DEPARTMENT OF

ELECTRONICS & COMMUNICATION ENGINEERING

LAB MANUAL

MICROWAVE ENGINEERING LAB

IV - B. Tech., I - Semester

PRASAD V POTLURI

SIDDHARTHA INSTITUTE OF TECHNOLOGY

(Autonomous, Accredited by NBA & NAAC, an ISO 9001:2008 certified institution)

(Sponsored by Siddhartha Academy of General & Technical Education)

VIJAYAWADA – 520 007,

ANDHRA PRADESH

PRASAD V POTLURI SIDDHATHA INSTITUTE OF TECHNOLOGY

DEPARTMENT OF E.C.E

MICROWAVE AND OPTICAL COMMUNCATIONS LAB

IV B.Tech First Semester

LIST OF EXPERIMENTS

Minimum twelve experiments to be conducted:

Part – A (Any 7 Experiments)

1. Reflex klystron characteristics
2. Gun diode VI characteristics
3. Attenuation measurement
4. Directional coupler characteristics
5. VSWR measurement
6. Impedance and frequency measurement
7. Waveguide parameters measurement
8. Scattering parameters of Circulator
9. Scattering parameters of Magic Tee

PART – B (Any 5 Experiments)

10. Characterization of LED
11. Characterization of Laser diode
12. Intensity modulation of laser output through an optical fiber
13. Design of fiber optic digital link for transmission of digital signals
14. Measurement of numerical aperture
15. Measurement of losses of analog optical link

Equipment required for laboratories:

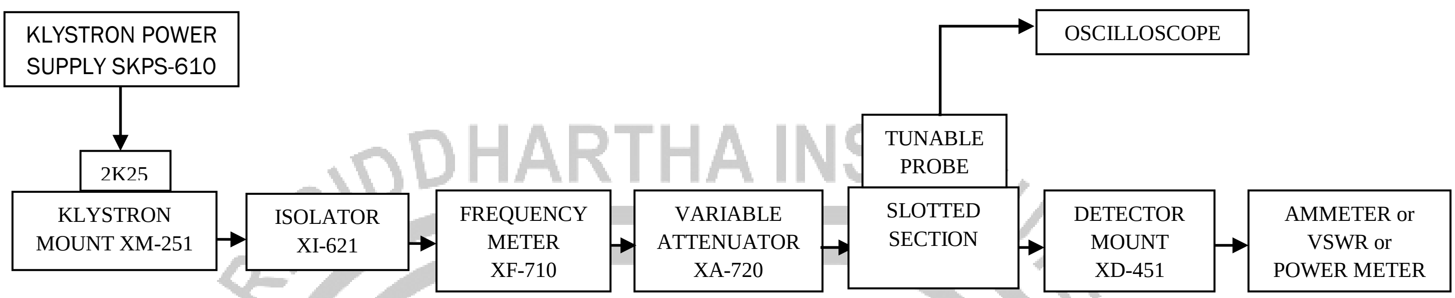
1. Regulated Klystron Power Supply
2. VSWR Meter
3. Micro Ammeter – 0 – 500 μA
4. Multimeter
5. CRO
6. GUNN Power Supply, Pin Modulator
7. Reflex Klystron
8. Crystal Diodes
9. Microwave components (Attenuation)
10. Frequency Meter
11. Slotted line Carriage
12. Probe detector
13. Wave guide shorts
14. Pyramidal Horn Antennas
15. Directional Coupler
16. E, H, Magic Tees
17. Circulators, Isolator
18. Matched Loads
19. Fiber Optic Analog Trainer based LED
20. Fiber Optic Analog Trainer based Laser
21. Fiber Optic Digital Trainer
22. Fiber Cables – (Plastic, Glass)

1. REFLEX KLYSTRON CHARACTERISTICS

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

APPARATUS Klystron power supply, Klystron tube, Isolator, Variable attenuator, Detector mount, Wave guide stand, VSWR meter and BNC cable.

SET UP FOR REFLEX KLYSTRON CHARACTERISTICS



THEORY

The reflex klystron is an oscillator tube with built in feedback mechanism. It uses the same cavity for bunching and for the output cavity. If we assume an initial AC field in the cavity the beam will be velocity modulated as it passes through the cavity up on entering the drift space, the beam is decelerated and reversed (reflected) by the large DC field set up by the repeller or reflector electrode at potential $-v_r$. Thus the beam is made to pass through the cavity again, but in opposite direction. By proper choice of the reflector voltage v_r the beam can be made to pass through the cavity on its return flight when the AC current phase angle is such that the field excited in the cavity by the returning beam adds in phase with the initial modulating field. The feedback is then positive and oscillations will be building up in amplitude until the system loses and non-linear effects prevent further build up.

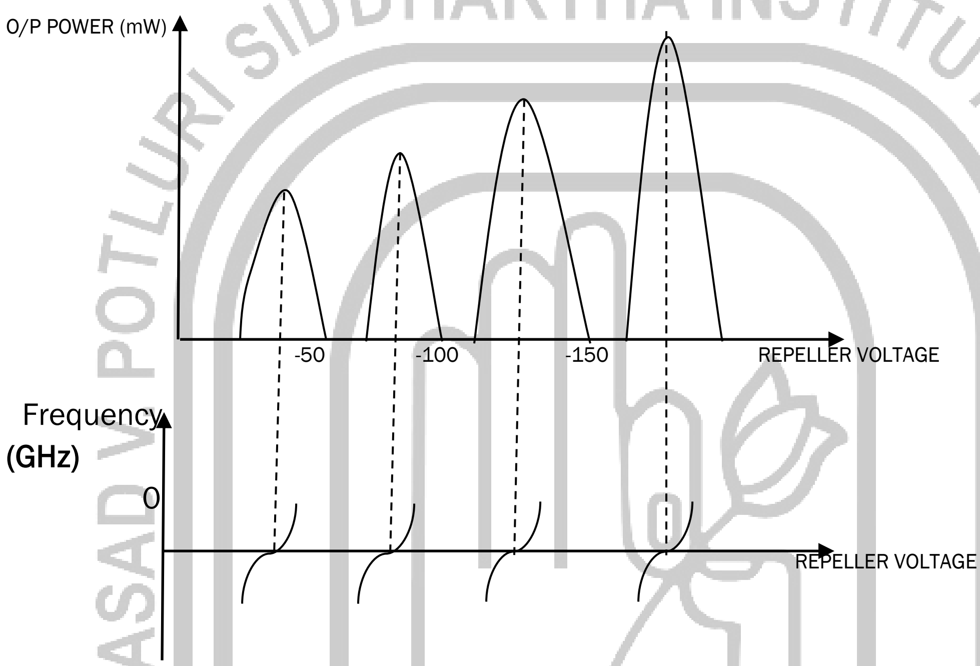
PROCEDURE

1. Connect the components and equipment as shown in the fig.
2. Set the variable attenuator to the maximum position (a zero micrometer reading)
3. Set the mod-switch of Klystron power supply to CW position, beam voltage control knob to fully anti-clockwise 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. Put the multimeter in DC microampere range of 250 micro amperes.
6. On the Klystron power supply, VSWR meter and cooling fan for the Klystron tube.
7. Put the meter switch to beam voltage position and rotate the beam voltage knob clockwise slowly up to 300 volts, 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 30 milliamps.
8. Change the reflector voltage slowly and watch on the micro. Set the voltage for maximum deflection in the meter. If no deflection is obtained change the multimeter switch position to 50 micro amperes.
9. Tune the plunger of Klystron mount for the maximum output.
10. Rotate the knob of frequency meter slowly and stop at that position, when there is less output current on multimeter .Read directly the frequency meter between two horizontal lines and vertical marker. If micrometer type frequency meter is used, read the control meter reading and find the frequency meter from its calibration chart.
11. Change the reflector voltages and read the current and frequency for each reflector voltage and plot the graph as shown in the figure.

OBSERVATIONS

S.No	Repeller voltage (V)	Current (mA)	Frequency (GHz)

MODEL GRAPH



RESULT

CONCLUSION

PRECAUTIONS

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling should be provided to reflex klystron.

