PRACTICAL FILE

MICROWAVE ENGINEERING

LAB

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING [ECE]

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EXPERIMENT-1

AIM -
To study the various components of microwave bench.

APPARATUS - Microwave bench, frequency meter

THEORY -

Among the microwave measurement devices, a setup of Microwave bench which consists of Microwave devices has a prominent place. This whole setup with few alternations is able to measure many values like guide wavelength, free space wavelength cut off wavelength, Klystron characteristics, Gunn Diode, power measurement etc.

Microwave Bench General Measurement Setup

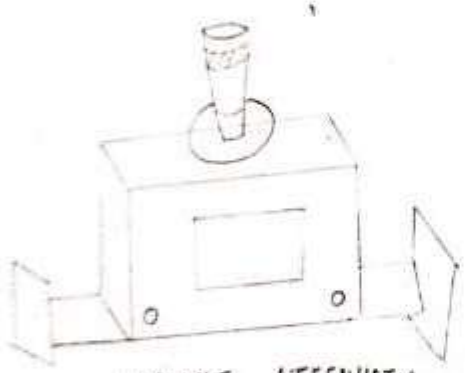
This setup is a combination of different parts which can be observed in the detail.

SIGNAL GENERATOR

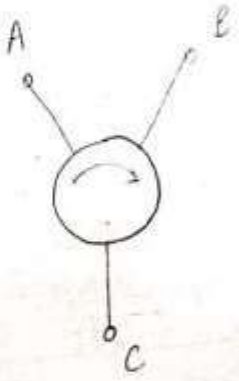
As the name implies, it generates a microwave signal in the order of a few milliwatts. This uses the velocity modulation technique to transfer continuous wave beam into milliwatt

WAVE GUIDE STAND

RECTANGULAR WAVEGUIDE

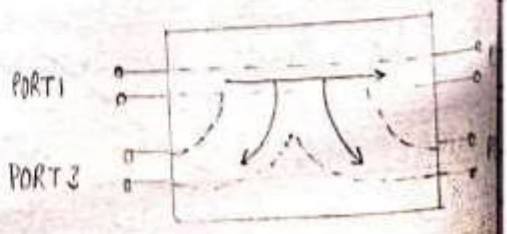


VARIABLE ATTENUATOR



CIRCULATOR

ISOLATOR.



DIRECTIONAL COUPLER

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PRECISION ATTENUATOR

This is the attenuator which selects the desired frequency and confines the output around 0 to 50 dB. This is variable and can be adjusted according to the requirement.

VARIABLE ATTENUATOR

This attenuator sets the amount of attenuation. It can be understood as a fine adjustment of values where the readings are checked against the values of precision attenuator.

ISOLATOR

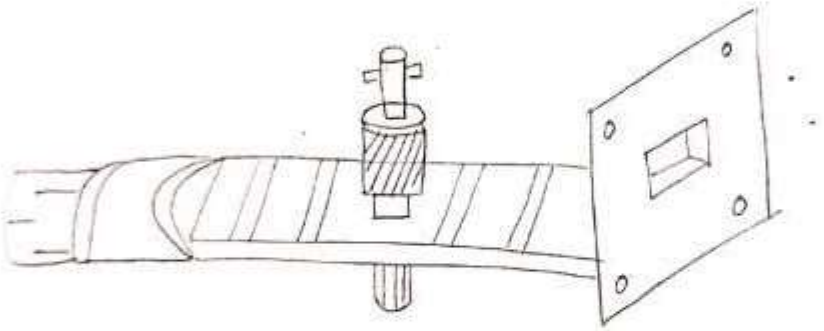
This removes the signal that is not required to reach the detector mount. Isolator allows to pass through the waveguide only in one direction.

FREQUENCY METER

This is the device which measures the frequency of the signal. With this frequency meter, the signal can be adjusted to its resonance frequency.

ISOLATOR

MATCHED TERMINATION



TUNABLE WAVEGUIDE DETECTOR

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CRYSTAL DETECTOR

A crystal detector probe and crystal detector mount are indicated in the above figure where detector is connected through the mount.

TUNABLE DETECTOR

The tunable detector is a detector mount which is used to detect the low frequency square wave modulated microwave signals. To provide a match between the microwave transmission system.

