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MICROWAVE&OPTICAL COMMUNICATIONS

Laboratory Manual

(R10 Syllabus)

LIST OF EXPERIMENTS

1. REFLEX KLYSTRON CHARACTERISTICS.
2. GUNN DIODE CHARACTERISTICS.
3. DIRECTIONAL COUPLER CHARACTERISTICS.
4. VSWR MEASUREMENT.
5. WAVELENGTH AND FREQUENCY MEASUREMENT
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12. MEASUREMENT OF NA.
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EXPERIMENT 1

Objective:

To study the characteristics of the Reflex Klystron Tube and to determine its Electronic tuning range.

Apparatus required:

· Klystron power supply

· Klystron tube with Klystron mounts

· Isolator

· Frequency meter

· Variable attenuator

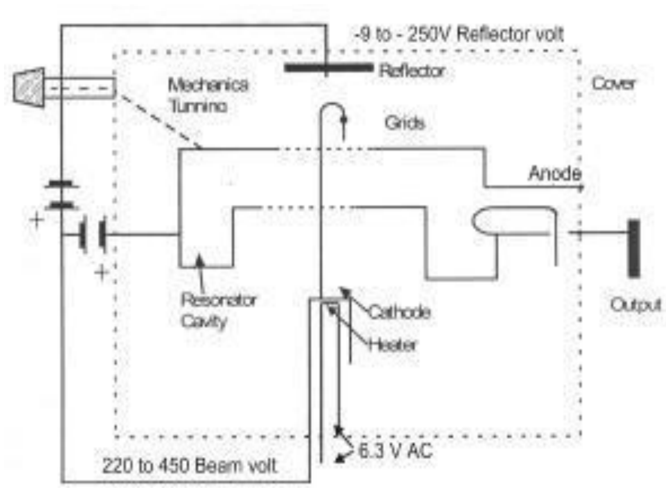
· Detector mount, Wave guide stand

· SWR meter and oscilloscope

· BNC cable

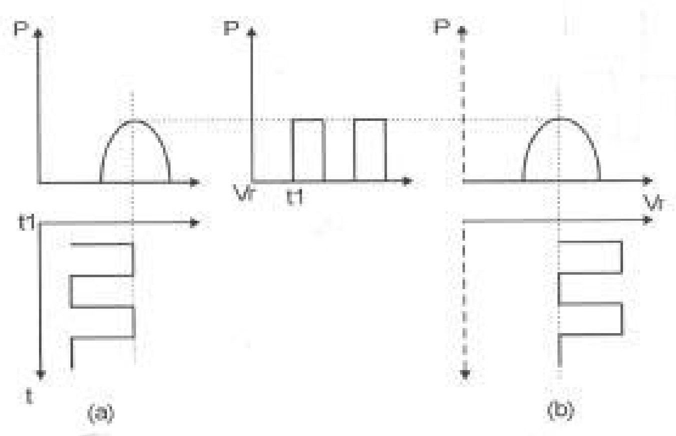
Theory:

The Reflex Klystron makes the use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated & passed through the positive resonator towards negative reflector, which retards and finally, reflects the electrons and the electrons turn back through the resonator. Suppose an RF-field exists between the resonators the electrons traveling forward will be accelerated or retarded, as the voltage at the resonator changes in amplitude.



Schematics Diagram of Klystron 2K25 **Fig. 1**

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 a time that the electrons are slowed down by the voltage then energy will be delivered to the resonator; and Klystron will oscillate. Fig. 2 shows the relationship between output power, frequency and reflector voltages.



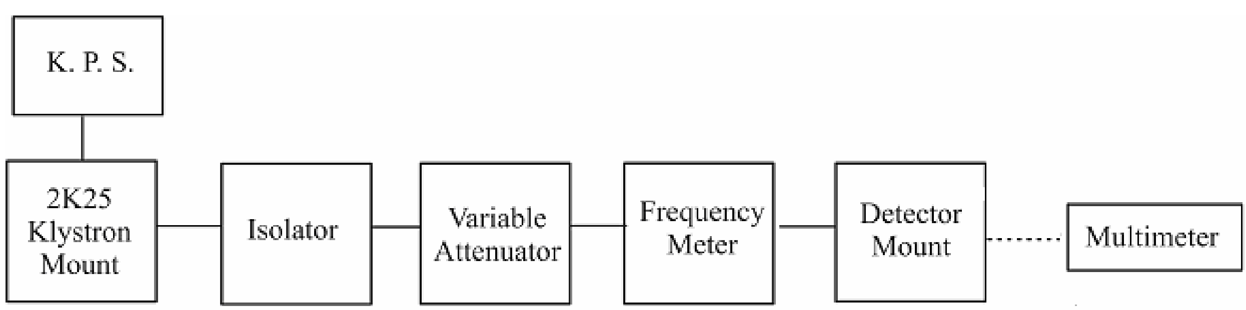
Square Wave modulation of the Klystron **Fig. 2**

The frequency is primarily determined by the dimensions of resonant cavity. Hence, by changing the volume of resonator, mechanical tuning of klystron is possible. Also, a small frequency change can be obtained by adjusting the reflector voltage. This is called Electronic Tuning The same result can be obtained, if the modulation voltage is applied on the reflector voltage as shown in the fig. D C

Procedure:

Carrier Wave Operation:

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



Setup for study of klystron tube **Fig. 3**

2. Set the Variable Attenuator at no attenuation position.

3. Set the mode switch of klystron power supply to CW position, beam voltage control knob to full anti-clock wise and reflector voltage control knob to fully clock wise and the meter select to beam voltage (V) position.

4. Set the multimeter in DC microampere range.

5. Switch 'ON' the klystron power supply, cooling fan for klystron tube. .

6. Set the meter switch to beam voltage position and rotate beam voltage knob clockwise slowly upto 300V reading. Observe beam current on the meter by changing the meter switch to beam current position. 'The beam current should not increase more than 25mA.

7. Change the reflector voltage slowly and observe on the multimeter. Set the voltage for maximum reading in the meter. If no reading is obtained, change the plunger position of klystron mount and detector mount. Select the appropriate range of multimeter.

8. Tune the plunger of klystron mount for the maximum output.

9. Rotate the knob of frequency meter slowly and stop at that position, when there is less output current on multi-meter. Read directly the frequency meter between two horizontal line and vertical marker. If micro meter type frequency meter is used, read micrometer frequency and find the frequency from its calibration chart.

10. Change the reflector voltage in step of 10 Volts & record the output current & frequency for each reppeler voltage follow the previous step for frequency measurement. For example:

Rep Voltage(v)	Frequency (GHz)
-270	8.7
-250	8.8
-230	8.9

Square Wave Operation:

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

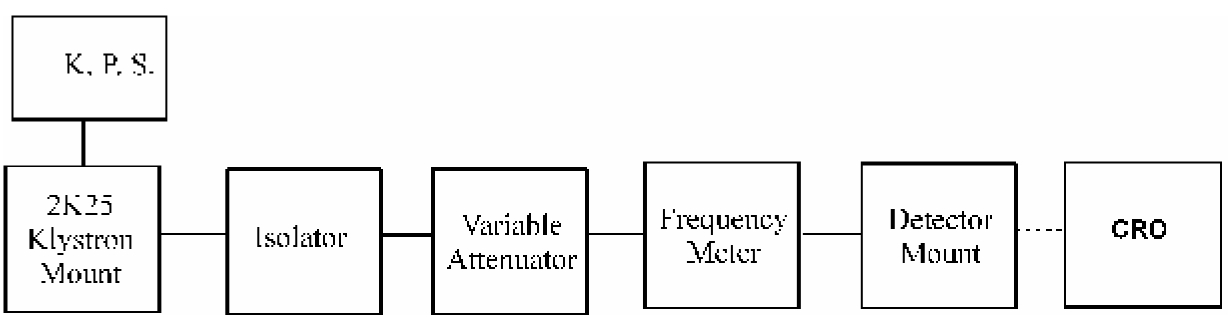


Fig. 4

2. Set Micrometer of variable attenuator for no attenuation position.

3. Set the range switch of SWR meter at appropriate position, crystal selector switch to crystal impedance position, mode select switch to normal position.

4. Now in K.P.S set Mod-selector switch to AM- MOD position. Beam voltage control knob to fully anticlockwise position. Reflector voltage control knob to the maximum clockwise position and meter switch to beam position.

5. Switch "ON" the Klystron Power Supply, SWR meter and cooling fan.

6. Change the beam voltage knob clockwise up to 250V.

7. Keep the AM-MOD amplitude knob and AM-FREQ knob at the mid-position.

8. Rotate the reflector voltage knob to get reading in SWR meter.

9. Rotate the AM-MOD amplitude knob to get the maximum output in VSWR meter.

10. Maximize the reading by adjusting the frequency control knob of AM-MOD.

11. If necessary, change the reading in SWR meter is greater than 0.0 dB or less than -10dB in the normal mode respectively. Further the output can be also reduced by Variable Attenuator for any particular position.

12. Find the oscillation by frequency by Frequency Meter as described in the earlier setup.

13. Connect oscilloscope in place of SWR meter.

Mode Study on Oscilloscope:

1. Set Mode selector switch to FM-MOD position with FM amplitude and FM Frequency knob at mid position. Keep beam voltage control knob fully anticlockwise and reflector voltage knob to fully clockwise.

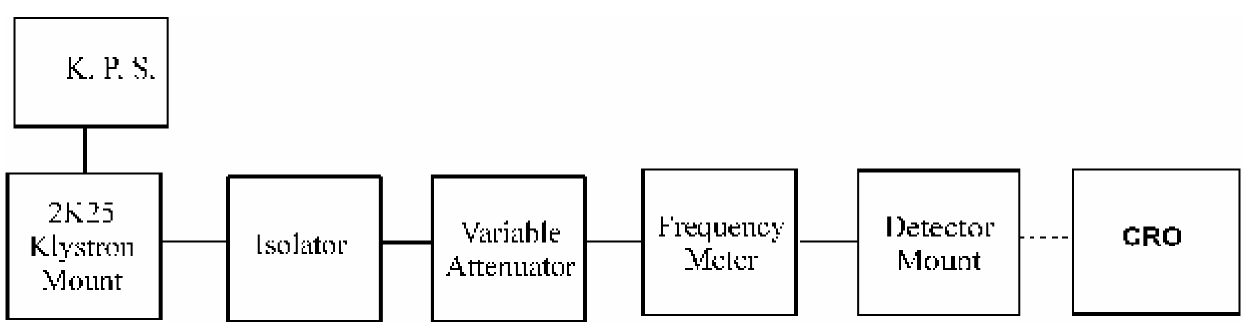
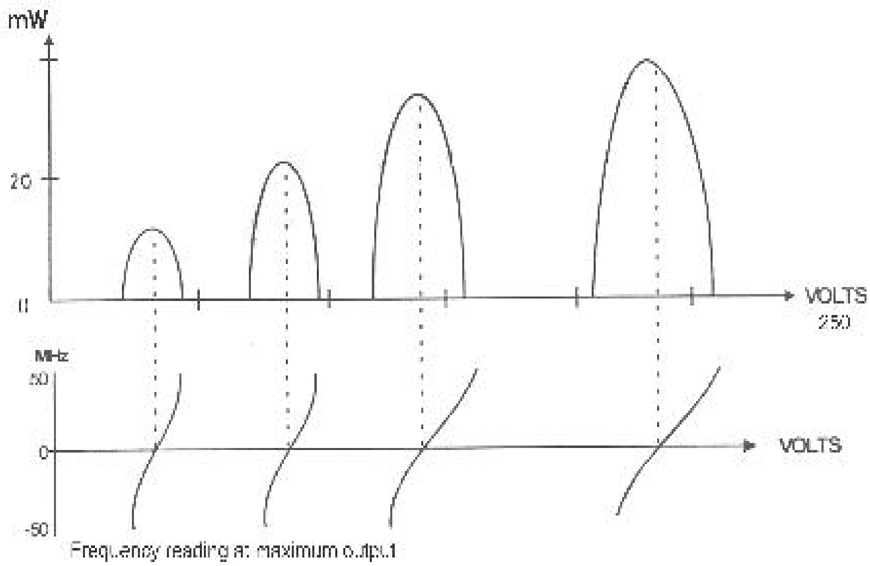


Fig. 5



Modes of 2k25 **Fig. 6**

2. Keep the time/division scale of oscilloscope around 100 Hz frequencies measurement and volt/ div to lower scale.

3. Switch On the klystron power supply and oscilloscope.

4. Keep amplitude knob of FM modulator to maximum position and rotate the reflector voltage anti clock wise to get modes as shown on the oscilloscope. The horizontal axis represents reflector voltage axis, and vertical axis represents output power.

