

# **MICROWAVE ENGINEERING AND OPTICAL LAB**

## **LABORATORY MANUAL**

**R16**

**IV/IVB.Tech (ECE)**

**I–Semester**

v



**MICROWAVE ENGINEERING AND OPTICAL LAB**

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**R16**

**IV/IVB.Tech(ECE)**



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# **I–Semester**



## ***DEPT.OF ELECTRONICS AND COMMUNICATION ENGINEERING***

**SIR C.R.REDDY COLLEGE OF ENGINEERING AND  
TECHNOLOGYELURU-534007**

## LABORATORY MANUAL

## R16

## LIST OF EXPERIMENTS

<i>S.No</i>	<i>Name Of The Experiment</i>	<i>Pg.No.</i>
<i>Part - A</i>		
<i>I</i>	<i>Study of Micro Wave Components</i>	<i>1</i>
<i>1.</i>	<i>Reflex Klystron Characteristics</i>	<i>5</i>
<i>2.</i>	<i>Gunn Diode Characteristics</i>	<i>13</i>
<i>3.</i>	<i>Attenuation Measurement</i>	<i>19</i>
<i>4.</i>	<i>Directional Coupler Characteristics</i>	<i>23</i>
<i>5.</i>	<i>Impedance and Frequency Measurement</i>	<i>26</i>
<i>6.</i>	<i>Scattering parameters of Circulator</i>	<i>35</i>
<i>7.</i>	<i>Scattering parameters of Magic Tee</i>	<i>38</i>
<i>8.</i>	<i>Radiation pattern of Horn and Parabolic Antennas</i>	<i>42</i>
<i>9.</i>	<i>Synthesis of microstrip antennas using HFSS</i>	<i>51</i>
<i>Part - B</i>		
<i>10.</i>	<i>Characterization of LED</i>	<i>60</i>
<i>11.</i>	<i>Intensity Modulation of Laser Output through Optical Link</i>	<i>62</i>
<i>12.</i>	<i>Measurement of Data Rate for Digital Optical Link, Losses for Analog Link</i>	<i>66</i>
<i>13.</i>	<i>Measurement of NA</i>	<i>71</i>
<i>14.</i>	<i>Bending Losses of Analog Link</i>	<i>74</i>
<b>ADDON EXPERIMENTS</b>		
<i>1.</i>	<i>Measurement Of Voltage Standing Wave Ratio (VSWR) And Reflection Coefficient.</i>	<i>78</i>



2.	<i>SpectrumAnalyzer:HarmonicsOfSineAnd squareWave.</i>	81
3.	<i>DeterminationOfResonanceAndDielectric ConstantOfAMicroStrip RingResonator.</i>	86



IV Year - I Semester

L	T	P	C
0	0	3	2

### MICROWAVE ENGINEERING & OPTICAL LAB

**Minimum Twelve Experiments to be conducted:**

**Part – A (Any 7 Experiments ( 8 & 9 compulsory)) :**

1. Reflex Klystron Characteristics.
2. Gunn Diode Characteristics.
3. Attenuation Measurement.
4. Directional Coupler Characteristics.
5. Impedance and Frequency Measurement.
6. Scattering parameters of Circulator.
7. Scattering parameters of Magic Tee.
8. Radiation Pattern of Horn and Parabolic Antennas.
9. Synthesis of Microstrip antennas (Rectangular Structure) Using HFSS.

**Part – B (Any 5 Experiments) :**

10. Characterization of LED.
11. Characterization of Laser Diode.
12. Intensity modulation of Laser output through an optical fiber.
13. Measurement of Data rate for Digital Optical link.
14. Measurement of NA.
15. Measurement of losses for Analog Optical link.

**Equipment required for Laboratories:**

1. Regulated Klystron Power Supply, Klystron mount
2. VSWR Meter
3. Micro Ammeter
4. Multi meter
5. CRO
6. GUNN Power Supply, Pin Modulator
7. Crystal Diode detector
8. Micro wave components (Attenuation)
9. Frequency Meter
10. Slotted line carriage
11. Probe detector
12. Wave guide shorts
13. SS Tuner
14. Directional Coupler
15. E, H, Magic Tees
16. Circulators, Isolator
17. Matched Loads
18. Pyramidal Horn and Parabolic Antennas
19. Turntable for Antenna Measurements
20. HFSS Software
21. Fiber Optic Analog Trainer based LED
22. Fiber Optic Analog Trainer based laser
23. Fiber Optic Digital Trainer





## LABORATORY MANUAL

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### STUDY OF MICROWAVE COMPONENTS



**RECTANGULAR WAVE GUIDE** :wave guides are manufactured to the highest mechanical and electrical standards and mechanical tolerances. W.G. sections of specified length can be supplied with flanges, painted outside and silver or gold plated in side.



**GUNN OSCILLATORS:**Gunn Oscillators are solid state microwave energy generators. These consist of waveguide cavity flanged 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.



**PIN MODULATORS:** Pin modulators are designed to modulate the CW output of Gunn Oscillators. These consists of a pin diode mounted inside a section of Wave guide flanged on it's both end.



## ISOLATORS

These are well matched devices offering which allows RF energy to pass through in forward direction with very little loss while RF power in the reverse direction is absorbed

### VARIABLE ATTENUATOR :

It consists of a resistive vane inside the waveguide to absorb the microwave power according to its position. Amount of attenuation depends on the depth of penetration of vane into the waveguide.

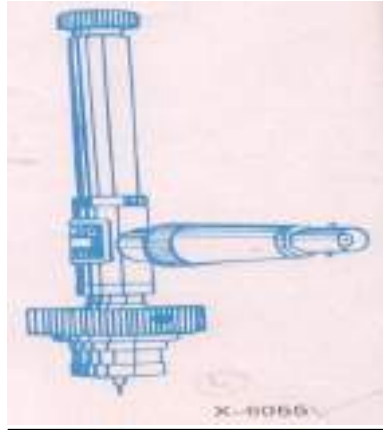


**FREQUENCY METER: Also called as wavemeter.** It is used to measure frequency of the signal over their respective frequency band.



### TUNABLE PROBE:

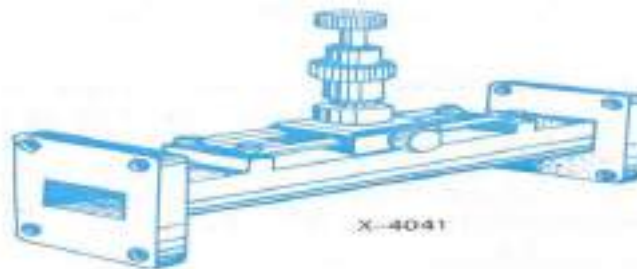
The depth of penetration into a wave guide - section is adjustable by the knob of the probe. The tip pick up the RF power from the line and this power is rectified by crystal detector, which is then fed to the VSWR meter or indicating instrument.



**MATCHED TERMINATION:** A termination producing no reflected wave at any transverse section of the waveguide. It absorbs all the incident power.



**SLIDE SCREW TUNERS:** 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 the wave guide. These 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 carriage carrying the screw, is provided over the slot.



**MOVABLE SHORT :** Movable shorts consist of a section of waveguide, flanged on one end and terminated with a movable shorting plunger on the other end. By means of this noncontacting type plunger, a reflection co-efficient of almost unity may be obtained.



**Exp no:****Date:****1. STUDY OF REFLEX KLYSTRON CHARACTERISTICS**

**AIM:** To study the Characteristics of Reflex Klystron tube & to determine its electronic tuning range and mode number.

**APPARATUS:**

Klystron power supply

Klystron mount tube

Isolator

Frequency Meter

Variable Attenuator

Detector mount

Wave guide stand

Cooling fan

Multimeter

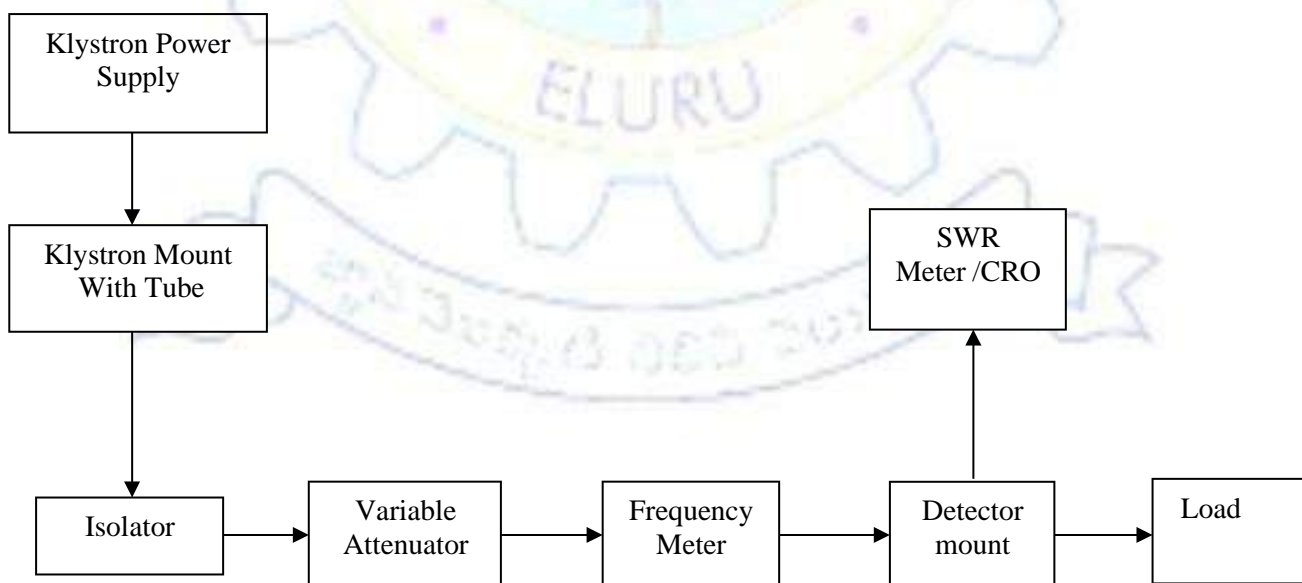
Cables and accessories

**THEORY:**


The reflex Klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. Electron Beam emitted is accelerated towards the anode cavity. After passing the gap in the cavity electron travel towards the repeller electrode which is at a high negative potential ( $V_r$ ). The electron beam never reach the repeller because of the negative field and returned back towards the gap. The accelerated electrons leave the resonator at an increased velocity and the retarded electrons leave at the reduced velocity. the electrons leaving the resonator will need different time to return, due to change in velocities. as a result, returning electrons group together in bunches. As the electron bunches pass through resonator, they interact with voltage at resonator grids. If the bunches pass the grid at such time that the electrons are slowed down by the voltage, energy will be delivered to the resonator; and klystron will oscillate. The dimension of resonant cavity primarily determines the frequency. A small frequency change can be obtained by adjusting the reflector voltage. This is called Electronic Tuning Range.

**PROCEDURE:**

1. Connect the components and equipments as shown in figure.
2. Keep the control knobs of klystron power supply as below
  - Mode switch of klystron power supply to CW position
  - Beam voltage control knob to full anti clockwise
  - reflector voltage control knob to fully clock wise
3. Set the multi-meter in DC microampere range.
4. Switch 'On' the klystron power supply & cooling fan for klystron tube.
5. Now in K.P.S set Mode select switch to AM- MODE position. Adjust the Repeller voltage to 70 to 270 volts and beam voltage to 300 volts and beam current should be around 5 to 30mA, modulation is set to AM.
6. Observe the perfect square wave on the CRO.
7. For different values of Repeller voltage (varying from 70V to 270V) note down the corresponding current from the multiMeter.
8. Frequency measurement  
Rotate the knob of frequency meter slowly till a 'dip' appears on CRO. Read directly the frequency meter between two horizontal lines and vertical marker.
9. Plot Repeller voltage vs power and Repeller Voltage vs frequency.

**EXPERIMENTAL SETUP:**

**TABULAR FORM**

Repeller voltage (v)	Power (mw)	Frequency (GHz)
		

**CALCULATIONS**

**1. Mode number n**

$$\frac{VO1}{VO2} = \frac{(n+1)+3/4 \text{ (at constant frequency)}}{n + 3/4} = \frac{N2}{N1}$$

where VO1 and VO2 are reflector voltages for two successive modes at maximum power points.

**2. ETS (Electronic Tuning Sensitivity)**

$$ETS = \frac{f2 - f1}{V2 - V1} \text{ MHz/V}$$

f2 and f1 being half power frequencies in GHz, and V2 and V1 are corresponding voltages for a particular mode.

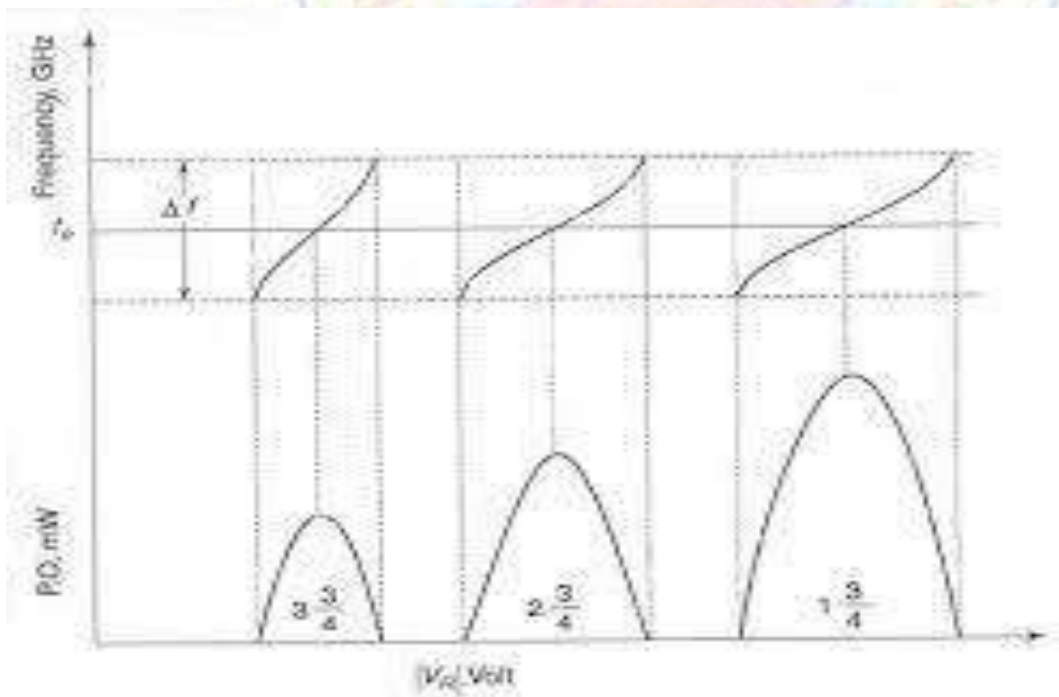
ETS for mode 1:

ETS for mode 2:

ETS

MODELWAVE

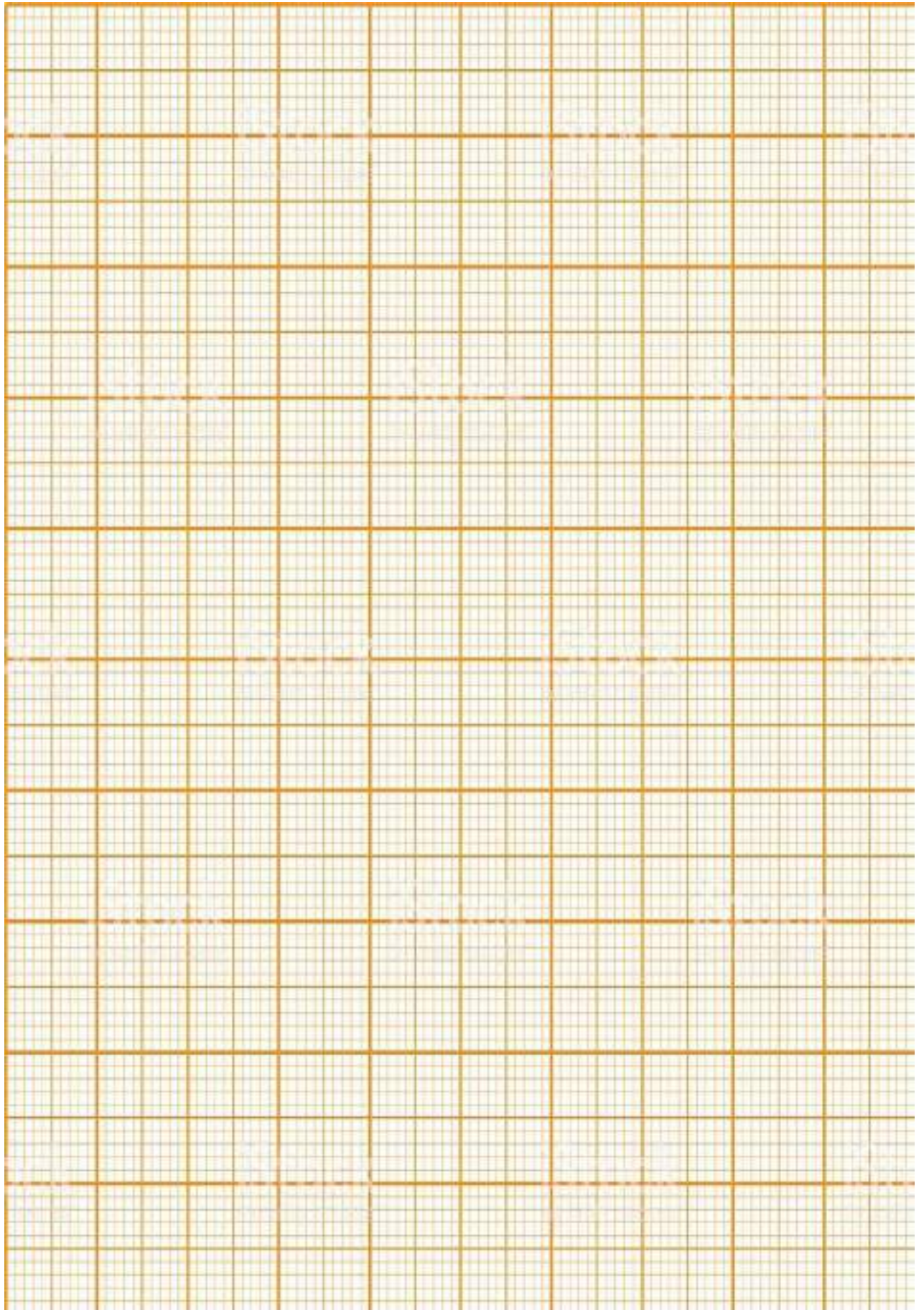
FORMS

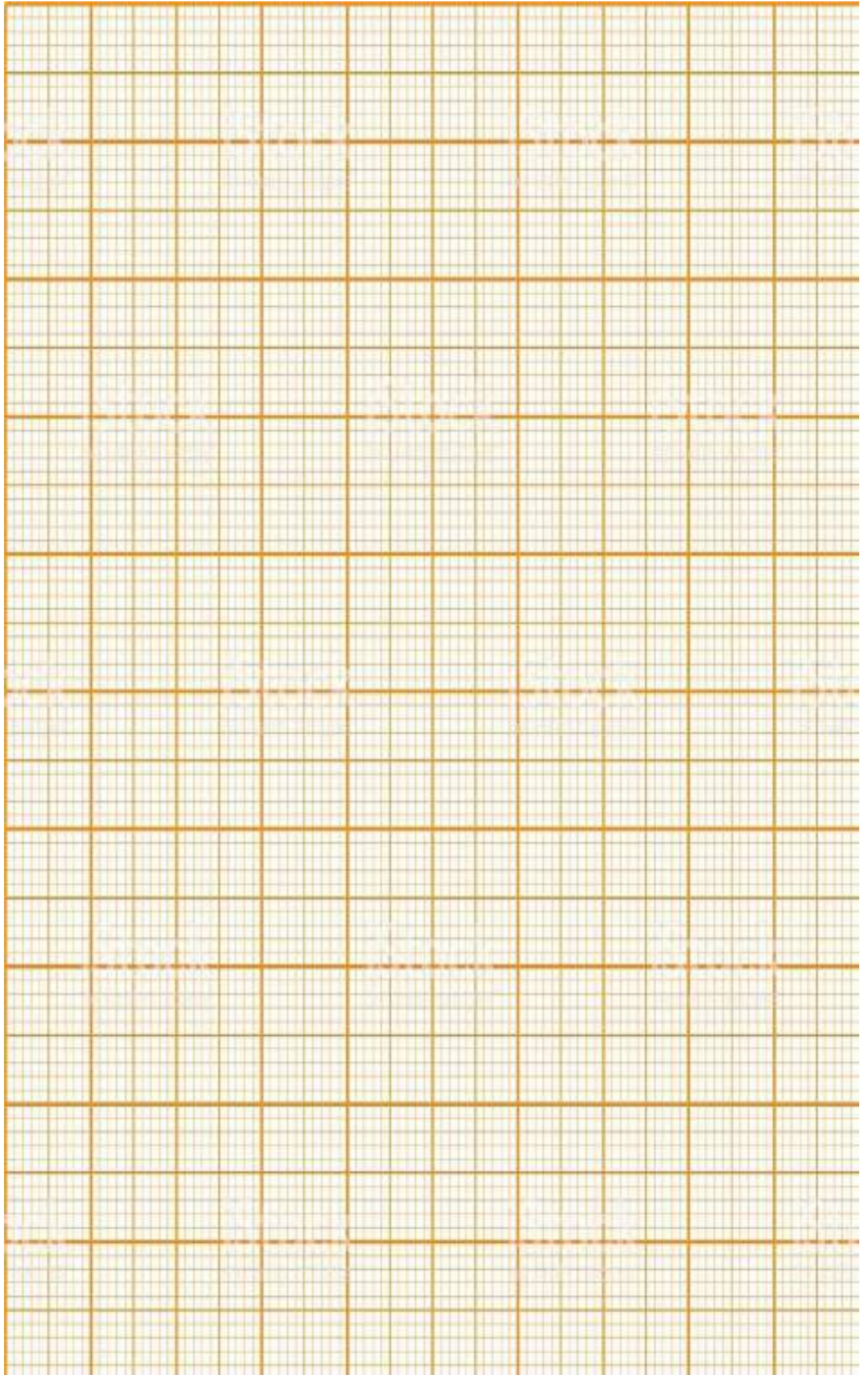


for mode 3:



GRAPH SHEET:







**PRECAUTIONS:**

1. Keep the cooling fan towards the Klystron tube.
2. Never keep the Repeller Voltage to zero volts.

**RESULT:****VIVA QUESTIONS:**

1. What is Bunching?
2. Where the Bunching occurs in Klystrons?
3. What is the operation principal of Reflex Klystron?
4. What is the Density modulation?
5. Klystron type tubes can operate at high frequencies the triodes. Why?
6. What is the effect of increasing number of cavities in Klystron?
7. What is linear Frequency modulation in Klystrons?
8. What is beam loading?
9. What is beam-coupling co-efficient?
10. What is the optimum value of Bunching parameter?
11. What is the relation between Anode voltage and Repeller voltage?
12. Why Repeller electrode is maintained at high negative potential?
13. Draw the equivalent circuit of Reflex Klystron?
14. What is the efficiency of Reflex Klystron?
15. Why square wave modulation of the source is preferred?

Exp no:

Date:

## 2. STUDY OF GUNN DIODE CHARACTERISTICS

**AIM:** To study the V-I Characteristics and Frequency Vs Power Characteristics of the Gunn Diode.

### APPARATUS:

1. Gunn power supply
2. Gunn oscillator
3. PIN modulator
4. Isolator
5. Variable attenuator
6. Frequency meter
7. Detector Mount
8. Power Meter/SWR meter

### THEORY:

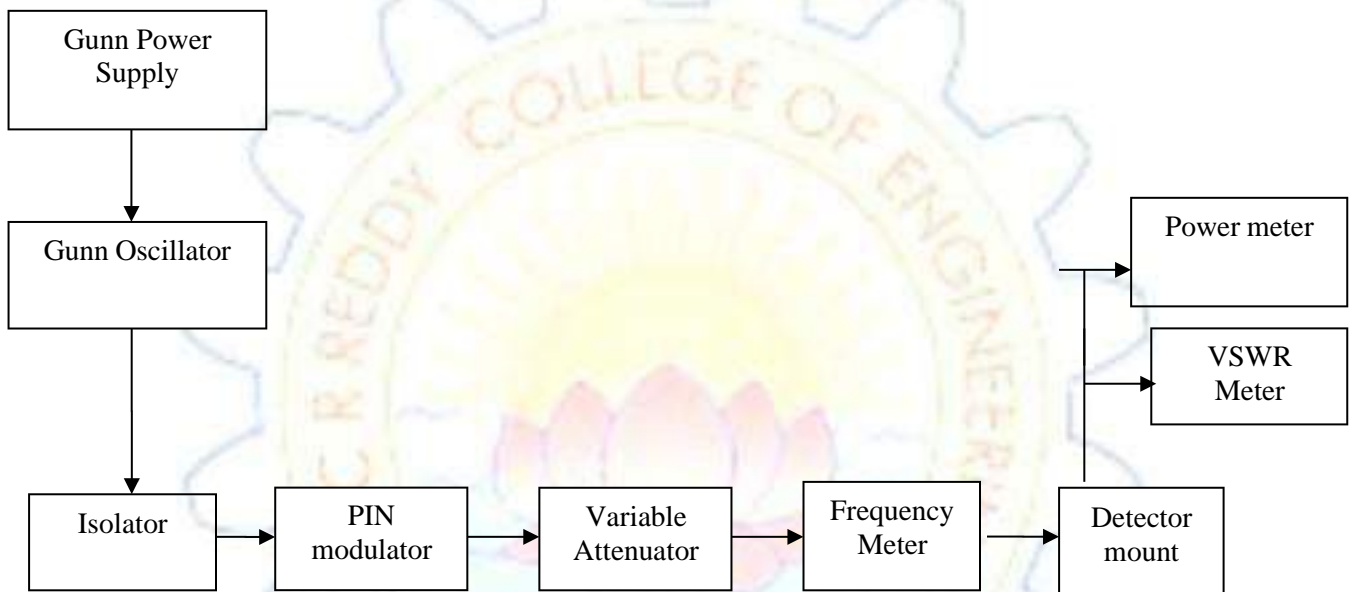
A **Gunn diode**, also known as a **transferred electron device (TED)**, is a form of diode, a two-terminal passive semiconductor electronic component, with negative resistance, used in high-frequency electronics. It is based on the "Gunn effect" discovered in 1962 by physicist J. B. Gunn. Its largest use is in electronic oscillators to generate microwaves, in applications such as radar speed guns, microwave relay data link transmitters, and automatic door openers. Because of their bulk negative resistance behaviour, these devices are ideally suited for use in low noise sources such as local oscillators.