There are three different tunable stubs :-
Tunable waveguide detector
Tunable co-axial detector
Tunable probe detector

RESULT -

The various components of microwave bench have been studied successfully.

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EXPERIMENT-2

AIM - To determine the frequency and wavelength using a frequency meter and slotted line section

EQUIPMENTS -

Klystron tube, Klystron power supply, Klystron mount, Isolater, Frequency meter, variable attenuator, slotted section waveguide, tunable probe, VSWR meter, waveguide stand, movable short / matched termination.

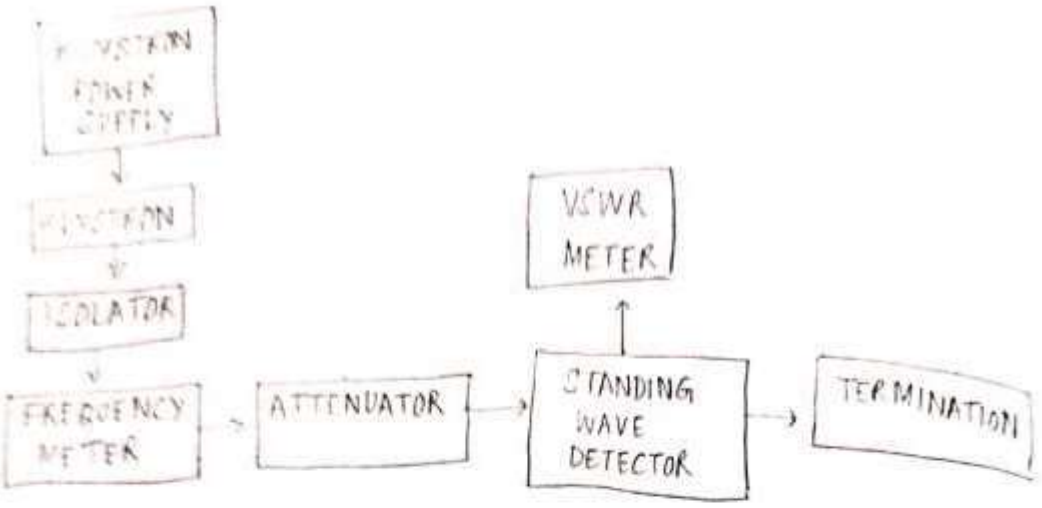
THEORY -

For dominant TE_{10} mode in rectangular waveguide λ_0, λ_g and λ_c are related as below :-

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

where λ_0 = free space wavelength
λ_g = guide wavelength
λ_c = cut off wavelength

For TE_{10} mode $\lambda_c = 2a$
where 'a' is the broad dimension waveguide



BLOCK DIAGRAM

★ Observation and Calculation

Frequency meter reading = 10.971 GHz

D_{min} = 12.4 cm D_{max} = 11.6 cm

a = 2.286 cm

$\lambda_c = 2a = 4.572$ cm

$\lambda_g = 4(D_{min} - D_{max}) = 3.2$ cm

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2} = \frac{1}{10.24} + \frac{1}{20.901}$$

$$= 0.0976 + 0.04 = 0.1376$$

$\lambda_0^2 = 7.87757$

$\lambda_0 = 2.62$ cm

From freq $\lambda_{0T} = c/f_0 = \frac{3 \times 10^8}{10.971 \times 10^9} = 2.73$ cm

$$\text{Error} = \frac{\lambda_{0T} - \lambda_{0P}}{\lambda_{0T}} \times 100 = 4.029\ \%$$

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RESULT-

The frequency and wavelength were measured using slotted line section and frequency meter.

