EXP NO: 2.1 STUDY OF POWER DISTRIBUTION IN DIRECTIONAL COUPLER

2.1.1 OBJECTIVE

To study the power distribution in various ports of directional coupler and measure the following parameters:

i) Insertion loss
ii) Coupling factor
iii) Directivity

And also design a multi hole directional coupler to find its directivity.

2.1.2 HARDWARE REQUIRED

Klystron power supply, Klystron with mount, Isolator, variable attenuator, CRO, Directional Coupler, Matched termination

2.1.3 INTRODUCTION

A directional coupler is a hybrid waveguide joint, which couple power in an auxiliary waveguide arm in one direction. It is a four-port device but one of the ports is terminated into a matched load (Refer figure 1).

Characteristics of a Directional Coupler

An ideal directional coupler has the following characteristics

i. If power is fed into port (1) the power is coupled in ports (2) and (3) i.e., power flows in the forward direction of the auxiliary arm port (3) but no power couples in port (4) i.e., in backward direction. Similarly power fed in (2) couples into ports (1) and (4) and not in (3).
ii. All the four ports are matched, i.e. if three of them are terminated in matched loads, the fourth is automatically terminated in a matched load.
iii. If power couples in reverse direction, power fed in (1) appears in ports (2) and (4) and nothing in (3), then such type of coupler is known as backward directional coupler. The conclusion is that in the auxiliary section the power is coupled in only one direction.

We will measure coupling coefficient, directivity and the main line insertion loss as a function of frequency.

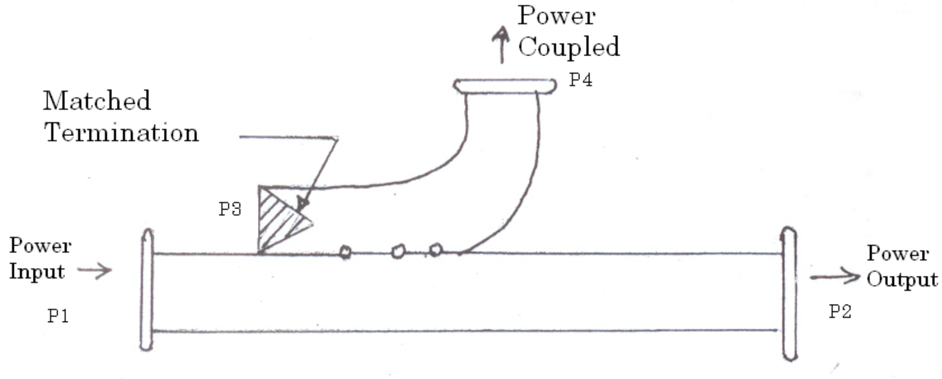


Figure 1: Directional coupler as a three – port device: Uni directional coupler

2.1.4 PRELAB QUESTIONS

1. How does power couple in directional coupler.
2. Give the applications of directional coupler
3. What is the purpose of measuring directivity, coupling factor?
4. Give the S matrix for directional coupler
5. What is the relation between directivity and isolation?

2.1.5 EXPERIMENT

2.1.5.1 PROCEDURE:

INSERTION LOSS

1. Set the equipment by connecting detector mount to the input end (without directional coupler).
2. Set mode 3 and observe the input voltage V_i. Do not alter till the end of the experiment.
3. Insert the directional coupler; terminate port 4 with matched termination.
4. Connect detector mount to port 2 and measure V_{12}.
5. Calculate insertion loss as per the formula.

COUPLING FACTOR

1. To measure coupling factor, terminate port 2 with matched termination, connect detector mount to port 4 and measure V_{14}.
2. Calculate coupling factor as per the formula.

DIRECTIVITY:

1. Setup the equipment as shown in fig. Terminate port 2 with matched termination and connect detector mount to port 4.
2. Measure the voltage at port 4 and note it as V_{14}.
3. Connect the directional coupler in reverse direction. ie, port 2 - input, port 1- matched termination, port 4 – detector mount.
4. Measure the voltage as V_{24}
5. Calculate directivity D as per the formula.