### PROCEDURE:

1. Assemble the test bench as shown in figure.
2. Initially set the variable attenuator for no attenuation.
3. Keep the control knob of Gunn Power Supply as below:
  - Gunn Bias Knob : Fully anticlockwise
  - Pin bias Knob : Fully anti-clockwise
  - Pin Mod frequency : Mid position
  - Mode switch : Internal Mod position
4. Keep the control knob of SWR meter as below
  - Range db Switch : 40dB/ 50dB
  - Crystal : 200 ohm
  - Mod switch : Normal position
  - Gain (coarse & fine) : mid position
  - SWR/dB switch : dB position

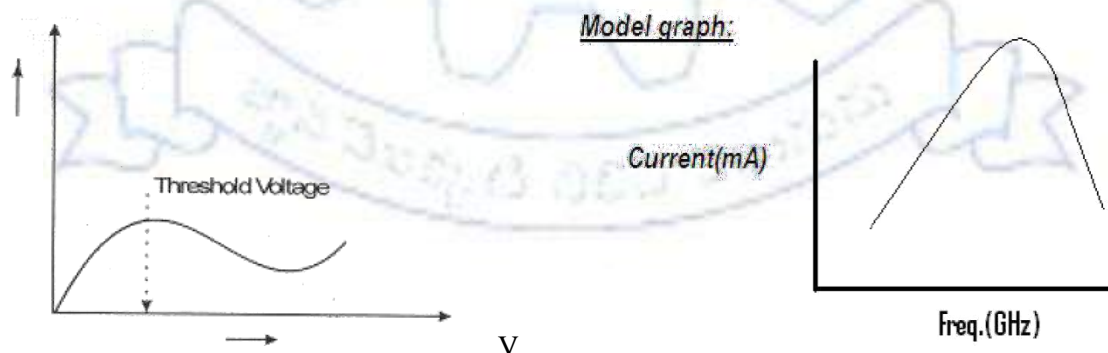
5. Switch ON the Gunn Power Supply and SWR Meter.
6. Slowly increase the Gunn bias supply in steps of 0.5 Volts and for each increment observe the Gunn current and plot the V-I characteristics.
7. Set the Gunn Bias voltage to 9.0 Volts, by changing Micrometer measure the power using power meter and find the corresponding frequency for each micrometer reading.
8. Plot the graph frequency Vs power.

#### EXPERIMENTAL SETUP:



#### MODEL GRAPHS

I



**TABULAR FORM: V-I CHARACTERISTICS**

S.No	Bias Voltage (volts)	Gunn Current

**TABULAR FORMS: FREQUENCY VS POWER**

Micrometer Reading (mm)	Corresponding Frequency (GHz)	Output Current	Output Power

**PRECAUTIONS:**

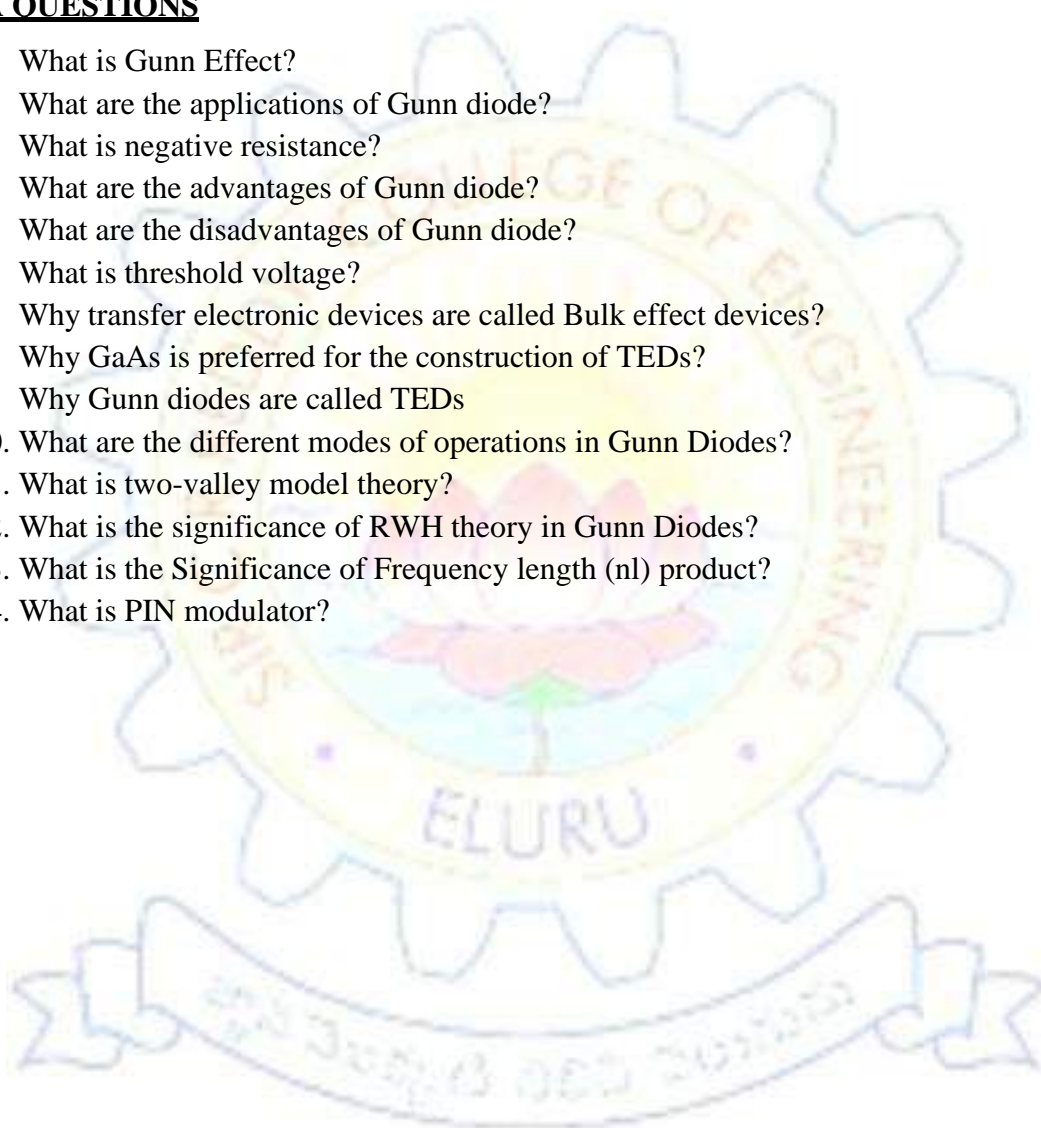
1. Do not apply the Gunn bias voltage greater than 12.0 Volts.
2. Keep the connections without gaps.

**RESULT:**

The Threshold voltage of the Gunn Diode found as .....

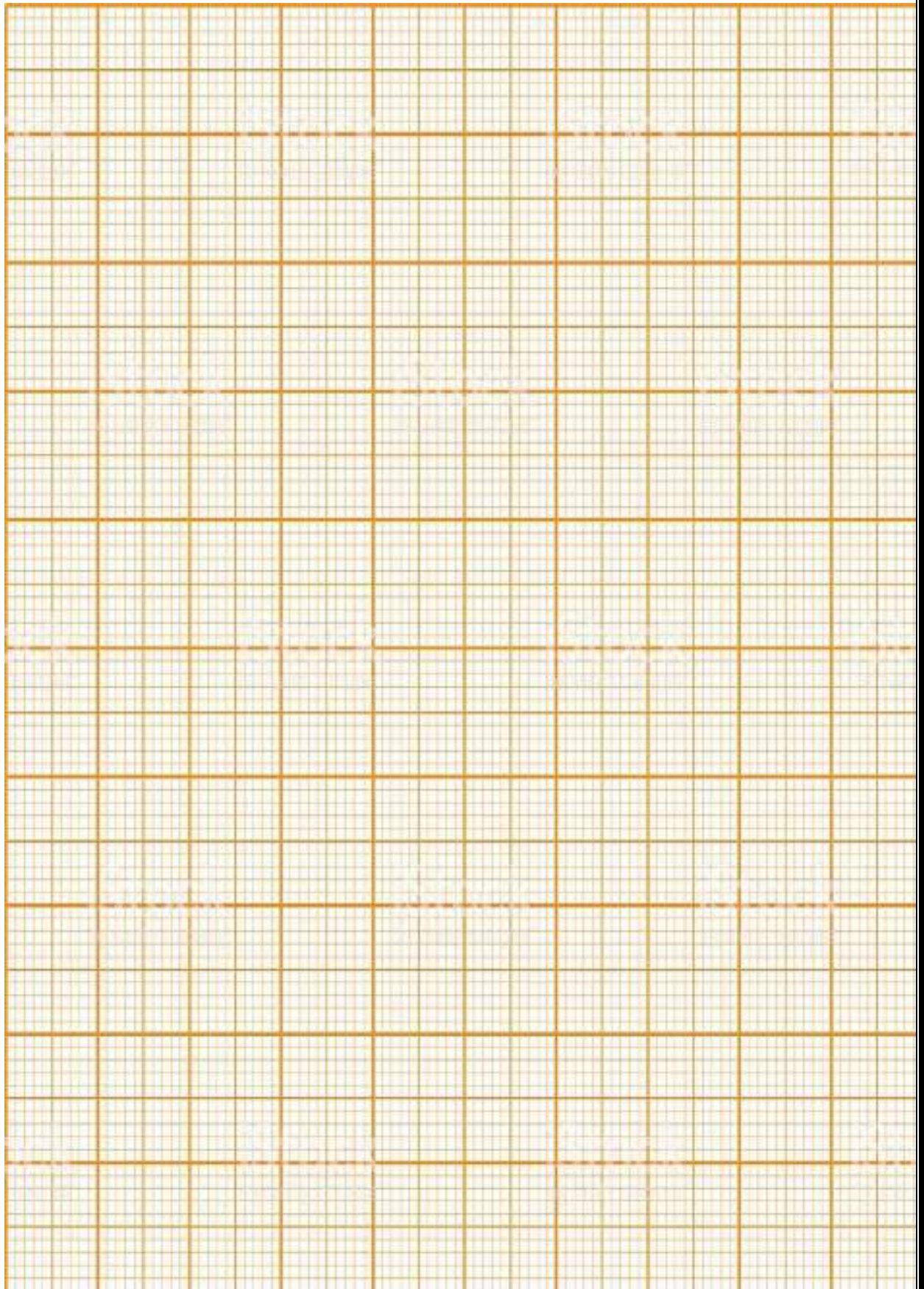
**VIVA QUESTIONS**

1. What is Gunn Effect?
2. What are the applications of Gunn diode?
3. What is negative resistance?
4. What are the advantages of Gunn diode?
5. What are the disadvantages of Gunn diode?
6. What is threshold voltage?
7. Why transfer electronic devices are called Bulk effect devices?
8. Why GaAs is preferred for the construction of TEDs?
9. Why Gunn diodes are called TEDs
10. What are the different modes of operations in Gunn Diodes?
11. What is two-valley model theory?
12. What is the significance of RWH theory in Gunn Diodes?
13. What is the Significance of Frequency length (nl) product?
14. What is PIN modulator?

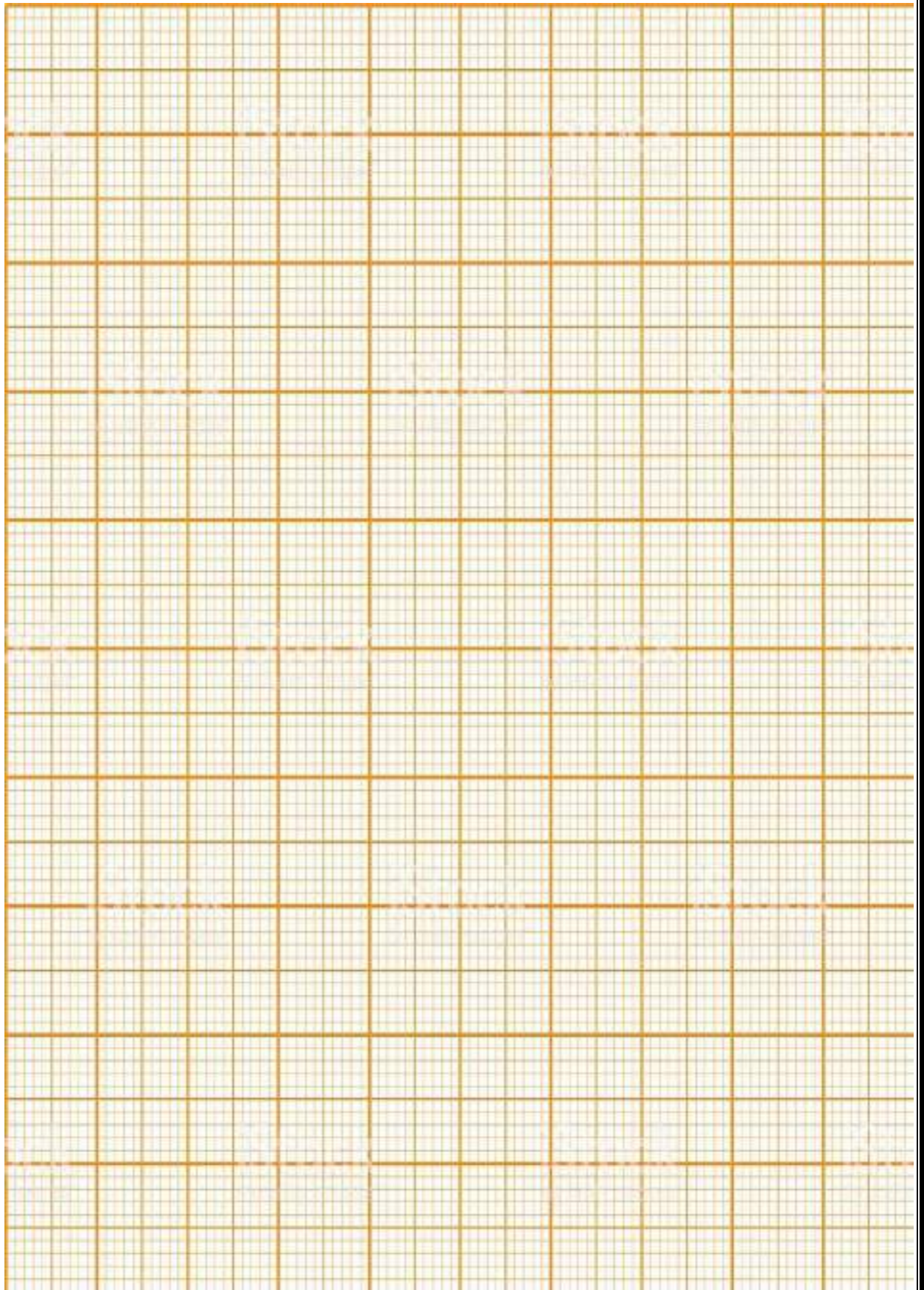




GRAPH SHEET:



GRAPH SHEET:



Exp no:

Date:

**3. ATTENUATION MEASUREMENT****AIM:**

To measure the attenuation factor of Microwave components (fixed Attenuators).

**APPARATUS:**

S.No.	Name of the item	Specifications	Quantity
1	Klystron Power Supply	Beam voltage 240-420 Vdc Repeller Supply 60-270 Vdc	1
2	Reflex Klystron tube with mount	Frequency:8.2 to 12.4 GHz	1
3	Isolator	Min Isolation: 20dB; Min Insertion loss:0.4dB	1
4	Frequency Meter	8.2 to 12.4 GHz	1
5	Variable Attenuator	Max Insertion loss: 0.2dB Attenuation:0-15dB	1
6	Slotted Section	Max VSWR:1.01	1
7	Detector Mount	8.2-12.4 GHz Detector: IN23	1
8	Fixed attenuators (5dB and 10dB)	Max. Insertion loss:0.2dB Max. VSWR:1.10	1
9	Oscilloscope	30MHz	1
10	BNC cables	---	1
11	Wave Guide Stands	---	5
12	Cooling fan for Reflex Klystron Oscillator	---	1

**THEORY:**

The attenuators are two-port bi-directional devices, which attenuates some power when inserted into transmission line. Attenuation in dB is given by the ratio of power absorbed or detected by the load without the microwave component in line to the power absorbed or detected by the load with the microwave component in line.

$$\text{Attenuation (A) in dB} = 10 \log P_1/P_2$$

Where  $P_1$  = power detected by the load without microwave component in the line

$P_2$  = power detected by the load with the microwave component in the line

The attenuator consists of a rectangular wave-guide with a resistive vane inside it to absorb the microwave power according to their position with respect to sidewall of the wave-guide. As electric field is maximum at centre in  $TE_{10}$  mode, the attenuation will be maximum if the vane is placed at the centre of the waveguide. Moving the vane from centre to the side wall attenuation will decrease. In the fixed attenuator the vane position is fixed whereas in variable attenuator, its position can be changed by the help of micrometer or by other methods.

### **BLOCK DIAGRAM:**

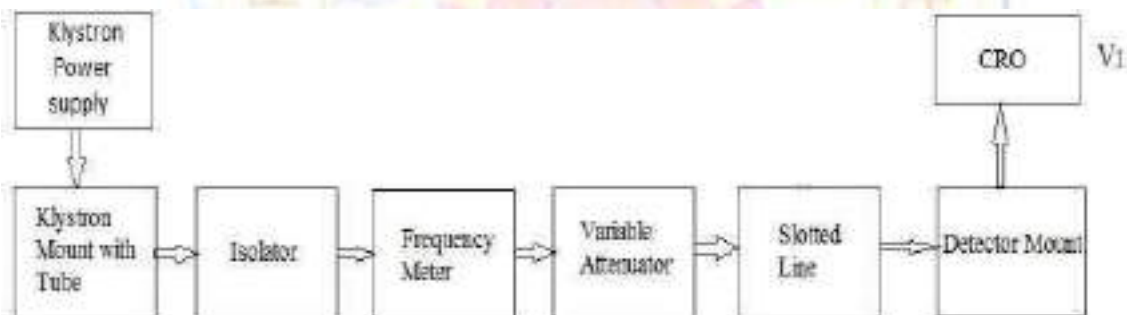


Figure: Setup-1 for Attenuation measurement

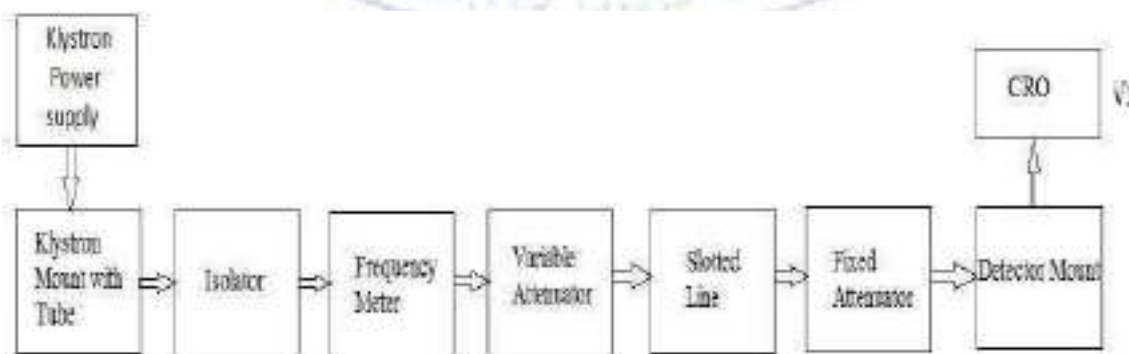


Figure: Setup-2 for Attenuation measurement

**PROCEDURE:**

1. Connect the components and equipments as shown in above figures.
2. Set the Variable Attenuator at minimum position.
3. Keep the Control Knobs of Klystron power supply as below
  - a. Beam voltage - OFF
  - b. Mod- switch - AM
  - c. Beam Voltage knob - fully anticlockwise
  - d. Reflector Voltage knob - fully clockwise
  - e. AM- Amplitude Knob - around fully clockwise
  - f. AM- Frequency Knob - Mid position.
4. Rotate the knob of frequency meter at one side fully.
5. Switch „ON“ the Klystron Power Supply, CRO and cooling fan for the klystron tube.
6. Switch „ON“ Beam voltage switch and rotate the beam voltage knob clockwise slowly up to 300V meter reading and observe beam current position. “The beam current should not increase more than 30mA”.
7. Change the repeller voltage slowly until get maximum amplitude of square wave onCRO.
8. Without fixed attenuator measure the amplitude (V1) of detector output voltage onCRO.
9. Connect the fixed attenuator (3dB) and measure the amplitude (V2) of detector outputvoltage on CRO.
10. Calculate the attenuation of connected attenuator by  $20 \log(V1/V2)$  dB.

Repeat the procedure for fixed attenuator 10 dB..

**OBSERVATIONS:**

Beam Voltage = 300 V  
 Repeller Voltage =  
 Current =

Attenuator Type	Without fixed attenuator Amplitude(V1)	With fixed attenuator Amplitude (V2)	Attenuation in dB
3 dB			
10 dB			

**CALCULATIONS:**

Attenuation (A) in dB =  $20 \log (V_1/V_2)$

For 3 dB attenuator:

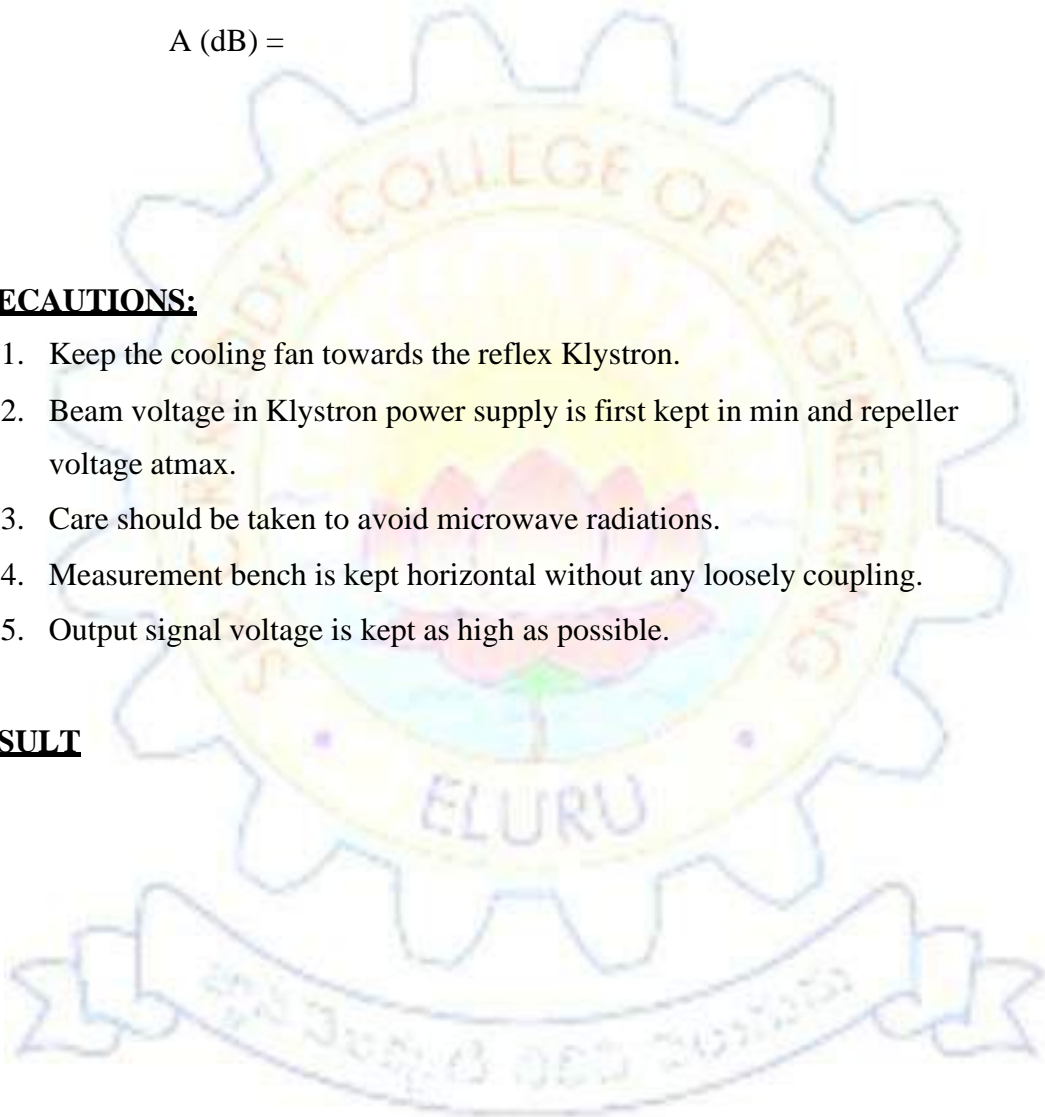
$$A \text{ (dB)} =$$

For 10 dB attenuator:

$$A \text{ (dB)} =$$

**PRECAUTIONS:**

1. Keep the cooling fan towards the reflex Klystron.
2. Beam voltage in Klystron power supply is first kept in min and repeller voltage at max.
3. Care should be taken to avoid microwave radiations.
4. Measurement bench is kept horizontal without any loosely coupling.
5. Output signal voltage is kept as high as possible.

**RESULT**

Exp no:

Date:

#### 4. STUDY OF DIRECTIONAL COUPLER CHARACTERISTICS

##### AIM:

To measure the coupling factor, Directivity, Isolation factor and insertion loss of a Directional Coupler.

##### EQUIPMENTS REQUIRED:

1. Klystron power supply
2. Klystron tube with mount
3. Isolator
4. Variable attenuator
5. Directional Coupler
6. Detector Mount
7. Matched Load
8. VSWR meter

##### THEORY:

A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consists of two transmission lines, main arm and auxiliary arm, electromagnetically coupled to each other. The diagram is given below. The power entering in port 1 in the main arm divides between port 2 and port 4 almost no power comes out of port 3. Power entering in port 2 is divided between port 1 and 3.