Frequency = 10.971 GHz
Wavelength → Theoretical = 2.73 cm
Practical = 2.62 cm

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CIRCUIT DIAGRAM

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EXPERIMENT - 3

AIM - To study the characteristics of Gunn diode and to determine the threshold voltage

APPARATUS -
Gunn power supply, Gunn oscillator XG-11, Isolator XL-621, frequency meter XF-710, pin modulator, matched termination

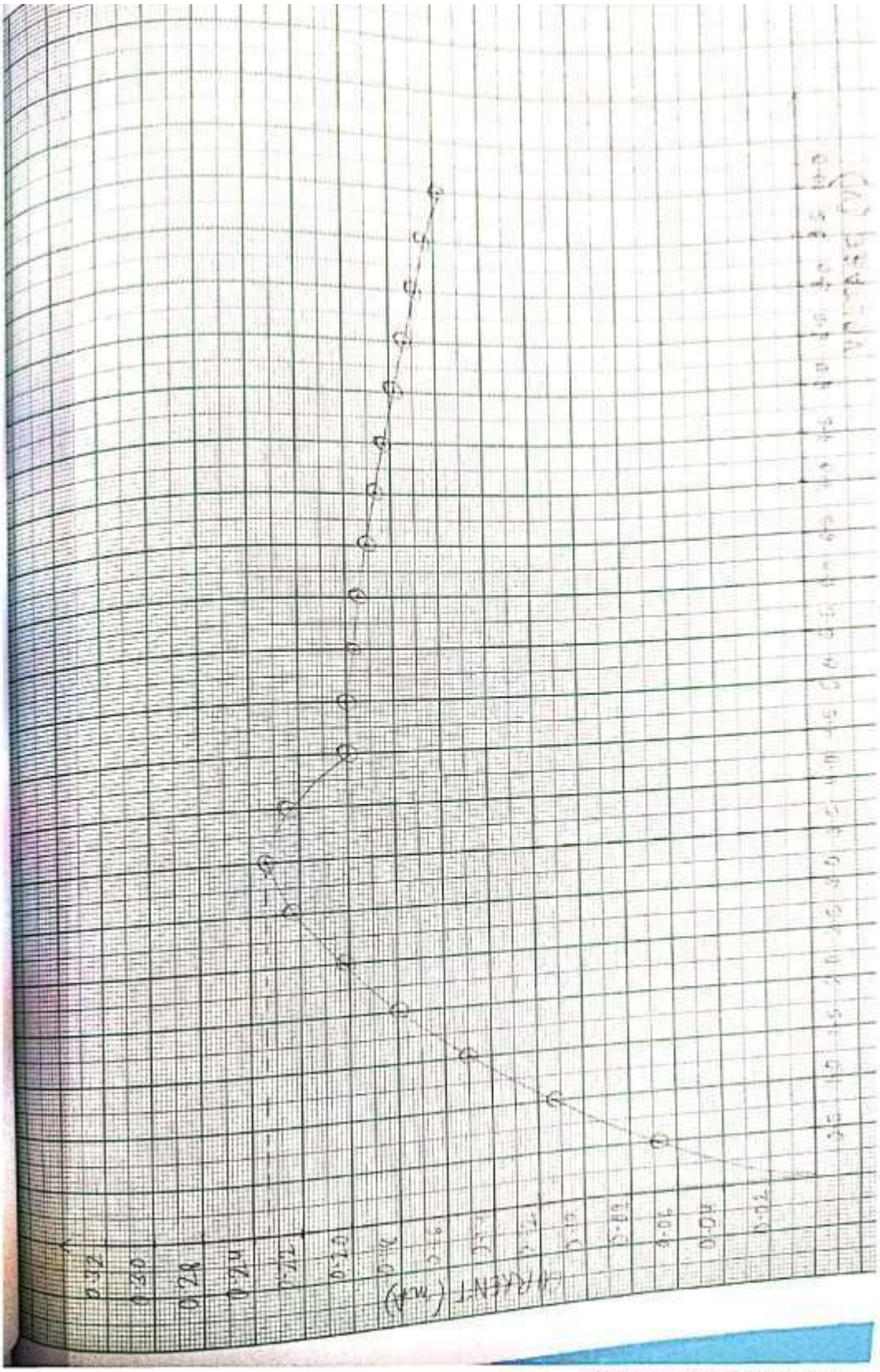
THEORY -

Transferred Electro Devices (TED's) are bulk devices that do not have any junctions or gates. They are fabricated with the compounds like GaAs, InP, CdTe. These operate on hot electrons. It also exhibits property of negative resistance. Gunn observed that periodic fluctuations of current passing through n-type GaAs specimen when applied voltage crosses critical value. The current increases till a certain value and falls off after crossing a certain voltage level.