5. Keep the meter switch of klystron power supply to beam voltage position & set Beam voltage to 250 V by beam voltage control knob.

AM MODE

S.No	Repeller Voltage	DIP Frequency(GHz)	O/P Voltage(CRO)	O/P Power in SWR meter

FM MODE

S.No	Repeller Voltage	DIP Frequency(GHz)	O/P Voltage(CRO)	O/P Power in SWR meter

EXPERIMENT 2

Objective:

To study V-I characteristics of Gunn Diode.

Apparatus required:

· Gunn oscillator

· Gun power supply

· PIN modulator

· Isolator

· Frequency meter

· Variable attenuator

· Detector mount

· Wave guide stands

· SWR Meter

· Cables and accessories.

Theory:

The Gunn Oscillator is based on negative differential conductivity effect in bulk semiconductors, which has two conduction bands minima separated by an energy gap (greater than thermal agitation energies). A disturbance at the cathode gives rise to high field region, which travels towards the anode. When this high field domain reaches the anode, it disappears and another domain is formed at the cathode and starts moving towards anode and so on. The time required for domain to travel from cathode to anode (transit time) gives oscillation frequency. In a Gunn Oscillator, the Gunn diode is placed in a resonant cavity. In this case the Oscillation frequency is determined by cavity dimension than by diode itself. Although Gunn oscillator can be amplitude modulated with the bias voltage. We have used separate PIN modulator through PIN diode for square wave modulation. A measure of the square wave modulation capability is the modulation depth i.e. the output ratio between, 'ON and 'OFF state.

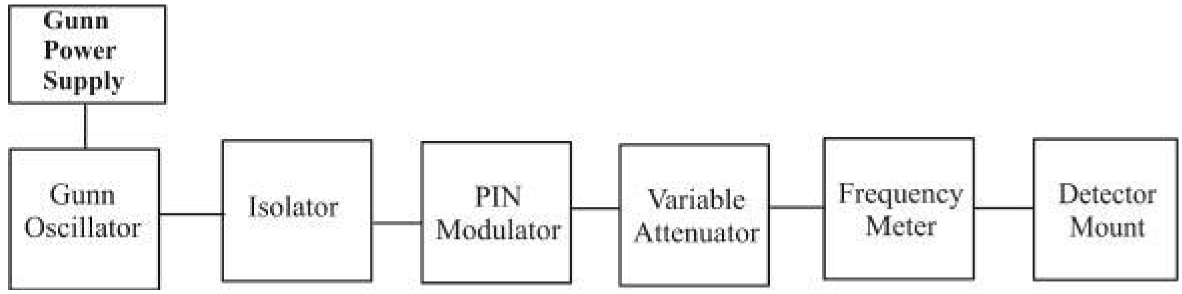
Procedure:

1. Set the components and equipment as shown in the fig.

2. Initially set the variable attenuator for no attenuation.

3. Keep the control knob of Gunn Power Supply as shown:

1. Gunn bias knob : fully anti- clockwise
2. PIN bias knob : fully anti- clockwise
3. PIN Mod frequency : mid position
4. Mode switch : CW Mode



Setup for Study of V-I characteristics of Gunn Diode **Fig. 7**

4. Keep the control knob of SWR meter as shown:

1. Range : 50dB position
2. Crystal : 200ohm
3. Mode switch : Normal position
4. Gain (coarse & fine) : mid position
5. SWR/dB switch : dB position

5. Set the micrometer of Gunn Oscillator at 10 mm position.

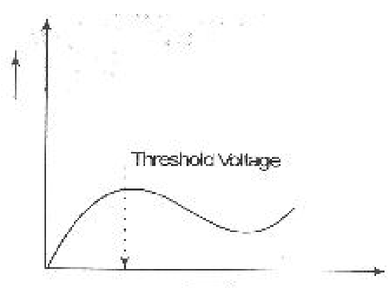
6. Switch ON the Gunn power supply SWR Meter and cooling fan

7. Measure the Gunn diode current corresponding to the various voltage controlled by Gunn bias knob through the panel do not exceed the bias voltage above 10.5 volts.

<u>Result and Analysis:</u>

8. Plot the voltage and current reading on the graph as shown in fig.

9. Measure the threshold voltage which, corresponds to maximum current.



I-V Characteristics of GUNN Oscillator **Fig. 8**

Note: Do not keep Gunn bias knob position at threshold position for more than 10-15 seconds. Reading should be obtained as fast as possible. Otherwise due to excessive heating, Gunn Diode may burn.

Sl.No	V(v)	I(mA)

Experiment 3

Objective:

To determine the frequency & wavelength in a rectangular waveguide working on TE10 mode

Apparatus required:

1. Gunn power supply
2. Gunn Oscillator
3. Isolator
4. PIN modulator
5. Frequency meter
6. Slotted section
7. Tunable probe
8. Wave guide stand
9. SWR meter
10. Matched termination.

Theory:

Mode represents in wave guides as either

TE m, n/ TM m, n

Where

TE – Transverse electric,

TM – Transverse magnetic

m – Number of half wave length variation in broader direction.

n – Number of half wave length variation in shorter direction.

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

Where d1 and d2 are the distance between two successive minima/maxima.

It is having highest cut off frequency hence dominant mode.

For dominant TE10 mode in rectangular wave guide λ_o, λ_g and λc are related as below.

Where λo is free space wave length

λ_g is guide wave length

λc is cutoff wave length

For TE10 mode,

$$\lambda c = 2a/m$$

Where m = 1 in TE10 mode and 'a' is broad dimension of waveguide. The following relationship can be proved $C = f\,\lambda$

Where C= 3 x 10^8 m/s is velocity of light and f is frequency.

Procedure:

1. Set up the components and equipments as shown in fig.

2. Set the variable attenuator at no attenuation position.

3. First connect the matched termination after slotted section.

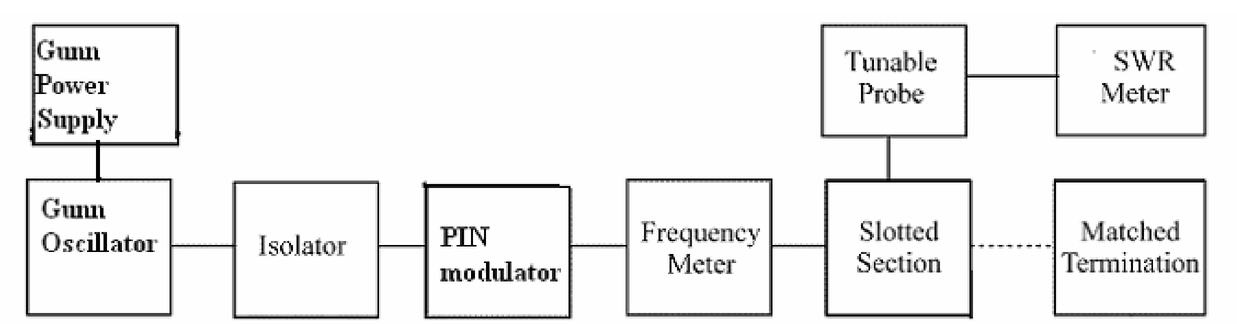
4. Keep the control knob of Gunn power supply as shown.

- Gunn bias knob : fully anti- clockwise direction
- PIN bias knob : fully anti- clockwise direction
- PIN Mod frequency : mid position
- Mode switch : Int. mode

5. Keep the control knob of SWR meter as shown.

- Range dB : 50 dB
- Crystal : 200 ohm
- Mode switch : Normal mode
- Gain (coarse & fine) : mid position
- SWR/dB : dB position

6. Set the micrometer of Gunn oscillator at 10 cm position.



Setup for study of frequency & wave length measurement **Fig. 9**

7. Switch on the Gunn power supply, SWR meter and cooling fan.

8. Observe the Gunn diode current corresponding to the various voltages controlled by the Gunn bias knob through the LCD, don't exceed the bias voltage above 10.5 volts.

9. Turn the meter switch of power supply to beam voltage position and set beam voltage at 300V with help of beam voltage knob, current around 15 to 20mA.

10. Tune the probe for maximum deflection in SWR meter.

11. Tune the frequency meter to get a 'dip' minimum reading on SWR LCD display and note down the frequency directly from frequency meter. Now you can detune the DRF meter.

12. Move the tunable probe along with the slotted line to get the maximum reading in SWR meter. Move the tunable probe to a minimum gain position record the probe position i.e. d_1.

13. Move the probe to next minimum position and record the probe position again i.e. d_2.

<u>Result and Analysis:</u>

14. Calculate the guide wavelength as twice the distance between two successive minimum positions obtained as above.

$$\lambda g = 2(d1-d2)$$

15. Measure the wave-guide inner broad dimension 'a' which will be around 22.86 mm for X band.

$$\lambda c = 2a$$

16. Calculate the frequency by following equation:

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

Where

c =3 x 10^8 meter/sec. i.e. velocity of light.

17. Verify with frequency obtained by frequency meter.

18. Above experiment can be verified at different frequencies.

Experiment 4

Objective:

To determine the Standing Wave-Ratio and Reflection Coefficient

Apparatus required:

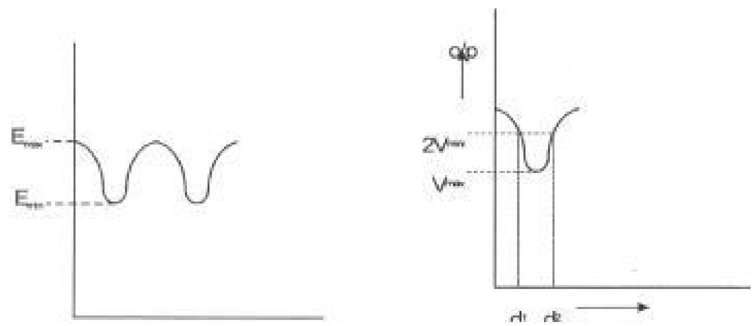
1. Gunn power supply
2. Gunn oscillator
3. SWR meter
4. Isolator
5. PIN modulator
6. Frequency meter
7. Slotted line
8. Tunable probe
9. S-S tuner
10. Matched termination

Theory:

It is a ratio of maximum voltage to minimum voltage along a transmission line is called VSWR, as ratio of maximum to minimum current. SWR is measure of mismatch between load and line.

The electromagnetic field at any point of transmission line may be considered as the sum of two traveling waves: the 'Incident Wave' propagates from generator and the reflected wave propagates towards the generator. The reflected wave is set up by reflection of incident wave from a discontinuity on the line or from the load impedance. The magnitude and phase of reflected wave depends upon amplitude and phase of .the reflecting impedance. The superposition of two traveling waves, gives rise to standing wave along with the line.

The maximum field strength is found where two waves are in phase and minimum where the line adds in opposite phase. The distance between two successive minimum (or maximum) is half the guide wavelength on the line. The ratio of electrical field strength of reflected and incident wave is called reflection between maximum and minimum field strength along the line.



