MICROWAVE AND OPTICAL COMMUNICATIONS LAB

for IV B.Tech ECE I Sem (R18)

Department of Electronics and Communication Engineering

MAHATMA GANDHI INSTITUTE OF TECHNOLOGY
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MAHATMA GANDHI INSTITUTE OF TECHNOLOGY

(Affiliated to Jawaharlal Technological University, Hyderabad)

Department of ECE

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WORK DAIRY

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Microwave & Optical Communications Lab

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1. REFLEX KLYSTRON CHARACTRISTICS

WARNING: DO NOT TOUCH THE KLYSTRON TUBE OR BRING FINGERS CLOSER TO THE POWER SUPPLY WIRES. KEEP THE COOLING FAN IN RUNNING.

OBJECTIVE:-To study the Characteristics of the reflex Klystron tube.

EQUIPMENT REQUIRED :- Klystron power supply, Klystron Tube, Isolator, Frequency meter, Variable attenuator, Detector mount, Wave guide stands, VSWR meter, and BNC cables etc.

THEORY:-The Klystron is a microwave tube that makes use of the property of velocity modulation to transform continues electron beam into microwave power. The electron beam that is emitted from the term ionic cathode is accelerated by the anode voltage and passes through the anode and the interaction gap of the cavity. The beam is returned through the interaction gap by the reflecting electric field set up the potential on the reflector, which is Negative with respect to the cathode. If the transit time in the reflecting field is (n+3/4) cycles of the resonant frequency of the cavity and if the loading is correct, microwave power will be generated and delivered to the out put load.

BLOCK DIAGRAM:

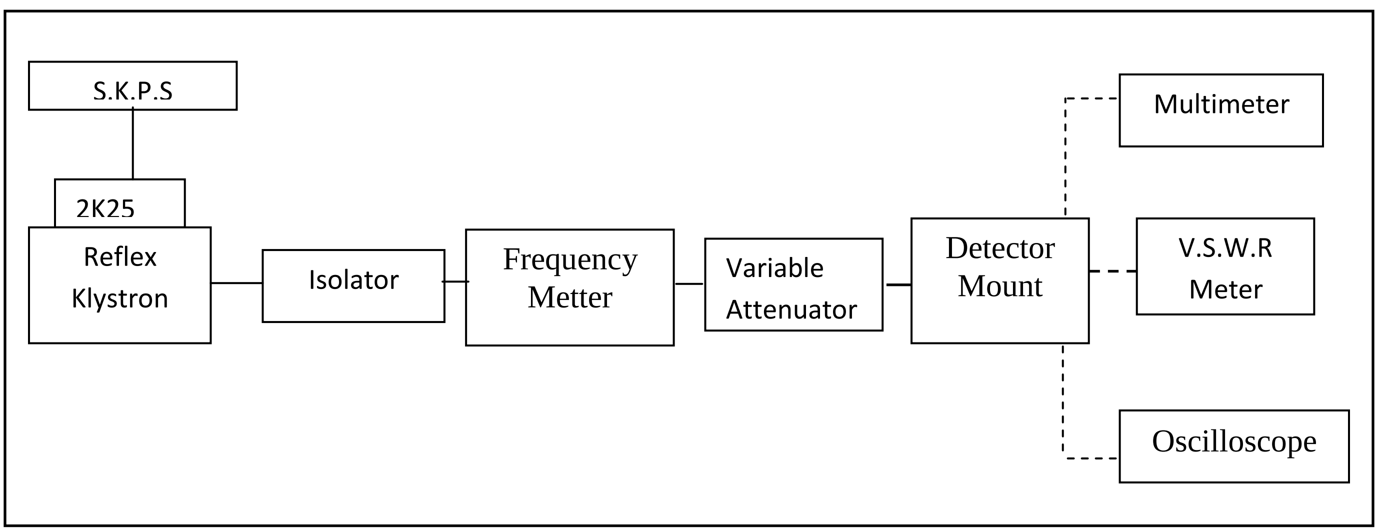


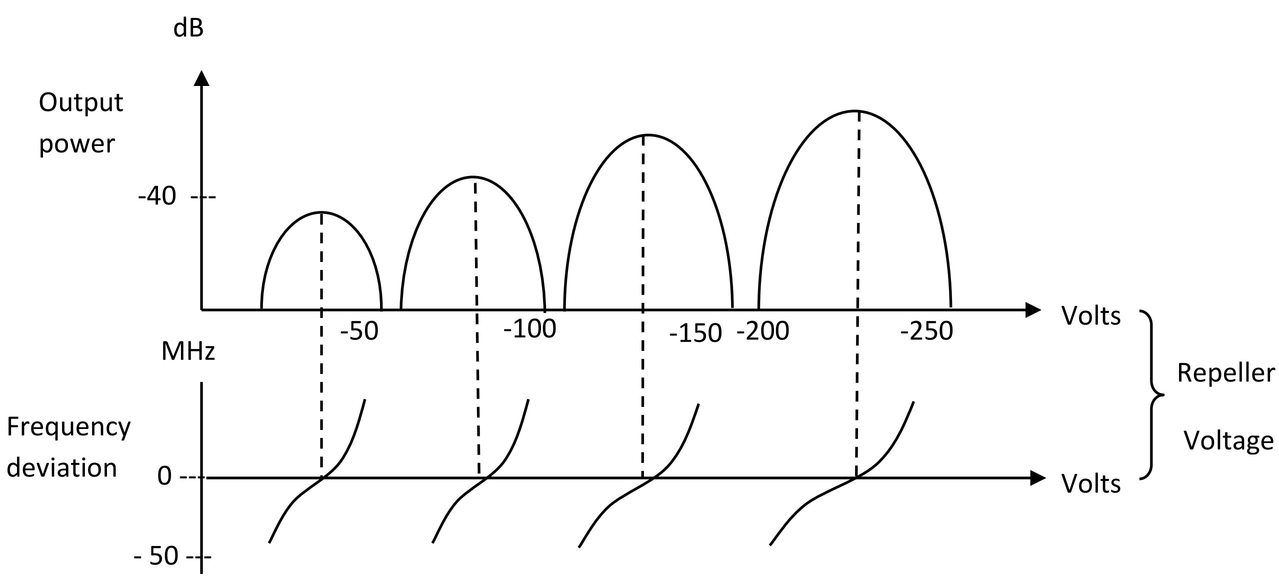
Fig . Set up for study of Klystron tube

PROCEDURE: -

1. Connect the component and equipments as shown in the fig.

2. Set the variable attenuator at the maximum position (zero micrometer reading)
3. Set the Mod-Switch of Klystron power supply to CW position, beam voltage control knob to fully anticlockwise and reflector voltage control knob to fully clockwise and the meter switch to OFF position.
4. Rotate the knob of frequency meter at one side fully
5. ON the Klystron power supply, VSWR meter and cooling fan for the Klystron tube.
6. Put the meter switch to beam voltage position and rotate the beam voltage knob clockwise slowly up to 300V meter reading. And observe beam current on the meter by changing meter switch to beam current position "the beam current should not increase more than 30mA"
7. Change the repellerr voltage slowly and watch on the power meter the voltage for maximum deflection. If no deflection is obtained, change the dB switch position to 50dB.
8. Tune the plunger of Klystron mount for the maximum output
9. Rotate the knob of frequency meter slowly and stop at that position, where dip comes. Read directly the frequency value between the two horizontal lines and vertical marker. If micrometer type frequency meter is used read the micrometer reading and find the frequency from its calibration chart.
10. Change the reflector voltages and read the power and frequency values for each reflector voltage and plot the graph as shown in the figure.

EXPECTED OUTPUT: Modes of 2K 25.



OBSERVATIONS:

Repeller Voltage(V)	Output power(dB)	Frequency (GHz)		Repeller Voltage(V)	Output Power(dB)	Frequency (GHz)
0				-110		
-10				-120		
-29				-130		
-30				-140		
-40				-150		
-50				-160		
-60				-170		
-70				-180		
-80				-190		
-90				-200		
-100				-220		

RESULT:

VIVA QUESTIONS

1. What are the limitations of vacuum tubes at microwave frequencies?
2. What is the range of microwave frequencies?
3. Why two cavity klystron is not used as an oscillator?
4. On what principle reflex klystron works?
5. Draw the Applegate diagram f reflex klystron?
6. How electronic tuning can be done in reflex klystron?
7. What are the applications of reflex klystron?
8. What is velocity modulation?
9. Define electronic admittance Y_e of the reflex klystron?
10. Write two differences between two cavity klystron and reflex klystron?

2. GUNN DIODE CHARACTERISTICS

WARNING: DO NOT KEEP GUNN BIAS KNOB POSITION AT THRESHOUD POSITION FOR MORE THAN 10-15 SECONDS. READING SHOULD BE OBTAINED AS FAST AS POSSIBLE. OTHERWISE, DUE TO EXCESSIVE HEATING, GUNN DIODE MAY BURN.

OBJECTIVE:-

To study the following characteristics of Gunn diode

i) V-I Characteristic
ii) Output power and frequency as a function of voltage

EQUIPMENT REQUIRED:-

Gunn Oscillator, Gunn power supply, Pin Modulator, Isolator, Frequency Meter, variable attenuator, Detector mount, Wave guide stands, SWR Meter, Cables and accessories etc.

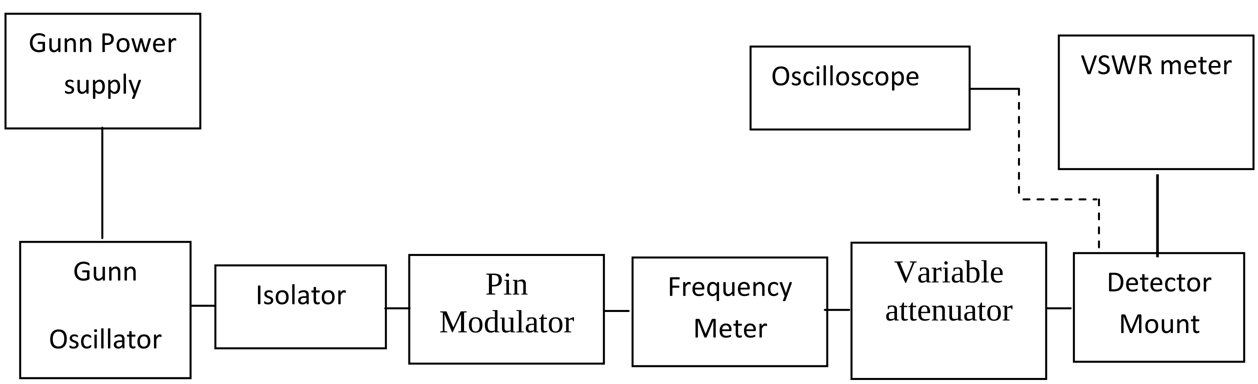


Fig. Set up for study of Gunn oscillator

PROCEDURE:-

1. Set the components and equipment as show in the fig.
2. Initially set the variable attenuator for mniimum attenuation
3. Keep the control knob of Gunn power supply as below: -

Meter Switch	-	'OFF'
Gunn bias knob	-	Fully anticlockwise
Pin bias knob	-	Fully anti-clockwise

Pin Mod frequency	-	Any position

4. Keep the control knob of VSWR meter as below: -

Meter Switch	-	Normal
Input Switch	-	Low Impedance
Range db Switch	-	40db/50db
Gain control knob	-	Fully clockwise

5. Set the micrometer of Gunn Oscillator for required frequency of operation.
6. 'ON' the Gunn power supply, VSWR Meter and cooling Fan.

A. VOLTAGE – CURRENT CHARACTERISTIC

1. Turn the meter switch of Gunn power supply to voltage position.
2. Measure the Gunn diode Current Corresponding to the various voltage controlled by Gunn bias knob through the panel meter and meter switch. Do not exceed the bias voltage above 10 volts.
3. Plot the voltage and current reading on the graph as shown in fig using table 1.
4. Measure the threshold voltage, which corresponds to maximum current.

B. OUT PUT POWER AND FREQUNCY AS A FUNCTION OF BIAS VOLTAGE

1. Turn the meter switch of Gunn power supply to voltage position.
2. Increase the Gunn bias to 10V.
3. Rotate PIN bias knob to around maximum position.
4. Tune the output in the VSWR meter through frequency control knob of modulation.
5. If necessary change the range dB switch of VSWR meter to higher or lower dB position to get deflection on VSWR meter. Any level can be set through variable attenuator and gain control knob of VSWR meter.
6. Measure the frequency by frequency meter and detune it.
7. Reduce the Gunn bias voltage in the interval of 0.5V or 1.0V and note down corresponding reading of output in VSWR meter and frequency . Plot the graph.
8. Use the reading of table 2 to drawn the power vs voltage curve and frequency vs voltage and plot the graph.
9. Measure the pushing factor (in MHz/volts), which is frequency sensitivity against variation in bias voltage for an oscillator. The pushing factor should be measured around 8 volt bias.