CALCULATIONS -
V_T (Threshold Voltage) = 3.5V
I_{max} = 0.24 mA

OBSERVATIONS:-

VOLTAGE (V)	CURRENT (mA)
0	0
0.08	0.011
0.17	0.022
0.26	0.034
0.35	0.046.
0.44	0.057
0.57	0.074
1.02	0.124
1.53	0.171
2.06	0.203
2.54	0.223
3.04	0.235
3.51	0.227
4.06	0.206
4.51	0.201
5.08	0.190
6.03	0.181
7.01	0.173
8.01	0.164
9.05	0.157
10.05	0.151
10.96	0.148
11.46	0.145
12.01	



RESULT -

The V-I characteristics of Gunn Diode has been observed. The threshold voltage is 3.5V and threshold current = 0.23 mA.

PRECAUTIONS -

1) Do not keep Gunn bias knob position at the threshold position for more than 10-15 second.
2) Reading should be obtained as fast as possible otherwise due to excessive heat Gunn diode may burn.
3) Care should be taken such that bias voltage should not exceed above 10V.

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EXPERIMENT-4

Aim: To measure the Isolation and insertion loss of Isolator

Apparatus Required: Klystron Tube, Klystron Power Supply, VSWR meter, Klystron Mount, Isolator, Frequency Meter, Variable Attenuator, Slotted line, Waveguide stand, BNC Cable

Theory:

- **Isolator:** It is a 2 port device with small insertion loss in forward direction and large in reverse direction attenuation
- **Insertion Loss:** Ratio of Power Supplied by a source to the input port to power delivered by a detector in coupling arm, i.e, output arm with other port terminated in the matched load is defined as insertion loss.
- **Isolation:** Ratio of power fed to input arm and the power detected at net coupled port with other port terminated in matched load.
- **Input VSWR:** Ratio of voltage maximum to voltage minimum of the standing wave existing on the line, when one port terminates the line and others have matched termination

Microwave power is sent down a transmission line from left and it reaches component. This power is the incident power, when it reaches back the component, a portion is reflected back down the transmission line where it came from and enters the component.

The power that actually comes out of component is called transmitted power. It is less than incident power due to 2 reasons

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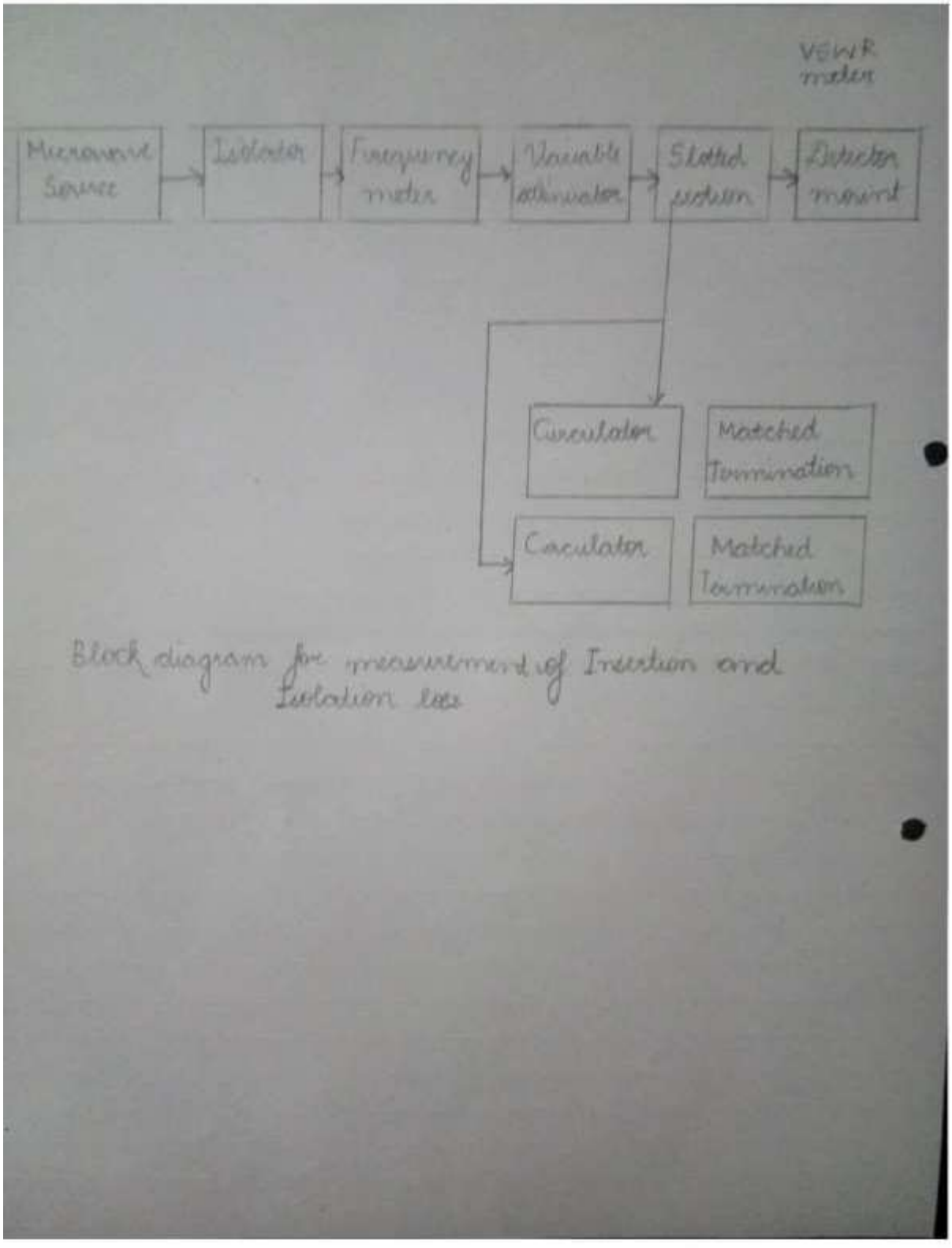
- Some of power gets reflected
- Some of the power gets absorbed.

