MWE Assignment

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1) Write dissimilarities b/w waveguide and two wire transmission line.

→ There is a cut-off value for the frequency of transmission depending upon the dimensions and shape of the wave guide. Only waves having freq. greater than cut-off freq. fc will be propogated. Hence waveguide acts as a high pass filter. In a 2-wire lossless transmission line all frequencies can pass through.

→ Waveguide is a one conductor transmission system. The whole body of waveguide acts as ground and the wave propagates through multiple reflection from the walls of Wave Guide.

→ The velocity of propogation of the wave inside the WG is quite different from that through free space due to multiple reflections from the walls of the waveguide.

→ In WG, we define which is called as the wave imp. which is analogous to the characteristic impedance Z_0 of 2-wire Tx system

→ The system of propogation in WG is in accordance with field theory while that in Tx line is in accordance with circuit theory and hence return conductor is not required in wave guide.

2) Define Frequency band and applications of microwave

Band designation	Frequency range.
L	1-2GHz
S	2-4
C	4-8
X	8-12

Ku	12 - 18
K	18 - 27
Ka	27 - 40
millimeter	40 - 0.300 THz
submillimeter	from 0.300 THz - 300 GHz.

Applications :-

→ Communication with submarines
→ Long distance point to point comm.
→ Broad casting & marine comm.
→ Television FM service, aviation & police
→ Radar, microwave & space comm.

3) Define cut-off freq, wave impedance, phase velocity & group velocity of rectangular waveguide

1) Cut-off frequency: The frequency at which γ just becomes zero is defined the cut-off frequency f_c

2) For any waveguide in the form of a hollow metal tube such as rectangular guide. the wave impedence of a travelling wave is ~~depend~~ independent on the frequency, but is the same through out the guide.

3) Phase velocity is defined as the rate at which the wave changes its phase in terms of guide wavelength

$$V_p = \frac{\omega}{\beta}$$

4) Group velocity is defined as the rate at which the wave propogates through waveguide

$$V_g = \frac{d\omega}{d\beta}$$

4) Write significance and properties of S- parameter.

Scattering parameter defines the components of microwave.

→ S. matrix is always a square matrix $(n \times n)$

→ It is always symmetrical in nature $(S_{ij} = S_{ji})$

→ $[S][S^*] = [I]$

→ $\sum_{i=1}^{n} S_{ij} S_{ji}^* = 0$ for $i \neq j$

→ Let $[S]$ be the S-matrix of a waveguide if the waveguide is shifted by length then the S-matrix of waveguide is $[S]e^{-j\beta l}$.

5) Define dominant & degenerate mode

→ Dominant mode is that mode for which the cut off wave length (λ_c) assumes a maximum value.

λ_{c10} has the maximum value, this is dominant mode in rectangular waveguide.

→ Some of higher ~~modes~~ order modes, having the same cut-off frequency are called degenerate mode. It is necessary that the higher order degenerate modes are not supported by the wave guide in the operating band of freq. to avoid undesirable components appearing at o/p along with losses.

6) Explain coupling probes.

When a short antenna in the form of a probe or loop in inserted into a wave guide, it will radiate and if it is placed correctly, the wanted mod will be set up. The probe is placed at a distance of $\lambda g/4$ from the shorted end of wave guide and the center of broader dimension of the waveguide. because at that point electric field is maximum. This probe will now act as an antenna which is polarized in the plane parallel to that of electric field.

7) Starting from maxwell's equations, derive the field component of TM/TE mode.

$$\nabla \times \bar{E} = -j\omega\mu \bar{H}$$

$$\begin{vmatrix} i & j & k \\ \partial/\partial x & \partial/\partial y & -\gamma \\ E_x & E_y & E_z \end{vmatrix} = -j\omega\mu\bar{H}$$

$$\frac{\partial}{\partial y} E_z + \gamma E_y = -j\omega\mu H_x$$

$$-E_x\gamma - \frac{\partial}{\partial x} E_z = -j\omega\mu H_y$$

$$\frac{\partial}{\partial x} E_y - \frac{\partial}{\partial y} E_x = -j\omega\mu H_z$$

$$H_y = \frac{E_x\gamma}{j\omega\mu} + \frac{\partial}{\partial x} E_z \cdot \frac{1}{j\omega\mu}$$

$$j\omega\mu \frac{\partial}{\partial y} H_z + \gamma \frac{\partial}{\partial x} E_z = -E_x\left[(-\omega^2\epsilon\mu) + \gamma^2\right]$$

$$\frac{-j\omega\mu}{h^2} \cdot \frac{\partial}{\partial y} H_z - \frac{\gamma}{h^2} \frac{\partial E_z}{\partial x} = E_x$$