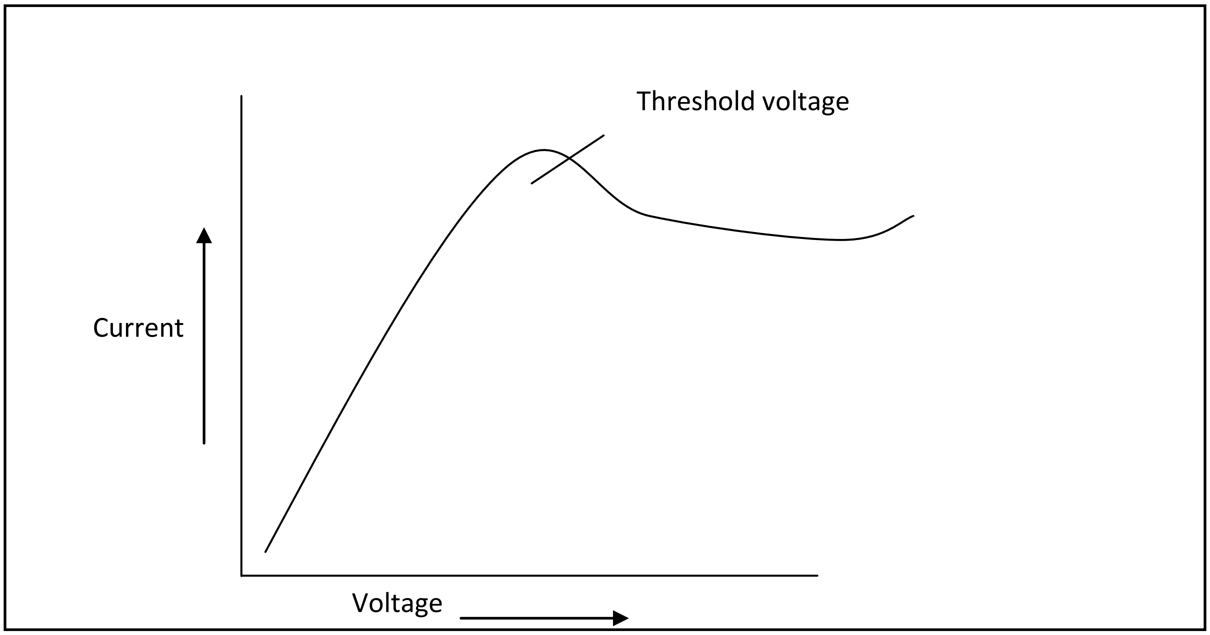


Fig. **V - I Curve of Gunn oscillator**

Table 1: V – I characteristics

S.No	Voltage (v)	Current(A)

Table 2: Freq vs Gunn bias

Sr.No	Bias Voltage	Frequency	Deviation
1	10 V		
2	9.5 V		
3	9 V		
4	8.5 V		
5	8 V		
6	7.5 V		
	-		

RESULT:

VIVA QUESTIONS

1. What are the materials used to fabricate Gunn diode?
2. How negative resistance is obtained with Gunn diode?
3. What is meant by RWH theory or two valley theory?
4. Instead of silicon why Gallium Arsinide is preffered for Gunn diode?
5. What are the conditions to semiconductor material to exhibit negative resistance?
6. What are the different modes of oscillations in Gunn diode?
7. Draw the J-E characteristics Gunn diode?
8. Write the applications of Gunn diode?
9. What do mean by negative resistance?
10. List out two device used in MW and negative resistance?

3. ATTENUATION MEASUREMENT

OBJECTIVE:- To study the attenuators (fixed type)

EQUIPMENT REQUIRED:- Microwave source, Isolator, frequency meter, Variable attenuator, Slotted line, VSWR, Attenuator, Matched load and BNC cables etc.

PROCEDURE:-

1. Set up the components and equipments as shown in fig.
2. Energize the microwave source for particular operation of frequency.
3. Set any reference level on the VSWR meter with the help of variable attenuator (not test attenuator) and gain control knob of power meter. Let it be P_1.
4. Carefully disconnected the detector mount from the slotted line, without disturbing any position on the set up. Place the test variable attenuator to the slotted line and detector mount to other port of test variable attenuator. Keep the micrometer reading of test variable attenuator to zero and record the reading of VSWR meter. Let it be P_2. Then the insertion loss of test attenuator will be P_1-P_2 db. This is also the attenuation presented by the fixed attenuator.
5. In case of variable attenuator, change the micrometer reading and record the VSWR meter reading. Find out attenuation value for different position of Micrometer reading and plot a graph.

Now change the operating frequency and whole step should be repeated for finding frequency sensitivity of fixed and variable attenuator.

Note: For measuring frequency sensitivity of variable attenuator the position of micrometer reading of the variable attenuator should be same for all frequencies in operation.

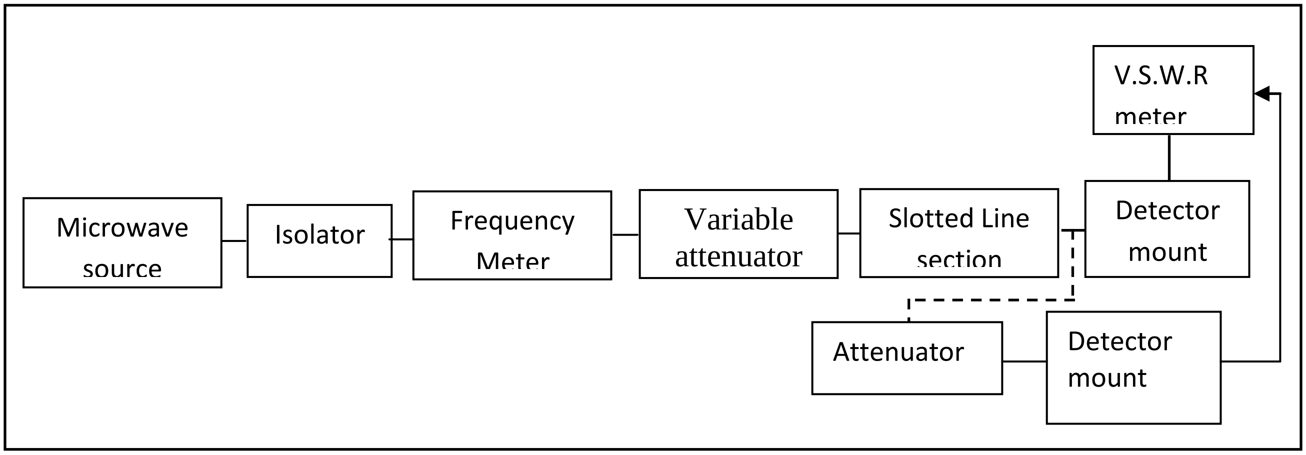


Fig.Insertion loss and attenuation Measurement of Attenuator.

OBSERVATIONS:- For Fixed attenuator

S. No	VSWR meter/power meter reading Without Fixed attenuator (dB)	VSWR meter/power meter reading With Fixed test attenuator (dB)	Attenuation (dB)

RESULT:

VIVA QUESTIONS

1. What do you mean by attenuation?
2. Draw the experimental setup to measure attenuation using power ratio method?
3. Draw the experimental setup to measure attenuation using reflector meter method?
4. What is the necessity of variable attenuation in the experimental setup?
5. How many methods are to measure attenuation. Explain any two methods to measure attenuation?
6. What is difference between attenuation and loss?
7. What is difference between attenuation and gain?
8. Explain flap attenuation?
9. Write two application of attenuator?
10. Which type of material is used for attenuation?

4. DIRECTIONAL COUPLER CHARACTERISTICS

OBJECTIVE:-

To study the function of multi hole directional coupler and measure the coupling factor, directivity and others

EQUIPMENT REQUIRED:-

Microwave source (Klystron or Gunn diode type), Isolator, frequency meter variable attenuator, slotted line, tunable probe, detector mount matched terminator, MHD coupler, wave guide stand, VSWR,BNC cables , and accessories etc.

PROCEDURE :-

1. Set up the equipments as shown in the fig.
2. Energize the microwave source for particular operation of frequency.
3. Tune the detector for maximum output.
4. Set any reference level of power on VSWR meter with the help of variable attenuator, gain control knob of VSWR meter, and note down the reading (reference level let X).
5. Insert the directional coupler as shown in second fig. With detector to the auxiliary port 3 and matched termination to port 2, without changing the position of variable attenuator and gain control knob of VSWR.
6. Note down the reading on VSWR meter on the scale with the help of range-db switch if required, let it is Y.
7. Calculate coupling factor hitch will be X-Y in db.
8. Now carefully disconnect the detector from the auxiliary port 3 and match termination from port 2 without disturbing the setup.
9. Connect the matched termination to the auxiliary port 3 and detector to port 2 and measure the reading on VSWR meter suppose it is Z
10. Compute insertion loss =X-Z in dB
11. Connect the directional coupler in the reverse direction that is port 2 to frequency meter side, matched termination to port 1 and detector mount to port 3, without disrobing the position of the variable attenuator and gain control knob of VSWR meter.
12. Measure and note down the reading on VSWR meter let it be Y_D
13. Compute the directivity as $Y-Y_D$
14. Repeat the same for another frequency.

OBSERVATIONS:

Note :- When measuring out put at any one port terminate other remaining port by matched load.

Input to port 1 P1 (Ref) = X =

P2 (dB) = Z =

P_3 (dB) = Y =

Input to port 2 P_4(dB) = Y_D =

1. Coupling factor X – Y = dB

2. Insertion Loss X – Z = dB

3. Directivity $Y - Y_D$ = dB

4. Isolation $X - Y_D$ = dB

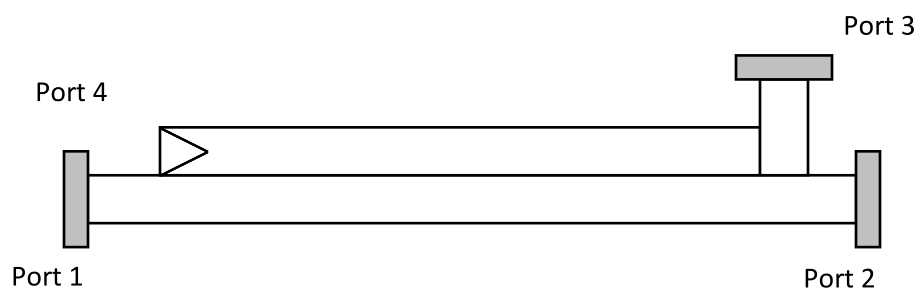


Fig. Multihole Directional Coupler

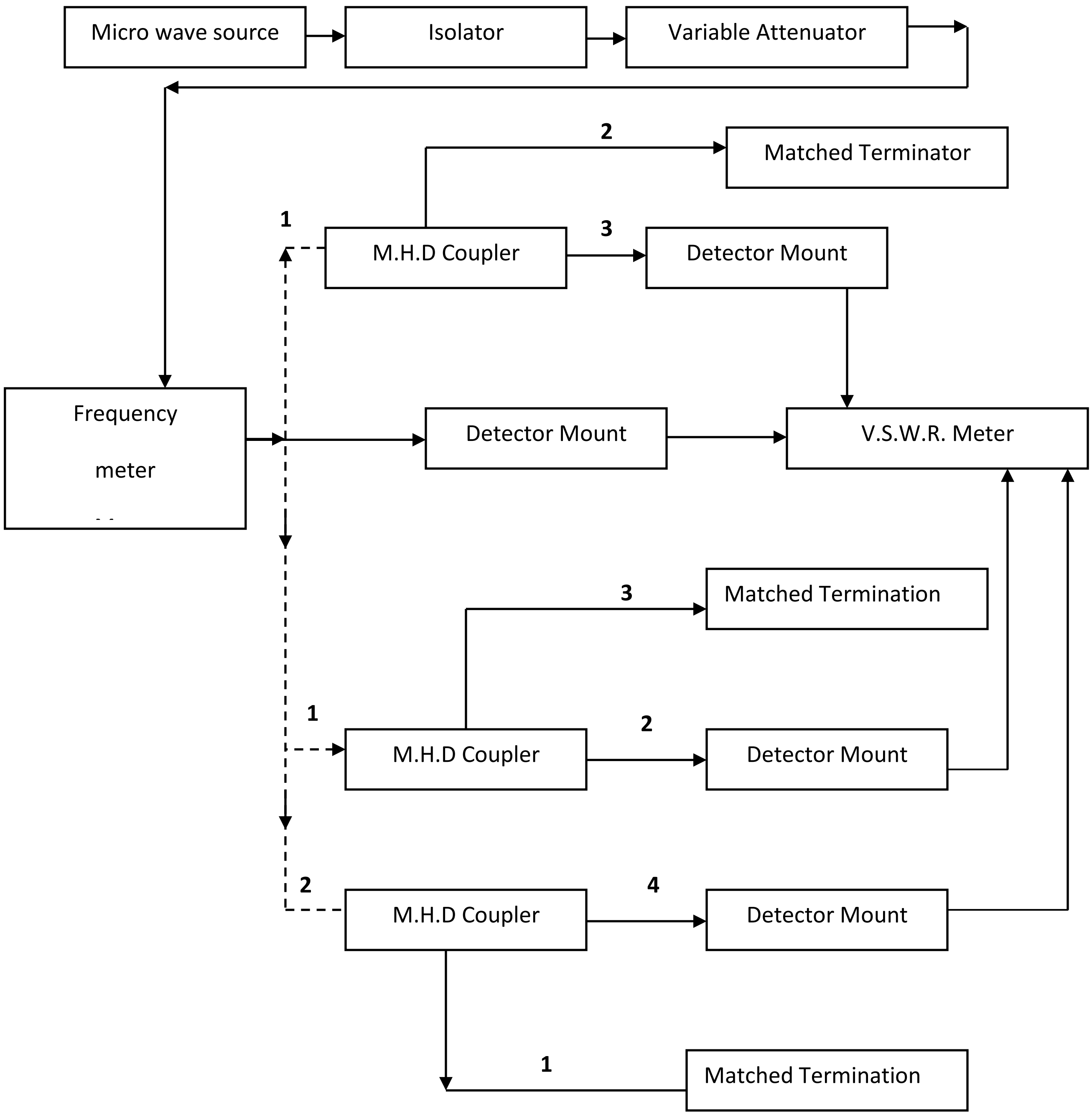


Fig. Measurement of Insertion Loss , Coupling factor & Directivity.

RESULT:

VIVA QUESTIONS

1. Write the properties of ideal directional coupler?
2. Define coupling factor © of the directional coupler?
3. Define directivity (D) of the directional coupler?
4. Write two applications of the directional coupler?
5. Write the s-matrix for ideal directional coupler?
6. Define insertion loss?
7. Define isolation?
8. What are the different types of directional coupler?
9. What is the electrical distance between eh two hole directional coupler?
10. How many wave guides are used in directional coupler?

