BAPATLA WOMEN'S ENGINEERING COLLEGE

MICROWAVE & OPTICAL COMMUNICATION LAB

EC- 361 (R20)

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Bapatla-522101

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BAPATLA WOMEN'S ENGINEERING COLLEGE::BAPATLA

AN ISO 9001-2015 CERTIFIED INSTITUTION

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ACADEMIC YEAR: 2021-2022

DEPARTMENT VISION & MISSION

VISION

To produce highly professional and socially responsible women engineers through world class quality technical education and research to meet industry and Society needs in the field of Electronics and Communication Engineering.

MISSION

M1- To inculcate quality education for women through innovative learning practices with the use of modern tools.

M2- To impart professional ethics and moral values through co-curricular and extra-curricular activities as individual and team member.

M3- Empowering graduates through industrial trainings/on-job training in collaboration with industries with-a-view to life-long learning.

PROGRAM EDUCATIONAL OBJECTIVES (PEO's)

1. To develop and implement Electronics and Communication systems by imparting technical knowledge, professional leadership and communication skills as an individual and team in a multi-disciplinary stream.
2. To train Graduates in solving complex problems, analyzing, designing and imparting research-based knowledge by using modern scientific tools to develop least cost-effective and innovative products.
3. To produce women graduates through life-long learning, who ensure ethical and moral behavior.

PROGRAM SPECIFIC OUTCOMES (PSO's)

1. To understand and analyze basic concepts of electronics and communication in various areas like signal processing, VLSI, embedded systems, communications, digital and analog devices.
2. Ability to design and develop computing systems using concepts of mathematics, electronics engineering and other related inter disciplines to assess and resolve societal, environmental, health safety and cultural issues with professional ethics.

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ACADEMIC YEAR: 2021-2022

Program Outcomes:

- **PO1: Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- **PO2: Problem analysis:** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **PO3: Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **PO4: Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- **PO5: Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools prediction and modelling to complex engineering activities with an understanding of the limitations.
- **PO6: The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice
- **PO7: Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and the need for sustainable development.
- **PO8: Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- **PO9: Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- **PO10:Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and receive clear instructions.
- **PO11:Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in team, to manage projects and in multidisciplinary environments.
- **PO12:Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

List of Experiments

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Add-On Experiments

Exp No.	Experiment Name	Page No.
1	To study microwave components	58
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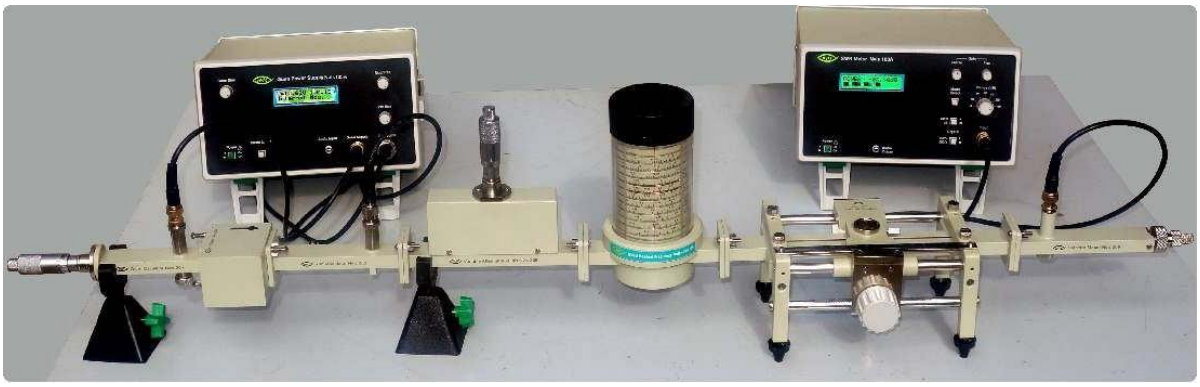
COURSE OUTCOMES

CO No.	Course Outcome Statement	Bloom's TaxonomyLevel
C361.1	**Identify** and demonstrate the working of various microwave components	**Analyze**
C361.2	**Analyse** the microwave measurement procedures	**Analyze**
C361.3	**Evaluate** the performance of waveguide components	**Evaluate**
C361.4	**Demonstrate** characteristics of various optical sources	**Apply**
C363.5	**Measure** data Rate, Numerical Aperture and Losses in Optical Link	**Evaluate**

MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF PROGRAMME OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
C361.1	3	3	2	3	-	-	-	-	-	-	-	1	2	-
C362.2	3	3	3	2	-	-	-	-	-	-	-	1	2	-
C363.3	3	3	3	2	-	-	-	-	-	-	-	1	2	-
C364.4	3	3	2	1	-	-	-	-	-	-	-	1	2	-
Avg	3	3	2.5	2	-	-	-	-	-	-	-	1	2	-

INTRODUCTION TO MICROWAVE BENCH



1. Klystron Power Supply NV102

Klystron Power Supply, is a state-of the-art solid-state, regulated power supply for operating low power klystrons. It consists of regulated beam supply, beam current and repeller supply voltage. In addition to AM and FM modulation of Beam current, a provision for externally modulating the klystron supply with desired signal waveform has been provided.

Technical Specifications:

Beam Supply : Voltage : 240 - 420 VDC, Variable

Current : 50 mA

Regulation : 0.5 % for 10% I/P variation

Ripple : < 5m Vrms

Repeller Supply : -18V to -270V DC Variable

Regulation: 0.25%, for 10% I/P variation

Filament Supply : 6.3 VDC (adjustable on rear panel)

Over-Load Trip Current : 65mA

Modulation : AM (Square) FM (Saw-tooth)

Frequency Range 180-1450 HZ ± 5%, 72-195 Hz ± 5%

Amplitude 0-110 Vpp 0-40 Vpp

External : Through External Modulating Signal

Display : Digital display for

1. Beam voltage

2. Beam Current

3. Repeller voltage

Modulation Slector : FM/AM/CW/Ext

3 ½ Digital Panel Meter : 2V

Meter Selector : Beam Voltage (V)/ Current (I)/ Rep. (Repeller)

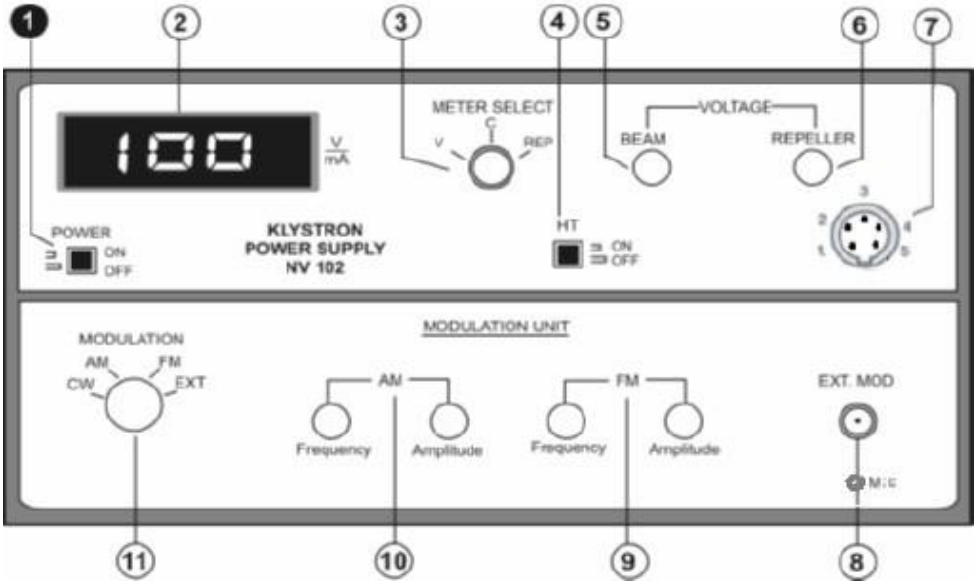
Connectors : a. 5-Pin connector

b. BNC for External Modulation

Power Supply : 230 V AC ± 10%, 50Hz

Dimensions (mm) : 345 x 283 x 153

Front Panel Control



1. **Power: Push button switch for supplying the power to instrument.**

2. **Display: for monitoring beam voltage (in volts), Repeller voltage and beam current (mA).**

   Beam voltage: 240 V to 420 V DC

   Repeller voltage: -18 V to -270 V DC

   Beam current: 0 to 50 m

3. **Meter Select Switch:** For selecting display mode in V – shows Beam voltage (volts), I shows Beam current (mA) & REP – shows Repeller voltage in volts.

4. **HT:** Output 'On'/'Off' switch.
5. **Beam voltage:** Adjust potentiometer, it is vary from 240 to 420 V DC.
6. **Repeller voltage:** Adjust potentiometer; it is vary from -18V to -270V DC.
7. **5-Pin connector :** Pin 1 - 5 = Beam voltage
   Pin 3 - 5 = Rep. Voltage
   Pin 2 – 4 = Heater voltage
8. **Ext. Mode:** To provide external modulating signal.
9. **FM Modulation:** Frequency potentiometer controls the frequency or the sweep modulating signal (50–150 Hz). Amplitude potentiometer controls the amplitude or sweep modulating signal (0-60Vpp)
10. **AM Modulation:** Frequency potentiometer controls the frequency or the square wave modulating signal (500 – 2000 Hz). Amplitude potentiometer controls the amplitude or square wave modulating signal (0 – 110Vpp).
11. **Modulation Selection switch:** For selecting modulation types CW mode – No modulation signal applied to the beam voltage. AM mode–A square wave modulating signal is applied to the beam voltage. FM mode–A sweep modulation is applied to the beam voltage, Ext mode–External modulating signal is accepted for modulation or beam current through BNC connector.
12. **Earphone Socket:** Here we can connect a MIC to give audio signal as a modulating signal.

SWR Meter NV103A:

The model NV 103A SWR meter is a high gain low noise, tuned voltmeter operating at fixed frequency. It is designed for making standing wave measurement in conjunction with a suitable detector and slotted line or wave guide section. It may be used as null detector in bridge circuit and as fixed frequency indicator. It is calibrated to indicate directly SWR or dB when used with square law devices such as crystal diode. It is adjusted for operation at 980Hz to 1020 Hz to avoid harmonics of the line frequency.

Technical Specifications:

Display : LCD (16 X 2)

Sensitivity : 0.1 V for 200 input impedance

Noise Level : Less than 0.02 V

Range : 0 – 60dB in 10dB steps

Input : Un-biased low and high impedance crystal biased crystal (200 and 200K)

Display Select : SWR 1 – 9dB 0 – 10

Modes : Normal

Audio

PC (this mode can be used only with Gunn based bench)

Gain Control : Adjusts the reference level, variable range 0-10dB (approximately)

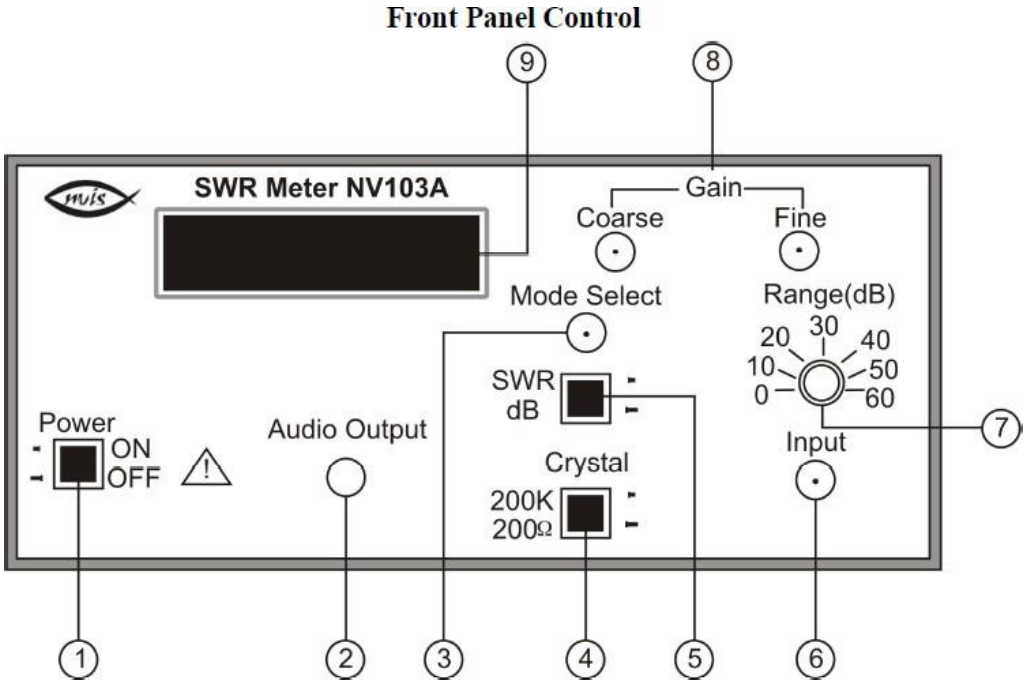
Input Connector : BNC (F)

Input Frequency : 1000Hz ± 10%

Power : 230 Volts AC ± 10%, 50Hz

Dimension (mm) : 300 × 222 × 122

Front Panel Control



1. Power: Push button switch for supplying power to instrument.

2. Audio Output: This socket is provided for connecting headphone.

3. Mode select: This switch is given to select different modes of SWR meter.

Modes are:

Normal: In this mode the 1 KHz square wave detected output is given to input of SWR meter. All the measurement of gain and SWR should be measure in this mode.

Audio: Select this mode if the input of pin modulator is an audio signal.

PC: Select this mode if the input of PIN modulator is PC data. (This mode can be used only with Gunn based bench)

4. **Crystal:** It is an input impedance selector switch for low & high inputs i.e. High 200K-Low 200Ω.
5. **SWR/dB:** This switch provided to select display modes either it reads in dB power or SWR of device.
6. **Input:** BNC (Female) connector for connecting signal to be measured.
7. **Range Switch:** A seven position attenuator minimum in 10 dB steps.
8. **Gain Coarse:** Control for adjustments of meter or any other convenient reading.
   Gain Fine: Control for fine adjustments of meter or any other convenient reading.
9. **LCD display in SWR & dB:** LCD display, for measuring SWR and gain.

1. REFLEX KLYSTRON CHARACTERISTICS

AIM: To study the characteristics of reflex klystron oscillator

APPARATUS:

1. Reflex Klystron power supply
2. Reflex Klystron tube with mount
3. Isolator
4. Frequency meter
5. Variable Attenuator
6. Slotted section
7. Detector Mount.
8. Waveguide stands
9. BNC (Bayonet Neill Concelman) Cable
10. SWR Meter
11. CRO

BLOCK DIAGRAM:

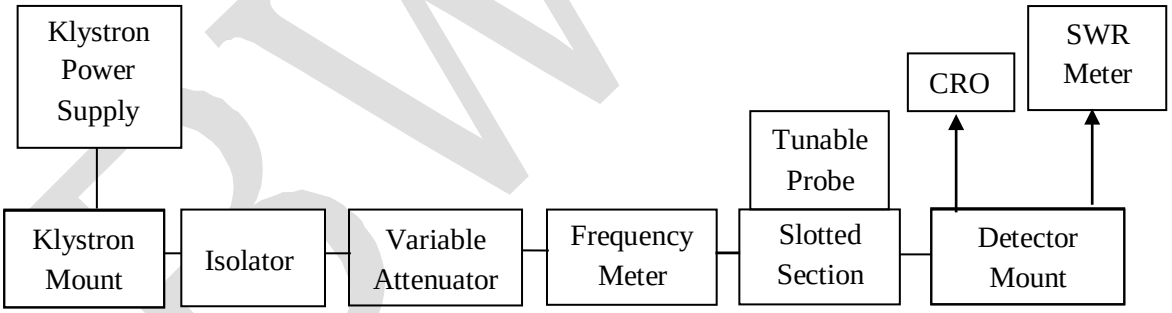


Fig. Microwave Test Bench setup for reflex klystron characteristics

THEORY:

The Reflex Klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. The electron beam emitted by the cathode is first velocity modulated by the cavity gap voltage. Some electrons accelerated by the accelerating field enter the repeller space with greater velocity than those with unchanged velocity. Some electrons decelerated by the retarding field enter the repeller region with less velocity. All electrons turned around by the repeller voltage then pass through the cavity gap in bunches

that occur once per cycle.