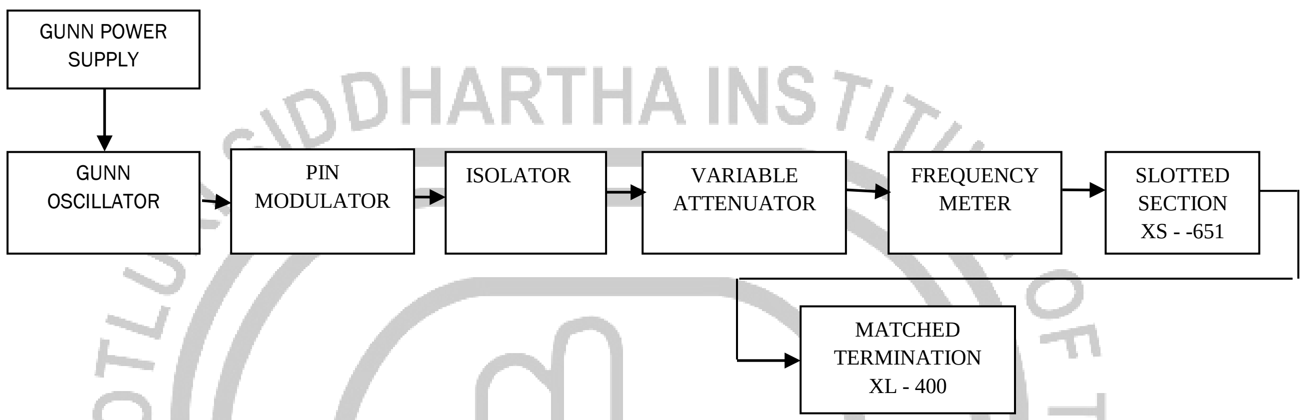
2. STUDY OF V-I CHARACTERISTICS OF GUNN DIODE

AIM Study of V-I characteristics of Gunn diode.

APPARATUS

X-Band Gunn Oscillator, Microwave bench, PIN modulator, Isolator, Frequency meter, Variable attenuator, Slotted section, Tunable probe, Detector Mount, Matched termination, Gunn power supply, Wave guide stand , BNC cable, Cooling fan.

BLOCK DIAGRAM



THEORY

Some bulk semiconductor materials such as Gallium arsenide (GA As), Indium phosphide (InP) and Cadmium Telluride (CdTe) have two closely spaced energy bands in the conduction band. At lower electric field strengths in the material, most of the electrons will be transmitted into higher energy band. In the higher energy band the effective electron mass is longer and hence the electron mobility is lower than what it is in the lower energy band. Since the conductivity is directly proportional to the mobility there is an immediate range of electric field strengths for which the fraction of electrons that are transferred into higher energy low mobility conduction is such that the average mobility and hence conductivity decreases with an increase in the electric field strength. Thus there is a range of voltage over which the current decreases with the increasing voltage and a negative instrumental of resistance is displayed by the device. A Gunn device is also called a transferred electronic device since the negative resistance arises from the transfer of electrons from the lower to higher energy band. The oscillations that occur in the material with energy band structure noted above was discovered by J.B.GUNN. The probability of obtaining negative differential resistance had been predicted earlier by Ridley and Watkins.

PROCEDURE

1. Set up the microwave test bench as shown in block diagram.
2. Keep the control knobs of power supply as detailed below:

ON/OFF switch	-	OFF
Gunn diode bias knob	-	fully anti-clockwise to keep the bias voltage to zero to start with.
PIN bias knob	-	fully anti-clockwise to keep the bias voltage to zero to start with
PIN mode frequency	-	middle position to keep frequency approx. to 1 kHz.

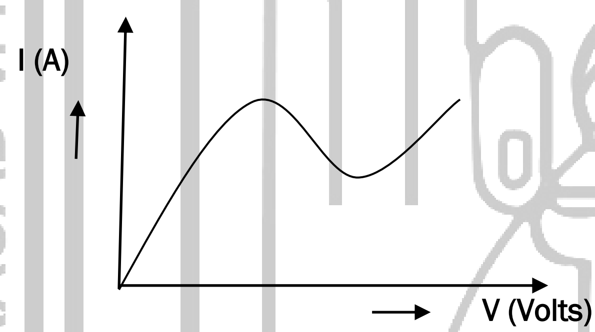
3. Do not apply any bias to PIN diode throughout the experiment.
4. Set the micrometer of Gunn oscillator cavity for required frequency of operation.
5. Switch on the Gunn power supply.

6. Measure the Gunn diode current corresponding to the various Gunn bias voltages in steps of 0.5 volts controlled by Gunn bias knob through the panel meter and DMP's switch. Do not exceed the bias voltage above 10 V.
7. Plot the voltage reading and current reading on the graph.
8. Read the threshold voltage V_t that corresponds to maximum current from the graph.

OBSERVATIONS

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

MODEL GRAPH



RESULT

CONCLUSION

PRECAUTIONS

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

3. MEASUREMENT OF ATTENUATION

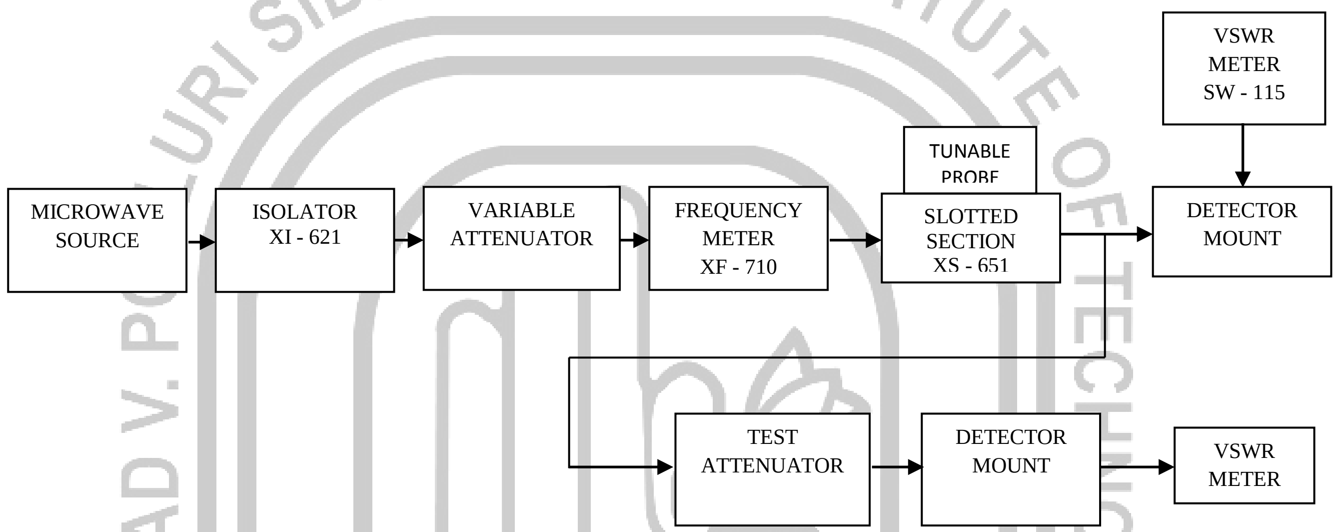
AIM To study the ATTENUATOR (fixed and variable type).

APPARATUS Microwave source

1. GUNN OSCILLATOR – XG 11
2. KLYSTRON TUBE – 2K25

Isolator (XI – 621), Frequency meter (XF-710), Variable Attenuator(XA-520), Slotted line (XS – 651) ,Tunable probe (XP-655), Detector mount (XD – 451), Matched termination (XL-400), Test attenuator a) Fixed b) Variable, Gunn power supply ,Cooling fan, BNC – BNC cable and TNC-TNC cable.

BLOCK DIAGRAM



THEORY

The attenuator is a two port bidirectional device which attenuates some power when inserted in to the transmission line.

$$\text{Attenuation A (dB)} = 10\, log\, \frac{p_1}{P_2}$$

Where P_1 is power detected by the load without the attenuator in the line

P_2 is the power detected by the load with the attenuator in the line.

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

Following characteristics of attenuators can be studied

1. Insertion loss (in case of variable attenuator).
2. Frequency sensitivity i.e. variation of attenuation with change in frequency at any fixed position of vane.

