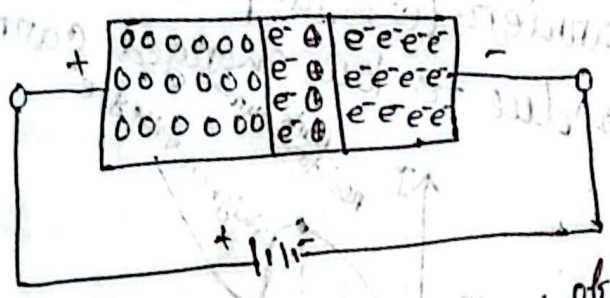


(b) Draw and explain Tunnel diode as an amplifier with a microwave circulator.

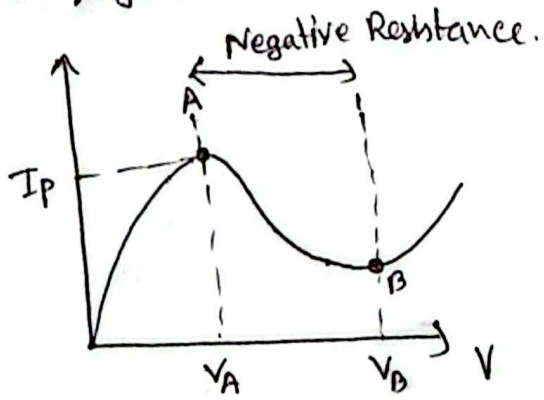
Soln

Tunnel diode:- A tunnel diode is a heavily doped PN junction diode has negative resistance characteristics due to tunneling effect.

- Used as low power amplifier and oscillator.



- Due to heavily doped the deplition region of the diode become narrow.
- When forward voltage is applied in (less voltage) current start to flow as depletion layer is small. So



Negative ~~reg~~ resistance, at ~~VA~~ $V_A - V_B$ point, increasing voltage but decreasing current.

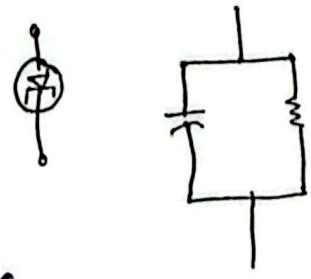
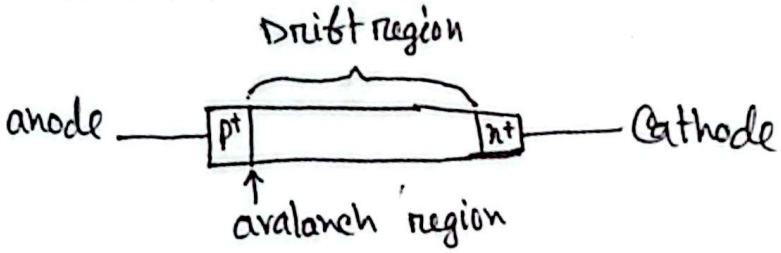


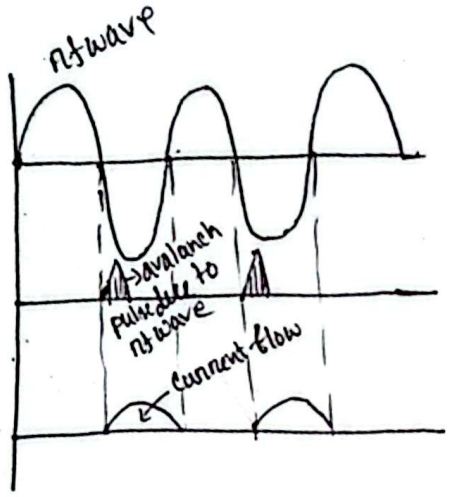
fig: symbol and equivalent of Tunnel diode.

(7)

(c) IMPATT Diode:-

It is consists of an cathode and anode with highly doped P and n type region and a n-type drift region. IMPATT diode works on reversed biased condition at the avalanch breakdown mode.





(d) Magnetron:-

A magnetron is a device that generates high power electromagnetic wave. It is basically considered as a self-excited microwave oscillator. And is also known as a crossed-field device.

A magnetron is basically a vacuum tube of high power having multiple cavities. It is also known as cavity magnetron because of the presence of anode in the resonant cavity of the tube. The operating principle of a magnetron is

such that when electrons interact with electric and magnetic field in the cavity then high power oscillations get generated.

