MADANAPALLE INSTITUTE OF TECHNOLOGY & SCIENCE

ANGALLU, MADANAPALLE – 517 325

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

MICROWAVE & OPTICAL COMMUNICATION LABORATORY MANUAL

IV – I B.Tech, ECE

2015-2016

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MICROWAVE AND OPTICAL COMMUNICATIONS LAB (9A04707)

Minimum Twelve Experiments to be conducted:

PART-A (Any 7 Experiments):

1. Reflex Klystron Characteristics.
2. Gunn Diode Characteristics.
3. Attenuation Measurement.
4. Directional Coupler Characteristics.
5. VSWR Measurement.
6. Impedance Measurement.
7. Waveguide parameters measurement.
8. Scattering parameters of Directional Coupler.
9. Scattering parameters of Magic Tee.

PART – B (Any 5 Experiments):

1. Characterization of LED.
2. Characterization of Laser Diode.
3. Measurement of Data rate for Digital Optical link.
4. Measurement of NA.
5. Measurement of losses for Analog Optical link.
6. Radiation Pattern Measurement of Antennas (at least two antennas).

Additional experiments:

1. Analog & Digital Optical link setup
2. Frequency Modulation and Demodulation using Fiber Optic links
3. Pulse Width Modulation and Demodulation using Fiber Optic links
4. Pulse Position Modulation and Demodulation using Fiber Optic links
5. Data Communication through Fiber Optic link using RS 232.
6. Measurement of Antenna Characteristics using XPO-ANT Antenna trainer.

Appendix-A

Equipment required for Laboratories:

1. Regulated Klystron Power Supply
2. VSWR Meter
3. Micro Ammeter
4. Multi meter
5. CRO
6. GUNN Power Supply, Pin Moderator
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)
23. Antenna Training System

DESCRIPTION OF MICROWAVE BENCH

Introduction:

The Measurement Techniques in Microwave frequencies is vastly different from that of the more conventional techniques. At Low Frequency, it is convenient to measure voltage and current and use them to calculate power. However at Microwave frequencies, they are difficult to measure since they vary with position in a transmission lines and hence they are of little value in determining power. Therefore at microwave frequencies, it is more desirable and simpler to measure power directly.

At microwave frequencies, quantities measured are relative and is not necessary to know their absolute values, i.e., it is sufficient to know the ratio of two power rather than exact input or output powers.

The parameter that can be conveniently measured at microwave frequencies are Frequency, Power, Attenuation, Voltage Standing Wave Ratio(VSWR), Phase, Impedance, Insertion Loss, Dielectric Constant Noise Factor.

Microwave Bench:

The general set up for measurement of any parameter in microwaves is called microwave test bench. The microwave test bench incorporates a range of instruments capable of allowing all types of measurements that are usually required for a microwave engineer. The bench is capable of being assembled or disassembled in a number of ways to suit individual experiments. A general block diagram of the test bench comprising of different components is shown below.

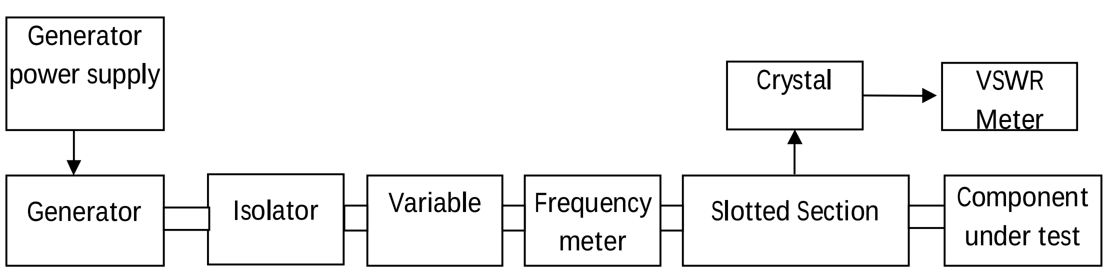


Fig.1. A typical Microwave bench setup

The lab is developed using components from the Scientific Instrument Company Limited. The specifications of the components given are according to SICO – Microwave products.

Klystron Power Supply:

Klystron Power Supply generates voltage required for driving the Reflex Klystron Tube 2k25. It is a stable, regulated and short circuit protected power supply. It has built in facility of square wave and saw tooth generators for amplitude and frequency modulation. The beam voltage range from 200V to 450V with maximum beam current, 50 mA. The provision is given to vary repeller voltage continuously from 270V DC to – 10V.

Gunn Power Supply:

Gunn Power Supply comprises of an electronically regulated power supply and a square wave generator designed to operate the Gunn oscillator and Pin Modulator. The supply voltage ranges from 0 to 12 V with a maximum current, 1A.

Reflex Klystron Oscillator:

At high frequencies, the performance of a conventional vacuum tube is impaired due to transit time effects, lead inductance and inter- electrode capacitance. Klystron is a microwave vacuum tube employing velocity modulation and transit time in achieving its normal operation. The reflex type, known as reflex Klystron, has been most used source of microwave power in Laboratory. It consists of an electron gun producing a collimated electron beam. The electron beam is accelerated towards the reflector by a dc voltage V_0, while passing through the positive resonator grids. The velocity of the electrons in the beam will be

$$V_{po} = \sqrt{\frac{2eV_o}{m}}$$

Where e and m being electronic charge and mass respectively.

The repeller, which is placed at a short distance from the resonator grids, is kept at negative potential with respect to cathode, and consequently it retards and finally reflects the electrons which then turn back through the resonator grids.

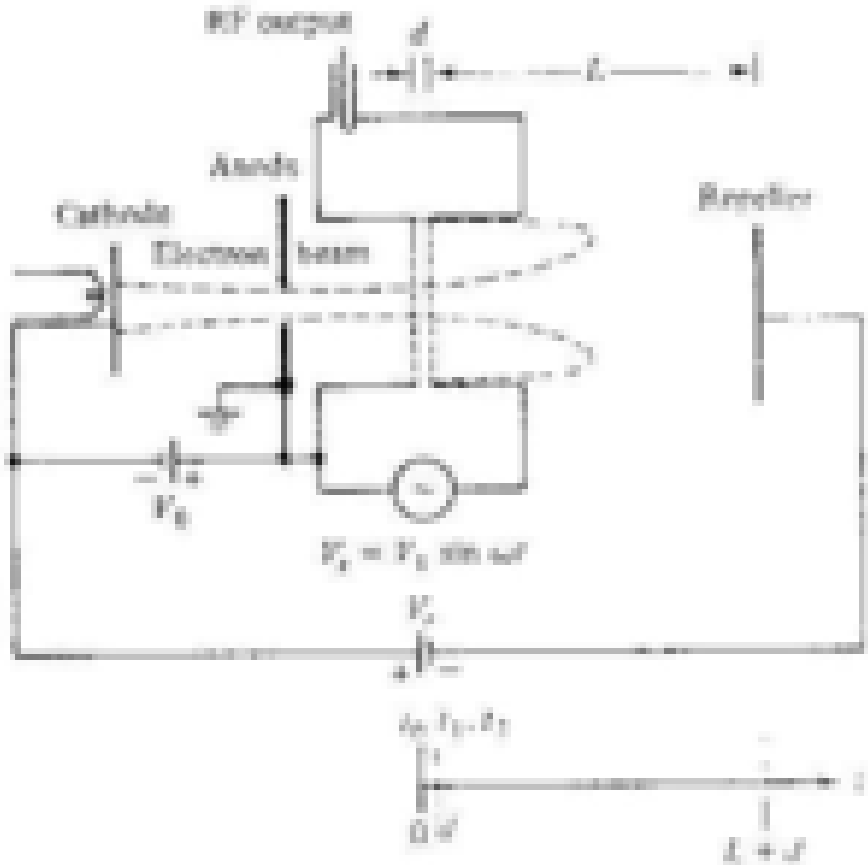


Fig. 2. Reflex Klystron Oscillator

<u>Basic Theory of Operation:</u>

To understand the operation of this device, assume that the resonator cavity is oscillating slightly, causing an ac potential, say V_1 sin wt in addition to V_o, to appear across the cavity grids. These initial oscillations could be caused by any small disturbance in the electron beam. In the presence of the RF fields, the electrons that traverse towards the repeller will acquire the velocity.

$$v = Vo\left\{1 + \frac{V_1}{V_o}\sin wt\right\}^{1/2}$$

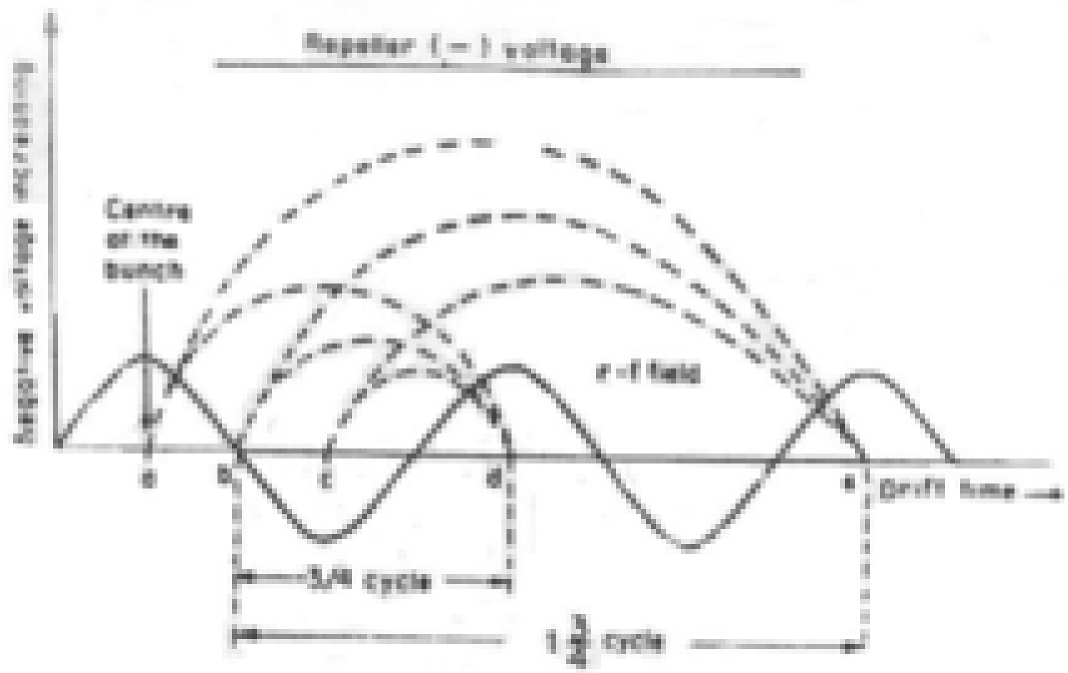


Fig. 3: Bunching process in Reflex Klystron

Thus we have a velocity modulated beam traveling towards the repeller, having velocities between $V_0\sqrt{1+\frac{V_1}{V_o}}$ and $V_0\sqrt{1-\frac{V_1}{V_o}}$ i.e., electrons leaving the cavity during the positive half-cycle are accelerated while electrons leaving the cavity during negative half cycle are decelerated. Obviously, the electrons traversing towards the repeller with increased velocity, i.e., faster ones, shall penetrate farther into the region of the repeller field (called drift space) as compared to the electrons traversing towards the repeller with decreased velocity, i.e., slower ones. But the faster electrons, leaving the cavity take longer time to return to the cavity than slower ones. Therefore the faster electrons catch up with slow ones. As a result the resulting electrons group together in bunches. The bunching action is shown in fig. 3. As the electron bunches cross the cavity, they interact with the voltage between the cavity grids. If the bunches pass through the grids at the time when the grid potential is such that the electrons are severally decelerated, the decelerated electrons give up their energy and this energy reinforces oscillations within the cavity. Hence under these conditions, sustained oscillations are possible. The electrons having spent much of their energy are then collected by the positive cavity wall near the cathode. Thus, it is clear that in its normal operation the repeller electrode does not carry any current and indeed this electrode can severely be damaged by bombardment. To protect the repelled from such damage, the repeller voltage V_R is always applied before the accelerating voltage V_0.