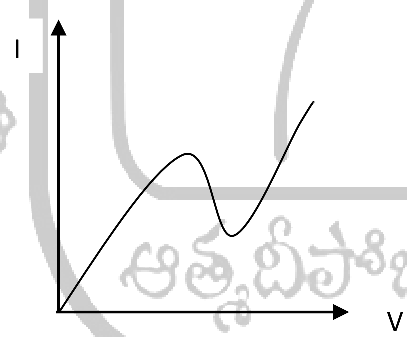
PROCEDURE

1. Connect the detector mount to the slotted line and tune the detector mount also for maximum deflection on VSWR meter. (Detector mount output should be connected to VSWR meter).
2. Set any reference level on the VSWR meter with the help of variable attenuator (not test attenuator) and gain control knob of VSWR meter let it be P_1.
3. Carefully disconnect 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 part of test variable attenuator. Keep the micro meter 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.
4. For measurement of attenuation of fixed and variable attenuator place the test variable attenuator to the slotted line and detector mount at the other port of test attenuator. Record the reading of VSWR meter let it be P_3 then the attenuation value of variable attenuator for particular position of micro meter reading will be (P_1-P_3) dB.
5. In case of the variable attenuator change the micro meter reading and record the VSWR meter reading. Find out attenuation value for different position of micro meter reading and plot a graph.
6. Now change the operating frequency and all steps should be repeated for finding frequency sensitivity of fixed and variable attenuator.

OBSERVATIONS

S.NO.	VOLTAGE (Volts)	CURRENT (A)

MODEL GRAPH



RESULT

CONCLUSION

PRECAUTIONS

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling should be provided to reflex klystron.

4. DIRECTIONAL COUPLER CHARACTERISTICS

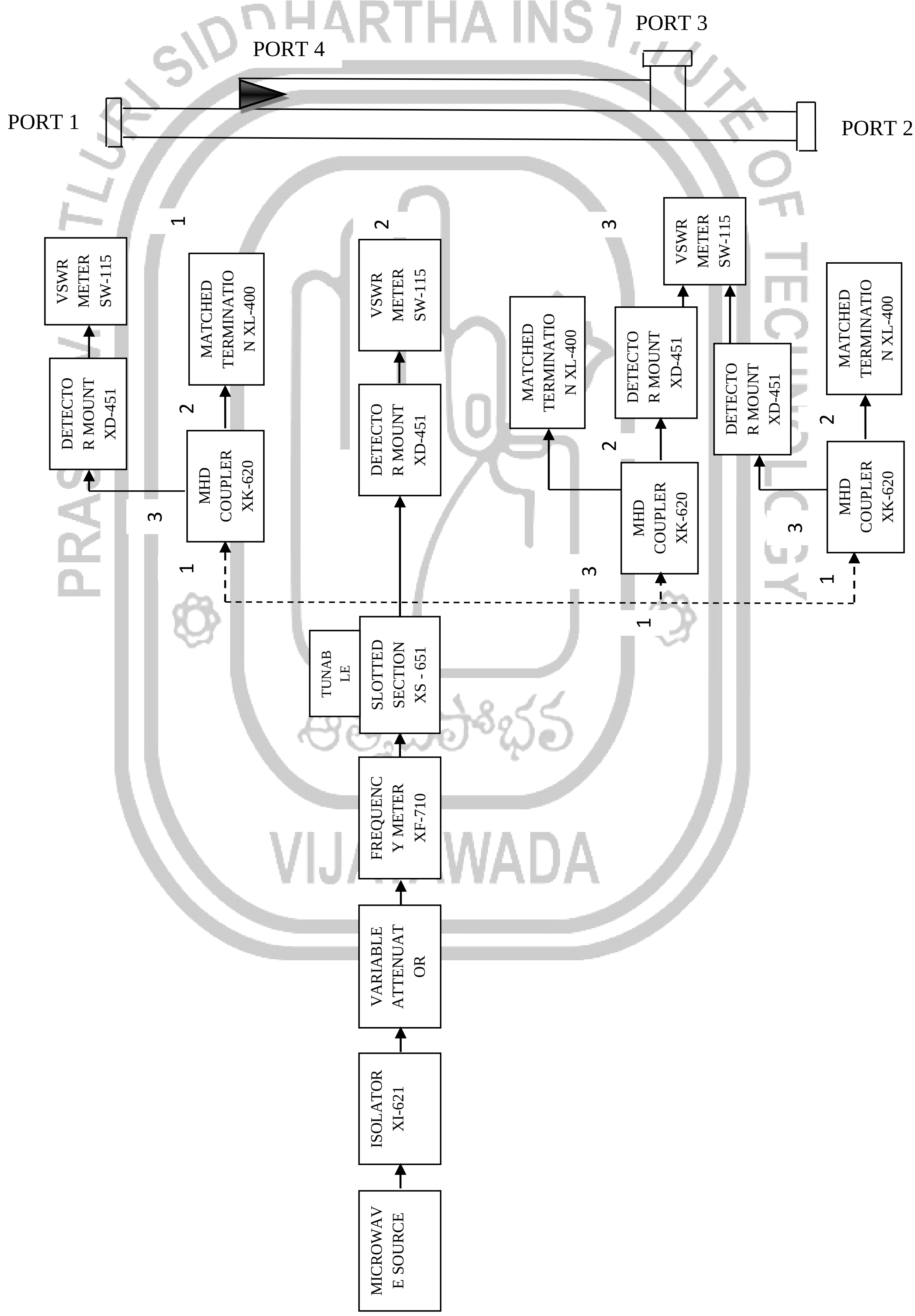
AIM To study the function of multi hole directional coupler by measuring the following parameters.

1. Coupling factor
2. Insertion loss
3. Directivity

APPARATUS

Microwave source (Klystron or Gunn diode), Isolator, Frequency meter, Variable attenuator, Slotted line, Tunable probe, Detector mount, Matched termination, MHD coupler, Waveguide Stand, Cables and Accessories, VSWR meter.

FIG.1 DIRECTIONAL COUPLER



THEORY

A directional coupler is a device which is used to measure the incident and reflected wave separately. It consists of two transmission lines the main arm and the auxiliary arm. Electromagnetically coupled to each other refers to the fig. The power entering in the main arm gets divided between port 2 and 3 and almost no power comes out in port 4 power entering at port 2 is divided between port 1 and 4.

The coupling factor is defined as

Coupling (dB) = 10 $\log_{10} (P_1 / P_3)$ where port 2 is terminated.

Isolation (dB) = 10 $\log_{10}(P_2 / P_3)$ where P_1 is matched with built in termination and power entering at port 1 the directivity of the coupler is a measure of separation between incident wave and the reflected wave directivity is measured indirectly as follows

Hence directivity D (dB) = 1-c = $10\log_{10} (P_2 / P_1)$

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

Insertion loss (dB) = $10\log_{10} (P_1 / P_2)$.

PROCEDURE

1. Set up the components and equipment as shown in the figure.
2. Energize the microwave source for particular frequency of operation.
3. Remove the multi hole directional coupler and connect the detector mount of the frequency meter. 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 figure 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 measurement.
6. Note down the reading on VSWR meter on the scale with help of range – dB switch if required let it be Y.
7. Calculate coupling factor which will be X-Y = C (dB).
8. Now carefully disconnect the detector from the auxiliary port 3 and match termination from point 2 without disturbing the set up.
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 the insertion loss X-Z in dB.
11. Repeat the steps from 1 to 4.
12. Connect the directional coupler in the reverse direction i.e. port 2 to frequency meter side matched termination to port 1 and detector mount to port 3 without disturbing the position of the variable attenuator and gain control knob of VSWR meter.
13. Measure and note down the reading on VSWR meter. Let it be Y_d. X – Y_d gives isolation.
14. Compute the directivity as Y – Y_d.
15. Repeat the same for other frequencies.