5. SCATTERING PARAMETERS OF WAVEGUIDE COMPONENTS

5 i) MEASUREMENT OF SCATTERING PARAMETERS OF CIRCULATOR

OBJECTIVE :-

To determine the s – parameters of 3-port Circulator

EQUIPMENT REQUIRED:-

Klystron tube, (Klystron Power Supply, Klystron Mount)or (Gunn oscillator with Power supply ,Pin modulator), Isolator, Frequency Meter, Variable Attenuator, Slotted Section, Tunable Probe VSWR Meter, Wave guide Stand, 3-port Circulator, Movable Short/Matched Termination. and BNC cables etc.

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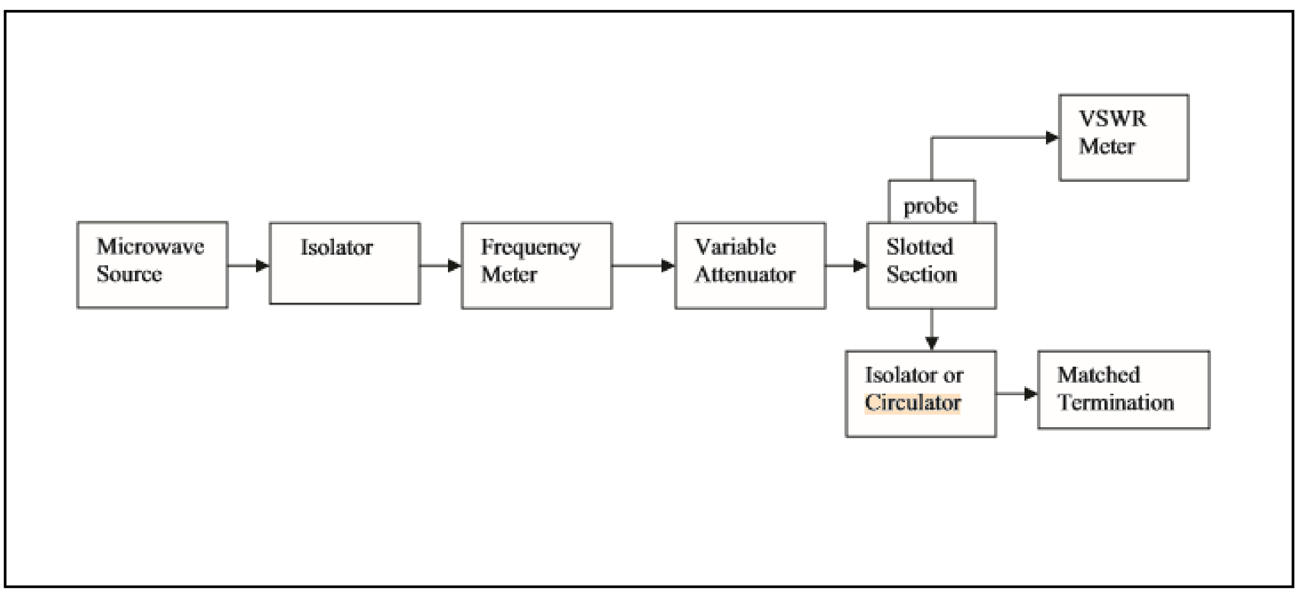

Fig . Set up for Measurement of S- parameters

PROCEDURE:

1. Remove the probe and circulator or isolator from slotted line and connect the detector mount to slotted section. The output of detector mount should be connected with VSWR meter.
2. Energize the microwave source for maximum output for a particular frequency of operation. Tune the detector mount for maximum output in VSWRmeter.
3. Set any reference level of power in VSWR meter with the help of variable attenuator and gain control knob of VSWR. Let it beP_1.
4. Carefully remove the detector mount from the setup. i.e. slotted line disturbing the position of setup. Insert the circulator between slotted line and detector mount. Keep input port to slotted line and detector to its output port. A matched termination should be placed at 3rd port in case ofcirculator.
5. Record the reading in the VSWR meter. If necessary, change range (dB) switch to high or lower position and read 10 dB changes for each set change of switch position. Let it beP_2.
6. Compute insertion loss given as P_1-P_2dB.
7. For measurement of isolation, the circulator has to be connected in reverse i.e. output port to slotted line and detector to input port with other port terminated by matched termination.
8. Record the reading of VSWR meter after and let it beP_3.
9. Compute isolation as **P_1-P_3** in**dB.**
10. The same experiment can be done for other ports ofcirculator.
11. Repeat the above experiment for other frequencies ofneeded.

OBSERVATIONS:

CALCULATIONS:

RESULT:

VIVA QUESTIONS:

1. What is the principle involved in circulators?
2. What is Faraday rotation?
3. Why the power applied at one port is given to the next clockwise port only but not to other ports?
4. Explain briefly the construction of circulator?
5. Where circulators are extensively used?
6. What is the peculiar property of ferrites?
7. What are the types of polarized waves present in circulators?
8. Given expression for angle of rotation.
9. What are the microwave devices that make use of Faraday rotation?
10. What are the differences between circulator and isolator?

5 ii) MEASUREMENT OF SCATTERING PARAMETERS OF E – PLANE TEE

OBJECTIVE :-

To determine the s – parameters of E- plane Tee junction

EQUIPMENT REQUIRED:-

Klystron tube, (Klystron Power Supply, Klystron Mount)or (Gunn oscillator with Power supply ,Pin modulator), Isolator, Frequency Meter, Variable Attenuator, Slotted Section, Tunable Probe VSWR Meter, Wave guide Stand, E- plane Tee junction, Movable Short/Matched Termination. and BNC cables etc.

PROCEDURE:

1. Set up the components and equipments.
2. Energize the micro-source for particular frequency of operation.
3. Set any reference level of power on VSWR meter with help of variable attenuator gain control knob of VSWR meter and note down the reading (reference level let x)
4. Insert the E-plane tee as shown in figure with detector to the port 1 and input as port 3 and matched termination to port 2 without changing position of variable attenuator and gain control knob of VSWR meter.
5. Note down the reading on VSWR meter on the scale with the help of range dB switch if required.
6. Without disturbing the position of variable attenuator and gain control knob. Carefully place the E-plane tee after slot frequency meter and matched termination to port 1 note the reading of VSWR meter. Let it be S_{32}.
7. Determine the amount of power coming out of port 1 or port 2 due to input at port3.
8. The same experiment may be repeated for other ports also.
9. Repeat the above experiment and other frequencies.

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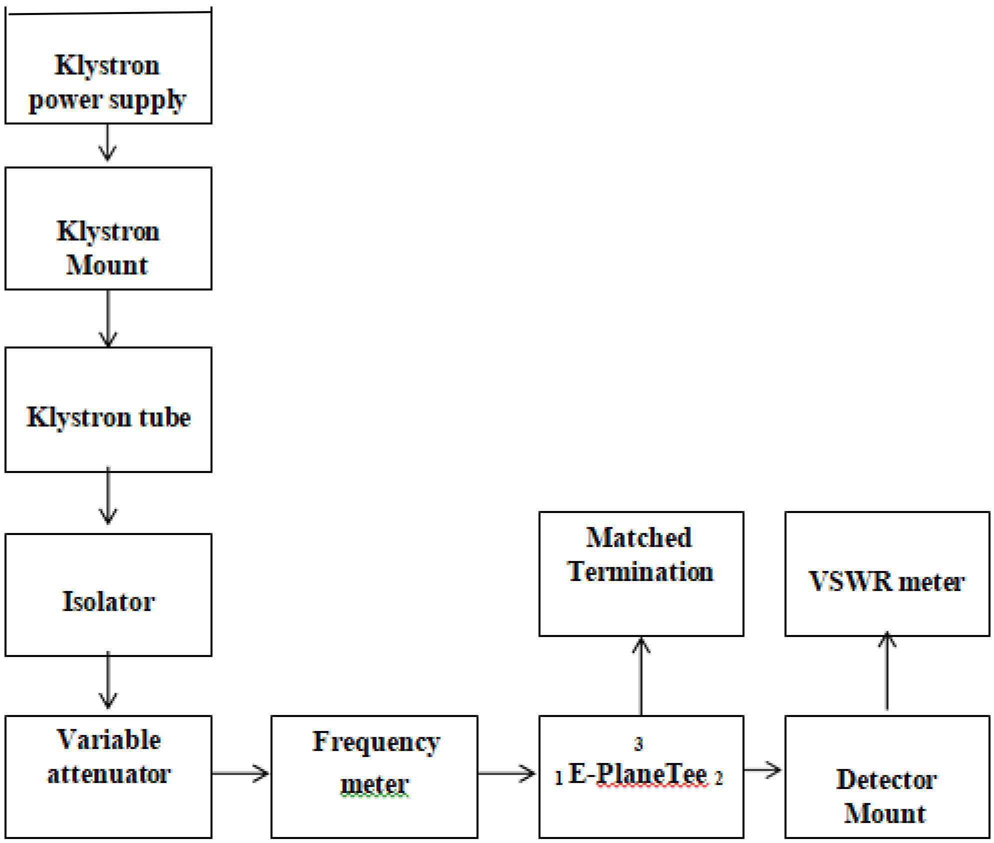

Fig. Study of E plane Tee

OBSERVATIONS:

1. Operating frequency =
2. Incident power P1 =
   - a. E arm =
   - c Port 2 =
3. Incident power P2 =
   - a. E arm =
   - c Port 1 =

4. Incident power E arm =

a. Port 1 =

b. Port 2 =

The scattering parameters are

$S_{21} = (P2/P1)^{1/2} =$

$S_{31} = (P3/P1)^{1/2} =$

$S_{32} = (P3/P2)^{1/2} =$

RESULT:

5 iii) MEASUREMENT OF SCATTERING PARAMETERS OF H – PLANE TEE

OBJECTIVE :-

To determine the s – parameters of H- plane Tee junction

EQUIPMENT REQUIRED:-

Klystron tube, (Klystron Power Supply, Klystron Mount)or (Gunn oscillator with Power supply ,Pin modulator), Isolator, Frequency Meter, Variable Attenuator, Slotted Section, Tunable Probe VSWR Meter, Wave guide Stand, H- plane Tee junction, Movable Short/Matched Termination. and BNC cables etc.

PROCEDURE:

10. Set up the components and equipments.
11. Energize the micro-source for particular frequency of operation.
12. Set any reference level of power on VSWR meter with help of variable attenuator gain control knob of VSWR meter and note down the reading (reference level let x)
13. Insert the H-plane tee as shown in figure with detector to the port 1 and input as port 3 and matched termination to port 2 without changing position of variable attenuator and gain control knob of VSWR meter.
14. Note down the reading on VSWR meter on the scale with the help of range dB switch if required.
15. Without disturbing the position of variable attenuator and gain control knob. Carefully place the H-plane tee after slot frequency meter and matched termination to port 1 note the reading of VSWR meter. Let it be S_{32}.
16. Determine the amount of power coming out of port 1 or port 2 due to input at port3.
17. The same experiment may be repeated for other ports also.
18. Repeat the above experiment and other frequencies.

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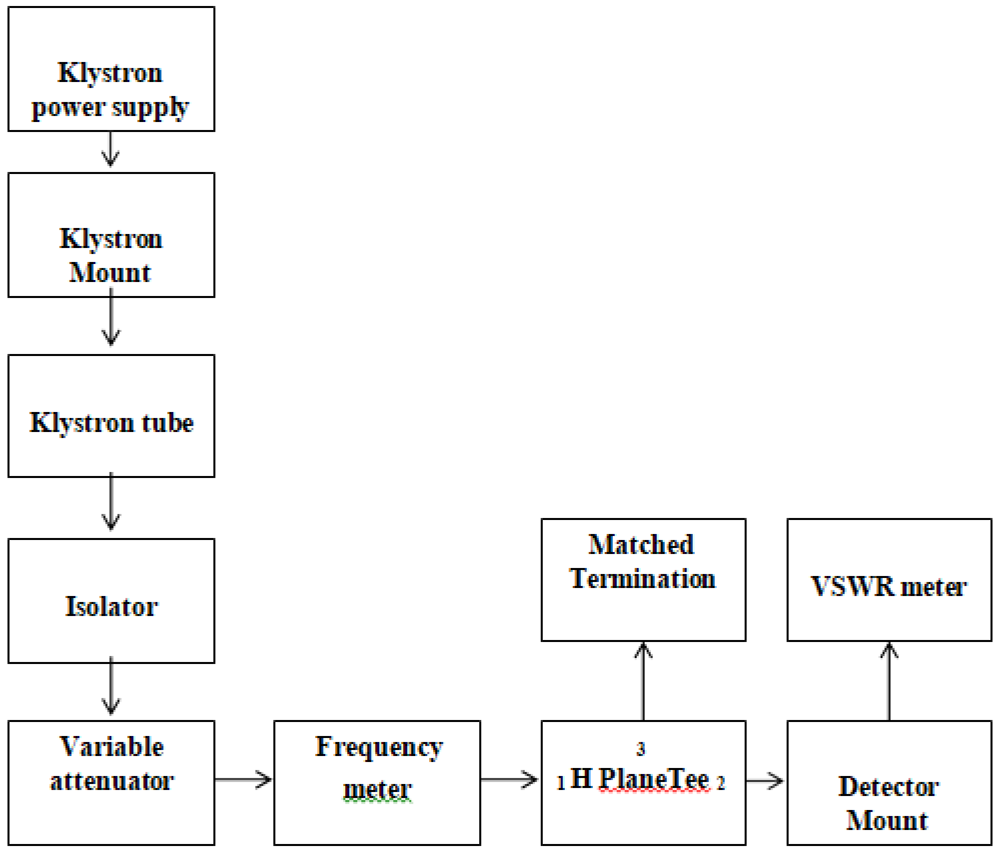


Fig. Study of H plane Tee

OBSERVATIONS:

1. Operating frequency =
2. Incident power P1 =
   a. H arm =
   c Port 2 =
3. Incident power P2 =
   a. H arm =
   c Port 1 =

4. Incident power H arm =

   a. P1 =

   b. P2 =

The scattering parameters are

$S_{21} = (P2/P1)^{1/2} =$

$S_{31} = (P3/P1)^{1/2} =$

$S_{32} = (P3/P2)^{1/2} =$

RESULT:

VIVA QUESTIONS:

1. In terms of construction, bring out the difference between E-plane tee and H-plane tee.
2. When TE10 mode is propagated into port 3 then, what are the power outputs at port 2 and port3.
3. Why E-plane tee is called as series tee?
4. What are the properties of scattering parameters?
5. If equal inputs are applied at port 1 and port 2 then what is the power output at port3.
6. In the E-plane tee what port is perfectly matched to the junction.
7. Explain about the properties of the E-plane tee.
8. What is the difference between E-plane tee and H-plane tee?
9. If the power is applied only at port 3 then what are the power outputs at port 1 and port 2.
10. Bring out the values of the various scattering parameters of E-plane tee.