On their return journey, the bunched electrons pass through the cavity gap during the retarding phase of the alternating field and give up their kinetic energy to the electromagnetic energy of the field in the cavity. The electrons are finally collected by the walls of the cavity of other grounded metal parts of the tube.

PROCEDURE:

1. Set the various components as per the block diagram.
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW
   Beam Voltage : Fully anti-clockwise
   Repeller Voltage : Fully clockwise
   Frequency Meter : Fully clockwise or anti-clockwise
   AM Amplitude & Frequency : Mid Position
   Attenuation : 10-15dB
3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω
   Range : 40 or 50dB
   Gain control knobs : Mid position
   SWR/dB Switch : dB position
4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam curren.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Connect the output of the detector mount to SWR meter and note the power in dB at range.
10. Connect the output of the detector mount to CRO and note the peak to peak output voltage.
11. Note down the corresponding frequency from frequency meter.

12. Vary the repeller voltage till the peak to peak voltage in CRO is maximum and note down the repeller voltage and its corresponding output voltage and frequency.
13. Change the repeller voltage in steps of ±10V and note down the corresponding repeller voltage, output voltage and frequency.
14. Repeat steps 12 & 13 for another two sets of values.
15. Plot the graph between repeller voltage and output voltage, repeller voltage and frequency.

OBSERVATIONS:

Initial Conditions:

Beam voltage : 300V

Beam current : 17mA

Repeller voltage : -297 V

Output voltage :

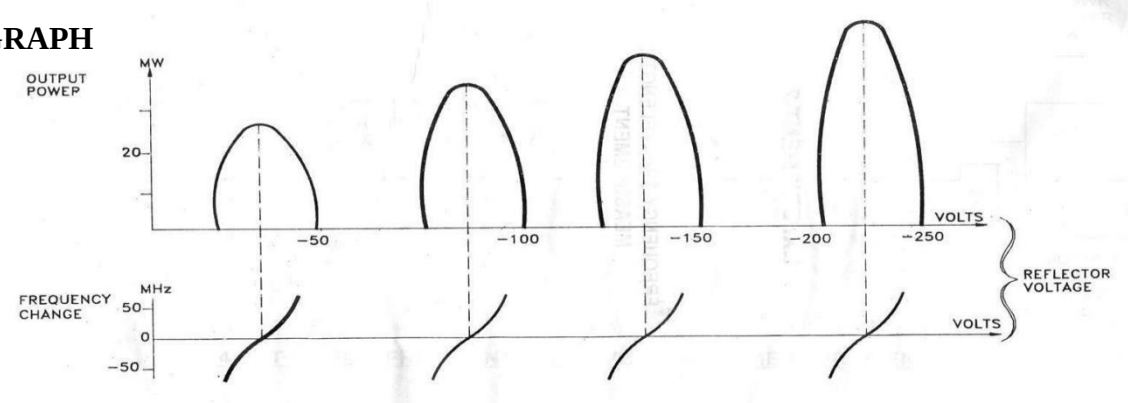
Frequency :

Power :

Tabular Column:

Repeller voltage (Volts)	**Output power in dB**	**Output power in (Watts)**	**Frequency (GHz)**

GRAPH



PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto - 270V**.**

APPLICATIONS:

This is most widely used in applications where variable frequency is desired.

i. In radar receivers

ii. Local oscillator in microwave receivers

iii. Signal source in microwave generator of variable frequency

iv. Pump oscillator in parametric amplifier.

RESULT: Hence the characteristics of the Reflex Klystron has been studied and obtained.

VIVA QUESTION:

1. Explain the operation of the reflex klystron tube.
2. What is the basic principle involved in microwave tubes.
3. What is the difference between velocity modulation and current density modulation?
4. What happens to the power output as the repeller voltage increases?
5. What are the various modes of operation in the reflex klystron?

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2. GUNN DIODE CHARACTERISTICS

AIM: To study the characteristics of Gunn Diode

APPARATUS:

1. Gunn power supply.
2. Gunn oscillator with micrometer.
3. PIN modulator.
4. Isolator.
5. Variable Attenuator.
6. Waveguide Diode Detector
7. CRO
8. BNC cables

BLOCKDIAGRAM:

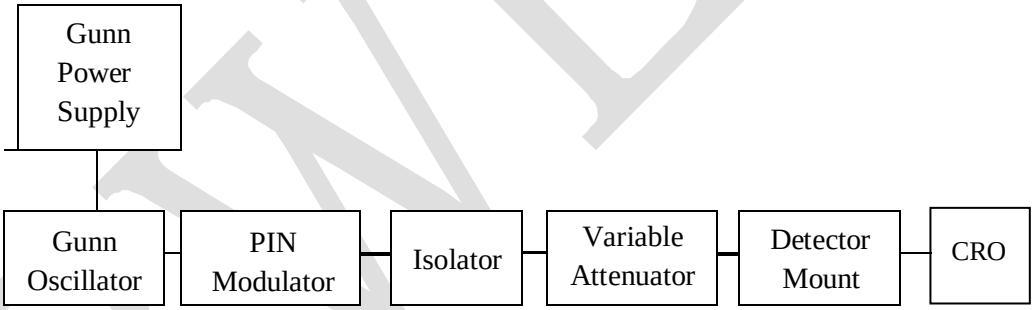

Fig. Microwave test Bench setup for Gunn Diode characteristics

THEORY:

Some bulk semiconductor materials such as Gallium arsenide (GA As), Indium Phosphide (InP) and Cadmium Telluride (CdTe) have two closely spaced energy bands in the conduction band. At lower electric field strengths in the material, most of the electrons will be transmitted into higher energy band. In the higher energy band the effective electron mass is longer and hence the electron mobility is lower than what it is in the lower energy band. Since the conductivity is directly proportional to the mobility there is an immediate range of electric field strengths for which the fraction of electrons that are transferred into higher energy low mobility conduction is such that the average mobility and hence conductivity

decreases with an increase in the electric field strength. Thus there is a range of voltage over which the current decreases with the increasing voltage and a negative instrumental of resistance is displayed by the device. A Gunn device is also called a transferred electronic device since the negative resistance arises from the transfer of electrons from the lower to higher energy band. The oscillations that occur in the material with energy band structure noted above was discovered by J.B.GUNN. The probability of obtaining negative differential resistance had been predicted earlier by Ridley and Watkins.

PROCEDURE:

1. Set the components as shown in figure.
2. Keep the control knobs of Gunn power supply as below
    - Meter switch should be off
    - Gunn bias knob-fully anticlockwise
    - Pin bias knob (mod amp) – fully anticlockwise
    - Pin mode frequency – any position
3. Set the micrometer of Gunn oscillator for required frequency of operation.
4. Switch on the Gunn power supply.
5. Measure the Gunn diode current corresponding to various Gunn bias voltages through the digital panel meter and meter switch. Do not exceed the bias voltage above 10V.
6. Plot the voltage and current reading on the graph and compare with expected graph.
7. Measure the threshold voltage which corresponds to maximum current.

OBSERVATIONS:

S. No	Voltage in (volts)	Current in (m Amps)

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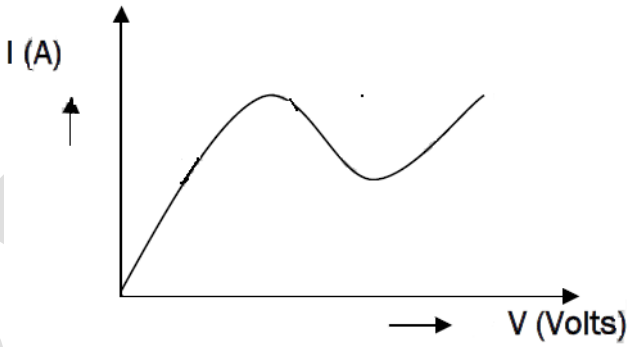
MODEL GRAPH:



PRECAUTIONS:

3. Do not keep Gunn bias knob at threshold position for more than 10-15 seconds.
4. Readings should be obtained as fast as possible otherwise excess heating may burn Gunn diode.

APPLICATIONS:

i. In radar transmitters.
ii. Broadband linear amplifiers.
iii. Low and medium power oscillator in microwave receivers.
iv. Fast combinational and sequential logic circuits.
v. As pump sources in par amp

RESULT: The characteristics of Gunn diode is observed.

VIVA QUESTIONS:

1. What are the different modes of Gunn diode?
2. What is Gunn Effect?
3. What are the applications of Gunn Diode?
4. Explain LSA Mode.
5. Explain the purpose of PIN modulator

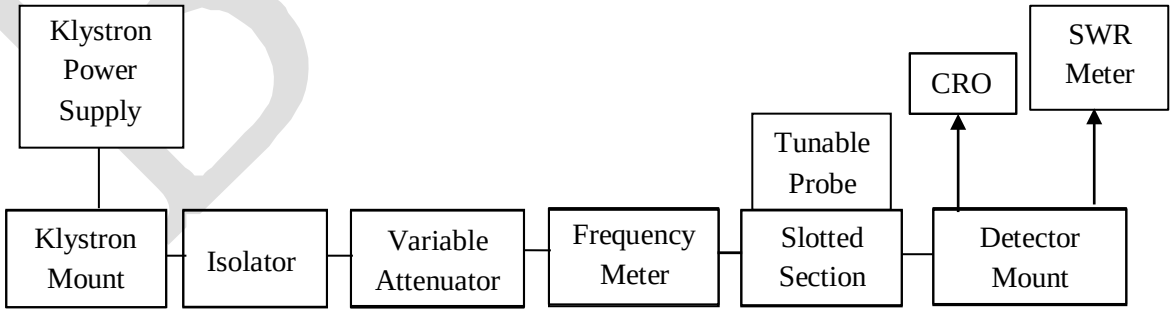
3. ATTENUATION MEASUREMENT

AIM: To measure power and frequency for different values of attenuation.

APPARATUS:

1. Klystron Power Supply
2. Klystron tube with mount
3. Isolator
4. Frequency Meter
5. Variable Attenuator
6. Slotted line
7. Waveguide Stand
8. Matched Termination
9. Detector Mount
10. CRO
11. BNC Cables
12. Cooling fans
13. SWR meter

BLOCK DIAGRAM



THEORY:

The attenuators are two port bi-directional devices which attenuate power when inserted into the transmission line.

$$\text{Attenuation A (dB)} = 10 \log_{10} [P1/P2]$$

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Where

P1= Power absorbed or detected by the load without the attenuator in the line.

P2= Power absorbed or detected by the load with attenuator in the line.

The attenuator consists of a rectangular waveguide with a resistive vane inside it to absorb microwave power according to their position with respect to side wall of the waveguide. As electric field is maximum at the center in TE_{10} mode, the attenuation will be maximum if the vane is placed at center of the waveguide. Moving from center towards the side wall, attenuation decreases in the fixed attenuator, the vane position is fixed where as in a variable attenuator, its position can be changed by help of micrometer or by other methods.

PROCEDURE:

1. Set the various components as per the block diagram.
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW
   Beam Voltage : Fully anti-clockwise
   Repeller Voltage : Fully clockwise
   Frequency Meter : Fully clockwise or anti-clockwise
   AM Amplitude & Frequency : Mid Position
   Attenuation : 10-15dB
3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω
   Range : 40 or 50dB
   Gain control knobs : Mid position
   SWR/dB Switch : dB position
4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller

voltage.

9. Connect the output of the detector mount to SWR meter and note the power in dB at range.
10. Connect the output of the detector mount to CRO and note the peak to peak output voltage.
11. Find the maximum frequency of oscillator by observing the clip of waveform by rotating the frequency meter. Let the frequency be fo.
12. Vary the value of attenuation from 0 dB to 10 dB and note down the corresponding values of voltage, power and frequency.

OBSERVATIONS:

Initial Conditions:

Beam voltage : 300V

Beam current : 17mA

Repeller voltage : - 297 V

Output voltage :

Frequency :

Power :

Tabular Form:

S.No.	Attenuation in dB	Power in dB	Voltage in Volts	Frequency in GHz

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PRECAUTIONS:

i) Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

ii) If the main supply failed in the middle of the experiment, come to 1^{st} condition (i.e.)

keep all the knobs in minimum positions and switch off main switches.

iii) Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V**.**

RESULT: Power and frequency are measured for different values of attenuation.

VIVA QUESTIONS:

1. What is the purpose of attenuation measurement in microwave engineering, and how does it impact signal quality?

2. Describe the working principle of the attenuator used in the experiment. How does it reduce the signal power?

3. What are the different types of attenuators used in microwave engineering? How do they differ in terms of frequency range and attenuation range?

4. In the attenuation measurement experiment, what is the significance of calibration? How does it ensure accurate measurement results?

5. What are the potential sources of error in attenuation measurement, and how can they be minimized to achieve accurate results?

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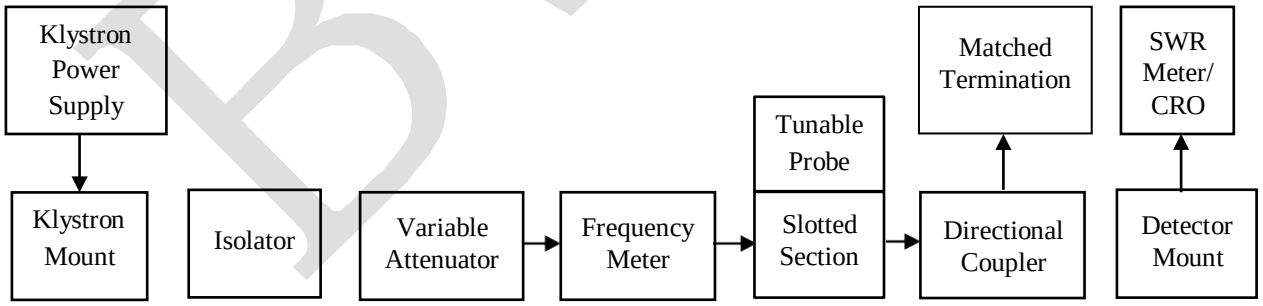
4. DIRECTIONAL COUPLER CHARACTERISTICS

AIM: To measure coupling coefficient, insertion loss, directivity and isolation of a directional coupler.