Power Frequency Characteristics:

The cavities used in reflex klystrons do not have infinite Q, as such each mode of operation will be spread over a narrow range of repeller voltages, Fig 4 shows the variation of frequency and power output versus repeller voltages along with mode number. It should, however, be noted that repeller voltage-mode number correspondence is valid only at the center of mode (maximum power) of operation. That is, the repeller voltage needed for calculations should be measured only at the peak (top) of the mode. The variation in repeller voltage from the peak of the modes causes change in transit time as a result the bunch is either not properly formed or starts debuching, thereby decreasing power and also a slight change in frequency observed

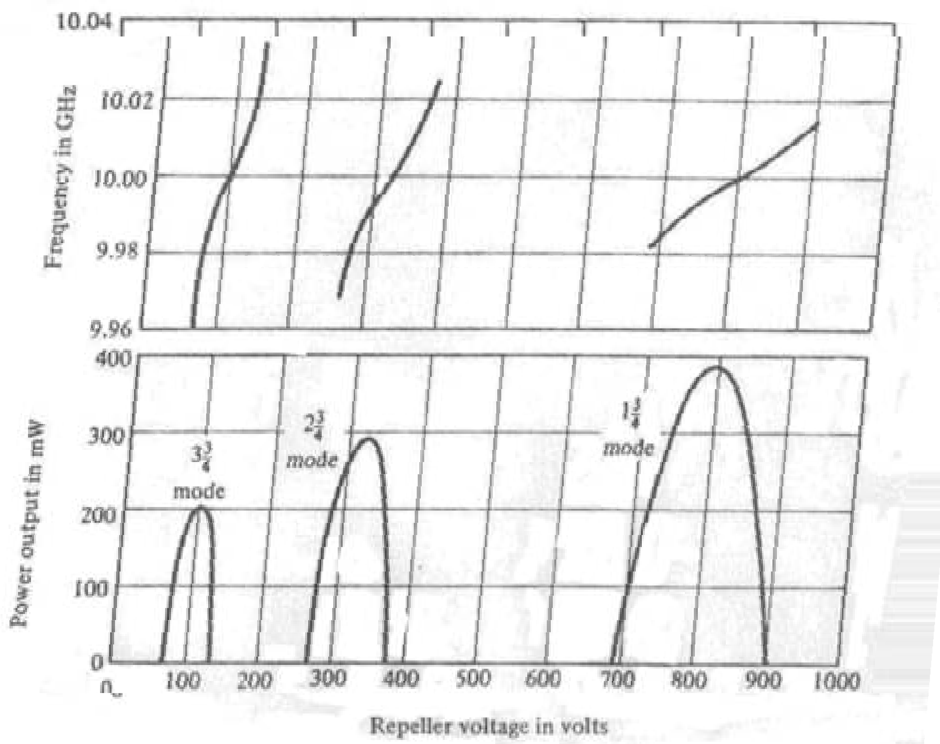


Fig .4: shows the variation of Frequency and Power output versus Repeller voltages along with mode number

Gunn Oscillator:

Gunn oscillator utilizes Gunn diode which works on the principle that when a d.c. voltage is applied across a sample of n type Gallium Arsnide (GaAs), the current oscillates at microwave frequencies. This does not need high voltage as it is necessary for Klystrons and therefore solid state oscillators are now finding wide applications. Normally, they are capable of delivering 0.5 watt at 10GHz, but as the frequency of operation is increased the microwave output power gets considerably reduced.

Gunn oscillators can also be used as modulated microwave sources. The modulation is generally provided by means of a PIN diode. PIN diode is a device whose resistance varies with the bias applied to it. When wave guide line is shunted with PIN

Diode and the diode is biased positively, it presents very high impedance thereby not affecting the line appreciably. However, it is negatively biased it offers a very low pedance, almost short-circuit thereby reflecting the microwave power incident on it. As impedance varies with bias, the signal is amplitude modulated as the bias varies. Since heavy power is reflected during negative biasing of PIN diode, so an isolator or an attenuator should invariably be used to isolate PIN diode avoid overloading of the latter.

Isolator:

Isolator is a two port device. This device permits untenanted transmission in one direction (forward direction) but provides very high attenuation in the reverse direction (backward direction). This is generally used in between the source and rest of the set up to avoid overloading of the source due to reflected power.

Variable Attenuator:

Attenuator is two port device. The device that attenuates the signal is termed as attenuator. Attenuators are categorized into two categories, namely, the fixed attenuators and variable attenuators. The attenuator used in the microwave set up is of variable type.

The variable attenuator consists of a strip of absorbing material which is arranged in such a way that its profusion into the guide is adjustable. Hence, the signal power to be fed to the microwave set up can be set at the desired level. This type of attenuator is called flap attenuator.

Frequency Meter:

Frequency meter is basically a absorption cavity resonator. The cavity is connected to a waveguide having been excited by a certain microwave source. The Cavity can be made to resonate at source frequency by adjusting its size by rotating the dial of frequency meter. At resonant frequency it sucks up some signal from the guide to maintain its stored energy. Thus if a power meter had been monitoring the signal power at resonating condition of the cavity it will indicate a sharp dip. The frequency can be read from the scale of direct reading frequency meter. If it is indirect reading frequency meter tuning can be achieved by a micrometer screw. The frequency can be obtained by using calibrating chart.

Slotted Section:

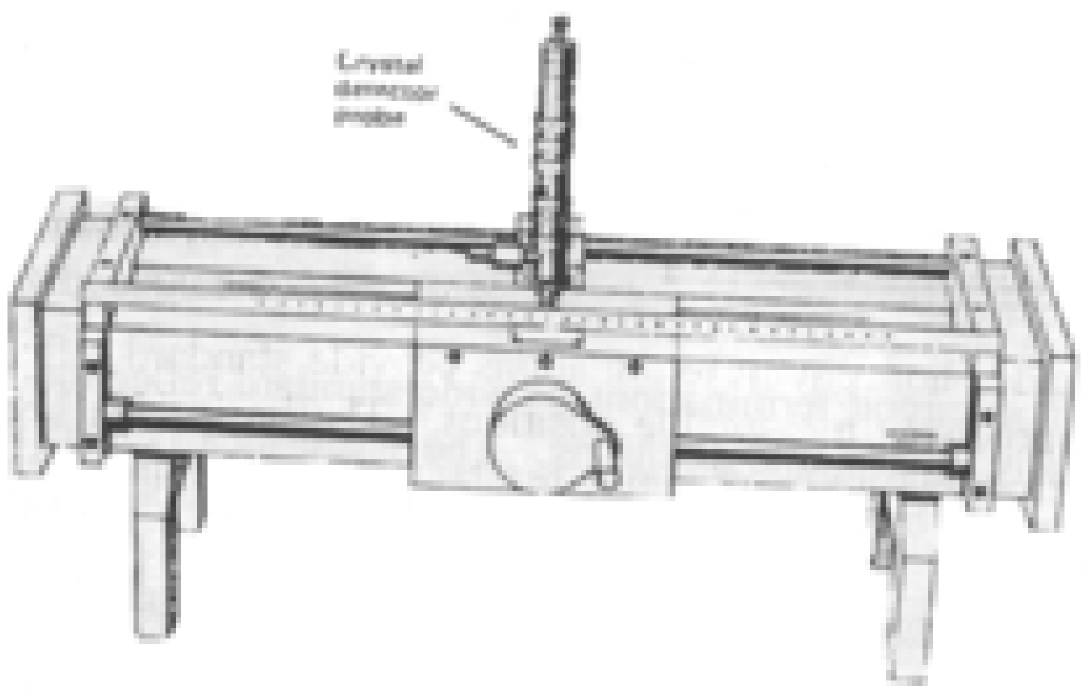


Fig.5: Slotted Section with Probe Carriage

To sample the field with in a wave guide, a narrow longitudinal slot with ends tapered to provide smoother impedance transformation and thereby providing minimum mismatch, is milled in the center of the top of broader dimension of the wave guide. Such section is known as slotted wave guide section. The slot is generally so many wave length long to allow many minimum of standing wave pattern to be covered. The slot location is such that its presence does not influence the field configurations to any great degree. A probe is inserted through the slot senses the relative field strength of the standing wave pattern inside the waveguide. The probe is placed on a carriage plate which can be moved

Along the waveguide. The probe is connected to a crystal detector and the output is connected to indicating meter. For detector tuning a tuning plunger is provided instead of a stub

Crystal Detector:

The simplest and the most sensitive detecting element is a microwave crystal Diode. It is a nonlinear, nonreciprocal device which rectifies the received signal and produces, a current proportional to the power input. Since the current flowing through the crystal is proportional to the square law detection property of a crystal is valid at a low power levels (<10 mw). However, at high and medium power level (>10mw), the crystal gradually becomes a linear detector.

Detector Mount is used for detection in which Crystal Detector is shunted in waveguide.

VSWR meter:

Direct-reading VSWR meter is a low-noise voltage tuned amplifier calibrated in dB and VSWR for use with square law detectors. A typical SWR meter has a standard tuned frequency of 1 KHz at which the microwave signal is modulated. Clearly the source of power to be used while using SWR meter must be giving us a 1 KHz square wave modulated output. The band width facilitates single frequency measurements by reducing noise while the widest setting accommodates a sweep rate fast enough for oscilloscope presentation.

The scale of VSWR meter is calibrated in VSWR and VSWR in dB. It has two normal and one expanded scale. In first normal scale VSWR from 1-3 can be measured and in second normal scale VSWR from 3 to 10 can be measured. To measure low VSWR(less than 1.3) expanded scale is used. The dB scale is present along with expanded dB scale. Using knob on the front panel chooses the normal scale or expanded scale.

Using the knobs on the front panel can change the gain in VSWR meter. Two knobs are present for changing gain from 0 to 10 dB. Gain can also be changed by 0 to 10 dB in steps of 10 dB using another knob. While measuring VSWR, gain should be either 50 or 60 dB. for accurate measurement of VSWR.

Both crystal and bolometer may be used in conjunction with the SWR meter. There is provision for high (2,500 – 10,000 ohm) and low (50-200 ohm) impedance crystal inputs. Input selector Switch is used to select the crystal or bolometer.

This instrument is the basic piece of equipment in microwave measuring techniques and is used in measuring voltage peaks, valleys, attenuation, gain and other parameter determined by the ratio of two signals.

Microwave Components:

Wave Guides:

A wave guide is a hollow metallic tube of a rectangular or circular cross section used to guide an electromagnetic wave. Wave guides are used principally at microwave frequencies. In laboratories x band (8 to 12 GHz) range of frequencies are used. Therefore a standard x band Rectangular wave guides are used having an inner width, 0.4 in and an inner length, 0.9 in.

In wave guides the electric & magnetic fields are confined to the space within the guides. Thus no power is lost through radiation, and even the dielectric loss is negligible, since the guides are normally air filled. However, there is some power loss as heat in the walls of the guides.

It is possible to propagate several modes of Electromagnetic waves within a wave guide. A given wave-guide has a definite cutoff frequency for each allowed mode and behaves as a high pass filter. The dominant mode in rectangular wave guides is TE_{10} mode. It is advisable to choose the dimensions of a guide in such a way that, for a given input signal only the energy of the dominant mode can be transmitted through the guide.

The cut off frequency for mn^{th} mode

$$f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

The corresponding cut off wave length λ_C

$$\lambda_c = \frac{c}{f_c} = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}$$

Where C is velocity of light.

a is inner broader dimension of wave guide.

b is inner narrow dimension of wave guide

mn indicates mode number.

The guide wave length λ_g related to free space wave length λ_0 & cut off wave length λ_C by

$$\frac{1}{\lambda_o} = \frac{1}{\lambda_g} + \frac{1}{\lambda_c}$$

<u>Tees:</u>

Wave guide junctions are used to split the line with proper consideration of the phase. The junctions that are widely encountered in microwave techniques are E – plane, H – plane and Magic Tees.

An E-plane tee is obtained by fastening a piece of a similar wave guide to the broader wall of the main waveguide section. The fastened wave guide, also known as series arm is parallel to the plane of the electric field of the dominant TE10 mode in the main waveguide.

An H-plane tee is obtained by fastening a piece of a similar wave guide perpendicular to the narrow wall of the main waveguide section. The fastened wave guide, also known as shunt arm should lie in the H plane of the dominant TE_{10} mode in the main waveguide.

Magic Tee is a combination of the E- plane tee and H plane tee. It has certain characteristics listed below.

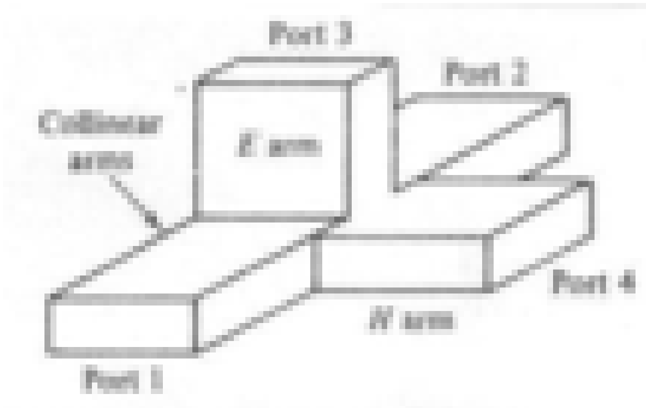


Fig.6:Magic Tee

1. If two waves of equal magnitude and the same phase are fed into port 1 and port 2, the output will be zero at E – arm and additive at H – arm.
2. If a wave is fed into H – arm, it will be divided equally between port 1 & port 2 of the collinear arms and will not appear at E – arm.
3. If a wave is fed into E – arm, it will produce an output of equal magnitude and opposite phase at port – 1 and port 2. The output at H – arm is zero.
4. If a wave is fed into one of the collinear arms at port 1 or port 2, it will not appear in the other collinear arm at port 2 or 1, appears at because E – arm causes a phase delay while the H – arm causes a phase advance

The Magic Tee can be used as:

1. In impedance bridge
2. As antenna duplexer
3. As Mixer
4. As modular, etc.

<u>Directional coupler:</u>

Directional coupler is a 4 port wave guide junction. It consists of a primary waveguide and a secondary waveguide connects together through apertures. These are unit directional coupler are required to satisfy (1) reciprocity 2) conservation of energy 3) all ports matched terminated.

For ideal Directional coupler input given in port1 is fed to port 2 and 3and not to port 4.