2.1.5.2 OBSERVATIONS AND CALCULATIONS:

Observations

V_i =
V_{12} =
V_{14}=
V_{24}=

INSERTION LOSS (L)

$L = 20\log_{10}(V_i/V_{12})$ dB

COUPLING FACTOR(C)

$C = 20\log_{10}(V_i/V_{14})$ dB

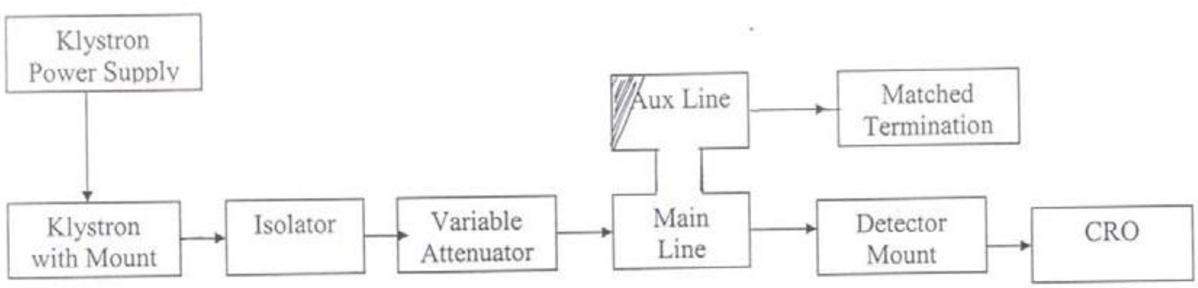
DIRECTIVITY (D)

$D = 20\log_{10}(V_{14}/V_{24})$ dB

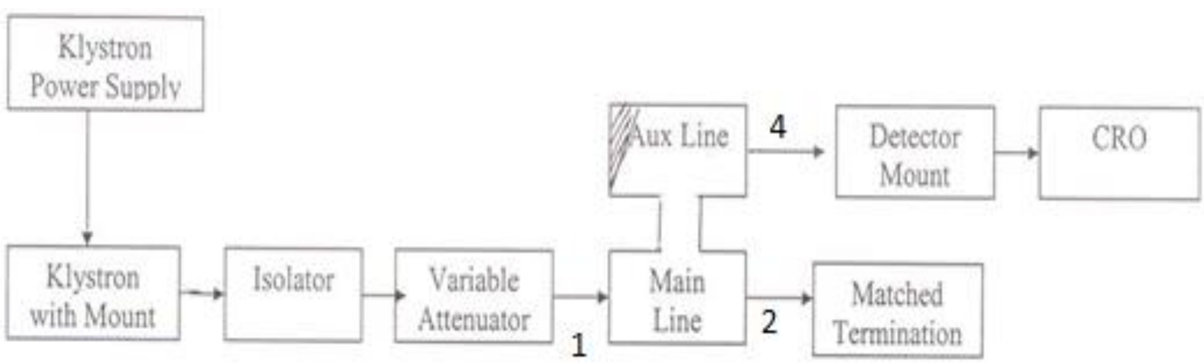
2.1.5.3 BLOCK DIAGRAM

Mode 3 setup:

Insertion Loss (V_{12}) measurement



Coupling Factor (V_{14}) measurement



2.1.5.4 DESIGN:

Design of a five-hole 30 dB directional coupler with Chebyshev distribution for wavelength ratio of 2 at the band edges.

n=5 r =2

The reverse voltage

$C_R \quad = 2[C_1\cos(5-1)\theta + C_2 \cos(5-3)\theta] + C_3$

$= 2[C_1\cos 4\theta + C_2 \cos 2\theta] + C_3$

$= 2[C_1 (8\cos^4\theta-8 \cos^2\theta+1] + C_2 (2\cos^2\theta-1)] + C_3$

At the band edge $f=f_1$ and $\theta=\theta_1 = \pi/1+r =\pi/3$

A change of variable according to $\cos\theta = x\cos\theta_1$ gives $\cos\theta = x\cos(\pi/3) = x/2$

$C_R \quad = 2[C_1(x^4/2-2x^2+1) + C_2 (x^2/2-1)] + C_3$

$= C_1 x^4+ (C_2-4 C_1) x^2 + (C_3+2C_1-2C_2)$

$= C_m T_{5-1}(x)$

$= C_m(8x^4-8x^2+1)$

Equating the coefficients

$C_1 = 8C$, $C_2 = 4 C_1-8 C_m$, $C_3 + 2C_1-2C_2 = C_m$,

$C_3 = 33C_m$

Now coupling

$C = 2(C_1 + C_2) + C_3=30dB$

$= 10^{-30/20}$

$= 0.0316$

(or)