APPARATUS:

1. Klystron Power Supply
2. Klystron tube with mount
3. Isolator
4. Frequency Meter
5. Variable Attenuator
6. Slotted line
7. Directional Coupler
8. Matched Termination
9. Waveguide Stand
10. SWR Meter
11. CRO
12. BNC cable

BLOCK DIAGRAM:



Fig; Microwave bench setup to calculate the parameters of a directional coupler

BWEC

Fig (a): To calculate P_2

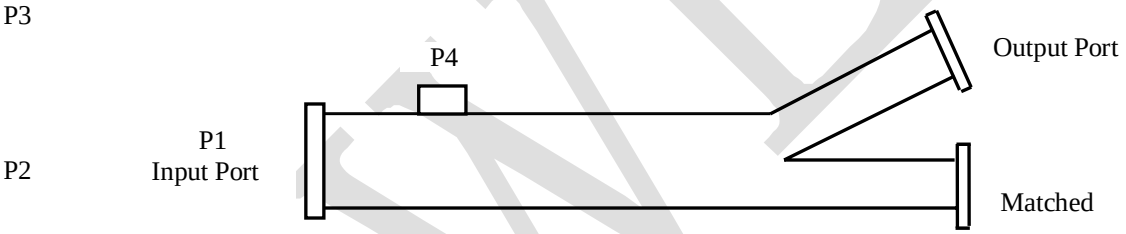


Fig (b): To calculate P_{3f}

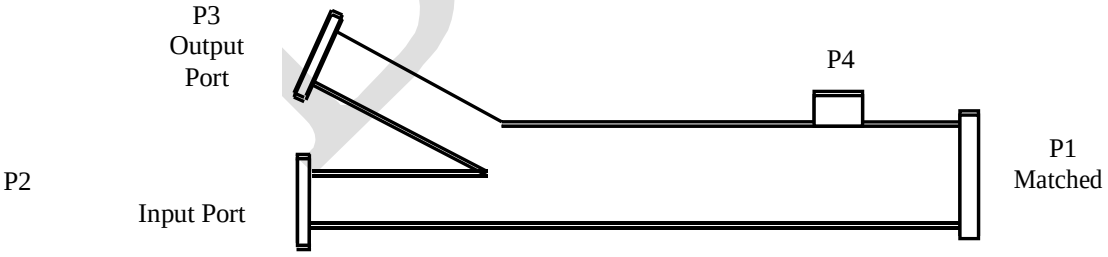


Fig (c): To calculate P_{3b}

THEORY:

A directional coupler is a 4 port device, which is used to measure incident and reflected waves separately, SWR.. It consists of two transmission lines, primary waveguide and secondary wave guide or auxiliary waveguide, electromagnetically coupled to each other. Directional couplers can be uni-directional (measures only incident power) or bi-directional (measures both incident and reflected powers). The power entering port 1 in the primary waveguide divides between ports 2 & 3 and almost no power comes out from port 4. Power entering port 2 is divided between port 1 & 4.

Coupling factor is defined as the ratio of incident power to forward power.

$$Coupling\ factor, C = 10\log_{10}\frac{P_1}{P}\ dB \qquad \text{—}_{3}$$

The directivity of a directional coupler is a measure of separation between incident wave and the reflected wave. It is measured as the ratio of the two power outputs from the auxiliary line when a given amount power is successfully applied to each terminals of the main lines with other ports terminated by material loads.

Directivity is defined as the ratio of forward power to the backward power in dB.

$$Directivity, D = 10\log_{10}\frac{P_{3f}}{P_{3b}}\ dB$$

When a directional coupler is connected to any microwave equipment, insertion loss occurs. It is defined as the ratio of incident power to the transmitted power. When directional coupler is reversed, incident power is known as transmitted power.

$$Insertion\ Loss, L = 10\log_{10}\frac{P_1}{P}\ dB \qquad \text{—}_{2}$$

$$Isolation, I = D * C$$

PROCEDURE:

1. Set the various components as per the block diagram.
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

HT (High Tension) Switch:	OFF Position
Meter Select	: Volts
Modulation	: CW
Beam Voltage	: Fully anti-clockwise
Repeller Voltage	: Fully clockwise
Frequency Meter	: Fully clockwise or anti-clockwise
AM Amplitude & Frequency	: Mid Position

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Attenuation : 10-15dB

3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω

   Range : 40 or 50dB

   Gain control knobs : Mid position

   SWR/dB Switch : dB position

4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Connect the tunable probe to SWR meter and note the power in dB at range.
10. Connect the detector mount to SWR meter and note down the power as P_1 or P_{ref}.
    NOTE: We can take power values either from SWR meter or from CRO.
11. Connect the directional coupler such that port 1 as input, port 2 as output and port 3 as matched, as shown in Fig (a) and note down the power as P_2.
12. Calculate the insertion loss using by using $L = P_{ref} - P_2$.
13. Connect the directional coupler such that port 1 as input, port 2 as matched and port 3 as output, as shown in Fig (b) and note down the corresponding forward power as P_{3f}.
14. Calculate the coupling factor using $C = P_{ref} - P_{3f}$.
15. Reverse the directional coupler and make connections such that port 1 as output, port 2 as input and port 3 as matched, as shown in Fig (c) and note down the corresponding reverse power as P_{3b}.
16. Calculate directivity using $D = P_{3f} - P_{3b}$.
17. Calculate isolation using $I = P_1 - P_{3b}$.
18. Verify with I = C+D.

OBSERVATIONS:

Initial Conditions:

Beam voltage : 300V

Beam current : 17mA

Repeller voltage : - 297 V

Output voltage :

Frequency :

Power :

Practical Calculations:

- P_{ref} (or) P_1 =
- P_2 =
- P_{3f} =
- P_{3b} =
- Insertion Loss, L = $P_{ref} - P_2$.
- Coupling factor, C = $P_{ref} - P_{3f}$.
- Directivity, D = $P_{3f} - P_{3b}$.
- Isolation, I = $P_1 - P_{3b}$.

PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1^{st} condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V**.**

RESULT: Insertion Loss, Coupling factor, Directivity and Isolation of a directional coupler are measured using microwave.

VIVA QUESTIONS:

1. What is directional coupler?
2. What is Insertion loss?
3. In a two hole directional coupler, what is the distance between two holes?
4. Name a few other types of directional couplers?
5. How many holes can be there in a Directional coupler?

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5. IMPEDANCE AND FREQUENCY MEASUREMENTS

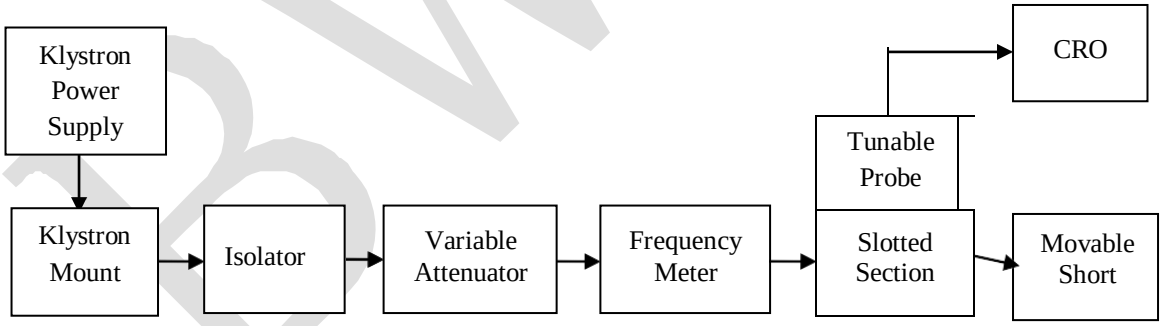
AIM: To measure unknown impedance using the Smith chart.

APPARATUS:

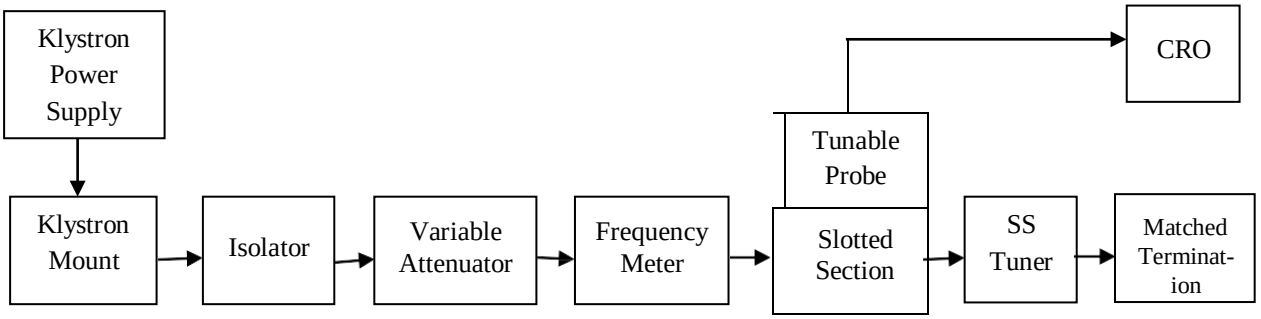
1. Klystron Power Supply
2. Klystron tube with mount
3. Isolator
4. Frequency Meter
5. Variable Attenuator
6. Slotted line
7. Waveguide Stand
8. SS tuner
9. Movable short
10. CRO

BLOCK DIAGRAM:

Set up 1:



Set up 2:



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THEORY:

The impedance at any point of a transmission line can be written in the form R+jX. For comparison, SWR can be calculated as:

$$SWR = \frac{1 + |\rho|}{1 - |\rho|}$$

where, ρ= reflection coefficient

The unknown terminating impedance can be determined by measuring standing wave ratio & distance of a convenient maxima or minima from the load. Normally for distance measurement minima is used because it is more sharply defined.

The detector mount is connected to the slotted line. By varying the slotted line and the position of one minima is determined. The detector mount is replaced by slide screw tuner to the slotted line. Two successive minima positions are noted. The twice of the difference between minima positions will be guide wavelength, λ_g. One of the minima is used as reference for impedance measurement. Find the difference of reference minima and maxima position obtained from unknown load. Let it be'd'. Take a smith chart, taking 'I' as centre draw a circle of radius equal to 'So'. Mark a point on the circumference of smith chart towards load side at a distance equal to d/1g. Join the centre with this point. Find the point where it cuts the drawn circle. The co-ordinates of this point will show normalized impedance of load.

PROCEDURE:

1. Set the various components as per the block diagram shown in set up 1.
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW
   Beam Voltage : Fully anti-clockwise
   Repeller Voltage : Fully clockwise
   Frequency Meter : Fully clockwise or anti-clockwise
   AM Amplitude & Frequency : Mid Position
   Attenuation : 10-15dB
3. Keep the control knobs of SWR meter as below:

Crystal Impedance	: 200Ω
Range	: 40 or 50dB
Gain control knobs	: Mid position
SWR/dB Switch	: dB position

4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Connect the output of the detector mount to SWR meter and note the power in dB at range.
10. Connect the output of the detector mount to CRO and note the peak to peak output voltage.
11. Note down the corresponding frequency from frequency meter.
12. Set the probe position on slotted section towards load side.
13. Move the probe along source side and note down the distance between two successive minimas or maximas d_1 and d_2.
14. Calculate using $\boldsymbol{\lambda_g = 2(d_1 \sim d_2)}$
15. Connect SS tuner to the slotted section as shown in set up 2.
16. Tune the SS tuner to get maximum p-p output in CRO.
17. Move the slotted line towards load and note down the distance $\boldsymbol{d_s}$on slotted line at minima in CRO.
18. Find the shift in minima by using $\boldsymbol{d = d_1 - d_s}$.
19. The value '**d'** will be positive if minimum shift is towards load and negative if it has shifted towards generator.
20. The obtained distance should be in terms of λ, $\boldsymbol{d_g = \frac{d\lambda}{\lambda_0}}$.
21. Move the probe on slotted line and find maximum peak to peak output V_{max} and minimum peak to peak output V_{min} on CRO.
23. Calculate $\boldsymbol{VSWR}$ using $\boldsymbol{VSWR = \frac{V_{max}}{V_{min}}}$.
24. Plot the impedance in Smith Chart.

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Impedance Measurement using Smith Chart:

1. Consider VSWR scale and draw a circle on smith chart with VSWR radius.
2. Locate a point 'P' at a distance $\boldsymbol{d_g}$ from the 0.0 moving in clockwise or anti-clockwise direction. It depends on getting minima towards generator or load.
3. Join the point P to the centre of Smith chart. The intersection of VSWR circle and this line gives load, reactive component or reactive circle and resistive component on real circle.
4. Normalized impedance is given by **R+jX** where R and X are the real and reactive components.
5. The multiplication with characteristic impedance will give the value of load impedance.

OBSERVATIONS:

Initial Conditions:

Beam voltage : 300V

Beam current : 17mA

Repeller voltage : -297 V

Output voltage :

Frequency :

Power :

Practical Calculations:

Without SS Tuner

- $\boldsymbol{d_1}$ =
- $\boldsymbol{d_2}$ =
- $\boldsymbol{\lambda_g = 2(d_2 \sim d_1)}$ or $\boldsymbol{\lambda_g = 2(d_1 \sim d_2)}$
- $\boldsymbol{\lambda_c = 2a}$
- $\boldsymbol{\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$

With SS Tuner

- $\boldsymbol{d_s}$ =

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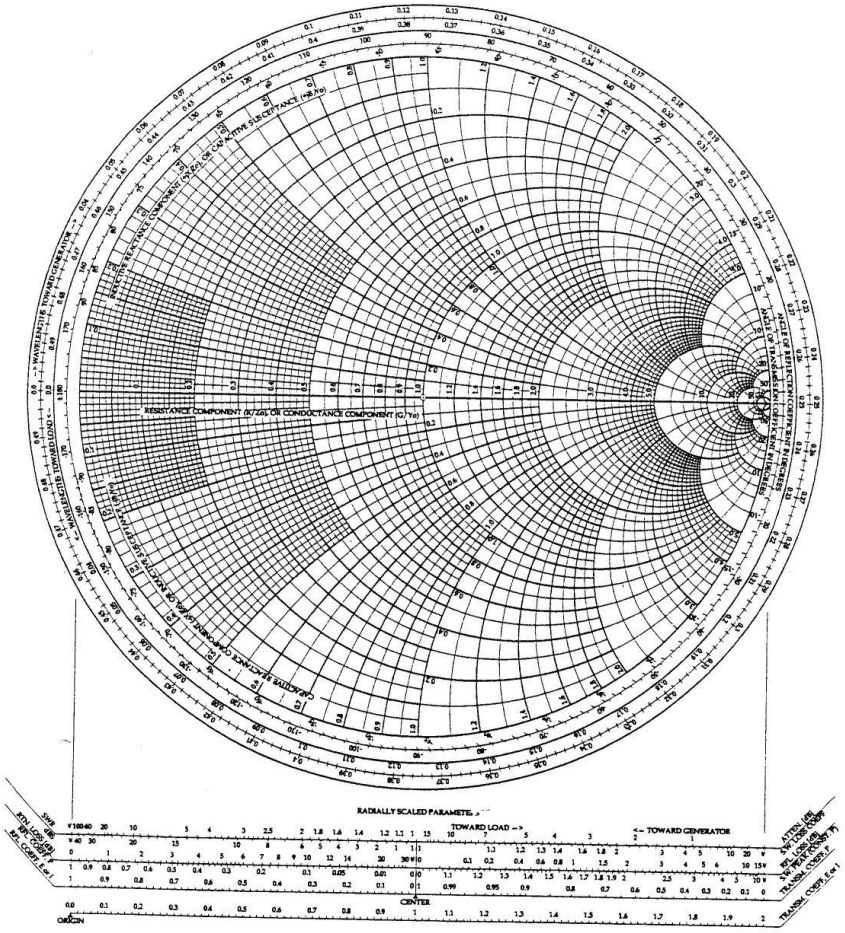
- $\boldsymbol{d = |d_s \sim d_1|}$ or $\boldsymbol{d = |d_s \sim d_2|}$
- $\boldsymbol{VSWR = \frac{V_{max}}{V_{min}}}$
- $\boldsymbol{d_g = \frac{d\lambda}{\lambda_0}}$
- $\boldsymbol{Z = R \pm jX}$

GRAPH:

The Smith Chart



PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply, "HT" should be 'OFF' before switching'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.)

keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70V to -270V**.**

APPLICATIONS:

VSWR can be measured by knowing the impedance.

RESULT: The unknown impedance is calculated using smith chart.

VIVA QUESTIONS:

1. What is a Klystron bench, and how does it contribute to impedance measurements in microwave applications?
2. How does a directional coupler function in the context of impedance measurements with a Klystron bench?
3. Explain the concept of standing wave ratio (SWR) and its significance in impedance measurements using a Klystron bench.
4. What are the primary advantages of using a Klystron bench over traditional methods like vector network analyzers for impedance measurements?
5. Describe a practical scenario where accurate impedance measurements using a Klystron bench are essential.

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6. SCATTERING PARAMETERS OF CIRCULATORS

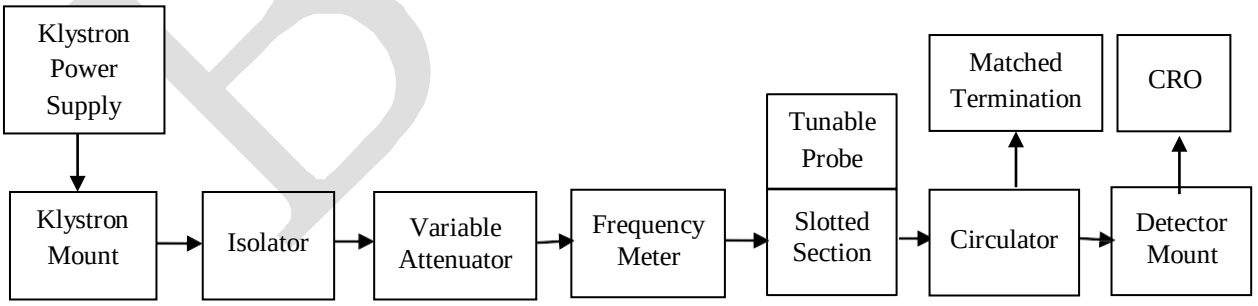
AIM: To study the properties and determine the scattering parameters of circulator.

APPARATUS:

6. Klystron power supply
7. Klystron tube with mount
3. Isolator
4. Frequency meter
5. Variable attenuator
6. Detector mount
7. Waveguide stands
8. VSWR meter
9. Matched termination
10. Slotted section
11. Circulator
12. BNC Cable
13. CRO

BLOCK DIAGRAM:

Set up 1: To calculate Scattering parameters of Circulator



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THEORY:

Circulator is defined as a device with ports arranged such that energy entering a port is coupled to an adjacent port but not coupled to the other ports. This is depicted in figure. Circulator can have any number of ports. Circulator is a multi-port junction. A wave incident in port 1 is coupled to port 2 only, a wave incident at port 2 is coupled to port 3 only and so on.

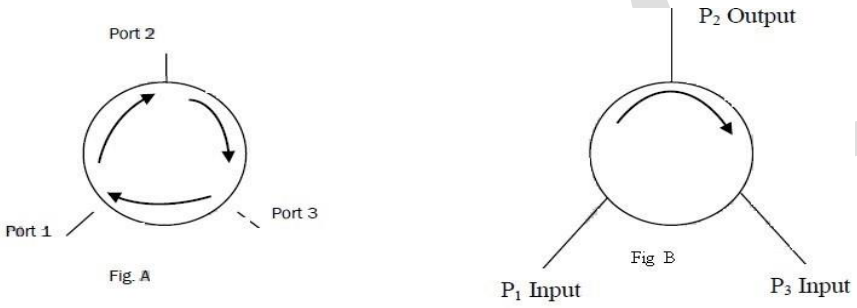


Fig: Circulator

Following are the basic parameters of isolator and circulator.

Insertion Loss: The ratio of power supplied by a source to the input port to the power detected by a detector in the coupling arm, i.e., output arm with other port terminated in the matched load is defined as insertion loss or forward loss.

Isolation: It is the ratio of power fed to input arm and the power detected at not coupled port with other port terminated in the matched load.

Input VSWR: The input VSWR of an isolator of circulator is the ratio of voltage maximum to voltage minimum of the standing wave existing on the line, when one port of it terminates a line and others have matched termination.

NOTE: When port which is not coupled to input port is terminated by matched termination, it makes as isolator.

PROCEDURE:

1. Set the various components as per the block diagram shown in set up 1..
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW
   Beam Voltage : Fully anti-clockwise
   Repeller Voltage : Fully clockwise
   Frequency Meter : Fully clockwise or anti-clockwise
   AM Amplitude & Frequency : Mid Position
   Attenuation : 10-15dB
3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω
   Range : 40 or 50dB
   Gain control knobs : Mid position
   SWR/dB Switch : dB position
4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Connect the output of the detector mount to SWR meter and note the power in dB at range.
10. Connect the output of the detector mount to CRO and note the peak to peak output voltage.
11. Note down the corresponding frequency from frequency meter.
12. Connect the detector mount to slotted line and calculate p-p output voltage in CRO, which is $S_{11}, S_{22}, S_{33}, S_{44}$.
13. Connect port 1 of magic tee to slotted line, port 2 to detector mount and ports 3 & 4 to matched termination and calculate p-p output voltage in CRO, which is S_{12}.
14. Repeat the same for all cases and find various scattering coefficients of magic tee.

NOTE: In all the cases, while taking values, adjust the repeller voltage and slotted section to get maximum p-p output in CRO.

OBSERVATIONS:

S-Matrix of Circulator:

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}$$

PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1^{st} condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V**.**

APPLICATIONS OF CIRCULATOR:

i. Used as duplexer for a radar antenna system.

ii. Two three port circulators can be used in tunnel diode or parametric amplifiers.

iii. Used as low power devices as they can handle low powers only.

RESULT:

The properties of circulator are studied and scattering parameters are calculated.

VIVA QUESTIONS:

1. How are S parameters measured?
2. What do S parameters mean?
3. What is S parameter s21?
4. What is S parameter in microwave?
5. What is the purpose of a circulator?

7. SCATTERING PARAMETERS OF MAGIC TEE

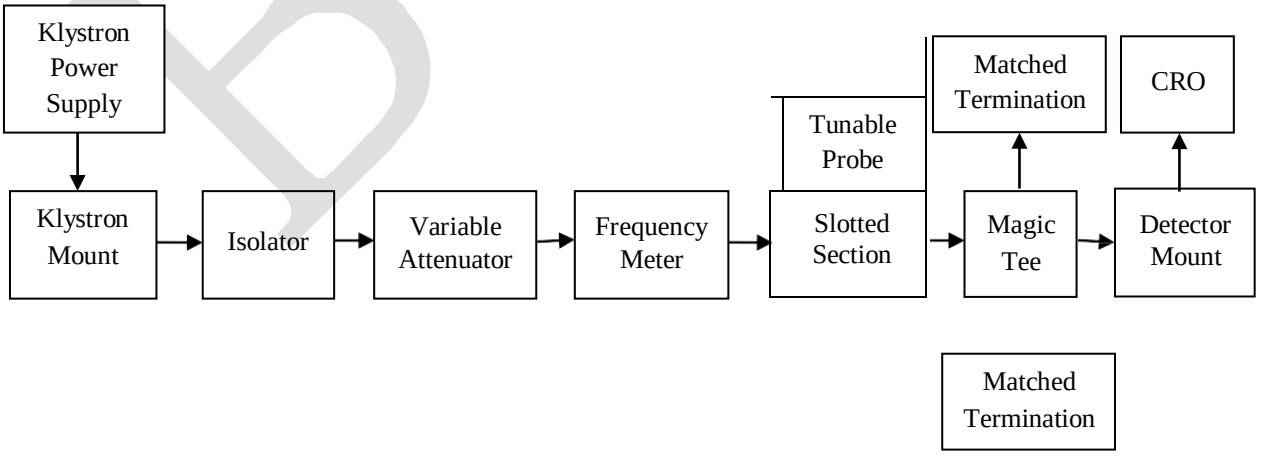
AIM: To study the properties and determine the scattering parameters of magic tee.

APPARATUS:

1. Klystron power supply
2. Klystron tube with mount
3. Isolator
4. Frequency meter
5. Variable attenuator
6. Detector mount
7. Waveguide stands
8. VSWR meter
9. Matched termination
10. Slotted section
11. Magic Tee
12. BNC Cable
13. CRO

BLOCK DIAGRAM:

Set up 1: To calculate Scattering parameters of Magic Tee



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THEORY:

The device magic tee is a combination of E and H-plane tee as shown in figure. Arm 3 is the H-arm and arm-4 is the E-arm. If the power is fed into arm 3 (H-arm), the electric field divides equally between 1 and 2 arms with the same phase and no electric field exists in arm 4 (E-arm). If power is fed into arm 4 (E – arm), it divides equally into arm-1 and arm-2 but out of phase with no power to arm-3, further if the power is fed in arm-1 and arm-2 simultaneously it is added in arm-3 (H-arm) and it is subtracted in E-arm i.e. arm-4.

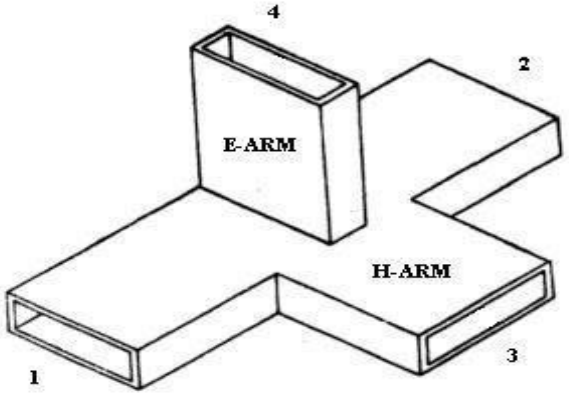

Fig: Magic Tee

The basic parameters to be measured for magic tee are defined below:

i. **Input VSWR:** Value of SWR corresponding to each port as a load to the line while other ports are terminated in matched load.

ii. **Isolation:** The isolation between E & H arms is defined as the ratio of the power supplied by the generators connected to the E-arm (port 4) to the power detected at H-arm (port 3) when side arms-1 and 2 are terminated in matched load. Hence

$$Isolation = 10\log_{10}\frac{P_4}{P_3}$$

Where,

P_3 = power delivered to arm-i

P_4 = power detected at j-arm

iii **Coupling Factor:** It is defined as $C_{ij} = 10^{-\alpha/20}$ where '**a**' is attenuation

PROCEDURE:

1. Set the various components as per the block diagram shown in set up 1..
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW
   Beam Voltage : Fully anti-clockwise
   Repeller Voltage : Fully clockwise
   Frequency Meter : Fully clockwise or anti-clockwise
   AM Amplitude & Frequency : Mid Position
   Attenuation : 10-15dB
3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω
   Range : 40 or 50dB
   Gain control knobs : Mid position
   SWR/dB Switch : dB position
4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Connect the output of the detector mount to SWR meter and note the power in dB at range.
10. Connect the output of the detector mount to CRO and note the peak to peak output voltage.
11. Note down the corresponding frequency from frequency meter.
12. Connect the detector mount to slotted line and calculate p-p output voltage in CRO, which is $S_{11}, S_{22}, S_{33}, S_{44}$.

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13.Connect port 1 of magic tee to slotted line, port 2 to detector mount and ports 3 & 4 to matched termination and calculate p-p output voltage in CRO, which is $\boldsymbol{S_{12}}$.

14.Repeat the same for all cases and find various scattering coefficients of magic tee.NOTE: In all the cases, while taking values, adjust the repeller voltage and slottedsection to get maximum p-p output in CRO

OBSERVATIONS:

Conditions to be satisfied for magic Tee:

1. $\boldsymbol{S_{11} = S_{22} = S_{33} = S_{44}}$ --- All ports are matched to the junction
2. $\boldsymbol{S_{34} = S_{43} = 0}$ --- Isolated Ports
3. $\boldsymbol{S_{42} = -S_{41}}$ --- Property of E-Plane Tee
4. $\boldsymbol{S_{31} = S_{32}}$ --- Property of H-Plane Tee

S-Matrix of Magic tee:

$$\begin{matrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{matrix}$$

PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V**.**

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APPLICATIONS OF MAGIC TEE:

i. Used for the measurement of impedance.

ii. It is used as a duplexer.

iii. Used as a mixer.

iv. Is used in microwave discriminator, Microwave Bridge.

RESULT:

The properties of Magic Tee are studied and scattering parameters are calculated.

VIVA QUESTIONS:

1. What are the properties of magic tee?
2. What is the isolation between E and H arm?
3. What is isolation in magic tee?

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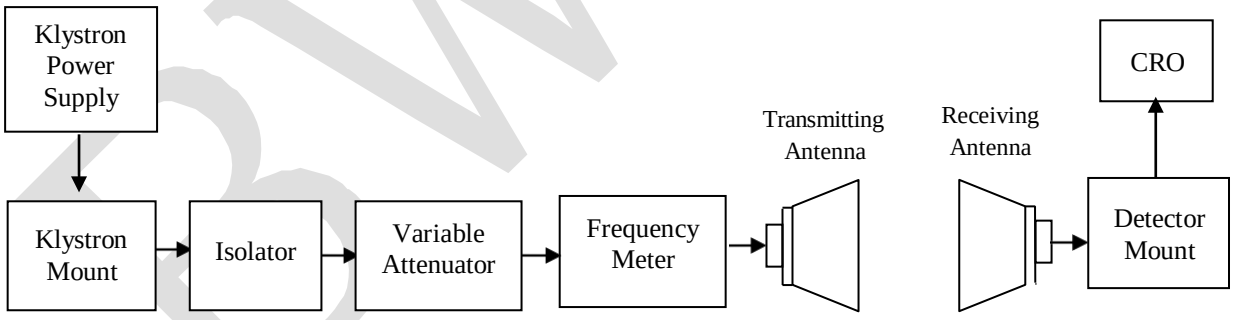
8. RADIATION PATTERN OF HORN/PARABOLIC ANTENNA

AIM: To measure the gain of horn antenna and draw the radiation pattern.

APPARATUS:

1. Reflex Klystron power supply
2. Reflex Klystron tube with mount
3. Isolator
4. Variable Attenuator
5. Frequency Meter
6. Detector Mount
7. Waveguide stands
8. Horn Antennas
9. BNC (Bayonet Neill Concelman) Cable
10. CRO

BLOCK DIAGRAM:



PROCEDURE;

1. Set the various components as per the block diagram.
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW

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Beam Voltage : Fully anti-clockwise

Repeller Voltage : Fully clockwise

Frequency Meter : Fully clockwise or anti-clockwise

AM Amplitude & Frequency : Mid Position

Attenuation : 10-15dB

3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω

   Range : 40 or 50dB

   Gain control knobs : Mid position

   SWR/dB Switch : dB position

4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Note down the corresponding frequency from frequency meter, f_0.
10. Vary the repeller voltage knob to get maximum p-p output voltage in CRO.
11. Connect the detector mount to frequency meter or slotted section and to CRO, and note the peak to peak voltage, which is transmitted power P_t.
12. Make sure the distance between transmitting and receiving horn antennas should not exceed 16cms.
13. Note down p-p output voltage in CRO, which is received power P_r.
14. Calculate wavelength $\boldsymbol{\lambda} = \frac{c}{f_0}$.
15. Calculate path difference, $\boldsymbol{S} = \frac{2D^2}{\lambda_0}$, where D is the maximum dimension or diameter of the aperture of horn antenna. D = 9.6cms.
16. Keep the transmitting and receiving antennas at line of sight i.e., $\mathbf{0}^\circ$ and note the received power P_r from CRO.
17. Note down received power P_r at different angles $\mathbf{5}^\circ, \mathbf{10}^\circ, \mathbf{15}^\circ, \mathbf{20}^\circ$ towards right and left.
18. Calculate the gain of antenna by using $\boldsymbol{G^2} = \frac{P_r}{P_t}[4\pi * \frac{}{\lambda_0}]$.
19. Draw the radiation pattern by taking angle versus received power.

20. Calculate half power beam width at 3dB point.

OBSERVATIONS:

Initial Conditions:

Beam voltage : 300V

Beam current : 17mA

Repeller voltage : - 297 V

Output voltage :

Frequency :

Power :

Practical Calculations:

Transmitted Power, P_t =

Wavelength, $\lambda_0 = \frac{c}{f_0}$ =

Path difference, $\boldsymbol{S} = \frac{2D^2}{\lambda_0}$ =

Gain of the antenna, $\boldsymbol{G^2} = \frac{\boldsymbol{P_r}}{\boldsymbol{P_t}} [\boldsymbol{4\pi} * \frac{}{\boldsymbol{\lambda_0}}]$.

Angle in Degrees	Received Power, P_r		Gain of Antenna, G	
	Left	Right	Left	Right
0°				
5°				
10°				
15°				
20°				

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Radiation Pattern:

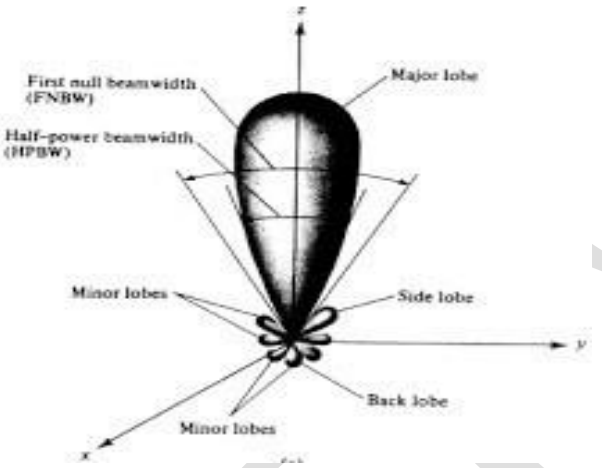

Fig: Radiation Pattern of Horn Antenna

PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1^{st} condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto **-** 270V**.**

RESULT: Gain of the horn antenna is calculated, radiation pattern is figured and beam width is measured.

VIVA QUESTIONS:

1. What is horn antenna & its applications ?
2. What is the directivity of horn antenna ?
3. How many types of horn antenna are there ?
4. What is the impedance of horn antenna ?
5. What are the characteristics of horn antenna ?

9. VERIFICATION OF WAVEGUIDE EXPRESSION

AIM: To measure guide wavelength of a rectangular waveguide

APPARATUS:

1. Reflex Klystron power supply
2. Reflex Klystron tube with mount
3. Isolator
4. Frequency meter
5. Variable Attenuator
6. Slotted section
7. Detector Mount.
8. Waveguide stands
9. BNC (Bayonet Neill Concelman) Cable
10. SWR Meter
11. CRO

BLOCK DIAGRAM:

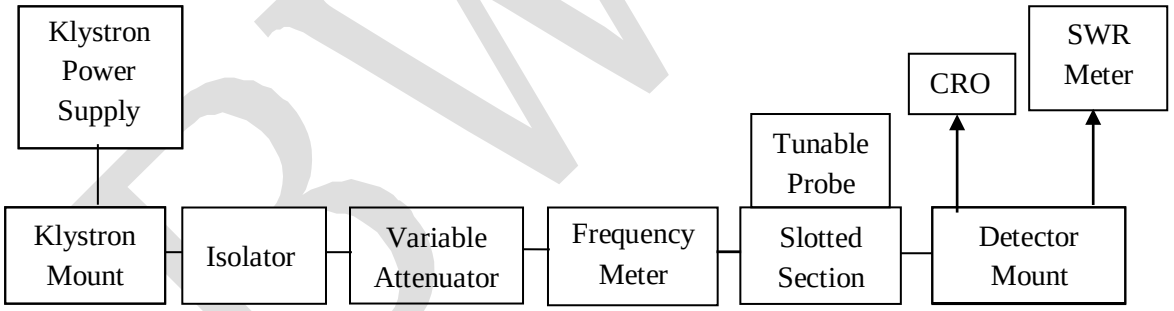

Fig. Microwave Test Bench setup to measure guide wavelength

THEORY:

Guide wavelength λ_g is defined as the distance travelled by the wave in order to undergo a phase shift of 2π radians i.e., $\lambda g = \frac{2\pi}{\beta}$. The wavelength in the waveguide is different from the wavelength in free space.

For dominant TE_{10} mode in a rectangular waveguide, the relation between guide wavelength λ_g, free space wavelength λ_0 and cut-off wavelength λ_c is given by

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2}$$

The modes in a rectangular waveguide are represented by TE_{mn} or TM_{mn}

Where,

TE = Transverse Electric

TM = Transverse Magnetic

m = no. of half wave variations in broader direction

n = no. of half wave variations in shorter direction

For TE_{10} mode, the cut-off wavelength is $\lambda_c = \frac{2a}{m}$

Where,

a = broader dimension or length of the waveguide = 2.3cms

m = 1 for TE_{10} mode

PROCEDURE:

1. Set the various components as per the block diagram.
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW
   Beam Voltage : Fully anti-clockwise
   Repeller Voltage : Fully clockwise
   Frequency Meter : Fully clockwise or anti-clockwise
   AM Amplitude & Frequency : Mid Position
   Attenuation : 10-15dB
3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω
   Range : 40 or 50dB
   Gain control knobs : Mid position
   SWR/dB Switch : dB position

4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Connect the output of the detector mount to SWR meter and note the power in dB at range.
10. Connect the output of the detector mount to CRO and note the peak to peak output voltage.
11. Find the maximum frequency of oscillator by observing the clip of waveform by rotating the frequency meter. Let the frequency be f_0.
12. Calculate free space wavelength using $\boldsymbol{\lambda_0 = \frac{c}{f_0}}$
13. Vary the repeller voltage till peak to peak voltage in CRO is maximum. Note down the repeller voltage and its corresponding p-p output voltage and frequency**.**
14. Vary the slotted section and note down the distances d_1 and d_2 between the two successive minimas or maximas.
15. Calculate guide wavelength using $\boldsymbol{\lambda_g = 2(d_2 \sim d_1)}$
16. Calculate the cut-off wavelength using $\boldsymbol{\lambda_c = 2a}$, where a=2.3cms
17. Find $\boldsymbol{\lambda_0}$ using the relation $\boldsymbol{\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$
18. Compare the value of $\boldsymbol{\lambda_0}$ in steps 12 & 17.

OBSERVATIONS:

Initial Conditions:

Beam voltage : 300V

Beam current : 17mA

Repeller voltage: -297 V

Output voltage :

Frequency :

Power :

Practical calculations:

- $\boldsymbol{\lambda_0} = c/fo$
- $\boldsymbol{d_1}$ =
- $\boldsymbol{d_2}$ =
- $\boldsymbol{\lambda_g = 2(d_2 \sim d_1)}$ or $\boldsymbol{\lambda_g = 2(d_1 \sim d_2)}$
- $\boldsymbol{\lambda_c = 2a}$
- $\boldsymbol{\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$

PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto - 270V.

RESULT: The guide wavelength of a rectangular waveguide is calculated.

VIVA QUESTIONS:

1. Explain the difference between the guide wavelength and the free-space wavelength in a rectangular Waveguide
2. Discuss the applications of knowing the guide wavelength
3. How is the guide wavelength defined in the context of a rectangular waveguide
4. What factors affect the determination of the guide wavelength in a rectangular waveguide

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10. CHARACTERISTICS OF LED

AIM: To obtain the V-I characteristics of Light Emitting Diode (LED).

APPARATUS:

1. LED
2. Regulated Power Supply (RPS) (0-30V)
3. Resistor- 1KΩ
4. Ammeter (0-200mA), Voltmeter (0-20V)
5. Bread board and Connecting wires

THEORY:

A light-emitting diode is a semiconductor light source that emits light when current flows through it. The robble of the optical transmitter is to convert an electrical input signal into the corresponding optical signal and then launch it into the optical fiber serving as a communication channel. The major component of optical transmitters is an optical source. Fiber-optic communication systems often use semiconductor optical sources such as light-emitting diodes (LEDs) and semiconductor lasers because of several advantages offered by them. Some of these advantages are compact size, high efficiency, good reliability, small emissive area compatible with fiber core dimensions, and possibility of direct modulation at relatively high frequencies. A forward-biased p–n junction emits light through spontaneous emission, a phenomenon referred to as electroluminescence. In its simplest form, an LED is a forward biased p–n homo-junction. Electroluminescence is a phenomenon in which a material emits light in response to the passage of an electric current.

PROCEDURE:

1. Make connections as per the circuit diagram.
2. Switch on the power supply and increase the input voltage (supply voltage) in steps.
3. Note down the corresponding current flowing through the diode and voltage across the diode for every step of the input voltage. LED emits light when current flows through it.
4. Tabulate the readings of voltage and current. Draw a graph between voltage and current.

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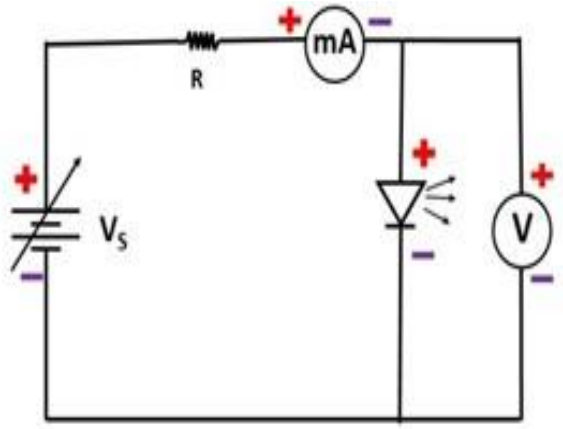
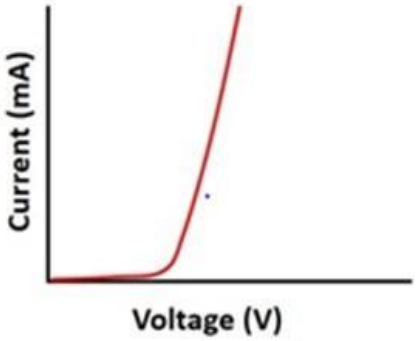
CIRCUIT DIAGRAM:



MODEL WAVEFORM:



OBSERVATIONS:

S.No	Applied Voltage (V)	Voltage (V)	Current (mA)

PRECAUTIONS:

1. Make all the connections correctly
2. Avoid loose connections

RESULT: The V-I characteristics of Light Emitting Diode are obtained.

VIVA QUESTIONS:

1. What is the basic principle of operation of an LED (Light Emitting Diode)

2. Explain the key characteristics that define the performance of an LED

11. CHARACTERISTICS OF LASER DIODE

AIM: To determine the AC characteristics of an intensity modulation for LASER and Fiber optic system.

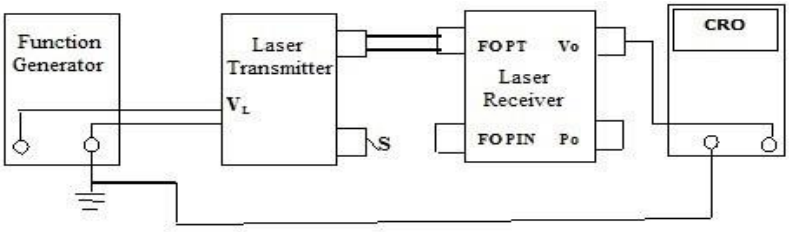
APPARATUS REQUIRED:

1. Transmitter Module
2. Receiver Module
3. Power Supply
4. Optical Fiber cable – 1meter
5. CRO -30MHz
6. CRO Probes
7. Connecting wires

THEORY:

The intensity modulation / demodulation system is realized using PHY- 159 transmitter module and the PHY -158 receiver unit linked through an optical fiber. We use PMMA FIBER cable. The laser carrier power P_o is set by adjusting the 'set I_f' knob in the middle. Laser selection of optimum carrier power is essential to minimize distortion. Limiting the depth of modulation also ensures distortion free transmission. Bandwidth of the system in the present case is limited by the photo detector. We should operate in the APC mode to obtain optical output proportional to the modulating signal V_{in}. We will however operate in the APC mode too. An ideal IM transmission system will have the relationship $V_{out} = G. V_{in}$ where G is a factor depends on the LCD conversion efficiency

EXPERIMENTAL SET-UP:



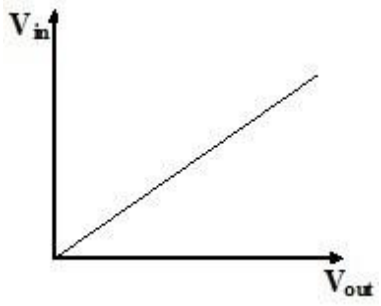
PROCEDURE:

1. Connect the fiber optic cable, input signal and output as shown in the experimental set-up.
2. Set the signal frequency and amplitude to 2 KHz(mid band frequency)and 100mV respectively.
3. Adjust the **IF** Knob to get output of 100mV(i.e., 0dB gain)
4. Slowly vary the input amplitude to 1000mV insteps of 100mV And note down the corresponding output amplitude
5. Tabulate and plot a graph V_{out} Vs V_{in}.

TABULAR COLUMN:

V_{in} (V)	**V_{out} (V)**	**Gain= V_{out}/V_{in}**

MODEL GRAPH:



PRECAUTIONS:

1. Make all the connections correctly
2. Avoid loose connections

RESULT:

VIVA QUESTIONS:

1. Explain the principle of operation of a laser diode. How does it differ from a light-emitting diode (LED)
2. What are the key characteristics that define the performance of a laser diode?
3. Describe the phenomenon of coherence in laser diodes.
4. Compare the beam characteristics of a laser diode with other light sources

12. MEASUREMENT OF DATA RATE FOR ANALOG OPTICAL LINK

AIM: To set up an 850nm fiber optic analog link. The linear relationship between the input and output is observed. The effect of gain control on the received signal is also observed, and finally the bandwidth of the link is measured.

APPARATUS:

1. OFT Trainer Kit
2. CRO and CRO probes
3. Function Generator
4. 1mm diameter 1m fiber

THEORY:

This experiment is familiarizing the user with OFT. An analog fiber optic link is to be setup in this experiment. The preparation of the optical fiber for coupling light into it and the coupling of the fiber to the LED and detector are described in appendix a. the LED used is an 850nm LED. The fiber is a multimedia fiber with a core diameter of 1000µm. the detector is a simple PIN detector.

The LED optical power output is directly proportional to the current driving the LED. Similarly, for the pin diode the current is proportional to the amount of light falling on the detector. Thus even though the LED and the pin diode are non-linear devices, the current in the pin diode is directly proportional to the driving current of LED. This makes the optical communication system a linear system.

PROCEDURE:

Setup:

1. The interfaces used in the experiment and the block diagram of the subsystems used in this experiment is shown in fig. The 1m and 3m optical fiber provided with OFT are used. Ensure that the ends of the fiber are clean.

Setting up the analog link :

2. Set the switch SW8 to the ANALOG position. Switch the power ON ,the power ON switch is located at the top right hand corner.
3. Feed a 1V p-p (peak-to-peak) sinusoidal signal at 1KHz (with zero d.c), from a function

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generator, to the ANALOG IN post P11 using the following procedure.

i) Connect a BNC-BNC cable from the function generator to the BNC socket I/03.

ii) Connect the signal post P11 using a patch cord.

With this, the signal from the function generator is fed through to the ANALOG IN signal post P11 from the I/03 BNC Socket.

Connect one end of the 1m fiber to the LED source LED1 in the optical Tx1 block. Observe the light output (red tinge) at the other end of the fiber.

4. Feed a 5V p-p rectangular signal at 0.5 Hz at P11.observe the signal on the oscilloscope. Now observe the intensity (brightness) of the light output at the other end of the fiber.

5. Connect the other end of the fiber to the detector PD1in the optical Rx1 block.

Input-Output Relationship Of Link:

6. Feed a sinusoidal wave of 1 KHz, 1V p-p [with zero dc] from the function generator to P11.the PIN detector output signal is available at P32 in the optical Rx1 block. Vary the input signal level driving the LED and observe the received signal at the PIN detector. Plot the received signal peak-peak amplitude with respect to the input signal peak-peak amplitude. What is the relationship?

7. Repeat step 6 using the 3m fiber instead of the 1m fiber. Plot the received signal amplitude at the PIN detector as a function of input signal amplitude**.**

GAIN CONTROL:

8. The PIN detector signal at P32 is amplified, with amplifier gain controlled by the GAIN potentiometer as shown in fig.With a 3V p-p input signal atP11, observe P31 as the gain potentiometer is varied. Note that the signal at P31 gets clipped below 0V and above 3.5V as shown in fig.

BAND WIDTH OF THE FIBER LINK:

9. Measure the band width of the link as follows:

Apply a 2V p-p sinusoidal signal (with zero d.c) at P11 and observe the output at P31.Adjust gain such that no clipping takes place. Vary the frequency of the input signal from 100Hz to 5MHz and measure the amplitude of the received signal. Plot the received signal amplitude as a function of frequency (using a logarithmic scale for frequency).Note the frequency range for which the response is flat.

10. Apply a square wave or triangular wave with 1V p-p and zero dc at the input of the transmitter [at P_{11}].Vary the frequency and observe the out put at P31.note the frequency at which the

received signal starts getting distorted. Explain this using the band width obtained in the previous step.

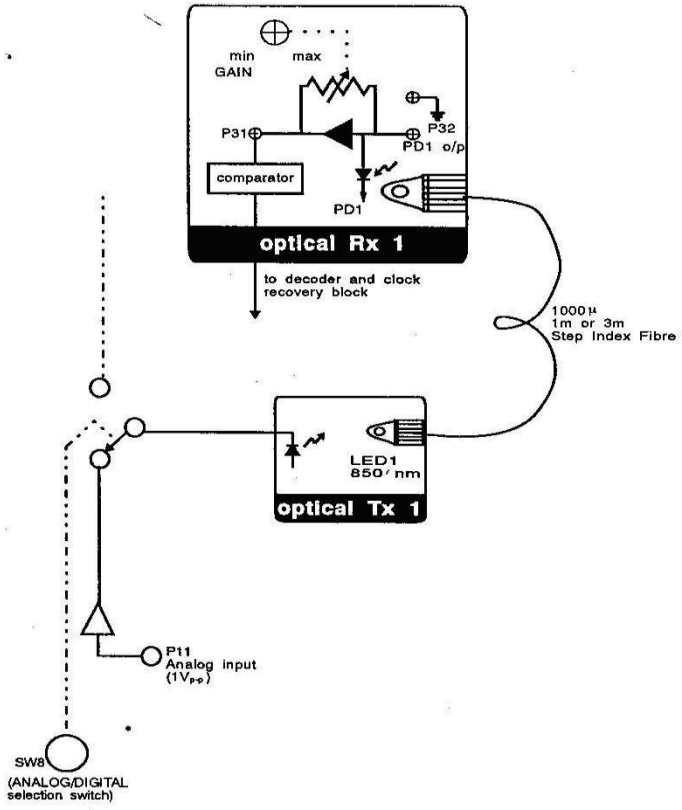

Fig: Block Diagram

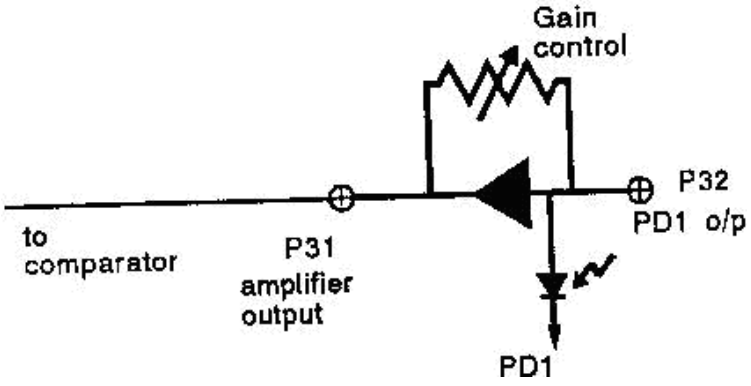

Fig: Gain control

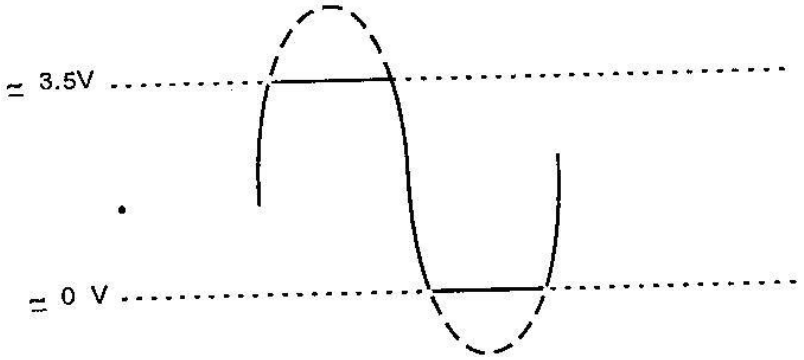

Fig: Signal at P_{31}

RESULT: The 650nm and 850nm analog links are set up and the maximum bit rates supportable on these links are measured.

VIVA QUESTIONS:

1. How is the data rate defined and measured in an analog optical link?
2. Describe the factors that affect the maximum achievable data rate in an analog optical link.
3. What are the different methods or instruments used to measure the data rate of an analog optical link?
4. Explain the concept of signal-to-noise ratio (SNR) in the context of data rate measurement for analog optical links. How does SNR affect the achievable data rate?
5. Discuss the challenges and techniques involved in achieving high data rates in analog optical links for applications such as video transmission or broadband communication.

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13. MEASUREMENT OF DATA RATE FOR DIGITAL OPTICAL LINK

AIM: Study of a 650nm fiber optic digital link**.**

APPARATUS:

1. ST2502 trainer with power supply cords
2. Optical Fiber cable.
3. Cathode ray oscilloscope with necessary connecting probe.

THEORY:

Fiber optic links can be used for transmission of digital as well as analog signals. Basically a fiber optic link contains three main elements a transmitter, an optical fiber and a receiver. The transmitter module takes the input signal in electrical form and then transforms it into optical energy containing the same information. The optical fiber is the medium, which takes the energy to the receiver.At the receiver, light is converted back into electrical form with the same pattern as fed to the transmitter.

Transmitter:

Fiber optic transmitters are composed of a buffer, driver and optical source. The buffer provides both an electrical connection and isolation between the transmitter and the electrical system the data. The driver provides electrical power to the optical source. Finally, the optical source converts the electrical current to the light energy with the same pattern. The optical source used is LED. The simple driver circuit is shown below.

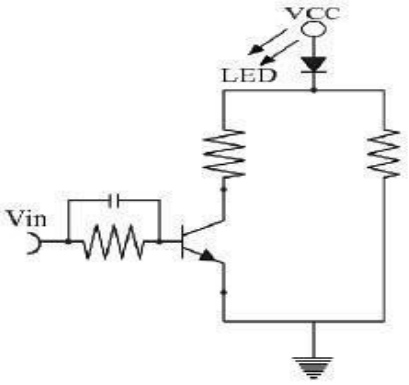

Fig.3.1 A simple drive circuit for binary digital transmission consisting a common emitter saturating switch.

The transmitter section comprises of Function Generator which generates input signals that are going to be used as information to transmit through optical fiber.

The Fiber Optic Link:
Emitter and Detector circuit on board form the fiber optic link. This section provides the light source for the optic fiber and the light detector at the far end of the fiber optic links. The optic fiber plugs into the connectors provided in this part of the board. Two separate links are provided.

The Receiver:
The comparator circuit and AC amplifier circuit form receiver on the board.

Block Diagram:

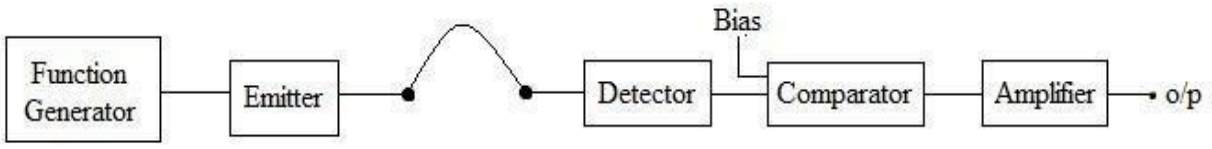

Fig.3.2 Digital Fiber Optic Link

PROCEDURE:

1. Connect the power supply to the board.
2. Ensure that all switched faults are off.
3. Make the following connections.
    - Connect the Function generator1KHZ square wave output to emitter's input.
    - Connect the fiber optic cable between emitter output and detector's input
    - Detector's output to comparator's input.
    - Comparator's output to AC amplifiers input.
    - On the board, switch emitters driver to digital mode.
4. Switch ON the power.
5. Monitor both the inputs to comparator. Slowly adjust the comparators bias preset, until DC level on the input lies midway between the high and low level of the signal on the positive input.
6. Observe the input to emitter with the output from AC amplifier and note that the two

signals are same.

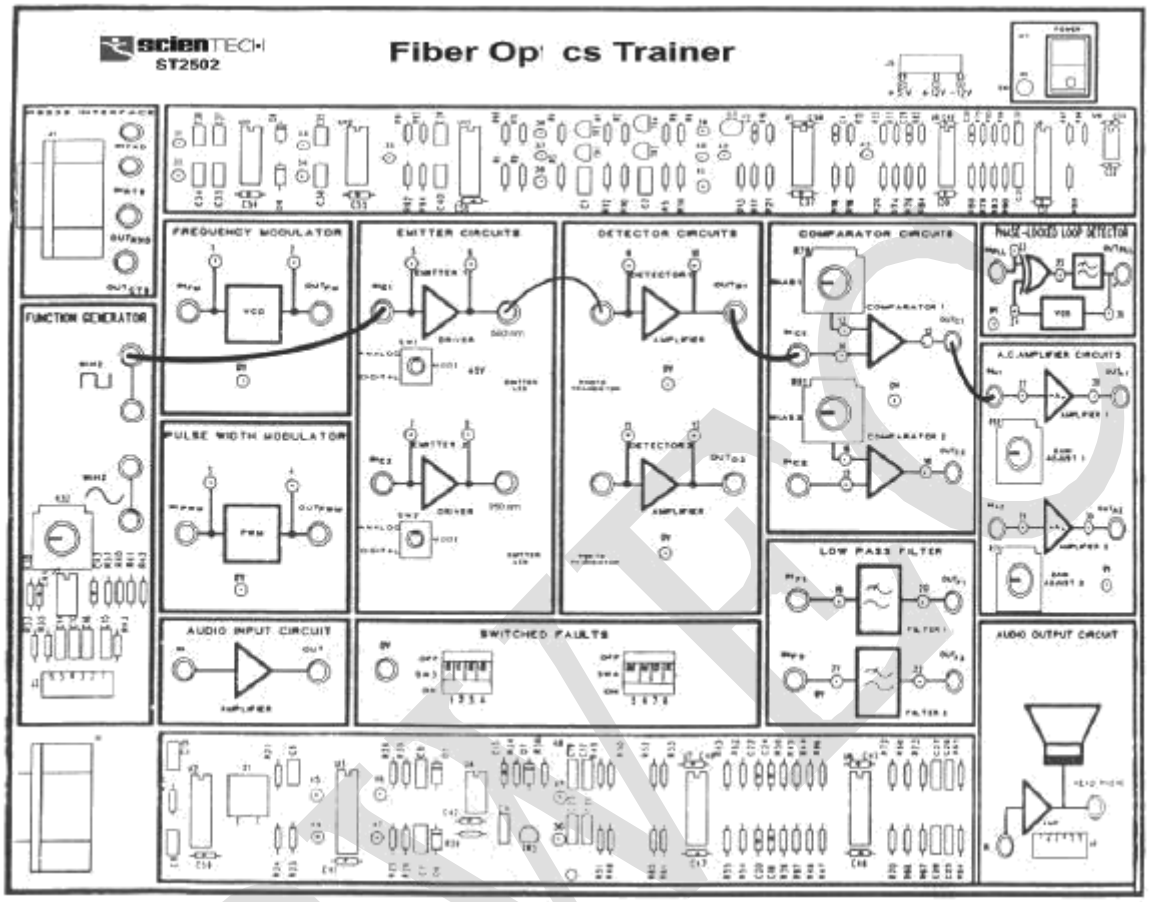

Fig.3.3 Connections on Trainer Kit

OBSERVATIONS:

Input Voltage = 0.16V

Comparator output = 0.05V

Amplifier output = 1V

RESULT:

The 650nm fiber optic Digital link has been established.

VIVA QUESTIONS:

1. What parameters define the data rate in a digital optical link, and how is it calculated or specified?

2. Describe the methods or instruments commonly used to measure the data rate of a digital optical link

3. Explain the significance of receiver sensitivity and link budget in determining the maximum achievable data rate in a digital optical communication system

14. MEASUREMENT OF NUMERICAL APERTURE(NA)

AIM: To estimate the Numerical Aperture of the 1mm diameter plastic fiber at 650 nm.

APPARATUS: 1.OFT Trainer Kit
2. Numerical Aperture Measurement Unit
3. 1mm diameter 1m fiber

THEORY:

Numerical aperture of the fiber is a measure of the acceptance angle of light in the fiber. Light which is launched at angles greater than this maximum acceptable angle does not get coupled to propagating modes in the fiber, and therefore does not reach the receiver at other end of the fiber. The NA is useful in the computation of optical power coupled from an optical source to the fiber, from fiber to a photo detector, and between two fibers.

PROCEDURE:
SETUP:

1. The interfaces used in the experiment and identify them on OFT kit with the diagram. The block diagram is shown in fig. ensure that the shorting plugs of Tx data shorting link S4, coded data shorting link S6, and Tx clock shorting link S5 in the Manchester coder block are in position. Also ensure that the shorting plug of clock select jumper JP1 is across the posts B&A1. A TTL signal from the multiplexer should now be driving LED2 in optical Tx2 block. This experiment is best performed in a less illuminated room.
2. Ensure that the cut planes of the 1m plastic fiber are perpendicular to the axis of the fiber. If required, prepare 1m of plastic fiber as per the instructions in appendix A.
3. Insert one end of fiber in to NA measurement unit as shown in figure. adjust the fiber such that its tip is 10mm from the screen.
4. Gently tighten the screw to hold the fiber firmly in place.
5. Connect the other end of the fiber to LED2 through the simplex connector. The fiber will project a circular patch of red light on to the screen. Now measure the diameter of the circular patch of red light in two perpendicular directions (BC and DE in Fig). the mean radius of the circular patch is given by

$$X = (DE + BC)/4$$

6. Carefully measure the distance d between the tip of the fiber and the illuminated screen (OA in Fig). The Numerical Aperture of the fiber is given by

$$NA = \sin(\Theta) = X/(\sqrt{(d^2+X^2)})$$

7. Repeat steps 3 to 6 for different values of d. compute the average value of Numerical aperture.

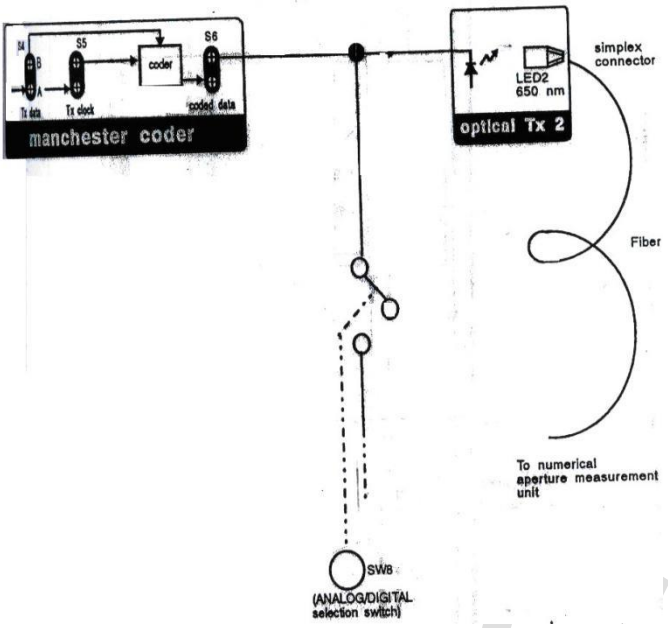

Fig: Block diagram

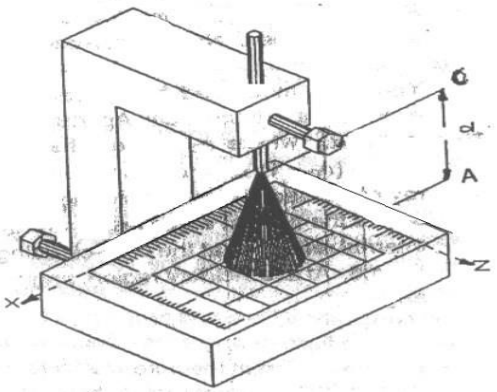

Fig: Numerical Aperture measurement unit

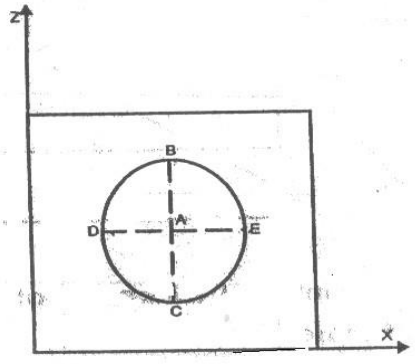

Fig: Circular path diameter

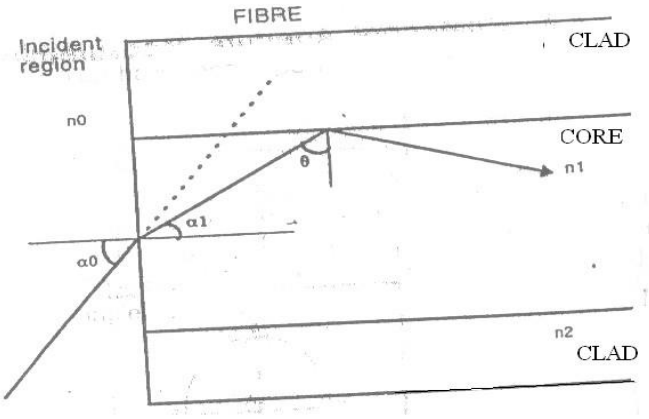

Fig: Total internal reflection of core cladding boundary of fiber

TABULAR FORM:

S.NO	BC	DE	X	d	NA

RESULT:

The Numerical Aperture of the 1mm diameter plastic fiber at 650 nm is measured.

VIVA QUESTIONS:

1. Define Numerical Aperture
2. Why numerical aperture is important in optical systems?
3. How is numerical aperture defined mathematically?

15. MEASUREMENT OF LOSSES IN ANALOG OPTICAL LINK

AIM : To measure the propagation loss, bending loss and connector loss in the optical fiber.

EQUIPMENTS REQUIRED :

1. Optical Trainer Kit (FCL-01 & 02)
2. 1 , 3 Meter & Connectorized Fiber Cable
3. Patch Chords
4. Power Supply
5. CRO

THEORY :

Optical fibers are available in different variety of materials. These materials are usually selected by taking into account their absorption characteristics for different wavelengths of light. In case of optical fiber, since the signal is transmitted in the form of light, which is completely different in nature as that of electrons, one has to consider the interaction of matter with the radiation to study the losses in fiber. Losses are introduced in fiber due to various reasons. As light propagates from one end of fiber to another end, part of it is absorbed in the material exhibiting absorption loss. Also part of the light is reflected back or in some other direction from the impurity particles present in the material contributing to the loss of the signal at the other and of the fiber. In general terms, it is known as propagation loss. Plastic fibers have higher loss of the order of 180 dB/Km. whenever the condition for angle of incidence of the incident light is violated, the losses are introduced due to refraction of light. This occurs when fiber is subjected to bending. Lower the radius of curvature more is the loss. Other losses are due to the coupling of fiber at LED & photo detector ends.

TABULATION :

PROPAGATION LOSS

P2 (1m fiber)	P1 (3m fiber)	Power = 10log(p1/p2) dB

CONNECTOR LOSS

P2 (1m fiber)	P1 (Connectorized fibers)	Loss = p2 – p1

PROCEDURE :

A) MEASUREMENT OF PROPAGATION LOSS

1. Make connections as shown in fig. Connect the power supply cables with proper polarity to FCL-01 & 02 kits. While connecting this, ensure that the power supply is OFF.
2. Keep the jumpers JP1, JP2, JP3 & JP4 on FCL-01 as shown in fig.
3. Keep the jumpers JP1 & JP2 on FCL-02 as shown in fig.
4. Keep switch S2 in VI position on FCL-01.
5. Switch on the power supply.
6. Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 1 meter fiber into the cap. Now tighten the cap by screwing it back.
7. Now rotate the optical power control pot P3 in FCL-01 in anticlockwise direction. This ensures minimum current flow through LED.
8. Slightly unscrew the cap of Photo Diode SFH250V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten cap by screwing it back.
9. Keep switch SW1 to SIGNAL STRENGTH position in FCL-02
10. Connect the output of Photo Diode detector post OUT to post IN of Signal Strength Indicator block.

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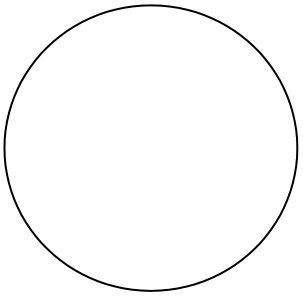
11. Observe the signal strength by adjusting the TRANSMITTER LEVEL using Intensity control pot P3.
12. Measure the light output using the SIGNAL STRENGTH section of the kit. The loss will be larger for a longer piece of fiber. In order to measure the loss in the fiber a short piece of fiber is used as a reference from the LIGHT TRANSMITTER

TABULATION :

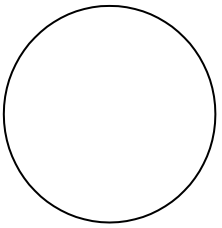
Bending loss

Bending (size)	Signal Strength
No bend	
Bend @1	
Bend@2	
bend@3	

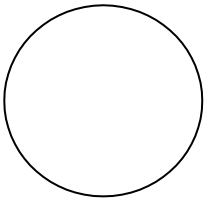
BEND@1



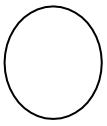
BEND@2



BEND@3



BEND@4



1. Now remove the 1 meter and insert the 3 meter fiber.
2. Loss in optical fiber systems is usually measured in dB. Loss of fiber itself is measured in dB per meter.
3. Subtract the length of the short fiber from the length of the long fiber to get the difference in the fiber lengths (3m – 1m). The extra length of two meters is what created the extra loss measured. Then take the signal strength reading obtained for the loss of the long fiber and convert it to dB using the equation.

Power = 10 log (P2 / P1) dB.
P2 – Reference reading by 1 meter fiber.
P1 – Reference obtained after replacing 3 meter fiber.

B) MEASUREMENT OF BENDING LOSS

1. Keep the connections with 1 meter fiber as per the above procedure.
2. Adjust the transmitter power so that the SIGNAL STRENGTH reading is 8. Now take the portion of the fiber and loop it to match the bends as shown in fig. As you match each bends write down the reading from signal strength indicator. Don't bend the fiber too tightly or it may not come back to shape.
3. Measure the loss for a number of different bends.

C) MEASUREMENT OF CONNECTOR LOSS

1. Keep the connections with 1 meter fiber as per the above procedure.
2. Adjust the transmitter power so that the SIGNAL STRENGTH reading is 8.
3. Remove the 1 meter fiber and insert 0.5 meter connectorized fibers through connecting sleeve. What reading you get on the signal strength? Now take your loss from this measurement, say 7dB and subtract it from 8dB. Your connector loss is then 8dB – 7dB = 1dB this is actual connector loss.

RESULT :

Thus the losses in optical fiber are measured.

VIVA QUESTIONS:

1. What are the main types of losses encountered in analog optical links?

2. Describe the methods used to measure fiber attenuation in an analog optical link

3. How are connector losses measured in analog optical links?

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To Study Microwave Components

AIM: To study the microwave components in detail.

RECTANGULAR WAVEGUIDE:

Waveguide is defined as a hollow metallic tube with rectangular or circular cross section which is used to guide the electromagnetic waves to pass through it. Waveguides are used at frequencies >3GHz.

Fig 1: Rectangular Waveguide

Specifications:

Band	X
Frequency Range (GHz)	8.2 – 12.4
Waveguide	WR 90

VARIABLE ATTENUATOR(NV206):

Attenuators are required to adjust power or to attenuate the power flowing in a waveguide. There are two types of attenuators: fixed and variable.
Fixed attenuators available in various range like 3db, 6db,10db etc. These attenuatorsare calibrated at center frequency of respective frequency band.
Variable attenuators can adjust power at different levels

Fig 2(a) Variable attenuator

Fig 2(b) Fixed attenuator

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Specifications:

Band	X
Frequency Range(GHZ)	8.2-12.4
Wave Guide	WR 90
Flange	UG-39/U
VSWR Max	1.25 at 10.5GHz
Average Power	2 Watts
Return Loss	-19.23 at 10.5GHz

TUNABLE PROBE(NV208):

Tunable probes are very useful devices to measure the SWR and impedances. Tunable probe consist of a crystal detector and a small wire antenna in coaxial housing. Its depth of penetration into the slotted section is variable. The tip of the tunable probe pickup the RF power from the line and this power is rectified by crystal detector which is then fed to the VSWR meter or indicating instrument like CRO.

Fig 3: Tunable Probe

Specifications:

Band	X
Frequency Range(GHZ)	8.2-12.4
Detector	IN23
Output Connector	BNC(F)
Type	Tunable

SLOTTED SECTION(NV207):

Slotted section is used to measure various parameters in microwave, for eg, to determine VSWR, phase and impedances .These consists of a slot in a center of wave guide in which we can connect a probe and probe can be moved . In slotted section, the position of probe can be measured by its Vernier scale. The distance travelled by the probe carriage is more than three times of half wavelength.

Fig 4:Slotted Section

Specifications:

Band	X
Frequency Range(GHZ)	8.2-12.4
Waveguide	WR -90
Flange	UG-39/U
Residual VSWR	1.01
Slope(dB)	(0-2dB)

DIRECT READING FREQUENCY METER(NV205):

Direct reading frequency meters are used to measure the microwave frequency accurately. The long scale length and numbered calibration marks provide high resolution, which is particularly useful when measuring frequency difference of small frequency changes.

Fig 5: Direct Reading Frequency Meter

Specifications:

Band	X
Frequency Range(GHZ)	8.2-12.4
Wave Guide	WR-90
Flange	UG-39/U
Calibration Accuracy	2%
Calibration Increment	5MHz
Max VSWR	1.28 at 10.5 GHz
Return Loss	-18.2 at 10.5 GHz

KLYSTRON MOUNT(NV203):

Klystron mounts are used to transmit microwave power from reflex klystron tube to rectangular wave guide. klystron mounts are designed by a selection of waveguide, one end of the wave guide is filled with a movable short plunger. A small hole on broad wall of the waveguide is provided through which coupling pin of reflex klystron tube enters in to the wave guide. By moving plunger (matching the impedance of klystron tube and wave guide), maximum output can be achieved.

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Fig 6: Klystron Mount

Specifications:

Band	X
Frequency(GHz)	8.2-12.4
Wave Guide	WR-90
Flange	UG-39/U

GUNN OSCILLATOR (NV201):

Gunn Oscillators are used to generate the micro wave signal. These consists of wave guide cavity hanged on one end and micrometer driven plunger fitted on the other end. A Gunn diode is mounted inside the wave guide with BNC(F) connector for DC bias. Micrometer is used to tune the output frequency of Gunn oscillator

Fig 7: Gunn Oscillator

Specifications:

Band	X
Frequency range(GHz)	8.2-12.4
Wave guide	WR 90
Flange	UG-39/U
Bias voltage max	10V
Normal power output	10mW
Frequency adjustment	By micrometer

PIN MODULATOR(NV202):

Pin diode modulators are used to provide amplitude or pulse modulation in wide range of microwave applications. These modulators uses pin diode which is mounted across the wave guide line with RF isolated DC bias voltage.

Fig 8: PIN Modulator

Specifications:

Band	X
Frequency range(GHz)	8.2-12.4
Wave guide	WR-90
Flange	UG-39/U
Bias voltage	0-12V_{P-P}
Output connector	TNC(F)

SLIDE SCREW TUNER(NV220):

Slide screw tuners are used for matching purposes by changing the penetration and position of a screw in the slot provided in the centre of wave guide. SS tuners consist of a section of wave guide flanged on both ends and a thin slot is provided in the broad wall of the

wave guide. A probe carriage carrying the screw is provided over a slot. A VSWR up to 20 can be tuned to a value less than 1.02 at certain frequency.

Fig 9: SS Tuner

Specifications:

Band	X
Frequency(GHz)	8.2-12.4
Wave guide	WR-90
Flange	UG-39/U
Max VSWR	20 : 1.02

WAVEGUIDE DETECTOR MOUNT(NV209):

A tunable detector mount is used for detecting microwave power through a suitable detector. It consists of a crystal detector mounted in a section of a waveguide and shorting plunger for matching purpose. The output from the crystal detector is fed to an indicating instrument like CRO or SWR meter.

Fig 10: Wave guide detector mount

Specifications:

Band	X
Frequency range(GHz)	8.2-12.4
Waveguide	WR-90
Flange	UG-39/U
Detector	IN21
Output equivalent	BNC(F)

MATCHED TERMINATION(NV212):

Matched terminations are used to terminate the waveguide transmission line operating at low average power. The loads are carefully designed to absorb all the applied power and VSWR of matched termination is low. These are used in the measurement of reflection coefficient and where the matched load is required.

Fig 11: Matched Termination

Specifications:

Band	X
Frequency Range(GHZ)	8-2 - 12-4
Waveguide	WR-90
Flange	UG-39/U
VSWR	1.03 at 10.5 GHz
Return loss	-33dB at 10.5 GHz
Average power	2W
Type	Fixed

MOVABLE SHORT (NV210)

Movable shorts are used to obtain a phase reference in the calibration of various experimental setups. These are used to vary the effective plane of reflection and therefore the phase of reflected wave. Movable shorts are used to measure the impedance of a device.

Fig 12: Movable short

Specifications:

Band	X
Frequency range(GHZ)	8.2-12.4
Waveguide	WG-90
Flange	UG-39/U
Reflection coefficient	0.98

2. Isolator (NV204)

A ferrite isolator which uses the property of faraday rotation is a two port device which provides unattenuated transmission in forward direction i.e is from port 1 to port 2 and very high attenuation in reverse direction i.e from port 2 to port 1.

Fig 13: Isolator

Specifications:

Band	X
Frequency range(GHZ)	8.2-12.4
Wave guide	WR-90
Flange	UG-30/U
Max VSWR	1.15
Min. Insertion loss	0.46 dB
Return loss	22.4dB
Min Isolation	20 dB

3. T-Circulator(NV 230)/Y Circulator(NV 2311)

A ferrite circulator, which uses the property of faraday rotation is a 3-port matched device. It has the peculiar property of coupling power to the adjacent in port clockwise direction and no transmission in anti-clock wise direction.

Fig 14(a): T-Circulator

Fig 14(b): Y Circulator

Specifications:

Band	X
Frequency range(GHZ)	8.2-12.4
Wave guide	WG-90
Flange	UG-39/U
Max VSWR	1.15
Min Insertion loss	0.46dB
Min Isolation	20dB
Return loss	22.4dB

4. E-Plane Tee (NV 221):

This is a series type T-junction consists of 3 sections of waveguide joined together in order to divide or compare power levels. The power entering into E-arm is divided equally into the other two ports with same magnitude but opposite in phase.

Fig 15: E-Plane Tee

Specifications:

Band	X
Frequency Range(GHz)	8.2-12.4
Wave guide	WR-90
Flange	UG-39/U
Max-length	200mm
Plunger Movement	65mm

5. H-plane Tee (NV222):

This is a shunt type T-junction consists of waveguides joined together for power combine or power dividing purpose. Like E-plane Tee, the power fed through H-arm is divided equally into other two ports with same magnitude and same phase.

Fig 16: H-Plane Tee

Specifications:

Band	X
Frequency Range(GHz)	8.2-12.4
Waveguide	WG-90
Flange	UG-39/U

6. Magic Tee (NV248):

Magic Tee is a 4 port hybrid T-junction combines the power dividing properties of E-plane and H-plane Tee. The advantage of magic tee is it is completely matched at all its ports.

Fig 17: Magic Tee

Specifications:

Band	X
Frequency Range(GHz)	8.2-12.4
Waveguide	WG-90
Flange	UG-39/U

7. Multihole Directional Coupler (NV226, NV253, NV228):

Directional coupler is a 4 port microwave waveguide junction consisting of primary waveguide and secondary waveguide (or) auxiliary waveguide. Directional couplers are designed to measure incident and reflected powers and also provide a signal path to a receiver. Directional coupler are available in 3, 6, 10, 20, 40 dB coupling.

Fig 18: Directional Coupler

Specifications:

Band	X
Frequency Range (GHz)	8.2-12.4
Wave guide	WG-90
Flange	UG-39/U
Max VSWR	1.06 at 10.5 GHz
Return loss	-31dB at 10.5 GHz
Coupling(dB)	10.1± 0.6
Directivity(min)	46.0dB (3%)

8. Waveguide Antennas (NV239-247):

There are several types of microwave antennas like standard gain, pyramidal horn, dielectric antenna, parabolic dish antenna etc. These are used to radiate microwave energy in the air and to receive the energy from the air.

Fig 19(a): Pyramidal Horn

Fig 19(b): Sectoral Horn

Fig 19(c): Parabolic Dish

Specifications:

Band	X
Frequency range(GHz)	8.2-12.4
Wave guide	WG-90
Flange	UG-39/U
Antenna Type	Gain
1. Pyramidal	16
2. Pickup	10
3. E-plane Sectoral	15
4. H-plane Sectoral	15
5. Parabolic dish	-
6. Standard gain	-

9. Waveguide Twist (NV216):

Waveguide twist is used to change the plane of polarization of a waveguide transmission line. Twist is made from a section of waveguide which has been precisely twisted. 90° twist is a standard available twist.

Fig 20: Waveguide Twist

Specifications:

Band	X
Frequency range(GHz)	8.2-12.4
Wave guide	WR-90
Flange	UG-39/U
VSWR	1.09 at 10.5 GHz
Return loss	-26.9dB at 10.5 GHz

10. Phase Shifter (NV238):

Phase shifters consist of dielectric slab or vane specially shaped to minimize reflection effect. Phase shifters are used to change effective electrical length of transmission line without changing its physical length. They are particularly useful in microwave bridge circuit where the phase and amplitude must be adjusted independently.

Fig 21: Waveguide Twist

Specifications:

Band	X
Frequency range(GHz)	8.2-12.4
Wave guide	WG-90
Flange	UG-39/U
VSWR	1.15 at 10.5 GHz
Return loss	-23.1db at 10.5 GHz
Calibration accuracy	±2.5°

RESULT

Thus all the microwave components are studied in detail.

TO DETERMINE ISOLATIONS, COUPLING COEFFICIENTS AND INPUT VSWR'S FOR E AND H PLANE WAVEGUIDE TEE AND MAGIC TEE JUNCTIONS

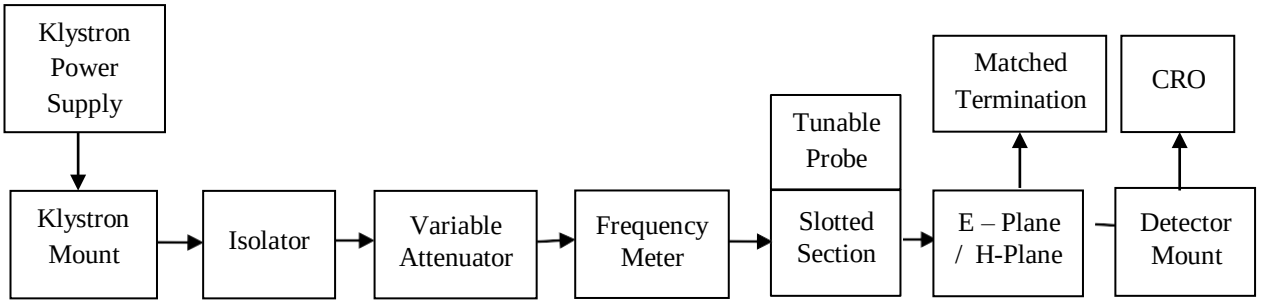
AIM: To measure isolation, coupling coefficient and input VSWR for E – Plane, H – Plane and Magic Tee.

APPARATUS:

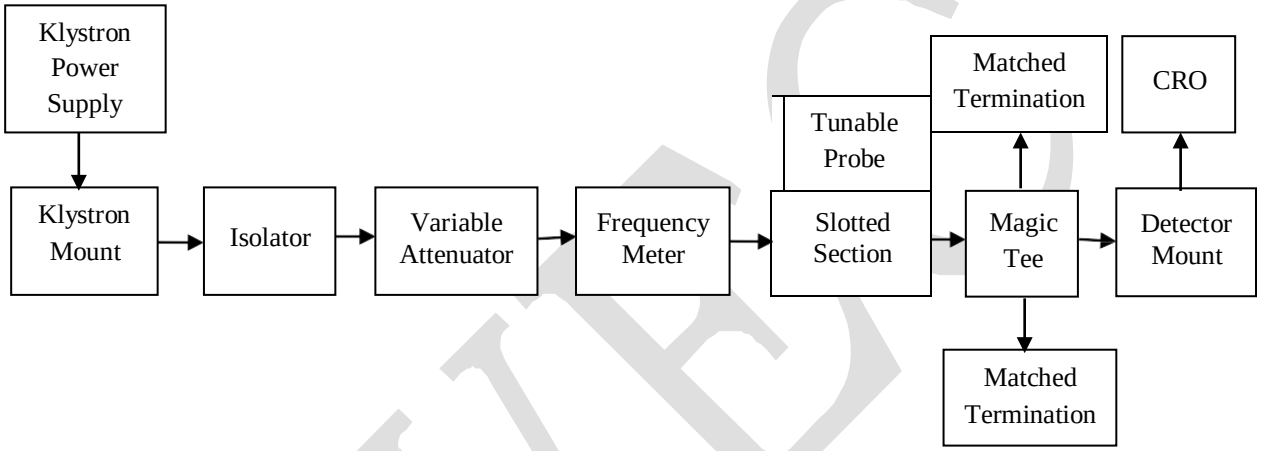
1. Klystron Power Supply
2. Klystron tube with mount
3. Isolator
4. Frequency Meter
5. Variable Attenuator
6. Slotted line
7. E Plane Tee
8. H Plane Tee
9. Magic Tee
10. Waveguide Stand
11. Matched Termination
12. Detector Mount
13. CRO
14. BNC Cables
15. Cooling fans

BLOCK DIAGRAM:

Set up 1: E – Plane / H - Plane



Set up 2: Magic Tee



THEORY:

A microwave junction is an interconnection of two or more microwave components. These are used to split all or part of microwave energy into particular directions. Microwave junction is a waveguide or coaxial junction with three or four independent ports.

An E-Plane Tee is a 3 port waveguide tee in which the axis of its side arm is parallel to the E-field of the main waveguide. E-Plane Tee is formed by cutting the rectangular slot along the broader dimension of the long waveguide and a side arm is attached as shown in Fig (a). Ports 1 and 2 are collinear ports and port 3 is E arm.

H-Plane Tee is a 3 port waveguide tee formed by cutting a rectangular slot along the width of the main waveguide and attaching another waveguide. The attached waveguide is H-arm, shown in Fig (b).

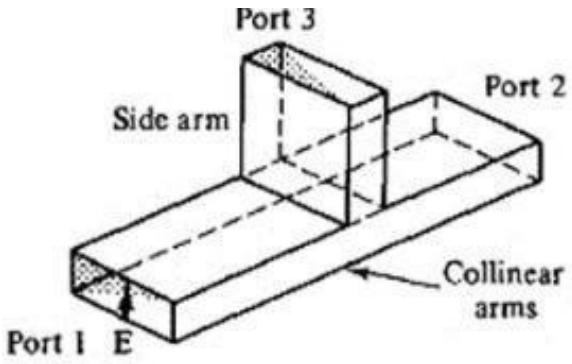


Fig (a): E Plane Tee Junction

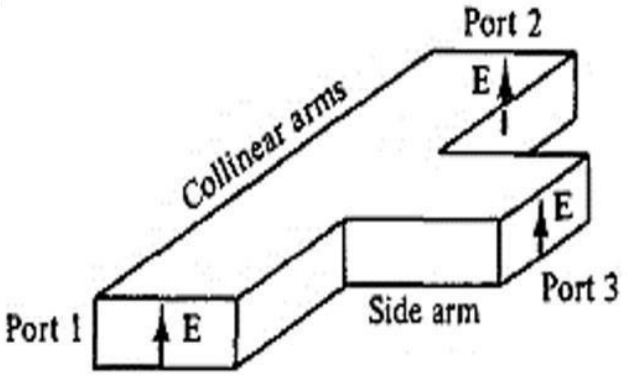


Fig (b): H Plane Tee Junction

PROCEDURE:

1. Set the various components as per the block diagram.
2. Before switching ON the power supply, keep the control knobs of the klystron power supply as below:

   HT (High Tension) Switch: OFF Position
   Meter Select : Volts
   Modulation : CW
   Beam Voltage : Fully anti-clockwise
   Repeller Voltage : Fully clockwise
   Frequency Meter : Fully clockwise or anti-clockwise
   AM Amplitude & Frequency : Mid Position
   Attenuation : 10-15dB
3. Keep the control knobs of SWR meter as below:

   Crystal Impedance : 200Ω

Range : 40 or 50dB

Gain control knobs : Mid position

SWR/dB Switch : dB position

4. Switch ON the klystron power supply, VSWR meter, cooling fan and set HT ON.
5. Change the modulation to AM.
6. Rotate the beam voltage knob clockwise slowly up to 300V.
7. Change the meter select switch to C and note down the corresponding beam current.
8. Change the meter select switch to Rep and note down the corresponding repeller voltage.
9. Connect the tunable probe to SWR meter and note the power in dB at range.

VSWR:

10. Connect the port 1 of E plane or H Plane or Magic Tee to the slotted line as input port and other ports to matched termination and output
11. By adjusting the slotted section, note down the values of V_{max} or V_{min}.
12. Calculate VSWR using $VSWR = \frac{V_{max}}{V_{min}}$.
13. Repeat the same for various inputs as shown in tabular column.

Isolation & Coupling Coefficient:

14. Connect the detector mount to the slotted section and note down the input voltage as (mv).
15. Connect E Plane/H Plane/Magic Tee and determine the corresponding voltages (mv) for each pair of ports by connecting one port to the source and measuring the output at other ports while the remaining ports are matched.
16. Determine isolation using $a = I_{ij} = 20 \log \frac{V_i}{V_j}$
17. Determine coupling coefficient using $C_{ij} = 10^{-a/20}$.

OBSERVATIONS:

Initial Conditions:

Beam voltage : 300V
Beam current : 17mA
Repeller voltage : - 297 V
Output voltage :
Frequency:
Power:

Tabular Columns:

Input VSWR

Name of the Tee	Output Port	V_{max}	V_{min}	$VSWR = \frac{V_{max}}{V_{min}}$
E Plane	2			
	3			
	1			
H Plane	2			
	3			
	1			

Isolation & Coupling Coefficient:

Name of the Tee	Port & Voltage		Isolation $\alpha = I_{ij} = 20\log\frac{V_i}{V_j}$	Coupling Coefficient $C_{ij} = 10^{-\alpha/20}$.
	Input Port & Voltage	Output Port & Voltage		
E Plane	1	2		
		3		
	3	2		
		1		
H Plane	1	2		
		3		
	3	2		
		1		

PRECAUTIONS:

i. Keep all the knobs in minimum position before going to switch 'ON' the powersupply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching'ON' the main supply.

ii. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.)keep all the knobs in minimum positions and switch off main switches.

iii. Don't increase the repeller voltage more than -70V(i.e.) it should be between -70Vto -270V**.**

RESULT: The isolation, coupling coefficient and input VSWR for E-plane and H-plane are calculated practically.