The characteristics of a directional coupler can be expressed in terms of its

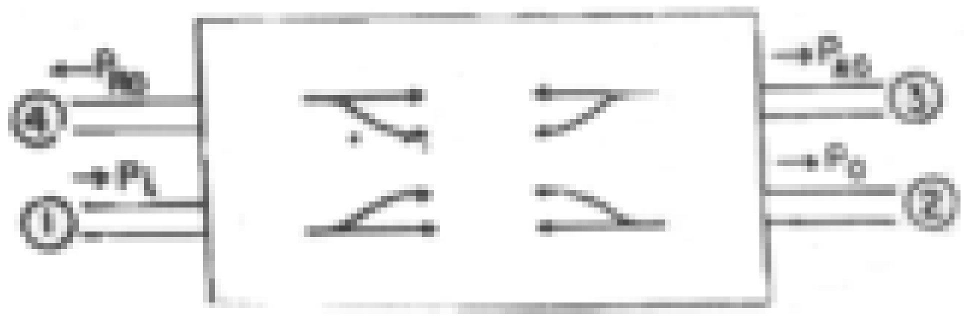


Fig.7: Directional Coupler

1) **Coupling factor:** The ratio, in decibels, of the power incident and the power coupled in auxiliary arm in forward direction.

$$C = 10\log_{10}\left(\frac{P_i}{P_f}\right) \text{ dB}$$

2) **Directivity**: The ratio expressed in decibels, of the power coupled in the forward direction to the power coupled in the backward direction of the auxiliary arm with un used terminals matched terminated.

$$D = 10\log_{10}\left(\frac{P_f}{P_b}\right) \text{ dB}$$

3) **Insertion loss**: The Ratio, expressed in decibels, of the power incident to the transmitted in the main line of the coupler when auxiliary arms are matched terminated.

$$L = 10\log_{10}\left(\frac{P_i}{P_t}\right) \text{ dB}$$

4) **Isolation**: The ratio, expressed in decibels, of the power incident in the main arm to the backward power coupled in the auxiliary arm, with other ports matched terminated.

$$I = 10\log_{10}\left(\frac{P_i}{P_b}\right) \text{ dB}$$

For ideal Directional coupler D and I are Infinite while C and L are zero.

The scattering matrix of directional coupler is

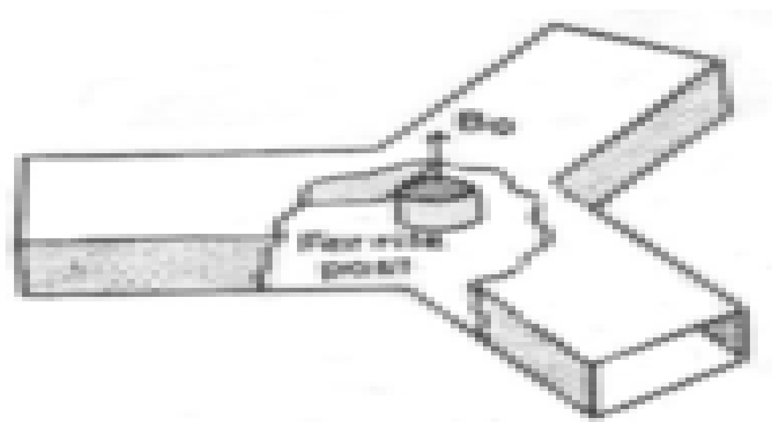
$$[S] = \begin{bmatrix} 0 & p & 0 & jq \\ p & 0 & jq & 0 \\ 0 & jq & 0 & p \\ jq & 0 & p & 0 \end{bmatrix}$$

Several types of directional couplers exist, such as a two-hole directional coupler, Schwinger directional coupler and Beth-hole directional coupler. Directional couplers are very good power samplers

Circulator:

A circulator is a passive microwave component which allows complete transmission from n to (n+1) port. Circulator can be constructed with the help of Magic Tees & gyrator or directional coupler with phase shifter or using ferrite material and so on.

A ferrite type circulator employs ferrite material at the center of the junction. This ferrite post will be magnetized normal to the plane of the junction. Electromagnetic wave, which propagates through the ferrite material, undergoes phase change during its transverse. The phase change is dependent upon the intensity of the magnetic bias and the length of the ferrite rod. The bias & dimensions of the ferrite are so chosen, such that the waves move unidirectional from n to (n+1) port.



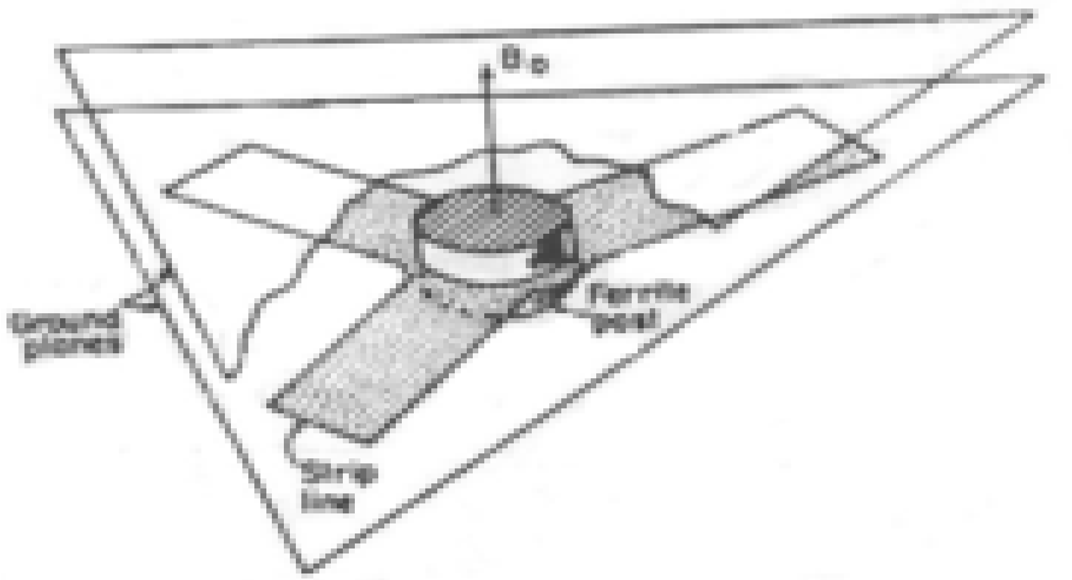


Fig.8: Three Port Circulators

The characteristics of the circulator:

1) **Insertions loss**: The ratio of power input at port n to the power detected at port n+1.

$$L = 10\log_{10}\left(\frac{P_n}{P_{n+1}}\right) \text{dB}$$

2) **Isolation:** The ratio of power at port n to the power detected at port n-1.

$$I = 10\log_{10}\left(\frac{P_n}{P_{n-1}}\right) \text{dB}$$

3) **Cross coupling**: The ratio of power input at port n to the power at any other port.

$$C_{13} = 10\log_{10}\left(\frac{P_1}{P_3}\right) \text{dB}$$

The scattering matrix of a three port circulator is

$$[S] = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

Circulators can be used as de coupling isolators and as duplexer.

PRECAUTIONS TO BE TAKEN IN MICROWAVE LAB

1. During operation of Klystron, Repeller should not carry any current. Therefore Negative voltage is always applied before applying the anode voltage. Otherwise, Repeller will be damaged if electrons are bombarded on the repeller.
2. While measuring power output, the frequency meter should be detuned.
3. To avoid loading of the Klystron, an Isolator should be connected between klystron and the rest of the set up.
4. Do not look into the wave guides during operation because microwave energy emanating out of the wave guide can damage the retina.
5. To have good accuracy the power level should be around 40 or 50 dB in the VSWR meter.

BEFORE SWITCHING 'ON' THE KLYSTRON POWER SUPPLY

Keep the beam voltage knob to fully anti clockwise and the repeller voltage knob to fully clockwise.

ENERGIZING / FIRING OF THE REFLEX KLYSTRON

1. Set cooling fan to blow air across the tube and turn on the filament voltage and wait for few minutes for the filament to get heated up.
2. Set the attenuator to a suitable level say 3 dB
3. Keep the modulation knob in AM position if the indicating meter is CRO or VSWR.
4. Apply the beam say 200 volts to obtain electron beam.
5. Adjust the repeller voltage to have maximum output in the indicating meter.
6. If needle goes out of scale in the VSWR meter, adjust the attenuation to get suitable power level.
7. Adjust the klystron mounting plunger for maximum output and repeat step 6 if desired.
8. Adjust the amplitude & frequency of AM to get a maximum output in indicating meter.

ENERGIZING GUNN DIODE

1. Before switching on the device keep the pin bias maximum ie , fully clockwise and Gunn bias minimum ie, fully anticlockwise.
2. Switch on the supply.
3. Do not increase Gunn bias voltage above 6V.
4. Keep the pin bias fully clock wise.
5. Connect the output of detector to CRO.
6. Adjust the tuning plunger of Gunn diode until a proper square wave is obtained in the CRO.
7. Calculate the frequency using direct reading frequency meter.

Experiment-1

STUDY OF REFLEX KLYSTON CHARACTERISTICS

Objective: To study the characteristics of the Reflex Klystron tube.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM 25)
3. Isolator (XI -621)
4. Frequency Meter (XF- 710)
5. Variable Attenuator (XA 520)
6. Detector Mount (XD-451)
7. Wave Guide Stand (XU-535
8. VSWR Meter (SW-115)
9. Oscilloscope

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.

Experimental set up:

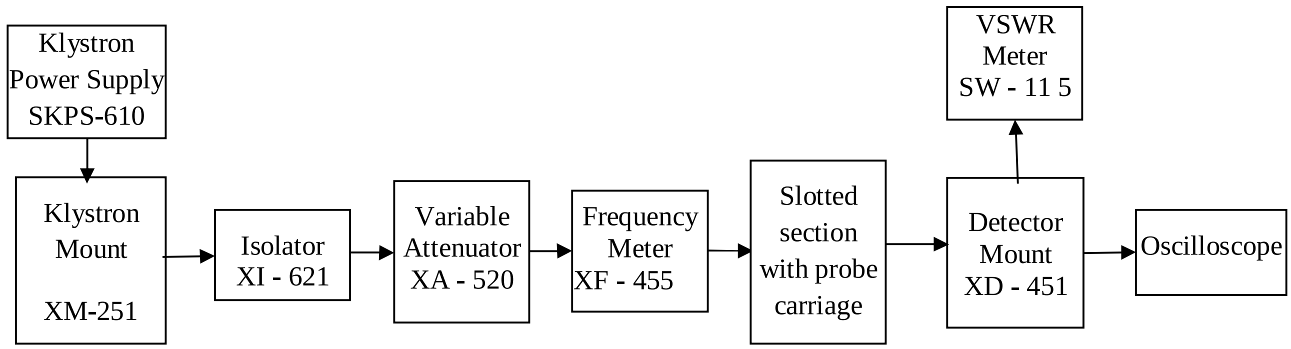


Fig.1.1 Experimental Set up to study characteristics of Klystron tube

Model Graph:

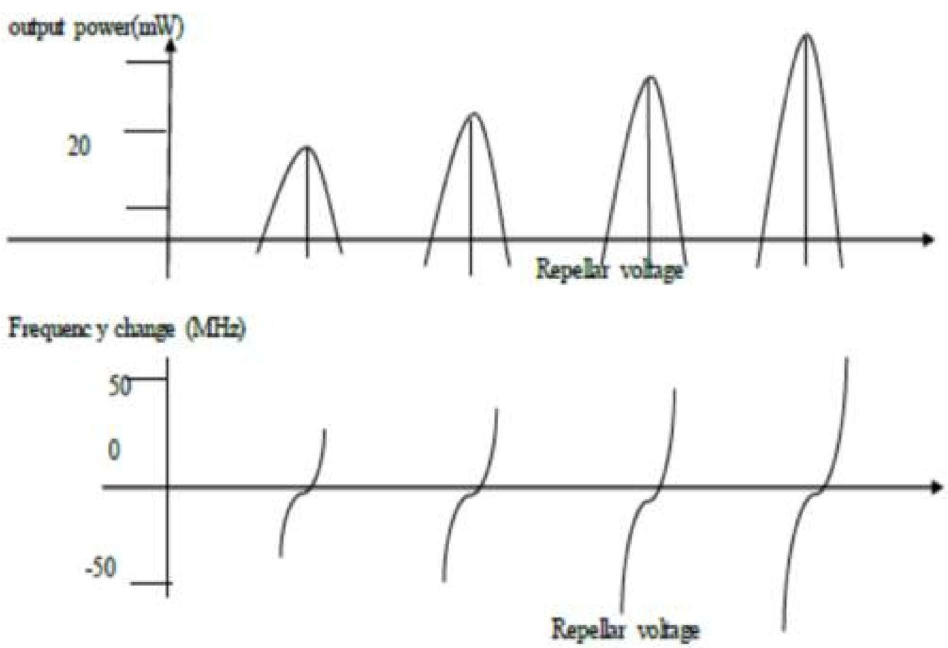


Fig.1.2 Characteristics of Klystron tube

Procedure:

Mode Study on Oscilloscope:

1. Set up the equipments as shown in Fig.1.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of VSWR meter as below:

Range db	------	40db/50db
Input Switch	------	Impedance Low
Meter Switch	------	Normal
Gain (Coarse-Fine)	------	Mid position approximately

4. Keep the Control knobs of Klystron Power Supply as below:

Meter Switch	------	OFF
Mod Switch	------	'FM'
Beam Voltage Knob	------	Fully Anti-Clockwise
Reflector Voltage Knob	------	Fully Clockwise
AM Frequency and Amplitude knob	------	Mid position approximately

5. 'ON' the Klystron Power Supply, VSWR Meter and Cooling Fan.
6. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.
7. Set mode selector switch to FM-MOD position, FM amplitude and FM frequency knob at mid position, keep Beam voltage knob fully anti-clock wise and Reflector voltage knob to fully clock wise and Beam switch to OFF position.
8. Keep amplitude knob of FM modulator to maximum position and rotate the reflector voltage anti-clock wise to get modes as shown in Fig.1.2, on the oscilloscope. The horizontal axis represents reflector voltage axis and vertical represents output power.
9. By changing the Reflector voltage and amplitude of FM modulation, any mode of Klystron tube can be seen on oscilloscope.
10. At each of the above steps measure the frequency by tuning the direct reading Frequency meter to have dip in the observed wave in CRO, and plot the graph Frequency Vs Repeller voltage to get mode curves, as shown in Fig.1.2.
11. The frequency meter should be detuned each time after measuring frequency.