5 IV) MEASUREMENT OF SCATTERING PARAMETERS OF A MAGIC TEE

OBJECTIVE:- To find out scattering parameters of Magic tee.

EQUIPMENT:- Gunn Oscillator and power supply, Variable attenuator, Frequency meter, Magic Tee, Power meter, Termination and Detection mount BNC cables etc.

THEORY:-The Magic Tee is a device used for combining power from two sources and for splitting power into two outputs in a wave guide system. For simpler inter connections T shaped junctions are used whereas more complex junction may be formed with this hybrid TEE rings. A hybrid junctions or Magic Tee is shown in figure below. Such a junction is symmetrical about an imaginary plane bisecting arms 3 & 4 and has some very useful and intersecting properties. The basic property is that arm 4 is connected to arms 1 & 2 but not to arm 3 and similarly arm 3 is connected to arms 1 and 2 but not to arm 4. All the foregoing characteristics apply to the determinant mode only and occur only if each arm is terminated in a correct load.

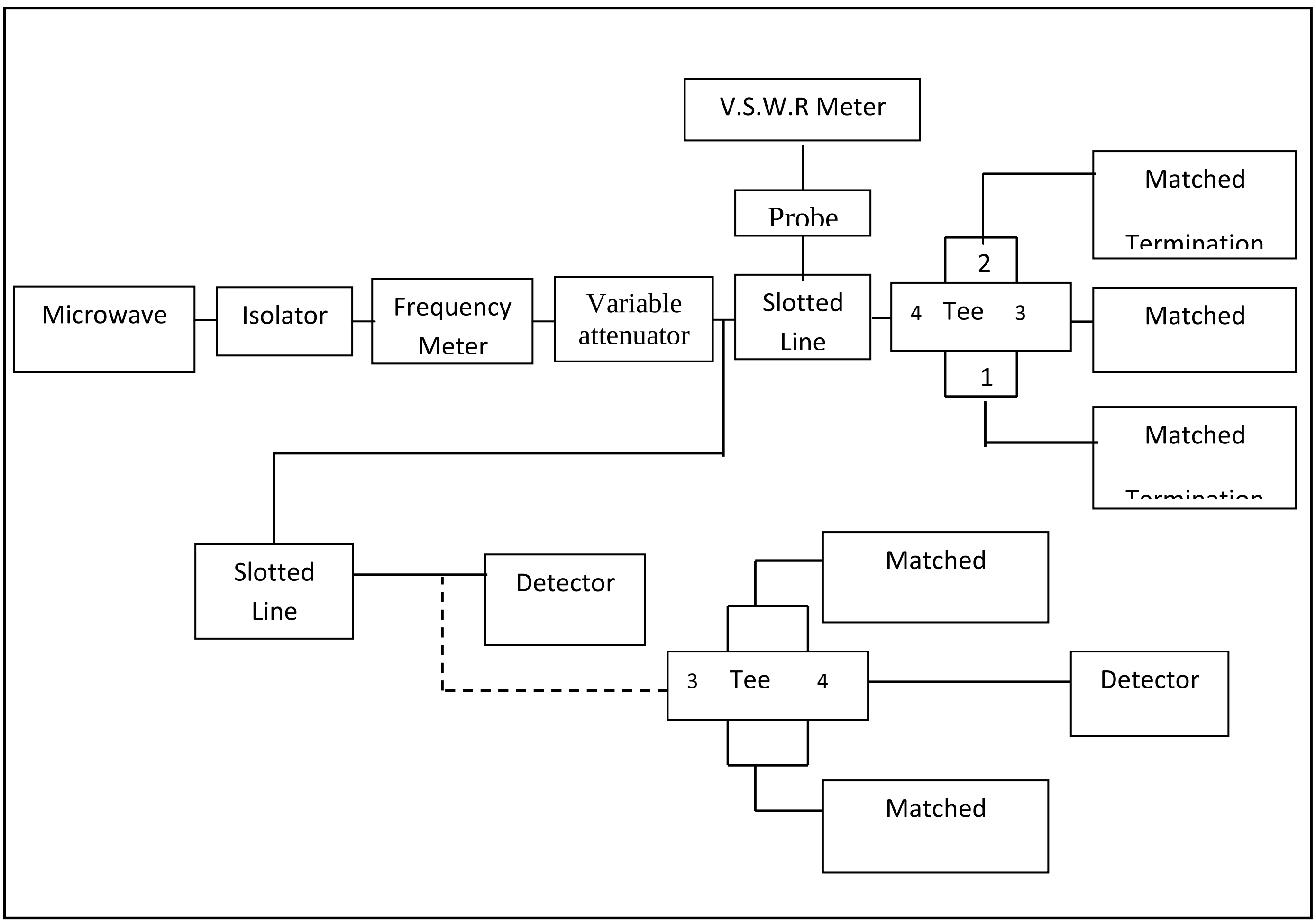


Fig. Study of magic Tee

PROCEDURE:-

1. Set up the components and equipments as shown in fig.
2. Energize the microwave source for particular operation of frequency.
3. With the help of variable attenuator and gain control knob of VSWR meter, set any power level in the VSWR meter and note down. Let it be P_3.
4. Without disturbing the position of variable attenuator and gain control knob, carefully place the magic Tee after slotted line keeping H-arm to slotted line, detector to `E` arm and match termination to arm 1 and 2 . Note down the reading of VSWR meter. Let it be P_4.
5. Determine the isolation between port 3 and 4 as $P_3 – P_4$ in db, i.e., $10 \log_{10} \frac{p_4}{p_3}$
6. Determine the coupling coefficient from equation given in the theory part, i.e.,

$\alpha = 10 \log \frac{p_4}{p_3}$, where p_i input power to arm "i" and p_j is the power detector at arm "j"

7. The same experiment may be repeated for other ports also.
8. Repeat the above experiment for other frequencies.

.**OBSERVATIONS:**

1. Operating frequency =
2. Incident power P1 =
   a. H arm =
   b. E arm =
   c Port 2 =
3. Incident power P2 =
   a. H arm =
   b. E arm =
   c Port 1 =

4. Incident power H arm =

a. P1 =

b. P2 =

c E arm =

5. Incident power E arm =

a. P1 =

b. P2 =

c H arm =

The scattering parameters are

$S_{21} = (P2/P1)^{1/2} =$

$S_{31} = (P3/P1)^{1/2} =$

$S_{41} = (P4/P1)^{1/2} =$

$S_{32} = (P3/P2)^{1/2} =$

$S_{42} = (P4/P2)^{1/2} =$

$S_{43} = (P4/P3)^{1/2} =$

$$[S] = \begin{pmatrix} 0 & S_{21} & S_{31} & S_{41} \\ S_{21} & 0 & S_{32} & S_{42} \\ & & & \end{pmatrix}$$

RESULT:

VIVA QUESTIONS

1. Write S- matrix for magic-tee?
2. What are the application of magic-tee?
3. What are the properties of magic-tee?
4. What is the difference between magic –tee and magic ring?
5. In magic ring what is the electrical distance between the ports?
6. How magic tee acts as an antenna duplexer?
7. Draw the equivalent circuit of a matched magic-tee?
8. What is the phase shift property of s-matrix?
9. What is the magic involved in magic-tee?
10. Draw the direction of electric field in magic –tee?

6. MEASUREMENT OF FREQUENCY

OBJECTIVE :-

To determine the wave length and frequency in a rectangular wave guide working in TE10 made.

EQUIPMENT REQUIRED:-

Klystron tube, (Klystron Power Supply, Klystron Mount)or (Gunn oscillator with Power supply ,Pin modulator), Isolator, Frequency Meter, Variable Attenuator, Slotted Section, Tunable Probe VSWR Meter, Wave guide Stand, Movable Short/Matched Termination. and BNC cables etc.

THEORY :-

For dominant TE10 mode in rectangular wave guide $\lambda_{0,}$ λ_g and λ_c are related as below.

$$\frac{1}{\lambda_0{}^2} = \frac{1}{\lambda_g{}^2} + \frac{1}{\lambda_c{}^2} \Rightarrow \lambda_g = \frac{\lambda_0}{\left[1-(\lambda_0/\lambda_c)^2\right]^{1/2}}$$

where λ_0 is free space wavelength, λ_g is guide wavelength, λ_c is cutoff wavelength

for TE10 mode. $\lambda_c = 2a$ where 'a' is broad dimension of wave guide. The following relationship can be proved.Where c is velocity of light and f is frequency.

BLOCK DIAGRAM:

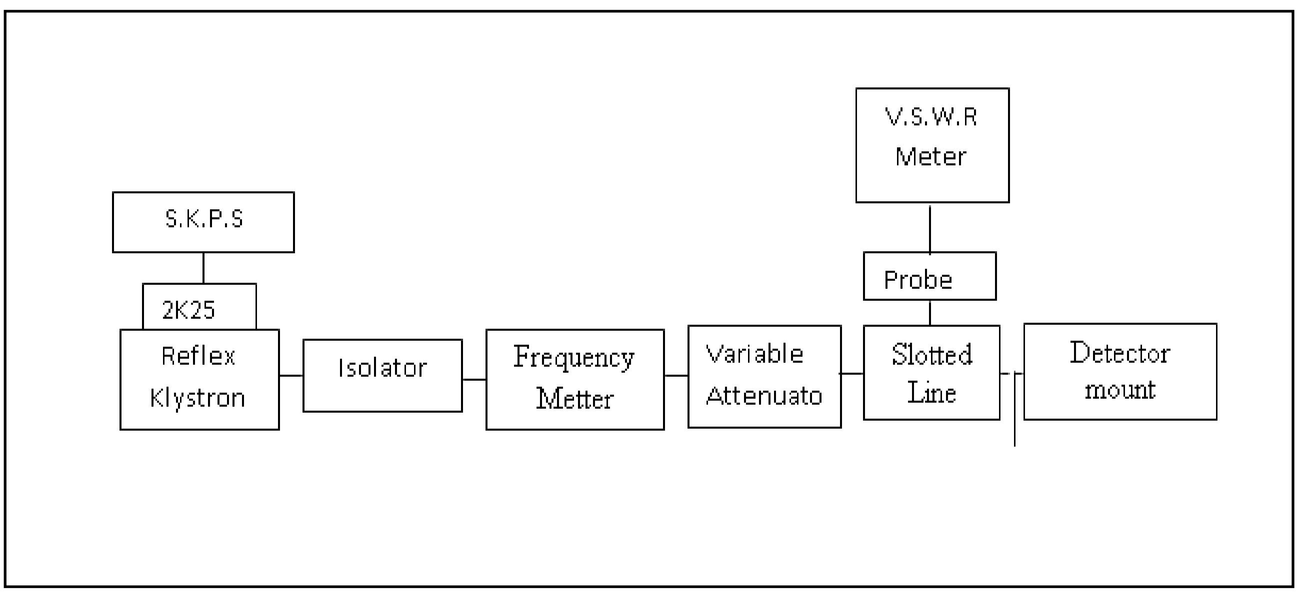


Fig . Set up for frequency measurement

PROCEDURE :-

1. Set up the components and equipments as shown in fig.
2. Energize the microwave source for particular operation of frequency.
3. Tune the probe for maximum deflection in VSWR meter.
4. Tune the frequency meter knob to get a ‘dip’ on the VSWR scale and note down the frequency directly from frequency meter.
5. Move probe along with the slotted line, the deflection in VSWR meter will vary. Move the probe to a minimum deflection position (d_1), to get accurate, reading; it is necessary to increase the VSWR meter range db switch to higher position. Note and record the probe position.
6. Move the probe to next minimum position (d_2) and record the probe position again.
7. Calculate the guide wavelength as twice the distance between two successive minimum position obtained as above i.e.,

   $\lambda_g = 2(d_2 - d_1)$

8. Measure the wave guide inner broad dimension ‘a’. (which will be around 22.86 mm for X-band.)
9. Calculate the frequency by the following equation: -

$$f = \frac{C}{} = C\sqrt{\frac{1}{\lambda g^2} + \frac{1}{\lambda c^2}}$$

Where $C=3*10^8$ meter/sec i.e velocity of light.

10. Verify with frequency obtained by frequency meter.

11. Above experiment can be verified at different frequencies.

CALCULATIONS:

OBSERVATIONS:

Measured Frequency	Observed minima (cm)		Calculated Wave length $\lambda_g = 2(d_2 - d_1)$	Calculated Frequency in free space
	d_1	**d_2**		

RESULT:

VIVA QUESTIONS

1. Explain how frequency can be measured in electronic method?
2. What is cavity resonator?
3. Draw the characteristics of a Absorption type cavity meter?
4. Draw the characteristics of a transmission type cavity meter?
5. How can you measure the frequency using slotted line method?
6. Explain how impedance can be measured using magicTee?
7. Explain how impedance can be measured using slotted line?
8. What is the relation between impedance reflection coefficient?
9. While measured the parameters what precautious you should take?
10. Draw the block diagram of microwave test bench?

7. MEASUREMENT OF IMPEDANCE OF GIVRN LOAD

OBJECTIVE :-

To determine the impedance of the given load

EQUIPMENT REQUIRED:-

Klystron tube, (Klystron Power Supply, Klystron Mount)or (Gunn oscillator with Power supply ,Pin modulator), Isolator, Frequency Meter, Variable Attenuator, Slotted Section, Tunable Probe VSWR Meter, Wave guide Stand, Movable Short/Matched Termination. and BNC cables etc.