Assuming power is entering from port 1, then

The coupling factor is defined as

$$\text{Coupling (dB)} = 10 \log_{10} P_1 / P_4$$

Main line insertion loss is the attenuation introduced in transmission line by insertion of coupler. It is defined as:

$$\text{Insertion loss} = 10 \log_{10} P_1 / P_2.$$

The directivity of the coupler is a measure of separation between incident wave and the reflected wave.

It is measured as the ratio of two power outputs from the auxiliary line when a given amount of power is successively applied to each terminal of the main line with other port terminated by matched load. Hence Directivity is given by

$$D \text{ (dB)} = 10 \log_{10} P_4 / P_3$$

Where  $P_4$  and  $P_3$  are the measured powers at port 4 and port 3.

Isolation factor is given by

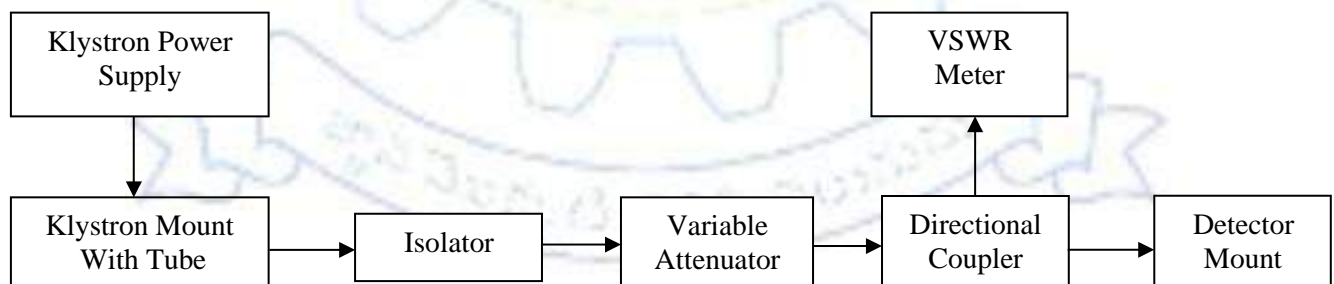
$$I \text{ (dB)} = 10 \log_{10} P_1 / P_3$$

### **PROCEDURE:**

1. Assemble the test bench as shown in the figure
2. Beam voltage knob should be at min position
3. Adjust the Repeller voltage to 70 to 100 volts and Beam voltage to 300 volts and beam current should be around 5 to 30mA, modulation is set to AM.
4. Energize the Klystron to get maximum power on the VSWR meter.
5. Measure the power( $P_1$ ) after variable attenuator by connecting the detector mount directly
6. Place the Directional coupler after Variable attenuator, measure power ( $P_2$ ) by connecting Detector mount to ( $P_2$ ) and matched load to ( $P_4$ )
7. Measure power( $P_4$ ) by connecting Detector mount to ( $P_4$ ) and matched load to ( $P_2$ )
8. To measure power( $P_3$ ), reverse the Directional Coupler and connect detector mount to ( $P_3$ ) and matched load to ( $P_2$ ).

Find the coupling factor, Directivity, Isolation factor and Insertion loss using the formulae.

### **EXPERIMENTAL SETUP:**





**CALCULATIONS:**

Coupling factor =  $10 \log (P1/P4)$

Directivity =  $10 \log (P4/P3)$

Insertion Loss =  $10 \log (P1/P2)$

Isolation factor =  $10 \log (P1/P3)$

**PRECAUTIONS:-**

1. Keep the Cooling fan towards the Klystron tube.
2. Never keep the Repeller voltage to zero volts.

**RESULT:-**

The parameters of Directional Coupler are

Coupling factor =

Directivity =

Isolation factor =

Insertion loss =

**Viva Questions:**

1. What is the use of directional coupler?
2. What are the important characteristic parameters of directional coupler?
3. What is insertion loss?
4. Give S-matrix of directional coupler?
5. Why S-parameters are preferred over other parameters?
6. What is the effect of high coupling factor?
7. How the directivity of given system can be improved?
8. What is the effect of increasing number of holes in the directional coupler?
9. What are the applications of directional coupler?

Exp no:

Date:

**5(A). MEASUREMENT OF AN UNKNOWN IMPEDANCE****AIM:**

To measure an unknown Impedance with Smith chart.

**EQUIPMENT REQUIRED:**

1. Gunn oscillator
2. Klystron power supply
3. Isolator
4. PIN modulator
5. Frequency meter
6. Variable attenuator, Slotted Line
7. Tunable probe
8. SWR meter
9. Wave guide stand
10. S.S. Tuner
11. Matched Termination

**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

$$S = \frac{1 + |R|}{1 - |R|}$$

Reflection Coefficient

$$R = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Where

$Z_0$  = Characteristics impedance of w/g at operating frequency.

$Z_L$  = Load impedance at any point.

The measurement is performed in following way:

The unknown device is connected to the slotted line and the  $SWR = S_0$  and the position of one minima is determined. Then unknown device is replaced by movable short to the slotted line. Two successive minima positions are noted. The twice of the difference between minima position will be guide-wave length. One of the minima is used as reference for Impedance measurement. Find the difference of reference minima and minima position obtained from unknown load. Let it be 'd'. Take a Smith chart taking '1' as center; draw a circle of radius equal to  $S_0$ . Mark a point on circumference of chart towards load side at a distance equal to  $d/g$ . Join the center with this point. Find the point where it cut the drawn circle. The coordination of this point this will show the normalized impedance of load.

**PROCEDURE:**

1. Set up the equipments as shown in the above figure.
2. Set the variable attenuator at no attenuation position.
3. Connect S.S tuner after slotted line.
4. Connect matched termination after S.S tuner.
5. Keep the control knobs of SWR meter as below.
6. Keep the Control knobs of Klystron power supply as below

<input type="checkbox"/> Range dB	:	40dB/50 dB position
<input type="checkbox"/> Crystal	:	200 ohm
<input type="checkbox"/> Mode Switch	:	Normal Position
<input type="checkbox"/> Gain (Coarse & fine)	:	Mid Position.
<input type="checkbox"/> SWR/dB switch	:	dB Position

7. Switch "ON" the Klystron Power Supply SWR meter and cooling Fan.

Beam voltage	:	off
Mode switch	:	on
Beam voltage knob	:	Fully anti clockwise
Repeller voltage knob	:	Fully clockwise
AM amplitude knob	:	Around fully clockwise
AM frequency knob	:	Around mid-position

8. Switch on the beam voltage and set beam voltage at 300v with the help of beam voltage knob.
9. Adjust the repeller voltage to get some deflection in VSWR.
10. Tune the probe for maximum deflection in VSWR meter.
11. Terminate with DUT and find two successive minima locations  $d_1$  and  $d_2$ .
12. Replace DUT with matched termination and find two successive minima locations  $d^1$  and  $d^2$
13. Move the probe towards the source and note down two consecutive minima positons and their difference is equal to half the guide wavelength.

$$\lambda_g = 2(d_1 - d_2)$$

14. Calculate  $d / \lambda_g =$

$$15. \text{ Calculate unknown impedance } z_L = \frac{z_{in}}{z_0} = \frac{1 - j s \tan \left( \pm \frac{2\pi d}{\lambda_g} \right)}{s - j \tan \left( \pm \frac{2\pi d}{\lambda_g} \right)}$$

**Using Smith Chart:**

1. Note down VSWR, shift minima  $d_1$  in terms of wavelength  $d/\lambda_g$ .
2. Use smith chart and draw a VSWR circle which pass through VSWR and the radius of circle gives the magnitude of reflection co-efficient.
3. Locate a point at a distance  $d/\lambda_g$  from short circuit moving in anti-clock wise direction (shifting towards generator) on circumference accordingly join the point of center of smith chart.
4. Point of intersection of VSWR circle and this time gives load reactive circle resistant component on radius.
5. The normalized impedance will be multiplied by characteristics impedance of guide, give load Impedance.

The characteristics impedance of guide is given by relation.

$$Z_o = \eta / \sqrt{1 - (\lambda_o/\lambda)^2}$$

**EXPERIMENTAL SETUP:****OBSERVATIONS:**

Beam voltage =  
 Repeller voltage =  
 Current =

**With short:**

Minima 1,  $d_1$  =  
 Minima 2,  $d_2$  =  
 Average  $d_{avg} = (d_1 + d_2)/2$  =

**Calculations:****With load :**

Minima 1,  $d'_1$  =  
 Minima 2,  $d'_2$  =  
 $d'_{avg}$  =

$$S = \text{VSWR} =$$

$$\lambda_g = 2(d_1 - d_2) =$$

$$d = d_{avg} - d'_{avg}$$

$$d/\lambda_g =$$

$$f =$$

$$\lambda_c = 2a =$$

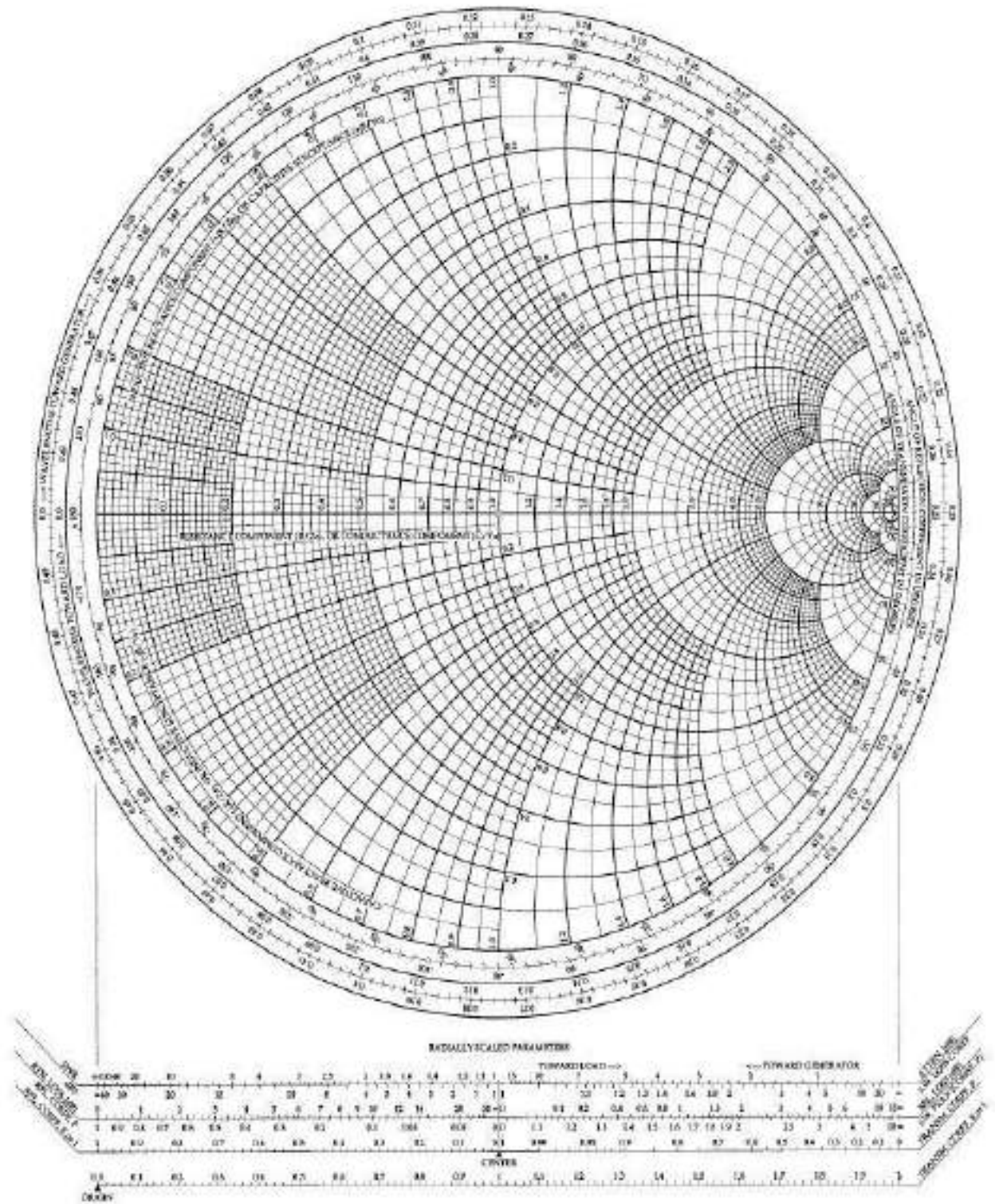
$$\lambda_o = c/f =$$

$$Z_o = \eta / \sqrt{1 - (\lambda_o/\lambda_g)^2}$$

$$z_L = \frac{z_{in}}{z_0} = \frac{1 - j s \tan \left( \pm \frac{2\pi d}{\lambda_g} \right)}{s - j \tan \left( \pm \frac{2\pi d}{\lambda_g} \right)}$$



SMITH CHART:

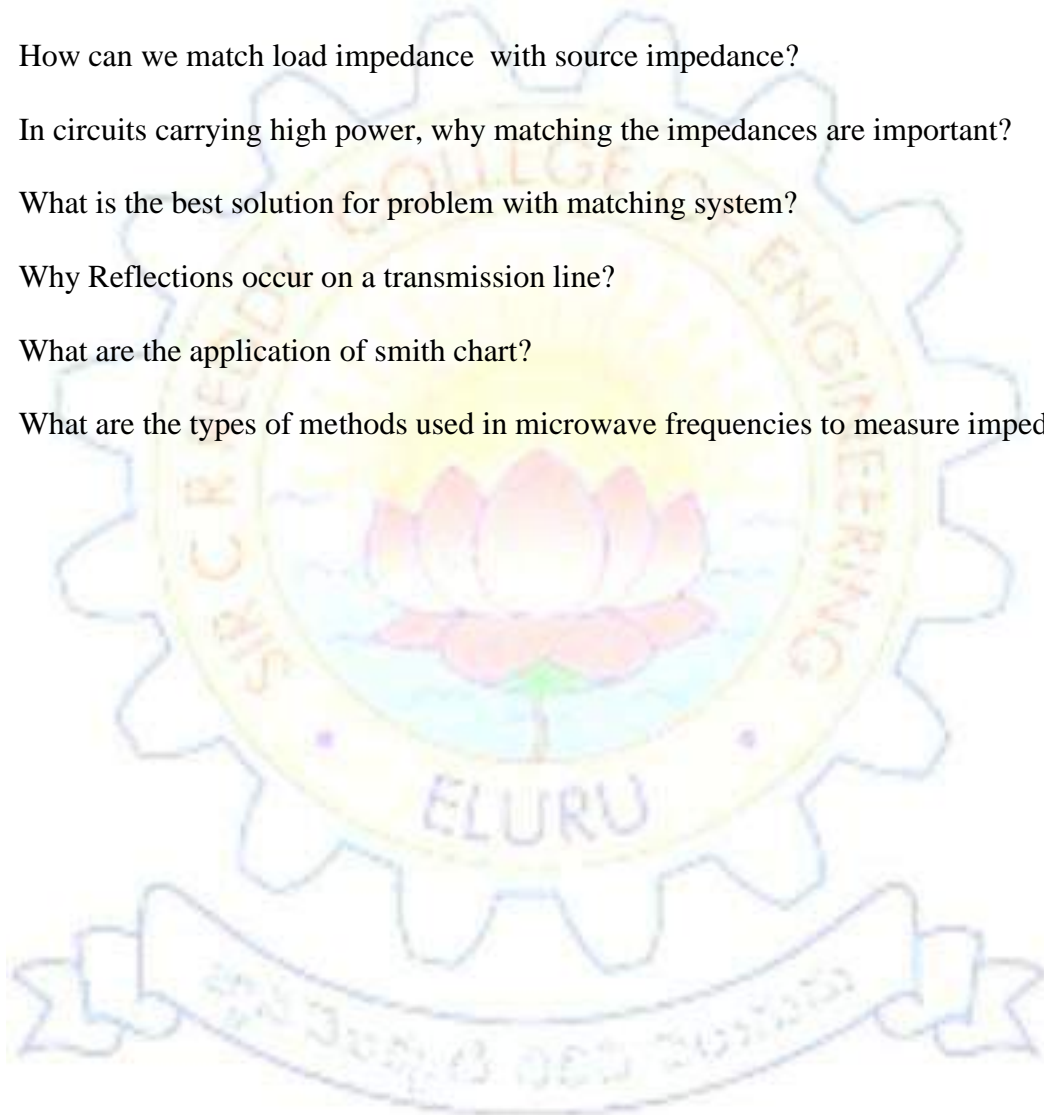


**PRECAUTIONS:**

1. Do not apply the Gunn bias voltage greater than 12.0 Volts.
2. Keep the connections without gaps.

**RESULT:****VIVA QUESTIONS:**

1. Define input impedance of an electrical network?
2. How can we match load impedance with source impedance?
3. In circuits carrying high power, why matching the impedances are important?
4. What is the best solution for problem with matching system?
5. Why Reflections occur on a transmission line?
6. What are the application of smith chart?
7. What are the types of methods used in microwave frequencies to measure impedance?



Exp no:

Date:

**5(B). MEASUREMENT OF FREQUENCY AND GUIDE WAVELENGTH****AIM:**

To determine the frequency and wavelength in a rectangular waveguide working in TE<sub>10</sub> mode.

**EQUIPMENTS:**

1. Klystron power supply
2. Klystron tube with mount
3. Isolator
4. Frequency meter
5. Variable attenuator
6. slotted line with probe detector
7. CRO/VSWR meter
8. Movable short/matched termination.

**THEORY:**

For dominant TE<sub>10</sub> mode in rectangular wave guides  $\lambda_o, \lambda_g$ , and  $\lambda_c$  are Related as below

$$1 / \lambda_o^2 = 1 / \lambda_g^2 + 1 / \lambda_c^2$$

Where,

$\lambda_o$  = free space wavelength

$\lambda_g$  = Guide wavelength

$\lambda_c$  = Cut off wavelength

For dominant TE<sub>10</sub> mode  $\lambda_c = 2a$  where  $a$  is broad dimension of wave guide .

The following relationship can be proved

$$C = f \lambda$$

Where,

$C$  is velocity of light and  $f$  is frequency.

**PROCEDURE:**

1. Set up the test bench as shown in fig
2. Beam voltage knob should be at min position
3. Switch 'ON' the Klystron power supply, VSWR meter/CRO and cooling fan.
4. Adjust the Repeller voltage-70 to 100 volts  
Beam voltage-230V  
beam current-5 to 30mA  
modulation is set to AM,  
AM-Amplitude knob Around fully clockwise,  
AM-Frequency knob Around mid Position

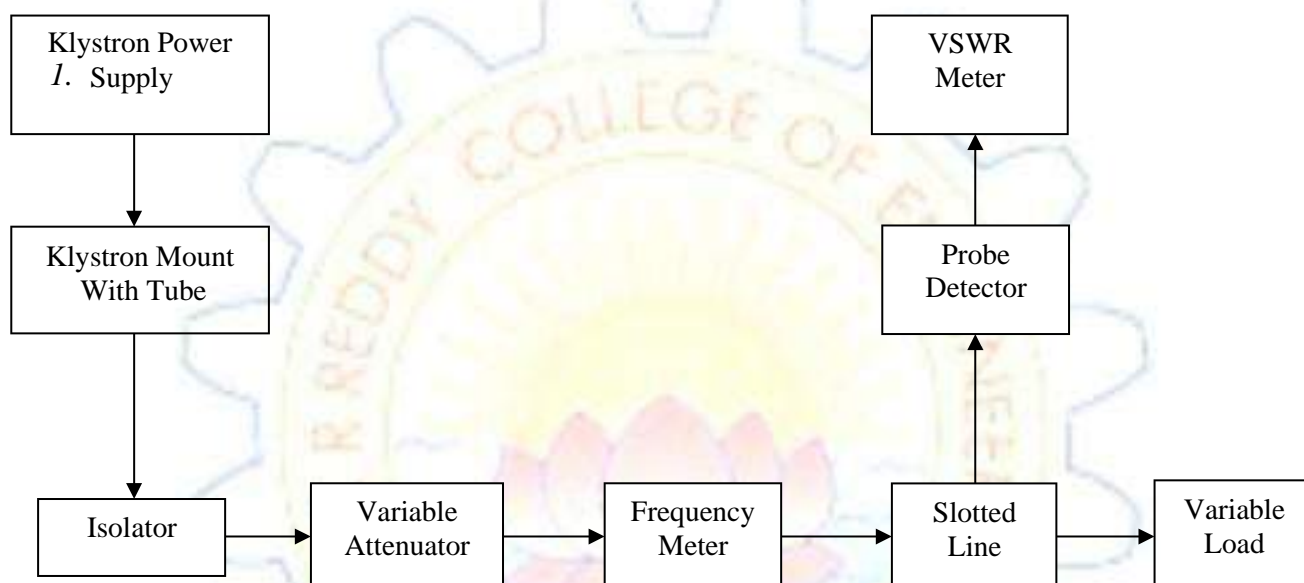


5. Observe the standing wave by moving the probe along the slotted line
6. Move the probe towards the source and note down two consecutive minimum positions and their difference is equal to half the guide wavelength

$$\lambda_g = 2(d_1 - d_2)$$

7. Set the probe at  $V_{\max}$  and Tune the frequency meter to get a 'dip' on the VSWR scale and note down the frequency directly from the frequency meter

### **EXPERIMENTAL SET UP**



### **Calculations:**

1. Guide wavelength

$$\lambda_g \text{ (Practical)} = 2(d_1 - d_2)$$

$$\lambda_g \text{ (Theoretical)} = \frac{\lambda_0}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_c}\right)^2}}$$

where  $\lambda_0 = c/f$

$$\lambda_c = 2a \quad \text{where } a = 2.286 \text{ cm}$$

2. Frequency can be calculated using the equation

$$f \text{ (Theoretical)} = c/\lambda = c \sqrt{1/\lambda_g^2 + 1/\lambda_c^2}$$

**PRECAUTIONS:-**

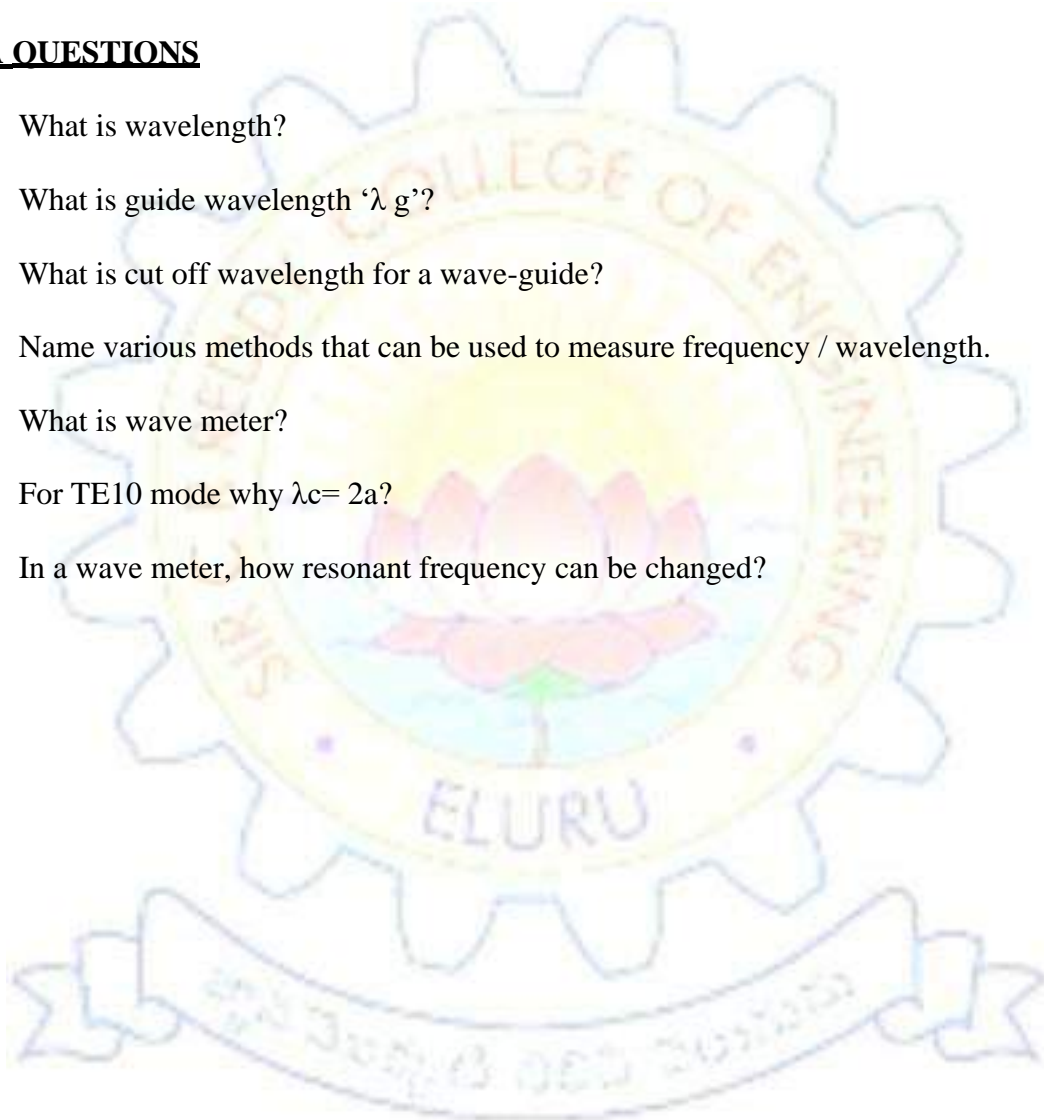
1. Keep the Cooling fan towards the Klystron tube.
2. Never keep the Repeller voltage to zero volts.

**RESULT:**

Guide wavelength of the X band waveguide is \_\_\_\_\_ and frequency of signal is

**VIVA QUESTIONS**

1. What is wavelength?
2. What is guide wavelength ' $\lambda_g$ '?
3. What is cut off wavelength for a wave-guide?
4. Name various methods that can be used to measure frequency / wavelength.
5. What is wave meter?
6. For TE<sub>10</sub> mode why  $\lambda_c = 2a$ ?
7. In a wave meter, how resonant frequency can be changed?



Exp no:

Date:

## 6. MEASUREMENT OF SCATTERING PARAMETER OF CIRCULATOR

### AIM:

To measure isolation and insertion loss of a three port Circulators/Isolator.

### THEORETICAL CONCEPT:

**ISOLATOR:** - The isolator is a two-port device with small insertion loss in forward direction and a large in reverse attenuation.