Observations:

Table 1.1 Tabular column to note down the different mode values:

MODE	Repeller Voltage (V)	Beam Current (mA)	Output Voltage (Vpp)	Frequency (GHz)
MODE 1				
MODE 2				
MODE 3				

Result:

Model Viva Questions:

1. Define velocity modulation?
2. Define density modulation?
3. Discuss various applications of reflex klystron.
4. Give the efficiency of reflex klystron?
5. Define electronic tuning range?
6. What is the difference between mechanical tuning and electronic tuning?
7. Reflex klystron consists of how many cavities?
8. What are the advantages of reflex klystron over two-cavity klystron?
9. In Reflex klystron how can you change the frequency of operation?
10. What is the range output power?
11. In Reflex klystron which mode has highest power?
12. Why first mode is not used in a reflex klystron?
13. What is mechanical tuning with reference to reflex klystron?
14. What is electronic tuning with reference to reflex klystron?
15. How can you change the frequency in a reflex klystron?
16. Give the difference between reflex klystron and multi cavity klystron?
17. In slotted section through the slot in the upper broad wall, how much power escapes?
18. How can you change a microwave reflex klystron to millimeter wave reflex klystron?
19. In the microwave bench a nonlinear detector is needed or not? Justify your answer?
20. Why three port Isolator is used in the microwave bench?

Experiment-2

STUDY OF I-V CHARACTERISTICS OF GUNN DIODE

Objective: To study the I-V Characteristics of Gunn diode.

Equipment Required:

1. Gunn Power Supply-GS-610
2. Gunn Oscillator XG-11
3. Isolator XI -621
4. Frequency Meter XF- 710
5. PIN Modulator XM-55
6. BNC Cables.

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.

Experimental set up:

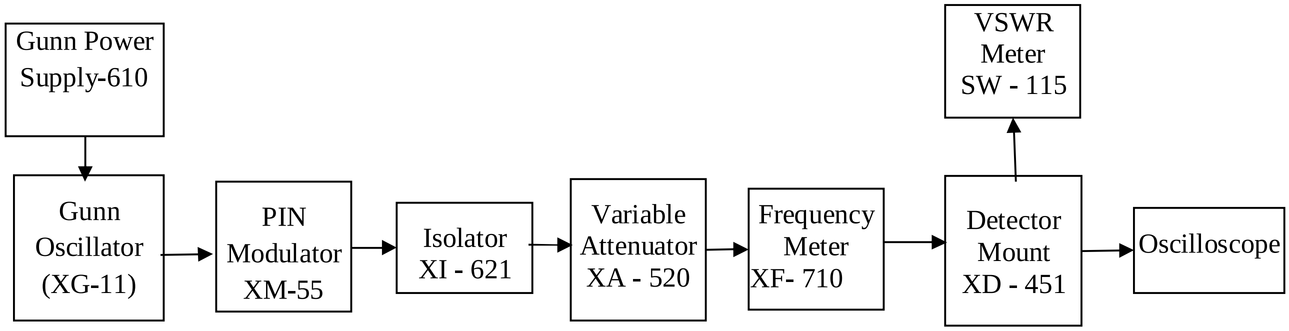


Fig.2.1 Experimental setup to Study I-V characteristics of Gunn diode

Model Graph:

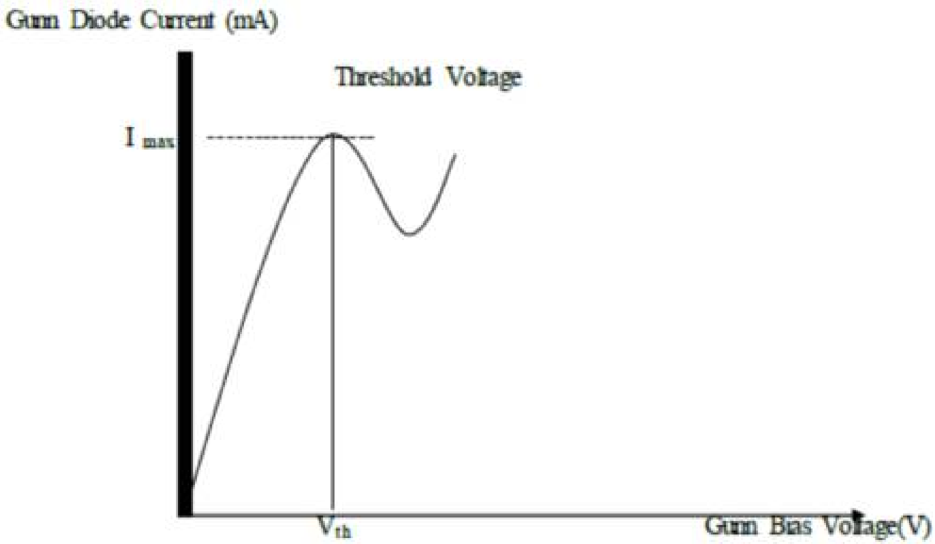


Fig.2.2 I-V characteristics of Gunn diode

Procedure:

1. Set up the equipment as shown in Fig.2.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of VSWR meter as below:

   Range db Switch ------ 40db/50db

   Input Switch ------ Impedance Low

   Meter Switch ------ Normal

   Gain Control Knob ------ Fully Clockwise
4. Keep the Control knobs of Gunn Power Supply as below:

   Meter Switch ------ OFF

   Gunn Bias Knob ------ Fully Anti-Clockwise

Pin Bias Knob	------	Fully Anti-Clockwise
Pin Mod Frequency	------	Any Position

5. ‘ON’ the Gunn Power Supply, VSWR Meter and Cooling Fan.
6. Vary the Gunn bias voltage and note down the corresponding Current values.
7. Do not exceed the bias voltage above 6 Volts.
8. Plot the Voltage and Current reading on the graph.
9. Measure the Threshold voltage which corresponds to maximum current.

Observations:

Table 2.1 Tabular column to note down the voltage and current values:

S.NO	Gunn Bias Voltage(Volts)	Gunn Diode Current(mA)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

Threshold Voltage V_{th} =_____V

***NOTE*:**

Do not keep Gunn bias knob position at threshold position for more than 10 seconds reading should be obtained as fast as possible otherwise excessive heating, Gunn diode may burn.

Result:

Model Viva Questions:

1. Define T.E.D?
2. Write the features of Gunn diode?
3. What are the specifications of Gunn diode?
4. Write the applications of Gunn diode.
5. List the advantages of Gunn diode.
6. List the disadvantages of Gunn diode.
7. Give the precaution to be taken while working with Gunn diode?
8. Who is discovered the Gunn diode.
9. Give the definition of Gunn Effect in the words of J.B.Gunn?
10. Which type semiconductor material is used for manufacture of Gunn diode?
11. What is –ve resistance region? Give its significance?
12. Name the different modes of oscillation in Gunn diode?
13. What is Quenched mode?
14. What are the requirements for a semiconductor material to make transfer electron effect?
15. In a Gunn diode when applied voltage is greater than threshold ——— formation takes place.
16. The field associated with the domain is greater than the other regions in the specimen. Justify?
17. What is two valley theory?
18. Name other devices which exhibit –ve resistance property?
19. What is the difference between +ve resistance & –ve resistance devices?
20. Give the application of Gunn diodes in electronic steering antennas?

Experiment-3

ATTENUATION MEASUREMENT

Objective: To measure the attenuation of the Attenuator

Equipment Required:

1. Microwave source
   a. Gunn oscillator - XG-11 (or)
   b. Klystron Tube - 2K25
2. Isolator - X1-21
3. Frequency meter - XF-710
4. Variable Attenuator - XA-520
5. Slotted line - XS-651
6. Tunable probe - XP-655
7. Detector mount - XD-451
8. Matched Termination - XL-400
9. Test attenuator - Variable Attenuator
10. Gunn Power Supply PIN Modulator/Klystron Power Supply + Klystron Mount.
11. Cooling Fan.
12. BNC- BNC cable.

Theory:

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

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 center in TE_{10} mode, the attenuation will be maximum if the vane is placed at center of the waveguide. Moving from center towards the side wall attenuation decreases in the fixed attenuator the vane position is fixed where as in variable attenuator; its position can be changed by the help of micro meter of by other methods.

Experimental set up:

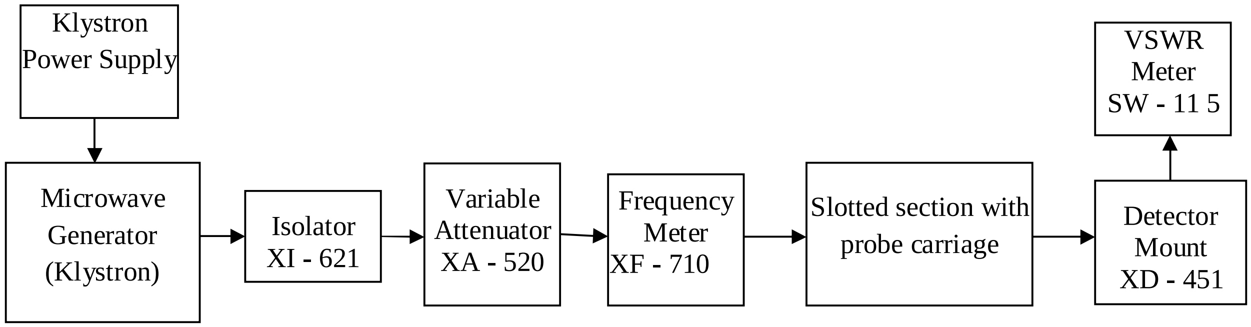


Fig.3.1 Experimental setup to obtain Insertion loss and Attenuation measurement

Model Graph:

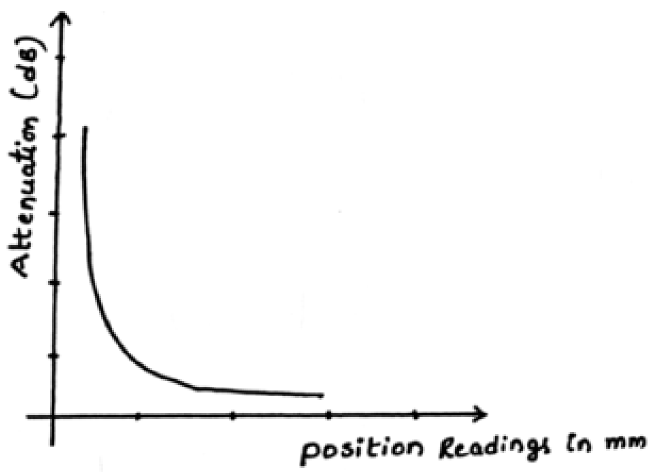


Fig.3.2.Graph for Variable Attenuator Measurement

Procedure:

Insertion Loss/Attenuation Measurement:

1. Set up the equipments as shown in Fig.3.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of VSWR meter as below:

Range dB	------	40dB/50dB
Input Switch	------	Impedance Low
Meter Switch	------	Normal
Gain (Coarse-Fine)	------	Mid position approximately

4. Keep the Control knobs of Klystron Power Supply as below:

Meter Switch	------	OFF
Mod Switch	------	'AM'
Beam Voltage Knob	------	Fully Anti-Clockwise
Reflector Voltage Knob	------	Fully Clockwise
AM Frequency and Amplitude knob	------	Mid position approximately

5. 'ON' the Klystron Power Supply, VSWR Meter and Cooling Fan.
6. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.
7. Set any reference power level on the VSWR meter with the help of gain control knob of VSWR meter. Let it be P_1.
8. Introduce the highly dissipative flap by rotating the precision variable attenuator knob into the waveguide.
9. Note down the power value in VSWR meter at different positions of the precision variable attenuator knob (say it as P_2).

Observations:

For Variable Attenuation Measurement: Power without attenuator P1 = ____ dB

Table 3.1 Tabular column to note down the Variable Attenuation values:

S.NO	Position on Variable Attenuator (mm)	Output Power (P2) dB	Attenuation (P1-P2) dB
1			
2			
3			
4			
5			
6			
7			
8			

Result:

Model Viva Questions:

1. Define attenuation?
2. List the different types of attenuators.
3. On which parameters the attenuation of EM waves in free space depends?
4. What are the units of attenuation constant?
5. What is the principle behind variable attenuator with and without ferrite rod?
6. As the number of passive devices increases in a microwave circuit the VSWR increases or decreases? Justify your answer?
7. Give one practical application where variable attenuator is needed?
8. What is the difference between attenuation and absorption?
9. Differentiate vane and flap type attenuators?
10. If the input power is 350mW and out power of an attenuator is 300mW. Calculate attenuation?

Experiment-4

DIRECTIONAL COUPLER CHARACTERISTICS

Objective: To study the characteristics of Multi Hole Directional (MHD) coupler.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM-25),
3. Isolator (XI -621), Frequency Meter (XF- 710),
4. Variable Attenuator (XA-520),
5. Slotted line (XS 565),
6. Tunable probe (XP-655),
7. Detector Mount (XD-451),
8. Wave Guide Stand (XU-535),
9. VSWR Meter (SW-115),
10. MHD (Multi Hole Directional) Coupler,
11. Matched Terminations (XL 400),
12. BNC -BNC Cable.

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.4.1 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) $= 10 \log_{10} \frac{P_1}{P_3}$; where port 2 is terminated.