Double Minima Method **Fig. 10**

Hence VSWR denoted by S is

$$S = \frac{E_{max}}{E_{min}}$$

$$= \frac{|E_I| + |E_r|}{|E_I| - |E_r|}$$

Where

EI = Incident Voltage, Er = Reflected Voltage

Reflection Coefficient, ρ is

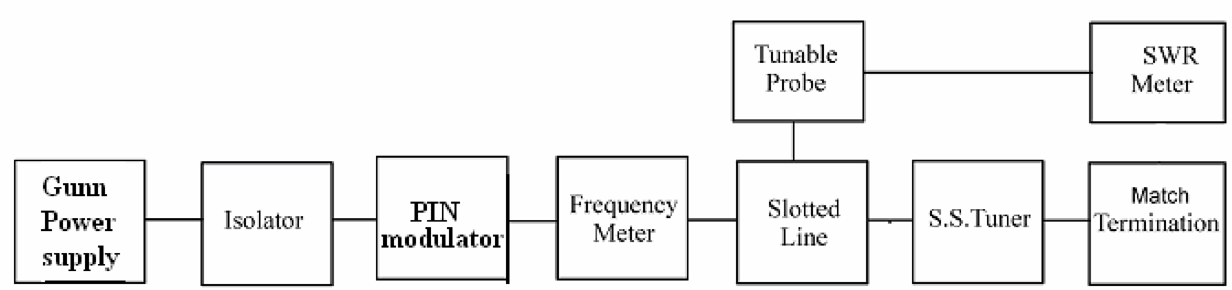
$$\rho = \frac{E_r}{E_I} = \frac{Z - Z_0}{Z + Z_0}$$

Where

Z is the impedance at a point on line, Zo is characteristic Impedance.

The above equation gives following equation

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



Setup for VSWR measurement **Fig. 11**

<u>Procedure:</u>

1. Set up the equipment as shown in the fig.

2. Keep variable attenuator at no attenuation position.

3. Connect the S.S tuner & matched termination after slotted line.

4. Keep the control knobs of Gunn power supply as shown:

- Gunn bias knob : fully anti- clockwise
- PIN bias knob : fully anti- clockwise
- PIN Mod freq. : mid position
- Mode switch : Int. mode position

5. Keep the control knob of SWR as shown:

- Range : 40dB/50dBposition
- Crystal : 200 ohm
- Mode switch : Normal
- Gain (coarse & fine) : mid position
- SWR/dB switch : dB position

6. Set the micrometer of Gunn oscillator at 10mm position.

7. Switch ON the Gunn power supply, SWR meter and cooling fan.

8. Observe the Gunn diode current corresponding to the various voltages controlled by Gunn bias knob through the LCD meter, do not exceed bias voltage above 10.5 volts.

9. If necessary change the range db-switch, variable attenuator position and gain control knob to get deflection in the scale of SWR meter.

10. Move the probe along with slotted line, the reading will change.

11. For low SWR set the S.S tuner probe for no penetration position.

a. Measurement of low and medium VSWR

i. Move the probe along with slotted line to maximum deflection in SWR meter in dB.

ii. Adjust the SWR Meter gain control knob or variable attenuator until the meter indicates 0.0 dB on normal mode SWR for 0.0 dB is 1.0 by keeping switches at SWR we can read it directly.

iii. Keep all the Control knobs as it is, move the probe to next minimum position. Keep SWR /dB switches at SWR position.

iv. Repeat the above step for change of S.S. Tuner probe path & record the corresponding SWR. Read SWR from display & record it.

v. If the SWR is greater than 10, follow the instructions that follow.

b. Measurement of High SWR (Double Minimum Method)

i. Set the depth of S.S tuner slightly more for maximum SWR.

ii. Move the probe along with slotted line until a minimum is indicated.

iii. Adjust the SWR meter gain control knob and variable attenuator to obtain a reading of 3 dB (or any other reference).at SWR meter.

iv. Move the probe to the left on slotted line until maximum reading is obtained i.e. 0 db on scale. Note and record the probe position on slotted line. Let it be d1. (Or power should be increased by 3 db).

v. Move the probe right along with slotted line until maximum reading is obtained on 0 db scale. Let it be d2.

vi. Replace the S.S tuner and terminator by movable short.

Result and analysis:

vii. Measure the distance between two successive minima position or probe.

Twice this distance is waveguide length. $\lambda g = 2(d_1 - d_2)$

[Since d_1 & d_2 (Min or Max) with Movable Short]

viii. Now calculate SWR using following equation

$$SWR = \lambda g / \Pi \, (d_1 - d_2)$$

[since d_1 & d_2 (Min or Max) with Matched Termination]

ix. For different SWR, calculate the refection coefficient.

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

Experiment 5

Objective:

Study the function of multi-hole directional coupler by measuring the following parameters:

1. To Measure main-line and auxiliary-line VSWR.

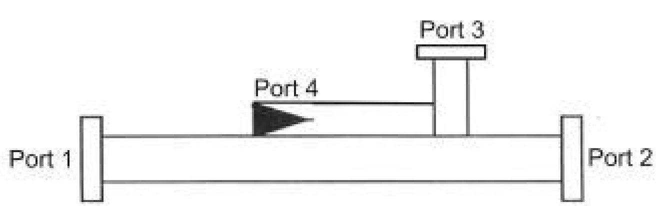
2. To Measure the coupling factor and directivity

Equipment Required:

- Microwave source (Klystron or Gunn Diode type)
- Isolator
- PIN modulator
- Frequency meter
- Variable attenuator
- Slotted line
- Tunable Probe
- Detector mount
- Matched Terminator
- MHD coupler
- Wave guide stand
- Cables & accessories
- VSWR meter

Theory:

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



Directional Coupler **Fig. 26**

$$\text{Coupling (db)} = 10 \log_{10} \left[\frac{P_1}{P_3}\right] \text{ where port 2 is terminated}$$

$$\text{Isolation} = 10 \log_{10} \left[\frac{P_2}{P_3}\right] \text{ where } P_1 \text{ is matched.}$$

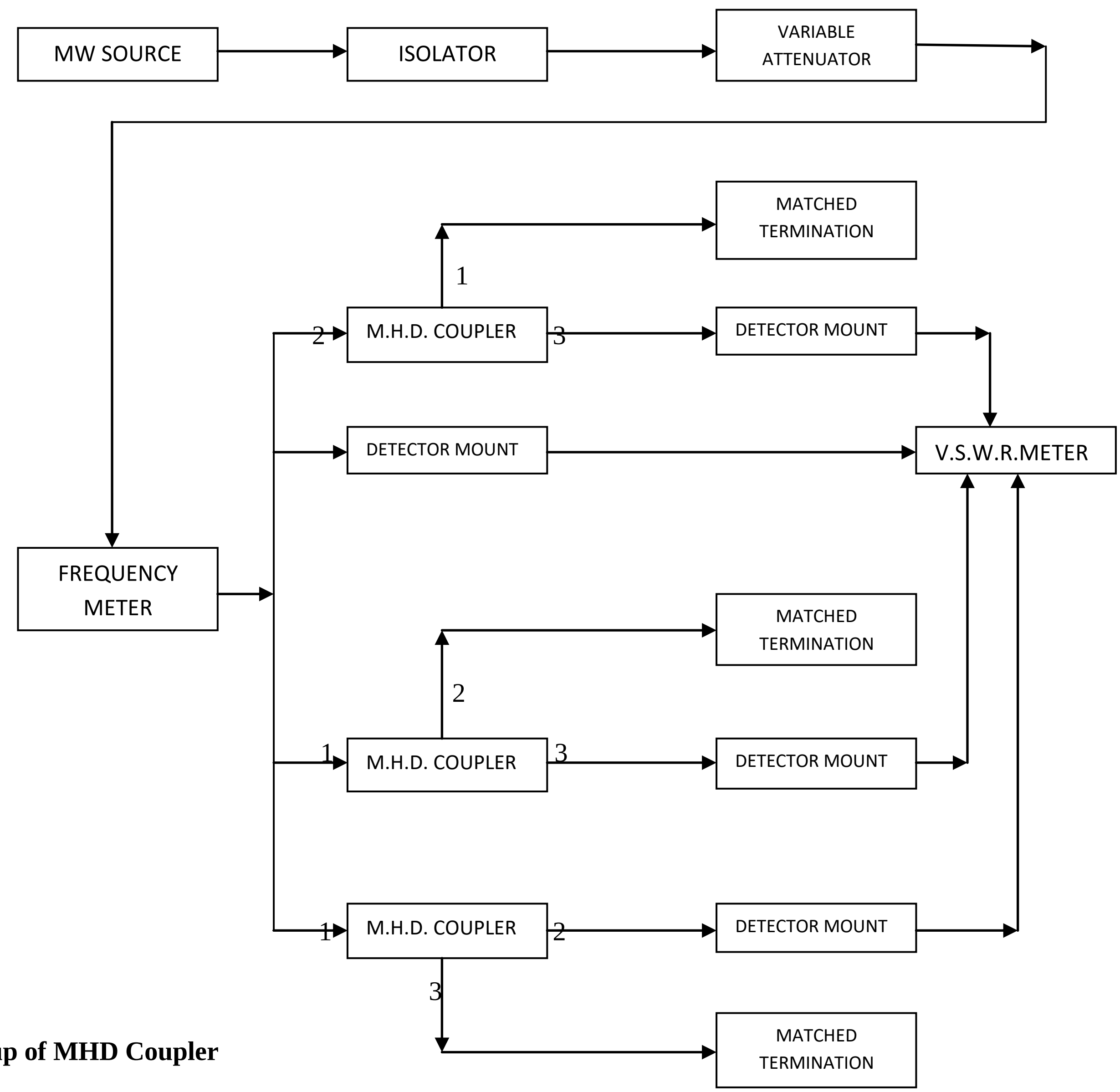
With built-in termination and power is entering at port 1. The directivity of the coupler is a measure of separation between incident and the reflected wave. It is measured as the ratio of two power outputs from the auxiliary line when a given amount of power is successively applied to each terminal of the main lines with the port terminated by material loads.

Hence the Directivity D(dB) = Isolation - Coupling = $10 \log_{10} \left[\frac{P_2}{P_1}\right]$

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

$$\text{Loss} = 10 \log_{10} \left[\frac{P_1}{P_2}\right] \text{ when power is entering at port 1.}$$

Procedure:



Setup of MHD Coupler

Measurement of Coupling Factor, Insertion Loss

a. Set up the equipments as shown in the fig.

b. Energize the microwave source for particular frequency operation as described operation of Klystron and Gunn Oscillator.

c. Remove the multi-hole directional coupler and connect the detector mount to the slotted line.

d. Set any reference level of power on SWR meter with the help of variable attenuator, gain control knob of SWR meter, and note down the reading. (Reference level let it be X)

e. 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 SWR meter.

f. Note down the reading on SWR meter on the scale with the help of ranged switch if required. (Let it be Y)

g. Calculate coupling factor, which will be X-Y in dB.

h. Now carefully disconnect the detector from the auxiliary port 3 and match termination from port 2 without disturbing the set-up.

i. Connect the matched termination to the auxiliary port 3 and detector to port 2 and measure the reading on SWR meter. Suppose it is Z.

Result and Analysis:

Calculate the coupling factor, which will be X-Y in db

Compute insertion loss X-Z db

Compute the isolation Z-Y.

Now Directivity = Isolation - Coupling

Experiment 6

Objective:

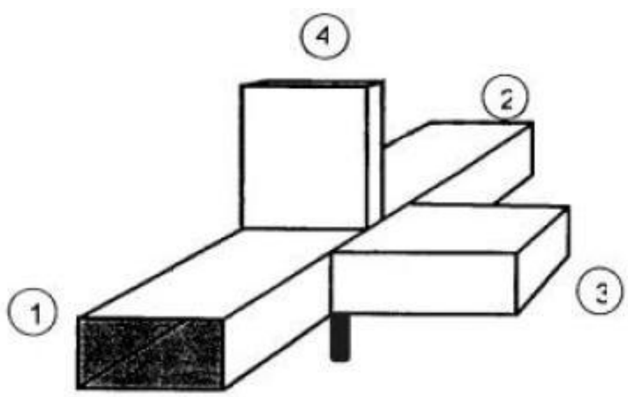
Study of Magic Tee.

