SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECB311 -OPTICAL AND MICROWAVE ENGINEERING

TOPIC– TEE JUNCTION

MICROWAVE PASSIVE COMPONENTS

➢Microwave passive devices are used inside microwave measurement instruments, and they are used to combine instruments to create more complex measurement systems.

➢In all cases, these devices will split, combine, filter, attenuate, and/or shift the phase of a microwave signal as it propagates through a particular transmission system.

➢Examples:

- Power Divider (TEE JUNCTIONS)
- Directional Coupler
- Magic Tee
- Attenuator
- Resonator

TEE JUNCTIONS

- MICROWAVE T- JUNCTIONS

  T junction is an intersection of three waveguides in the form of English alphabet T'. There are several types of Tee junctions.

- In microwave circuits a waveguide or coaxial-line with Three independent ports is commonly referred to as a Tee junction.

TEE JUNCTIONS

- They are used to connect branch (or) section of the waveguides in series or parallel with the main waveguide transmission line
- providing means of splitting and also of combining power in a waveguide system.

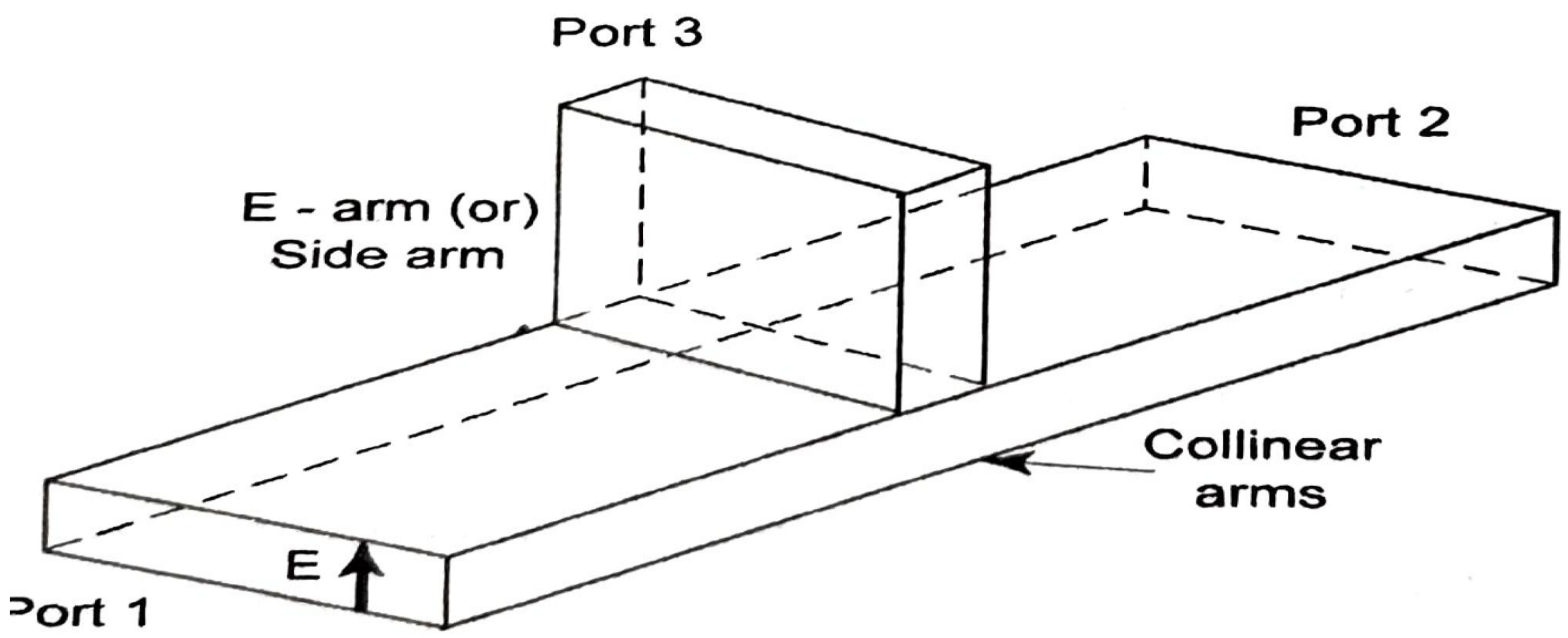
- The two basic Types are

  i) E -plane Tee (Series)

  (ii) H-plane Tee (Shunt).

E-PLANE TEE (SERIES TEE)

- An E-plane tee is a waveguide tee in which the axis of its side arm is parallel to the E- field of the main guide.
- Ports I and 2 are the collinear arms and port 3 is the E- arm (side arm).
- A rectangular slot is cut along the broader dimension of a long waveguide and a side arm is attached



E-PLANE TEE (SERIES TEE)

- When the waves are fed into the side arm (port 3)
- The waves appearing at port 1 and port 2 of the collinear arm will be in opposite phase and in the same magnitude.

$$S13 = -S23$$

- In general, the power out port 3 (side or E arm) is proportional to the difference between instantaneous powers entering from ports I and 2.
- <u>Difference Arm</u>

  If two input waves are fed into port I and port 2 of the collinear arm, the output wave at port 3 will be opposite in phase and subtractive. Sometimes, this third port is called the difference arm

SCATTERING MATRIX FOR E-PLANE TEE

- For E-plane tee, [S] is a3 x3 matrix since there are 3 ports,

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} \quad \ldots (1)$$

The scattering coefficient due to difference arms are,

$$S_{23} = -S_{13} \quad \ldots (2)$$

- The equation represents that the outputs at ports 1 and 2 are out of phase by 180 °with an input at port 3.

SCATTERING MATRIX FOR E-PLANE TEE

If port 3 is perfectly matched to the junction,

$$\boxed{S_{33} = 0} \quad \ldots (3)$$

Using symmetric property, $S_{ij} = S_{ji}$

$$\boxed{\begin{aligned} S_{12} &= S_{21} \\ S_{13} &= S_{31} \\ S_{23} &= S_{32} \end{aligned}} \quad \ldots (4)$$

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{12} & S_{22} & -S_{13} \\ S_{13} & -S_{13} & 0 \end{bmatrix} \quad \ldots (5)$$

SCATTERING MATRIX FOR E-PLANE TEE

Apply unity property of [S] matrix for equation(5), we get

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

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

R_1C_1: $|S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 = 1$ ... (6)

R_2C_2: $|S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2 = 1$ ... (7)

R_3C_3: $|S_{13}|^2 + |S_{13}|^2 = 1$ ... (8)

SCATTERING MATRIX FOR E-PLANE TEE

Using zero property of [S] matrix, we get

R_3C_1: $S_{13}.S_{11}^* - S_{13}S_{12}^* = 0$ ... (9)

By equating equations (6) and (7), we get

$$|S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 = |S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2$$

$$\boxed{S_{11} = S_{22}} \quad \text{... (10)}$$

From Equation (8), we get the value of S_{13} as

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

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

$$\boxed{|S_{13}| = \frac{1}{\sqrt{2}}} \quad \text{... (11)}$$

SCATTERING MATRIX FOR E-PLANE TEE

From equation (9),

$$S_{13}\left(S_{11}^{*}-S_{12}^{*}\right) = 0$$

$$S_{11}^{*} - S_{12}^{*} = 0$$

$$\boxed{S_{11} = S_{12} = S_{22}} \qquad \ldots (12)$$

By using equations (10), (11) and (12) in equation (6), we get

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

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

$$\boxed{S_{11} = \frac{1}{2}} \qquad \ldots (13)$$

SCATTERING MATRIX FOR E-PLANE TEE

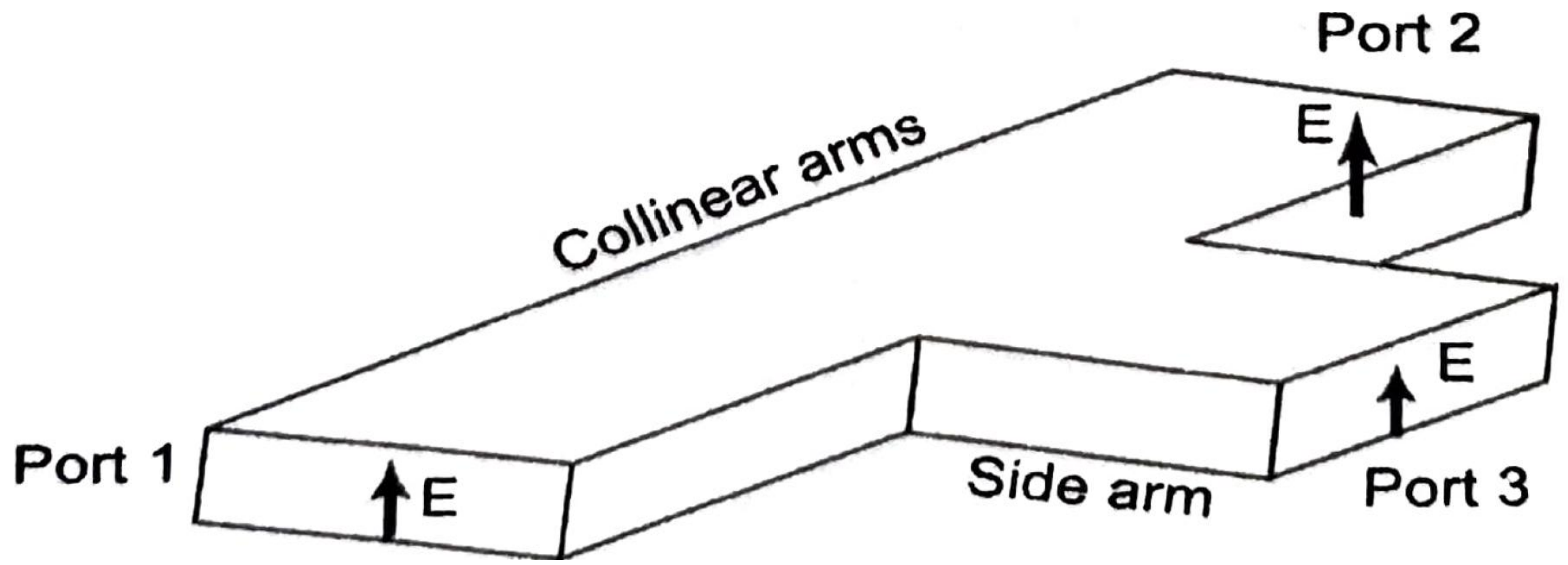
- Thus the equation represents the scattering matrix for E-plane tee.

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

H-PLANE TEE (SHUNT TEE)

- H-plane tee junction is formed by cutting a rectangular slot along the width of a main waveguide and attaching another waveguide the side arm called the H-arm.
- The port 1 and port 2 of the main waveguide are called collinear ports and port3 is the H-arm (or) Side arm.
- An H - plane tee is a waveguide tee in which the axis of its side arm is "shunting'" the E - field (or) parallel to the H- field of the main guide.
- Sum Arm:
- In a H-plane tee if two input waves are fed into port1 and port 2 of the collinear arm, the output wave at port 3 will be in phase and additive. Hence,the third port is called the sum arm.

H-PLANE TEE (SHUNT TEE)



- For H-plane tee, [S] is a 3 x3 matrix since there are 3 ports.

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} \longrightarrow \quad (1)$$

SCATTERING MATRIX FOR H-PLANE TEE

- If the input is fed into the port 3, then the wave will split equally into port I and port 2 in phase and in the same magnitude.
- Here, the scattering coefficients S13 and S23 must be equal.

S13 =S23

$$S_{13} = S_{23} \quad \ldots (2)$$

From the symmetric property, $S_{ij} = S_{ji}$

$$S_{12} = S_{21}$$
$$S_{23} = S_{32} = S_{13}$$
$$S_{13} = S_{31} \quad \ldots (3)$$

Since port 3 is perfectly matched to the junction.

$$S_{33} = 0 \quad \ldots (4)$$

SCATTERING MATRIX FOR H-PLANE TEE

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

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

$$|S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 = 1 \qquad \ldots (6)$$

Similarly,

R_2C_2: $|S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2 = 1 \qquad \ldots (7)$

R_3C_3: $|S_{13}|^2 + |S_{13}|^2 = 1 \qquad \ldots (8)$

SCATTERING MATRIX FOR H-PLANE TEE

Using zero property of [S] matrix, we get

R_3C_1: $$S_{13} . S_{11}^{*} + S_{13} S_{12}^{*} = 0 \quad \ldots (9)$$

From equation (8),

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

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

$$\boxed{S_{13} = \frac{1}{\sqrt{2}}} \quad \ldots (10)$$

SCATTERING MATRIX FOR H-PLANE TEE

Comparing equations (6) and (7), we get

$$|S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 = |S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2$$

$$|S_{11}|^2 = |S_{22}|^2$$

$$\boxed{S_{11} = S_{22}} \quad \ldots (11)$$

From equation (9),

$$S_{13}\left(S_{11}^* + S_{12}^*\right) = 0, \qquad \text{since } S_{13} \neq 0,$$

SCATTERING MATRIX FOR H-PLANE TEE

$$S_{11}^{*} + S_{12}^{*} = 0$$

$$S_{11}^{*} = -S_{12}^{*} \quad \ldots (12)$$

Using above value in equation (6), we get

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

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

$$\boxed{S_{11} = \frac{1}{2}} \quad \ldots (13)$$

From equations (11), (12) and (13),

$$\boxed{S_{12} = -\frac{1}{2} \qquad S_{22} = \frac{1}{2}} \quad \ldots (14)$$

SCATTERING MATRIX FOR H-PLANE TEE

- This equation represents the scattering matrix for H-plane tee.

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

We know that $[b] = [s][a]$

$$\begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & -\frac{1}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix}$$

ASSESSMENT

1. Why E plane Tee junction is called as Series Tee?

   Answer:

   As the axis of the side arm is parallel to the electric field, this junction is called E-Plane Tee junction. This is also called as Voltage or Series junction. The ports 1 and 2 are 180° out of phase with each other.

2. The diagonal elements of the s matrix of a resistive T junction are:

   Answer: zero

3. Why third port is sum arm in H plane Tee?

   Answer: The output wave at port 3 will be in phase and additive.

THANK YOU