Isolation (dB) = $10\log_{10}\frac{P_2}{P_3}$; where P_1 is matched terminated 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 = $10\log_{10}\frac{P_2}{P_1}$

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

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

Experimental set up:

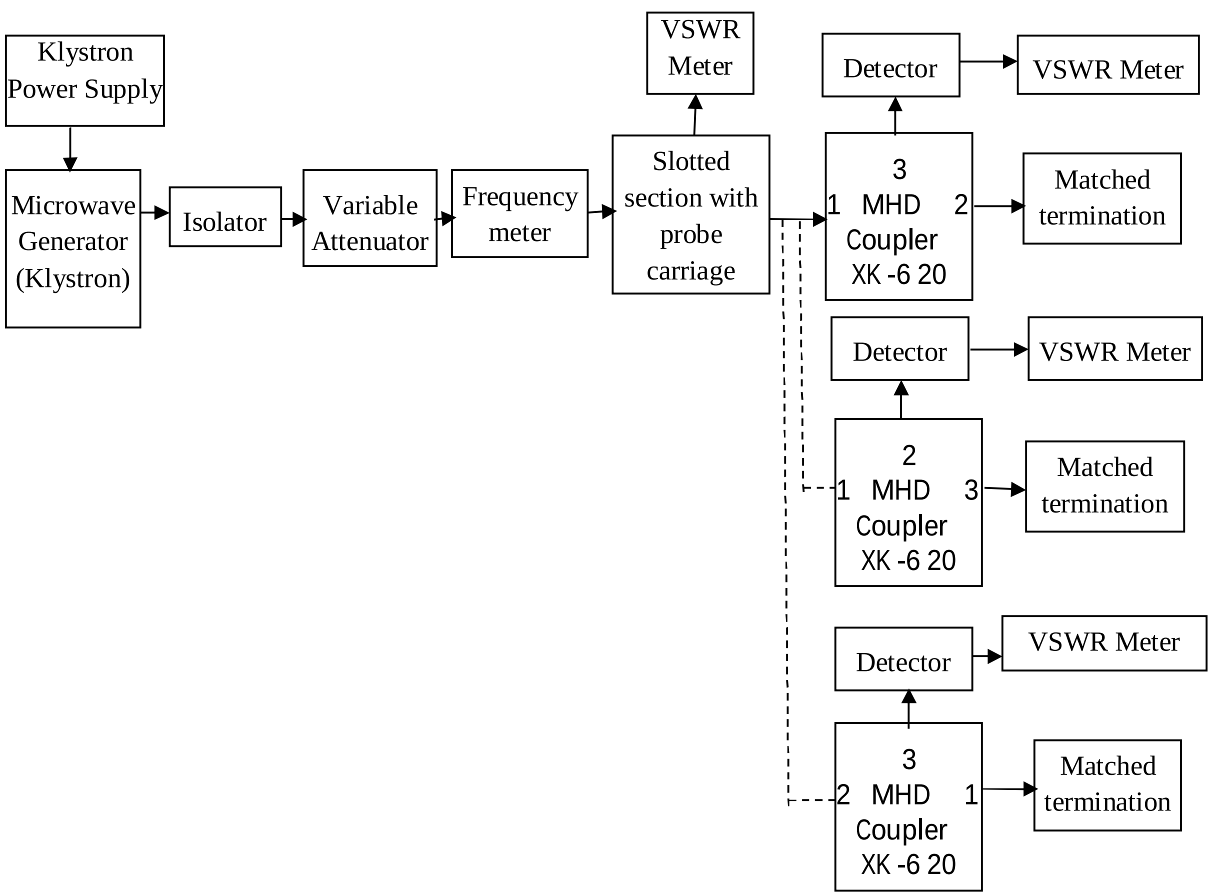


Fig.4.1. Experimental set up for multi-hole directional coupler

Procedure:

1. Set up the equipments as shown in Fig.4.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of VSWR meter as below:

Range dB	------	40dB/50dB
Input Switch	------	Impedance Low
Meter Switch	------	Normal
Gain (Coarse-Fine)	------	Mid position approximately

4. Keep the Control knobs of Klystron Power Supply as below:

Meter Switch	------	OFF
Mod Switch	------	'AM'
Beam Voltage Knob	------	Fully Anti-Clockwise
Reflector Voltage Knob	------	Fully Clockwise
AM Frequency and Amplitude knob	------	Mid position approximately

5. 'ON' the Klystron Power Supply, VSWR meter and Cooling Fan.
6. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage in between 240V to 300V.
7. Connect the detector to the Slotted section and adjust the gain control to get 0 dB in the VSWR meter. Note down the power along with range dB. i.e. input power say P_1
8. Connect the directional coupler as shown in the experimental set up. When necessary, change the range switch to next higher range. Note down the power in VSWR meter in dB scale along with range dB at port 2, when port 3 is matched termination.
9. **Calculate Insertion loss:**

$$L = (P_2 - P_1) \text{ dB}$$

10. Interchange the detector at port 2 to port 3 and port 2 is matched terminated.
11. Measure the power at port 3 by connecting detector. When necessary, change the range switch to next higher range. Note down the power using VSWR meter in dB scale along with range dB at port 3 (forward coupled power)
12. **Calculate Coupling coefficient:**

$$C = (P_3 - P_1) \text{ dB}$$

13. Reverse the Directional coupler. Connect the port 2 of Directional coupler to input side and matched termination to port 1 and connect detector to the port 3, the port 4 is auxiliary arm.

14. Measure the power in the auxiliary arm. When necessary, change the range switch to next higher range. Note down the power using VSWR meter in dB scale along with range dB at port 3^I (Backward Power, P4)
15. **Calculate Directivity:**

$$D = (P_3^I - P_3) \text{ dB}$$

16. **Calculate Isolation:**

I = C+D (Coupling coefficient + Directivity)

Calculations:

Transmitted Power (P_1) = ______dB

Received Power (P_2) = ______dB

Forward Coupled power (P_3) = ______dB

Backward Power ($P_4 = P_3^I$) = ______dB

Result:

Model Viva Questions:

1. What is the significance of directional coupler?
2. Define coupling factor?
3. Define directivity?
4. Define transmissions loss?
5. Define reflection loss?
6. List the applications of directional couplers?
7. Write the scattering matrix of ideal directional coupler?
8. Which type of directional coupler is used in this laboratory?
9. The microwave directional coupler is a device that sample part of…………….
10. If the coupling factor is not sufficient, how can you increase the power handling?
11. Capability of your power meter?
12. Give the directivity an ideal directional coupler?
13. Name the various types of directional couplers?
14. Draw the neat diagram of bifurcated directional coupler.
15. In an ideal directional coupler the back power is …….?
16. What is the difference between single hole directional coupler and multi hole directional coupler?
17. Why the fourth port of the directional coupler used in this laboratory is matched terminated?
18. Directional coupler is reciprocal / non reciprocal?
19. Directional coupler is active / passive?
20. Among directional coupler, Magic Tee, E-plane Tee, H-plane Tee, rat race junction and attenuator which one can be used for power measurement ?Explain.

Experiment-5

VSWR MEASUREMENT

Objective: To measure the low, medium and high VSWR of the given loads and determine the reflection coefficient.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM-25),
3. Isolator (XI -621), Frequency Meter (XF- 710),
4. Variable Attenuator (XA-520),
5. Slotted line (X 565),
6. Tunable probe (XP-655),
7. Detector Mount (XD-451),
8. Wave Guide Stand (XU-535),
9. VSWR Meter (SW-115),
10. Movable short/ Termination (XL 400) or any unknown load,
11. BNC -BNC Cables.

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.

Experimental set up:

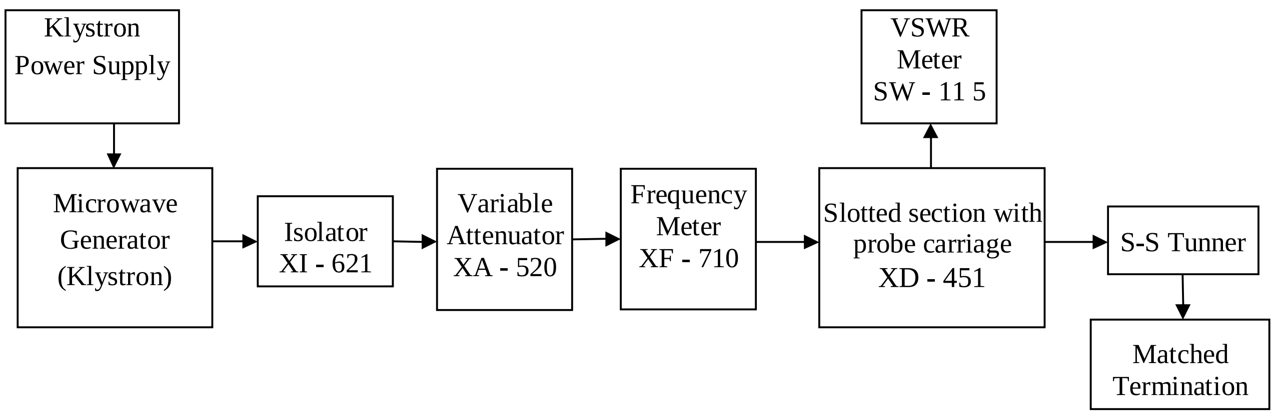


Fig.5.1 Experimental set up for VSWR measurement

Model Graphs:

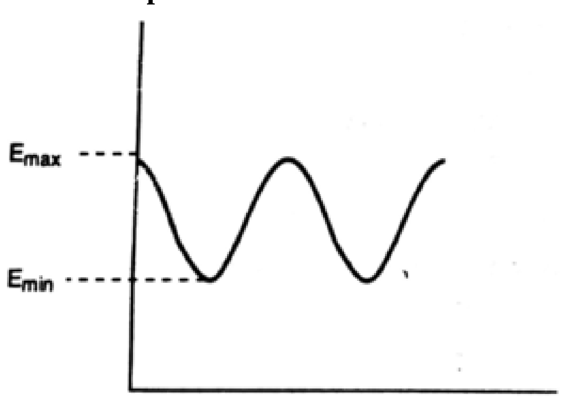


Fig.5.2 (a) Standing Wave

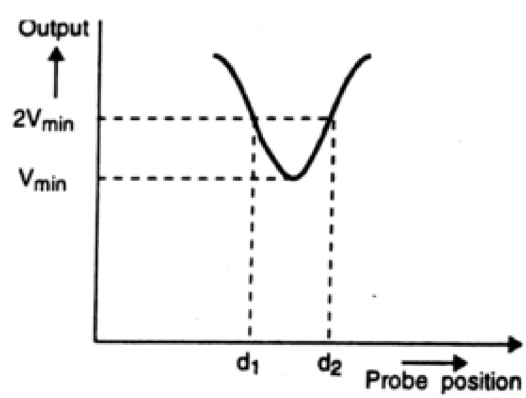


Fig.5.2 (b) Double Minimum Method

Procedure:

Measurement of Low & Medium VSWR:

1. Set up the equipments as shown in Fig.5.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of VSWR meter as below:

Range dB	------	40dB/50dB
Input Switch	------	Impedance Low
Meter Switch	------	Normal
Gain (Coarse-Fine)	------	Mid position approximately

4. Keep the Control knobs of Klystron Power Supply as below:

Meter Switch	------	OFF
Mod Switch	------	'AM'
Beam Voltage Knob	------	Fully Anti-Clockwise
Reflector Voltage Knob	------	Fully Clockwise
AM Frequency and Amplitude knob	------	Mid position approximately

5. 'ON' the Klystron Power Supply, VSWR Meter and Cooling Fan.
6. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.
7. Move the probe along the slotted line to get maximum deflection in VSWR Meter.
8. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates1.0 on normal VSWR scale.
9. Keep all the control knobs as it is, move the probe to next minimum position. Read the VSWR value on scale.
10. Repeat the above step for change of S.S. tuner probe depth and record the corresponding VSWR value on the scale (Medium VSWR).
11. If the VSWR is between 3.2 and 10, change the range dB switch to next higher position and read the VSWR on second scale of 3 to 10.

Measurement of High VSWR (>10): (Double Minimum Method)

12. Set the depth of S-S tuner. Tune slightly more for maximum VSWR.
13. Move the probe along Slotted line until a minimum is indicated.
14. Adjust the VSWR meter gain control knob and variable attenuator to obtain a reading of 3 dB of the normal dB scale of VSWR meter.

15. Move the probe to the left on slotted line until full scale deflection is obtained, i.e., 0 dB on 0-10 dB scale. Note and record the probe position on the slotted line. Let it be d1.
16. Move the probe to the right on slotted line until full scale deflection is obtained, i.e., 0 dB on 0-10 dB scale. Note and record the probe position on the slotted line. Let it be d2.
17. Remove the SS tuner and terminator by Movable Short.
18. Measure the distance between two successive minima position of the probe (Say as d_3 & d_4). Twice this distance is the guide wavelength, $\lambda g = 2(d3 - d4)$.