Insertion Loss = $20 \log \frac{V_1}{V_2}$

Result : The Isolation and Insertion loss of Isolator was measured.

Precautions:

1. Avoid loose connections
2. Avoid errors due to parallax.



Block diagram for measurement of Insertion and Isolation loss

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EXPERIMENT- 5

Aim: To measure the isolation and insertion loss of Circulator

Apparatus: Klystron tube, Klystron Power supply, VSWR meter, Circulator, DSO

Theory:

- **CIRCULATOR:** It is a passive, non-reciprocal, three or four terminal / port device in which a microwave entering at any port is transmitted to the next port in rotation. i.e. if input is provided at port 1 then the output will be observed at port 2 only. Similarly if the input is given at port 2, the output is observed at port 1.

- **Insertion Loss:** The Loss of microwave power resulting from the insertion of a device (circulator) in the transmission line.

$$\text{Insertion Loss} = 20 \log \frac{V_{in}}{V_f} \quad (dB)$$

where V_{in} = Input voltage

V_f = Output voltage when Circulator is in forward direction.

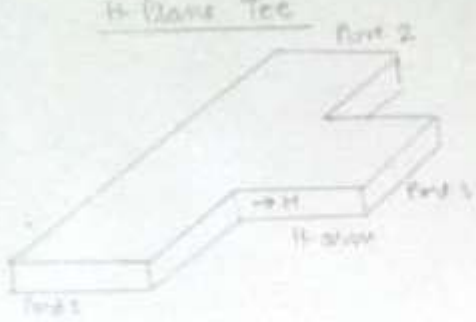
- **Isolation Loss:** It is the insertion loss in the open path of a device

$$\text{Isolation loss} = 20 \log \frac{V_{in}}{V_r}$$

$V_r \rightarrow$ (reverse direction output voltage)

Result: The isolation and insertion loss of circulator were measured.

H-Plane Tee

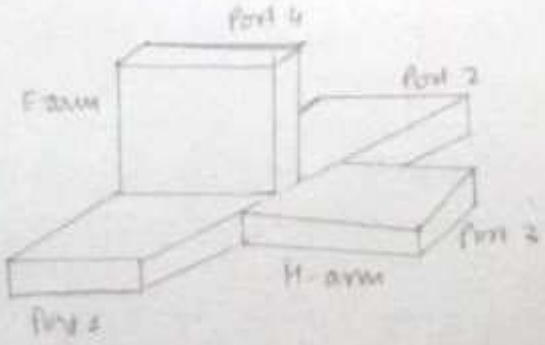


Port 1 and Port 2 are in phase

E-Plane Tee

Port 1 and Port 2 are out of phase

Magic Tee (E-H Plane Tee)



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EXPERIMENT- 6

Aim: To study E-plane, H-plane and Magic Tee.