OBSERVATIONS

1. Coupling factor

   X= dB

   Y = dB

   Coupling factor in dB = X – Y

2. Insertion loss

   X= dB

   Z = dB

   Insertion loss in dB = X – Z

3. Directivity

$Y =$ dB

$Y_d =$ dB

Directivity = $Y - Y_d$

RESULT

CONCLUSION

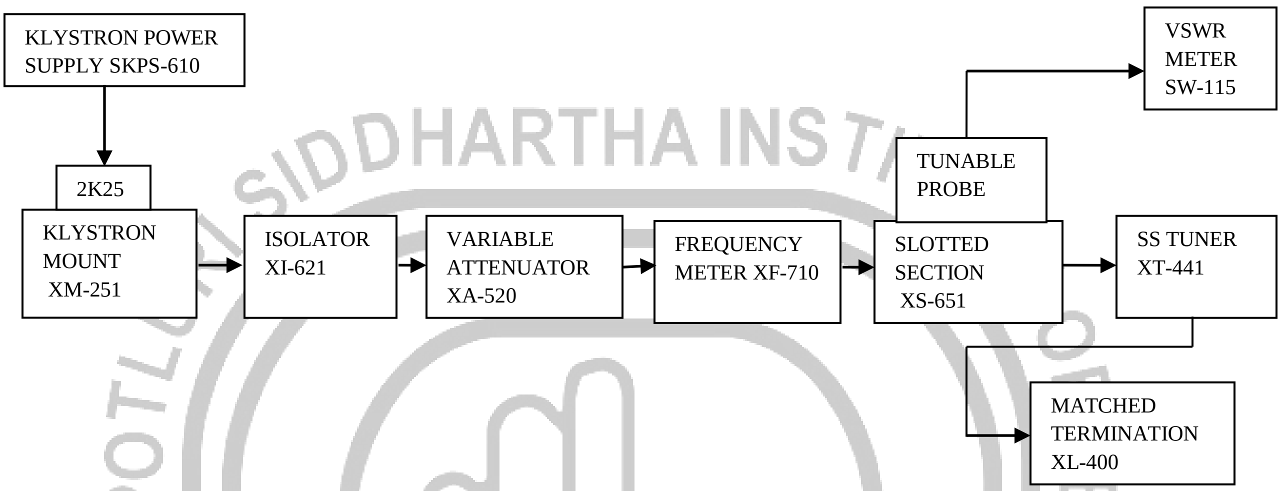
PRECAUTIONS

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling should be provided to reflex klystron.

5. VSWR MEASUREMENT

AIM To determine the Standing-Wave Ratio and Reflection Coefficient.

APPARATUS Klystron tube (2K25), Klystron power supply (SKPS-610), VSWR meter (SW-115), Klystron mount (XM-251),Isolator(XI-621), frequency meter(XF-710), Variable attenuator(XA-520), Slotted line(XS-651), Tunable probe(XP-655), Waveguide stand(XU-535), Movable short/Termination (XL-400) or any unknown load and BNC cable, SS tuner (XT- 441).



THEORY

The electromagnetic field at any point of a transmission line (eg a wave guide) may be considered as the sum of two travelling waves. The incident wave propagates from the generator, the reflected wave propagates towards the generator .The reflected wave is set up by the reflection of the incident wave from a discontinuity on the line or from a load impedance not equal to the characteristic impedance of the line. The magnitude and phase of the reflected wave depends upon the amplitude and phase of the reflecting impedance. The magnitude also depends on the amplitude losses on the line. On a lossy line the reflected (and incident) wave will be attenuated. If the line is uniform and infinitely long there would be no reflected wave. The same applies for a line of finite length which is matched i.e. has a load equal to the characteristic impedance of the line. The presence of two travelling waves gives rise to standing wave along the line. The electrical (and mechanical) field varies periodically with distance. The maximum field strength is found where the two waves add in phase and the minimum where the two waves add in opposite phase. Figure above shows the voltage standing wave patterns for different load impedances. The distance between two successive minima (or maxima) is half the wavelength on the transmission line. The ratio between the electrical fields of the reflected and incident wave is called the voltage reflection coefficient, being a vector, which means that is phase varies along the transmission line. The voltage standing wave ratio VSWR on a transmission line is defined as the ratio between maximum and minimum field strengths along the line.

$\rho = Er / E_i$,

$S = E_{max} / E_{min} = (E_i + E_r) / (Ei - E_r)$

$\rho = (S - 1) / (S+1)$

PROCEDURE

1. Set up the equipment as shown in the figure.
2. Keep the variable attenuator in minimum position.
3. Keep the control knob of VSWR meter as below

   Range - 40dB/50dB

I/p switch	-	low impedance
Meter switch	-	normal
Gain	-	mid position approximate.

4. Keep the control knob of the Klystron power supply as below.

Beam voltage	-	OFF
Mod switch	-	AM
Beam voltage knob	-	fully anti-clockwise
Repeller voltage knob	-	fully clockwise
AM amplitude knob	-	around fully clockwise
AM frequency	-	mid position

5. Switch ON the Klystron power supply, VSWR meter and cooling fan.
6. Switch ON the beam voltage and set beam voltage at 250V.
7. Rotate the reflector voltage knob to get deflection in VSWR meter.
8. Tune the output by turning the reflector voltage, amplitude and frequency of AM modulation.
9. Tune plunger of klystron mount and probe for maximum deflection in VSWR meter.
10. If required change the range dB switch variable attenuator position and gain control knob to get deflection in the scale of VSWR meter.

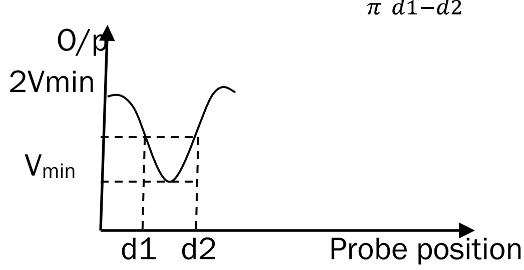
A. Measurement of Low and Medium VSWR

1. Move the probe along the slotted section to get maximum deflection in VSWR meter.
2. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates1.0 on normal VSWR scale.
3. Keep all the control knob as it is, move the probe to next minimum position. Read the VSWR on scale.
4. Repeat the above step for change of S.S tuner probe depth and record the corresponding SWR.
5. If the VSWR is between 3.2 and 10, change the range dB switch to next higher position and read SWR on second VSWR scale of 3 to 10.

B. Measurement of high VSWR (Double minimum method)

1. Get the depth of S.S tuner slightly more for maximum VSWR.
2. Move the probe along with slotted line until minimum is indicated.
3. Adjust the VSWR meter gain control knob and variable attenuator to obtain a reading of 3 dB in the normal dB scale (0 to 10 dB) of VSWR meter.
4. Move the probe to the left on slotted line until full scale deflection is obtained on 0-10 dB scale. Note and record the probe position on slotted line let it be d_1.
5. Repeat the step-3 and move the probe right along the slotted line until full scale deflection is obtained on 0 – 10 dB normal dB scale. Let it be d_2.
6. Repeat the S.S tuner and termination by movable short.
7. Measure the distance between two successive minima positions of the probe, twice the distance is guide wavelength λ_g.
8. Compute SWR from the following equation

$$SWR = \frac{\lambda g}{\pi\ d1 - d2} - E_q E_d$$



OBSERVATIONS

1. Low VSWR =

2. High VSWR =

With variable short d_1=

d_2=

With matched termination d_3=

d_4=

$$SWR = \frac{\lambda g}{\pi \ d1 - d2}$$

Reflection coefficient= S-1/S+1 =

RESULT

CONCLUSION

PRECAUTIONS

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling fan should be provided to reflex klystron.

6. IMPEDANCE MEASUREMENT

AIM To measure unknown impedance using the Smith chart.

EQUIPMENT

Klystron Tube 2K25, Klystron Power supply SKPS – 610, Klystron Mount XM-251,Isolator XI-621, Frequency Meter XF-710, Variable Attenuator XA-520, Slotted line XS-565, VSWR Meter, Waveguide Stand SU 535, SS tuner(XT441), Movable Short/Termination , etc.