Calculate the VSWR: $VSWR = \frac{\lambda g}{\pi(d1-d2)}$

Calculations:

Low VSWR =

Medium VSWR =

High VSWR Measurement:

d_1 =___cm

d_2 =___cm

d_3= ___cm

d_4 =___cm

$\lambda g = 2(d3 - d4)$ = ___cm

$VSWR = \frac{\lambda g}{\pi(d1-d2)}$=_____

Reflection coefficient (for high VSWR) = $\frac{S-1}{S+1}$ =

Result:

Model Viva Questions:

1. Define V.S.W.R?
2. Why do we measure the VSWR?
3. Give the range of V.S.W.R. and reflection coefficient?
4. Give the frequency range of the reflex klystron.
5. Which type of method is followed in high VSWR measurement?
6. What are the advantages of VSWR meter?
7. Define reflection coefficient?
8. If V_{max} =3V and V_{min} =1.5V in the standing wave pattern Calculate the VSWR?
9. As impedance mismatch increases, how VSWR varies?
10. If the reflected voltage is 25V and incident voltage is 50V calculate the reflection coefficient.
11. What is the significance of expanded scale in VSWR meter?
12. Using VSWR meter we can measure power in the transmission line?
13. What is the difference between scattering coefficient and reflection coefficient?
14. What is the difference between VSWR meter and Network Analyzer?
15. If the microwave bench is facilitated with X-band spectrum analyzer, what modification is needed in the bench?

Experiment-6

IMPEDANCE MEASUREMENT

Objective: To measure the unknown impedance of a given component.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM-25),
3. Isolator (XI -621), Frequency Meter (XF- 710),
4. Variable Attenuator (XA-520),
5. Slotted line (XS 565),
6. Tunable probe (XP-655),
7. Detector Mount (XD-451),
8. Wave Guide Stand (XU-535),
9. VSWR Meter (SW-115),
10. Movable short/ Termination (XL 400) or any unknown load,
11. BNC -BNC Cable.

Theory:

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

$$Z_L^I = \frac{1 - jS\, Tan\beta . d_{min}}{S - j\, Tan\, \beta . d_{min}}$$

Where, S = VSWR

d_{min} = distance of first minima from the load.

A screw projecting into the waveguide offers variation in the admittance with the insertion of the screw. The depth of screw, changes only the reactive part of the admittance, so if the line is matched, the load offered by the screw for a certain depth is

$$Y = 1 + j\,b$$

Where *b* is the susceptance due to the screw

The unknown impedance can also be determined by using Smith chart, once the VSWR and position of minima is known with the load.

Experimental set up:

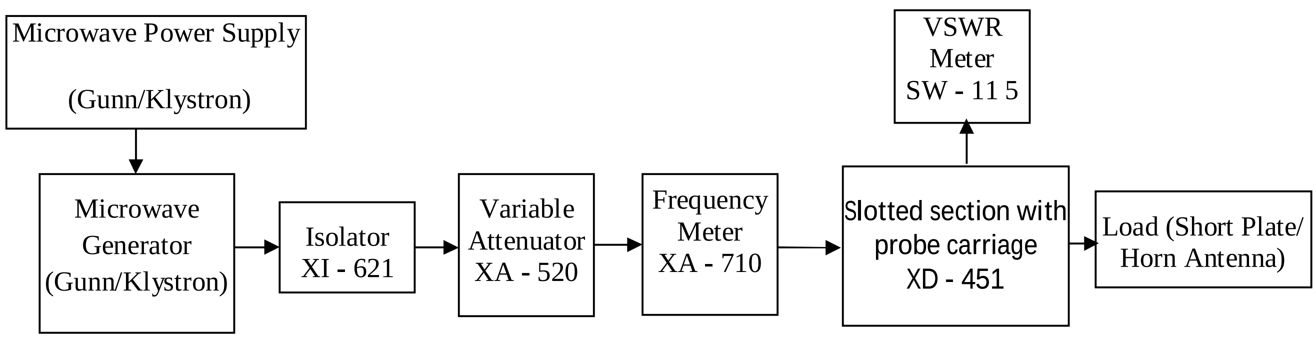


Fig .6.1 Experimental set up for Impedance Measurement

Procedure:

1. Set up the equipments as shown in Fig.6.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of VSWR meter as below:

   Range dB ------ 40dB/50dB

   Input Switch ------ Impedance Low

   Meter Switch ------ Normal

   Gain (Coarse-Fine) ------ Mid position approximately
4. Keep the Control knobs of Klystron Power Supply as below:

   Meter Switch ------ OFF

Mod Switch	------	'AM'
Beam Voltage Knob	------	Fully Anti-Clockwise
Reflector Voltage Knob	------	Fully Clockwise
AM Frequency and Amplitude knob	------	Mid position approximately

5. 'ON' the Klystron Power Supply, VSWR Meter and Cooling Fan.
6. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.
7. Assemble the components with detector as load.
8. Move the probe carriage to the position of voltage maximum and adjust detector tuning for peak meter reading when attenuator is set to suitable level.
9. Measure VSWR when load end is terminated with a matched load. If it is greater than 1.02, reduce it to this value by adjusting probe depth and stub length or with tuning section.
10. Terminate the line with load (horn) and measure load VSWR and Guide wavelength λ_g
11. Note down the position of voltage minimum (d_3).
12. Remove the horn carefully and terminate the line in a short circuit. Record the position of minimum (shift < λ_g /4) towards generator end (d_4).
13. Calculate shift in minimum of load from reference plane $d = d_4 - d_3$ in wavelength units (d / λ_g).
14. Calculate the load impedance using below formula:

$$\boldsymbol{Z_L = \eta \cdot Z_L^l} \textbf{ Ohms,}$$

Where $\boldsymbol{\eta}$ is Free Space Impedance i.e., 377 Ω or 120π

$$\boldsymbol{Z_L^l = \frac{1 - jS\,Tan\beta . d_{min}}{S - j\,Tan\,\beta . d_{min}}}$$

Calculations:

S (VSWR Value of the Horn Antenna) =1.5

d_1 =___cm

d_2 =___cm

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

$\beta = 2/\lambda_g$ = ____

d_3 =____cm

d_4 =____cm

$d_{min} = d_4 - d_3$ = ____cm

$$Z_L^I = \frac{1-jS\,Tan\beta.d_{min}}{S-j\,Tan\,\beta.d_{min}} = \_\_\_\_\_\_\_\text{Ohms.}$$

$$Z_L = \eta \cdot Z_L^I = \_\_\_\_\_\_ \textbf{ ohms}$$

Result:

Model Viva Questions:

1. Define microwaves?
2. Give the characteristics of microwaves?
3. What are the advantages of microwaves?
4. Give various microwave frequency bands?
5. List the applications of microwaves?
6. What are the various parameters of microwave?
7. If the impedance has +ve phase that indicates……?
8. If the impedance has -ve phase that indicates……?
9. What is the impedance offered by free space for the propagation of EM waves?
10. Give the relation for intrinsic impedance in terms of E and H?
11. Define characteristic impedance?
12. If the load impedance is not equal to characteristic impedance, what happens in the transmission line?
13. Why impedance is complex?
14. Non ideal directional couplers and detectors are sources of error. Justify the statement?
15. Explain the principal of reflectometer?
16. Why the amplitude of the signal decreases, when slot section output terminal is open?
17. What is the importance of impedance matching in microwave circuits?
18. What is the need for optimum design of horn?
19. How impedance matching can be achieved between feed element and feed transmission line?
20. In a slot section over how much interval series of minimas / maximas occurs?

Experiment-7

WAVEGUIDE PARAMETERS MEASUREMENT

Objective: To measure the waveguide parameters and to study the standing wave pattern in waveguide.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM-25),
3. Isolator (XI -621), Frequency Meter (XF- 710),
4. Variable Attenuator (XA-520),
5. Slotted line (XS 565),
6. Tunable probe (XP-655),
7. Detector Mount (XD-451),
8. Wave Guide Stand (XU-535),
9. VSWR Meter (SW-115),
10. Cathode ray oscilloscope.
11. Movable short/ Termination (XL 400) or any unknown load,
12. BNC -BNC Cable.

Theory:

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

$$\frac{1}{\lambda_o^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

λ_o is free space wavelength

λ_g is guide wavelength

λ_c is cut-off wavelength

For TE_{10} mode = 2a where a=0.9" is the broader dimension of waveguide.

Experimental set up:

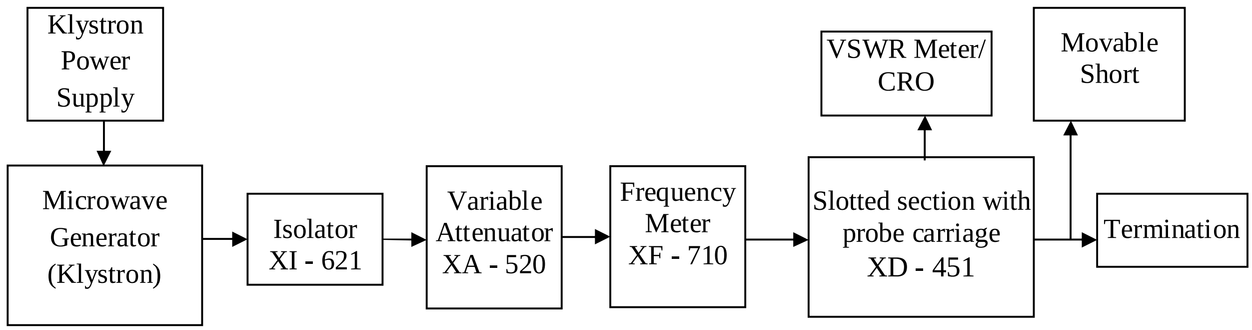


Fig.7.1 Experimental set up for frequency & wave-length measurement

Procedure:

1 Set up the equipments as shown in Fig.7.1.

2 Keep variable attenuator at maximum position.

3 Keep the Control knobs of VSWR meter as below:

a. Range dB ------ 40dB/50dB

b. Input Switch ------ Impedance Low

c. Meter Switch ------ Normal

d. Gain (Coarse-Fine) ------ Mid position approximately

4 Keep the Control knobs of Klystron Power Supply as below:

a. Meter Switch ------ OFF

b. Mod Switch ------ 'AM'

c. Beam Voltage Knob ------ Fully Anti-Clockwise

d. Reflector Voltage Knob ------ Fully Clockwise

e. AM Frequency and Amplitude knob ------ Mid position approximately

5 'ON' the Klystron Power Supply, VSWR Meter and Cooling Fan.

6 Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.

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 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 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 to VSWR meter range dB switch to higher position. Note and record the probe position. Say it as d_1.

15 Move the probe to next minimum position and record the probe position again. Say it as d_2.

16 Calculate the guide wavelength as twice the distance between two successive minimum position obtained as above [λ_g=2d. Where d=d_2-d_1].

17 Calculate the cut off wavelength by measuring the broader dimension of a waveguide. λ_c=2a. Where a=2.286cm Broader dimensions of standard x-band waveguide.

18 Calculate free space wavelength by using the relation $\frac{1}{\lambda_o^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$. Calculate the frequency f =c/λ_o.

19 Compare this with the frequency meter reading observed in step 12.

Calculations:

d_1 =_____cm

d_2 =_____cm

λg = 2(d $_1$- d $_2$) =_____cm

$$\frac{1}{\lambda_o^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

λ_o = _____cm

Theoretical frequency f_T = C/ λ_o = _____G Hz

Practical frequency f_P = _____G Hz

Result:

Model Viva Questions:

1. What are the features of the wave-guide?
2. Define cut off wavelength for the dominant TE_{10} mode.
3. Define cut off wavelength in rectangular wave-guide?
4. Define guide wavelength?
5. Define cut off frequency in circular wave-guide?
6. Write the relation for free space wavelength in terms of guide wavelength and cut off wave length?
7. Cut off wave length for dominant mode in rectangular wave guide is__________
8. Plot the pattern of TE_{20}?
9. What are dominant modes? Give examples?
10. What are degenerate modes? Give examples?
11. Define phase velocity?
12. Define group velocity?
13. Give the relation between group velocity, phase velocity and free space velocity?
14. The phase velocity is greater than the free space velocity. Justify?
15. Explain the nonexistence of TEM mode in a rectangular wave guide with theoretical analysis?
16. Explain the nonexistence of TEM mode in a rectangular wave guide with mathematical analysis?
17. Name different types of wave guides?
18. Give the significance of proper coupling in wave guide joints?
19. Give at least one limitation of flexible wave guide?
20. Give applications of waveguide slots?

Experiment-8

SCATTERING PARAMETERS OF DIRECTIONAL COUPLER

Objective: To measure the S-Parameters (magnitude) of the Multi hole Directional Coupler.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM-25),
3. Isolator (XI -621), Frequency Meter (XF- 710),
4. Variable Attenuator (XA-520),
5. Slotted line (XS 565),
6. Tunable probe (XP-655),
7. Detector Mount (XD-451),
8. Wave Guide Stand (XU-535),
9. VSWR Meter (SW-115) or Micro Ammeter
10. MHD (Multi Hole Directional) Coupler
11. Matched Terminations (XL 400)
12. BNC -BNC Cable.

Theory:

A directional coupler is a 4-port network that is designed to divide and distribute power. Although this would seem to be a particularly done and simple task, these devices are both very important in microwave systems, and very difficult to design and construct. Two of the reasons for this difficulty are our desire for the device to be:

1. Matched
2. Lossless

Thus, we require a matched, lossless, and (to make it simple) reciprocal 4-port device!
Recall that a matched, lossless, reciprocal, 4-port device was difficult to even mathematically determine, as the resulting scattering matrix must be (among other things) unitary.

However, we were able to determine two possible mathematical solutions, which we called the symmetric solution:

$$S = \begin{bmatrix} 0 & \propto & j\beta & 0 \\ \propto & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \propto \\ 0 & j\beta & \propto & 0 \end{bmatrix}_{4\times4}$$

And the asymmetric solution:

$$S = \begin{bmatrix} 0 & \propto & \beta & 0 \\ \propto & 0 & 0 & -\beta \\ \beta & 0 & 0 & \propto \\ 0 & -\beta & \propto & 0 \end{bmatrix}_{4\times4}$$

Wherein for both cases, the relationship:

$|\alpha^2| + |\beta^2| = 1$

Must be true in order for the device to be lossless (i.e., for **S** to be unitary).