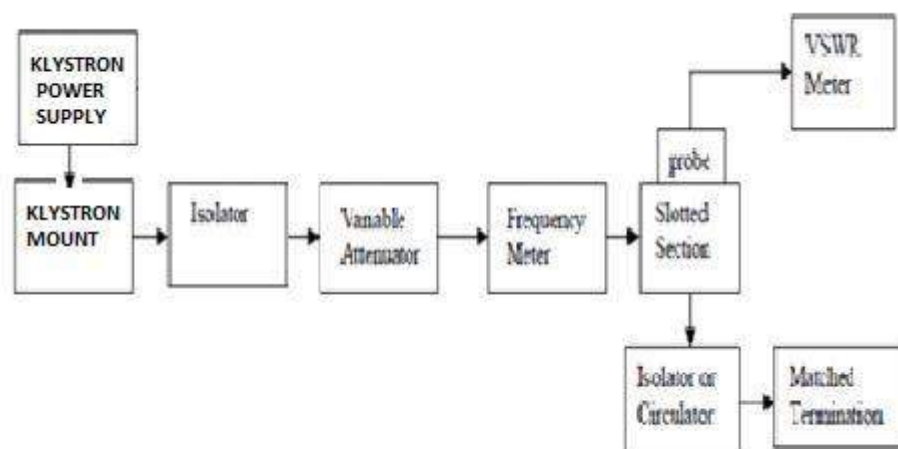
**CIRCULATOR:** - the circulator is a multi-port junction that permits transmission in certain ways. A wave incident in port 1 is coupled to port 2 only; a wave incident at port 2 is coupled to port3 only and so on. Following is the basic parameters of isolator and circulator for study.

**A. 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.

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

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

### EXPERIMENTAL SETUP



**SPECIFICATION OF APPARATUS USED:**

Klystron tube, Klystron power supply, Klystron mount, Isolator, Circulator, Slotted Section, Tunable probe, Frequency Meter, Variable Attenuator, Detector mount, Wave guide stand, Cooling fan, VSWR meter, Cables and accessories.

**PROCEDURE:****(a) Input VSWR Measurement:**

- (1) Set up the components and equipment as shown above with input port of isolator or circulator towards slotted line and matched load on other ports of it.
- (2) Energize the microwave source for particular operation of frequency.
- (3) With the help of slotted line, probe and VSWR meter, find out SWR of the isolator or circulator as describe earlier for low and medium SWR measurements.
- (4) The above procedure can be repeated for other ports or for other frequencies.

**(b) Measurement of Insertion loss & Isolation:**

- (1) Remove the probe and isolator or circulator from slotted line and connect the detector mount to the slotted section. The output of the detector mount should be connected with VSWR meter.
- (2) Energize the microwave source for max. Output for a particular frequency of operation. Tune the detector mount for maximum output in VSWR meter.
- (3) Set any reference level of power in VSWR meter with the help of variable attenuator, gain control knob of VSWR meter and note down the reading (let it be P1).
- (4) Carefully remove the detector mount from slotted line without disturbing the position of set up. Insert the isolator / circulator between slotted line and detector mount port to slotted line and detector at its output port. A matched termination should be placed at third port in case of circulator.
- (5) Record the readings in the VSWR meter. If necessary change range – db switch to high or lower position and taking 10 db changes for one set change of switch position (let it be P2).

- (6) Compute insertion loss on P1-P2 in db.
- (7) For measurement of isolation, the isolator or circulator has to be connected reverse, i.e., output port to slotted line and detector to input port with other port terminated by matched termination. After setting a reference level without isolator or circulator in the set up as described in insertion loss measurement. Let same P1 level is set.
- (8) Record the reading of VSWR meter after inserting the isolator or circulator (let it be P3).
- (9) Compute isolation as P1 – P3 in db.
- (10) The same experiment can be done for other ports of circulator.
- (11) Repeat the same for other frequency.

**PRECAUTIONS:**

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

**RESULT & COMMENTS:** Measured values are follows:

VSWR =

Insertion loss =

Isolation loss =

**APPLICATION:**

Used for calculation of losses in circulators and isolators.

**VIVA:**

1. What is Microwave Isolators?
2. Why Isolator is Uniline?
3. What is Non Reciprocal Devices?
4. What is Insertion Loss?
5. What is Reflection Loss?

Exp no:

Date:

**7. MEASUREMENT OF SCATTERING PARAMETER OF MAGIC TEE****AIM:**

Measurement of Scattering Parameters of Magic-Tee

**EQUIPMENT REQUIRED:**

- Microwave source
- Isolator
- Variable attenuator
- PIN modulator
- Frequency meter
- Slotted line
- Tunable probe
- Magic Tee
- Matched termination
- Wave guide stand
- Detector mount
- VSWR meter and accessories.

**THEORY:**

The device magic Tee is a combination of the E and H plane Tee. Arm 3, the H-arm forms an H plane Tee

and arm 4, the E-arm forms an E plane Tee in combination with arm 1 and 2 a side or collinear arms. If

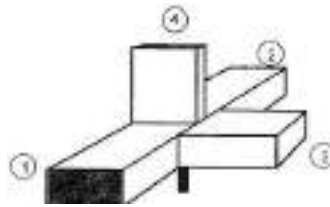
power is fed into arm 3 (H-arm) the electric field divides equally between arm 1 and 2 in the same phase,

and no electrical field exists in arm 4. Reciprocity demands no coupling in port 3 (H-arm). If power is fed

in arm 4 (E-arm), it divides equally into arm 1 and 2 but out of phase with no power to arm 3.

Further, if

the power is fed from arm 1 and 2, it is added in arm 3 (H-arm), and it is subtracted in E-arm, i.e. arm 4.



The basic parameters to be measured for magic Tee are defined below.

### 1. Input VSWR

Value of SWR corresponding to each port, as a load to the line while other ports are terminated in matched load

### 2. Isolation

The isolation between E and H arms is defined as the ratio of the power supplied by the generator 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,

$$\text{Isolation (dB)} = 10 \log_{10} \left[ \frac{P_4}{P_3} \right]$$

Similarly, isolation between other parts may also be defined

### 3. Coupling coefficient.

It is defined as  $C_{ij} = 10^{-\alpha / 20}$

Where

$\alpha$  = attenuation / isolation in dB

'i' is input arm

'j' is output arm.

Thus

$\alpha$  = attenuation / isolation in dB

'i' is input arm.

'j' is output arm.

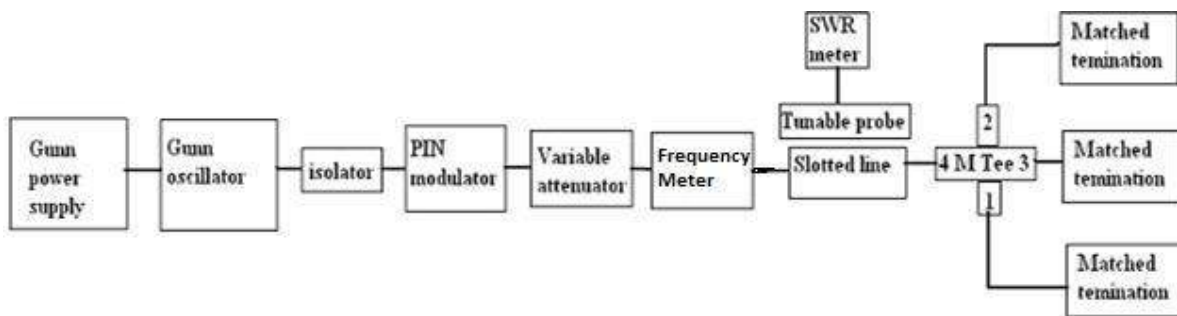
Thus

$$\alpha = 10 \log_{10} \left[ \frac{P_i}{P_j} \right]$$

Where

$P_i$  is the power delivered to arm i

$P_j$  is power detected at j arm.

**BLOCK DIAGRAM:**

Setup for the study of Magic Tee

- Measurement of Isolation and Coupling Coefficient
- Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
- With the help of variable attenuator and gain control knob of SWR meter, set any power Level in the SWR meter and note down. Let it be P3.
- Without disturbing the position of variable attenuator and gain control knob, carefully place the Magic Tee after slotted line keeping H-arm connected to slotted line, detector to E arm and matched termination to arm 1 and 2. Note down the reading of SWR meter. Let it be P4.
- In the same way measure P1 & P2 by connecting detector on these ports one by one.
- Determine the isolation between port 3 and 4 as P3-P4 in dB.
- Determine the coupling coefficient by P3- P1 for port P1 & P2.
- Repeat the above experiment for other frequencies.

**Tabulation:**

INPUT PORT	INPUT POWER(db)	o/p port	o/p power (db)
P3(H-plane)		P1	
		P2	
		P4	
P4(E-plane)		P1	
		P2	
		P3	

**CALCULATIONS:**

$$13=31=1-3=$$

$$23=32=2-3=$$

$$14=41=1-4=$$

$$24=42=2-4=$$

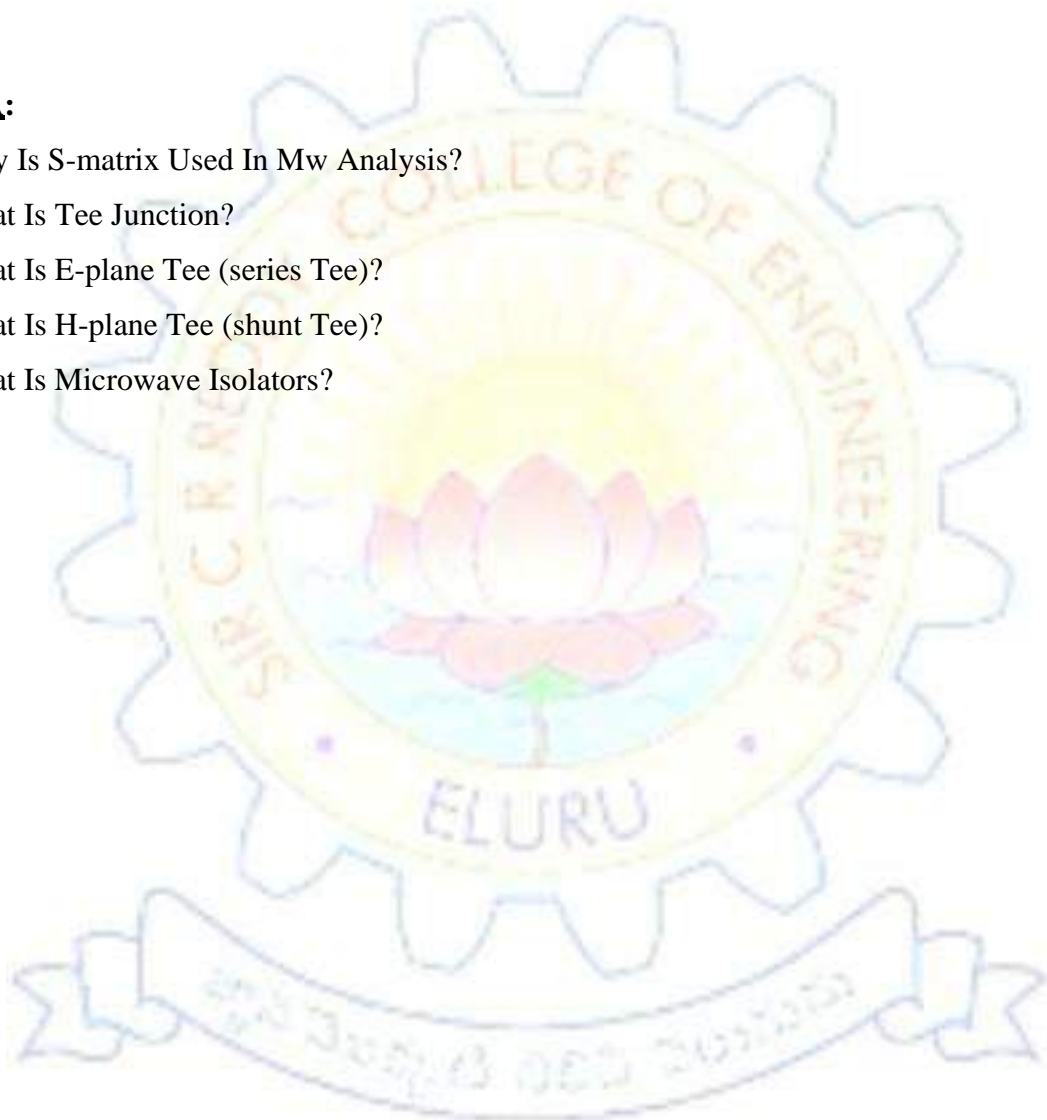


$$S = \begin{bmatrix} 0 & 0 & S_{13} & S_{14} \\ 0 & 0 & S_{23} & S_{24} \\ S_{31} & S_{32} & 0 & 0 \\ S_{41} & -S_{42} & 0 & 0 \end{bmatrix}$$

**RESULT:** Thus We observed the properties of the Magic Tee and also determined the various scattering parameters of Magic-Tee.

**VIVA:**

1. Why Is S-matrix Used In Mw Analysis?
2. What Is Tee Junction?
3. What Is E-plane Tee (series Tee)?
4. What Is H-plane Tee (shunt Tee)?
5. What Is Microwave Isolators?



**Exp no:****Date:****8. RADIATION PATTERN OF A HORN ANTENNA AND PARABOLIC ANTENNA****AIM:**

To measure the polar pattern and the gain of a waveguide Antennas (For NV9002).

**EQUIPMENTS REQUIRED:**

1. Klystron power supply
2. Klystron tube with mount
3. Isolator
4. Variable attenuator
5. Directional Coupler
6. Detector Mount
7. Matched Load
8. VSWR meter

**THEORY:**

If a transmission line propagating energy is left open at one end, there will be radiation from this end. In case of a rectangular wave-guide this antenna presents a mismatch of about 2:1 and it radiates in many directions. The match will improve if the open wave-guide is a horn shape.

The Radiation pattern of an antenna is a diagram of field strength or more often the power intensity as a function of the aspect angle at a constant distance from the radiating antenna. An antenna pattern is of course three dimensional but for practical reasons it is normally presented as a two dimensional pattern in one or several planes. An antenna pattern consists of several lobes, the main lobe, side lobes and the back lobe. The major power is concentrated in the main lobe and it is required to keep the power in the side lobes and back lobe as low as possible.

The power intensity at the maximum of the main lobe compared to the power intensity achieved from an imaginary omni -directional antenna (radiating equally in all directions) with the same power fed to the antenna is defined as gain of the antenna.

### 3dB Beam Width:

- This is the angle between the two points on a main lobe where the power intensity is half the maximum power intensity.
- When measuring an antenna pattern, it is normally most interesting to plot the pattern far from the antenna.

Far field pattern is achieved at a minimum distance of

$$2D^2/\lambda_0 \quad \text{-(for rectangular Horn antenna)}$$

Where, D is the size of the broad wall of horn aperture

$\lambda_0$  is free space wave length.

It is also very important to avoid disturbing reflection. Antenna measurement are normally made at outdoor ranges or in so called anechoic chambers made of absorbing materials.

Antenna measurements are mostly made with unknown antenna as receiver. There are several methods to measure the gain of antenna. One method is to compare the unknown antenna with a standard gain antenna with known gain. Another method is to use two identical antennas, as transmitter and other as receiver. From following formula the gain can be calculated.

$$P_r = \frac{P_t \lambda_0 G_1 G_2}{(4\pi S)^2}$$

Where,

$P_t$  is transmitted power,

$P_r$  is received power,

$G_1, G_2$  is gain of transmitting and receiving antenna,

S is the radial distance between two antennas,

$\lambda_0$  is free space wave length.

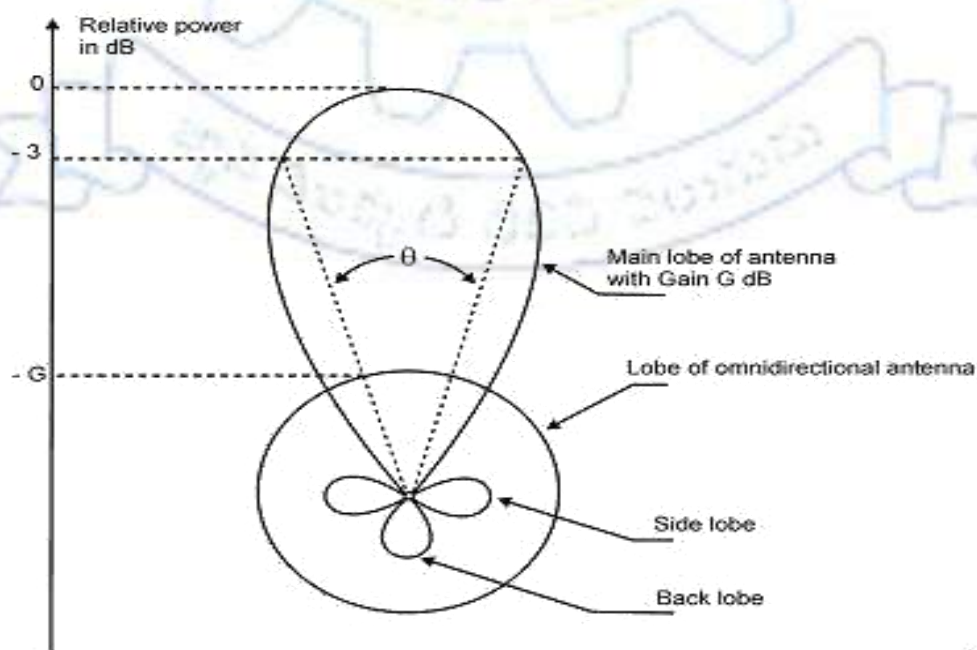
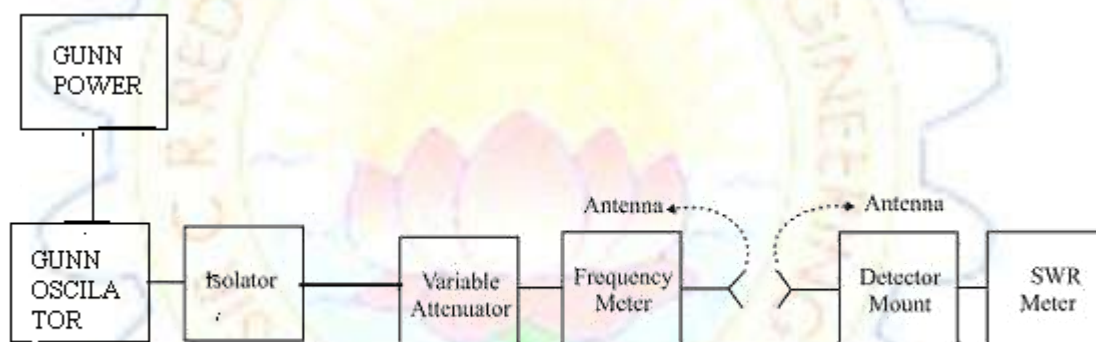
If both, transmitting and receiving antenna are identical having gain  $G$  then above equation becomes.

$$P_r = \frac{P_t \lambda_0 G^2}{(4\pi S)^2}$$

$$G = \frac{4\pi S}{\sqrt{\lambda_0}} \sqrt{\frac{P_r}{P_t}}$$

In the above equation  $P_t$ ,  $P_r$  and  $S$  and  $\lambda_0$  can be measured and gain can be computed. As is evident from the above equation, it is not necessary to know the absolute value of  $P_t$  and  $P_r$  only ratio is required which can be measured by VSWR meter.

### EXPERIMENTAL SETUP:



**Model radiation Pattern Diagram**

**PROCEDURE:****Antenna Radiation Pattern Plotting:**

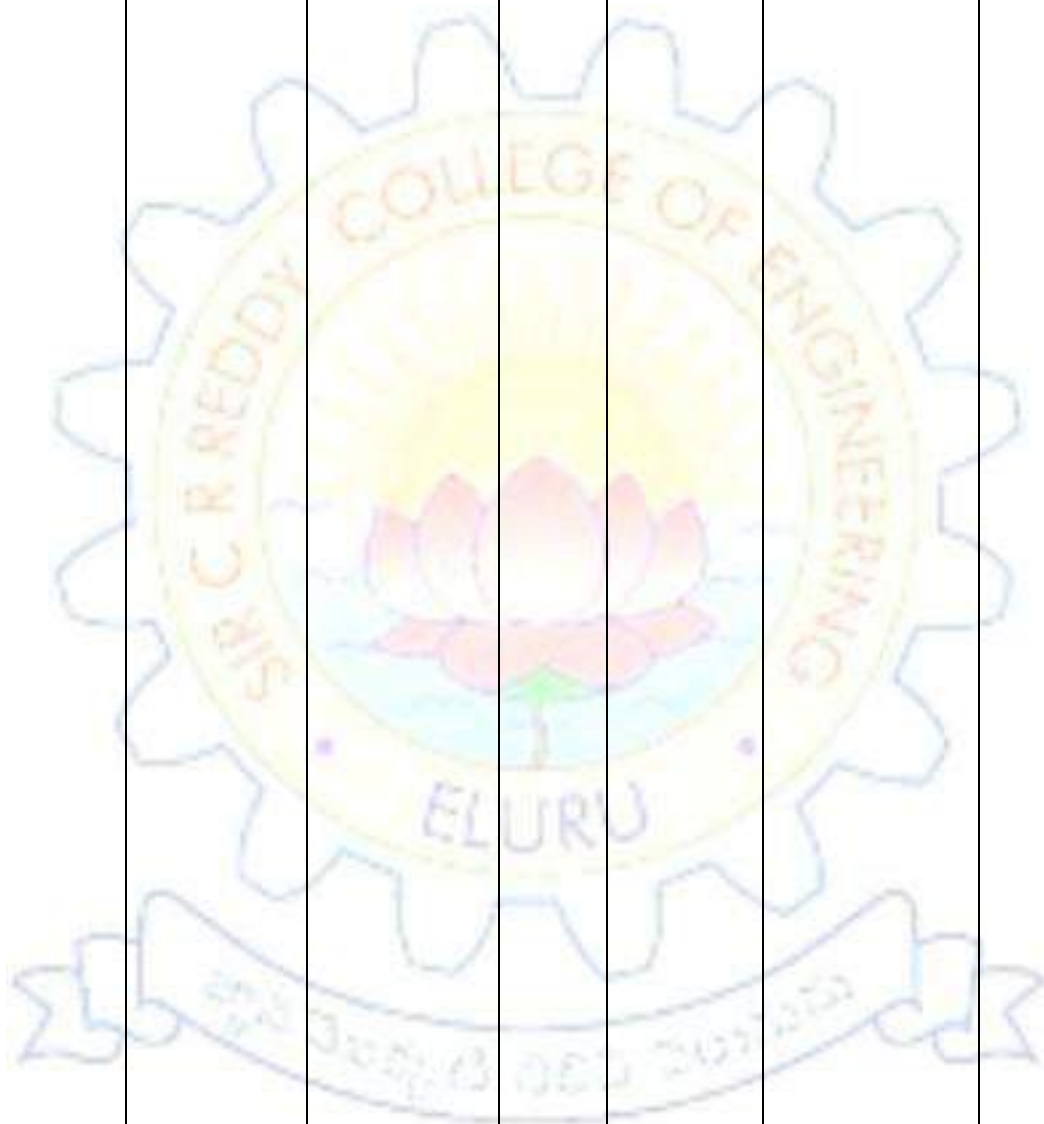
1. Set up the equipments as shown in the figure, keeping the axis of both antennas in same axis line and for start connect horn antenna at both the ends.
2. Energize the Microwave source for maximum output at desired frequency with square wave modulation as per procedure described in experiment
3. Obtain full scale deflection (0 dB) at any convenient range switch position of the SWR Meter by gain control knob of SWR meter or by variable attenuator.
4. Turn the receiving horn to the left in  $2^\circ$  or  $5^\circ$  steps up to and note the dB reading. When necessary change the range switches to next higher.
5. Draw the radiation pattern (power vs. angle)
6. Now you can replace the antenna by another given antenna at the receiver position.
7. From diagram determine 3dB width (beam width) of horn antenna.

**GAIN MEASUREMENT:**

1. Set up the equipments as shown in fig. Both horns should be in line. Connect standard gain horn antenna (16dB) at transmitter end and any other antenna for which gain is to be measured at the receiver end.
2. Keep the range dB switch of VSWR meter at appropriate position.
3. Energize the Gunn Oscillator for maximum output at desired frequency with modulating amplitude and frequency of potentiometer and by tuning of detector
4. Obtain maximum reading in SWR meter with variable attenuator. Record this reading as  $P_r$  (received power).
5. Replace the transmitting horn by detector mount and change the appropriate range db position to get the reading (do not touch the gain control knob) Note and record the range db position and reading as  $P_t$ .
6. Now change the horn antenna at the receiver end.
7. Now repeat the same procedure for parabolic antenna.