THEORY

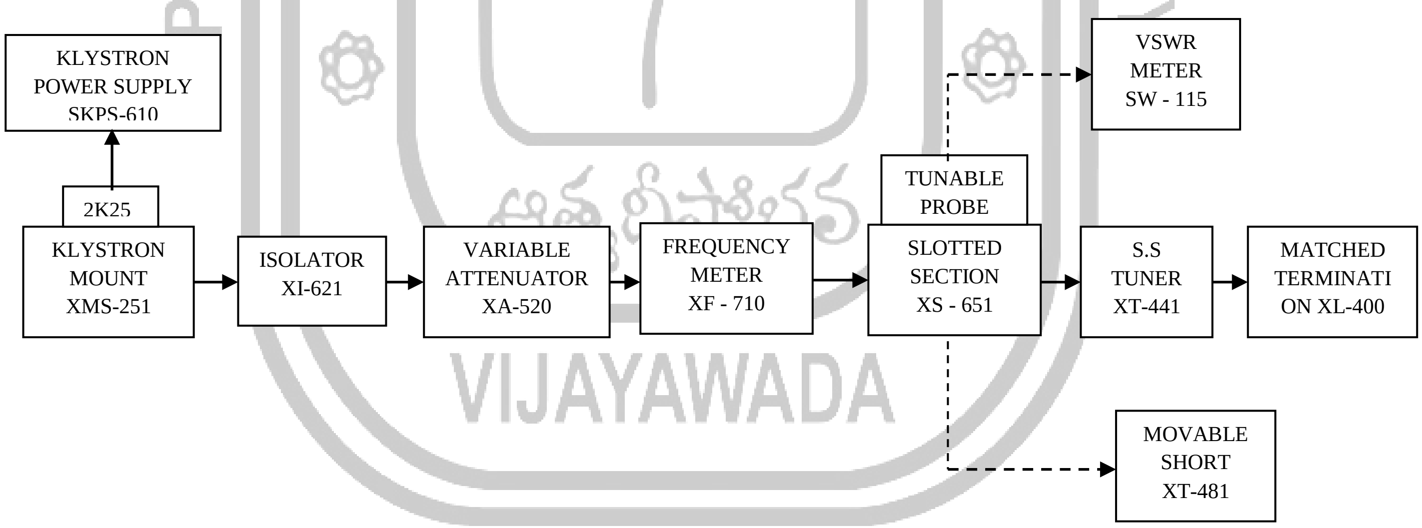
The impedance at any point on a transmission line can be written in the form R+jX.

This SWR can be calculated $S = \frac{1+R}{1-R}$

Where R is reflection coefficient = $\frac{Z-Z_0}{Z+Z_0}$

where Z_0 is the characteristic impedance of the waveguide at the operating frequency. Z is the load impedance. The unknown device is connected to the slotted section and the position of one minima is determined. The unknown device is replaced by Movable short to the slotted section. Two successive minima positions are noted. Twice the difference between the minima positions will be guide wavelength. One of the minima is used as reference for impedance measurement. Find the difference of reference minima and minima position obtained from unknown load. Let it be'd'. Take a Smith chart, taking 'l' as center; draw a circle of radius equal to 'S_0'. Mark a point on circumference of Smith chart towards load side at a distance equal to d/λ_g. Join the center with this point. Find the point where it cuts the drawn circle. The coordinates of this point will show the normalized impedance of the load.

SET UP FOR IMPEDANCE MEASUREMENT



PROCEDURE

1. Set up the equipment as shown in the figure.
2. Set the variable attenuator at minimum position.
3. Keep the control knobs of VSWR Meter as below
   - Range - 50 dB position
   - Input switch - Crystal Low Impedance
   - Meter switch - Normal position
   - Gain (Coarse – fine) - Mid position
4. Keep the control knobs of Klystron power supply as below
   - Beam voltage switch -'OFF'

Mod switch - AM
Beam Voltage Knob - Fully anti-clockwise
Reflector voltage - Fully clockwise
AM – amplitude - Around fully clockwise
AM- Frequency Knob - Around Mid position

5. Switch 'ON' the Klystron power supply, VSWR meter and Cooling fan.
6. Switch 'ON' the Beam Voltage Switch position and set beam voltage at 300 V with the help of beam voltage knob.
7. Adjust the reflector voltage knob to get some deflection in VSWR meter.
8. Maximize the deflection 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. Keep the depth of the pin of SS Tuner around 3-4 mm and lock it.
14. Move the probe along the slotted section to get maximum deflection.
15. Adjust VSWR meter gain control knob and variable attenuator until the meter indicates 1.0 on the normal dB SWR scale.
16. Move the probe to next minima position and note down the SWR S_0 on the scale. Also note down the probe position, let it be 'd_x'.
17. Remove the SS Tuner and matched termination and place movable short at slotted section. The plunger of short should be at zero.
18. Note the position of two successive minima position. Let it be d_1 and d_2. Hence $\lambda_g = 2(d_1 - d_2)$.

$$d = d_x - d_1$$

19. Calculate d/λ_g.
20. Find out the normalized impedance as described in the theory section.
21. Repeat the same experiment for other frequency if required.

OBSERVATIONS

$d_1 =$ mm.
$d_2 =$ mm
$\lambda_g = 2(d_1 - d_2)$ mm.
SWR = S_0 =
d =
d/λ_g =
Normalized impedance =

RESULT

CONCLUSION

PRECAUTIONS

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling should be provided to Reflex klystron.

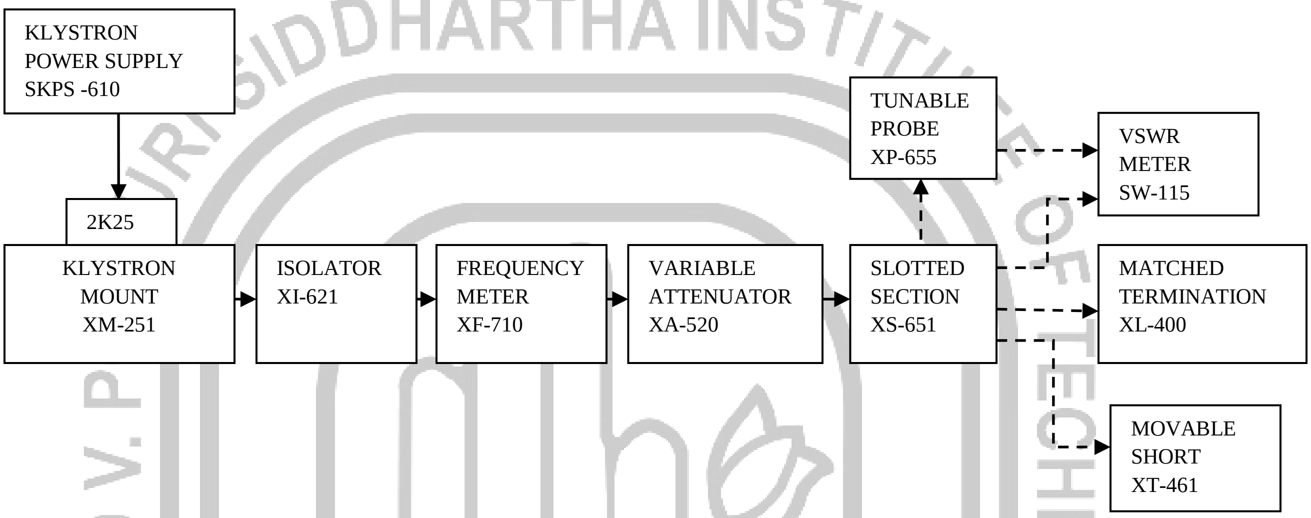
7. WAVEGUIDE PARAMETERS MEASUREMENT

AIM To determine the frequency and wave length in a Rectangular Waveguide working in TE_{10} mode.

EQUIPMENT

(a) Klystron Tube 2K25, (b) Klystron Power Supply SKPS-610, Klystron Mount XM-251, Isolator XI-621, Frequency meter XF-710, Variable Attenuator XA-520, Slotted section XS -651, Tunable Probe XP-655, VSWR Meter SW-115, Waveguide Stand XU-535, Movable Short XT-481, Matched Termination XL-400.

SETUP FOR FREQUENCY & WAVELENGTH MEASUREMENT



THEORY

For dominant TE_{10} mode rectangular waveguide λ_0, λg, λ_c and are related as below

$$1/\lambda_0^2 = 1/\lambda g^2 + 1/\lambda_c^2$$

λ_0 is free space wavelength
λ_g is guide wavelength
λ_c is cut-off wavelength

For TE_{10} mode = 2a where 'a' is the broader dimension of waveguide.

PROCEDURE

1. Set up the components and equipments as shown in figure.
2. Set up variable attenuator at minimum attenuation position.
3. Keep the control knobs of VSWR meter as below

   Range - 50 dB
   Input switch - crystal low impedance
   Meter switch - Normal position
   Gain (Coarse & fine) - Mid position
4. Keep the control knobs of klystron power supply as below
   Beam voltage - OFF
   Mod – switch - AM
   Beam voltage knob – Fully anti-clockwise
   Reflector voltage – Fully clockwise
   AM-Amplitude knob - Around fully clockwise
   AM-Frequency knob – Around mid-position
5. Switch on the klystron power supply, VSWR meter and cooling fan.