For most couplers we will find that α and β can (at least ideally) be represented by a real value c, known as the Coupling coefficient.

$$\beta = c \quad \alpha = \sqrt{1 - C^2}$$

Experimental set up:

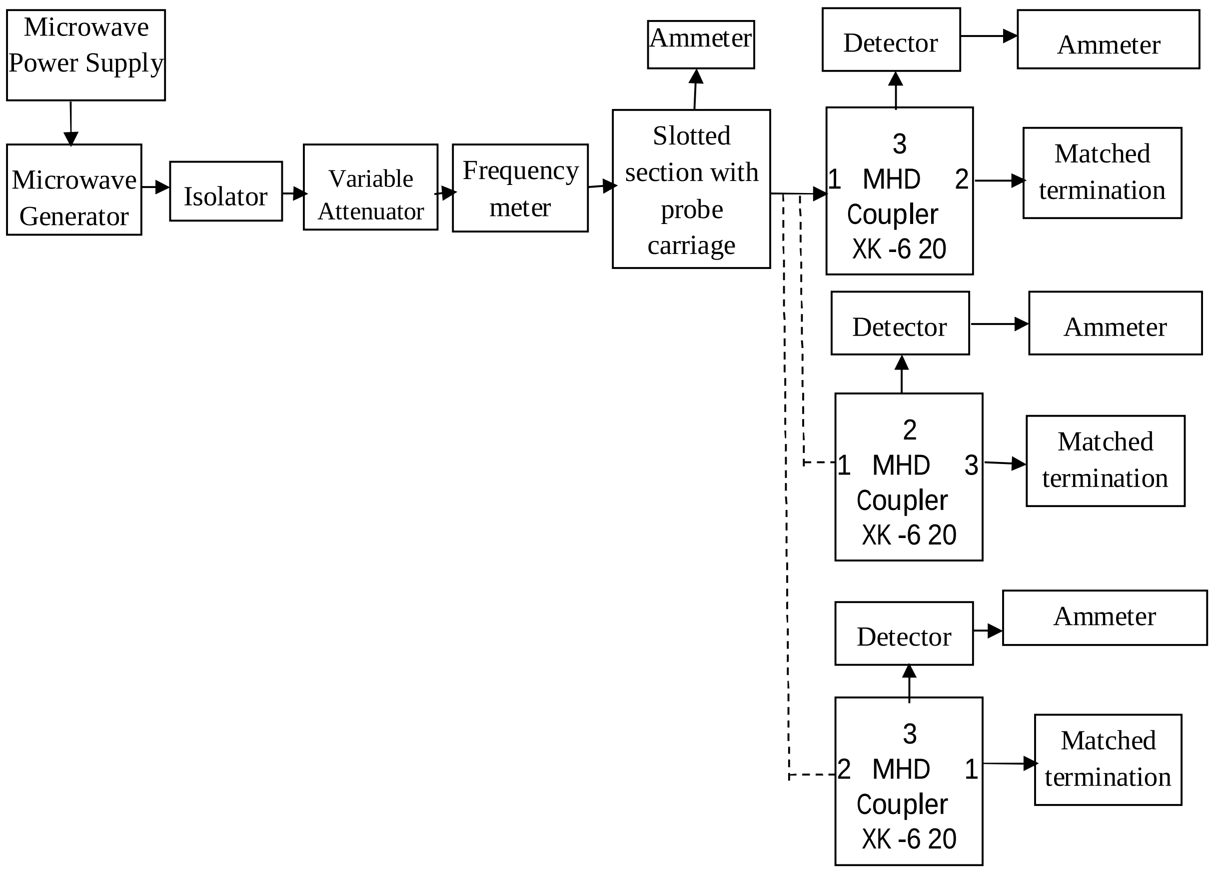


Fig .8.1 Experimental setup of study of MHD Coupler (Transmission Coefficients)

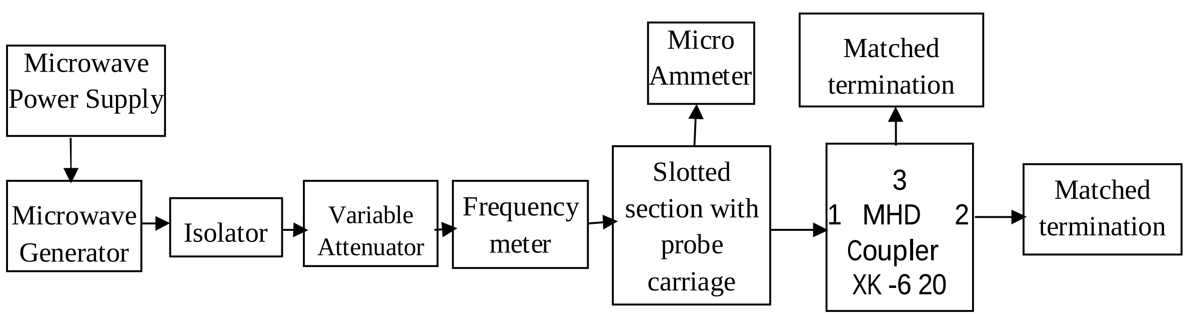


Fig .8.2 Experimental setup of study of MHD Coupler (Reflection Coefficients)

Procedure:

Measurement of Transmission coefficients:

1. Set up the equipments as shown in Fig.8.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of Klystron Power Supply as below:

Meter Switch	------	OFF
Mod Switch	------	'AM'
Beam Voltage Knob	------	Fully Anti-Clockwise
Reflector Voltage Knob	------	Fully Clockwise
AM Frequency and Amplitude knob	------	Mid position approximately

4. 'ON' the Klystron Power Supply, Ammeter and Cooling Fan.
5. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.
6. Adjust attenuator and tune the tunable detector (for maximum power) to get a fixed amount of power.
7. Note the ammeter reading 'I_1'(here i/p corresponds to port1).This is input to MHD coupler.
8. Without disturbing the set up replace the tunable detector with the given MHD coupler, with its port1 connected as shown in figure8.1. Connect port2 and port3 with matched terminations and port4 with a tunable matched detector and micro ammeter. Note the micro ammeter reading (1_4).

$$S_{41} = \sqrt{\frac{I_4}{I_1}}$$

9. Now connect matched loads at port 3 and 4 and tunable detector at port2 and find ammeter reading I_2

$$S_{21} = \sqrt{\frac{I_2}{I_1}}$$

10. Similarly find S_{31}.
11. Connect port2 in place of port1. Repeat the above procedure to find S_{32},S_{42},S_{12} (here input corresponds to port2).
12. Similarly find S_{13}, S_{23}, S_{43} (with input port as port3)

Measurement of Reflection coefficients:

13. Assemble the set up as shown in figure 8.2 with port1 connected to slotted section. Observe the standing wave pattern on the slotted line and note down I_{max} and I_{min}. Calculate the

$$VSWR = \sqrt{\frac{I_{max}}{I_{min}}}$$

$$\text{And} \quad S_{11} = \frac{VSWR-1}{VSWR+1}$$

14. Remove the MHD coupler and connect port2 in place of port1. Repeat the above procedure to find S_{22}.
15. Similarly find S_{33} and S_{44}.
16. Write the Scattering parameters in matrix form.

Calculations:

Transmission Coefficients:

S_{12} =	S_{13} =	S_{14} =	S_{21} =
S_{23}=	S_{24} =	S_{31} =	S_{32} =
S_{34} =	S_{41} =	S_{42} =	S_{43} =

Reflection Coefficients:

VSWR value of the port 1 is S_1 = ______

VSWR value of the port 2 is S_2 = ______

VSWR value of the port 3 is S_3 = ______

VSWR value of the port 4 is S_4 = ______

Reflection Coefficient:

$$|S_{ij}| = \frac{S_k-1}{S_k+1}$$

Where $i=j=k$= 1,2,3,4

Scattering Matrix of the MHD coupler, $S = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}_{4\times 4} =$

Result:

Model Viva Questions:

1. List the applications Directional Coupler.
2. What are the features of Directional Coupler?
3. Write the scattering matrix of Directional Coupler.
4. Write the scattering characteristics of Directional Coupler.
5. Draw the diagram of Directional Coupler?
6. Measuring S_{32} means…………?
7. Why $S_{11}=S_{22}=S_{33}=S_{44}=0$ in a Directional Coupler?
8. Why $S_{13}=S_{31}=0$ in a Directional Coupler?
9. Why $S_{12}=S_{21}=P$ in a Directional Coupler?

Experiment-9

SCATTERIG PARAMETERS OF MAGIC TEE

Objective: To measure the S-Parameters (magnitude) of the Magic Tee.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM-25),
3. Isolator (XI -621), Frequency Meter (XF- 710),
4. Variable Attenuator (XA-520),
5. Slotted line (XS 565),
6. Tunable probe (XP-655),
7. Detector Mount (XD-451),
8. Wave Guide Stand (XU-535),
9. VSWR Meter (SW-115),
10. Magic Tee (XE 345/350)
11. Matched Terminations (XL 400)
12. BNC -BNC Cable and TNC-TNC Cable.

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) $= 10\log_{10}\left[\frac{P_4}{P_3}\right]$

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 $\alpha = 10\log_{10}\left[\frac{P_4}{P_3}\right]$

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

Experimental set up:

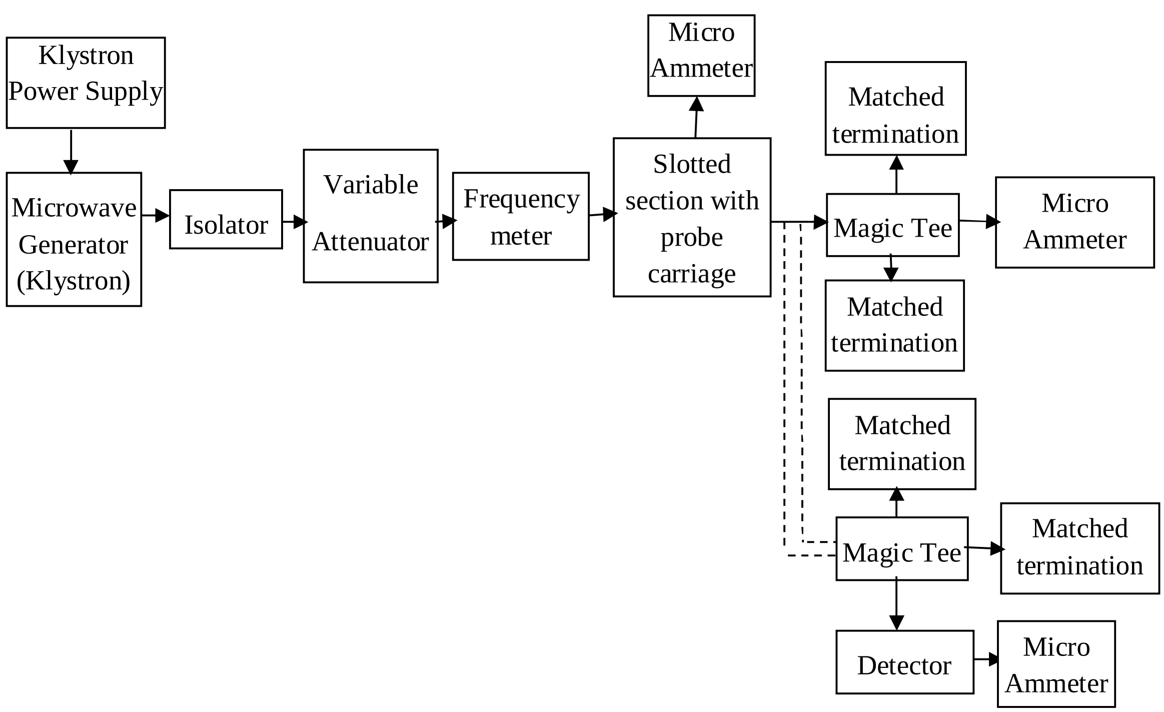


Fig .9.1 Experimental setup of study of Magic Tee (Transmission Coefficients)

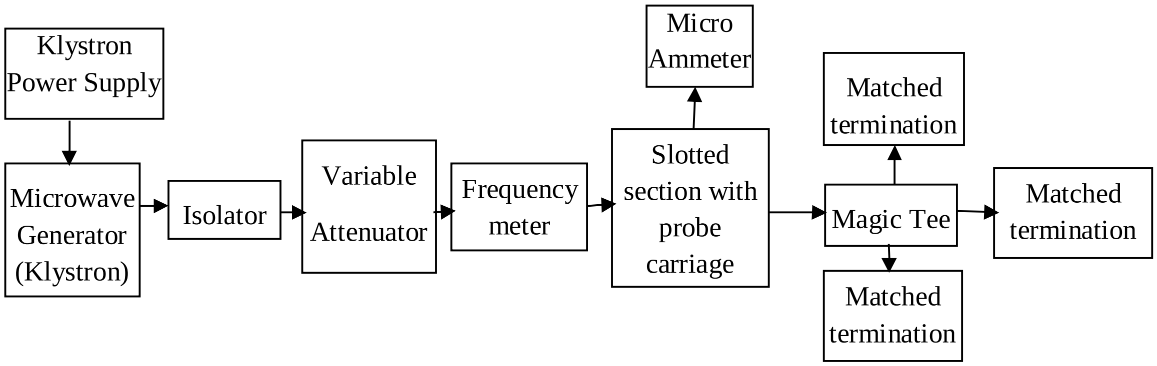


Fig .9.2 Experimental setup of study of Magic Tee (Reflection Coefficients)

Procedure:

Measurement of Transmission coefficients:

1. Set up the equipments as shown in Fig.9.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of Klystron Power Supply as below:

Meter Switch	------	OFF
Mod Switch	------	'AM'
Beam Voltage Knob	------	Fully Anti-Clockwise
Reflector Voltage Knob	------	Fully Clockwise
AM Frequency and Amplitude knob	------	Mid position approximately

4. 'ON' the Klystron Power Supply, Ammeter and Cooling Fan.
5. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.
6. Adjust attenuator and tune the tunable detector (for maximum power) to get a fixed amount of power.
7. Note the ammeter reading 'I_1'(here i/p corresponds to port1).This is input to Magic Tee.
8. Without disturbing the set up replace the tunable detector with the given Magic Tee, with its port1 connected as shown in figure9.1. Connect port 2 and port3 with matched terminations and port4 with a tunable matched detector and micro ammeter. Note the micro ammeter reading (1_4).

$$S_{41} = \sqrt{\frac{I_4}{I_1}}$$

9. Now connect matched loads at port 3 and 4 and tunable detector at port2 and find ammeter reading I_2

$$S_{21} = \sqrt{\frac{I_2}{I_1}}$$

10. Similarly find S_{31}.
11. Connect port2 to in place of port1. Repeat the above procedure to find S_{32}, S_{42}, S_{12} (here input corresponds to port2).
12. Similarly find S_{13}, S_{23}, and S43.