Apparatus: Klystron power supply, klystron with mount, isolator, variable attenuator, slotted section, Magic Tee, Matched termination, detector mount, E-plane, H-plane tee

Theory:

- **H-Plane Tee**
  - An auxiliary waveguide arm is fastened perpendicular to the narrow wall of main guide
  - Three port device with axis of side arm parallel to the planes of magnetic field of main guide.
  - Perpendicular arm generally input and other 2 arms are in shunt to input ∴ also called Shunt Tee.
  - Properties

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

- Symmetry $S_{ij} = S_{ji}$ ∴ $S_{12} = S_{21}$ $S_{23} = S_{32}$, $S_{13} = S_{31}$
- Perfectly matched port $S_{33} = 0$
- Unitary matrix $[S][S^*] = I$

- **E- Plane Tee**
  - An auxiliary wave guide is fastened to broader wall of the main guide.
  - Three port device, with axis of side arm parallel to the planes of electric field of main guide.
  - It causes load connected to the branches appear in series (Series Tee)

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- Properties

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

- S_{13} & S_{23} out of phase by 180° $S_{23} = -S_{13}$
- Perfectly matched port, $S_{33} = 0$
- Symmetry, $S_{12} = S_{21}$, $S_{23} = S_{32}$, $S_{13} = S_{31}$
- Identity matrix $[S][S^*] = I$