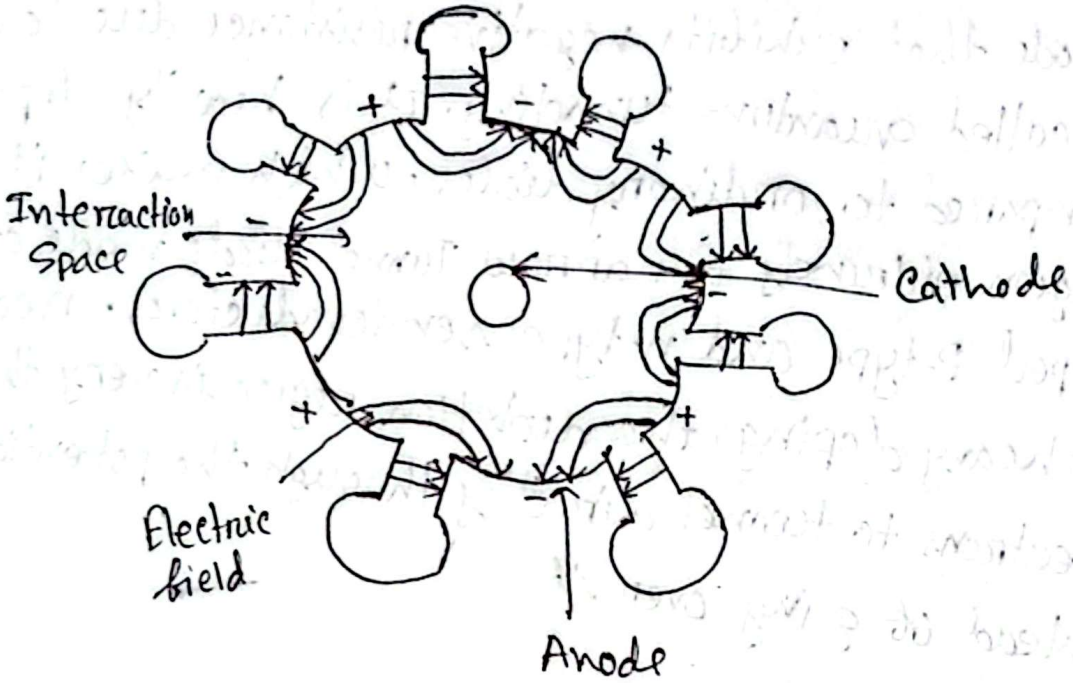
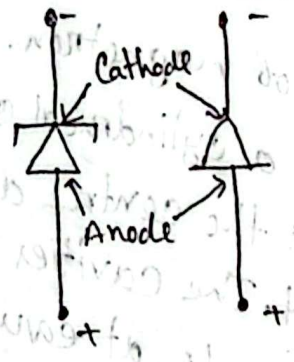


fig: Structure of magnetron.

A cylindrical magnetron has a cylindrical cathode of a certain length and radius present at the centre around which a cylindrical anode is present. The cavities are present at the circumference of the anode at equal spacing.

(e) Tunnel diode:-

A tunnel diode is a special type of two-terminal semiconductor diode that exhibits negative resistance due to a phenomenon called quantum tunneling. It is heavily doped compared to ordinary diodes, which makes its depletion region extremely narrow. Tunnel diode made of heavily doped P-type and n-type semiconductors. Because of heavy doping, the depletion region is very thin. Allows electrons to tunnel directly through the potential barrier instead of going over it.



Symbol of Tunnel diode

The basic manufacturing material of a tunnel diode is germanium, gallium arsenide or gallium antimonide. It is not formed using silicon as its basic material.

In the tunnel diode, the doping concentration is very high. The concentration of doped impurity in a tunnel diode is thousand times more as compared to any normal diode.

(a) Microwave isolators:-

A microwave isolator is a two-port non-reciprocal passive device that allows electromagnetic (microwave) energy to pass in one direction while providing very high attenuation in the opposite direction. It acts like a "one-way valve" for microwave. Microwave isolators generally work based on Faraday rotation in ferrite materials. A ferrite (a magnetic material) placed in a waveguide or stripline causes the microwave signal's polarization to rotate when subjected to a magnetic field. By combining this rotation with properly aligned resistive ~~terminator~~ terminations, power is transmitted in one direction but absorbed (not reflected back) in the other.

There are different types of microwave isolators:-

1. Ferrite isolators.
2. Resonance isolators.
3. Load isolators.

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(6) Wavemeter:- A wavemeter is a microwave measuring instrument used to determine the frequency (or wavelength) of microwave signals. It is basically a tunable resonant cavity that absorbs maximum power when its resonant frequency matches the frequency of the microwave under test. To measure the wavelength or frequency of electromagnetic or radio waves. Often measure the wave's frequency, from which the wavelength can be calculated. Wavemeter used in electronics, telecommunications, optics, and laser systems.

There are different types of wavemeter:-

① Wavelength meters.

② Absorption wavemeters.

③ Scanning wavemeters.

~~Freq~~ Frequency can be calculated using:

$$f = \frac{c}{\lambda}$$

f = frequency.

c = speed of light.

λ = wavelength.

(1) Dielectric Constant :-

The dielectric constant (also called relative permittivity, ε_r) is a measure of how much a material can store electrical energy in an electric field compared to vaccum.

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$

Where, ε = absolute permittivity of the material,

ε_0 = permittivity of free space (8.854×10^{-12} F/m).

Thus, the dielectric constant is a dimensionless quantity.

if $\varepsilon_r = 1 \rightarrow$ The material behaves like free space (air ≈ 1)

if $\varepsilon_r > 1 \rightarrow$ The material stores more electric energy

(example: water ≈ 80, glass $\approx 4-10$)

It indicates how easily a material can be polarized when exposed to an electric field.

Dielectric materials act as electrical ~~is~~ insulators, preventing the flow of electric current. When an electric field is applied, the molecules within the dielectric material ~~can~~ become polarized, aligning their electric dipoles. This induced polarization stores electrical energy within the material.

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