Propogation of TM mode in □ wave guide

$\cdot$ $H_z = 0$ & $E_z \neq 0$

wave eq. $\frac{\partial^2 E_z}{\partial x} + \frac{\partial^2 E_z}{\partial y} + h^2 E_z = 0$

Assume $E_z = XY$

$$Y \frac{\partial^2 X}{\partial x^2} + X \frac{\partial^2 Y}{\partial y^2} + h^2 XY = 0$$

$$\frac{1}{X} - \frac{\partial^2 X}{\partial x^2} + \frac{1}{Y^2} \frac{\partial^2 Y}{\partial y^2} + h^2 = 0$$

Put, $\frac{1}{X} \frac{\partial^2 X}{\partial x^2} = -B^2$ — ①, $\frac{1}{Y} \frac{\partial^2 Y}{\partial y^2} = -A^2$ — ②

$h^2 = A^2 + B^2$

Solve ① & ②, $X = C_1 \cos Bx + C_2 \sin Bx$

$Y = C_3 \cos Ay + C_4 \sin Ay$

$E_z = X.Y = (C_1 \cos Bx + C_2 \sin Bx)(C_3 \cos Ay + C_4 \sin Ay)$

5) Sketch dominant mode in rectangular waveguide

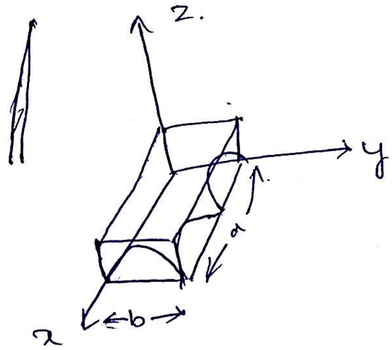
$$\lambda_{c_{mn}} = \frac{2ab}{\sqrt{m^2b^2 + n^2a^2}}$$

For TE_{01} mode, $\lambda_{c01} = \frac{2ab}{\sqrt{a^2}} = 2b.$

For TE_{10} mode, $\lambda_{c10} = \frac{2ab}{\sqrt{b^2}} = 2a$

For TE_{11} mode, $\lambda_{c11} = \frac{2ab}{\sqrt{a^2+b^2}}$

λ_{c10} is the dominant mode $\because$ magnitude of a is greater



9) Derive S-matrix of E-M plane Tee junction with diagram and its application.

i) 4x4, S matrix

ii) $S_{33} = S_{44} = 0$

iii) $S_{34} = S_{43} = 0$

iv) $-S_{14} = S_{24}$

v) $S_{13} = S_{23}$

vi) Symmetry property.

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{22} & S_{23} & S_{24} \\ S_{13} & S_{23} & 0 & 0 \\ S_{14} & S_{24} & 0 & 0 \end{bmatrix}$$

$S_{14} = -S_{24}$
&
$S_{23} = S_{13}$

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{22} & S_{13} & -S_{14} \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{bmatrix}$$

$\Rightarrow [S] \times [S^*] = I$

$\Rightarrow |S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1$

$|S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1$

$|S_{13}|^2 + |S_{13}|^2 = 1$

$|S_{14}|^2 + |S_{14}|^2 = 1$

$(S_{14})(S_{11}^*) - (S_{14})(S_{12}^*) = 0$

$S_{11} = S_{12}$

$S_{13} = 1/\sqrt{2} \Rightarrow S_{14} = 1/\sqrt{2}$

$\Rightarrow 2|S_{11}|^2 + \frac{1}{2} + \frac{1}{2} = 1$

$\Rightarrow \cancel{2}\, S_{11} = 0 \quad ; \quad S_{12} = 0$

$\Rightarrow 0 + |S_{22}|^2 + 1/2 + 1/2 = 1$

$S_{22} = 0$

$$\begin{bmatrix} 0 & 0 & 1/\sqrt{2} & 1/\sqrt{2} \\ 0 & 0 & 1/\sqrt{2} & -1/\sqrt{2} \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \end{bmatrix}$$

I) $a_3 = a \; ; \; a_1 = a_2 = a_4 = 0$

$b_1 = 1/\sqrt{2}\, a \; ; \; b_2 = \frac{1}{\sqrt{2}} a \; , \; b_3 = 0 \; , \; b_4 = 0$

II) $a_4 = a$, $a_1 = a_2 = a_3 = 0$

$b_1 = \frac{1}{\sqrt{2}} a$, $b_2 = \frac{-1}{\sqrt{2}} a$

III) $a_1 = a_2 = a$; $a_3 = a_4 = 0$

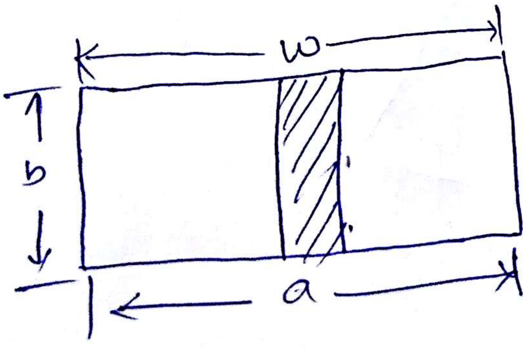
$b_1 = 0$, $b_2 = 0$, $b_3 = \sqrt{2} a$, $b_4 = 0$

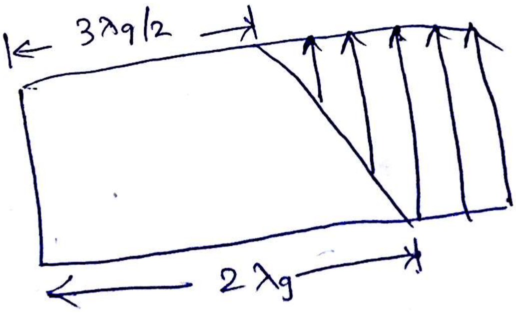
10) Write the classification of attenuators & explain any one.

Attenuators are commonly used for measuring power gain or loss in dB's, for providing isolation b/w instruments, for reducing the power i/p to a particular stage to prevent overloading and also for providing the signal generators with a means of calibrating their o/p accurately so that precise measurement could be made. Attenuation can be classified as fixed or variable types.

Fixed attenuators :-

They are used where fixed amount of attenuation is to be provided. If such a fixed attenuator absorbs all the energy entering into it, we call it as a WG terminator. This normally consists of a short section of WG with a toppered plug of absorbing material at the end.





11) Define cavity resonator & derive expression for resonant cavity.

When one end of the waveguide is terminated in a shorting plate there will be reflection & standing wave forms.

The microwave cavity resonator is akin to a tuned circuit a low frequency having a resonant freq

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

WKT for □ WG.

$$h^2 = \gamma^2 + \omega^2\mu\epsilon = A^2 + B^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$$

$$\omega^2\mu\epsilon = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \gamma^2$$

$$\gamma = j\beta \Rightarrow \gamma^2 = j^2\beta^2 = -\beta^2$$

$$\omega^2\mu\epsilon = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \beta^2$$

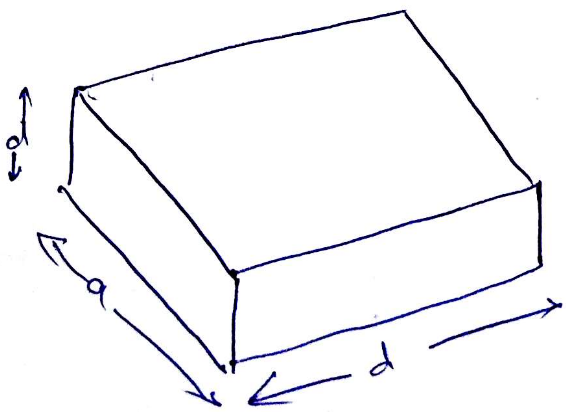
$p = 1, 2, 3, \ldots, \infty$, d = length of the resonator

$$\beta = \frac{p\pi}{d}, \quad f = f_0, \quad \omega = 2\pi f_0 = \omega_0$$

$$\omega_0^2\mu\epsilon = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{p\pi}{d}\right)^2$$

$$f_0 = \frac{1}{2\pi\sqrt{\mu\epsilon}}\left[\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{p\pi}{d}\right)^2\right]^{1/2}$$

$$f_0 = \frac{c}{2}\left[\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2\right]^{1/2}$$



□ cavity resonator.