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.



Magic Tee **Fig. 28**

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 I 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 **$C_{ij} = 10^{-\alpha/20}$**

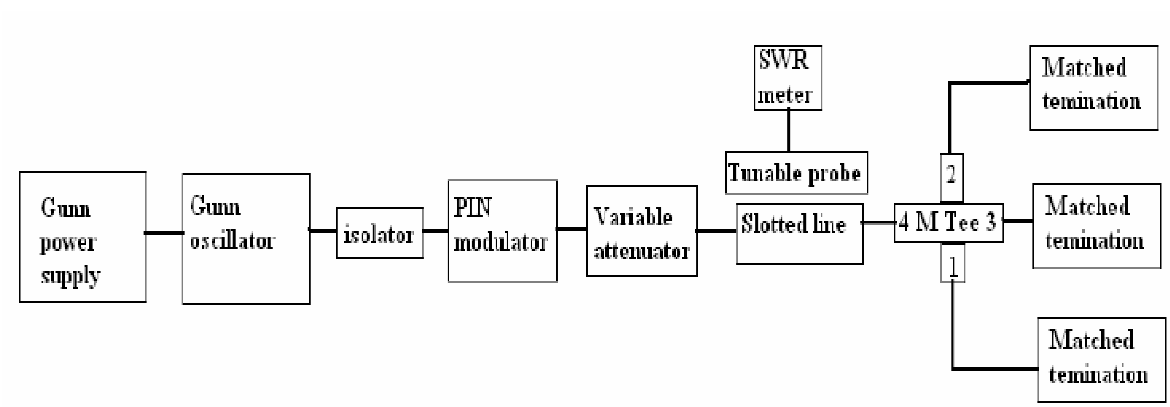
Where

α = 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.

Procedure:



Setup for the study of Magic Tee

1. VSWR Measurement of the Ports

a. Set up the components and equipments as shown in fig. keeping E arm towards slotted line and matched termination to other ports.

b. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.

c. Measure the SWR of E-arm as described in measurement of SWR for low and medium value.

d. Connect another arm to slotted line and terminate the other port with matched termination. Measure the SWR as above. Similarly, SWR of any port can be measured.

2. Measurement of Isolation and Coupling Coefficient

a. Remove the tunable probe and Magic Tee from the slotted line and connect the detector mount to slotted line.

b. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.

c. 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.

d. 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.

e. In the same way measure P1 & P2 by connecting detector on these ports one by one.

f. Determine the isolation between port 3 and 4 as P3-P4 in dB.

g. Determine the coupling coefficient by P3- P1 for port P1 & P2.

h. Repeat the above experiment for other frequencies.

Experiment 7

Objective:

To Study the Isolator and Circulators.

Equipment Required:

- Microwave source
- Power supply for source
- Isolators
- Circulators
- Frequency meter
- Variable attenuator
- Slotted line
- Tunable probe
- Detector mount
- VSWR meter

Theory:

***Isolator**:* An isolator is a two-port device that transfers energy from input to output with little attenuation and from output to input with very high attenuation.

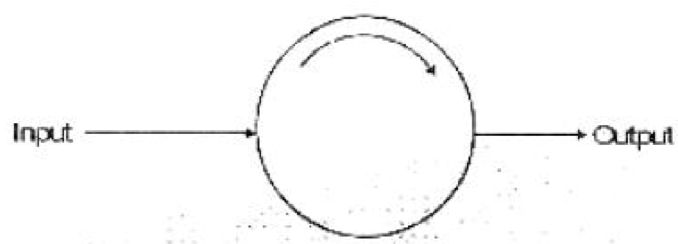


Fig. 30

***Circulator**:* The circulator is defined as a device with ports arranged such that energy entering a port is coupled to an adjacent port but not coupled to other ports. Refer to the fig. A wave incident on port 1 is coupled to port 2 only, a wave incident at port 2 is coupled to port 3 only and so on.

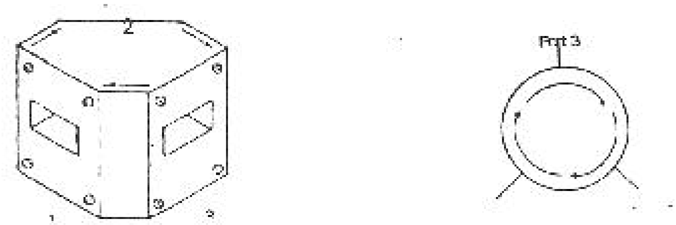


Fig. 31

Following are the basic parameters of isolator and circulator for study.

1. *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.

2. *Isolation*

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

3. *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 other have matched termination.

Note: When port which is not coupled to input port is terminated by matched termination it marks as Isolator. (Two port device).

<u>Procedure:</u>

1. *Input VSWR Measurement*

a. Set up the components and equipments as shown in the fig with input port of isolator or circulator towards slotted line and matched load on other ports of it

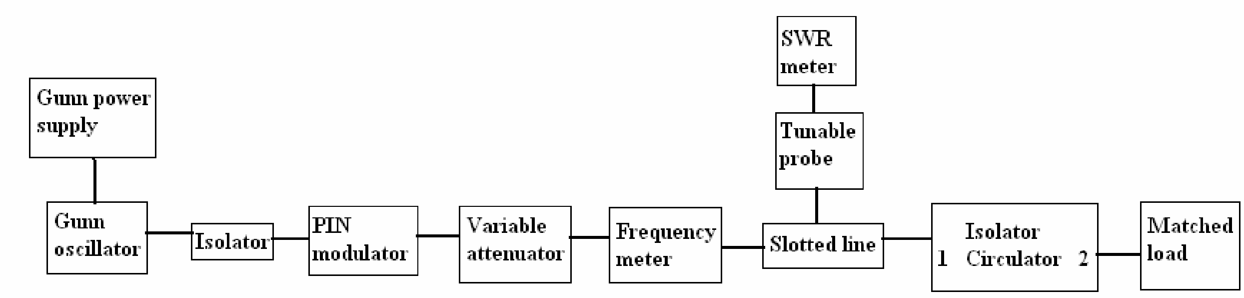


Fig. 32

Measurement of VSWR of Isolator or Circulator

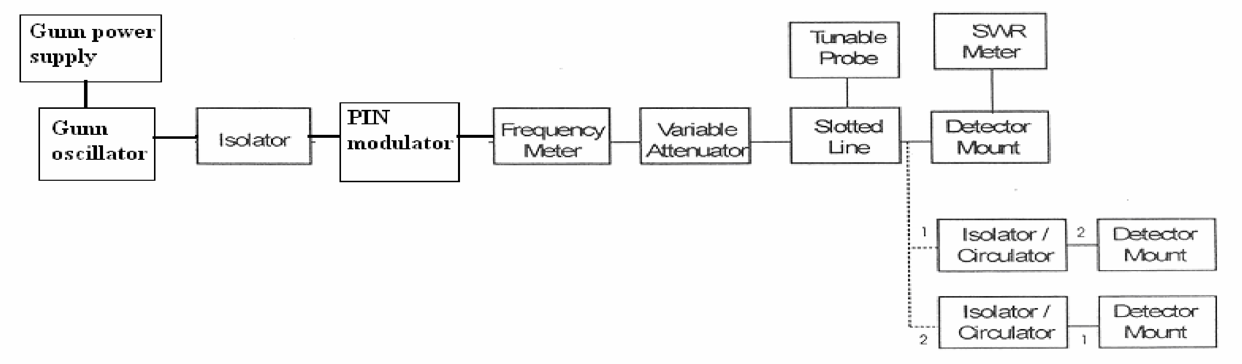
b. Energize the microwave .source for particular operation of frequency.

c. With the help of slotted line, probe and SWR meter. Find SWR, of the isolator or circulator as described for low and medium SWR measurements.

d. The above procedure can be repeated for other ports or for other frequencies.

2. *Measurement of Insertion Loss and Isolation*

a. 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 SWR meter.



Setup for Measurement Loss & Isolation of Isolator & Circulator Fig. 33

b. Energize the microwave source for maximum output particular frequency of operation. Tune the detector mount for maximum output in the SWR Meter.

c. Set any reference level of power in SWR meter with the help of variable attenuator and gain control knob of SWR meter. Let it be P1.

d. 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. Keeping input port to slotted line and detector at its output port. A matched termination should be placed a third port in case of circulator.

e. Record the reading in the SWR meter. If necessary change range –dB switch to high or lower position. Let it be P2.

f. For measurement of isolation, the isolator or circulator has to be connected in reverse i.e. output port to slotted line and detector to input port with another port terminated by matched termination (in case circulator) after setting a reference level without isolator or circulator in the set up as described in insertion loss measurement. Let it be P3.

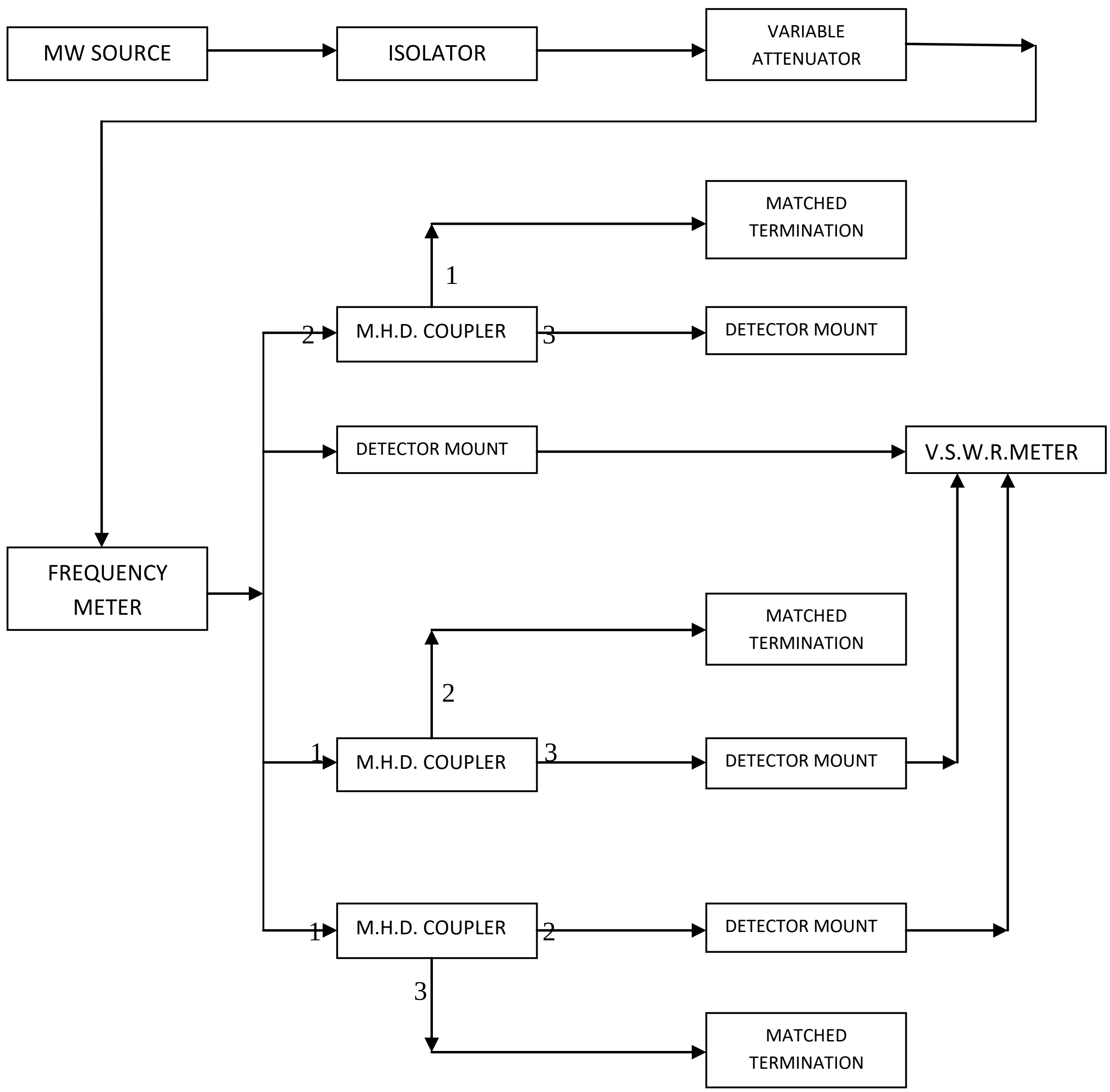
Result and Analysis:

g. Compute insertion loss on P1 – P2 in dB.

h. Compute isolation as P1 **-** P3 in dB.

i. The same experiment can be done for other ports of circulator.

j. Repeat the above experiment for other frequencies if required.