BLOCK DIAGRAM :-

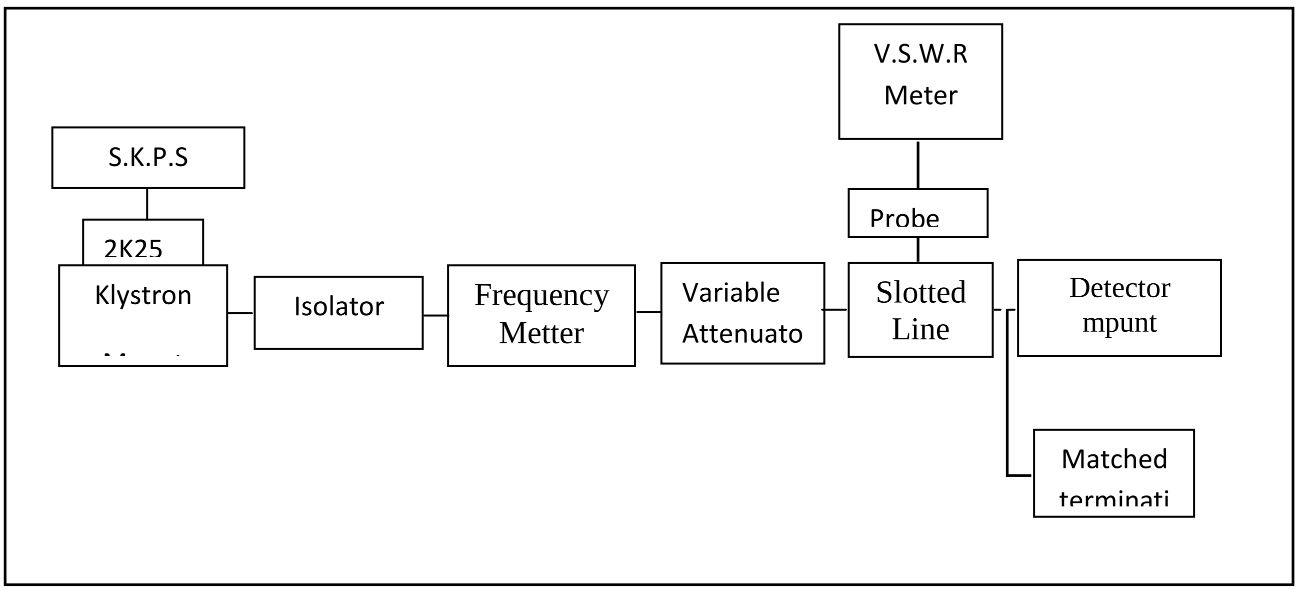


Fig . Set up for Wave length Measurement.

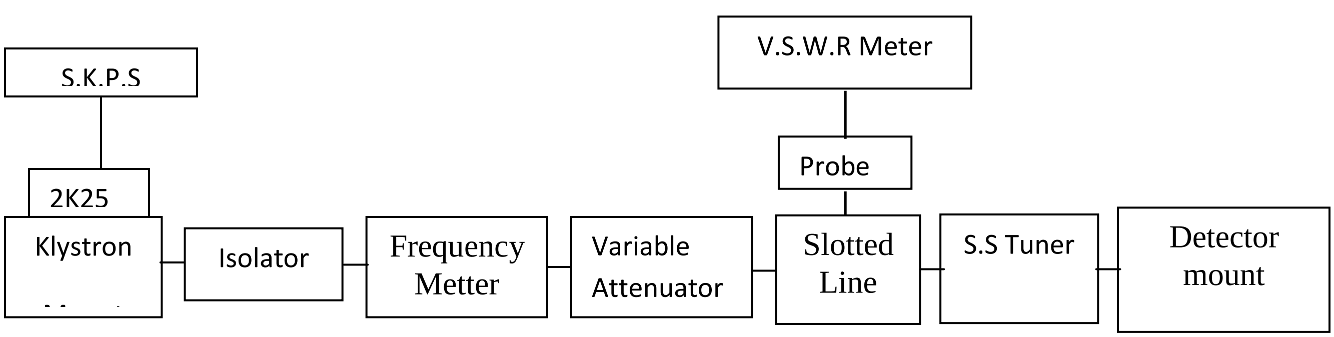


Fig. Set up for VSWR Measurement

PROCEDURE:

1. Setup the components and equipments as shown in the figure.
2. Setup the variable attenuator at minimum attenuation position.
3. Keep the control knobs of VSWR meter as shown below:
   a) Range 40dB
   b) i/P switch – crystal low impedance
   c) meter switch – normal position
   d) Gain (coarse and fine) = mid positions

4. Keep the control knobs of klystron power supply as:
   a) Beam voltage –off
   b) Mod switch –AM
   c) Beam voltage knob – fully anticlockwise.
   d) Repeller voltage = fully clockwise
   e) AM amplitude knob = around fully clockwise.
   f) AM frequency knob = around mid position.

5. Switch the klystron power supply, VSWR meter and cooling fan switch.
6. Switch 'ON' the beam voltage switch to set beam voltage at 300v with the help of beam voltage knob.
7. Adjust the repeller voltage to get some deflection in VSWR meter.
8. Maximize the deflector with AM amplitude and frequency control knob of power supply.
9. Tune the plunger of klystron mount for maximum deflection.
10. Tune the reflector voltage knob for maximum deflection.
11. Tune the probe for maximum deflection in VSWR meter.
12. Tune the frequency meter knob to get a 'dip' on the VSWR scale and note down the frequency directly from frequency meter.
13. Move the probe along the slotted line to get maximum deflection.
14. Adjust VSWR meter gain control knob and variable attenuator until the meter indicates 10 on the normal dB SWR scale.
15. Move the probe to next minima position and note down the SWR 'SO' on the scale. Also note down the probe position. Let it bed.
16. Note the position of 2 successive (maxima) or minima positional Let it be as d1 and d2.
    Hence $\lambda g = 2(d2-d1)$

17. Calculate λg
18. Find out normalized impedance as described.
19. Repeat above for different frequencies.

OBSERVATIONS:

i. Movableshort:

Distance (cm)	Power (dB)
	(min-1)
	(max-1)
	(min-2)
	(max-2)

ii. MatchedTermination

Distance (cm)	Power (dB)
	(min-1)
	(max-1)
	(min-2)
	(max-2)

CALCULATIONS:

$\lambda g= 2(d_2-d_1) =$

where d2 – is distance at min-2 or max-2 d1 - is distance at min-1 or max-1

RESULT:

VIVA QUESTIONS:

1. What are the various methods used for the measurement of impedance?
2. How impedance can measured by using slotted line?
3. How can you determine whether the impedance is inductive or capacitive?
4. How impedance can be measured by using magic tee?
5. What is the purpose of slotted line for the measurement of impedance?
6. How impedance can be measured by using reflectometer?
7. What is the purpose of variable attenuator?
8. How impedance can be determined by using directional couplers?
9. Why standing waves are produced in the waveguide?
10. What is meant by reflection coefficient and how impedance can be determined?

8. VSWR MEASUREMENT

OBJECTIVE:-

To determine low/medium standing – wave –ratios for different loads.

EQUIPMENT REQUIRED:-

Klystron tube, Klystron Power Supply, VSWR Meter, Klystron Mount, Isolator, frequency Meter, Variable attenuator, Slotted line, Tunable probe, Wave guide Stand, Moveable Short/Termination or any unknown load ,BNC Cable, and S-S tuner etc.

THEORY:-V.S.W.R (Voltage standing wave ratio) is defined as ratio of maximum to minimum field strength along the line.

Hence, VSWR [S] = $\backslash V_{max}/V_{min}$

PROCEDURE:-

1. Set up the equipment as shown in the fig.
2. Switch ONthe Power supply, VSWR Meter and cooling Fan.
3. Energize the microwave source for particular operation of frequency.
4. Move the probe along slotted line to a position where maximum deflection is seen in VSWR Meter.
5. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicated 1.0 on normal SWR Scale.
6. Keep all the Controls knob as it, move the probe to immediate minimum position. This reading corresponds to SWR. Read the VSWR on scale and record it.
7. Repeat the above step after change of S.S. tuner probe depth and record the corresponding SWR.
8. If the VSWR is between 3 and 10, change the range dB switch to next higher position and read the VSWR on lower VSWR scale.

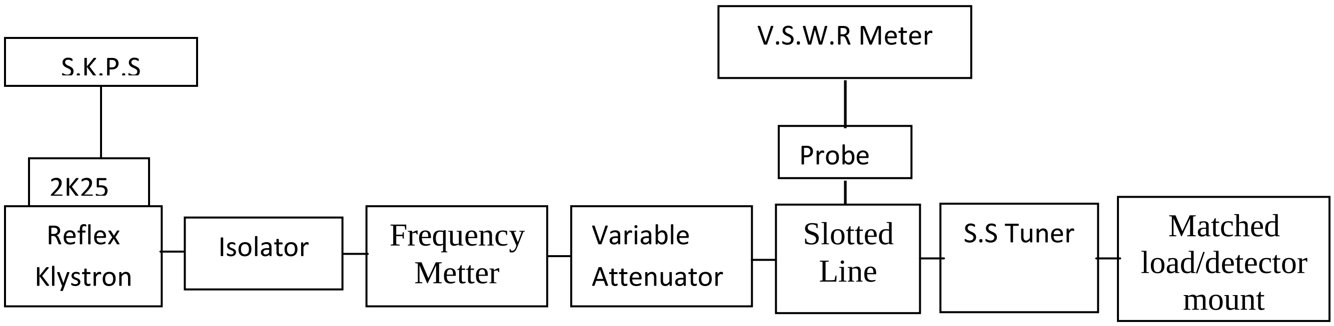


FIG. Set up for VSWR Measurement

OBSERVATIONS:

RESULT:

8. VSWR MEASUREMENT WITH SHORT CIRCUIT LOAD

OBJECTIVE:-

To determine high standing – wave –ratio with the given short circuit load

.

EQUIPMENT REQUIRED:-

Klystron tube, Klystron Power Supply, VSWR Meter, Klystron Mount, Isolator, frequency Meter, Variable attenuator, Slotted line, Tunable probe, Wave guide Stand, Moveable Short/Termination or any unknown load ,BNC Cable, and S-S tuner etc.

THEORY:- V.S.W.R (Voltage standing wave ratio) is defined as ratio of maximum to minimum field strength along the line.

Hence, VSWR [S] = $\backslash V_{max}/V_{min}$

PROCEDURE:-

Energize the microwave source for particular operation of frequency.

1. Set the depth of S.S Tuner slightly more for maximum VSWR.
2. Move the probe the with Slotted line until a minimum is indicated. Note the power reading (P) there. Get the power level which is 3dB less than the measured one (P – 3dB).
3. Move the probe to the left on slotted line until the needle points to the 3dB less. Note and record the probe position on slotted line. Let it be $d_{1.}$
4. Then move the probe right until the needle points to the 3dB less. Record the probe position on slotted line Let it be d_2
5. Measure the distance between two successive maxima positions. Twice this distance is guide wavelength λg.
6. Compute SWR by following equation.

$$\mathrm{SWR} = \frac{\lambda_g}{\pi(d_1 \sim d_2)}$$

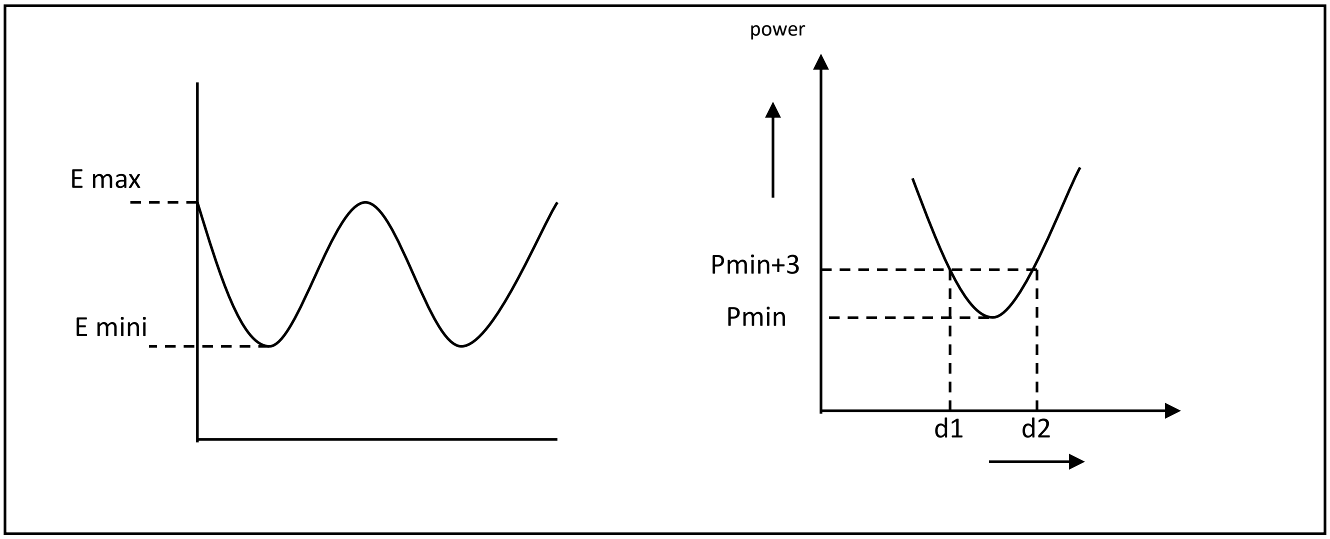


Fig.Standing Wave. **Fig. Double Minima method**

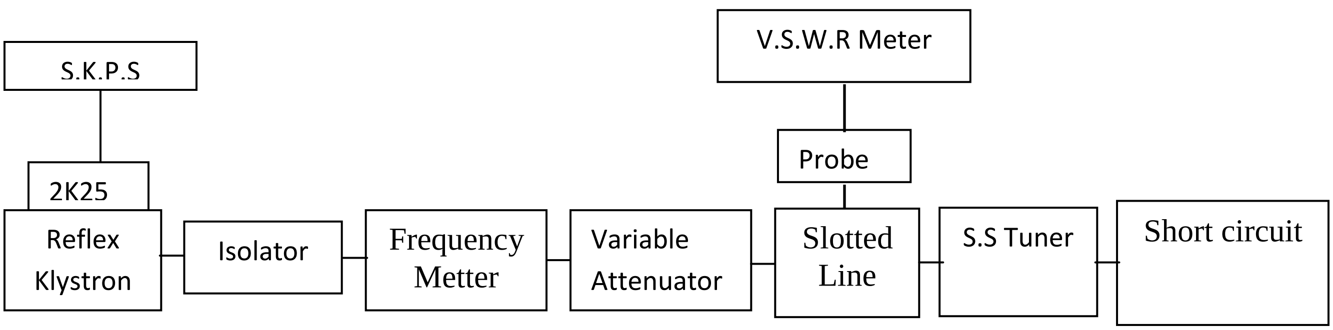


FIG. Set up for high VSWR Measurement

OBSERVATIONS:

RESULT:

VIVA QUESTIONS

1. Define VSWR?
2. Define reflection coefficient?
3. What is the relation between VSWR and reflection coefficient?
4. How a residual VSWR of slotted line arises?
5. While measuring VSWR what are the possible sources of errors occurred?
6. What is the distance between two adjacent minimas or two maximas in standing wave?
7. If VSWR > 10 which method is preferable?
8. In double minima method to find VSWR what is the formula?
9. What is the formula for return loss?
10. Explain how VSWR can be found in double minima method?

