

**Innovative Teaching through Simulation and Demonstration
for B.E-E.C.E-IV Year- VII SEM**

Course: Microwave Engineering

**Verification of Operational Characteristics
of Microwave Components using
MATLAB-Simulink**

BY

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Figures & material Courtesy: Source Internet: Mathworks

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Verification of Power division characteristics of E-Plane Tee & H-Plane Tee using MATLAB-Simulink

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Block Diagram

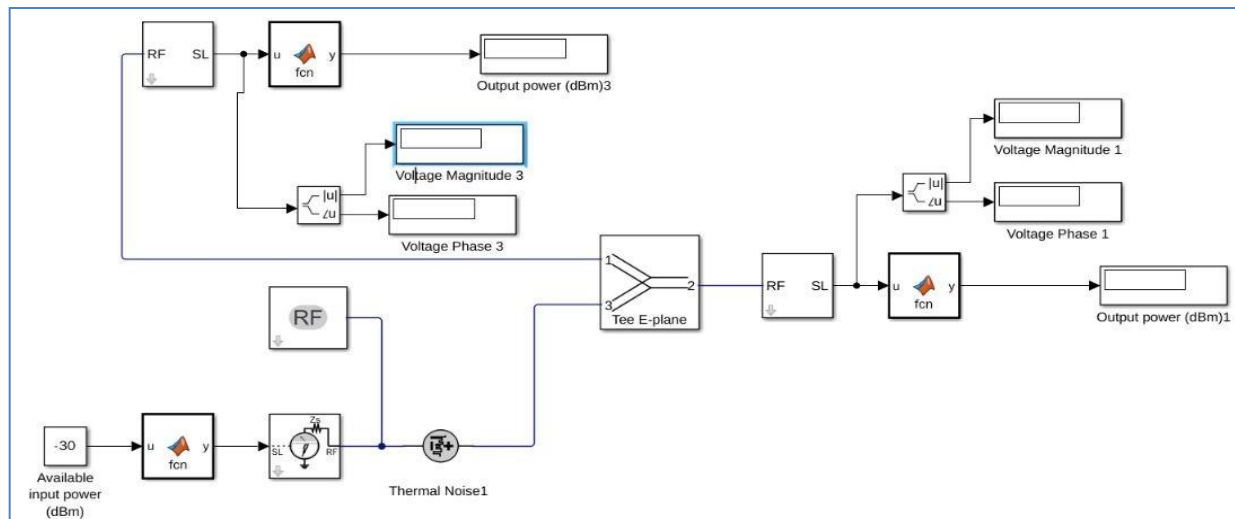


Fig. Simulink model of E-Plane Tee

Theory:

It is clear from the sketch of the E plane tee that an auxiliary waveguide arm is fastened to the broader wall of the main guide. Thus it is also a three port device in which the auxiliary arm axis is in parallel to the plane of the electric fields of the main guide, and the coupling from the main guide to the auxiliary guide is by means of electric fields. Therefore, it is also known as E plane tee. It is clear that it causes load connected to its branches to appear in series. So it is often referred to as a series tee. As indicated in fig, the two main guide arms are symmetrical with respect to the auxiliary guide arm.

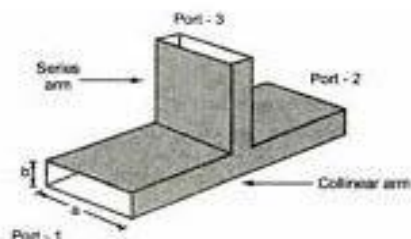


Fig. E-Plane Tee

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As such if power is fed from the auxiliary arm, it is equally distributed in the two arms 1 and 2 when they are terminated in equal loads. However as depicted in the field configuration, the power flowing out in arm 1 is 180 out of phase to the one in arm 2. As such this tee is known as 'subtractor' or 'differencer'.