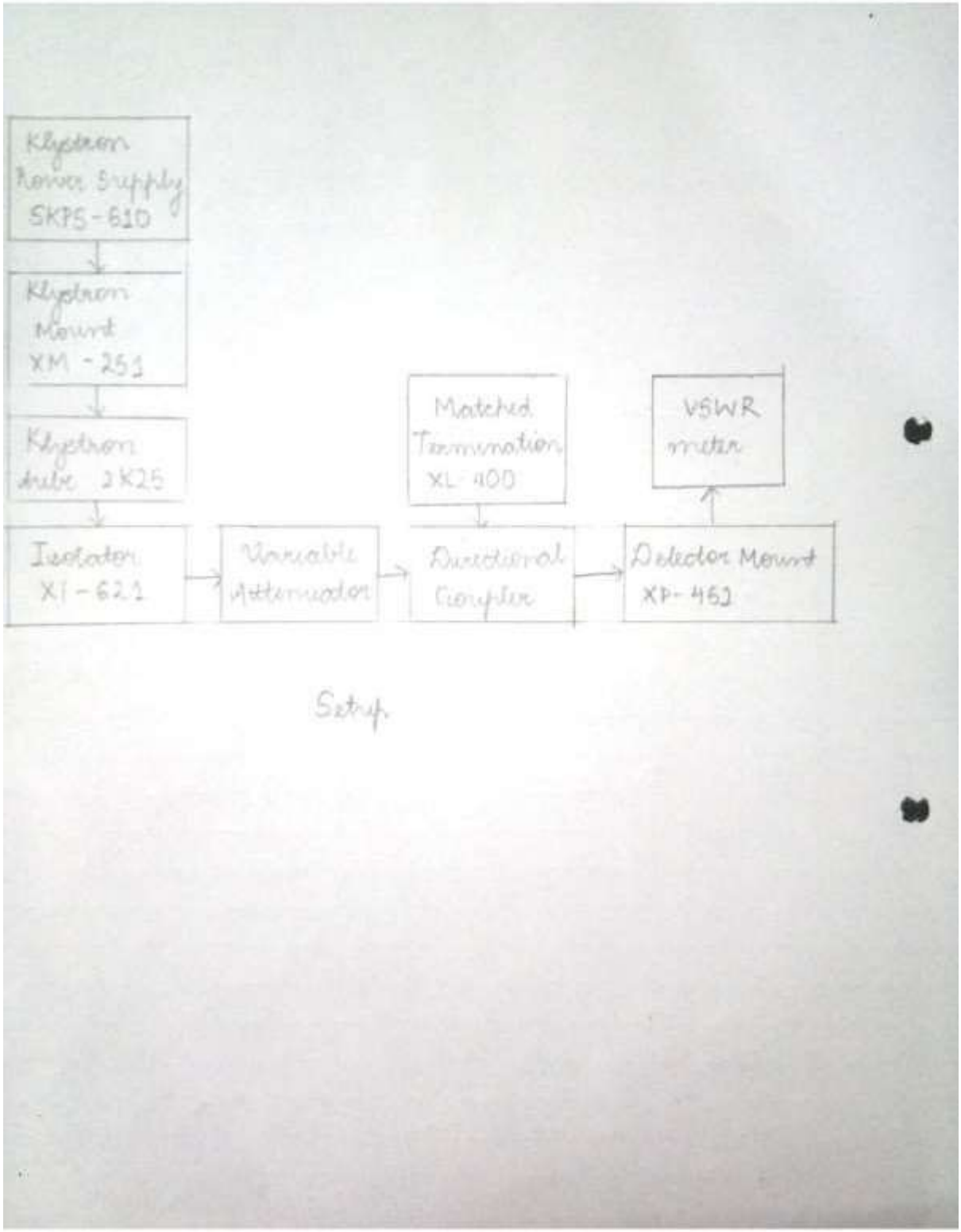
• Magic Tee

- It is formed by attaching 2 simple waveguide one parallel and other series to a rectangular waveguide with already 2 port.
- Also called Hybrid Tee, E-H Plane Tee.
- Arms of waveguide make 2 ports collinear (1 and 2) while Port 3 is called H-arm (sum port / Parallel Port) and Port 4 is called E-arm (Difference Port / series Port)
- Properties

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

- $S_{23} = S_{13}$ (H-Plane Tee), $S_{24} = -S_{14}$ (E-Plane Tee)
- $S_{34} = S_{43} = 0$, E & H arm isolated
- Symmetry $S_{12} = S_{21}$, $S_{13} = S_{31}$, $S_{14} = S_{41}$, $S_{23} = S_{32}$, $S_{24} = S_{42}$, $S_{34} = S_{43}$
- Perfectly matched ports $S_{33} = S_{44} = 0$, & $[S][S^*] = I$

Result: E Plane Tee, H-plane Tee and Magic Tee were studied.



Setup.

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EXPERIMENT- 7

Aim: To measure coupling factor, directivity and isolation of directional coupler

Apparatus: Klystron power supply, Klystron- tube, Klystron mount, Isolator, Frequency meter, variable attenuator, VSWR meter

Theory:

Directional coupler is a device with which it is possible to measure the incident and reflected wave separately.

1. It consists of 2 transmission lines one main arm and the auxiliary arm, electromagnetically coupled to each other. The power entering the main arm gets divided between port 2 and 3 and almost no power comes out in Port 4. Power entering at port 2 is divided between Port 1 and 4.

Coupling factor: Coupling (dB) (C) $= 10 \log_{10}\left[\frac{P_1}{P_3}\right]$

where port 2 is terminated

Isolation (dB) (I) $= 10 \log_{10}\left[\frac{P_2}{P_3}\right]$ where Port 1 is matched.

2. With built in termination and power entering at Port 3, the directivity of coupler is a measure of separation between incident and reflected wave.

Directivity: D (dB) $= 10 \log_{10}\left[\frac{P_2}{P_1}\right] = I - C$

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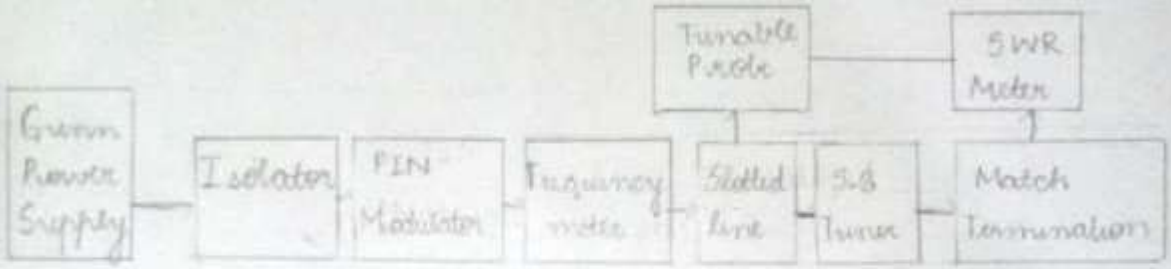
Main line VSWR is SWR measured, looking into the main line input terminal when the matched loads are placed at all other ports

Insertion loss (dB) = $10 \log_{10} \left[\frac{P_1}{P_2}\right]$

Result

The coupling factor, directivity and isolation of directional coupler were measured.



Setup for VSWR measurement

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EXPERIMENT- 8

Aim: To measure VSWR and Reflection Coefficient.

Apparatus: Gunn Power Supply, Gunn oscillator, SWR meter, Isolator, PIN modulator, Frequency meter, Slotted line, Tunable probe, S-S tuner, Matched termination.

Theory

- VSWR is the ratio of maximum voltage to minimum voltage along a transmission line.
- As a ratio of maximum to minimum current SWR is measured of mismatch Between load and line.

- The electromagnetic field at any point of transmission line may be considered as the sum of two travelling waves.
- The Incident wave propagates from generator. The reflected wave ~~is~~ propagates towards the generator. The reflected wave is set up by reflection of incident wave from the discontinuity on the line.

- The maximum field strength is found where two waves are in phase and minimum where the line adds in the opposite phase. The distance between 2 successive minimum (or maximum) is half the guide wavelength on the line.

- VSWR is denoted by S

$$\text{VSWR} = S = \frac{E_{max}}{E_{min}} = \frac{|E_i| + |E_r|}{|E_i| - |E_r|}$$

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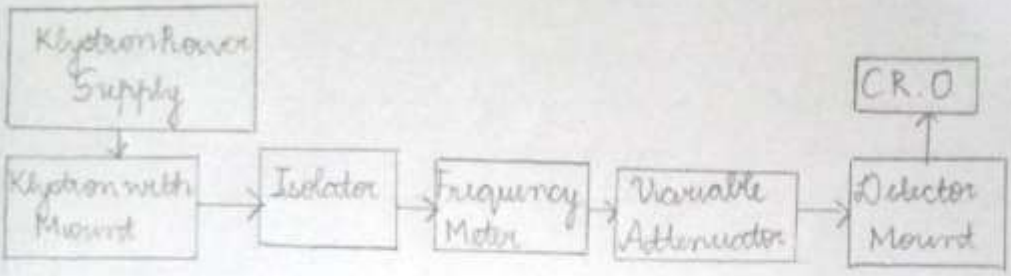
where E_I = Incident voltage and
E_R = Reflected Voltage

where $\rho = \frac{E_r}{E_I} = \frac{z - z_0}{z + z_0} = \frac{s-1}{s+1}$

where ρ = Reflection coefficient

z = Impedance at a point on line
z_0 = Characteristic impedance

Result
The VSWR and Reflection coefficient were measured.



Mode Characteristic of Reflex Klystron

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EXPERIMENT- 9

Aim:- To study the characteristics of reflex klystron.

Apparatus:- Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, variable attenuator slotted section with Probe carriage, CRO, movable short.

Theory:- Klystron is a microwave vacuum tube employing velocity modulation. These electrons move towards the repeller ie the electrons leaving the cavity during the positive half cycle are accelerated while those during negative half cycle are decelerated. The faster ones penetrate lesser in the field of repeller voltage. But, faster electron leaving the cavity take longer time to return and hence catch up with slower ones. In the cavity electrons bunch and interact with the voltage between the cavity grids.

It consists of an electron gun producing a collimated electron beam.

It bunches pass through grids at time the grid at time the grid potentials at such that electrons are decelerated they give by energy. The electrons are then collected by positive cavity wall near cathode. To protect repeller from damage repeller voltage is applied before accelerating voltage.

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Result

The characteristics of reflex Klystron were studied.

Precautions

1. Use fan to keep the klystron temperature low
2. Ensure tight connections of temperature
3. Avoid cross connection of threads.