MEASUREMENT OF RADIATION PATTERN

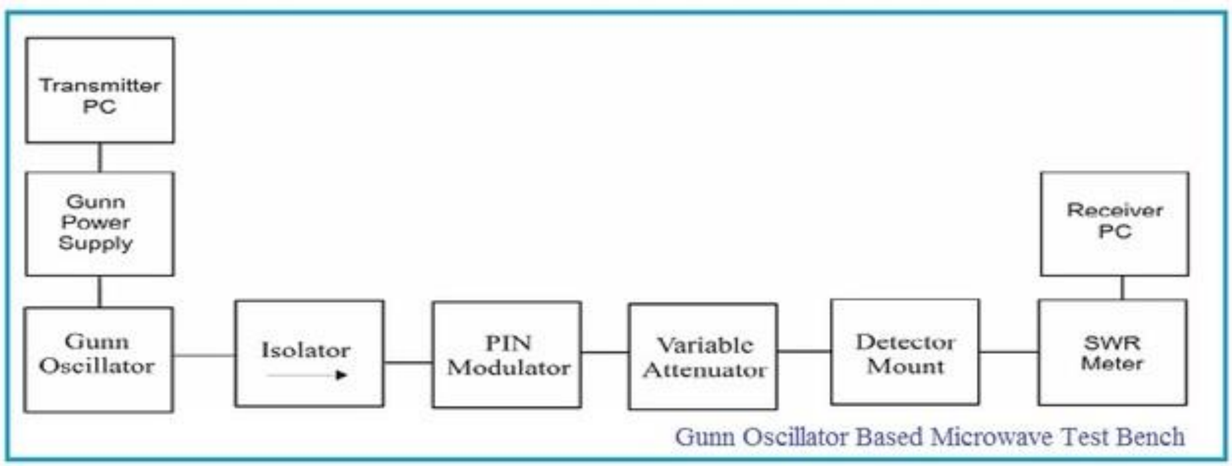
OBJECTIVE :-

To measure the radiation pattern of given microwave antenna

EQUIPMENT REQUIRED:-

Gunn oscillator with Power supply ,Pin modulator, Isolator, Frequency Meter, Variable Attenuator, Slotted Section, Tunable Probe VSWR Meter, Wave guide Stand, Horn antenna, Parabolic antenna, Movable Short/Matched Termination. and BNC cables etc.

BLOCK DIAGRAM:



PROCEDURE:

1) Connect the blocks as shown above.
2) Fire the Gunn diode and turn it for maximum output.
3) Measure length and breadth of horn antenna.
4) Set the transmitting and receiving horn antenna separated by a distance $R=2D^2/\lambda_0$. Where D is the maximum dimension of horn antenna.
5) Adjust the height and azimuth of the receiving antenna for the maximum output. Set the pointer to zero degree.
6) Note the transmitted and received powers.
7) Move the receiving antenna orientation in steps of 10 degrees in one plane

and note the corresponding power readings from VSWR meter or RF Power meter. Tabulate the readings

8) Move the receiving antenna orientation in steps of 10 degrees in the other plane and note the corresponding power readings from VSWR meter or RF Power meter. Tabulate the readings
9) Plot the radiation pattern in both the planes.

Operating Conditions:

1) Gunn Supply voltage =
2) Gunn Diode Current=
3) Operating frequency =
4) Transmitted power, P_t =
5) Received power, P_r =

Observations:

Part A) To find gain of antenna

Half power beam width =

Gain (G) =

Part B) Radiation pattern:

(a) Radiation pattern of horn antenna (H - Plane)

Angle (degrees)	Received power (dB)

(b) **Radiation pattern of horn antenna (E - Plane)**

Angle (Degrees)	Received Power(dB)

Result: Thus the field intensity measurement of a horn antenna was studied andthe following parameters were found.

9: CHARACTERISATION OF 660 & 850 NM LEDs

AIM OF THE EXPERIMENT

The aim of the experiment is to study the relationship between the LED dc forward current and the LED optical power output and determine the linearity of the device at 660nm as well as 850nm. The conversion efficiencies of the two LEDs will also be compared.

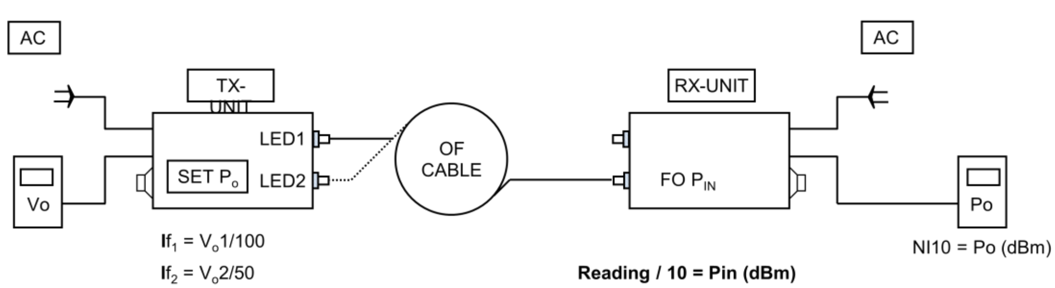
BASIC DEFINITIONS

LEDs and laser diodes are the commonly used sources in optical communication systems, whether the system transmits digital or analogue signals. In the case of analogue transmission, direct intensity modulation of the optical source is possible, provided the optical output from the source can be varied linearly as a function of the modulating electrical signal amplitude. LEDs have a linear optical output with relation to the forward current over a certain region of operation. It may be mentioned that in many low-cost, short-haul and small bandwidth applications, LEDs at 660nm, 850nm and 1300nm are popular. While direct intensity modulation is simple to realize, higher performance is achieved by fm modulating the base-band signal prior to intensity modulation.

The relationship between an LED optical output Po and the LED forward current I_F is given by Po = $K.I_F$, (over a limited range), where K is a constant.

PROCEDURE WITH BLOCK SCHEMATIC

The schematic diagram for characterization of the LEDs converter is shown.



SET UP LED CHARACTERISATION

The step by step procedure is given here:

STEP 1: Connect one end of Cable1 to the LED1 port of FO Analog Transmitter and the other end to the FO PIN (power meter) port of FO Analog Receiver.

STEP 2: Set DMM1 to the 200mV range and connect the green wires marked Po on the RX unit to it. The power meter is ready for use. Po = (Reading) / 10 dBm.

STEP 3: Set DMM2 to the 200.0mV range and connect it between the Vo1 and ground in the TX unit. I_{F1} = Vo1 (mv) / 100 in ma.

STEP 4: Plug the AC mains for both units. Adjust the SET Po knob on the TX unit to the extreme anticlockwise position to reduce I_{F1} to 0. The reading on the power meter should be out of range.

STEP 5: Slowly turn the SET Po knob clockwise to increase I_{F1}. The power meter should read -30.0dB approximately. From here change I_{F1} in suitable steps and note the power meter readings, Po. Record upto the extreme clockwise position.

STEP 6: Repeat the complete experiment for PO LED2 and tabulate the readings for Vo2 & Po. I_{F2} = Vo2 (mv) / 50 in ma. Apply the correction of 2.2 dB discussed in Experiment 1 for the 850nm LED.

TABLE OF READINGS FOR 660NM

S No	**V01 (mv)**	**IF1 = Vo1 / 100 (ma)**	**Po (dBm)**

TABLE OF READINGS FOR 850NM

S No	V01 (mv)	IF1 = Vo1 / 100 (ma)	Po (dBm)	Po (dBm) corrected

RESULT:

10. CHARACTERISTICS OF LASER DIODES

AIM OF THE EXPERIMENT

The aim of the experiments is to study

(a) Optical Power **(Po)** of the Laser Diode Vs Laser Diode Forward Current **(IF)**

(b) Monitor Photo Diode Current **(IM)** Vs Laser Optical Power Output **(Po)**

BASIC DEFINITIONS AND CONCEPTS

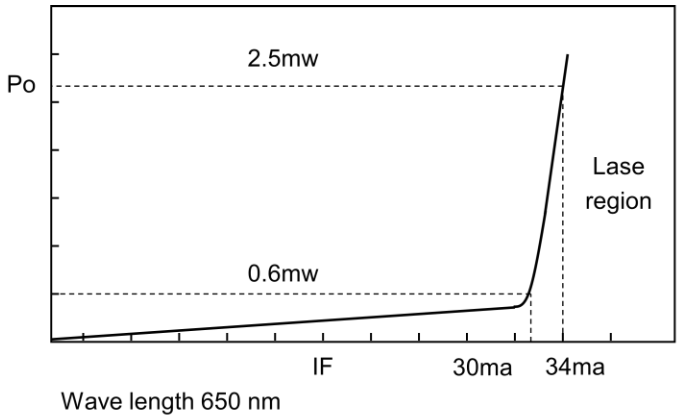
LEDs and laser diodes are the commonly used sources in optical communication systems,, whether the system transmits digital or analogue signals. In the case of analogue transmission, direct intensity modulation of the optical source is possible, provided the optical output from the source can be varied linearly as a function of the modulating electrical signal amplitude. LEDs have a linear optical output with relation to the forward current over a certain region of operation. It may be mentioned that in many low cost, smart haul and small bandwidth applications, LEDs at 660nm, 850nm and 1300nm are popular. While direct intensity modulation is simple to realize, higher performance is achieved by FM modulating the base band signal prior to intensity modulation.

Laser Diodes (LDs) are used in telecom, datacom and video communication applications involving high speeds and long hauls . All signal mode optical fiber communication systems use lasers in the 1300nm and 1550nm windows. Lasers with very small line widths also facilitate realization of wave length division multiplexing (WDM) for high density communication over a singe fiber. The inherent properties of LDs that make them suitable for such applications are, high coupled optical power into the fiber (typical greater than 1mw), high stability of optical intensity, small line widths (less than 0.05nm in special devices), high speed (several GHz) and high linearity (over a specified region suitable for analogue transmission). Special lasers also provide for regeneration/amplification of optical signals within an optical fiber. These fibers are known as erbium doped fiber amplifiers. LDs for communication applications are available in the wave length regions 650nm, 780nm, 850nm, 980nm, 1300nm and 1550nm. Even though a variety of laser diode constructions are available there are a number of common features in all of them. We have selected a very simple device (650nm/2.5mw) to demonstrate the functioning of a laser diode.

Specifications of a typical laser diode at 650 nm is summarized below,

SPECIFICATIONS OF THE LASER MODULE @ 25^0C

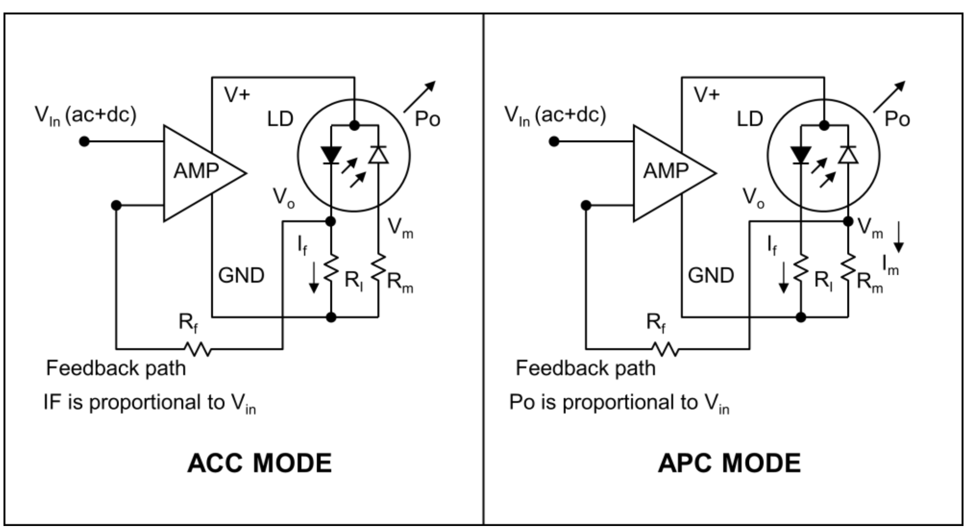
Symbol	Parameter	Typical	Unit
*Po	CW output power	2.5	mW
*lop	Operating Current	30	mA
*Wp	Wave length at peak emission	650	nm
*MTTF	Mean Time feature	10,000	hrs



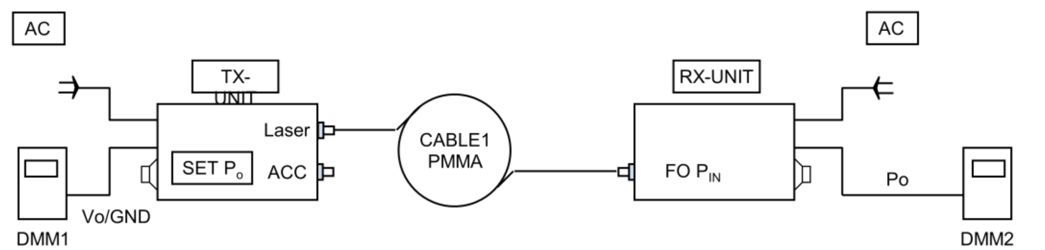
Typical Characteristics of a Laser Diode

Monitor Photo Detector (MPD), Automatic Power Control and Automatic Current Control Modes of Operation

A laser diode has a built in photo conductor, which one can employ to monitor the optical intensity of the laser at a specified forward current. This device is also effectively utilized in designing an optical negative feedback control loop, to stabilize the optical power of a laser in the steep lasing region. The electronic circuit scheme that employs the monitor photo diode to provide a negative feedback for stabilization of optical power in known as the automatic power control mode (APC). If a closed loop employs current control alone to set optical power then this mode is called the automatic current control mode (ACC). The disadvantage of ACC scheme is that the optical power output may not stable at a given current due to the fact that small shifts in the lasing characteristics occur with temperature changes and ageing. The disadvantage of the APC is that the optical feedback loop may cause oscillations, if not designed properly.