Procedure:- Verification of E-Plane Tee

- 1) Open Simulink and select the library browser
- 2) Select the RF Block Set and Circuit envelope
- 3) Goto elements and select the component required
- 4) Construct attenuator circuit as shown in the block diagram
- 5) Open the Input Blocks and verify the power level and frequency
- 6) Observe different parameters in the Simulink to RF at the input and RF to Simulink block at the output
- 7) Verify that both the blocks have the same carrier frequency
- 8) Open the E-Plane Tee block and check for the properties
- 9) Run the Simulation and observe the Power reaching the ports
- 10) Change the input level, frequency to verify the output

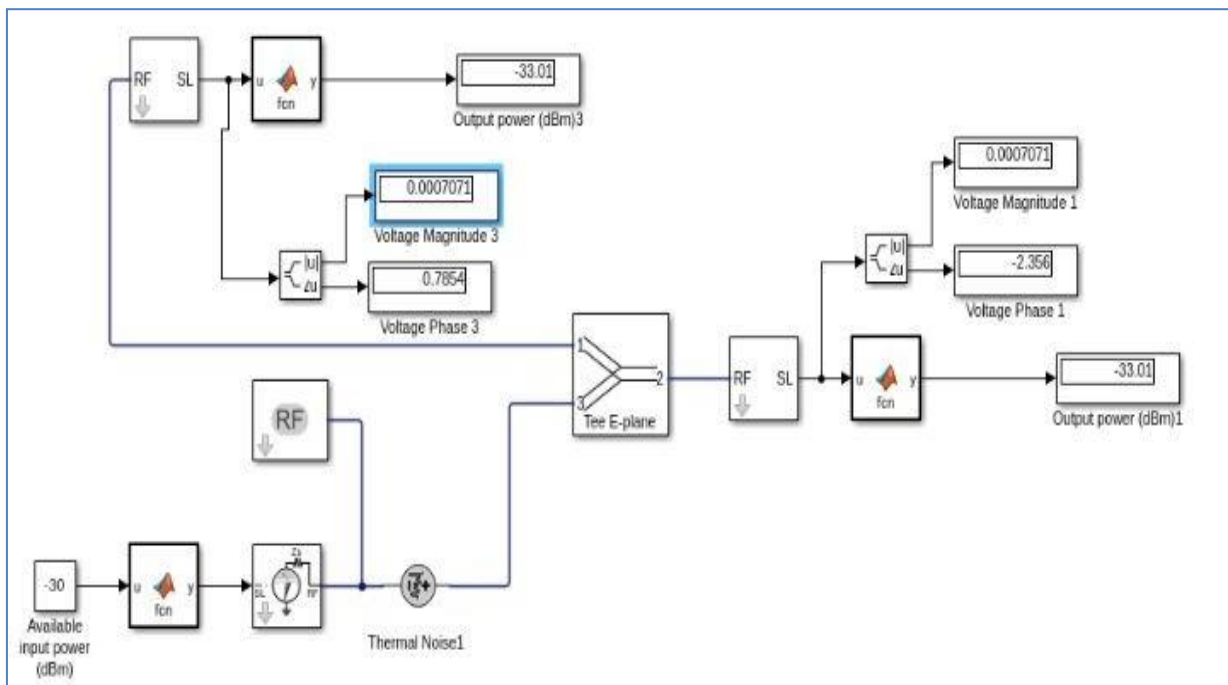


Fig. I/P Port:3; Output ports:1,2

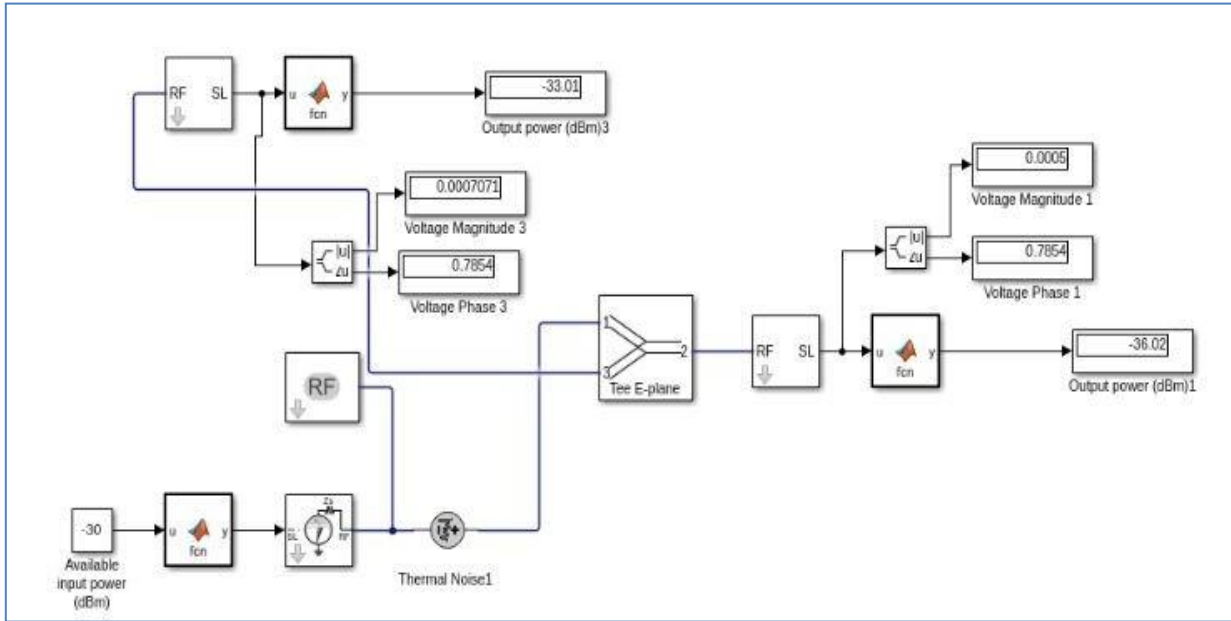


Fig. I/P Port:1; Output ports:2,3

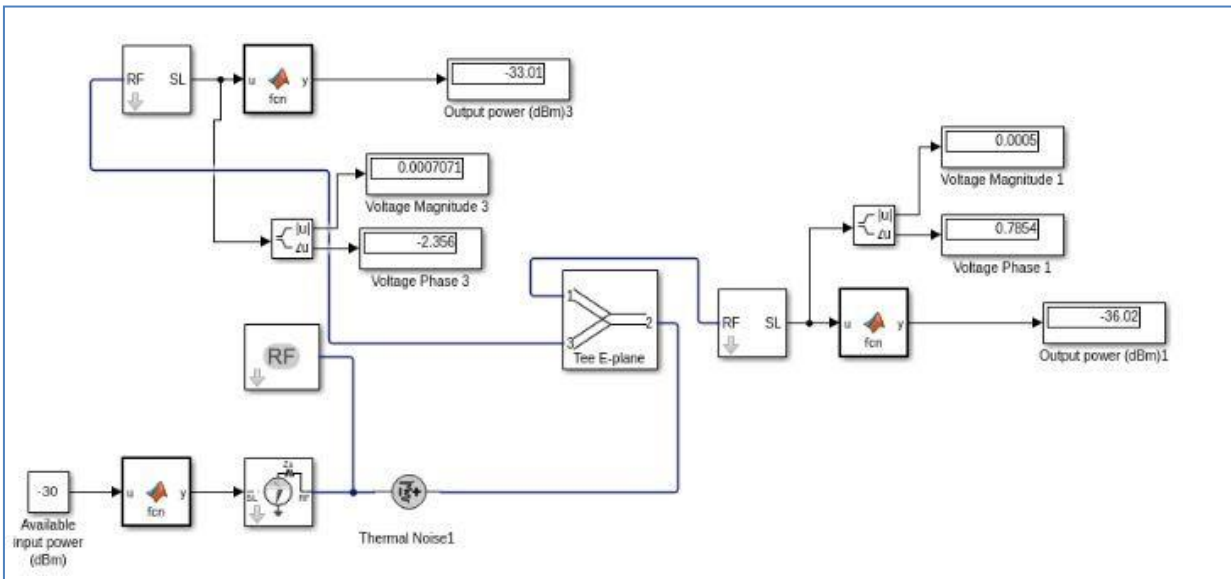


Fig. I/P Port:2; Output ports:1,3

Design of H-Plane Tee

Block Diagram

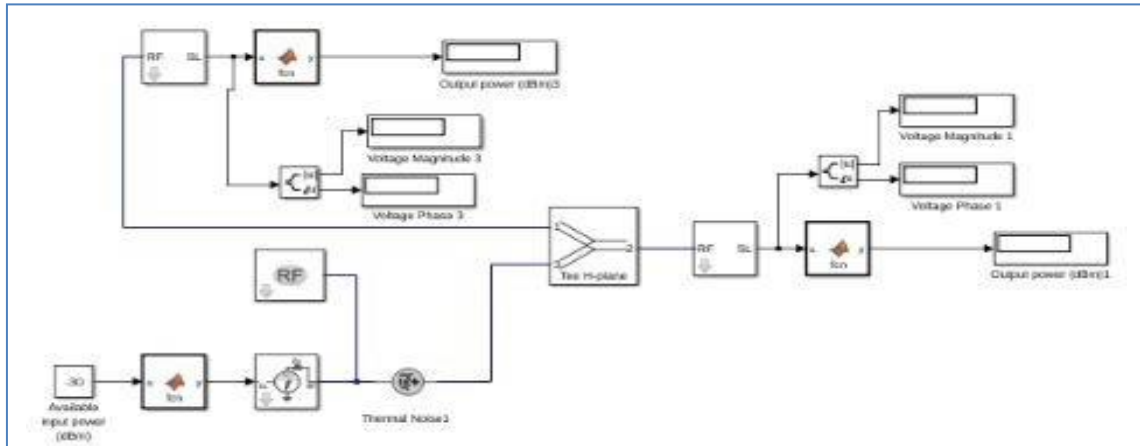


Fig. Simulink model of H-Plane Tee

Theory:

It is clear from the sketch that an auxiliary waveguide arm is fastened perpendicular to the narrow wall of a main guide, thus it is a three port device in which axis of the auxiliary or side arm is parallel to the planes of the magnetic field of the main of the main guide and the coupling from the main guide to the branch guide is by means of magnetic fields. Therefore, it is also known as H plane tee. The perpendicular arm is generally taken as input and other two arms are in shunt to the input and hence it is also called as shunt tee. Because of symmetry of the tee; equivalent circuit of H plane, when power enters the auxiliary arm, and the two main arms 1 and 2 are terminated in identical loads, the power supplied to each load is equal and in phase with one another. If two signals of equal amplitude and in same phase are fed into two main arms 1 and 2, they will be added together in the side arm. Thus H plane tee is an 'adder'.

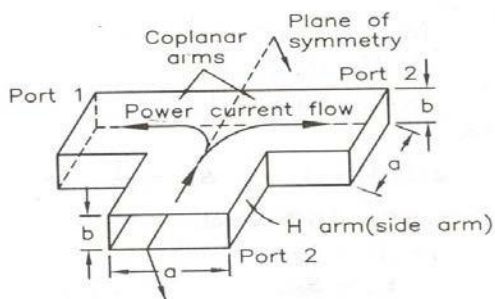


Fig. H-Plane Tee

Procedure:- Verification of H-Plane Tee

- 1) Open Simulink and select the library browser
- 2) Select the RF Block Set and Circuit envelope
- 3) Goto elements and select the component required
- 4) Construct attenuator circuit as shown in the block diagram
- 5) Open the Input Blocks and verify the power level and frequency
- 6) Observe different parameters in the Simulink to RF at the input and RF to Simulink block at the output
- 7) Verify that both the blocks have the same carrier frequency
- 8) Open the H-Plane Tee block and check for the properties
- 9) Run the Simulation and observe the Power reaching the ports
- 10) Change the input level, frequency to verify the output

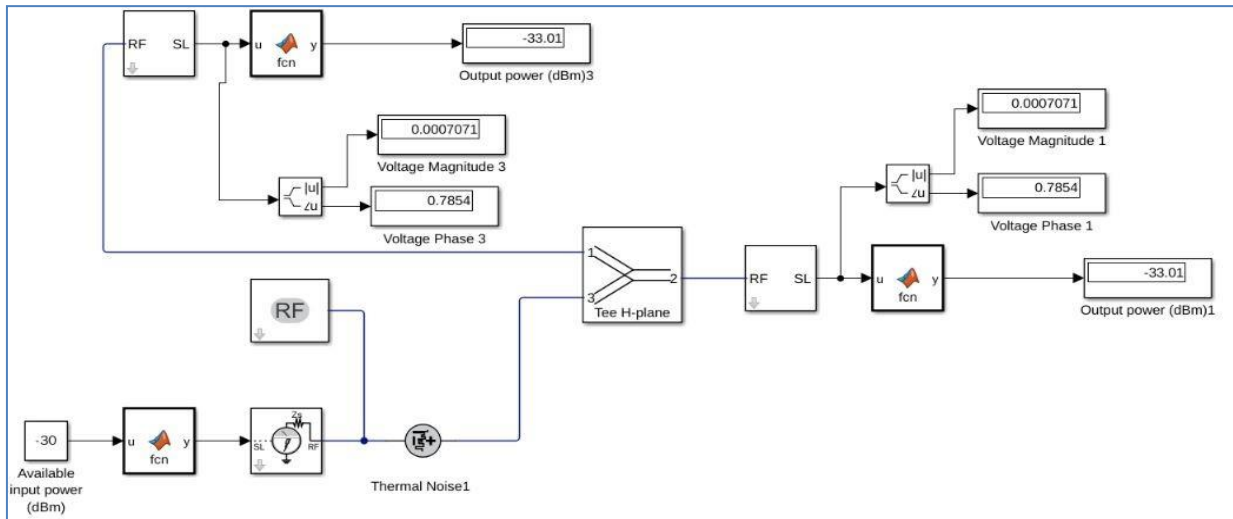


Fig. I/P Port:3; Output ports:1,2

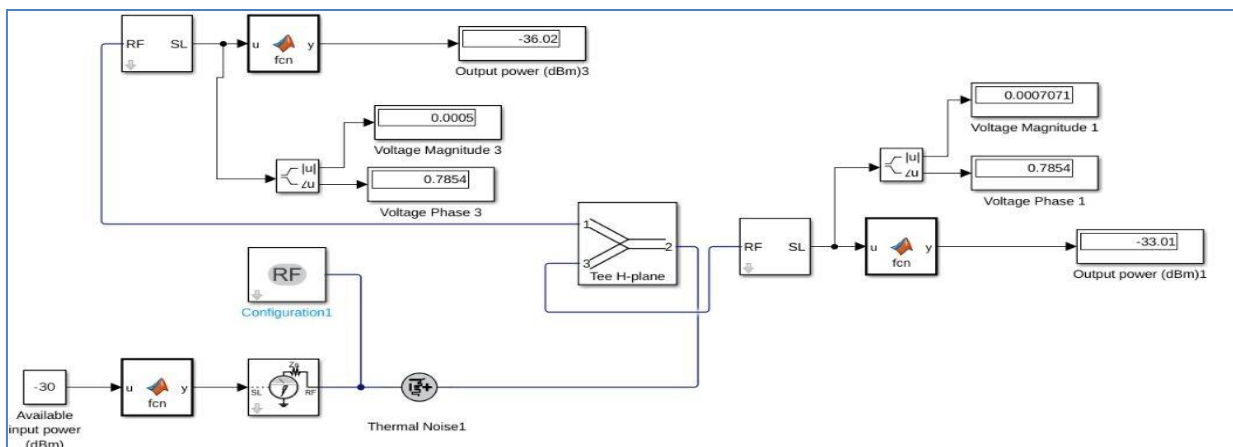


Fig. I/P Port:2; Output ports:1,3

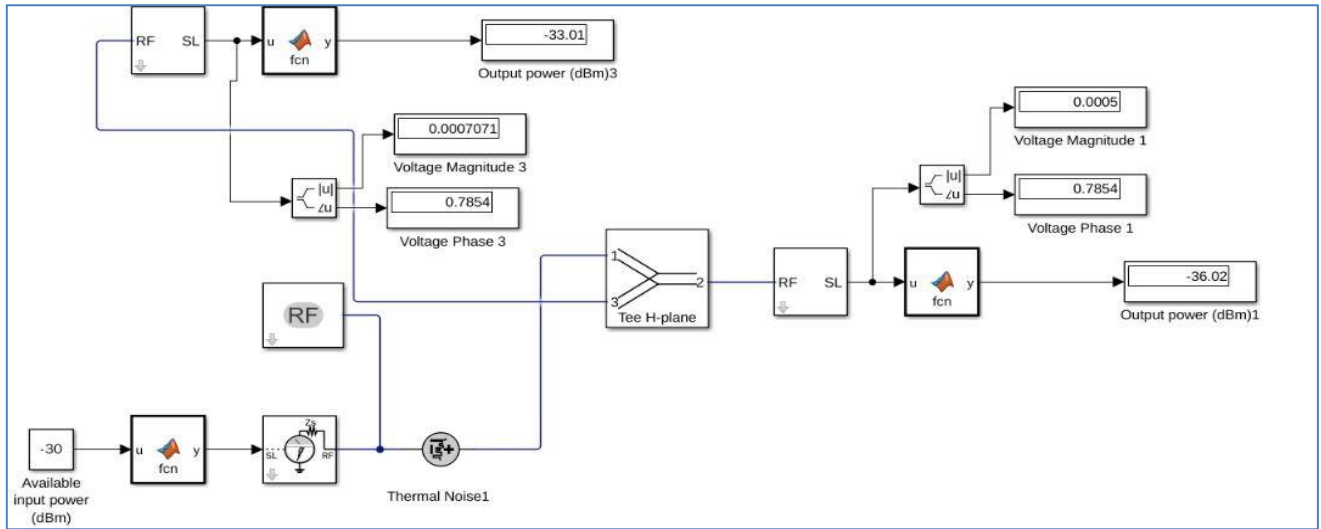


Fig. I/P Port:1; Output ports:2,3

OBSERVATIONS:

Table -1 (E-Plane Tee observations)

Input Power = -30dBm

S.No	P1	P2	P3	Power Division
P1	I/P	P1-6dB With $+45^0$	P1-3dB With $+45^0$	P2=P1/4(Quarter Power) P3=P1/2 (Half Power)
P2	P2-6dB With $+45^0$	I/P	P2-3dB With -45^0	P1=P1/4(Quarter Power) P3=P1/2 (Half Power)
P3	P3-3dB With $+45^0$	P3-3dB With -45^0	I/P	P1=P1/2(Half Power) P3=P1/2 (Half Power)

Table -2 (H-Plane Tee observations)

Input Power = -30dBm

S.No	P1	P2	P3	Power Division
P1	I/P	P1-6dB With 0^0	P1-3dB With 0^0	P2=P1/4(Quarter Power) P3=P1/2 (Half Power)
P2	P2-6dB With 0^0	I/P	P2-3dB With 0^0	P1=P1/4(Quarter Power) P3=P1/2 (Half Power)
P3	P3-3dB With 0^0	P3-3dB With 0^0	I/P	P1=P1/2(Half Power) P3=P1/2 (Half Power)

Result:

I. E-Plane Tee: 1. When the power is applied to port 3 (E-Plane), the power is equally divided

into the port 1 and port 2 with 180° phase difference.

2. When the power is applied to port 1, the quarter power is divided port 2 and half power is divided into port3 with 180° phase difference.

3. When the power is applied to port 2, the quarter power is divided port 1 and half power is divided into port3 with 180° phase difference.

II. H-Plane Tee: 1. When the power is applied to port 3 (H-Plane), the power is equally divided into the port 1 and port 2 without any phase difference.

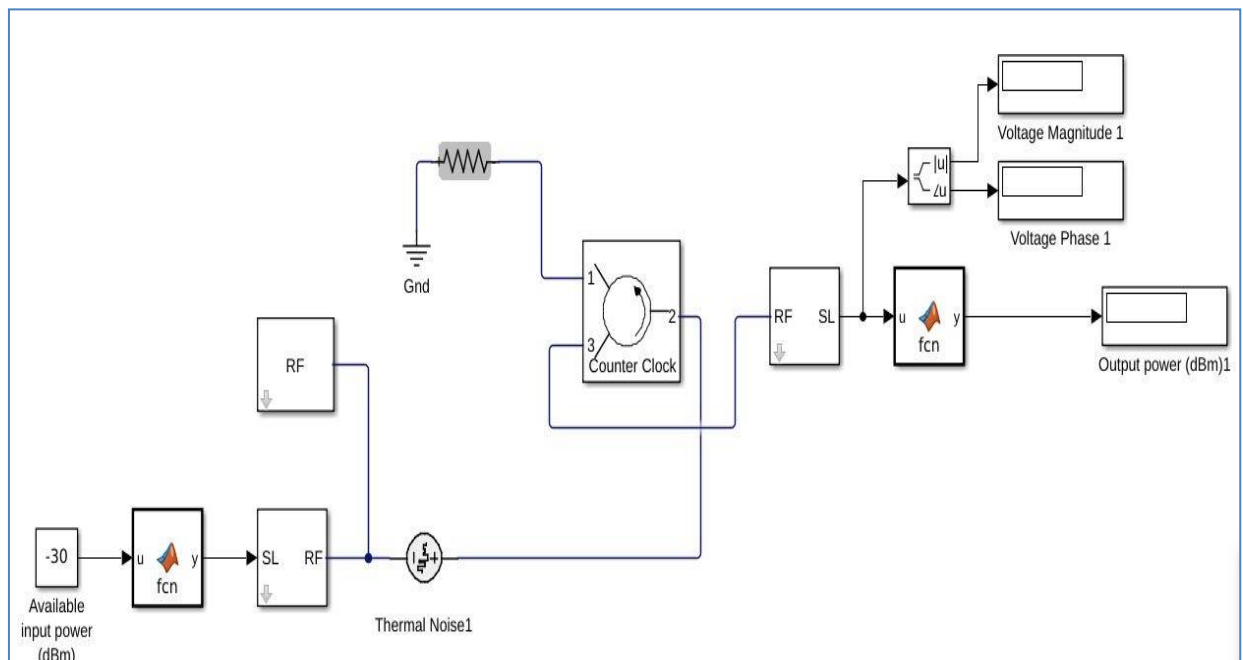
2. When the power is applied to port 1, the quarter power is divided port 2 and half power is divided into port3 without any phase difference.

3. When the power is applied to port 2, the quarter power is divided port 1 and half power is divided into port3 without any phase difference.

Verification of **Scattering matrix of Isolator**

To verify the isolator characteristics using MATLAB

Block Diagram



Simulink model of Isolator

Theory: An Isolator is a two-port device that transfers energy from input to output with little

attenuation and from output to in

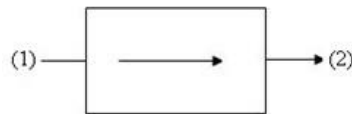
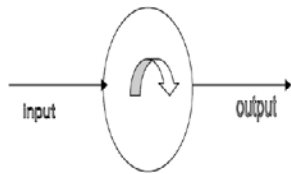


Fig. (a) Isolator

Fig. Isolator



The isolator, shown in Fig. can be derived from a three-port circulator by simply placing a matched load (reflection less termination) on one port.

An isolator introduces a very small loss of about 0.5 to 1.0 db in a wave travelling in the forward direction (1 to 2) but a very high attenuation of about 20 to 30db in a wave travelling in the reverse direction (2 to 1).

Isolator is used to improve the frequency stability of the microwave generators (Klystrons & Magnetrons) where the reflection from the load effects the generating frequency.

A. Insertion Loss

Insertion Loss is the ratio of power detected at the output port to the power supplied by source to the input port, measured with other ports terminated in the matched Load. It is expressed in dB.

$$\text{Insertion loss}_{\text{dB}} = 10 \log_{10} (p_1/p_2)$$

B. Isolation

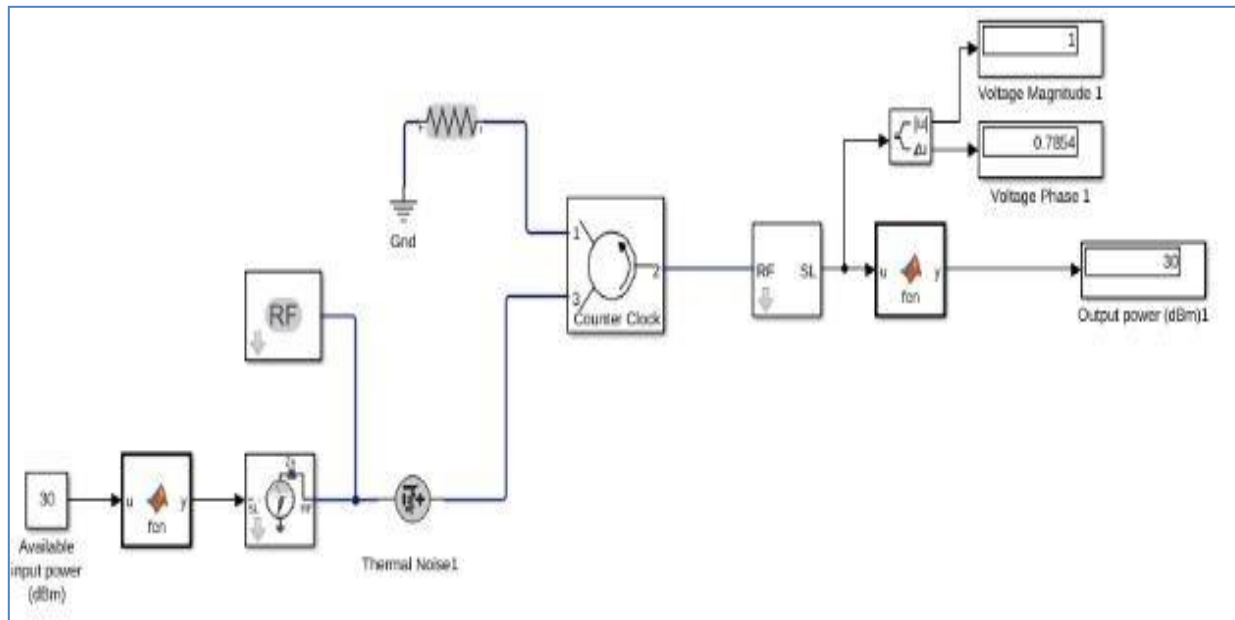
Isolation is the ratio of power applied to the output to that measured at the input. This ratio is expressed in db. The isolation of a circulator is measured with the third port terminated in a matched load.