MW SOURCE
ISOLATOR
VARIABLE ATTENUATOR
MATCHED TERMINATION
1
2
M.H.D. COUPLER
3
DETECTOR MOUNT
DETECTOR MOUNT
V.S.W.R.METER
FREQUENCY METER
MATCHED TERMINATION
2
1
M.H.D. COUPLER
3
DETECTOR MOUNT
1
M.H.D. COUPLER
2
DETECTOR MOUNT
3
MATCHED TERMINATION

Experiment 8

Objective:

To study and plot the radiation pattern of LED

Equipments Required:

1. ST2510 Trainer with power supply cord
2. Digital multi-meter
3. Blue, Red and Green LED

Connection Diagram:

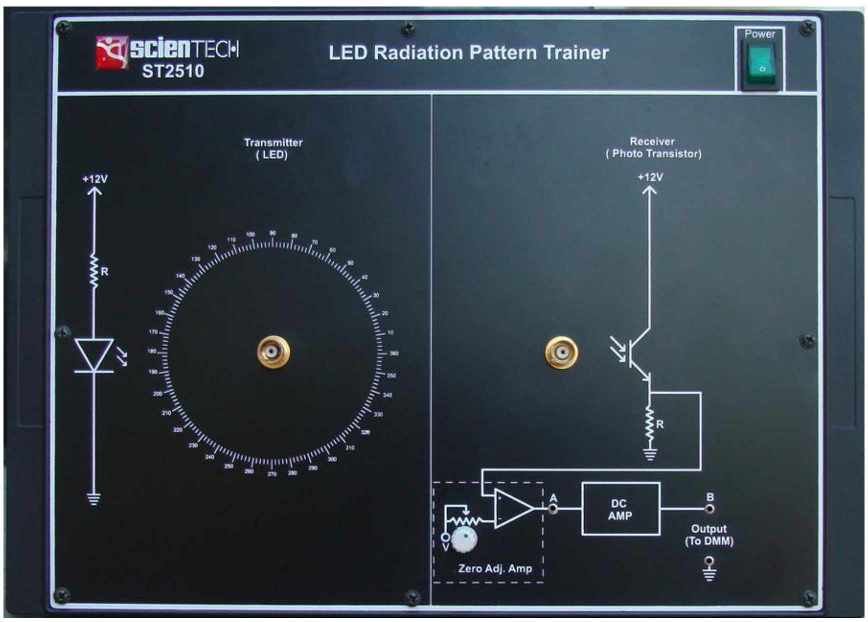


Figure 1.1 **ST2510**

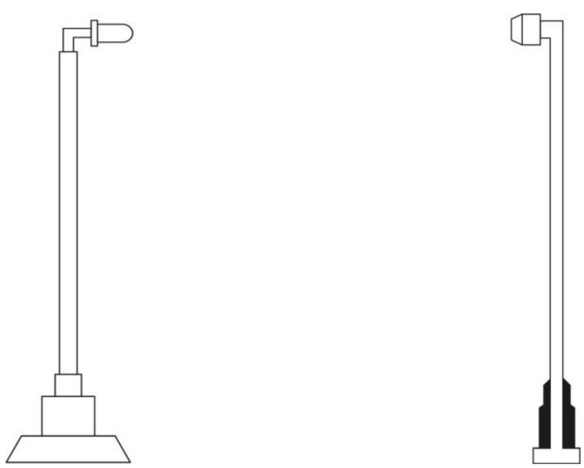


Figure 1.2 **A** **B**

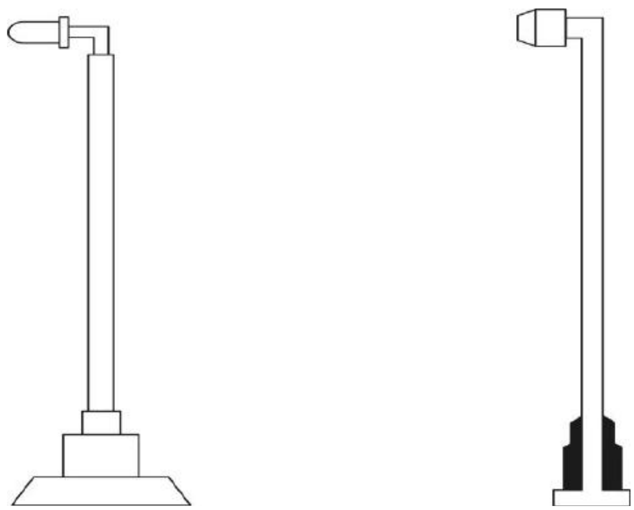


Figure 1.3

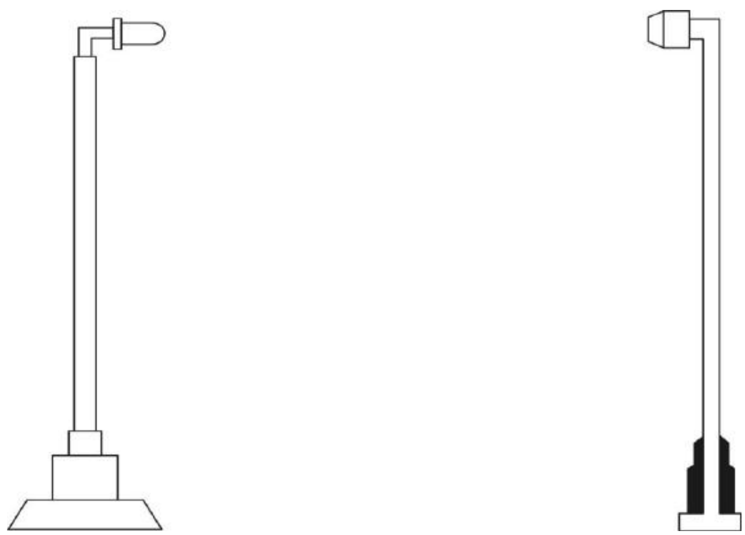


Figure 1.4

Theory:

Light Emitting Diode (LED):

A light-emitting diode (LED) is a semiconductor device that emits incoherent narrow spectrum light when electrically biased in the forward direction. This effect is a form of electroluminescence. The color of the emitted light depends on the chemical composition of the semi conducting material used.

A LED is a special type of semiconductor diode. Like a normal diode, it consists of a chip of semi conducting material impregnated, or doped, with impurities to create a structure called a p-n junction. Charge carriers - electrons and holes flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon as it does so. The light emitted at a p-n junction is proportional to the bias.

Electroluminescence occurs when minority carriers recombine with carriers of the opposite type in a diode's band gap. The wavelength of the emitted light varies primarily due to the choice of semiconductor materials used, because the band gap energy varies with the semiconductor.

An LED is a device which converts electrical energy into light. It emits light by spontaneous emission. When the minority charge carriers recombine radiatively with the majority charge carriers, photons are emitted. This is the basic light generation process in semiconductor.

Symbol of LED

The longer lead of LED in figure 1 indicates anode and the shorter lead indicate cathode terminal. In LED current flows always from anode to cathode. LED requires 0.6V for conduction. Radiant light intensity is measured in lumens. The lumen is defined such that 683 lumens of light are provided by 1 watt of monochromatic radiation at a wavelength of 555nm.

Materials used for LED:

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have made possible the production of devices with ever shorter wavelengths, producing light in a variety of colors. Conventional LED is made from a variety of inorganic minerals, producing the following colors:

· Aluminum Gallium Arsenide (Al Ga As) - red and infrared
· Gallium aluminum phosphide - green
· Gallium arsenide/phosphide (Ga As P) - red, orange-red, orange, and yellow
· Gallium Nitride (Ga N) - green, pure green (or emerald green), and blue
· Gallium phosphide (Ga P) - red, yellow and green
· Zinc selenide (Zn Se) - blue

LED Structures:

The basic structures of various kinds of LEDs are:

1. Surface emitting type
2. Edge emitting type

The surface emitting LEDs emit the light in a direction perpendicular to the pn –junction plane and hence, to the surface, allows more efficient coupling to the optical fiber. The coupling efficiency is not good in surface emitting and improved by using an edge emitting LED.

The edge emitting LEDs emit the light in a direction parallel to the junction plane.
And radiation comes out from the edge of pn- junction.

Procedure:

- Connect the LED mast in the left BNC female of the board i.e. Transmitter side as shown in figure 1.2 A.
- Connect the phototransistor mast in the right BNC female of the board i.e. receiver side as shown in figure 1.2 B.

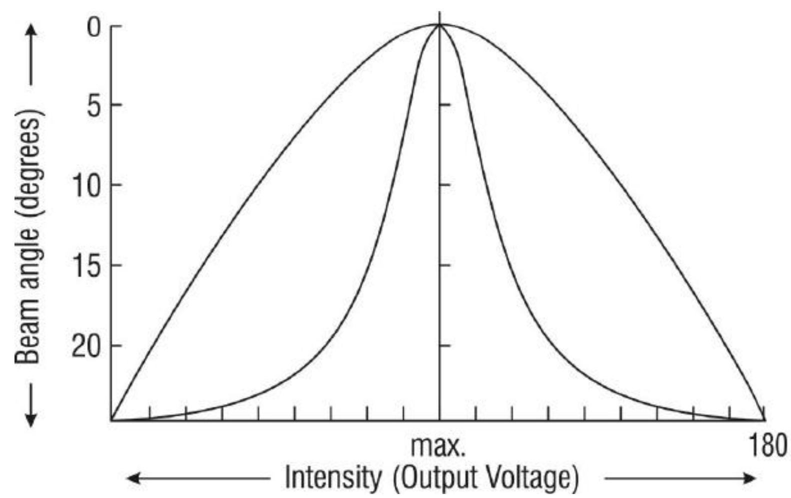
1. Insert Blue LED in LED mast such that longer lead goes to positive terminal and shorter lead goes to negative terminal indicated on the mast. Longer lead indicates anode of LED and shorter lead indicates cathode of LED.
2. Put LED in out of phase with respect to phototransistor i.e. 180 degree (same as figure 1.3).
3. Turn ‘On’ the power supply of the trainer.
4. Connect digital voltmeter in between socket A and ground.

5. Adjust potentiometer so that the output voltage at socket A is approximately zero.
6. Put LED in same phase with respect to phototransistor i.e. 360/0 degree. (Same as figure1.4).
7. Connect digital voltmeter in between socket B and ground.
8. Measure output voltage at Socket B with respect to ground.
9. Rotate LED with few degrees and measure voltage change in output.
10. Repeat this process for full 360 degree rotation.
11. When LED and phototransistor are in phase then output voltage is maximum, and if both are out of phase then output voltage is minimum.
12. Tabulate the results in the following manner.
13. Repeat the procedure from 1 to12 point with green LED and Red LED.
14. Plot the graph between input angle Vs output voltage.
15. Match plot with reference plot provided in manual.

Observation Table:

S. No	Input Angle Rotation (degrees)	Output Voltage
1.		
2.		
3.		

Expected Graph:



Experiment 9

Objective :

Study of Characteristics of LASER Diodes
(i) Optical Power (Po) of LASER Diode vs LASER Diode Forward Current (IF)
(ii) Monitor photodiode current (IM) vs LASER Optical Power Output (Po)

Equipments Needed:

1. Digital Multi-meters

Basic Definitions and Concepts :

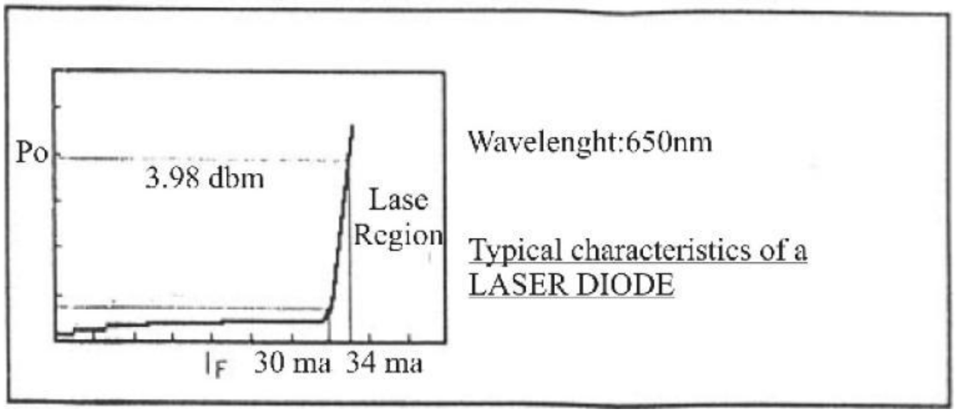
LEDs and LASER Diodes are the commonly used sources in optical communication systems, whether the system transmits digital or analogue signals. In the case of analogue transmission, direct intensity modulation of the optical sources is possible provided the optical output from the source can be varied 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.

LASER Diodes are used in telecom, data com and video communication applications involving high speeds and long hauls. All single mode optical fiber communication systems use LASERs in the 1300nm and 1550 nm windows. LASERs with very small line widths also facilitate realization of wavelength division multiplexing (WDM) for high density communication over a single fiber. The inherent properties of LASER diodes that make them suitable for such applications are high coupled optical power into the fiber (Typically greater than 1 mW), high stability of optical intensity, small line-widths (less than 0.05 nm in special devices), high speed (several GHz) and high linearity (over a specified region suitable for analogue transmission). Special LASERs also provide for generation/ amplification of, optical signals within an optical fiber. These fibers are known as erbium doped fiber amplifiers; LASER diodes for communication applications are available in the wavelength 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/2.5 mw) to demonstrate the functioning of a LASER diode. Specifications of typical LASER diode at 650 nm are summarized below.

Symbol	Parameter	Typical	Unit
P_O	CW output power	2.5	mW
I_{OP}	Operating current	30	mA
W_P	Wavelength at peak emission	650	Nm
MTTF	Mean Time to Failure	10,000	hrs

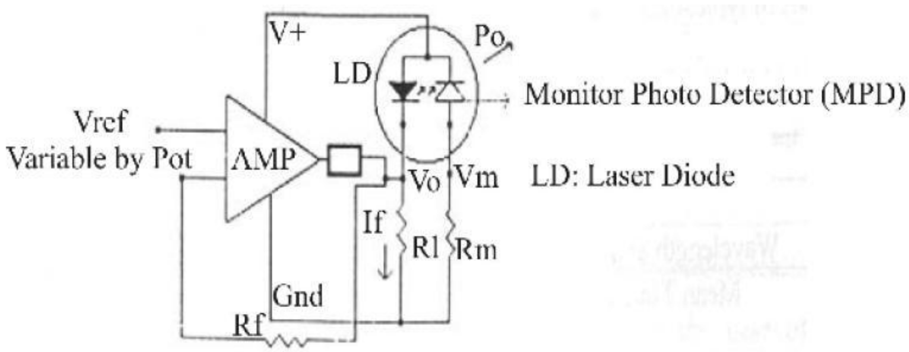
Specifications for LASER Diodes



Monitor Photo Detector (MPD) Automatic Power Control and Automatic Current Control Modes of Operation **Figure 2.1**

A LASER diode has a built in photo detector, 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 photodiode to provide a negative feedback for stabilization of optical power is 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.



Schematic of a LASER diode Operation (ACC Mode) **Figure 4**

Precautions to be observed while handling LASER Diodes :

- LASERs are highly ESD sensitive, use proper ESD protected facility
- No LASER beam should LASER diode be viewed directly of from a highly reflecting surface
- LASERs are highly sensitive to transients

Procedure with Block Schematic for Po vs IF experiments :

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

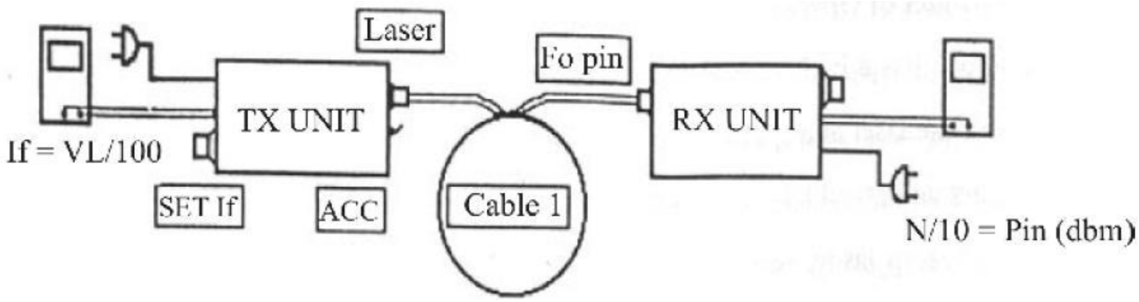


Figure 5

1. Connect the 2 meter PMMA FO cable (cable 1) to TX Unit and couple the LASER light to the power meter FO PIN on the RX Unit as shown. Select ACC mode of operation.
2. Set DMM 1 to the 2000 mV range. On the RX side connect the wires marked Po to it. Turn it on. The power meter is now ready for use. Po = (reading)/10 dBm. It required change the DMM range to 200mV.
3. Set DMM2 to the 200.0 mV range and connect it between the wire VL and ground on the TX unit. IF = VL /100Ω.
4. Adjust the SET IF on the TX knob to the extreme anticlockwise position to reduce IF to zero. The power meter reading will normally be below -40dBm or out of range.
5. Slowly turn the SET IF knob clockwise to increase IF and Po, Note IF and Po readings. Take closer reading prior to and above the LASER threshold of LASER Diode.
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 LASER Diode current. It should look like as shown below:

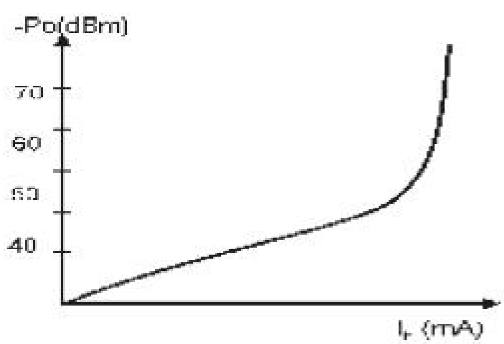


Figure 6

Table of Readings: (ACC Mode/PMMA Cable)

Sr. No	V_L (mV)	$I_F = V_L$ /100mA	Po (dBm)
1			
2			
3			
4			

Inferences: From the above Table it is seen that the LASER optical output does not increase appreciably for IF below the threshold LASER Diode current Ith. Above Ith, Po increases steeply Po is very steep. The LASER threshold LASER Diode may be determined from the graph or by recording closer readings.

Procedure with Block Schematic for IM vs Po Experiment:

The schematic diagram for study of the monitor photodiode current as a function of LASER DIODE optical output Po is shown in figure 6 and is self explanatory.

1. Connect the 2-meter PMMA FO cable to Po port of and couple the LASER light to FO PIN the power meter as shown.
2. Set DMM 1 to the 2000 mV range. On the RX Unit, connect the Wires marked Po to it. Turn it on. The power meter is now ready for use. Po = (Reading)/10 dBm

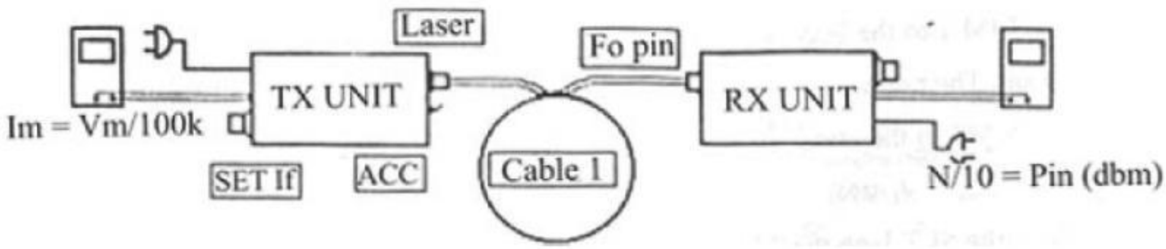


Figure 7

3. Set DMM2 to the 200.0mV range and connect it between the VM and ground on the TX Unit.
4. Adjust the SET If knob to the extreme anticlockwise position to reduce IM to the minimum value. There will be a negligible offset voltage.
5. Change Po in suitable Steps and note the VM readings. Record up to the extreme clockwise position.
6. Plot the graph IM vs Po on a semi-log graph sheet IM = (VM)/ (100K).

Table of Readings, ACC/PMMA Cable

Sr. No	Po (dBm)	V_M (mV)	I_M (µ)=(V_M)/ 100k
1			
2			
3			
4			

Inferences:
From the above Table it is seen that the MPD photo current sharply increases, above the threshold LASER Diode Po, following the pattern of the first part of experiment. The threshold LASER Diode Po and IF (threshold LASER Diode) may be computed from the plot

Experiment 10

Objective: Study of Intensity Modulation Technique using digital Input signal

The objective of this experiment is to obtain intensity modulation of digital signal, transmit it over fiber optic cable and demodulate the same at the receiver end to get back the original signal.