6. Switch on the beam voltage switch and set beam voltage at 250 volts with the help of beam voltage knob.
7. Adjust the reflector voltage to get some deflection in VSWR meter.
8. Maximize the deflection 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 to get some deflection in VSWR meter.
11. Tune the reflector voltage knob for maximum deflection.
12. Tune the frequency meter knob to get a dip on the VSWR scale and note down the frequency directly from frequency meter.
13. Replace the termination with movable short and detune the frequency meter.
14. Move the probe along the slotted line. The deflection in VSWR meter will vary. Move the probe to a minimum deflection position, to get accurate reading if necessary increase the VSWR meter range dB switch to higher position. Note and record the probe position.
15. Move the probe to next minimum position and record the probe position again.
16. Calculate the guide wavelength as twice the distance between two successive minimum positions obtained as above.
17. Measure the waveguide inner broad dimension 'a' which will be around 22.86 mm for X-band.
18. Calculate the frequency by following equation

    $F = c/\lambda = C \ (1/\lambda_g^2 + 1/\lambda_c^2)^{1/2}$ - Eq. Ed

    Where $c = 3 \times 10^8$ meter/sec .i.e. velocity of light
19. Verify with frequency obtained by frequency meter.
20. Above experiment can be verified at different frequencies.

OBSERVATION

First minima position d_1 =

Second minima position d_2 =

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

Broader dimension of wave guide 'a' = 2.2 cm

$\lambda_c = 2a$=

c = speed of light=3×10^8 m/s

$$f = \frac{c}{\lambda_c} = c\left(\frac{1}{\lambda_c^2} + \frac{1}{\lambda_g^2}\right)^{1/2}$$ - Eq. Ed =

Frequency reading from frequency meter =

RESULT

CONCLUSION

PRECAUTIONS

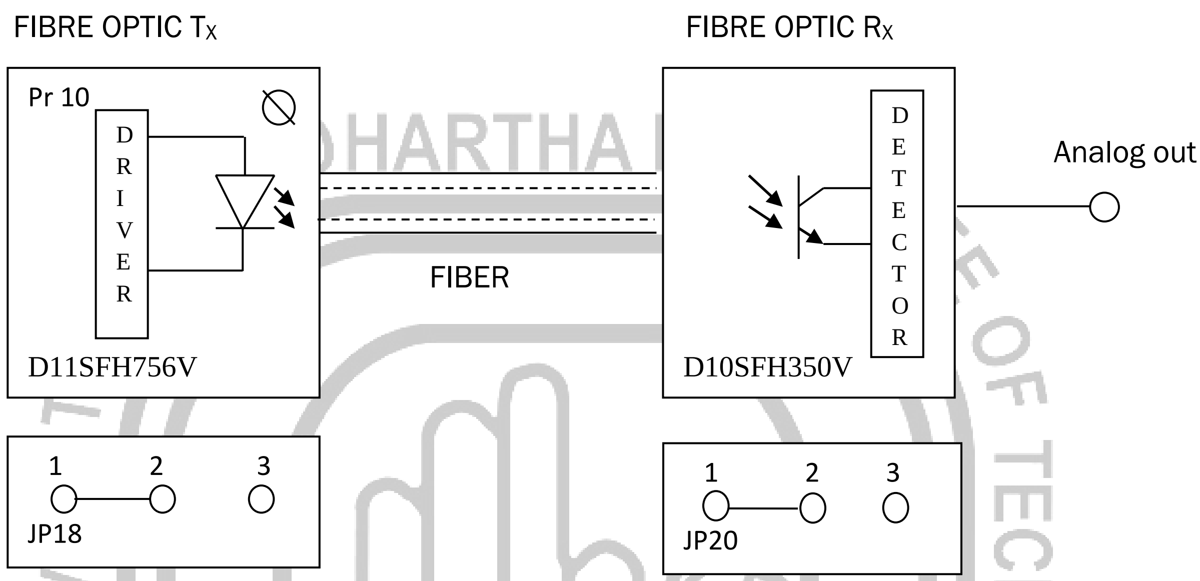
5. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
6. While modulating repeller should never become positive with respect to cavity.
7. Cooling should be provided to reflex klystron.

8. CHARACTERIZATION OF LED

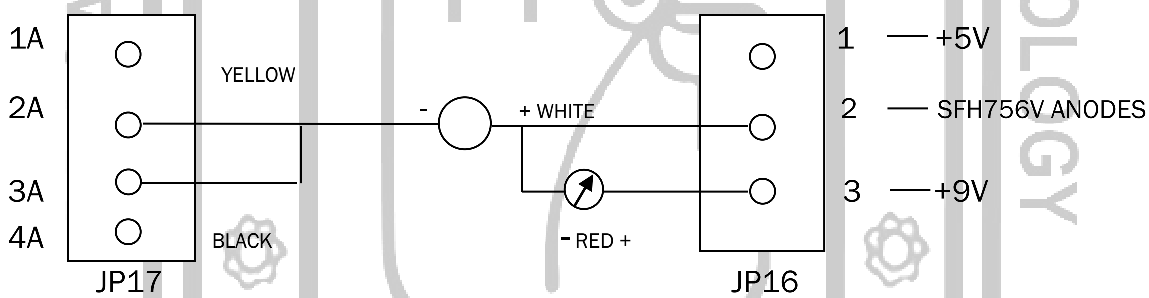
AIM To study the characteristics of fibre optic LED and plot the graph of forward current v/s output optical energy and also to study the photo detector response.

APPARATUS
Multimeter, Ammeter, Experimental kit, Fibre optic cable, Patch cords.

CHARACTERISTICS OF FIBER OPTIC LED



JUMPER SETTING DIAGRAM



1A = EMITTER OF Q3 (2NN907); 2A = CATHODE OF SFH 756V; 3A = COLLECTOR OF Q1 (2N3904); 4A = CATHODE OF SFH450V

THEORY

In optical fibre communication system, electrical signal is first converted into optical signal with the help of E/O conversion device as LED. After this optical signal is transmitted through optical fiber, it is retrieved in its original electrical form with the help of O/E conversion device as photo detector.

Different technologies employed in chip fabrication lead to significant variation in parameters for various emitter diodes. All the emitters distinguish themselves in offering high output power coupled in to the important peak wavelength of emission, conversion efficiency, to be useful in fiber transmission applications as LED must have a high radiance output. Fast emission response time and high quantum efficiency, its radiance is a measure of optical power radiated into unit solid angle per unit area of the emitting light source. High radiances are necessary to couple sufficiently high optical power levels into a fiber.

PROCEDURE

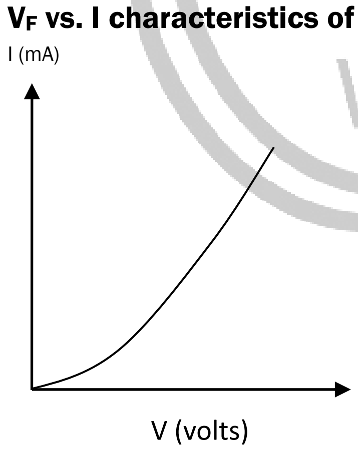
1. Confirm that the power switch is in OFF position.
2. Make the jumper settings as shown in the jumper diagram.

3. Insert the jumper connecting wires (provide along with the kit) in jumper JP17 and JP16 at position shown in fig.
4. Connect the ammeter and volt-meter with the jumper wires connected to JP17 and JP16 as shown in the fig.
5. Keep the potentiometer Pr10 in its maximum position (anti-clockwise rotation) and Pr9 in its minimum position (clockwise rotation) .Pr10 is used to control current flowing through the LED and Pr9 is used to vary the amplitude of the received signal at phototransistor.
6. To get the VI characteristics of LED, rotate Pr10 slowly and measure forward current and corresponding forward voltage. Take number of such readings for various current values and plot VI characteristics graph for the LED.
7. For each reading taken above, find out the power which is product of V and I. This is the electrical power supplied to the LED. Data sheets for the LED specify optical power coupled into plastic fiber when the forward current is 10mA as 200μW of optical energy. Hence the efficiency of the LED comes out to be approx. 1.15 %.
8. With this efficiency assumed, find out optical power coupled into plastic optical fiber for each of the reading in step 7. Plot the graph of forward current v/s output optical power of the LED.
9. Data sheets for the phototransistor detector specified responsivity as 0.8mA for 10μW of incident optical energy. In our experimental kit, when Pr9 is at its minimum position, 100 ohms of resistance is in series of emitter and ground of phototransistor.
10. Connect the 30 cm optical fiber cable supplied with the kit between LED SFH756V (660nm) and phototransistor SFH350V (Analog detector).
11. From the transfer characteristics obtained in step 8, launched known optical energy in to plastic fiber and measure output voltage at ANALOG OUT TERMINAL. Find out the current flowing through the phototransistor with this voltage value and 100 ohms of resistance.
12. Repeat step 11 for various launched optical energy values and plot the graph for the responsivity of phototransistor. Find out the portion where detector response is linear.
13. Insert the jumper connecting wires (provided along with the kit) in jumper JP17 and JP16 at positions shown in the fig. and do the same procedure above for another source.

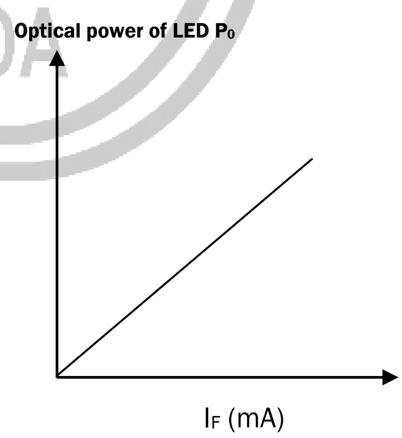
OBSERVATIONS

Forward voltage of LED - V_F (V)	Forward current of LED - I_F (mA)	Electrical Power P_i= V*I	Optical Power of LED $P_o = P_i * 1.15\%$ μW

V_F vs. I characteristics of LED



I_F vs. P_0 characteristics of LED



RESULT

CONCLUSION

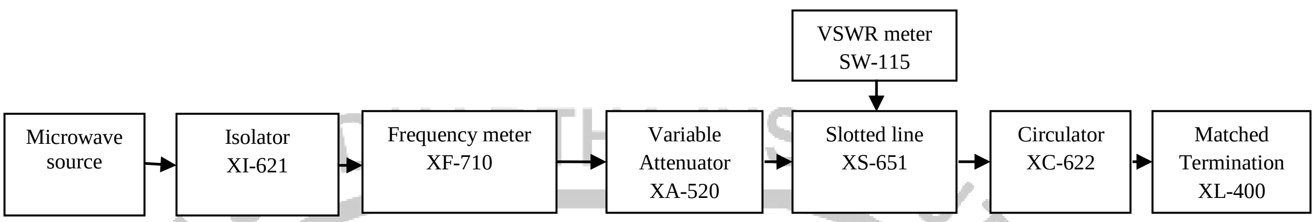
PRECAUTIONS Before connecting power supply to the equipment be sure patch cards are connected correctly, jumpers are correct as per experimental position.

9. STUDY OF CIRCULATOR

AIM To study the X-band Microwave circulator.

APPARATUS Microwave source, Isolator, frequency meter, variable attenuator, slotted line, Circulator, matched termination, VSWR meter and BNC probe.

BLOCK DIAGRAM



THEORY

A 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. This is depicted in fig. below. Circulator can have any number of ports.

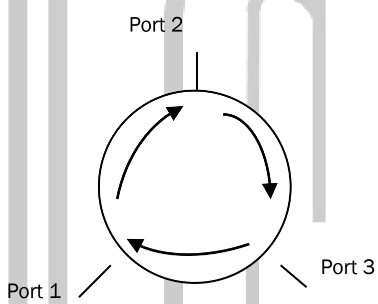


Fig. A

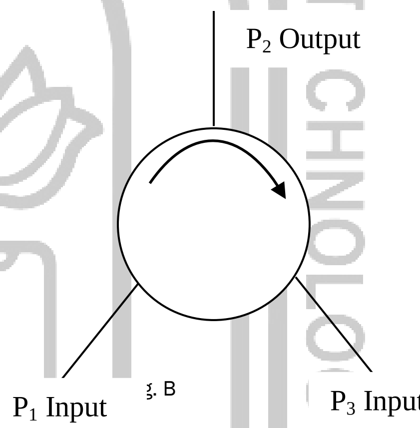


Fig. B

The important parameters of Circulator are

1. Insertion loss
   Insertion loss is the ratio of power detected at the output port to the power supplied by source to the input port measured with other ports terminated in the matched load. It is expressed in dB.
2. Isolation
   It is the ratio of power applied to the output that measured at input. This ratio is expressed in dB.The isolation of circulator is measured with the third port terminated in a matched load.
3. Input VSWR
   The input VSWR of a circulator is the ratio of voltage maximum to voltage minimum of the standing wave existing in the line with all ports except the test port are matched.

PROCEDURE

Input VSWR measurement

1. Setup the components and equipment as shown in the figure shown above with the input port of the circulator connected to the slotted line and matched load on other ports.
2. Energize the microwave source for a particular frequency of operation.
3. With the help of slotted line, probe and VSWR meter find out VSWR of the circulator as described for low and medium SWR measurement.

4. The above procedure can be repeated for other ports.

Measurement of insertion loss and Isolation

1. Remove the probe and circulator from the slotted line and connect detector mount to the slotted section. The output of the detector mount should be connected to the VSWR meter.
2. Energize the microwave source for maximum output for a particular frequency of operation. Tune the detector mount for maximum output in the VSWR meter.
3. Set any reference level of power in VSWR meter with the help of variable attenuator and gain control knob of the VSWR meter. Let it be P_1.
4. Carefully remove the detector mount from the slotted line without disturbing the position of the setup. Insert the circulator between slotted line and detector mount .Keep input port to the slotted line and detector to its output port. A matched termination should be placed at the third port.
5. Record the reading in the VSWR meter, if necessary change the range (dB) switch to high or lower position and read 10 dB change for each step. Change of switch position. Let it be P_2..
6. Compute Insertion loss as $P_1.P_2$ in dB.
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 and let it be P_3.
9. Compute isolation as $P_1.P_3$ in dB.
10. The same experiment can be done for other ports of the circulator.

OBSERVATIONS

VSWR

INSERTION LOSS $P_1.P_2$=

ISOLATION $P_1.P_3$ =

RESULT

CONCLUSION

PRECAUTIONS

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling should be provided to Reflex Klystron.