$$\text{Isolation}_{\text{dB}} = 10 \log_{10} (p_2/p_1)$$

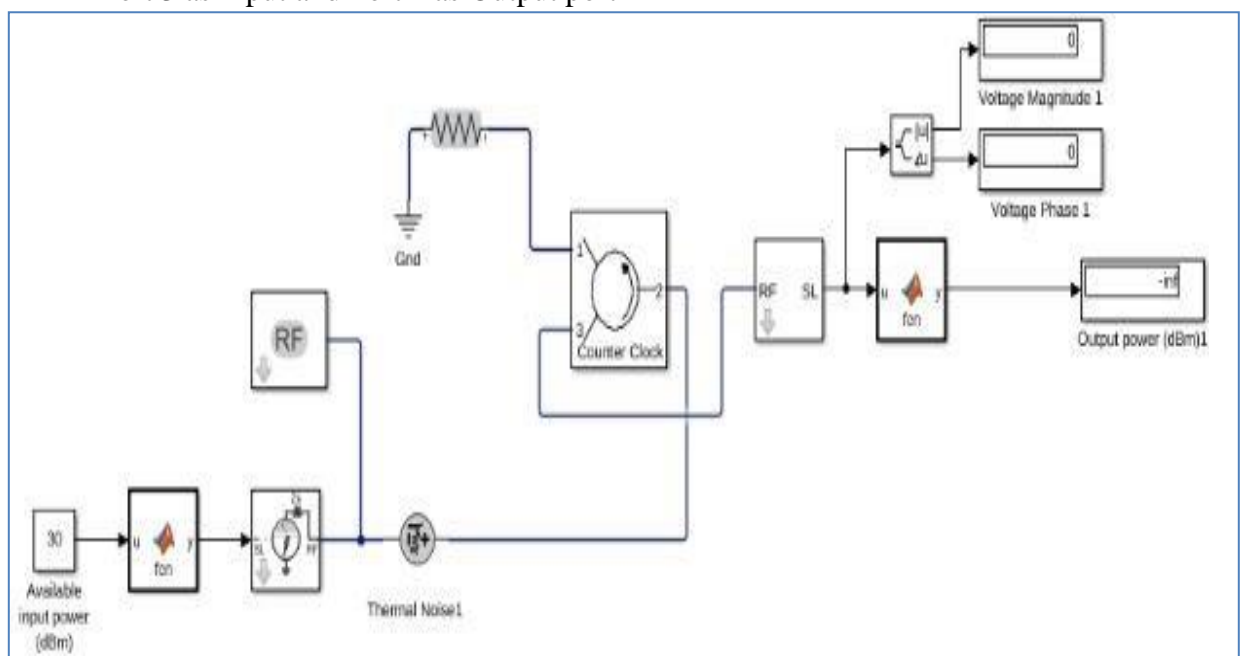
Procedure:

- 1) Open Simulink and select the library browser
- 2) Select the RF Block Set and Circuit envelope
- 3) Goto elements and select the component required
- 4) Construct Circulator circuit as shown in the block diagram
- 5) Remove the blocks connected to port 1 and connect the input to the port 2 and set the port 3 as output port
- 6) Connect the resistor to port 1 and terminate the other end with the ground
- 7) Open the Input Blocks and verify the power level and frequency
- 8) Observe different parameters in the Simulink to RF at the input and RF to Simulink block at the output

- 9) Verify that both the blocks have the same carrier frequency
- 10) Open the Isolator block and check for the properties
- 11) Run the simulation to verify the power level and interchange the input and output ports and the run the simulation
- 12) Note the out put and you will observe that there will be transfer of power in only in one direction.
- 10) Change the input level, frequency to verify the output



Port 3 as Input and Port 2 as Output port



Port 2 as Input and Port 3 as Output port

OBSERVATIONS: (Isolator)

Input power = -30dBm

S.No	I1	I2	Insertion Loss	Isolation
(1)	i/p			
(2)		i/p		

S PARAMETERS:

$$s_{ii} = \sqrt{\text{Anti log} \frac{P_{ii}}{10}} \quad \text{or} \quad s_{ii} = \frac{VSWR_i - 1}{VSWR_i + 1}$$

$$s_{ij} = \sqrt{\text{Anti log} \frac{(P_j - P_i)}{10}} \quad \text{or} \quad s_{ij} = \sqrt{\frac{b_j}{a_i}}$$

Where P_i = power output at port i, P_j = power input at port j
Where b_j = current at output port j, a_i = power input at port i

The S matrix of Isolator

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

Result: The Isolator transmits the signal in only one direction, but not in the other direction