$2(8+24) C_m+33 C_m=0.0316$

$97 C_m= 0.0316$

$C_m = 3.264X10^{-4}$

Coupling values of the holes are

$C_1 =8 C_m = 26.08x10^{-4}$

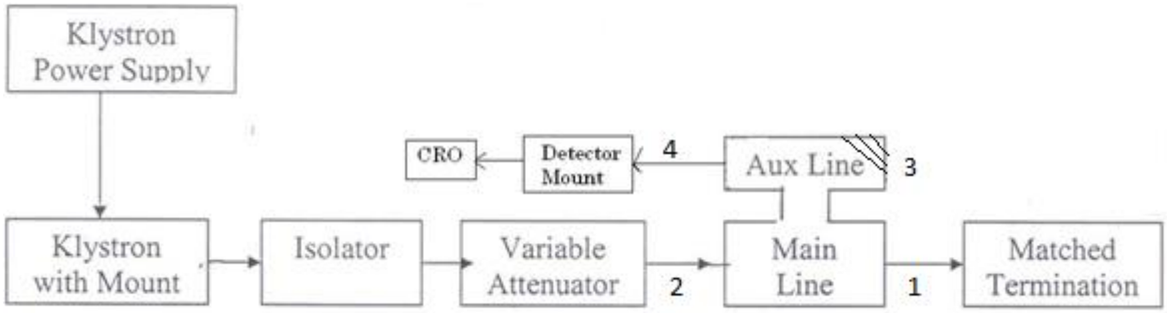
$C_2 =24C_m =78.24x10^{-4}$

$C_3 =33 C_m=107.58x10^{-4}$

Directivity $D = - C_1+20\log (1/ C_m)$

D=39.7dB

DIRECTIVITY MEASUREMENT



2.1.6 POST LAB QUESTIONS:

1. Explain how back power is zero in a directional coupler with neat diagram.
2. What is multi hole directional coupler?
3. What are the factors used to determine the parameters of directional coupler?
4. List the applications of directional coupler.
5. A directional coupler having the directivity of 35dB, forward voltage V_{14}= 10mV. Calculate its input voltage and V_{24}
6. A four-port directional coupler has 4:1 power splitting ratio and has dissipation loss of 3dB. The coupler directivity is 40 dB. What fraction of input power P1 will go to ports P2 and P3?

2.1.7 RESULT:

Thus, the power distribution in various ports of a directional coupler was studied and the following parameters are calculated.

Coupling factor ____________
Directivity ____________
Insertion loss ____________

EXP NO. 2.2 STUDY OF POWER DISTRIBUTION IN E PLANE, H PLANE AND MAGIC TEE

2.2.1 OBJECTIVE

To determine isolations and coupling coefficients for E, H plane Tee and Magic Tee junctions.

2.2.2 HARDWARE REQUIRED

Klystron power supply, Klystron with mount, isolator, variable attenuator, Magic Tee, Matched termination, detector mount, CRO

2.2.3 INTRODUCTION

H Plane Tee:

Figure 1 shows the sketch of H plane tee. 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 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. Thus H plane tee is an `adder'.

E Plane Tee:

Figure 2 shows the sketch of E plane tee. 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 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. E plane tee divides the power equally and 180 out of phase. Thus E plane Tee is a subtract or / differentiator.

Magic Tee:

An interesting type of T junction is the hybrid tee, commonly known as `magic tee' which is shown in Figure 3. The device as can be seen from Fig. is a combination of the E arm and H plane tees. Arm 3, the H arm forms an H plane tee and arm 4, the E arm, forms an E plane tee in combination with arms 1 and 2. The central lines of the two tees coincide and define the plane of symmetry, that is, if arms 1 and 2 are of equal length, the part of structure on one side of the symmetry plane shown by shaded area is the mirror image of that on the other. Arms 1 and 2 are sometimes called as the side or collinear arms. The `magic Tee' is derived from the manner in which power divides among the various arms. If power is fed into arm 3, the electric field divides equally between arms 1 and 2 and the fields are in phase. Because of symmetry of the T junction, no net electric field parallel to the narrow dimension of the waveguide is excited in arm 4. Thus no power is coupled in port 4. Reciprocity demands no coupling in port 3 if power is fed in 4. Another property that results from the symmetry of the junction is, if power is fed in E or H arm, it is equally divided between arms 1 and 2.

2.2.4 PRELAB QUESTIONS:

1. What is Tee junction? Give two examples
2. What is the other name for Hybrid ring?
3. Name some wave guide components used to change the direction of the guide through an arbitrary angle
4. What is the S matrix of H plane Tee junction?
5. List some Applications of magic Tee.