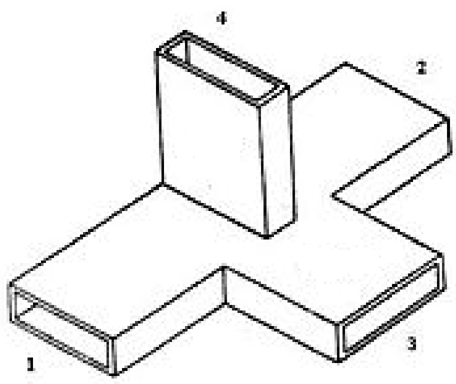
10. STUDY OF MAGIC TEE

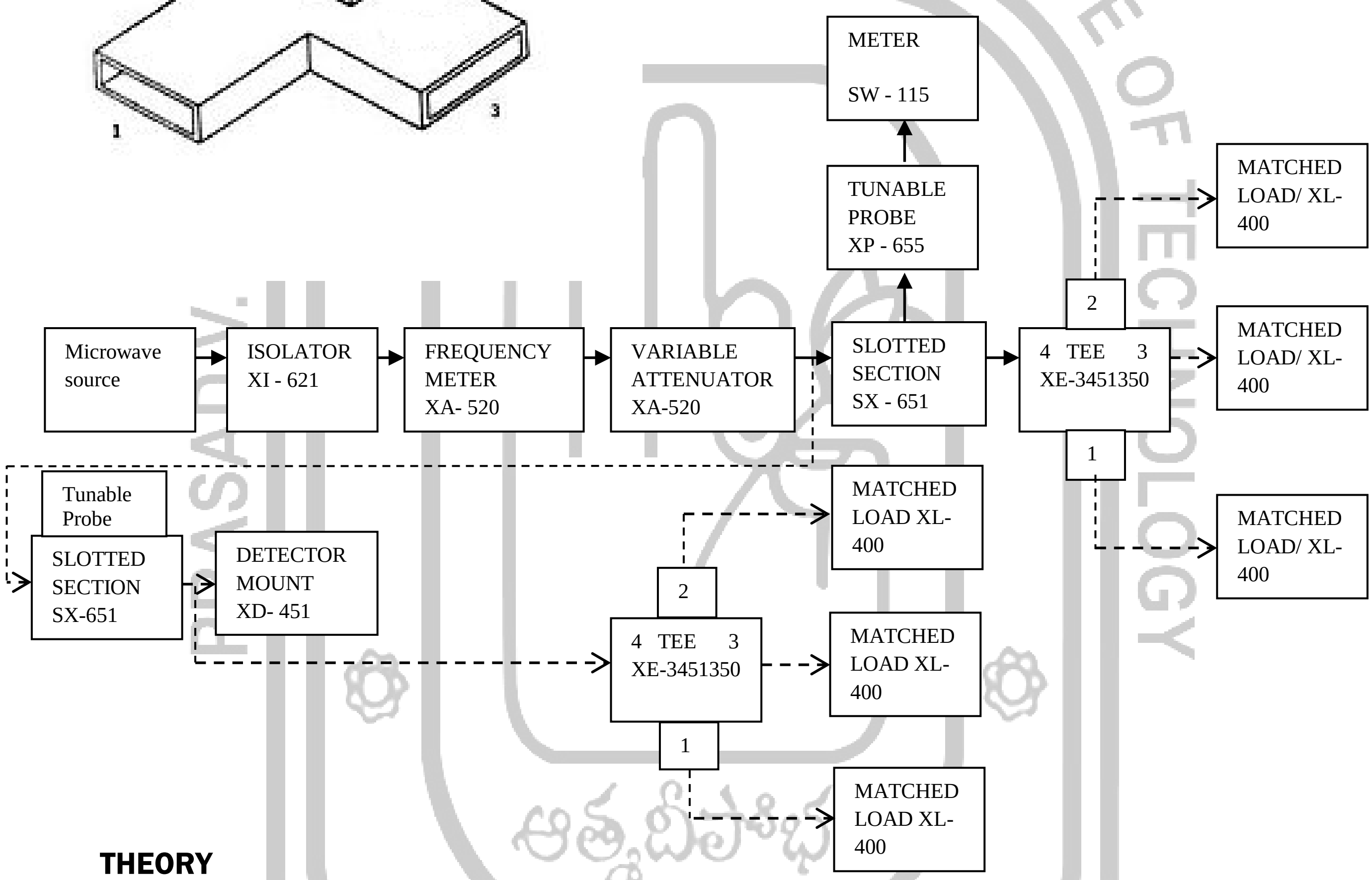
AIM To study the Magic TEE.

APPARATUS

Microwave source, Isolator, Variable attenuator, frequency meter, slotted line, tunable probe, magic tee, matched termination, waveguide stand, Detector mount, VSWR meter, BNC probes.

Magic TEE Diagram





THEORY

The device Magic Tee is a combination of E and H plane Tee. Arm 3 is the H-arm and arm 4 is the E-arm. If the power is spread into arm 3 the electric field divides equally between arms 1 and 2 with the same phase and no electric field exists in arm 4. If power is feed in arm 4 it divides into arm 1 and 2 but out of phase with no power to arm 3, further if the power is fed into arm 1 and 2 simultaneously it is added in arm 3 and subtracted in arm 4.

The basic parameters to be measured for magic Tee are defined as follows:

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

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 to the power detected at H- arm when side arms 1 and 2 terminate in matched load.

Isolation (dB) = $10 \log_{10} [p_4/p_3]$

Similarly isolation between other ports may also be defined.

Coupling Factor

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

Where α is attenuation / isolation in dB

When I is input and J is output arm

Thus $\alpha = 10 \log_{10}[p_4 / p_3]$

Where p_3 is the power delivered into arm 'I' and p_4 is power detected at 'J' arm.

PROCEDURE

VSWR measurement:

1. Set up the components and equipment as shown in fig above keeping E arm towards slotted line and matched termination to other ports.
2. Energize the microwave source for particular frequency of operation.
3. Measure the VSWR of the E arm as described in measurement of SWR for low and medium value.
4. Connect another arm to slotted line and terminate the other port with matched termination. Measure the VSWR as above. Similarly VSWR of any port can be measured.

Measurement of Isolation:

1. Remove the untunable probe and magic tee from the slotted line and connect the detector to mount slotted section.
2. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
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 section keeping H arm connected to slotted section detector to E arm and matched 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 $P3-P_4$ in dB.
6. Determine the coupling coefficient from equation given in the theory.
7. The same experiment may be repeated for other ports also.

OBSERVATIONS

VSWR =

Isolation (dB) = $10 \log_{10} [p_4 / p_3]$ =

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

$\alpha = 10 \log_{10} [p_4 / p_3]$ =

RESULT

CONCLUSION

PRECAUTIONS

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.
2. While modulating repeller should never become positive with respect to cavity.
3. Cooling should be provided to Reflex klystron.

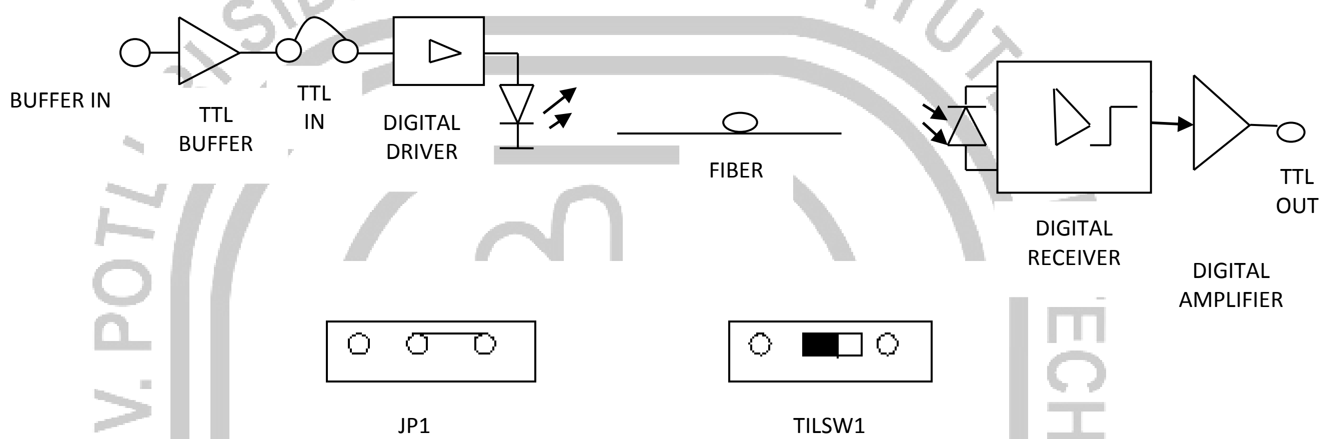
FIBER OPTIC DIGITAL LINK

AIM To study the fiber optic digital link with the help of 1310 nm laser diode.

APPARATUS

1. Fiber optic kit – E
2. Glass fiber cable
3. Patch cards
4. CRO
5. Signal generator
6. Power supply

STRUCTURE OF DIGITAL FIBER OPTIC COMMUNICATION SYSTEM



THEORY

The laser diode, fiber and detector can be configured for the digital applications to transmit binary data over fiber. The digital communication system is a suitable for transmission of TTL digital signals. The TTL signal modulates the intensity of light radiation emitted by the laser diode. In reception the fiber is connected to the photo detector which supplies the voltage output. There is a broad band amplifier and an interface which supplies TTL compatible signals.

PROCEDURE

1. Confirm that the power switch in OFF position and then connected to the kit.
2. Make the jumper settings and connections as shown in the fig.
3. Connect external signal generator to buffer in post of TTL buffer section and keep the signal generator in TTL mode and set the square wave frequency of about 1 MHz
4. Connect buffer out post to TTL in post of transmitter.
5. Switch on the power supply and signal generator.
6. Check the output signal of the TTL buffer at the post buffer out in kit. It should same as that of the applied input signal.
7. Connect the fiber between laser diode and detector as per the instructions. Observe the output signal at TTL outpost in receiver section on CRO and it should be the reproduction of the original transmitted signal.
8. Vary the frequency of the input signal and observe the output response. Observe the variation in duty cycle and determine the maximum bit rate that can be transmitted on the digital link.

OBSERVATIONS

1. Input wave form
2. Output wave form

RESULT

CONCLUSION

PRECAUTIONS

1. The laser diode emits radiation at 1310 nm which is invisible to the human eye and cause eye damage if the output beam is viewed directly.
2. When use never stare at the optical port of the laser diode when its dust cap is removed.