Equipments Required:

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

Connection Diagram:

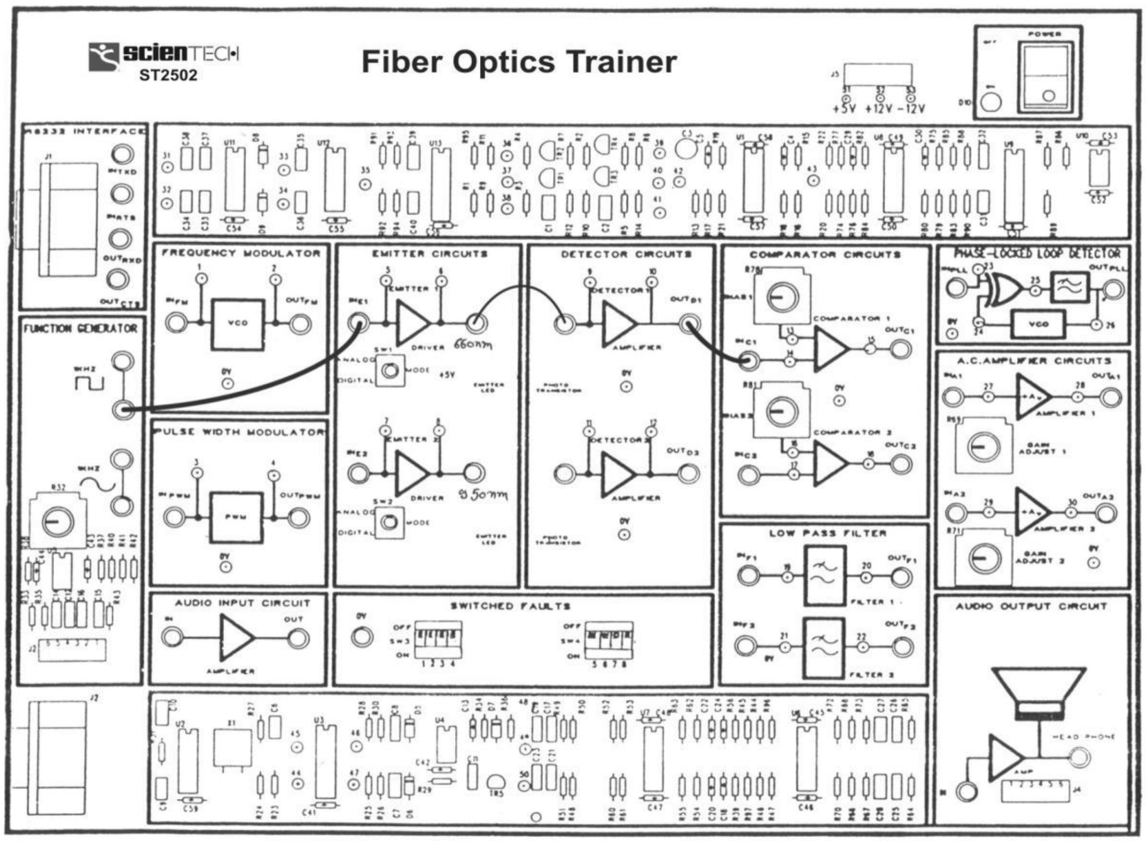


Figure 3.1

Procedure:

1. Connect the power supply cord to the main power plug & to trainer ST2502.
2. Make the following connections as shown in figure 3.1.

a. Connect the 1 KHz square wave socket in function generator block to emitter 1 input.

b. Connect an optic fiber link between emitter 1 output & Detector 1 input with the help of connector provided.

c. Detector output to comparator l's non-inverting (+ve) input.

3. Switch the mode switch in emitter block to digital mode. This ensures that signal applied to the driver's input cause the emitter LED to switch quickly between ‘On’ & ‘Off’ states.
4. Examine the Input to emitter 1 TP 5 on an oscilloscope this 1 KHz square wave is now being used to amplitude modulate emitter I emitter LED.

5. Examine the output of detector 1 TP 10. This should carry a smaller version of original 1 KHz square wave illustrating that the modulated light beam has been reconverted into an electrical signal.
6. Monitor both input to comparator 1, at TP 13 & 14 and slowly adjust the "Comparator bias 1 preset until the DC Level on the negative input TP 13 lies midway between the high & low level of the signal on the positive input TP. 14. This DC level is comparator's threshold level.
7. Examine the output of comparator 1 TP15 Note that the original digital modulating signal has been reconstructed at the receiver.
8. Once again carefully flex the fiber optic cable we can see that there is no change in output on bending the fiber. The output amplitude is now independent of the bend radius of the cable and that of length of cable, provided that detector output signal is large enough to cross the comparator threshold level. This illustrates one of the advantages of amplitude modulation of a light beam by digital rather than analog means. Also, non-linear ties within the emitter LED & photo transistor causing distortion of the signal at the receiver output are the disadvantages associated with amplitude modulating a light source by analog means. Linearity is not a problem if the light beam is switched ‘On’ & ‘Off’ with a digital signal, since the detector output is simply squared up by a comparator circuit. To overcome problems associated with amplitude modulation of a light beam by analog means, analog signals are often used to vary or modulate some characteristic of a digital signal (e.g. frequency or pulse width.). The digital signal being used to switch the light beam ‘On’ & ‘Off’.

Experiment 11

Objective: Measurement of losses for analog optical link
Part A: Study of Propagation Loss in Optical Fiber
To measure propagation or attenuation loss in optical fiber
Part B: Study of Bending Loss

Equipments Required:
1. ST2502 trainer with power supply cord
2. Optical Fibre cable
3. Cathode ray oscilloscope with necessary connecting probe
4. Mandrel

(Part A)

Connection Diagram:

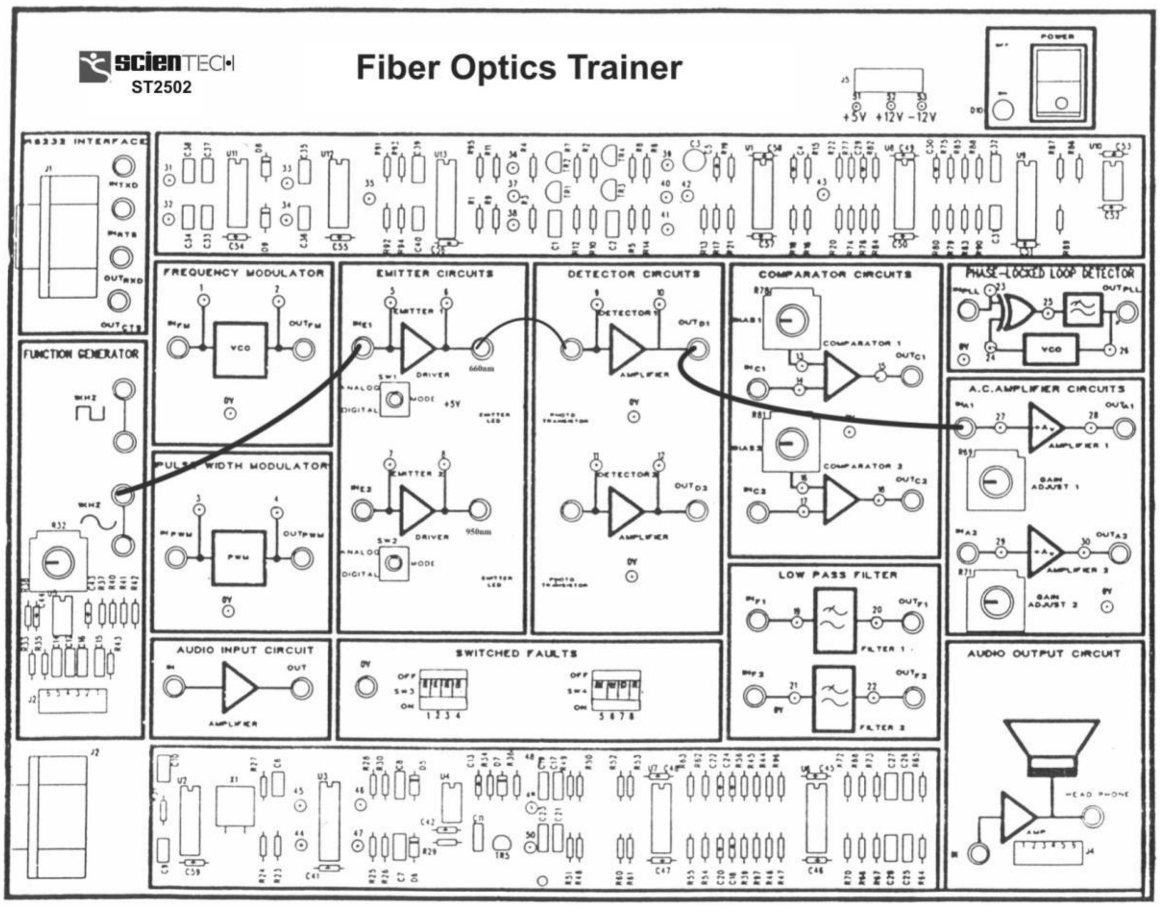


Figure 4.1

Procedure:

1. Connect power supply cord to the main power plug & to trainer ST2502.
2. Make the following connections as shown in figure 7.1.

a. Function generator’s 1 KHz sine wave output to Input 1 socket of emitter 1 circuit via 4 mm lead.

b. Connect 0.5 m optic fiber between emitter 1 output and detector l's input.

c. Connect detector 1 output to amplifier 1 input socket via 4mm lead.
3. Switch ON the Power Supply of the trainer and oscilloscope.
4. 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 1 of Emitter 1.
5. Observe the output signal from detector TP10 on CRO.
6. Adjust the amplitude of the received signal same as that of transmitted one with the help of gain adjust potentiometer in AC amplifier block. Note this amplitude and name it V1.
7. Now replace the previous FG cable with 1 m cable without disturbing any previous setting.
8. Measure the amplitude at the receiver side again at output of amplifier 1 socket TP 28. Note this value end name it V2.
Calculate the propagation (attenuation) loss with the help of following formula.

$$V1 / V2 = e^{-\alpha (L1 + L2)}$$

Where α is loss in nepers / meter
1 neper = 8. 686 dB
L 1 = length of shorter cable (0.5 m)
L 2 = Length of longer cable (1 m)

(Part B)

Connection Diagram:

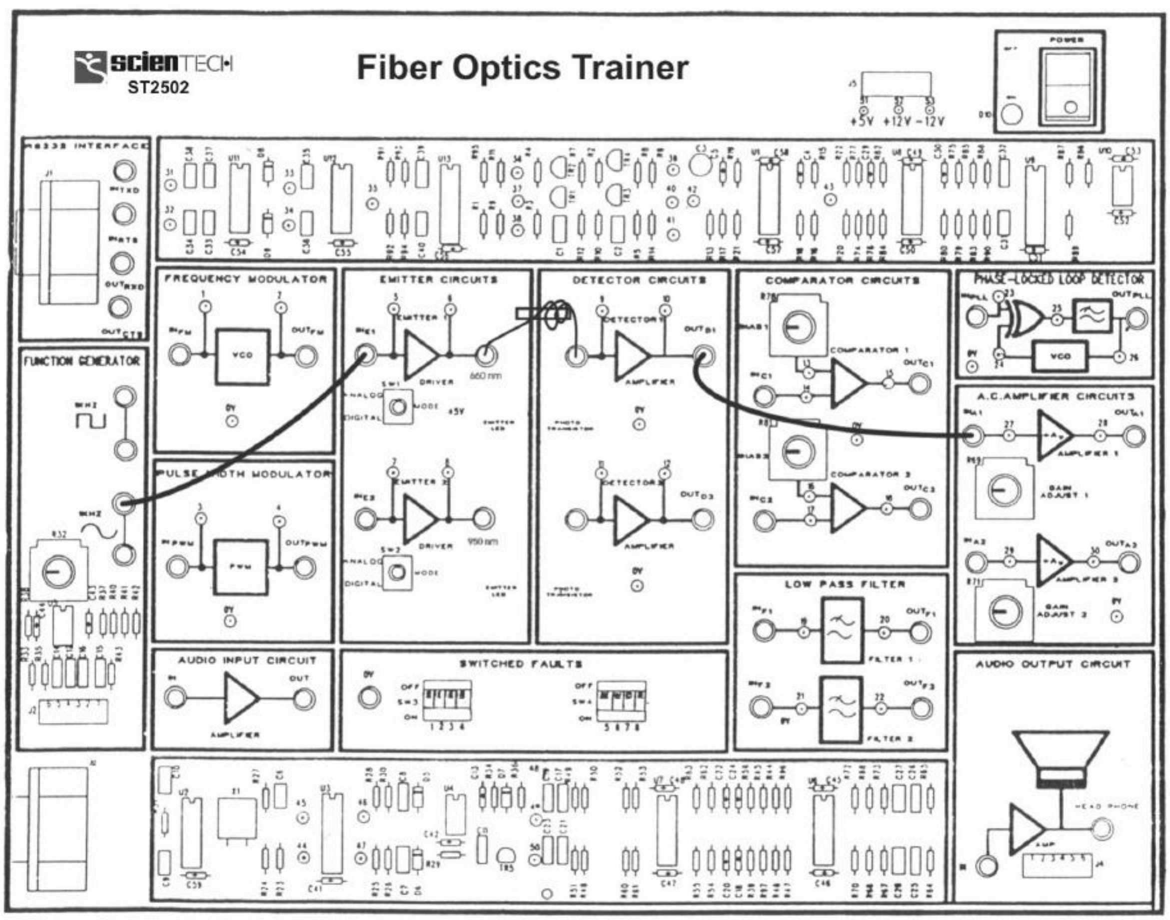


Figure 4.2

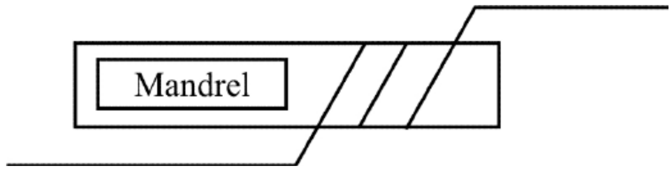


Figure 4.3

Procedure:

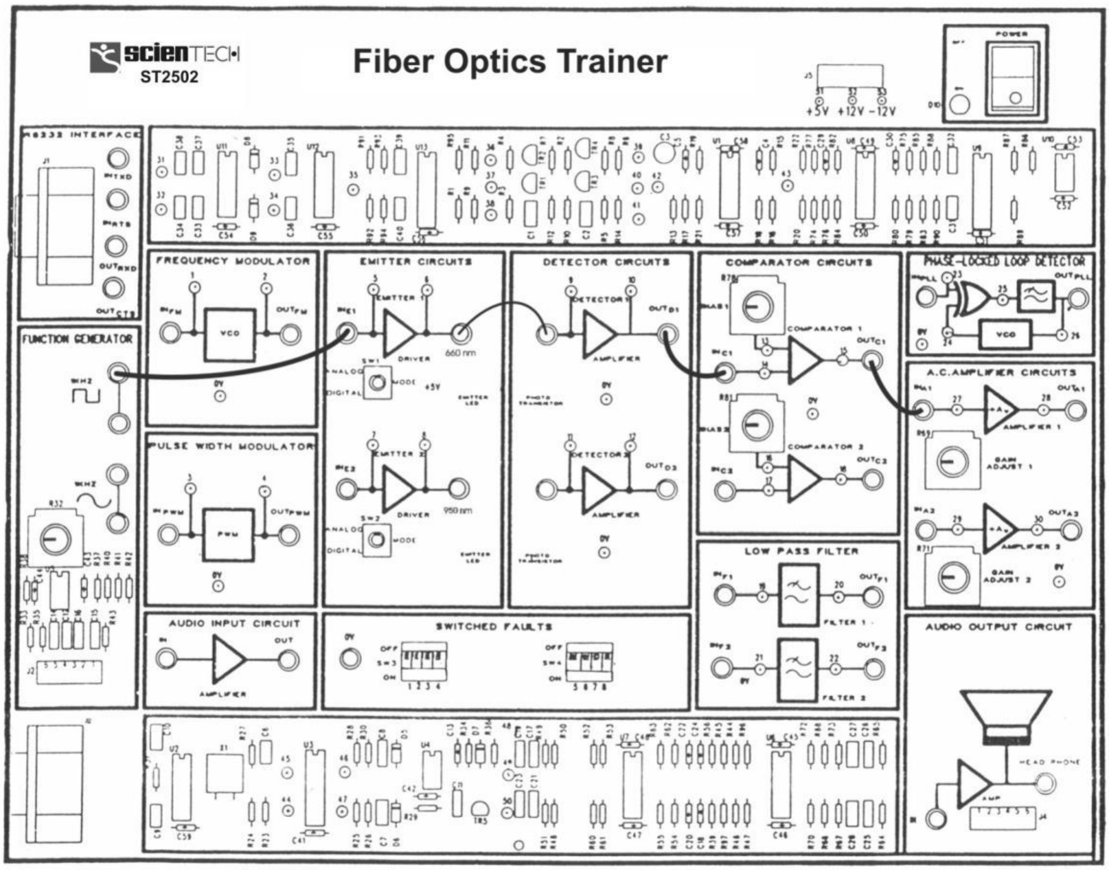
1. Connect power supply cord to the main power plug & to trainer ST2502.
2. Make the connections as shown in figure 4.2.
   a. Function Generator 1 KHz sine wave output to input socket of emitter Circuit via 4 mm lead.
   b. Connect 0.5 m optic fiber between emitter output and detectors input.
   c. Connect Detector output to amplifier input socket via 4mm lead.
3. Switch ‘On’ the power supply of the trainer and oscilloscope.
4. 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.
5. Observe the output signal from detector (TP8) on CRO.
6. 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 $V1$.
7. Wind the fiber optic cable on the mandrel and observe the corresponding AC amplifier output on CRO, it will be gradually reducing, showing loss due to bends.

Experiment 12

Objective: Measurement of Data rate or Bit Rate for Digital Optical Link

Equipments Required:
1. ST2502 trainer with power supply cord
2. Optical Fiber cable
3. Oscilloscope with power supply cord

Connection Diagram:



Procedure:

1. Set up the fiber optic digital link as explained earlier, and ensure that the link is working satisfactorily.
2. Remove the on board TTL output from the emitter input and connect the TTL output of square wave generator to emitter input.
3. Keep the frequency at 10 KHz.
4. Observe the received output on the oscilloscope.
5. Vary the frequency of the TTL input observing the output each time (You can adjust the comparator's bias preset).
6. Note the frequency at which the output is distorted or reduces to zero. The bit rate supported by the link is twice the frequency reading corresponding to zero/distorted output in bits per second.

Experiment 13

Objective: Measurement of Numerical Aperture
Measurement of the Numerical Aperture (NA) of the fiber

Equipments Required:

1. ST2502 trainer with power supply cord
2. Optical Fibre cable
3. Numerical Aperture measurement Jig

Connection Diagram:

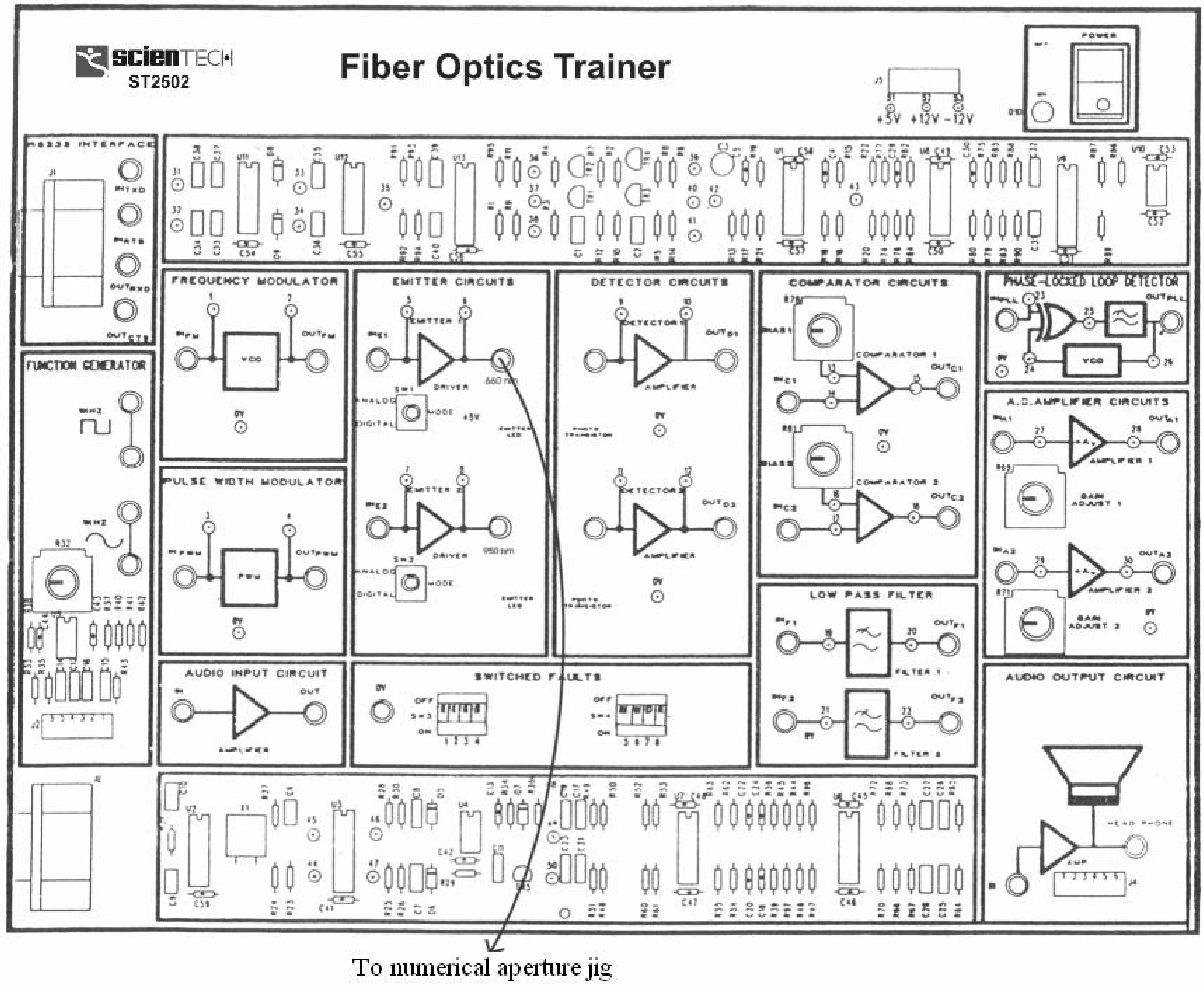


Figure 6.1

Procedure:

1. Connect the Power supply cord to mains supply and to the trainer ST2502.
2. Connect the frequency generator's 1 KHz sine wave output to input of emitter 1 circuit. Adjust its amplitude at 5Vpp.
3. Connect one end of fiber cable to the output socket of emitter 1 circuit and the other end to the numerical aperture measurement jig. Hold the white screen facing the fiber such that its cut face is perpendicular to the axis of the fiber.

4. Hold the white screen with 4 concentric circles (10, 15, 20 & 25mm diameter) vertically at a suitable distance to make the red spot from the fiber coincide with 10 mm circle.

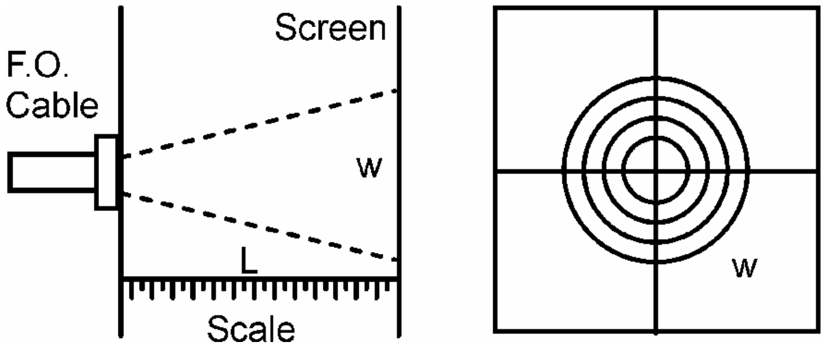


Figure 6.2

5. Record the distance of screen from the fiber end L and note the diameter W of the spot.
6. Compute the numerical aperture from the formula given below

$$NA = \frac{W}{\sqrt{4L^2 + W^2}} = \sin\theta_{max}$$

7. Vary the distance between in screen and fiber optic cable and make it coincide with one of the concentric circles. Note its distance.
8. Tabulate the various distances and diameter of the circles made on the white screen and computes the numerical aperture from the formula given above.

Inferences: The N.A. recorded in the manufacturer's data sheet is 0.5. The variation in the observation is due to fiber being used. The Acceptance Angle is given by $2\sin\theta_{max}$. The deviation from the data sheet is again due to fiber being used.