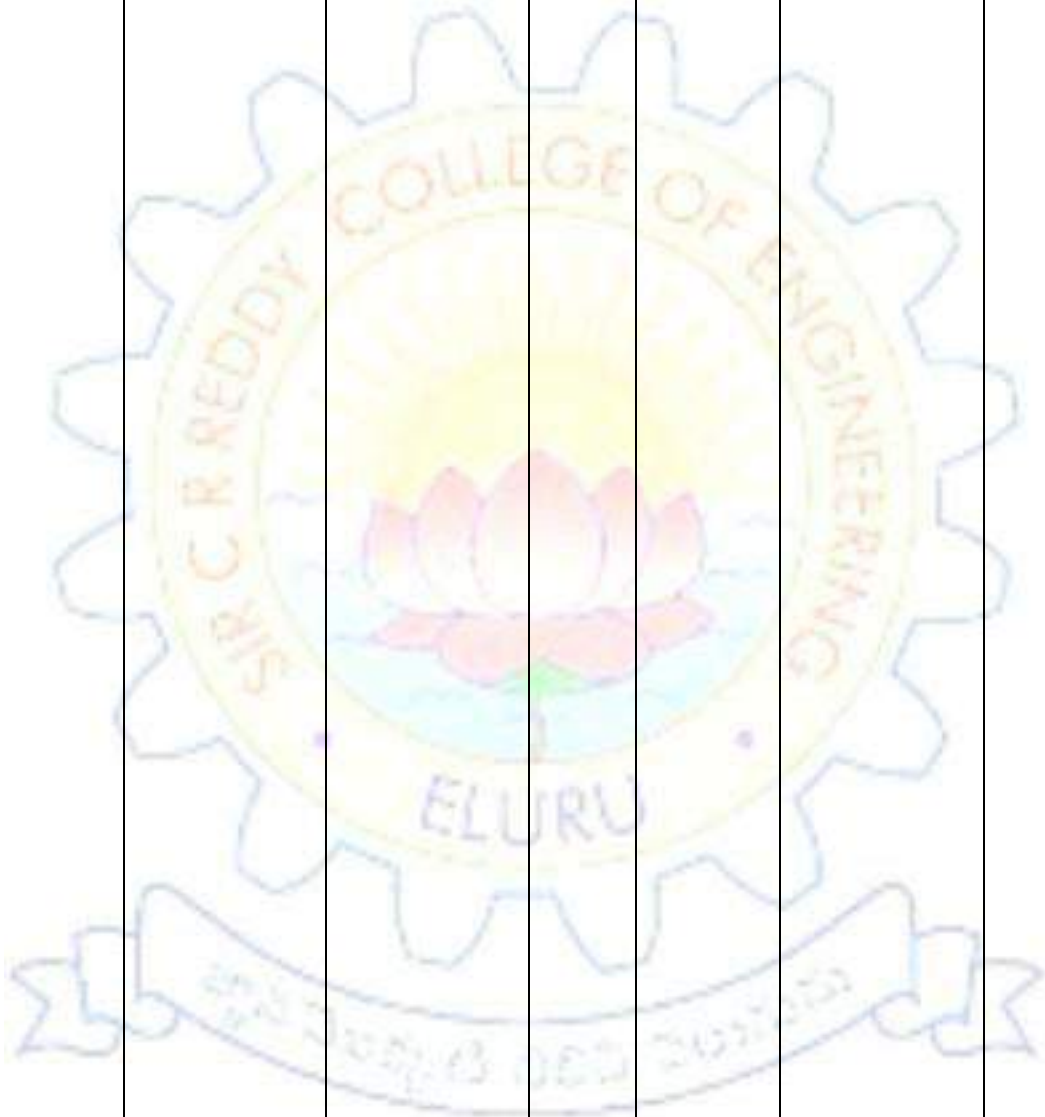
**TABULAR FORM:** For Horn Antenna

S. No	Angle in degrees	Power level in dB $\mu$ V	Normalized Power	S. No	Angle in degrees	Power level in dB $\mu$ V	Normalized Power



**TABULAR FORM:** For Parabolic Antenna

S. No	Angle in degrees	Power level in dB $\mu$ V	Normalized Power	S. No	Angle in degrees	Power level in dB $\mu$ V	Normalized Power



**PRECAUTIONS:**

1. Ensure tight connections of the Apparatus.
2. Avoid cross connections of the thread.

**RESULT AND ANALYSIS:**

$$Pr = \frac{Pt \lambda^0 G1 G2}{(4\pi S)^2}$$

Where,  $P_t$  = transmitter power

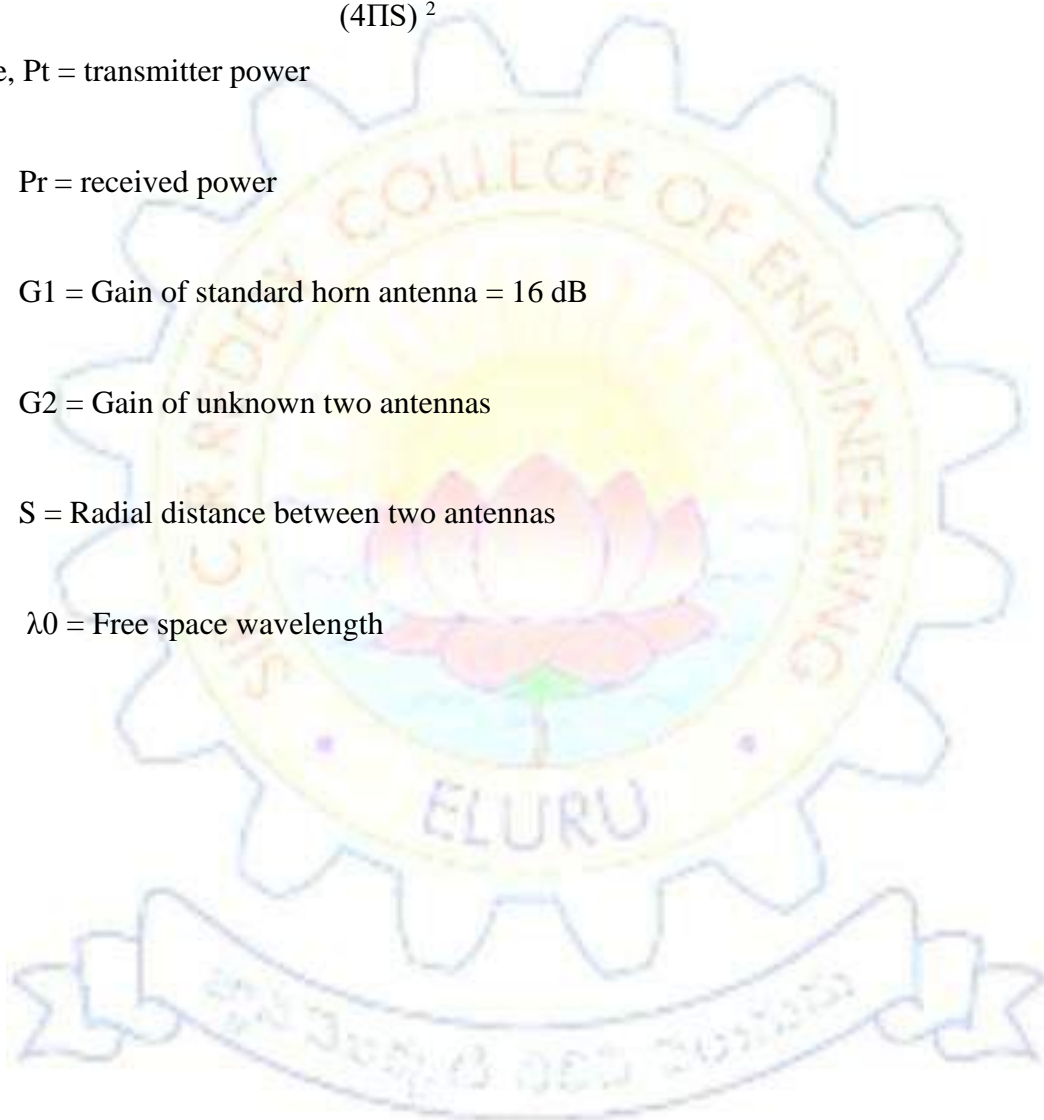
$P_r$  = received power

$G_1$  = Gain of standard horn antenna = 16 dB

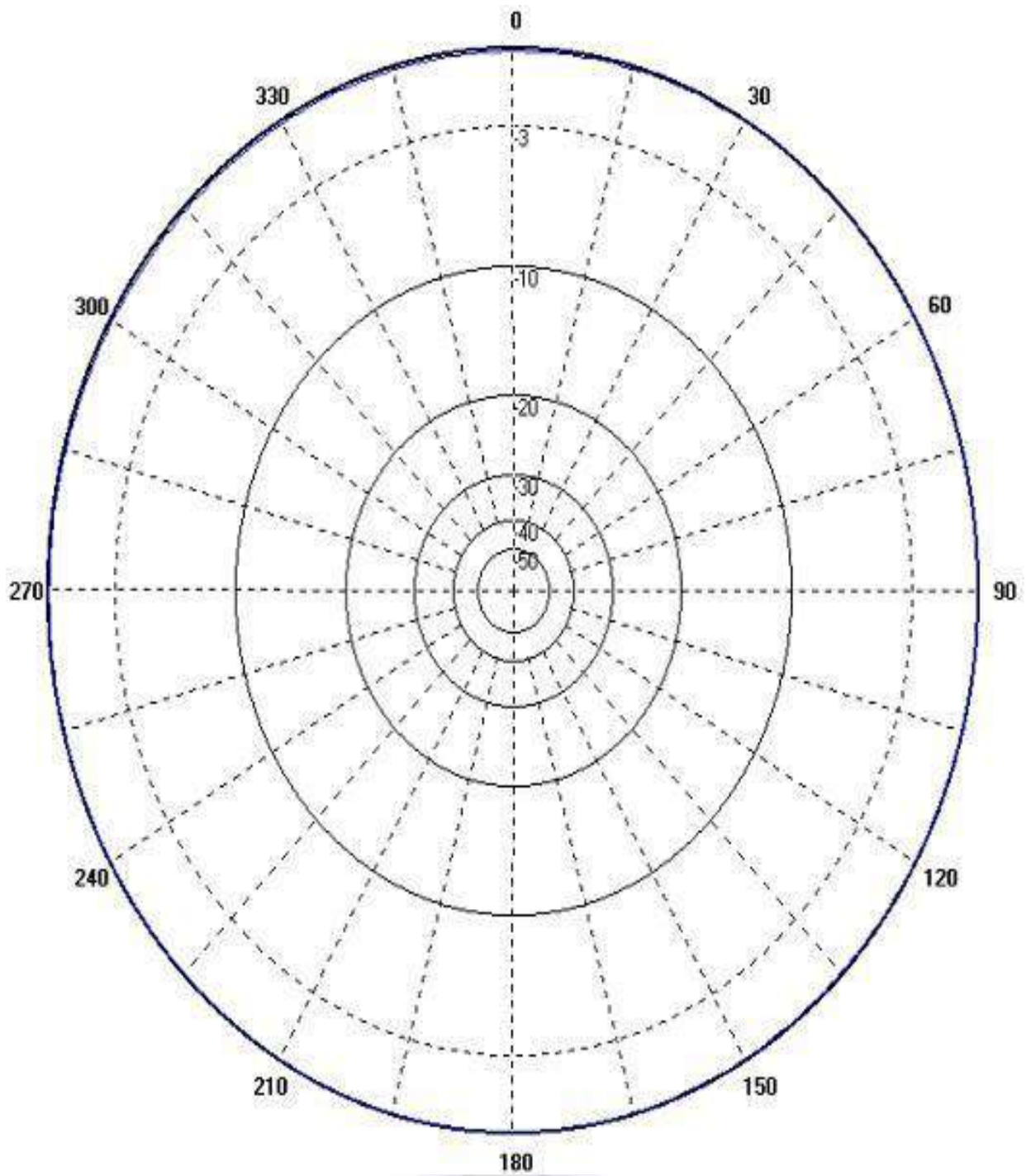
$G_2$  = Gain of unknown two antennas

$S$  = Radial distance between two antennas

$\lambda_0$  = Free space wavelength

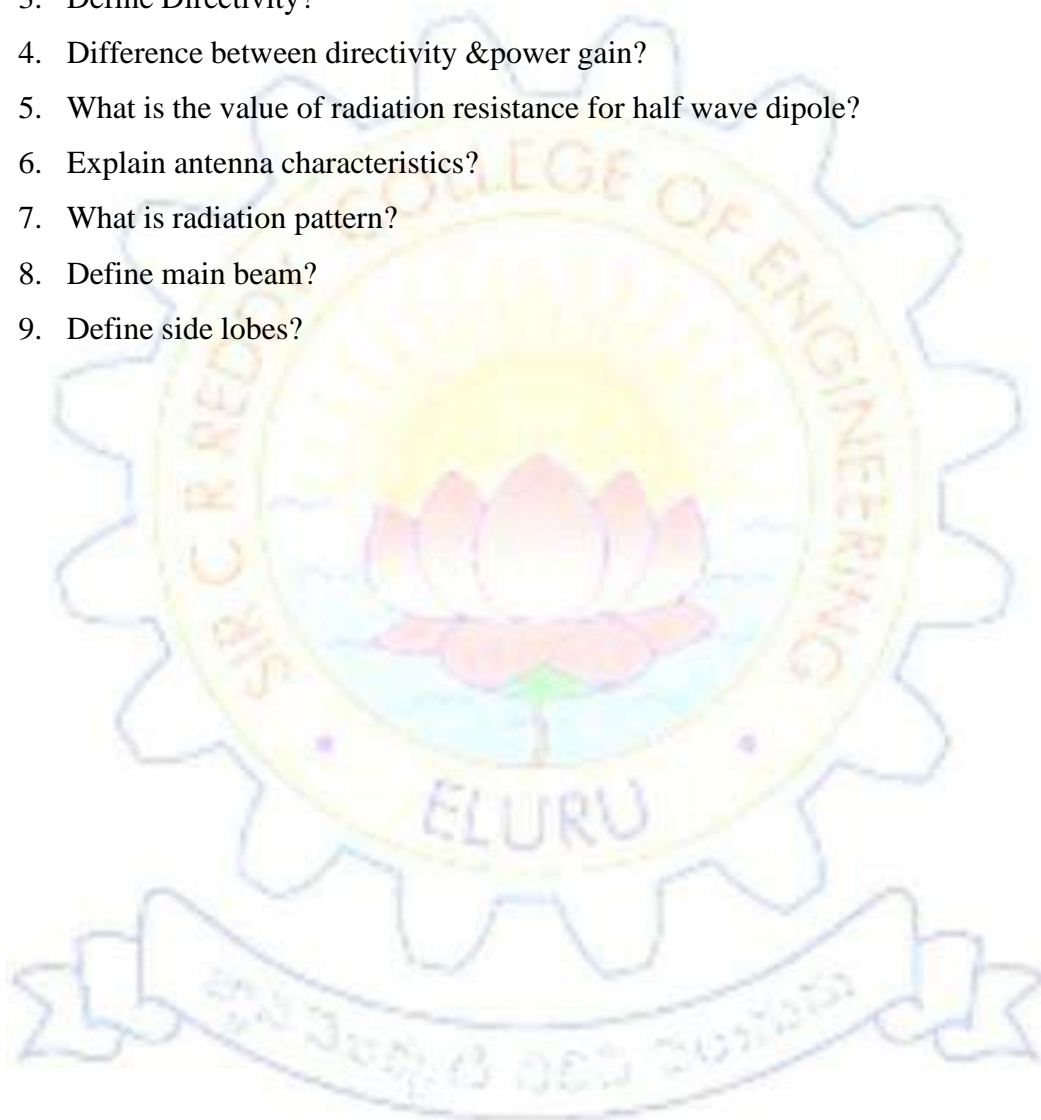




**POLAR GRAPH:**

**RESULT:****VIVA QUESTIONS:**

1. Define antenna?
2. Define radiation pattern?
3. Define Directivity?
4. Difference between directivity & power gain?
5. What is the value of radiation resistance for half wave dipole?
6. Explain antenna characteristics?
7. What is radiation pattern?
8. Define main beam?
9. Define side lobes?



Exp no:

Date:

## 9. SYNTHESIS OF MICROSTIP ANTENNAS USING HFSS

### AIM:

The objective is to simulate a microstrip patch antenna resonating at a frequency of 7.55 GHz. The Length,  $L$ , of the substrate can be approximated by  $\lambda_0/2$ , where  $\lambda_0$  is the free space wavelength. We will consider a simple design example which employs a strip line to feed the patch antenna from its radiating edge.

### PROCEDURE:

Open HFSS and save a New Project

#### **How to start HFSS?**

**HFSS** should be installed on the computer or station you are working on. There should be an **HFSS** icon on the desktop you can double click on it to launch HFSS, or you can go to “**Start**” button on the lower left corner of your screen, click on it, then go to “**Programs**” button and a list of programs will pop up. Go to “**Ansoft<< HFSS << HFSS**”.

#### **How to Open a New Project?**

As you start **HFSS**, a project is listed in the project tree in the **Project Manager** window and is named **project1** by default. Project definitions, such as material assignment, boundary conditions, and excitation ports are stored under the project name.

#### **Save the Project**

On the **File** menu, click **Save As**. Use the file browser to locate the folder in which you want to save the project, such as C:\Ansoft\HFSS9\Projects, and then double-click the folder’s name. Type **Patch** in the **File Name** text box and click **Save**. Now, the project is saved in the folder you selected by the file name with an extension of hfss: **patch.hfss**.

#### **Insert an HFSS Design**

On the **Project** menu, click **Insert HFSS Design**. The new design is listed in the project tree. It is named *Model* by default. The **3D Modeler** window appears to the right of the **Project Manager**.

Figure 1: HFSS window

You can rename the model by right-clicking on the Model and then click **Rename**. Type the name then press **Enter**.

#### **Select a Solution type**

Now you need to specify the design’s solution type. As you set up the design for analysis, available settings will depend upon the solution type. For this design, you will choose **Driven Modal** as the solution type, which is appropriate when calculating mode-based  $S$  parameters of antenna problems driven by a source.

On the **HFSS** menu, click **Solution Type**. In the **Solution type** dialog box, select **Driven Modal**, and then click **OK**.

#### **Set the Drawing Units**

You will now set the units of measurement for drawing the geometric model.

On the **3D Modeler** menu, click **Units**. In the **Set Model Units** dialog box, click **mm** in the **Select Units** pull-down list, and then click **OK**.

### Creating the Model

The patch antenna is created by three bricks: the first for the radiating plate, the second for the microstrip line, and the third for the substrate. The ground plane is specified by a perfect electrically conducting boundary condition.

The coordinates are assigned as follows.

The starting point for the ground plane and substrate is at (0,0,0).

The Length,  $L$ , of the substrate and the width,  $W$ , are chosen as 28.1 mm and 32 mm, respectively.

As for the patch, the length  $\sim \lambda/2 \sim 12.45$  mm and the width of the patch is half that of the ground and substrate = 16 mm. However, the patch's starting point is at (28.1/4, 32/4, 0).

The patch's starting point is located at  $1/4$  of the total width of the ground plane and stretches its length 12.45 mm in the positive  $x$ -direction.

Similarly for the  $y$ -direction, the patch is at  $1/4$  of the total length of the ground plane located in the  $x$ - $y$  plane ( $z=0$ ).

Moreover, the feed line should be located some where between the values of the starting point and ending point of the patch.

Although the feed line is located at the midpoint, we have to shift the feed line a little to the upper or lower side to achieve impedance matching. In our case it is the total length of the patch divided by 4 plus the starting point of the patch equals the starting point of the feed:  $[(12.45/4)+7.025]=10.13$  mm.

The feed's full length value is chosen to be almost  $1/5$  of the patch's length ( $12.45/5 = 2.49$ ).

Note that the  $y$ -ordinate has to be at the starting of the patch which is 8 mm and stretches across the positive  $x$ -axis 2.49 mm. As for the boundary, it is stretched 5 mm around the substrate plane in the positive  $z$  direction. Finally, the port is the  $x$ - $z$  plane ( $y=0$ ) where its  $x$  starting point is the same as the feed's starting point and the  $z$  point covers the whole face from -0.794 to 0.794.

Understanding the dimensions of the project is very important. Now follow the following tables of coordinates.

**Table 1: Patch**

Startin Point(mm)	Full Length(mm)
$x = 7.025$	$dx = 12.45$
$y = 8$	$dy = 16$
$z = 0$	$dz = 0.05$

**Table 2: Micro trip Line**

Startin Point(mm)	Full Length(mm)
$x = 10.13$	$dx = 2.49$
$y = 0$	$dy = 8$
$z = 0$	$dz = 0.05$

**Table 3: Ground Plane**

Startin Point(mm)	Full Length(mm)
x = 0	dx = 28.1
y = 0	dy = 32
z = -0.794	dz = 0

Table 4: Substrate

Startin Point(mm)	Full Length(mm)
x = 0	dx = 28.1
y = 0	dy = 32
z = 0	dz = -0.794

Table 5: Port

Startin Point(mm)	Full Length(mm)
X = 10.13	Dx = 2.49
y = 0	dy = 0
z = -0.794	dz = 0.794

Table 6: Boundary

Startin Point(mm)	Full Length(mm)
x = -5	dx = 33.1
y = 0	dy = 37
z = -0.794	dz = 5.794

### Drawing the Model

Drawing the model would now be easy. All you have to do is to fill in the coordinates.

First, let's

start by drawing the ground plane. Please refer to the coordinates of the Ground Plane, Table 3.

Select the menu item **Draw> Box**. Using the coordinate entry fields in Table 3, enter the box

position (x, y, z) then enter the opposite corner of the base rectangle (dx, dy, dz), where dx, dy,

and dz stand for full length, full width, and full height respectively. The dimensions of the ground

plane are given.

A properties dialog window appears, makes sure you have your coordinates set right in the

**Position, Xsize, Ysize, and Zsize values.**

Click on **Attribute tab** and enter **gnd** in the value of the name. Click on material;

assign PEC

(Perfect Electric Conductor) material to the object. Then choose the **Color** and

**Transparency**

value of your preference. Click the **OK** button.

Second, let's draw the substrate. The substrate has the same dimensions of the ground plane.

Remember that the ground plane lies at  $z = -0.794$  and is of zero thickness ( $dz=0$ ), so the substrate

has to be of 0.794 mm in thickness and since the starting point was at zero, so the full height is in

$-z$ -direction. **Draw > Box** using the coordinates in Table 4, set the position of the box ( $x, y, z$ ) and

enter the opposite corner of the box ( $dx, dy, dz$ ). The properties dialog window pops up make sure

all your coordinates are right. Click the Attribute tab; enter **Substrate** in the name value box.

Now assign the material to be **Rogers RT/Duroid 5880(tm)** of relative permittivity 2.2.

Click

**OK**. Again choose **Color** and **Transparency** value of your preference. Click the **OK** button.

Third, we create the patch. Knowing that the patch should be in the center, the coordinates are

easy to calculate from the ground and substrate dimensions. The center of the patch, the ground

plane, and the substrate are the same and is at  $(28.1/2, 32/2, 0)$ . Subtract the center point

coordinates from the substrate coordinates to calculate the starting point and the full length, width and height of the patch are given. **Draw > Box** using the coordinates in

Table 1, set the position of the box ( $x, y, z$ ) and enter the opposite corner of the box ( $dx, dy, dz$ ).

The properties dialog window pops up, make sure all your coordinates are right.

Click the Attribute tab; enter **Patch** in the name value box. Now assign the material to be **PEC**.

Click **OK**. Again choose **Color** and **Transparency** value of your preference. Click the **OK** button.

Fourth, create the microstrip line. The microstrip line's position is chosen somewhere between the

ends of the patch. In reality it should be at the middle, however, it is shifted more to one side of the patch for impedance matching purposes. **Draw > Box** using the coordinates in Table 2, set the

position of the box ( $x, y, z$ ) and enter the opposite corner of the box ( $dx, dy, dz$ ). The properties dialog window pops up, make sure all your coordinates are right. Click the Attribute tab; enter **StripLine** in the name value box. Now assign the material to be **PEC**. Click **OK**. Again choose **Color** and **Transparency** value of your preference. Click the **OK** button.

We know that the **Patch** and **StripLine** should be one object. So, we need to unite them. Note that both objects are of the same material. Click on both objects that you need to unite, i.e.

**Patch**

and **StripLine** in the history tree. Click on one and hold the **CTRL** key and click on the other. Click **3D Modeler > Boolean > Unite**. The two objects are united now. You can always check your steps in the history tree and in case you need to delete a previous step/command, click **Edit**

**> Undo.**

### **Assign Boundary**

Now the model has been created, we need to assign boundary conditions. In HFSS, radiation boundaries are used to simulate open problems that allow waves to radiate infinitely far into space. HFSS absorbs the wave at the radiation boundary, essentially ballooning the boundary infinitely far away from the structure. In our case, our **ABC** (Absorbing Boundary condition) is an air box.

**Draw > Box** using the coordinates in Table 6, set the position of the box ( $x, y, z$ ) and enter the opposite corner of the box ( $dx, dy, dz$ ).

The properties dialog window pops up, make sure all your coordinates are right. Click the **Attribute** tab; enter **Air** in the name value box. Now assign the material to be **Air**. Click **OK**. Again choose **Color** and **Transparency** value of your preference. Click the **OK** button. The boundary condition should satisfy a certain distance from the antenna. Normally, its value is chosen between  $\lambda/8$  to  $\lambda/12$ , where  $\lambda$  is calculated from  $\lambda=c/f$ , where  $c$  is  $3 \times 10^8$  m/s and  $f$  is the frequency in (Hz).

### **Assign Excitation**

Having the entire model set now, the only missing part is the excitation. The excitation is a waveguide port at the beginning of the micro strip line. The reference plane of this port is located

directly at the beginning of the radiating plane. Antennas are excited through the port. We need to

create the port. **Draw > Box** using the coordinates in Table 5, set the position of the box ( $x, y, z$ ) and enter the opposite corner of the box ( $dx, dy, dz$ ). The properties dialog window pops up, make

sure all your coordinates are right. Click the **Attribute** tab; enter **Port** in the name value box. No

material is assigned. Click **OK**. Again choose **Color** and **Transparency** value of your preference. Click the **OK** button.

Choose the object **Port** from history tree, right-click and assign excitation. In our case, it is **waveport**. Click **waveport**, name it as your preference, then click **Next**, now define your integration line. Normally, integration line is defined from the bottom middle point to the upper middle point. Keep other values as default. Click **Finish**.

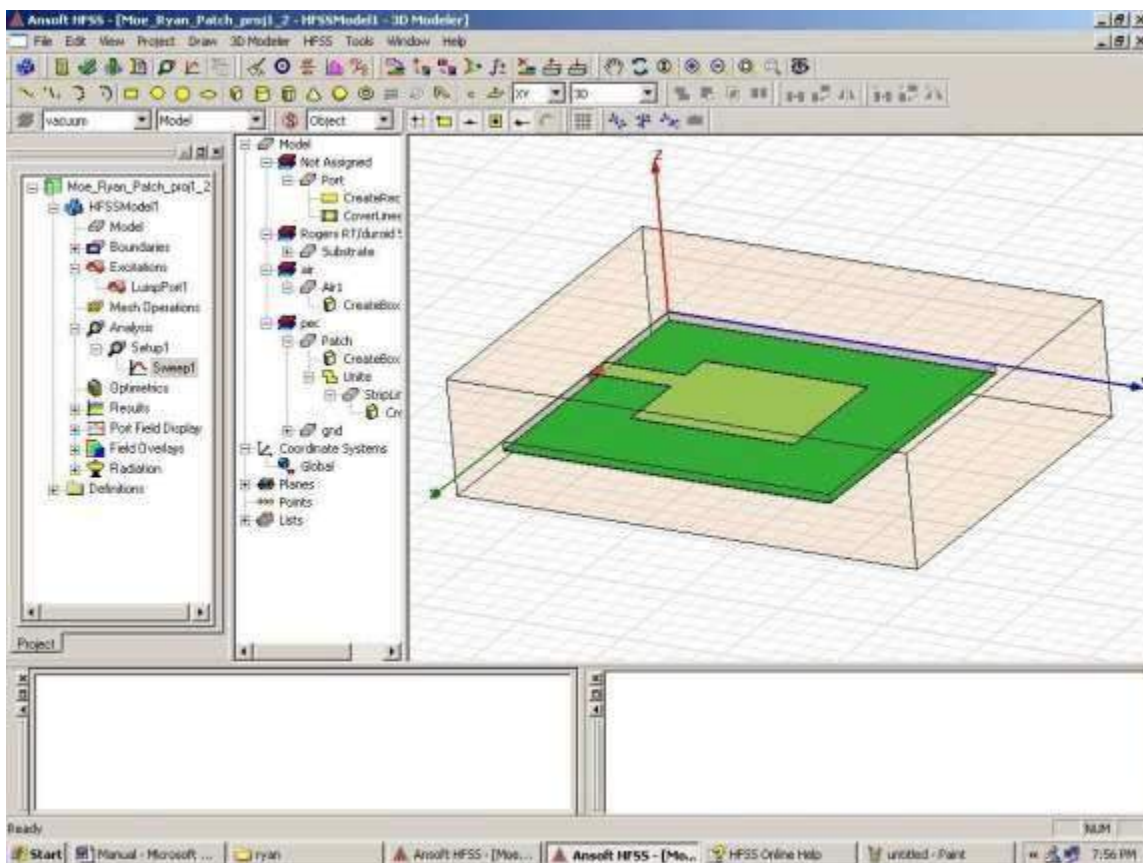


Figure 4: Final model

### Analyze

To start the solution process, select the menu item **HFSS > Analyze**.



Figure 5: Analysis window

### Solution Data

To view the **Profile/Convergence/Matrix Data**, select the menu item **HFSS > Results >**

### Solution Data

Note: The Solution Data window can be also displayed by right-click on the Setup1 under analysis on the HFSS design tree. Note also that the default view is Profile. Select the Convergence tab first, and then Plot radio button to view a graphical representations of the convergence data. Click **Close** button.



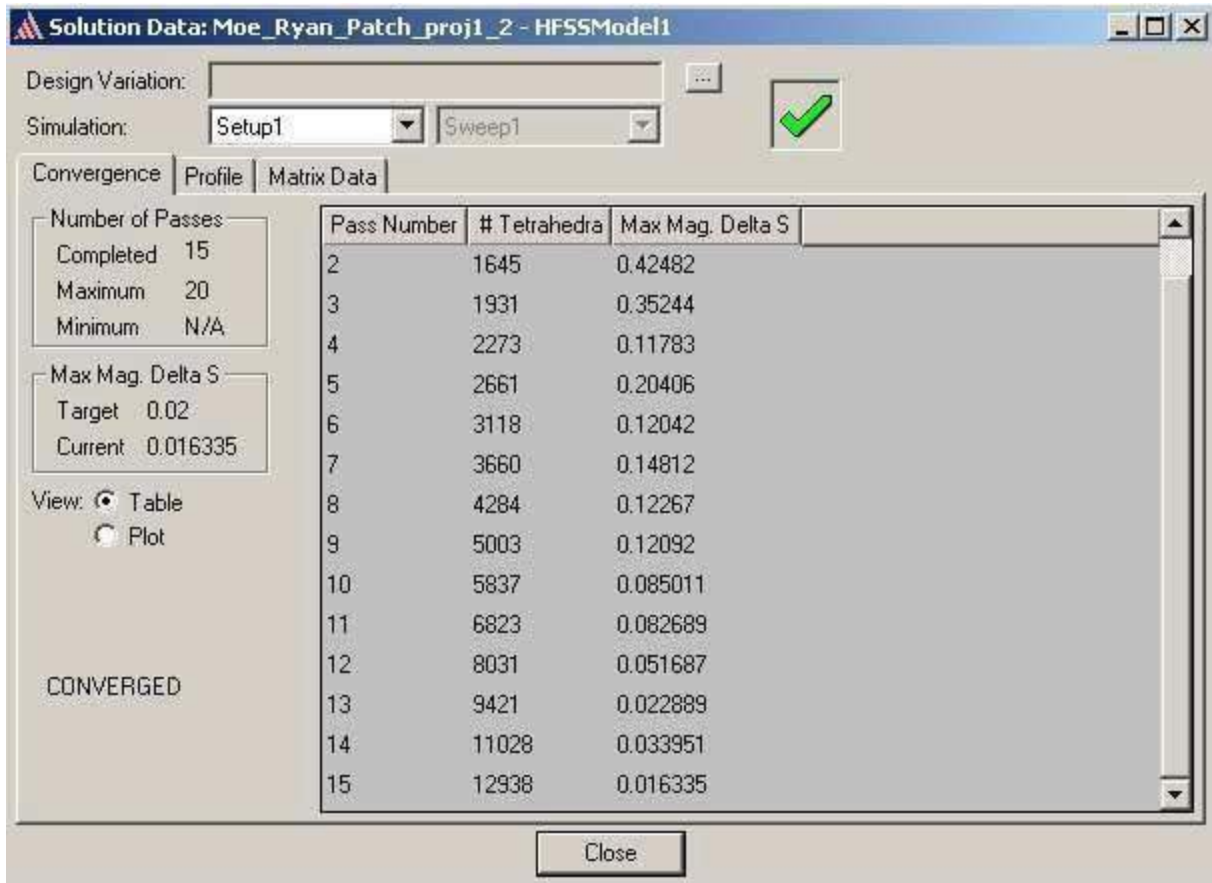


Figure 6: Convergence data

The simulation will stop as soon as the results converge, which is at pass 15.

### Create Reports

Create Modal S-Parameter Plot versus Frequency

To create a report, select the menu item **HFSS > Results > Create Report**. Set Report Type to **Modal S Parameters, Display Type to Rectangular** then click **OK** button. In the Traces Window, set Solution to Setup1: Adaptive1. In the Y tab, set Category to S Parameter, Quantity to

S (waveport, waveport), Function to dB and click **Add Trace** button. Click **Done** button. Note that you can create any type of report it all depends on what you want to analyze specifically.

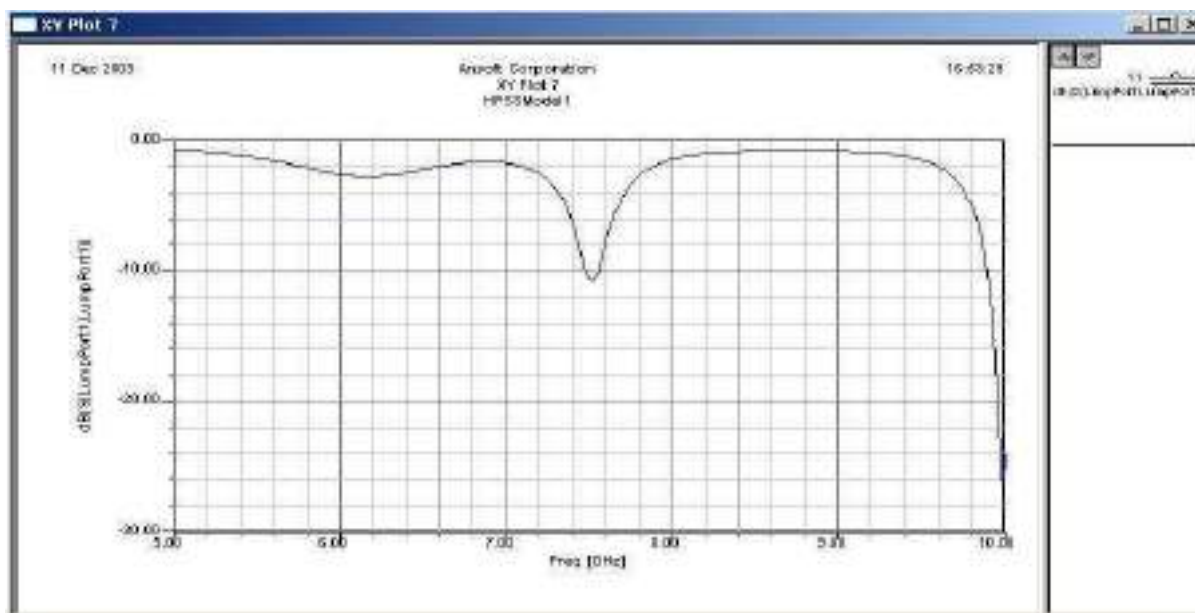


Figure 7: S-parameter

The antenna is resonating around 7.5 GHz.

Note: More accurate results could be achieved by zooming in the simulation between 7.00 GHz and 8.00 GHz. (Change the **Start** and **Stop** values to 7 GHz and 8 GHz, respectively then run simulation again).

Moreover, we notice that  $Z_{in}$  at 7.55 GHz is  $96.492 \Omega$ . To view  $Z_{in}$ , go to **HFSS<Results<Solution Data** click on **Z Matrix** and drag the frequency menu to 7.54 GHz and read the Magnitude of the input impedance.



Figure 8: Input impedance

### **Radiation Pattern:**

Create infinite sphere. Then go to **HFSS< Results< Create Report**. When the new window pops

up change the **Report Type** to **Far Field** and **Display type** to **3D Polar Plot**. Click **Add Trace**

then OK.

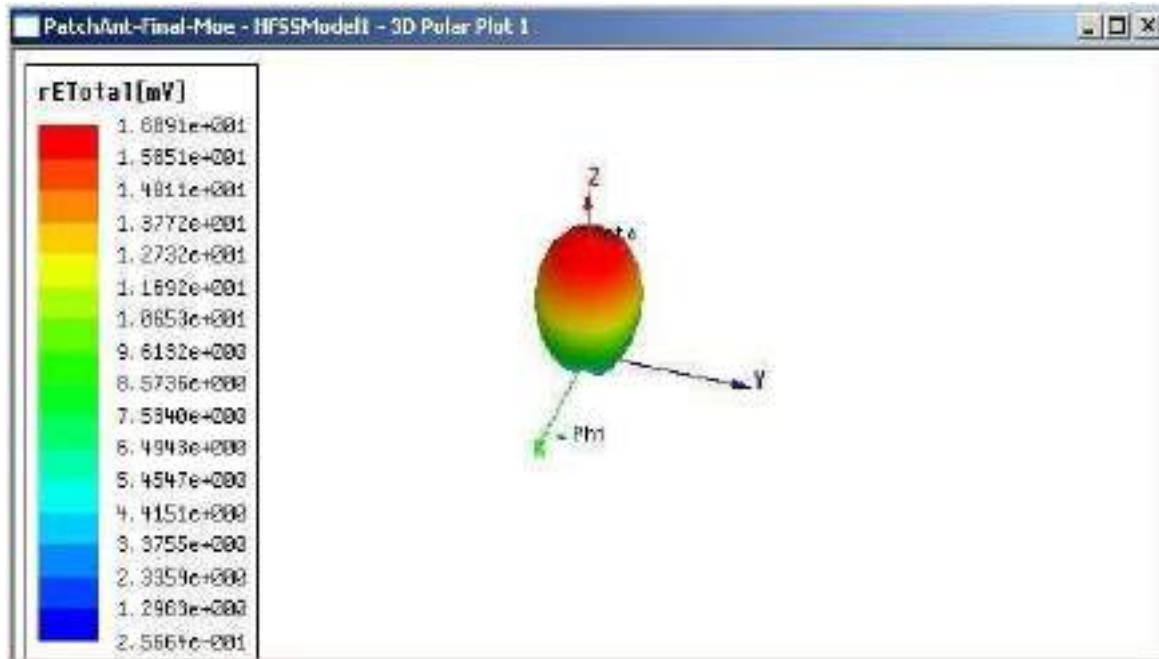


Figure 9: Far field radiation pattern over an infinite sphere

An interesting exercise for the reader is to adjust the position of the feed such that the input impedance of the patch is matched to that of the feed line. This can be achieved by creating a parameterized model of the geometry and search for the feed position which will yield a minimum value of the reflection coefficient.

### **RESULT:**

### **VIVA QUESTIONS:**

1. What are the limitations of microstrip patch antenna?
2. Why microstrip antenna is preferred over any other type of antennas?
3. What are the advantages of microstrip patch antenna?
4. What are the applications of microstrip patch antenna?

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**10.****CHARACTERIZATION OF LED****AIM:**

V-I characteristics of Photo LED

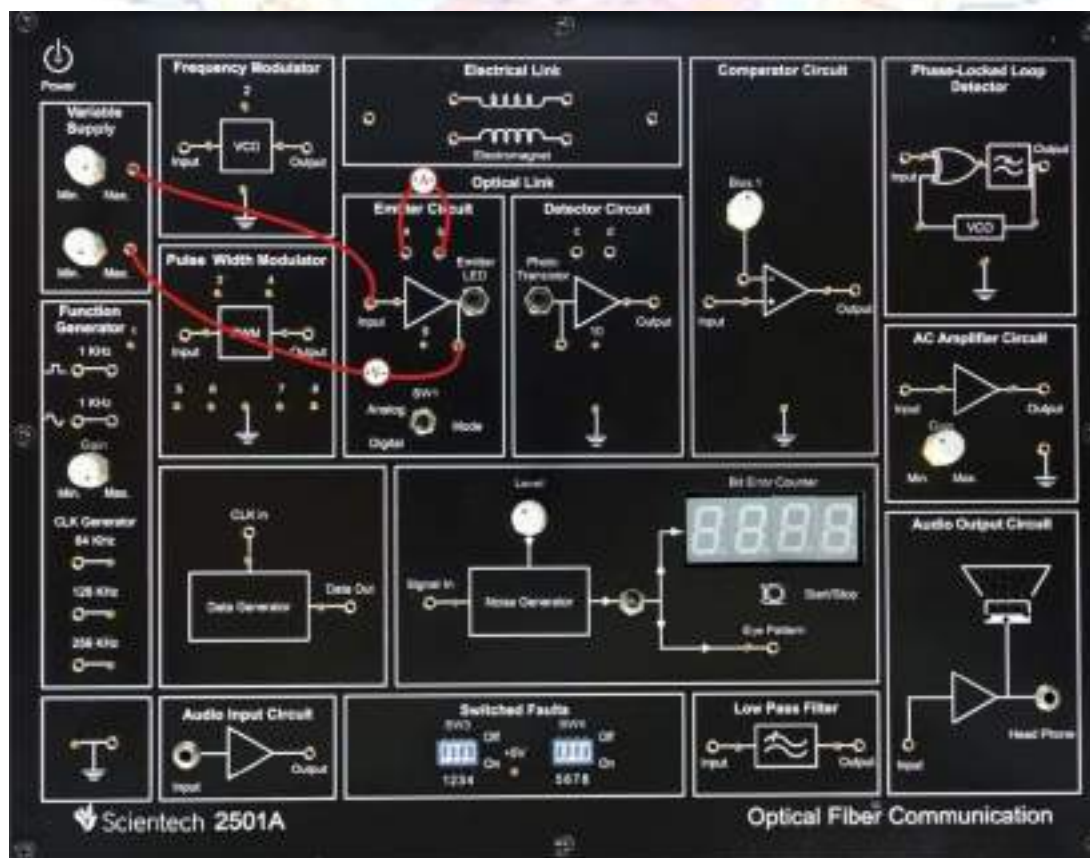
The aim of this experiment is to plot the V - I characteristic of LED.

**EQUIPMENTS REQUIRED:**

- Scientech 2501A TechBook with Power Supply and mains cord
- Optical Fibre cable
- Scientech Oscilloscope
- Scientech Digital Multimeter

**THEORY:**

LED's and LASER diodes are the commonly used sources in optical communication systems, whether the system transmits digital or analog signal. It is therefore, often necessary to use linear electrical to optical converter to allow its use in intensity modulation & high quality analog transmission systems. LED's have a linear optical output with relation to the forward current over a certain region of operation.

**CONNECTION DIAGRAM:**

**PROCEDURE:**

- Connect the TechBook Power Supply with mains cord to TechBook Scientech2501A.
- Ensure that all switched faults are in OFF condition.
- Put the mode switch SW1 to Digital to drive the emitter in Digital mode.
- Make connections as shown in the above figure
  - ☒ Connect the variable Power Supply 1 to the emitter input. Keep the level of the supply to minimum position.
  - ☒ Connect an Ammeter between point 'a' and 'b' to measure the forward current ( $I_f$ ).
  - ☒ Connect a Voltmeter between emitter input and variable Power Supply 2 to measure the forward voltage ( $V_f$ ). Keep the level of the supply to maximum position. It measures the voltage drop across the 1kohms (connected in series with Photo LED) current limiting resistors.
- Switch 'On' the Power Supply of TechBook and Oscilloscope.
- Adjust the Power Supply potentiometer to its minimum setting fully counter clockwise. Now look down the emitter LED socket and slowly advance the setting of the potentiometer until in subdued lighting the light from LED is just visible.
- Vary the potentiometer gradually so as to vary the forward voltage (as 1.5, 2.0.....), note the corresponding  $I_f$  (forward current).
- Record these values of ( $V_f$ ) and ( $I_f$ ) & plot the characteristic between these two.

**OBSERVATION:**

Sr.	$V_f$	$I_f$ (Approx.)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

**RESULT:**

Exp no:

Date:

## 11. INTENSITY MODULATION OF LASER OUTPUT THROUGH AN OPTICAL FIBER

### AIM:

The aim of the experiment is to study the following ac characteristics of a linear intensity modulation system:

(i) gain characteristics of FO linear intensity modulation system  $V_{in}(ac)$  Vs  $V_o(ac)$  for fixed carrier power  $P_o$  and signal frequency  $F_o$ .

### APPARATUS REQUIRED:

S.No EQUIPMENT QUANTITY

1 LASER Diode transmitter Kit 1

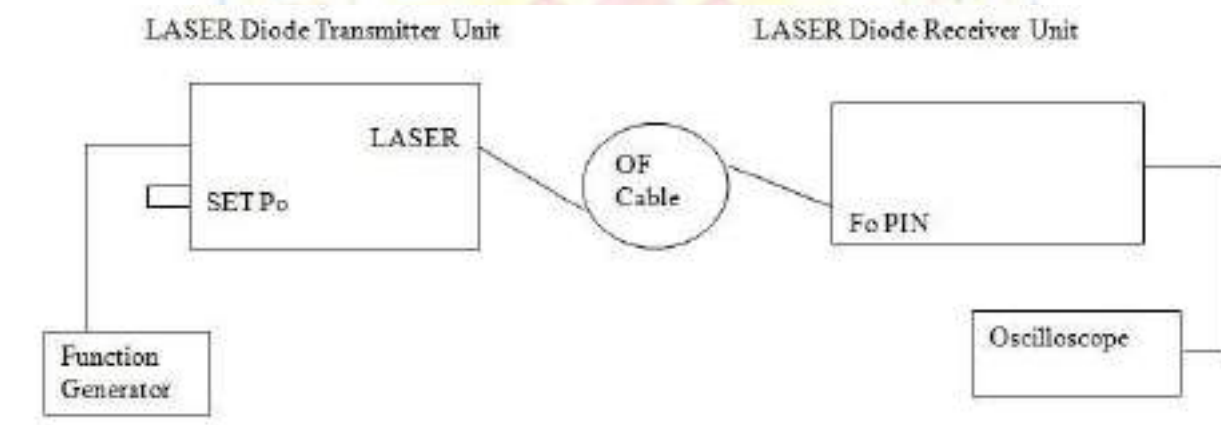
2 LASER Diode receiver Kit 1

3 Optical Fiber cable 1

4 Function Generator 1

5 CRO 1

### BLOCK DIAGRAM:



### THEORY:

Linear Intensity Modulator: selection of optimum carrier power is essential to minimize distortion. Limiting depth of modulation also ensures distortion free transmission.

(a) Select an  $I_F(dc) = 10\text{mA}$  (corresponding to carrier power  $P_o$  of  $-14\text{dbm}$  to  $17\text{dbm}$ ) as dc operating point.

(b) For  $V_{in}(ac) = 200\text{mv}(P-P)$ , we get  $I_F(ac) = 2\text{mA}(p-P)$  corresponding to variations from  $9\text{mA}$  to  $11\text{mA}$ . This is well within the linear region. The modulation may be distortion free for a  $V_{in}(ac)$  of  $1\text{V}(p-p)$ . One may compute values of  $I_F(dc)$  or  $P_o(CW)$  (optical carrier power) for different peak to peak input signals,  $V_{in}(ac)$ .

(c) The loss due to the optical fiber cable may be overcome by proper selection of demodulator again.

**PROCEDURE:**

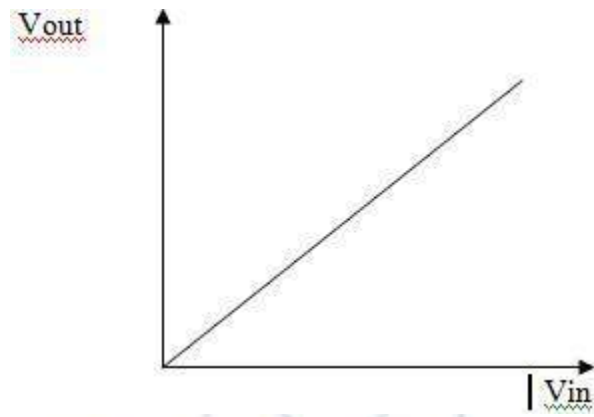
1. Connect one end of cable1 to the Fo port of analog transmitter. First connected to FO pin to set the carrier power level ,Po .After setting Po, it is removed and connected to FO PT to study the system.
2. Connect Vin(ac) and GND on the Transmitter unit to a function generator(10Hz to 500 KHz sinewave O/P,10mV to 2Vp-p O/P)
3. Connect Vout of receiver unit to CH2 of a dual trace oscilloscope. Give the function generator output to CH1.
4. plug the AC mains. Adjust the SET Po Knob to set the optical carrier power to 15dbm with Vin disconnected from the function generator .Disconnect cable1 from Fo PIN port and connect to FOPT.
5. Connect Vin to function generator. Set signal frequency and amplitude to 2KHZ and 100mv respectively .Observe the transmitted (Vin) and received(Vout) signals on the oscilloscope with identical range settings. Coincide the two waveforms.A djust SET Rin suitably to obtain the unity gain for system.
6. Next,set Vin o suitable values from 10mV to 2Vp-p and note down values of Vout.Tabulate and plot a graph Vout Vs Vin .Compute Vout/Vin.

**OBSERVATIONS:**

Frequency,fo= 2KHz,carrier level Po=-15dbm,System Gain=1.0

Vin (mV)	Vout(mV)	Gain=Vout/Vin
20		
40		
60		
80		
100		
120		
140		
160		
180		
200		
220		
240		
260		
280		
300		

**MODEL GRAPH:**

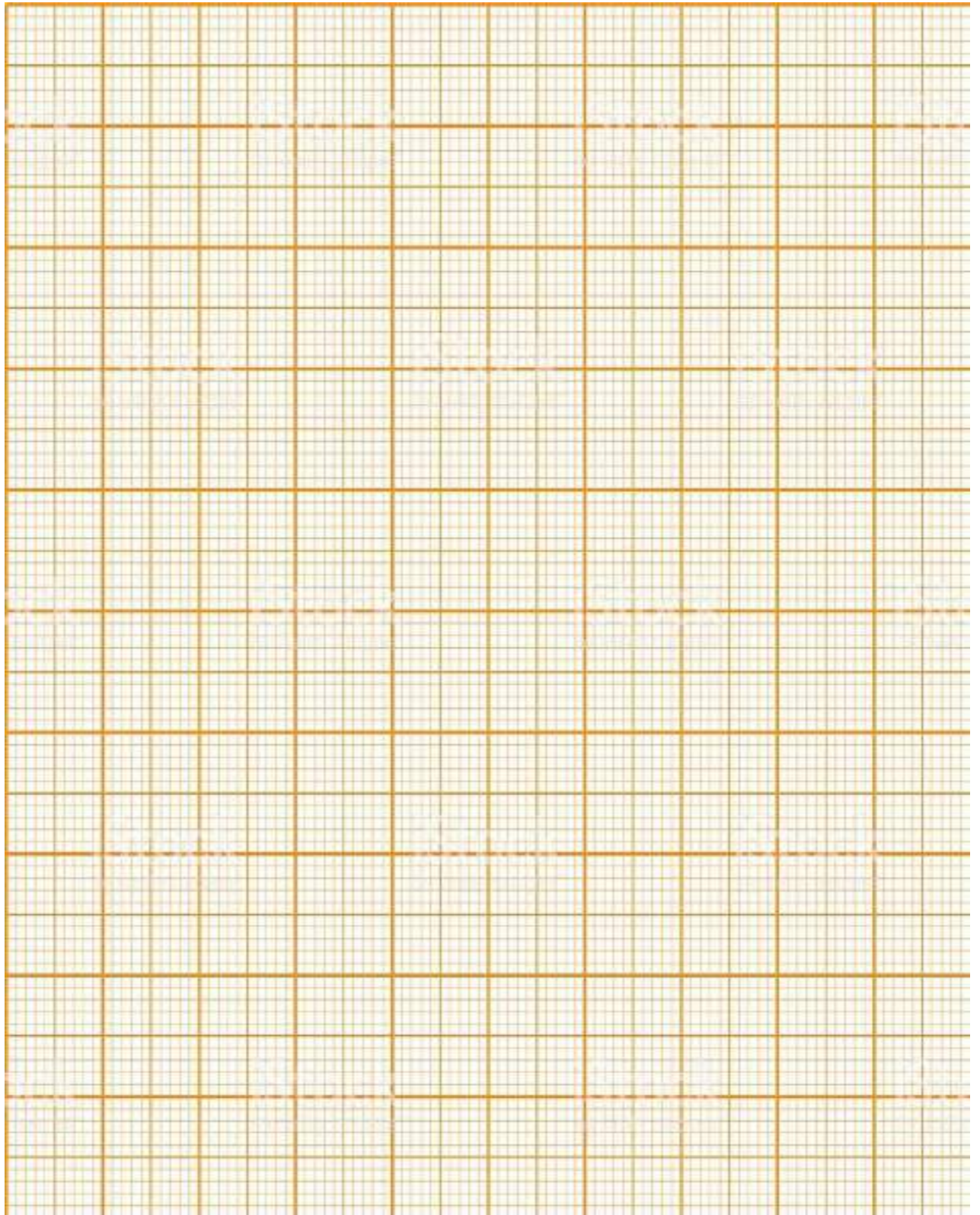


**RESULT:**





GRAPH SHEET:



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Date:

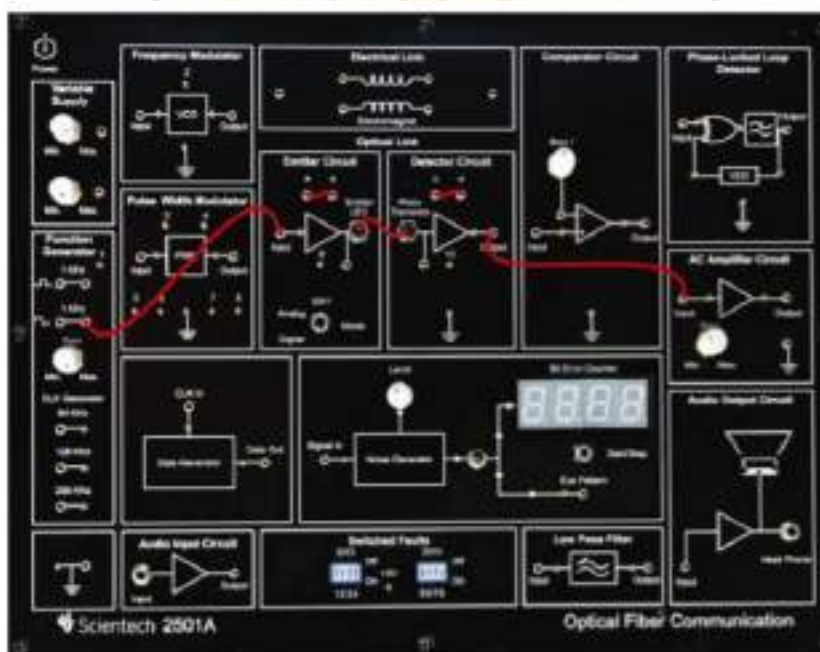
## 12. OPTICAL FIBER ANALOG LINK AND DIGITAL LINK

### AIM:

Study of 650 nm Fiber Optic Analog link & Digital link. In this experiment you will study the relationship between the input signal and received signal.