(a) Optical Power (Po) of the Laser Diode Vs Laser Diode Forward Current (IF)



SET UP FOR Po Vs IF MEASUREMENT

PROCEDURE:

The schematic diagram for study of the LD Po as a function of LD forward current IF is shown below and is self explanatory

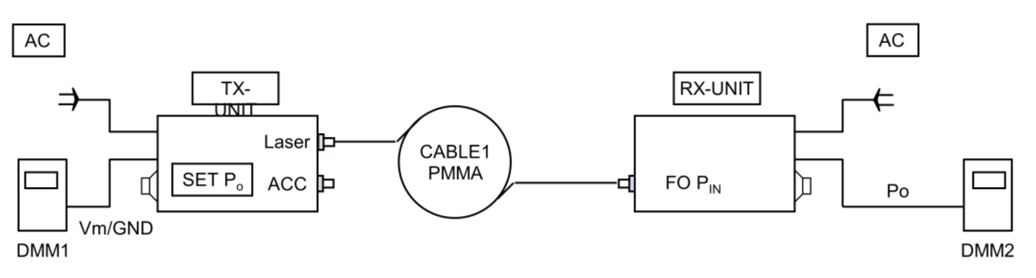
1. Connect the 2 meter PMMA FO cable (cable 1) to Tx unit and couple the laser light to the power meter on the Rx unit as shown. Select ACC mode operation.
2. Set DMM1 to the 2000mV range and on the Rx side connect to the terminals marked Po to it. Turn it on. The power meter is now ready for use. Po = (reading)/10 dBm
3. Set DMM2 to the 200mV range and connect it between Vo and GND and on the Tx unit. (IF = Vo/100).
4. Adjust the SET IF on the Tx knob to the extreme anticlockwise position to reduce IF to 0. the power meter reading will normally be below -40 dBm or out of range.
5. Slowly turn the SET Po knob clockwise to increase IF and Po. Note IF and Po readings prior to and above the Lase threshold.
6. Plot the graph Po Vs IF on a semi log graph sheet. Determine the slopes prior to lasing and after lasing. Record the laser threshold current.

Table of Readings (ACC Mode/PMMA Cable)

INFERENCES

From the above table it is seen that the laser optical output does not increase appreciably for I_F below the threshold current I^{th}. Above I^{th}, Po increases steeply Po is very steep. The Lase threshold may be determined from the graph or by recording closer readings.

b) Monitor Photo Diode Current (IM) Vs Laser Optical Power Output (Po)



SET UP FOR IM Vs Po MEASUREMENT

PROCEDURE:

The schematic diagram for study of the monitor photodiode current as a function of LD optical output Po is shown below and is self explanatory.

1. Connect the 2 meter PMMA FO cable to Po port and couple the laser light to the power meter

as shown.

2. Set DMM1 to the 2000mV range and on the Rx side connect to the terminals marked Po to it.

Turn it on. The power meter is now ready for use. Po = (reading)/10 dBm

3. Set DMM2 to the 200mV range and connect it between Vo and GND and on the Tx unit.

4. Adjust the SET Po knob to the extreme anticlockwise position to reduce IM to minimum value.

there will be negligible offset voltage..

5. Slowly turn the SET Po knob clockwise to and note VM readings.

6. Plot the graph IM Vs Po on a semi log graph sheet. IM = (VM)/(100K)

Table of Readings (ACC Mode/PMMA Cable)

INFERENCES

From the above table it is seen that the MPD photo current sharply increase above the threshold Po, following the pattern of the first part of experiment. The threshold Po and I_F (threshold) may be computed from the plot.

11. DESIGN & EVALUATION OF A LASER DIODE INTENSITY MODULATION SYSTEM

AIM OF THE EXPERIMENT

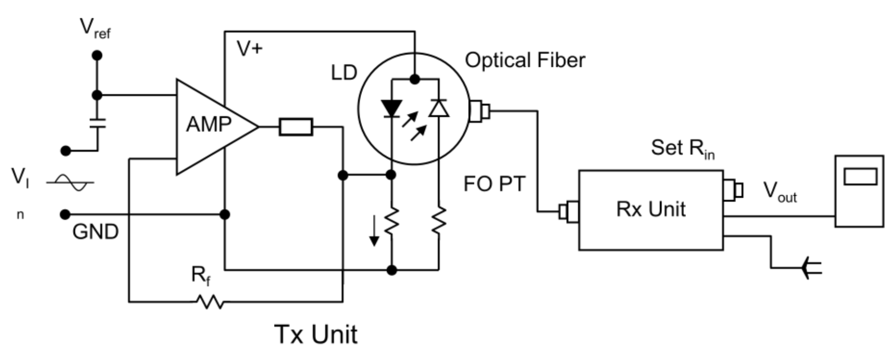
The aim of the experiments is to study the following ac characteristics of an intensity modulation laser and fiber optic system.

(a) V_{in} (ac) Vs V_{out} (ac) for fixed carrier power Po and signal frequency, Fo

(b) V_{in} max Vs Po for known distortion free V_{out} at fixed Fo

BASIC DEFINITIONS AND CONCEPTS

The intensity modulation / demodulation system is realized using the Tx unit and the Rx unit linked through an optical fiber. We use the 2 meter PMMA fiber cable.

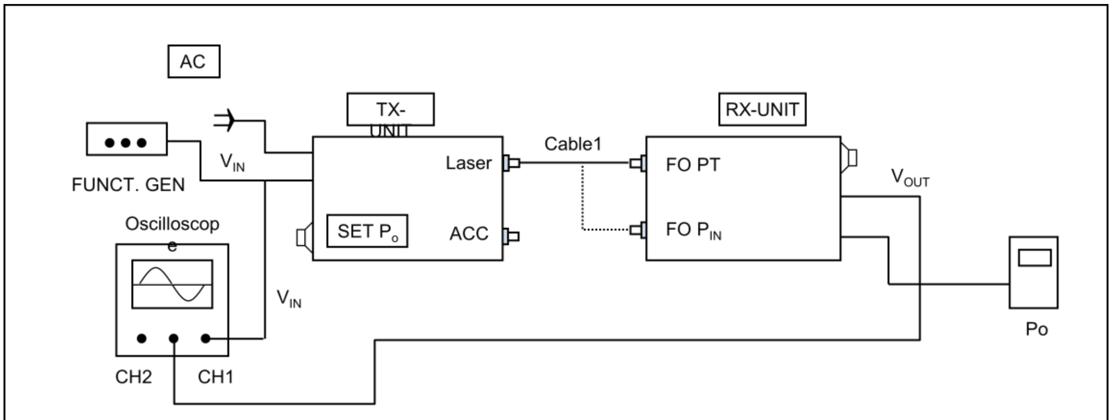


Schematic of IM studies

The laser carrier power, Po is set by adjusting the SET Po knob in the middle Lase region. Selection of optimum carrier power is essential to minimise distortion. Limiting depth of modulation also ensures distortion free transmission. The bandwidth of the system in present case is limited by the photo detector. We may choose to operate in the ACC mode to obtain optical output proportional to the modulating signal V_{in}.

An ideal IM transmission system will have the relationship $V_{out} = G. V_{in}$, where G is a factor dependent on the LD conversion efficiency, loss in the optical transmission path and the laser photo detector conversion efficiency. Distortion results from the LD being biased in the non linear region. Bandwidth is limited by the slowest device in the system, in this case it is photo transistor. Speed can be increased by using a PIN diode, which is inherently a faster device.

BLOCK SCHEMATIC:



SET UP FOR IM STUDY

PROCEDURE:

1. Connect one end of the PMMA FO cable (cable 1) to the port on the Tx unit. The other end is first connected to FO PIN (on Rx unit) to set the carrier power level of the laser. Then it is removed and given to FO PT (Rx unit) to study the response of the IM system.

2. Set DMM to the 2000mV range. Connect it to Po. The power meter now ready for use. Po = reading / 10 dBm.

3. On the Tx unit connect V_{in} to a function generator (10Hz to 500KHz sine wave output, 10mV to 2000mV p-p output). The black lead is ground. Give the function generator output to CH1, as shown.

4. On the Rx unit, connect V_{out} to CH2 of the dual oscilloscope. Connect the black lead to ground.

5. Plug the AC mains for both systems.

6. With the PMMA FO cable connected to the power meter, adjust the SET Po knob to set the optical carrier power Po to a suitable level say, -14dBm. Next disconnect the cable from the power meter and connect to FO PT.

7. Set signal frequency and amplitude to 2KHz and 100mV respectively. Observe the transmitted

and received signals on the oscilloscope. Set R_{in} suitably to get $V_{out} = V_{in}$ or a known gain or minimum gain. The system gain is now set. Next, vary V_{in} is suitable values from 10mV to 200mV p-p and note the values of V_{out}. Tabulate and plot graph V_{out} Vs V_{in}.

<u>TABLE OF READINGS</u> : V_{OUT} Vs V_{IN}

Frequency = 2KHz, Carrier Level Po = -   dBm, initial gain =

7. Set signal frequency and frequency to 2KHz and po to -25 dBm. Disconnect V_{in} before Po measurement. Set V_{in} to its maximum value for distortion free V_{out}. Note the values of V_{in} and V_{out}. Repeat this for other values of Po and record change in gain if any. You may additionally observe the waveforms in the oscilloscope dc coupled position too.

TABLE OF READINGS : V_{IN} max Vs Po

Frequency = 2KHz, initial gain = minimum

You may also compare the ACC and the APC modes in the case of IM. The experiment may be repeated for other settings gain.

RESULT:

12. ENCODING METHODS FOR FIBEROPTIC DIGITAL TRANSMISSION

Aim of the Experiment:

The aim of the experiment is to study the following encoding methods used in optical fiber digital transmission.

1. Baseband or Non Return to Zero (NRZ) Transmission
2. Return to Zero Coding (RZ)
3. Non Return to Zero Inverted Coding (NRZI)
4. Biphase Coding
5. Manchester Coding

Basic definitions

A modulation code is defined as a rule by which a serial train of binary data (comprising ones and zeroes) is converted to a signal suitable for transmission. Some of the commonly used codes are listed for study in this experiment. There are a few others which are outside the scope of this experiment.

In serial data transmission, a 'symbol' is a signal level (low or high) that is held for length of time (symbol width or symbol time). The capacity of a channel is the symbol rate (inverse of symbol time). This is the symbols per second or baud. Channel capacity has the units of symbols per second or baud. Some modulation codes require several symbols per bit of data. For example, self clocking codes require two symbols per bit of data. The various codes are described below. Relative features of the codes are given in the table. The waveform diagram depicts the patterns for the serial train 1100.

NON RETURN TO ZERO (NRZ) : This is a level type code and is one that is widely used in serial data transmission. A '0' is low level and a '1' is a high level.

RETURN TO ZERO (RZ) : This is an impulse type code where a '1' is represented by a high level that returns to zero. Its advantage is power conversion as transmission takes place only for a '1'.

NON-RETURN-TO ZERO INVERTED (NRZI): This is an edge type code where a '0' is represented by an edge and a '1' is represented by no edge.

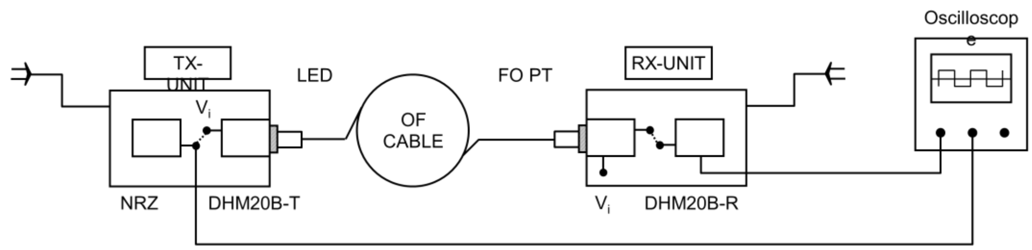
BIPHASE (Space) is an edge type invertible self-clocking code in which each bit cell starts with an edge and for a '0' an additional edge occurs during the middle of the bit cell.

MANCHESTER : This is a level type of code in which a '1' bit cell is initially high and then has a high to low transition in the middle of the bit cell. A '0' bit cell is initially low and has a low to high transition in the middle of the bit cell.

PROCEDURE WITH BLOCK SCHEMATIC

The schematic diagram is shown below and is self explanatory.