2.2.5 EXPERIMENT

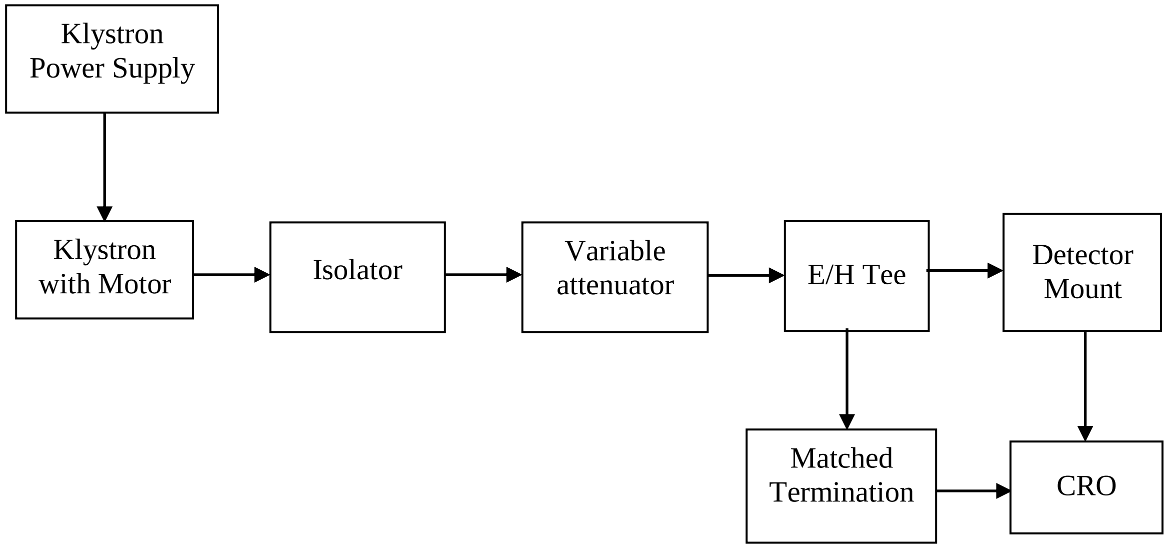
2.2.5.1 PROCEDURE:

E Plane & H Plane Tee and Magic Tee: Isolation & Coupling Coefficient

1. Energize the microwave source and set mode 3.
2. Note down the input voltage as Vi (mv) (should not alter the setting)
3. Now connect the magic tee/E-Plane/H-Plane Tee.
4. Determine the corresponding voltages V_j (mv) for each pair of ports by connecting one port to the source and measuring the output at other port while the remaining ports are connected to matched termination.
5. Determine the isolation and coupling coefficients for the given Tee using the following formula.

2.2.5.2 BLOCK DIARGAM

Characteristics of E & H Plane Tee



2.2.5.3 (i) TABULATION:

E-Plane & H–Plane Tee

V_{in} =1V

Nature of Tee	Voltage(mv)				Isolation (I_{ij}) dB	Coupling Coefficient $Cij = 10^{I_{ij}/20}$
	I/P		O/P			
E-Plane	1st Arm		2nd 2			C_{12}
			3rd			C_{13}
	3rd Arm		2nd 2			C_{32}
			1st			C_{31}
H=Plane	1st arm		2nd 2			C_{12}
			3rd			C_{13}
	3rd Arm		2nd 2			C_{32}
			1st			C_{31}

Isolation between port 1 and 2 is $I_{12} = 20 \log_{10} (V_1 / V_2)$ dB, and when matched load and detector are interchanged $I_{13} = 20 \log_{10} (V_1 / V_3)$ dB .

The coupling coefficient by the formula $C = 10^{-\alpha/20}$ Where α is the attenuation in dB between the input (i) and detector (j) arm when the third arm is terminated in a matched load.

Thus $\alpha = 10 \log P_i / P_j$ dB

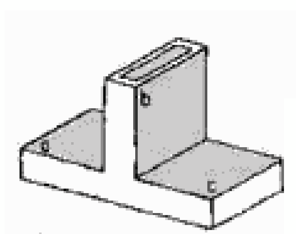
where P_i is the power delivered to 'i' arm and

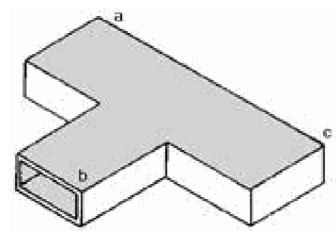
P_j is the power detected in arm j.