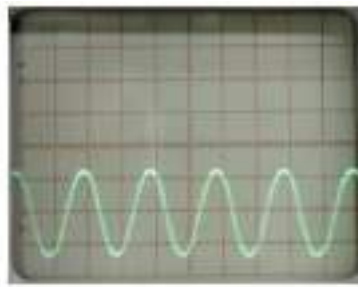
### EQUIPMENTS REQUIRED:

- Sciencetech 2501A TechBook with Power Supply
  - Optical Fiber cable
  - Sciencetech Oscilloscope with necessary connecting probe
- Connection Diagram: (Analog Link)

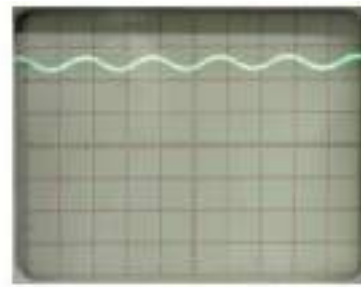


### PROCEDURE:

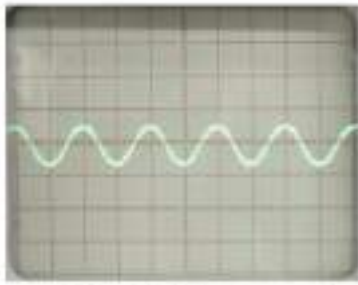
- Connect the TechBook Power Supply with mains cord to TechBook Sciencetech 2501A.
  - Ensure that all switched faults are OFF.
  - Make the connections as shown in next figure
1. Connect the Function Generator 1 KHz sine wave output to emitter input.
  2. Connect the fiber optic cable between emitter output and detector input.
  3. Connect the detector output to AC amplifier input.
- Put the mode switch SW1 to Analog to drive the emitter in analog mode.
  - Switch 'On' the Power Supply of the TechBook and Oscilloscope.
- Observe the input to emitter with the output from AC amplifier on Oscilloscope.
- Observation: Observe the waveforms as shown below.  
Both the input and output waveforms are same.



Input to Emitter circuit  
(CH1-2V/div; TB- 0.5mS)



Input to Emitter LED  
(CH1-2V/div; TB- 0.5mS)



Output of Detector circuit  
(CH1-0.2V/div; TB- 0.5mS)



Output of AC Amplifier circuit  
(CH1-2V/div; TB- 0.5mS)

### CONNECTION DIAGRAM: (DIGITAL LINK)



### PROCEDURE:

- Connect the TechBook Power Supply with mains cord to TechBook Scientech 2501A.
- Ensure that all switched faults are OFF.
- Make the connections as shown in next figure
- Connect the Function Generator 1 KHz square wave output to emitter input
- Connect the fiber optic cable between emitter output and detector input.
- Connect the detector output to comparator input.
- Put the mode switch SW1 to Digital to drive the emitter in digital mode.
  - Switch 'On' the Power Supply of TechBook and Oscilloscope.
- Monitor both the inputs of comparator. Slowly adjust the comparator bias potentiometer,

until DC level on the input lies mid-way between the high and low level of the signal on the positive input.

**OBSERVATIONS:**

Observe the waveforms as shown below.

Both the input and output waveforms are same.



Input to Emitter circuit  
(CH1-5V/div; TB- 0.5mS)



Input to Emitter LED  
(CH1-5V/div; TB- 0.5mS)



Output of Detector circuit  
(CH1-2V/div; TB- 0.5mS)

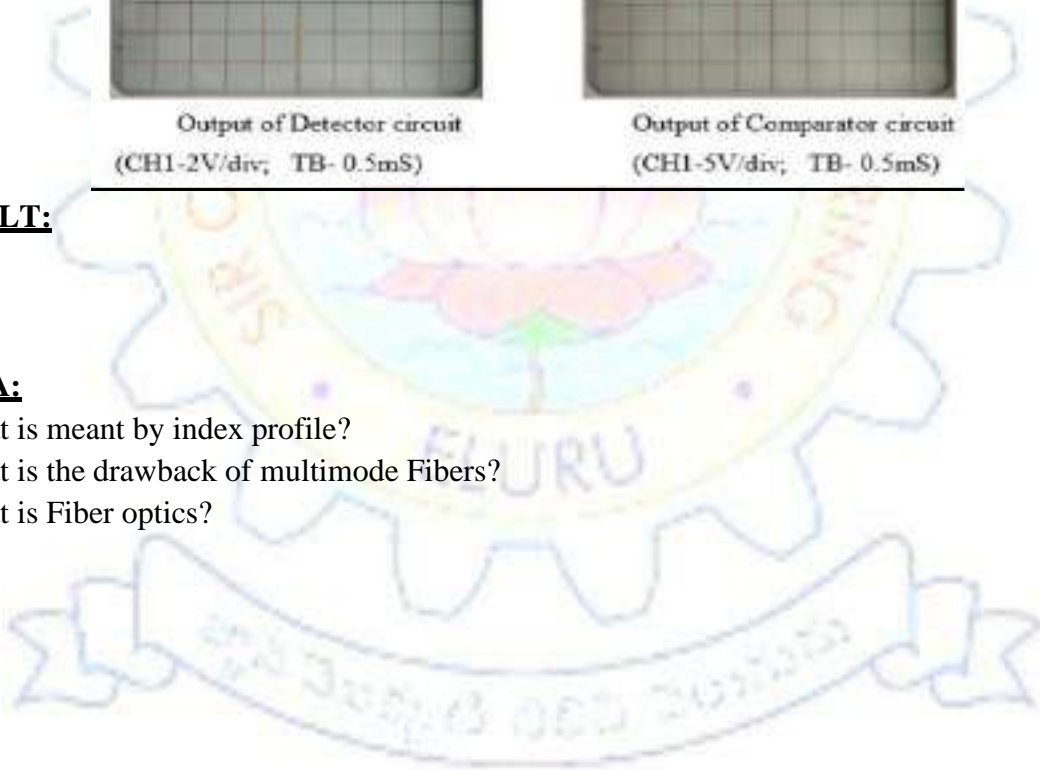


Output of Comparator circuit  
(CH1-5V/div; TB- 0.5mS)

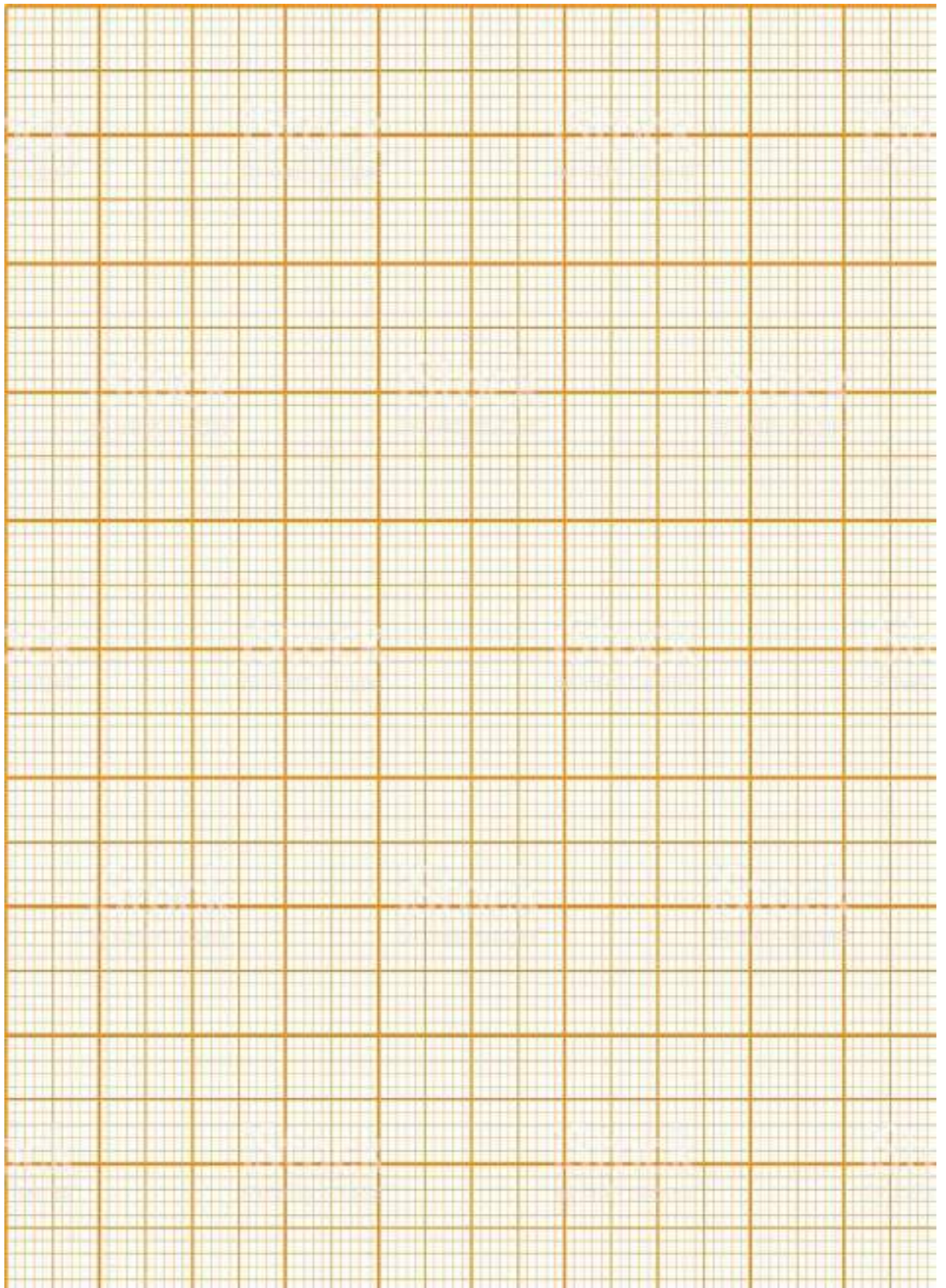
**RESULT:**

**VIVA:**

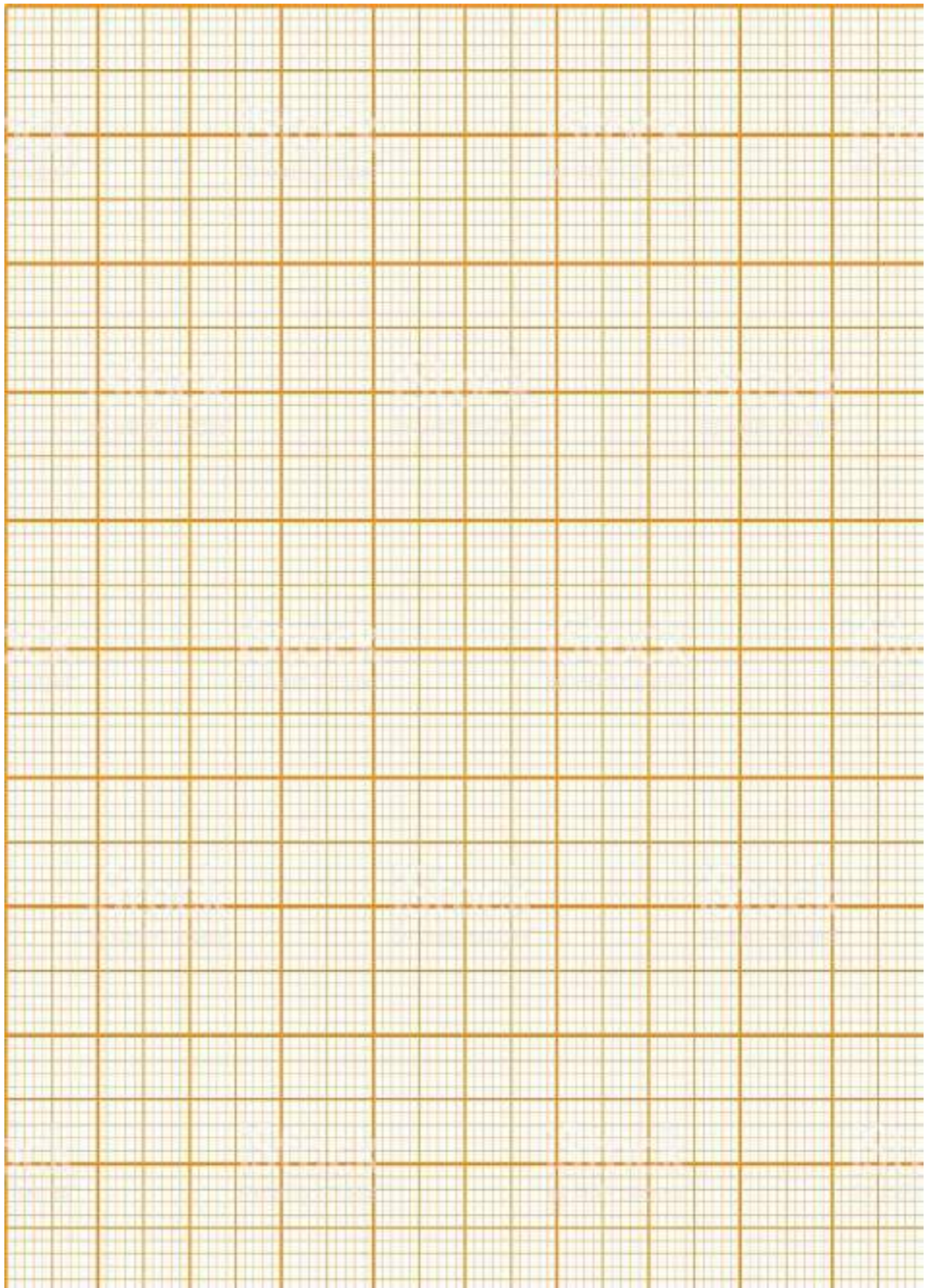
- What is meant by index profile?
- What is the drawback of multimode Fibers?
- What is Fiber optics?



GRAPH SHEET:



GRAPH SHEET:



Exp no:

Date:

**13.STUDY OF NUMERICAL APERTURE OF OPTICAL FIBER****AIM:**

The objective of this experiment is to measure the numerical aperture of the plastic fiber provided with the kit using 660nm wavelength LED.

**EQUIPMENTS:**

1. Power supply.
2. Experimental kit.
3. 1-meter fiber cable.
4. NA JIG.

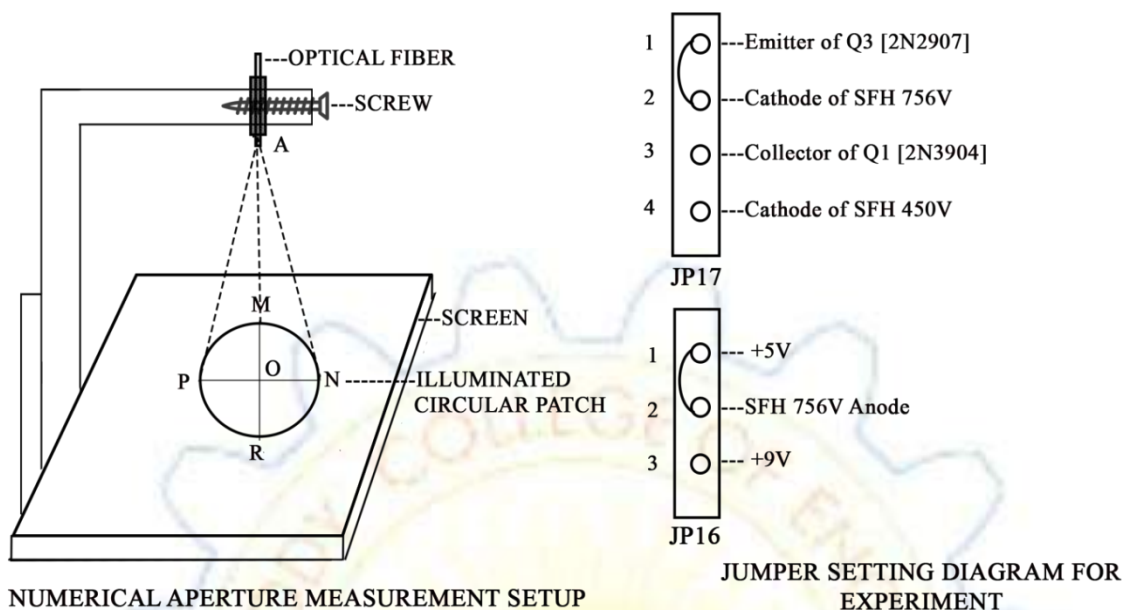
**THEORY:**

The Numerical Aperture (NA) is a measure of how much light can be collected by an optical system such as an optical fiber or a microscope lens. The Numerical Aperture is related to the acceptance angle  $\theta_a$ , which indicates the size of a cone of light that can be accepted by the fiber. Both numerical aperture and acceptance angle are linked to the refractive index via:

$$NA = n_a \sin \theta_a = (n_1^2 - n_2^2)^{1/2}$$

Where  $n_1$  = refractive index of core  
 $n_2$  = refractive index of cladding  
 $n_a$  = refractive index of air (1.00)

One way of measuring the NA of this fiber is to fill the fiber with light and measure the characteristics of the light leaving the fiber.

**EXPERIMENTAL SETUP:****PROCEDURE:**

1. Refer to figure and make the following connections.
2. Slightly unscrew the cap of LED SFH756 (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tighten the cap by screwing it back.
3. Now short the jumpers as shown in the jumper diagram.
4. Connect the power cord to the kit and switch on the power supply.
5. Insert the other end of the fiber into numerical aperture measurement jig. Hold the white sheet facing the fiber. Adjust the fiber such that its cut face is perpendicular to the axis of the fiber.
6. Keep the distance of about 10mm between the fiber tip and the screen. Gently tighten the screw and thus fix the fiber in the place.

Now observe the illuminated circular patch of light on the screen.

7. Measure exactly the distance **d** and also the vertical and horizontal diameters **MR** and **PN** as indicated in the figure.
8. Mean radius is calculated using the following formula  $r = (\mathbf{MR} + \mathbf{PN}) / 4$
9. Find the numerical aperture of the fiber using the formula  $NA = \sin \theta_{\max} = r / \sqrt{d^2 + r^2}$

Where  $\theta_{\max}$  is the maximum angle at which the light incident is properly transmitted through the fiber.



**TABULAR FORM:**

R (Cm)	(cm)	m)	cm)	$\theta_{\max}$	

**CALCULATIONS**

$$r = (MR + PN) / 4 =$$

$$NA = \sin \theta_{\max} = r / \sqrt{d^2 + r^2}$$

Average numerical aperture =

**RESULT:****VIVA QUESTIONS:**

1. How the light will propagate through fiber optic cable?
2. What are different types of fibers?
3. Explain about light ray reflection at the core cladding interface?
4. Define critical angle?
5. Define Numerical aperture?
6. Explain about the significance of Numerical aperture.
7. How Numerical aperture will change with respect to diameter of the fiber?

Exp no:

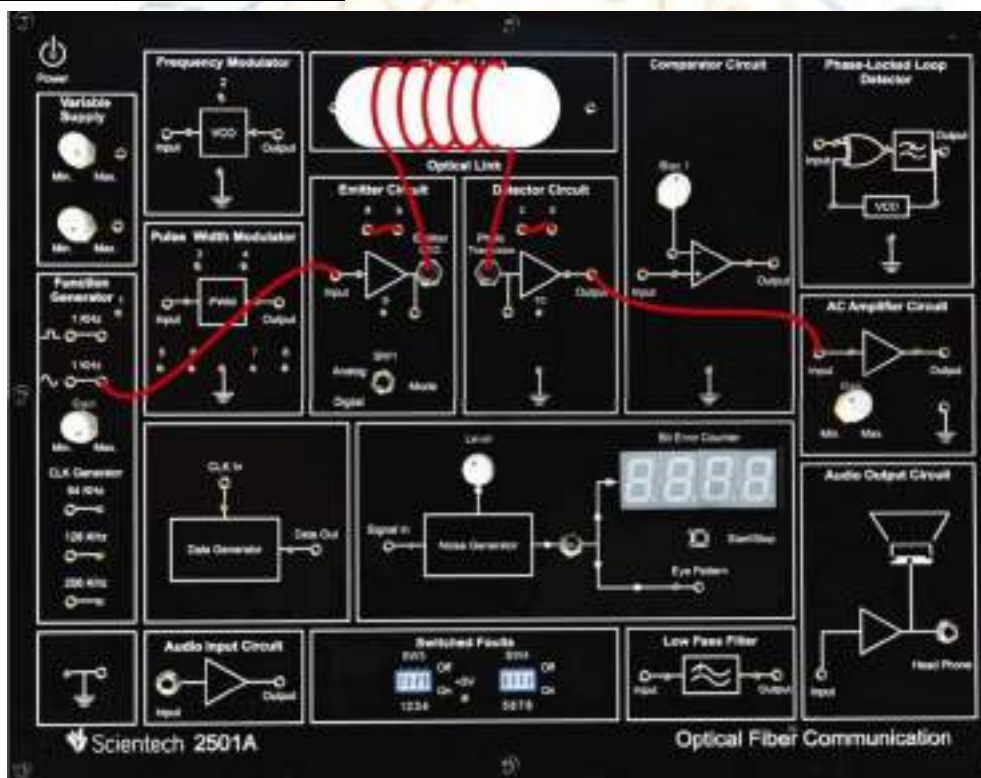
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**14. STUDY OF BENDING LOSSES IN ANALOG LINK****AIM**

Study of Bending Loss in Analog Link

**EQUIPMENTS REQUIRED:**

- Sciencetech 2501A TechBook with Power Supply cord
- Optical Fiber cable
- Sciencetech Oscilloscope with necessary connecting probe
- Mandrel

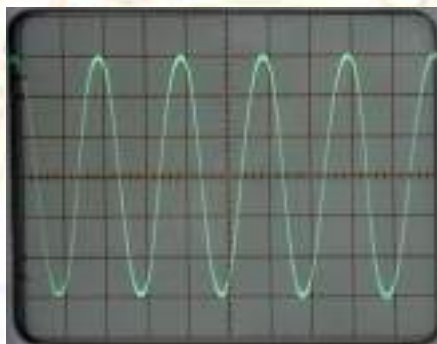
**CONNECTION DIAGRAM:****PROCEDURE:**

- Connect the TechBook Power Supply with mains cord to TechBook Sciencetech2501A.
- Make the connections as shown in next figure
  - ☒ Connect Function Generator 1 KHz sine wave output to emitter input.
  - ☒ Connect 0.5 m optic fiber between emitter output and detectors input.
  - ☒ Connect Detector output to amplifier input.
- Put the mode switch SW1 to Analog to drive the emitter in analog mode.

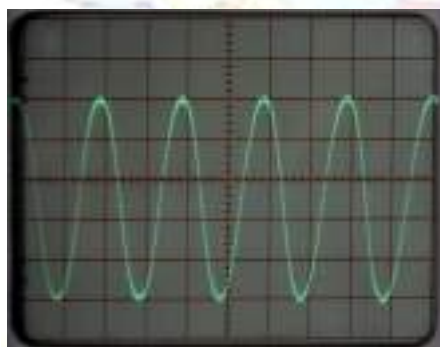
- Switch 'On' the Power Supply of the TechBook and Oscilloscope.
- Set the Oscilloscope channel 1 to 0.5 V/ Div and adjust 4-6 div amplitude by using X 1 probe with the help of variable pot in Function Generator Block at input of Emitter.
- Observe the output signal from detector on Oscilloscope.
- Adjust the amplitude of the received signal as that of transmitted one with the help of gain adjusts potentiometer in AC amplifier block. Note this amplitude and name it  $V_1$ .
- Wind the fiber optic cable on the mandrel and observe the corresponding AC amplifier output on Oscilloscope, it will be gradually reducing, showing loss due to bends.

### **OBSERVATIONS:**

Observe the waveforms as shown below.



Input to Emitter Circuit (CH1-0.2V/div; TB- 0.5mS)



Detector output (for 1m Cable)  
bending)(CH1-0.1V/div; TB- 0.5mS)

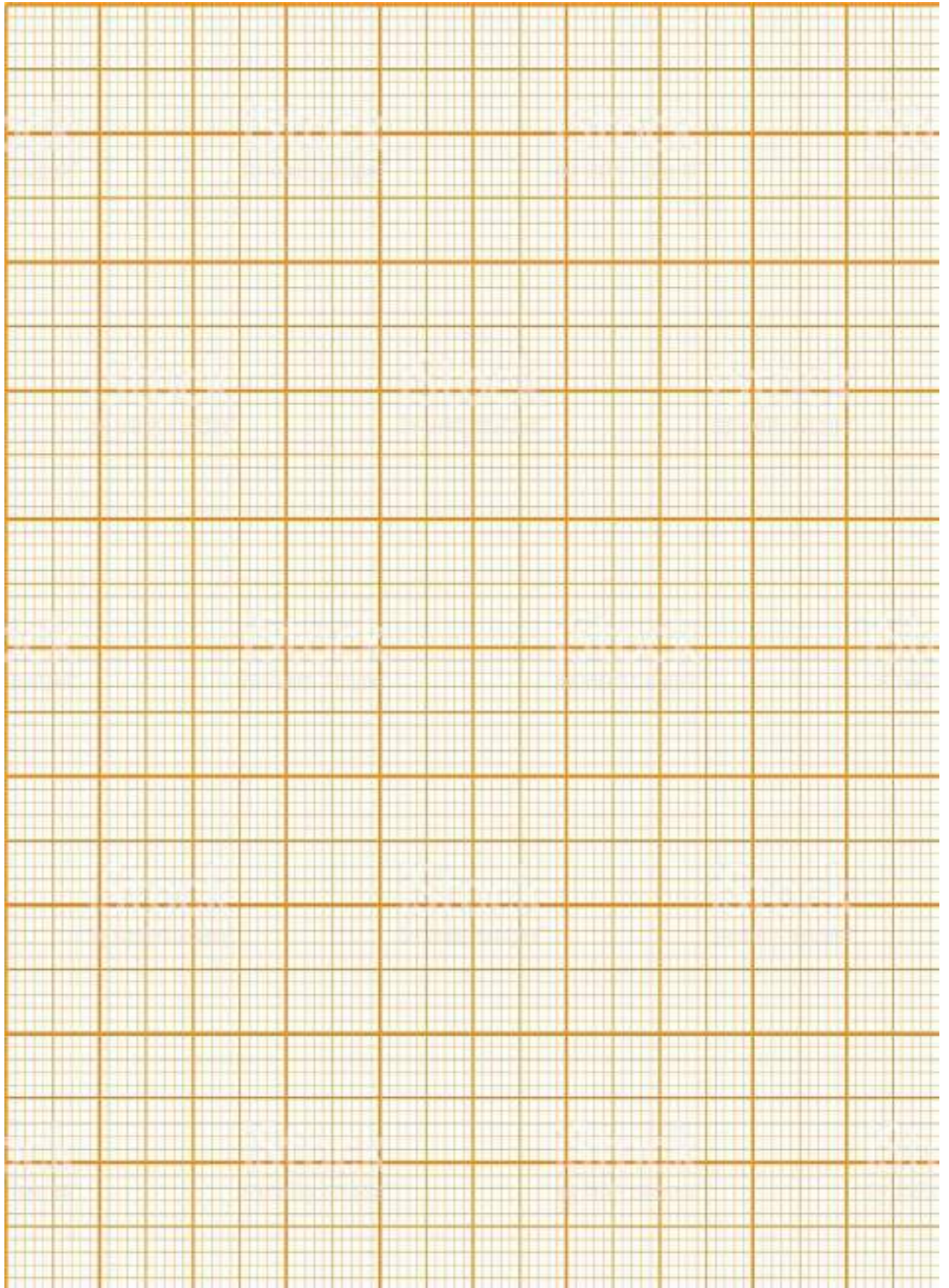


Detector output (after  
bending)(CH1-0.1V/div; TB- 0.5mS)

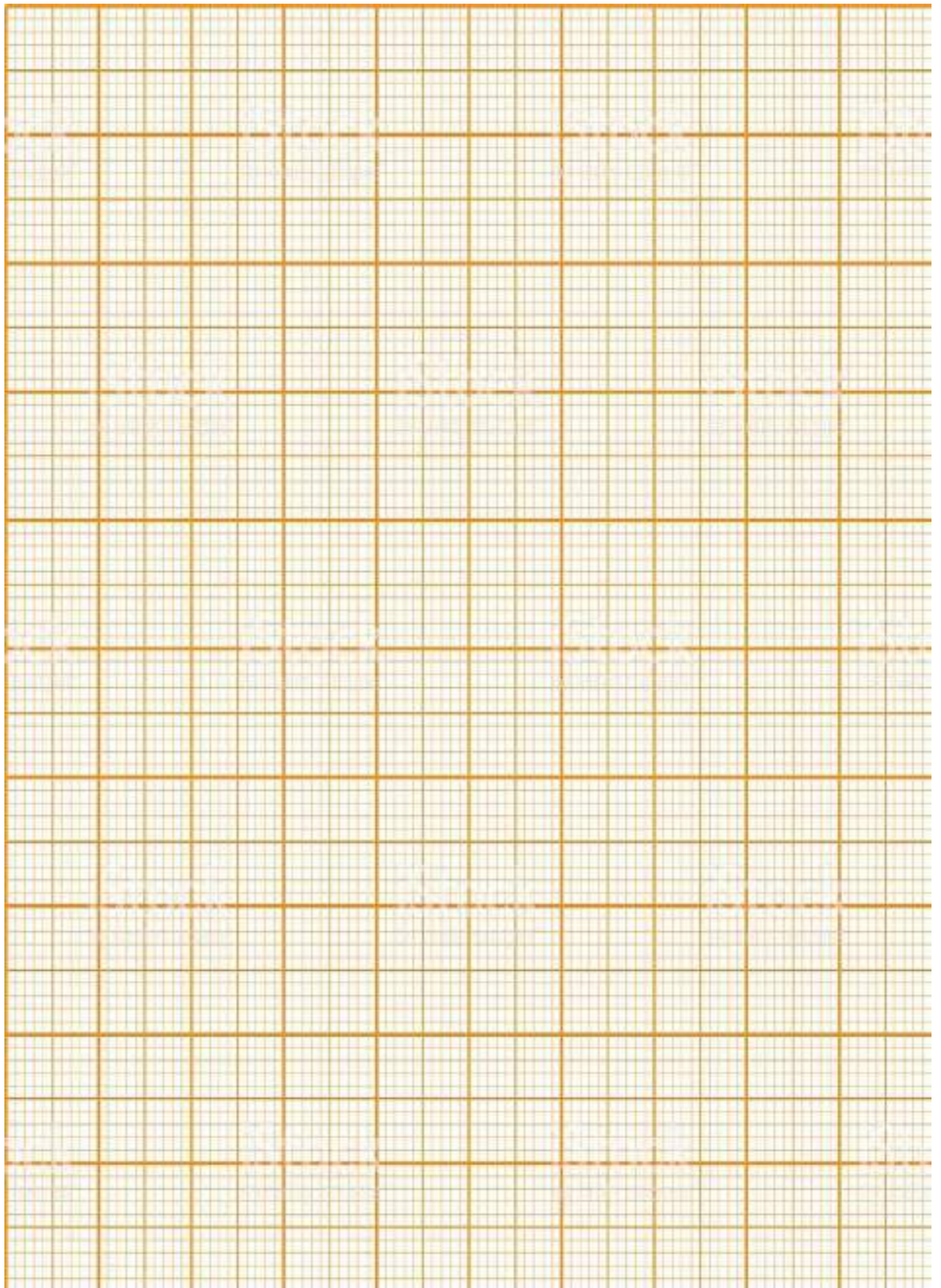
### **QUESTIONS:**

- What is the reason of bending losses?
- What is core and cladding?
- What is the function of cladding?

GRAPH SHEET:



GRAPH SHEET:



**ADD ON EXPERIMENTS**

Exp no:

Date:

**1. MEASUREMENT OF VOLTAGE STANDING WAVE RATIO (VSWR) AND REFLECTION COEFFICIENT.****AIM:**

To measure low and high VSWR and reflection coefficient.

**EQUIPMENT REQUIRED:**

1. Klystron power supply
2. Klystron tube with mount
3. Isolator
4. Variable Attenuator
5. Frequency Meter
6. Slotted line with probe detector
7. Variable Load

**THEORY:**

The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to. VSWR stands for Voltage Standing Wave Ratio, and is also referred to as Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. The ratio of electrical field strength of reflected and incident wave is called Reflection coefficient.

**PROCEDURE:**

1. Assemble the test bench as shown in the figure
2. Control knobs of VSWR meter are kept as below:
 

Range dB	-	40dB/50dB
Input switch	-	impedance low (200 $\Omega$ )
Meter switch	-	Normal
Gain (Coarse-Fine)	-	Mid position
3. The control knobs of Klystron power supply are kept as below:
 

Meter switch	-	'OFF'
Mode switch	-	'AM'
Beam voltage knob	-	Fully anticlockwise

Reflector voltage knob - Fully clockwise

AM frequency & amplitude knob - mid position

4. Klystron power supply, VSWR meter and cooling fan are switched ON.
5. Meter switch of Klystron power supply is switched to Beam voltage position and beam voltage is set to 300V .
6. Meter switch of Klystron power supply is switched to repeller position and repeller voltage is set at 70V to 270V and SS tuner to mid position.

#### **MEASUREMENT OF LOW VSWR:**

1. Rotate repeller voltage knob to set deflection in VSWR.
2. Adjust the gain control knob of VSWR meter or tuning probe of slotted line or variable attenuator until the meter indicates 1.00 on normal SWR scale or 0 dB. By keeping switches at SWR we can read it directly.
3. Keep all the Control knobs as it is, move the probe to next minimum position and note down the corresponding VSWR value.

#### **MEASUREMENT OF HIGH VSWR (Double Minimum Method):**

1. Set the depth of S.S tuner slightly more for maximum SWR.
2. Replace the short with a movable load and vary gain control knob if required and tuning probe until VSWR >4.
3. Move the probe along with slotted line until a minimum is indicated. Note the probe position as d1 and power as d2.
4. Move the probe along with slotted line towards load until power is increased by 3dB. Note and record the probe position on slotted line. Let it be d2.
5. Move the probe along with slotted line towards source until power is increased by 3dB. Note and record the probe position on slotted line. Let it be d3.
6. Measure the distance between two successive minima position or probe. Twice this distance is waveguide length.  $\lambda_g = 2(d1-d2)$ .
7. Now calculate SWR using following equation

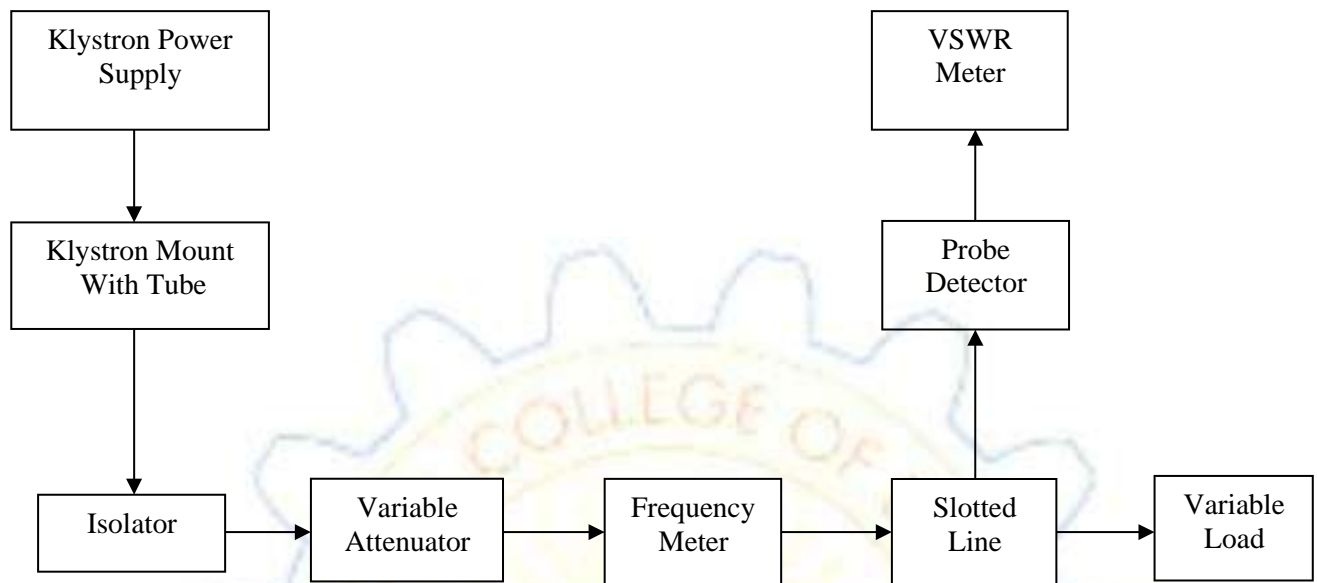
$$SWR = \lambda_g / \Pi (d2-d3)$$

8. For different SWR, calculate the reflection coefficient.

$$|\rho| = S-1/S+1$$

#### **MEASUREMENT OF HIGH VSWR using SWR meter**

1. Adjust the repeller voltage until a maximum square wave is observed on CRO.
2. Move the probe to minimum position of slotted line
3. Keep the switch present at the back of SWR meter in high SWR position and note the corresponding SWR value.

**EXPERIMENTAL SETUP:****CALCULATIONS:**

VSWR,

S=

Reflection coefficient

$$= \frac{-1}{+1}$$

**PRECAUTIONS:**

1. Keep the cooling fan towards the Klystron tube.
2. Never keep the Repeller voltage to zero volts

**RESULT:**

VSWR=

Reflection coefficient =

**VIVA QUESTIONS :**

1. What is reflection coefficient?
2. What is the value of K for matched load?
3. What is the relation between reflection coefficient and VSWR?
4. What is VSWR meter?
5. What are the possible errors in the measurement of VSWR?
6. What is the function of the detector probe in the slotted line section?



**Exp no:**      **Date:**

## **2. SPECTRUM ANALYZER: HARMONICS OF SINE AND SQUARE WAVE.**

### **AIM:**

1. To measure Harmonics of Sine wave by using Spectrum Analyzer.
2. To measure Harmonics of Square wave by using Spectrum Analyzer.

### **EQUIPMENT USED:**

1. Spectrum Analyzer
2. Signal source
3. BNC – BNC cable

### **THEORY:**

A spectrum analyzer or spectral analyzer is a device used to examine the spectral composition of some electrical, acoustic, or optical waveform. It may also measure the power spectrum. There are analog and digital spectrum analyzers: An *analog* spectrum analyzer uses either a variable band-pass filter whose mid-frequency is automatically tuned (shifted, swept) through the range of frequencies of which the spectrum is to be measured or a super heterodyne receiver where the local oscillator is swept through a range of frequencies.

A digital spectrum analyzer computes the discrete Fourier transform (DFT), a mathematical process that transforms a waveform into the components of its frequency spectrum.

Some spectrum analyzers (such as "real-time spectrum analyzers") use a hybrid technique where the incoming signal is first down-converted to a lower frequency using super heterodyne techniques and then analyzed using fast Fourier transformation (FFT) techniques.

### **Typical functionality:**

#### **Frequency range**

Two key parameter for spectrum analysis are frequency and span. The frequency specifies the center of the display. Span specifies the range between the start and stop frequencies, the bandwidth of the analysis. Sometimes it is possible to specify the start and stop frequency rather than center and range.

#### **Marker/peak search**

Controls the position and function of markers and indicates the value of power. Several spectrum analyzers have a "Marker Delta" function that can be used to measure Signal to Noise Ratio or Bandwidth.

#### **Bandwidth/average**

Is a filter of resolution? The spectrum analyzer captures the measure on having displaced a filter of small bandwidth along the window of frequencies.

### **Amplitude**

The maximum value of a signal at a point is called amplitude. A spectrum analyzer that implements amplitude analysis is called a Pulse height analyzer.

### **View/trace**

Manages parameters of measurement. It stores the maximum values in each frequency and a solved measurement to compare it.

### **Uses:**

Spectrum analyzers are widely used to measure the frequency response, noise and distortion characteristics of all kinds of RF circuitry, by comparing the input and output spectra. In telecommunications, spectrum analyzers are used to determine occupied bandwidth and track interference sources. Cell planners use this equipment to determine interference sources in the GSM/TETRA and UMTS technology. In EMC testing, spectrum analyzers may be used to characterize test signals and to measure the response of the equipment under test.

### **PROCEDURE:**

1. Switch on the Spectrum Analyzer and check if the instrument is meeting the Calibrated requirements else refer to the manual supplied along with the Instrument
2. Switch on the signal source and set as given below

FUNCTION KNOBE :	SINE WAVE/SQUARE WAVE
FREQUENCY KNOBE:	1 M HZ
FREQ. VARIABLE KNOB:	MAX
LEVEL KNOB:	MIN
ATTENUATION P.B SWITCHES:	BOTH PRESSED

3. Set the Spectrum Analyzer as given below

CENTER FREQUENCY:	000.0
ATTENUATION:	ALL DEPRESSED
SCAN WIDTH	2MHZ / div

4. Connect Spectrum Analyzer and signal generator via, BNC – BNC cable

Typical spectrum analyzer display, showing power vs. frequency/wavelength a spectrum analyzer or spectral analyzer is a device used to examine the spectral components. fig 1.2

5. On connecting both the instruments you shall observe a spectral lines other than the Zero frequency line as shown in fig 1.2

6. Now switch on the MARKEB PUSH button. MK is lit and the display shows the Marker frequency. The marker is shown on the screen as a vertical needle. Now adjust the marker knob so as to align the needle with the highest spectral line. The Reading as obtained on the display in the fundamental frequency.
7. Now move on the marker to the adjacent spectral lines on RHS and note down the Display readings. These readings correspond to the harmonic frequencies.
8. Also note down the levels of each spectral line on the CRT display.
9. Repeat (7) and (8) till you can observe spectral lines and note down the readings
10. Repeat the same experiment by selecting the function of square wave in function generator.



Fig 1.1 A spectrum analyzer

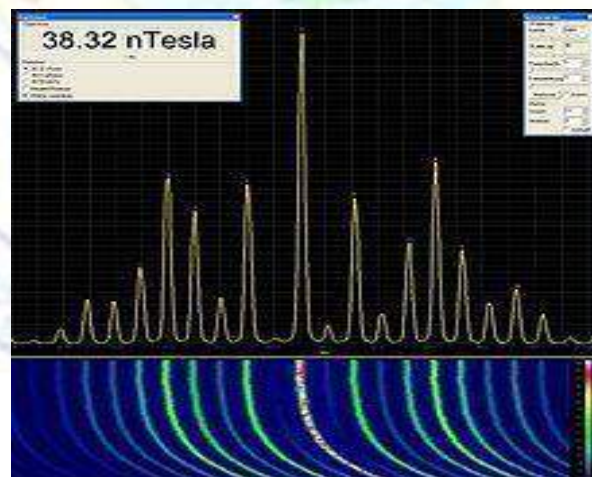


Fig1.2 Spectral components

**OBSERVATIONS: SINE WAVE**

Fundamental frequency	Frequency on display	Level in dBm
1 MHz	1 <sup>st</sup> harmonic : 2 <sup>nd</sup> harmonic: 3 <sup>rd</sup> harmonic:	
2MHz	1 <sup>st</sup> harmonic : 2 <sup>nd</sup> harmonic: 3 <sup>rd</sup> harmonic:	
3MHz	1 <sup>st</sup> harmonic : 2 <sup>nd</sup> harmonic: 3 <sup>rd</sup> harmonic:	

**OBSERVATIONS: SQUARE WAVE**

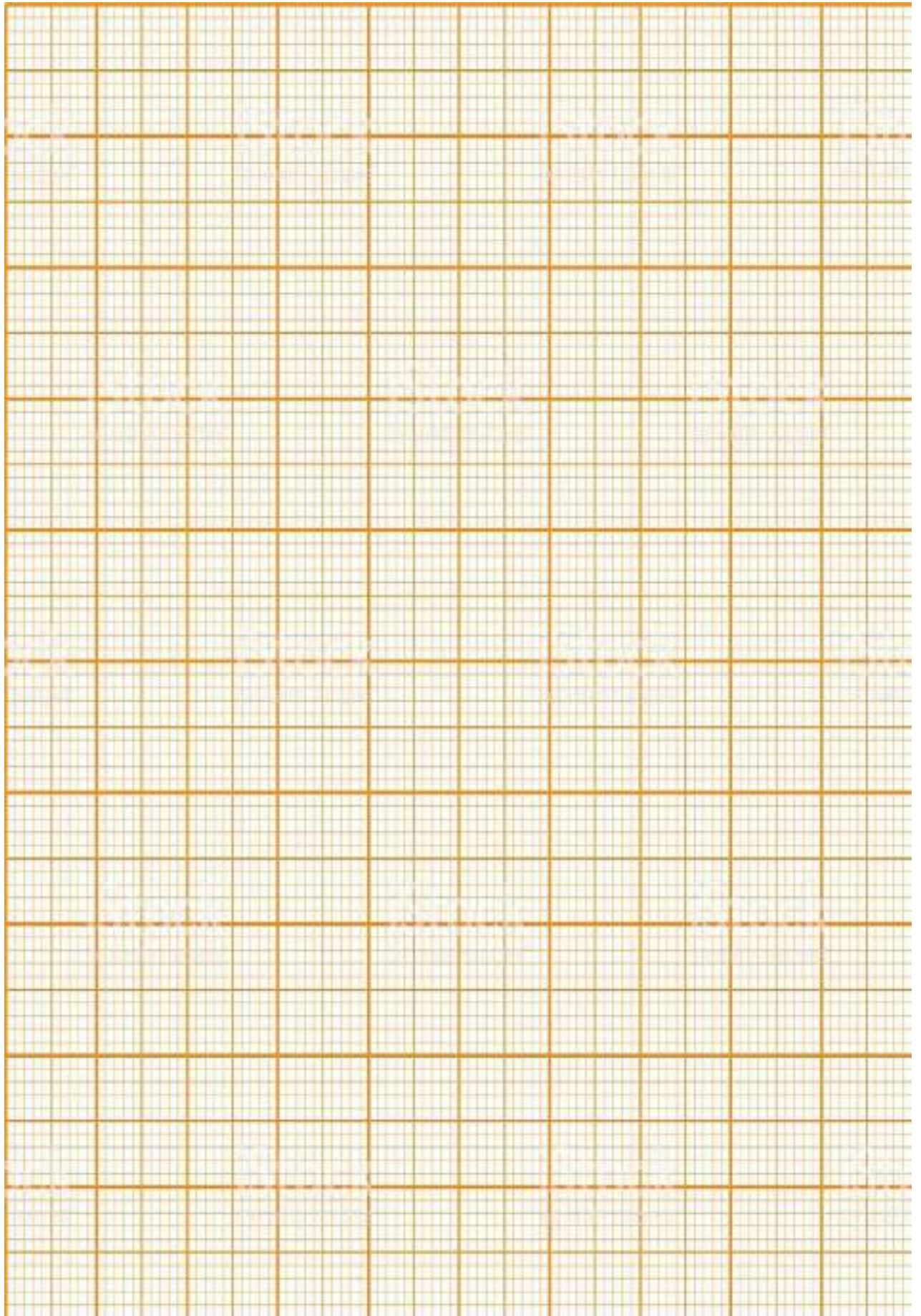
Fundamental frequency	Frequency on display	Level in dBm
1 MHz	1 <sup>st</sup> harmonic : 2 <sup>nd</sup> harmonic: 3 <sup>rd</sup> harmonic:	
2MHz	1 <sup>st</sup> harmonic : 2 <sup>nd</sup> harmonic: 3 <sup>rd</sup> harmonic:	
3MHz	1 <sup>st</sup> harmonic : 2 <sup>nd</sup> harmonic: 3 <sup>rd</sup> harmonic:	

**PRECAUTIONS:**

Never exceed the input to the Spectrum Analyzer beyond 10m Vrms with no attenuation and 1 Vrms with all attenuation switches pressed

**RESULT:****VIVA QUESTIONS:**

1. What is a spectrum analyzer?
2. What are harmonics?



### **3.DETERMINATION OF RESONANCE AND DIELECTRIC CONSTANT OF A MICRO STRIP RING RESONATOR.**

#### **AIM:**

To determine the resonance and dielectric constant of a micro strip ring resonator.

#### **APPARATUS:**

1. S3663 Micro strip Trainer
2. Ring resonator
3. SMA adapter

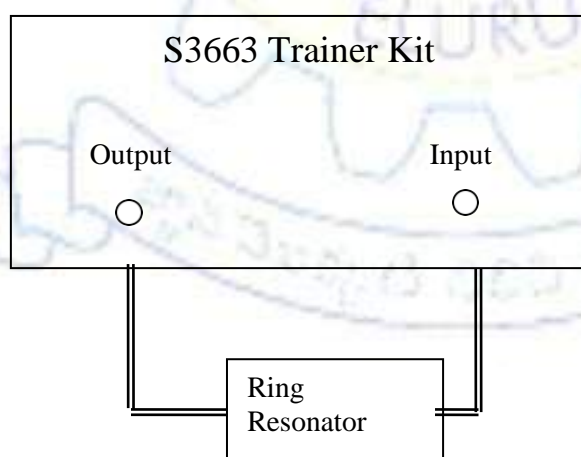
#### **THEORY:**

The edge coupled **microstrip ring resonator** is commonly used to determine microwave substrate properties, in particular the dielectric constant and loss tangent. It is also well known that under certain circumstances, a **microstrip ring** circuit can act as a narrowband antenna.

#### **PROCEDURE:**

1. Connect the S3663 as shown in the fig. Connect one cable to the output and the other is to be connected via attenuator pad to the input. Connect the SMA connectors of the cable to the ring resonator.
  2. By varying the frequency from 900MHz, note down the corresponding power.
- Now adjust the frequency to get the maximum output from the resonator. This is the frequency of resonance.

#### **BLOCK DIAGRAM**



**CALCULATIONS**

The value of  $\epsilon_r$  can be found from these formulas

$$\epsilon_{eff} = \frac{\epsilon + 1}{2} + \frac{\epsilon - 1}{2} \left[ 1 + \frac{12h}{w} \right]^{-1/2}$$

$$\Delta L = \frac{h}{\epsilon_{eff}}$$

$$L_{eff} = L + 4\Delta L$$

$$L_{eff} = \frac{c}{f \sqrt{\epsilon_{eff}}}$$

$$f = \frac{c}{L_{eff} \sqrt{\epsilon_{eff}}}$$

Here L=mean perimeter of the ring=4\*39.5=158mm

h=thickness of substrate=1.6mm

w= width of substrate=1.5 mm

Theoretical frequency f = \_\_\_\_\_ for  $\epsilon_r$

**TABULAR FORM:**

Frequency (MHz)	Power

**RESULT**

$\epsilon_r =$

f (Practical) =

f (theoretical) =

**VIVA**

1. What is a ring resonator?