The step by step procedure is given here



SET UP FOR A CODE TESTING

STEP 1: Connect one end of Cable1 to the LED port of the FODTX and the other end to the FO port of FODRX. **While connecting the cable please note that minimum force should be applied. At the same time ensure that the connector is not loosely coupled the receptacle.**

STEP2: Connect NRZ encoder output to Vin on the TX side. Also connect it to Ch1 of a dual trace oscilloscope. Connect Vo on the RX side to Ch2 of the oscilloscope.

STEP3: Set Rin to 200W using a DMM to measure the resistance.

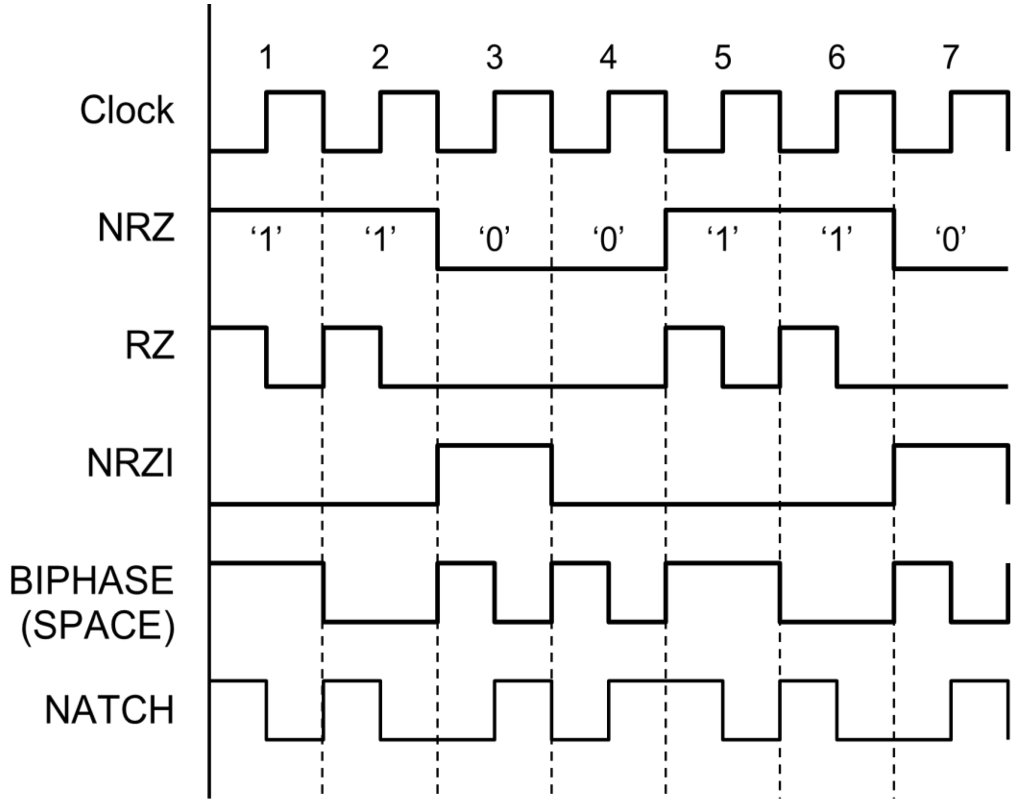
STEP4:Now turn the power on for the TX and RX units. The NRZ waveform should appear on Ch1. It should be a 5KHz square wave.

STEP5: Adjust Rth until the waveform on CH2, is almost identical to the NRZ.

STEP6:Next connect Vo to NRZ input of the decoder on the RX side and connect the oscilloscope CH2 to Vout. Reset both the Tx and Rx systems once . Observe the decoded Vout and compare with the NRZ encoder output. Read the serial code 1100 (this is repeated cyclically).

STEP7: Repeat Step 6 for other waveforms one after the other, connecting the appropriate jumper on the Tx and Rx sides and resetting the system each time. The oscilloscope probes shall remain on the NRZ output (as this is the base band test signal for other codes) and Vout. Match the received signals with the expected waveforms.

EXPECTED WAVEFORMS:



Waveforms for different coding techniques

RESULT:

13.: DETERMINATION OF NUMERICAL APERTURE OF OPTICAL FIBERS

AIM OF THE EXPERIMENT

The aim of the experiments is to study the numerical aperture of the optical fibers available.

BASIC DEFINITIONS

Numerical aperture of any optical system is a measure of how much light can be collected by the optical system. It is the product of the refractive index of the incident medium and the sine of the medium ray angle.

$NA = ni.\sin\theta_{max}$,   ni for air is 1, hence $NA = \sin\theta_{max}$

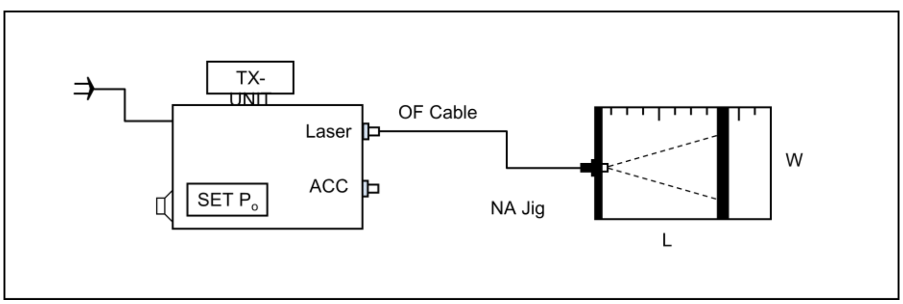
For a step index fiber, as in the presence case, the numerical aperture is given by
$N = (n_{core}^2 - n_{cladding}^2)^{1/2}$

For very small differences in refractive indices the equation reduces to $NA = n_{core}(2\Delta)^{1/2}$, where Δ is the fractional difference in refractive indices.

The experimenter, may refer to the specifications of the PMMA fiber given in appendix I and record the manufacturer's NA, $n_{cladding}$, n_{core} and θ.

PROCEDURE WITH BLOCK SCHEMATIC

The schematic diagram of the numerical aperture measurement system is shown in below and is self explanatory.



1. Connect one end of the PMMA FO cable to Po of Tx unit and the other end to the NA jig.
2. Plug the AC mains. Light should appear at the end of the fiber on the NA jig. Turn the SET Po knob clockwise to set to maximum Po. The light intensity should increase.
3. Hold the white scale-cum screen, provided in the kit vertically at a distance of 15mm (L) from the emitting fiber end and view the red spot on the screen. A dark room will facilitate good contrast. Position the screen-cum-scale to measure the diameter (W) of the spot. Choose the

largest diameter.

4. Compute NA from the formula NA = $\sin\theta_{max} = W/(4L^2+W^2)^{1/2}$. Tabulate the reading and repeat the experiment for 10mm, 20mm and 25mm distance.

Table of readings:

S No	**L (mm)**	**W (mm)**	**NA =** $W/(4L^2+W^2)^{1/2}$	**Θ = sin -1 (NA)**

INFERENCES

The numerical aperture as recorded in the manufacturer's data sheet is 0.5 typically. The value measured here is 0.437. The lower reading recorded is mainly due to the fiber being under filled. The acceptance angle is given by 2max. The value of 52 degrees recorded in the experiment is close to the range of 55-60 degrees. The lower reading is again due to the fiber being under filled.

The procedure may be repeated for cable2 too. Since the power from the smaller core fibers will not be intense, we may have to carry out the experiment in a dark room.

14. LOSSES IN OPTICAL FIBRES AT 660NM & 850NM

AIM OF THE EXPERIMENT

The aim of the experiment is to study various types of losses that occur in optical fibers and measure losses in dB of two optical fiber patch cords at two wavelengths, namely, 660nm and 850nm. The coefficients of attenuation per meter at these wavelengths are to be computed from the results.

BASIC DEFINITIONS

Attenuation in an optical fiber is a result of a number of effects. This aspect is well covered in the books referred to in Appendix II. We will confine our study to measurement of attenuation in two cables (Cable1 and Cable2) employing an SMA - SMA In-line-adaptor. We will also compute loss per meter of fiber in dB. We will also study the spectral response of the fiber at 2 wavelengths, 660nm and 850nm and compare with the plot in Appendix II.

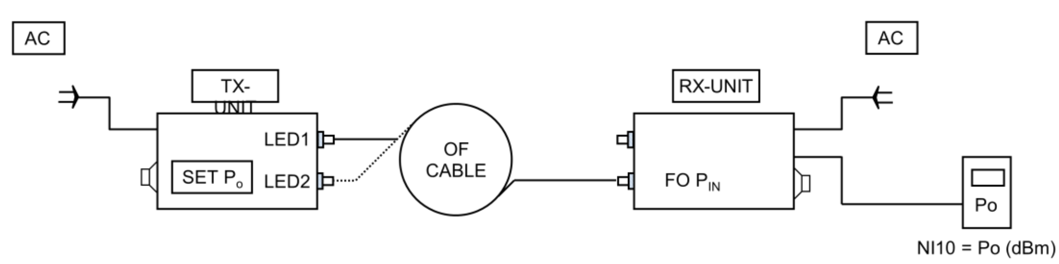
The optical power at a distance, L, in an optical fire is given by $P_L = P_O\, 10^{(-\alpha L / 10)}$ where Po is the launched power and α is the attenuation coefficient in decibels per unit length. The typical attenuation coefficient value for the fiber under consideration here is 0.3 dB per meter at a wavelength of 660 nm. Loss in fibers expressed in decibels is given by -101og (P_o / P_F) where, Po is the launched power and P_F is power at the far end of the fiber. Typical losses at connector junctions may vary from 0.3 dB to 0.6 dB.

Losses in fibers occur at fiber - fiber joints or splices due to axial displacement, angular displacement, separation (air core), mismatch of cores diameters, mismatch of numeral apertures, improper cleaving and cleaning at the ends.

The loss equation for a simple fiber optic link is given as:

Pin (dBm) - Pout (dBm) = $L_{J1} + L_{FIB1} + L_{J2} + L_{FIB2} + L_{J3}$ (dB): Where, L_{J1}(dB) is the loss at the LED - connector junction, L_{FIB1}(dB) is the loss in cable1, L_{J2}(dB) is the insertion loss at a splice or in - line adaptor, L_{FIB2}(dB) is the loss in cable2 and L_{J3}(dB) is the loss at the connector - detector junction.

PROCEDURE WITH BLOCK SCHEMATIC



SET UP FO LOSS MEASUREMENT

The step by step procedure is given here:

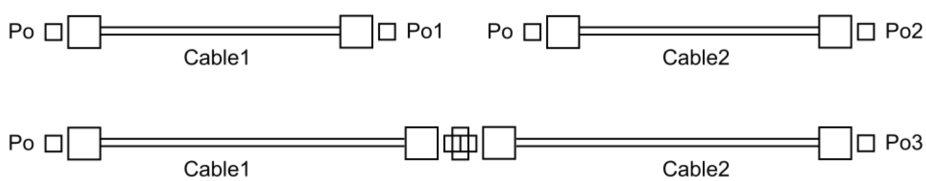
STEP1: Connect one end of Cable1 to the LED1 port of the FO Analog Transmitter and the other end to the FO PIN port (power meter port) of FO Analog Receiver.

STEP2: Set the DMM to the 2000mV range. Connect the pair of wires marked Po on FO Analog Receiver to the DMM, red lead of DMM to Po+ black lead of the DMM to Po- terminals. Turn the DMM on. The power meter is now ready for use.

STEP3: Plug the AC mains for both units. Connect the optical fibre path cord, Cable1 securely, as shown, after relieving all twists and strains on the fibre. <u>While connecting the cable please note that minimum force should be applied. At the same time ensure that the connector is not loosely coupled to the receptacle</u>. After connecting the optical fibre cable properly, adjust SET Po knob to set power of LED1 to a suitable value, say, -15.0dBm (the DMM will read 150mV). Note this as P_{o1}.

STEP4: Wind one turn of the fibre on the mandrel (round plastic tube) as shown in Experiment 1 and note the new reading of the power meter P_{o2}. Now the loss due to bending and strain on the plastic fibre is P_{o1}- P_{o2} dB. For more accurate readout set the DMM to the 200.0mV range and take the measurement. Typically the loss due to the strain and bending the fibre is 0.3 to 0.8 dB.

STEP5: Next remove the mandrel and relieve Cable1 of all twists and strains. Note the reading P_{o1}. Repeat the measurement with Cable2 (5metres) and note the reading P_{o2}. Use the in - line SMA Adaptor and connect the two cables in series as shown. Note the measurement P_{o6}.



Loss in Cable1 = P_{o3} - P_{o2} - L_{ila} Loss in Cable2 = P_{o3} - P_{o1} - L_{ila}

Assuming a loss of 1.0dB in the in - line adaptor (L_{ila} = 1.0dB), we obtain the loss in each cable. The difference in the losses in the two cables will be equal to the loss in 4 meters of fibre (assuming that the losses at connector junctions are the same for both the cables). The experiment may be repeated in the higher sensitivity range of 200.0mV. The experiment also may be repeated for other Po settings such as -20dBm, -25dBm, -30dBm etc.

TABLE OF READINGS FOR 660NM

Sl N0	Po1 (dBm)	Po2 (dBm)	Po3 (dBm)	LOSS IN CABLE1(dB)	LOSS IN CABLE2(dB)	LOSS IN CABLE3(dB)	LOSS/meter (dB) AT 650NM

STEP6: Repeat the entire experiment with LED2 at 850nm and tabulate in 1.4.2

NOTE:

The power meter has been calibrated internally to read power in dBm at 660nm. However the calibration has to be redone manually for measurements at 850nm. The PIN has a 66% higher sensitivity at 850nm as compared to 660nm for the same input optical power. This corresponds to sensitivity higher by 2.2dB. To calibrate the power meter at 850nm, deduct 2.2dB from the measured reading. In computing losses in cables and fibers this gets eliminated while solving equations.

TABLE OF READINGS FOR 850NM

RESULT: