SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A++' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECB311 -OPTICAL AND MICROWAVE ENGINEERING

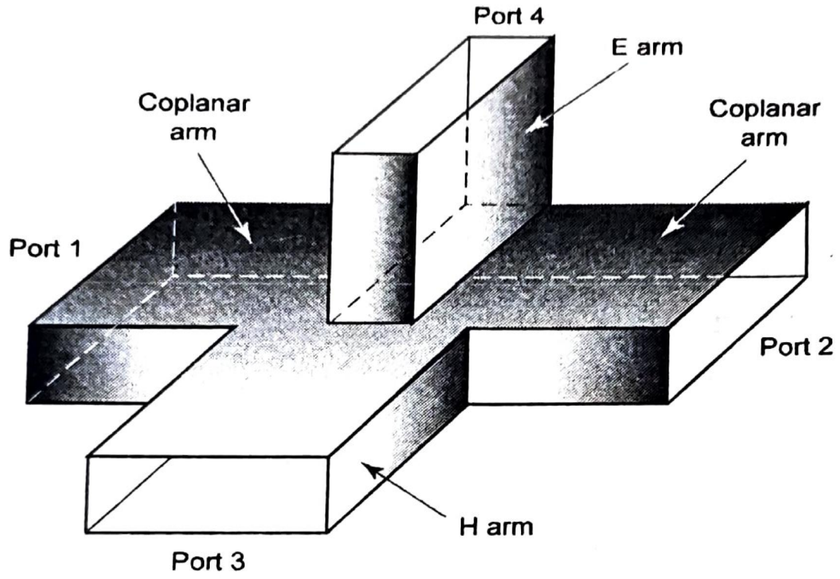
TOPIC– HYBRID TEE

Hybrid Tee or Magic-T

- A hybrid junction is a four - port network in which a signal incident on any one of the port divides between two output ports with the remaining port being isolated
- A magic tee is a combination of the E -plane tee and H -plane tee.
- Ports 1 and 2 are collinear arms
- Port 3 is the H- arm and port 4 is the E-arm.
- Rectangular slots are cut both along the width and breadth of a long waveguide and side arms are attached

CHARACTERISTICS OF MAGIC TEE

- If two in phase waves of equal magnitude are fed into ports 1 and 2, the output at port 4 is subtractive and hence zero and the total output will appear additively at port 3.
- port 4 is called the difference (or) E-arm
- port 3 is the sum (or) H- arm



CHARACTERISTICS OF MAGIC TEE

- A wave incident at port 4 (E - arm) divides equally between ports 1 and 2 but opposite in phase with no coupling to port 3 (H-arm).
- A wave incident at port 3 (H- arm) divides equally between ports 1 and 2 are in phase with no coupling to port 4 (E - arm).

$$S_{43} = S_{34} = 0 \qquad \text{-------- (1)}$$

- A wave fed into one collinear port I or 2 will not appear in the other collinear port 2 or 1. Hence, two collinear ports 1 and 2 are isolated from each other.

$$S_{12} = S_{21} = 0 \qquad \text{-------- (2)}$$

CHARACTERISTICS OF MAGIC TEE

- For an ideal, lossless magic – T matched at ports 3 and 4.

$$S_{33} = S_{44} = 0 \qquad \text{--- (3)}$$

- [S] is a 4 x4 matrix since there are 4 ports.

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} \qquad \ldots (4)$$

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

$$\boxed{S_{12} = S_{21},\ S_{13} = S_{31},\ S_{14} = S_{41},\ S_{23} = S_{32},\ S_{24} = S_{42},\ S_{34} = S_{43}} \qquad \ldots (5)$$

Port 3 has H-plane tee section,

$$S_{23} = S_{13} \qquad \ldots (6)$$

Similarly, port 4 has E-plane tee section

$$S_{24} = -S_{14} \qquad \ldots (7)$$

SCATTERING MATRIX OF MAGIC TEE

By substituting equations (1), (3), (5),(6) and (7) in equation (4), the S – matrix for a magic – T matched at ports 3 and 4 is given by,

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{22} & S_{13} & -S_{14} \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{bmatrix} \quad \ldots (8)$$

$$[S].[S]^{*} = [I]$$

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{22} & S_{13} & -S_{14} \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{bmatrix} \begin{bmatrix} S_{11}^{*} & S_{12}^{*} & S_{13}^{*} & S_{14}^{*} \\ S_{12}^{*} & S_{22}^{*} & S_{13}^{*} & -S_{14}^{*} \\ S_{13}^{*} & S_{13}^{*} & 0 & 0 \\ S_{14}^{*} & -S_{14}^{*} & 0 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

SCATTERING MATRIX OF MAGIC TEE

R_1C_1: $$|S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1 \quad \ldots (9)$$

R_2C_2: $$|S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2 + |S_{14}|^2 = 1 \quad \ldots (10)$$

R_3C_3: $$|S_{13}|^2 + |S_{13}|^2 = 1 \quad \ldots (11)$$

R_4C_4: $$|S_{14}|^2 + |S_{14}|^2 = 1 \quad \ldots (12)$$

By equating equations (9) and (10), we get

$$|S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 + |S_{14}|^2 = |S_{12}|^2 + |S_{22}|^2 + |S_{13}|^2 + |S_{14}|^2$$

$$\boxed{|S_{11}| = |S_{22}|} \quad \ldots (13)$$

SCATTERING MATRIX OF MAGIC TEE

From equation (11),

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

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

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

$$\boxed{|S_{13}| = \frac{1}{\sqrt{2}}} \quad \ldots (14)$$

From equation (12),

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

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

$$\boxed{|S_{14}| = \frac{1}{\sqrt{2}}} \quad \ldots (15)$$

SCATTERING MATRIX OF MAGIC TEE

By substituting equations (14) and (15) in equation (9), we get

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

$$|S_{11}|^2 + |S_{12}|^2 = 0$$

which is valid if,

$$\boxed{S_{11} = S_{12} = 0} \qquad \ldots (16)$$

From equations (13) and (16), we get

$$\boxed{S_{22} = 0} \qquad \ldots (17)$$

SCATTERING MATRIX OF MAGIC TEE

The [S] of magic tee is obtained by substituting the scattering parameters from equations (16) and (17) in equation (8), we get

$$[S] = \begin{bmatrix} 0 & 0 & S_{13} & S_{14} \\ 0 & 0 & S_{13} & -S_{14} \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{bmatrix} \quad \ldots (18)$$

Using the equations(14) and (15), the scattering matrix for an ideal hybrid tee may be stated in [S]- matrix in the following form as,

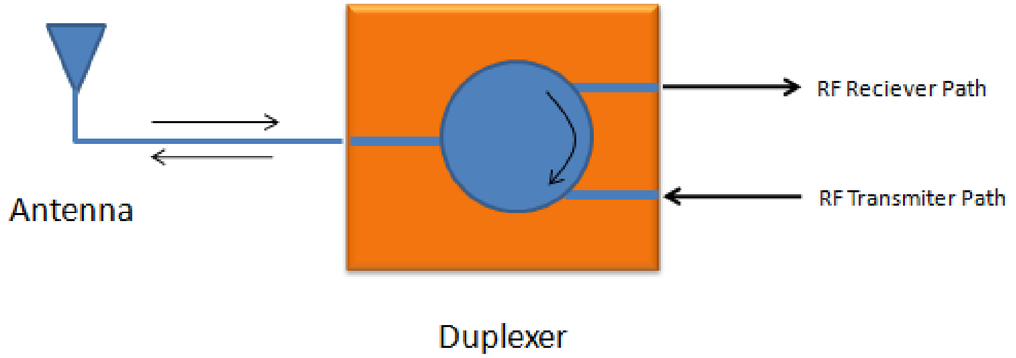
$$[S] = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & -1 \\ 1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \end{bmatrix} \quad \ldots (19)$$

APPLICATIONS

- Now we understand that ports 1 and 2 are perfectly matched to the junction. As this is a 4 port junction, whenever two ports are perfectly matched, the other two ports are also perfectly matched to the junction.
- The junction where all the four ports are perfectly matched is called as Magic Tee Junction.
- **Applications:**
  - Measurement of impedance
  - As duplexer
  - As mixer
  - As an isolator

Magic Tee As duplexer

- The duplexer is a circuit which works as both the transmitter and the receiver, using a single antenna for both the purposes.
- Port 1 and 2 are used as receiver and transmitter where they are isolated and hence will not interfere.
- An antenna is connected to E-Arm port. A matched load is connected to H-Arm port, which provides no reflections. Now there exists transmission or reception without any problem.



ASSESSMENT

1. Why Hybrid Tee junction is called as Magic Tee?

   Answer:

   The junction where all the four ports are perfectly matched is called as Magic Tee Junction

2. A magic tee is to be used as CW duplexer. Then port 1, port 2, port 3 (E arm), port 4 (H arm) respectively should be connected to

   (a): CW transmitter, antenna, receiver and matched load

   (b): CW transmitter, matched load, receiver and antenna

   (c): CW transmitter, receiver , antenna and matched load

   (d): matched load, antenna, receiver and CW transmitter

Answer: c

THANK YOU