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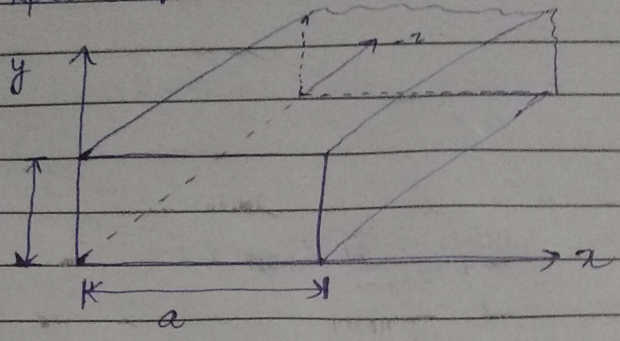
Ans 1) a



The TE_{mn} modes in a rectangular guide are characterized by $E_z = 0$. In other words, the z component of the magnetic field, H_z must exist in order to have energy transmission in guide.

$$\nabla^2 H_z = \gamma^2 H_z$$

$$H_z = \left[A_m \sin\left(\frac{m\pi x}{a}\right) + B_n \cos\left(\frac{m\pi x}{a}\right)\right] \times \left[C_n \sin\left(\frac{n\pi y}{b}\right) + D_n \cos\left(\frac{n\pi y}{b}\right)\right] e^{-j\beta z}$$

will be determined in accordance with the given boundary conditions, where $k_x = m\pi/a$ and $k_y = n\pi/b$ are replaced.

$$\nabla \times E = -j\omega\mu H$$
$$\nabla \times H = j\omega\epsilon E$$

In rectangular coordinates, components are -

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

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

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

$$\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z} = j\omega\epsilon E_x$$

$$\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x} = j\omega\epsilon E_y$$

$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = j\omega\epsilon E_z$$

with the substitution $\frac{\partial}{\partial z} = -j\beta g$ $E_z = 0$

$$\beta g E_y = -\omega\mu H_x$$

$$\beta g E_x = \omega\mu H_y$$

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

$$\frac{\partial H_z}{\partial y} + j\beta_g H_y = j\omega\epsilon E_x$$

$$-j\beta_g H_x - \frac{\partial H_z}{\partial x} = j\omega\epsilon E_y$$

$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = 0$$

$$E_x = \frac{-j\omega\mu}{K_c^2}\frac{\partial H_z}{\partial y}$$

$$E_y = \frac{j\omega\mu}{K_c^2}\frac{\partial H_z}{\partial x}$$

$$E_z = 0$$

$$H_x = \frac{-j\beta_g}{K_c^2}\frac{\partial H_z}{\partial x}$$

$$H_y = \frac{-j\beta_g}{K_c^2}\frac{\partial H_z}{\partial y}$$

where $K_c^2 = \omega^2\mu\epsilon - \beta_g^2$ has been replaced

Differentiating w.r.t x and y and then substituting the result

It is generally concluded that normal derivate H_z must vanish at conducting surface

$$\frac{\partial H_z}{\partial n} = 0$$

$$H_z = H_{oz}\cos\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-j\beta_g z}$$

where H_{oz} is amplitude constant

$$E_x = E_{ox}\cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)e^{-j\beta_g z}$$

$$E_y = E_{oy}\sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)e^{-j\beta_g z}$$

$$E_z = 0$$

$$H_x = H_{ox} \sin\left(\frac{m\pi x}{a}\right) \cos\left(\frac{n\pi y}{b}\right) e^{-j\beta g z}$$

$$H_y = H_{oy} \cos\left(\frac{m\pi x}{a}\right) \sin\left(\frac{n\pi y}{b}\right) e^{-j\beta g z}$$

$$H_z = 0$$

Ans (1) (b) If the signal frequency is in the microwave range, the widespread H, Y, and Z parameters (used in basic network theory) cannot be measured for following reason -

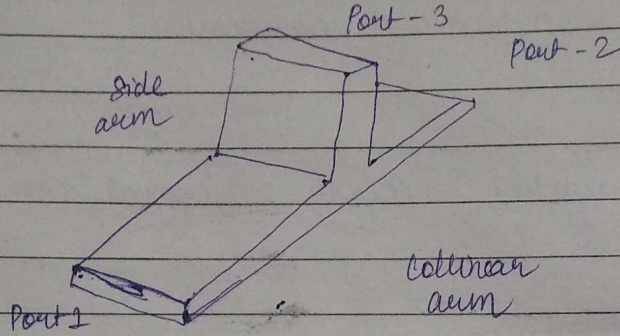
It is hard to measure total voltage and current at the ports of the device under test. Active device may be unstable or self-destruct with short and open circuit. S parameter measure traveling waves rather than total voltage and currents. Following advantages -

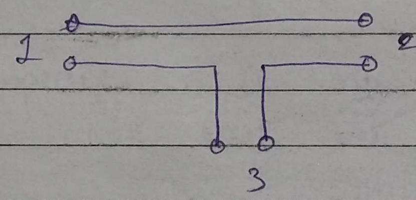
The basic measurements to determine the S-parameters are familiar and well established microwave measurement reflection, coefficient, attenuation (gain), phase S parameter are analytically convinient; they allow for calculations of system performance by cascading individual component. Flow graph analysis can be used, which simplifies the analysis of microwave system.

Properties of Scattering matrix [S]

1. Square matrix Property — It is always a square matrix [n×n]

Ans (2) (a) An E-plane tee junction is formed by attaching simple waveguide to the broader dimension of rectangular waveguide, which already has two port. The arms of rectangular waveguides make two port called collinear ports i.e. Port 1 and Port 2.





Properties of E-plane tee

Properties of E-plane tee can be defined by $[S]_{3\times 3}$ matrix

It is a 3X3 matrix

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}$$

- Scattering coefficients S_{13} and S_{23} are out of phase by 180°

$$S_{23} = -S_{13}$$

- Port is perfectly matched to junction $S_{33} = 0$

2. Unitary Property $[S][S^*] = [I]$, product of matrix and its complex conjugate = unitary matrix.

3. Symmetry Property — It is symmetric $S_{ij} = S_{ji}$ the input to output to input doesn't change the transition properties, being a passive component.

4. For perfect matched network diagonal elements will be zero

From symmetric property

$S_{ij} = S_{ji}$

$$\therefore \quad [S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{12} & S_{22} & -S_{13} \\ S_{13} & -S_{13} & 0 \end{bmatrix}$$

From unitary property

$$[S][S]^* = I$$

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{12} & S_{22} & -S_{13} \\ S_{13} & -S_{13} & 0 \end{bmatrix} \begin{bmatrix} S_{11}^* & S_{12}^* & S_{13}^* \\ S_{12}^* & S_{22}^* & -S_{13}^* \\ S_{13}^* & -S_{13}^* & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Noting R_3 row and C_3 column

R_1C_1 : $S_{11} S_{11}^* + S_{12} S_{12}^* + S_{13} S_{13}^* = 1$

R_3C_1 : $S_{13} S_{11}^* - S_{13} S_{12}^* = 1$

$S_{11} = S_{22}$

$2|S_{13}|^2$ or $S_{13} = \frac{1}{\sqrt{2}}$

$S_{13} (S_{11}^* - S_{12}^*)$

or $S_{11} = S_{12} = S_{22}$

$\therefore \quad S_{11} = \frac{1}{2}$

We get

$$[S] = \begin{bmatrix} 1/2 & 1/2 & 1/\sqrt{2} \\ 1/2 & 1/2 & -1/\sqrt{2} \\ \frac{1}{\sqrt{2}} & -1/\sqrt{2} & 0 \end{bmatrix}$$

Application of E-plane tee

- It is used to measure the impedance
- For a linearly polarized antenna, this is plane containing the electric field vector and direction of maximum radiation.
- Wi-fi device, cordless telephone & weather radar system.

Ans (2) (b) Types of planar transmission line —

(1) Microstrip

It is the simplest structure to fabricate beginning with thin dielectric substrate with metal on both side. One metal sheet is kept as the electrical ground while the other is patterned using photolithography.

(2) Copolanar waveguide

CPW supports a quasi TEM mode of propagation with the active metallization and ground planes on the same side of the substrate

(3) Stripline

Stripline is a symmetric structure somewhat like coaxial line completely flattened out so that the centre conductor is rectangular metal strip and the outer grounded metal is a extended rectangular box.

(4) Embedded differential line

The simple transmission structure is formed by having just two conductors embedded in a substrate with no specific ground plane.

Ans (3) (a)

(i) η intrinsic impedance

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}} = \sqrt{\frac{j2\pi(4\times10^{9})\times4\pi\times10^{-7}}{4+j2\pi(4\times10^{9})(20\times8.8\times10^{-12})}}$$

$$= \sqrt{\frac{31583\angle 90^{\circ}}{5.98\angle 40^{\circ}}}$$

$$= 72.7\angle 21 = 67.87 + j26.1\ \Omega$$

(ii) $$\beta = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} = \sqrt{31583\angle 90^{\circ}\times5.982\times\angle 48^{0}}$$

$$= 434\angle 69^{0} = 155.75 + j405.75\ \Omega$$

(iii) $$v_p = \frac{\omega}{\beta} = \frac{2\pi f}{\beta} = \frac{2\pi\times4\times10^{9}}{405.75}$$

$$= 0.62\times10^{8}\ m/s$$

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Ans (3) (b) Properties of magic tee as 3dB power combiner —

The properties of E-H plane tee can be defined by its $[S]_{4\times4}$ matrix

It is a 4x4 matrix as there are 4 possible inputs and 4 possible outputs

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

As it has H-plane tee section

$$S_{23} = S_{13}$$

As it has E-plane tee section

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

The E-arm port and H arm port are so isolated that the other won't deliver an output, if an input is applied at one of them. Hence

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

From symmetry property, we have
$$S_{ij} = S_{ji}$$

$$S_{12} = S_{21}, \quad S_{13} = S_{31}, \quad S_{14} = S_{41}$$
$$S_{23} = S_{32}, \quad S_{42} = S_{24} \quad S_{34} = S_{43}$$

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$$S_{34} = S_{44} = 0$$

From unitary property $[S][S]^* = [I]$

Some other properties —

(i) If a signal of equal phase and magnitude is sent to port 1 and 2, then the output at port 4 is zero and output at port 3 will be sum of both port 1 and 2.

(ii) If a signal is sent to port 4, then the power is divided b/w port 1 & 2 equally but in opposite phase, while there is no output at port 3.

(iii) If a signal is fed at port - 3 then the power is divided equally but in opposite phase, while there would be no output at port 4.