For example, when the attenuation measured between arms 1 and 2 is 3 dB when arm 3 terminated in matched load, then the coupling coefficient between arms 1 and 2,

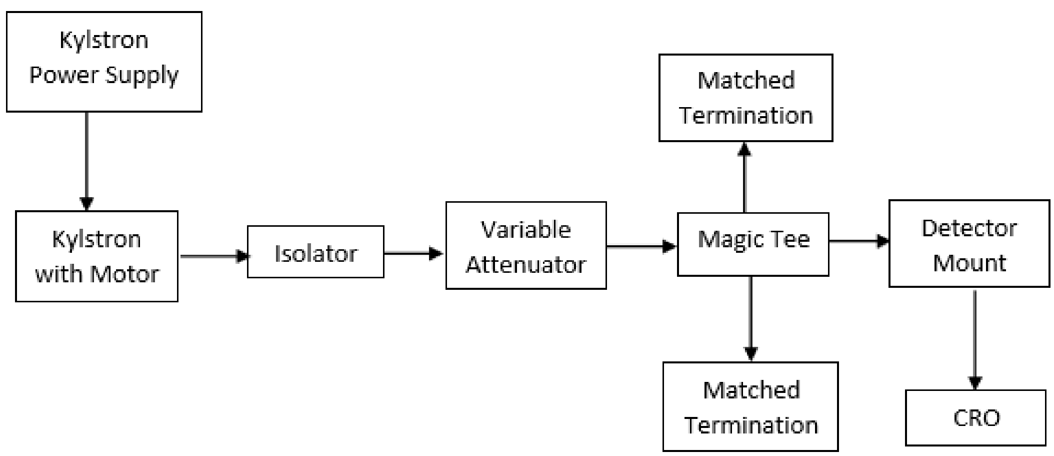
$C12 = 10^{-\alpha/20} = 10^{-3/20} = 0.708$ dB

E-Plane Tee **H- Plane Tee**

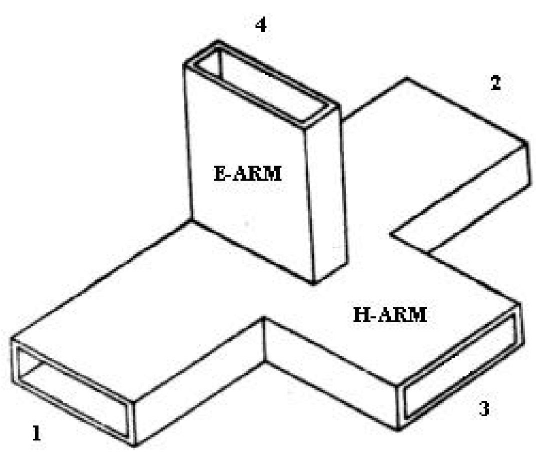




Characteristics of Magic Tee



Magic Tee



2.2.5.3 (ii) TABULATION:

Magic Tee

<table>
<tr><th colspan="2">Magic Tee orientation</th><th rowspan="2">V_i (mv)</th><th rowspan="2">V_j(mv)</th><th rowspan="2">I_{ij} (dB)</th><th rowspan="2">C_{ij}</th></tr>
<tr><th>Input Arm-i</th><th>Output arm-j</th></tr>
<tr><td rowspan="3">1</td><td>2</td><td rowspan="3"></td><td></td><td></td><td></td></tr>
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2.2.6 POST LAB QUESTIONS:

1. Microwave components used to connect branch waveguide to the main waveguide or transmission line are known as
2. What are series and shunt Tee?
3. Justify the name 'Magic' in magic tee.
4. Why phase change of 180 degree is observed in series tee in electric field and not in shunt Tee?
5. How does power equally divide between two collinear arms?
6. If a microwave signal with 1V 0 phase is fed at port3 of E-plane Tee, then what will be the output at port1 and port2?
7. If 1V microwave signal is fed to both port1 and port2 of H-plane Tee then, what is the output at port3?
8. If a microwave signal with 1V is fed at port3 of Magic Tee, then what will be the output at port4?

2.2.7 RESULT:

Thus, the power distribution in various ports of E, H and magic tee was studied. Isolations and coupling factor are determined.