Measurement of Reflection coefficients:

13. Assemble the set up as shown in figure 9.2 with port 1 connected to slotted section. Observe the standing wave pattern on the slotted line and note down I_{max} and I_{min}. Calculate the

$$VSWR = \sqrt{\frac{I_{max}}{I_{min}}}$$

And $$S_{11} = \frac{VSWR-1}{VSWR+1}$$

14. Remove the Magic Tee and connect port2 in place of port1. Repeat the above procedure to find S_{22}.
15. Similarly find S_{33} and S_{44}.
16. Write the Scattering parameters in matrix form.

Calculations:

Transmission Coefficients:

S_{12} =	S_{13} =	S_{14} =	S_{21} =
S_{23}=	S_{24} =	S_{31} =	S_{32} =
S_{34} =	S_{41} =	S_{42} =	S_{43} =

Reflection Coefficients:

VSWR value of the port 1 is S_1 = ______

VSWR value of the port 2 is S_2 = ______

VSWR value of the port 3 is S_3 = ______

VSWR value of the port 4 is S_4 = ______

Reflection Coefficient: $\left|S_{ij}\right| = \frac{S_k - 1}{S_k + 1}$

Where i=j=k= 1,2,3,4

Scattering Matrix of the Magic Tee, S = $\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}_{4\times 4}$ =

Result:

Model Viva Questions:

1. List the applications Magic Tee.
2. What are the features of Magic Tee?
3. Write the scattering matrix of Magic Tee.
4. Write the scattering characteristics of Magic Tee.
5. What is the magic in a tee junction?
6. Explain felid distribution across the arms of the Magic Tee?
7. Write the symmetric properties of Magic Tee.
8. H- Plane junction means.
9. E- plane junction means
10. If arm 1& arm 2 of Magic Tee fed with two signals Pi& P, calculate the field strength at arm-3.
11. What is folded Magic Tee?
12. Draw the field distribution in a H-plane tee.
13. Draw the field distribution in an E-plane tee.
14. Draw the field distribution in an EH-plane tee.
15. Draw the diagram of Magic Tee?
16. Explain how Magic Tee works as a power splitter?
17. Measuring S_{32} means…………?
18. Why S_{11}=S_2=S_{33}=S_{44}=0 in a Magic Tee?
19. Why S_{12}=S_{21} =0 in a Magic Tee?
20. How Magic Tee can be used as mixer?
21. How Magic Tee can be used for impedance measurement?

PART – B (Any 5 Experiments)

Experiment-1

STUDY OF CHARACTERISTICS OF LED

Objective: a) To plot the volt-ampere characteristics of a LED.

b) To determine the cut-in voltage, dynamic & static forward bias resistance.

Equipment Required:

1. Semiconductor trainer module containing bread board
2. LED CQ124
3. 1KΩ - resistor – 1no.
4. Voltmeter (0-30V)
5. Ammeter (0-200mA)

Theory:

In optical fiber 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.

Experimental set up:

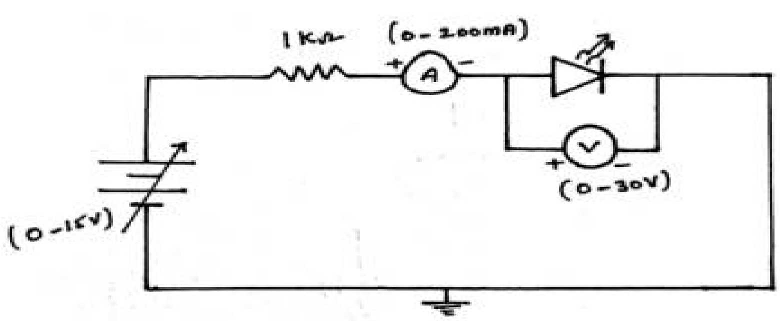


Fig.1.1 Circuit diagram to obtain V-I characteristics of LED

Model Graph:

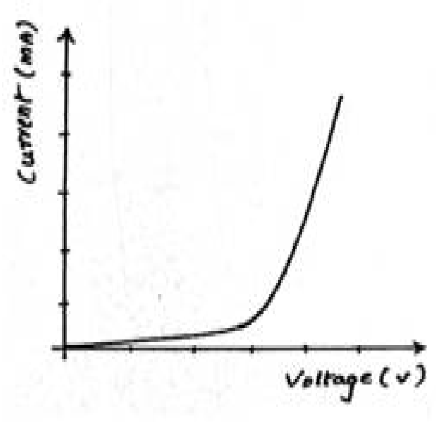


Fig.1.2 V-I characteristics of LED

Procedure:

1. Connect the equipment as shown in Fig.1.1
2. Use CQ124 LED and make it forward bias connection.
3. Increases the voltage applied to diode gradually in steps and note the ammeter and voltmeter readings and plot is drawn.

Table1.1: Observations:

Sno	Voltage(V)	Current (mA)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

Precautions:

1. Do not connect the ammeter across the supply (or) to diode.
2. Do not connect the voltmeter in series with the diode.
3. Select the meters of proper range which are somewhat greater than required ratings.

Calculations:

Cut in voltage= _____Volts

Static Resistance = $\frac{V}{I}$ = ______ KΩ

Dynamic Resistance = $\frac{\Delta V}{\Delta I}$ =_______KΩ

Result:

Model Viva Questions:

1. What is the basic principle of LED?
2. LED is coherent or non-coherent? Explain.
3. Which type of materials are used for the manufacture of LEDs?
4. What are direct and indirect materials, between them which one is used for LED
5. What is the difference between LED and Laser?
6. What is the difference between recombination process of direct and indirect materials.
7. What is the frequency and wavelength of the LED used in your experiment?
8. Define threshold voltage for LED?
9. Give the applications and advantages of LED?

Experiment-2

STUDY OF CHARACTERISTICS LASER DIODE

Objective: To study VI Characteristic of Laser Diode.

Equipment Required:

1. Link – E Fiber Optic Trainer Kit.
2. Glass Fiber Cable with ST connector: 1 No.
3. Patch cords.
4. Voltmeter.(1 No)
5. Ammeter.(1 No)
6. Power Supply.

Theory:

To obtain a laser action in a semiconductor, the medium should be prepared in a form a p-n junction diode with highly degenerate p- type and n-type region, in this way the inverse is produced in the junction region. this can be achieved by forward biasing the junction .when the junction Is forward biased with a voltage that is nearly equal to the energy gap voltage , electron and holes are injected across the junction in sufficient number to create a population inversion in a narrow zone called the active region .

The amount of population inversion, and hence the gain is determined by the current flowing in the laser diode. At low current values the losses offset lasing action. In this case the radiation exists due to spontaneous emission which increases linearly with the drive current. Beyond a critical value of the current (the threshold value), the lasing commences and the radiative out pout increases rapidly with increasing current, as shown in fig 2.1.

Experimental set up:

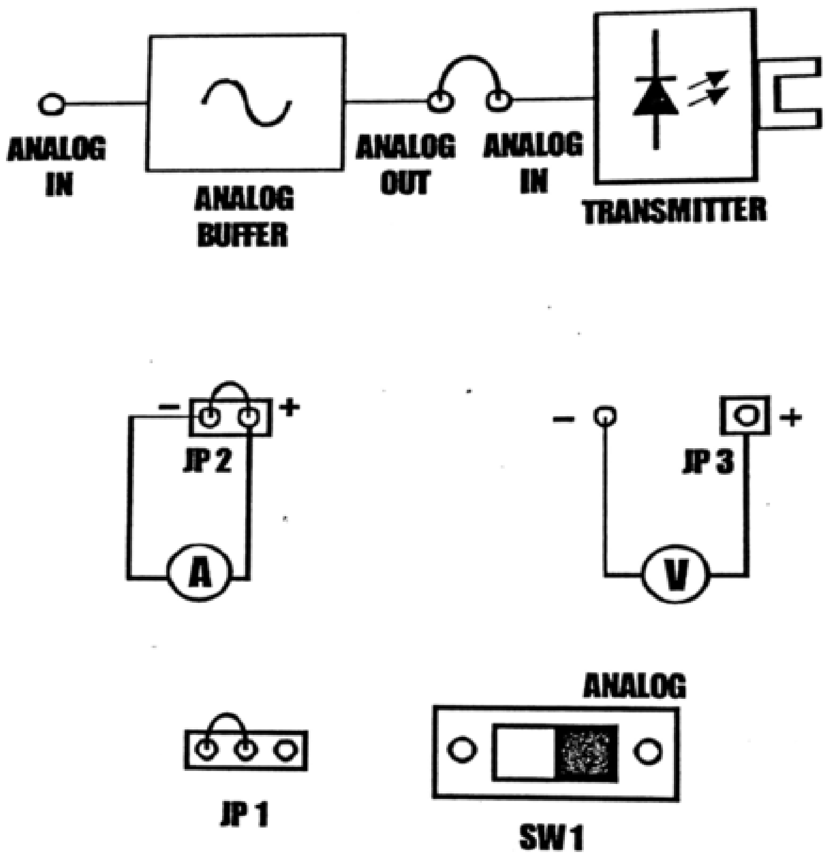


Fig.2.1 Link - E set up to study VI characteristics of LASER

Model Graph:

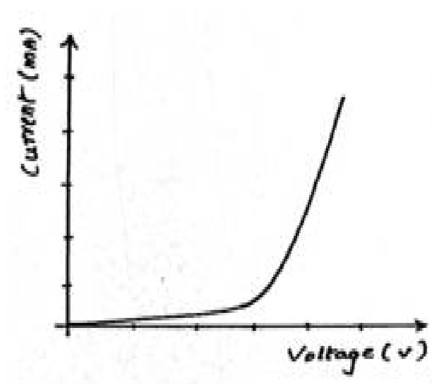


Fig.2.2 LASER characteristics

Procedure:

1. Confirm that the power switch is in OFF position and then connect it to the kit.
2. Make the jumper settings and connection as shown in the block diagram.

3. Insert the jumper connecting wires (provided along with the kit) in jumper JP1, JP2 and JP3 at positions shown in the diagram.
4. Connect the ammeter and volt-meter with the jumper wires connected to JP1, JP2 and JP3 as shown in the block diagram.
5. Keep the potentiometer P5 in anti-clockwise rotation; it is used to control intensity of laser diode.
6. Connect external signal generator to ANALOG IN post of Analog buffer and apply sine wave frequency of 1MHz, 1V p-p signal precisely.
7. Then connect ANALOG OUT post to ANALOG IN post of transmitter.
8. Then Switch on the power supply.
9. To get the I-V characteristics of Laser diode, rotate P5 slowly and measure forward current and corresponding forward voltage at JP1, JP2 and JP3 respectively.
10. Take number of such readings for various current values and plot I-V characteristics graph.

Observations:

Table 2.1 Tabular column to note down the Voltages and Currents:

S.NO	**Voltage (volts) [JP3]**	**Current (mA) [JP2]**
1		
2		
3		
4		
5		

Threshold Voltage = ____V

Result:

Model Viva Questions:

1. LASER means.
2. What are the steps involved for the production of laser?
3. Why laser light is coherent?
4. What are the necessary and sufficient conditions for the production of Laser?
5. What is population inversion, give its condition?
6. What is saturation intensity?
7. Which state is responsible for the production laser?
8. What is optical resonator, give its significance in lasing action?
9. What are the various loses associated with optical resonator ensemble?
10. Differentiate spontaneous emission and stimulated emission?
11. In laser how can you design the characteristics of output radiation?
12. How photon emission possible in Si during recombination? Discuss the necessary action?
13. Compare semiconductor lasers with chemical laser?
14. Give at least one defense application of lasers?
15. Compare the life time of different states in lasing action?
16. Compare the principal of LED and solar cell?
17. Name different types of semiconductor lasers?
18. Give the advantages of semiconductor lasers?
19. What is Q-switching and mode locking in lasing action?
20. Why laser light is monochromatic?

Experiment-3

MEASUREMENT OF DATA RATE FOR DIGITAL OPTICAL LINK

Objective: To measure the date rate of digital optical link.

Equipment Required:

1. Link – A Fiber Optic Trainer kit.
2. 20 MHz Dual Trace Oscilloscope.
3. 1 Meter Fiber cables.
4. Power supply.

Experimental set up:

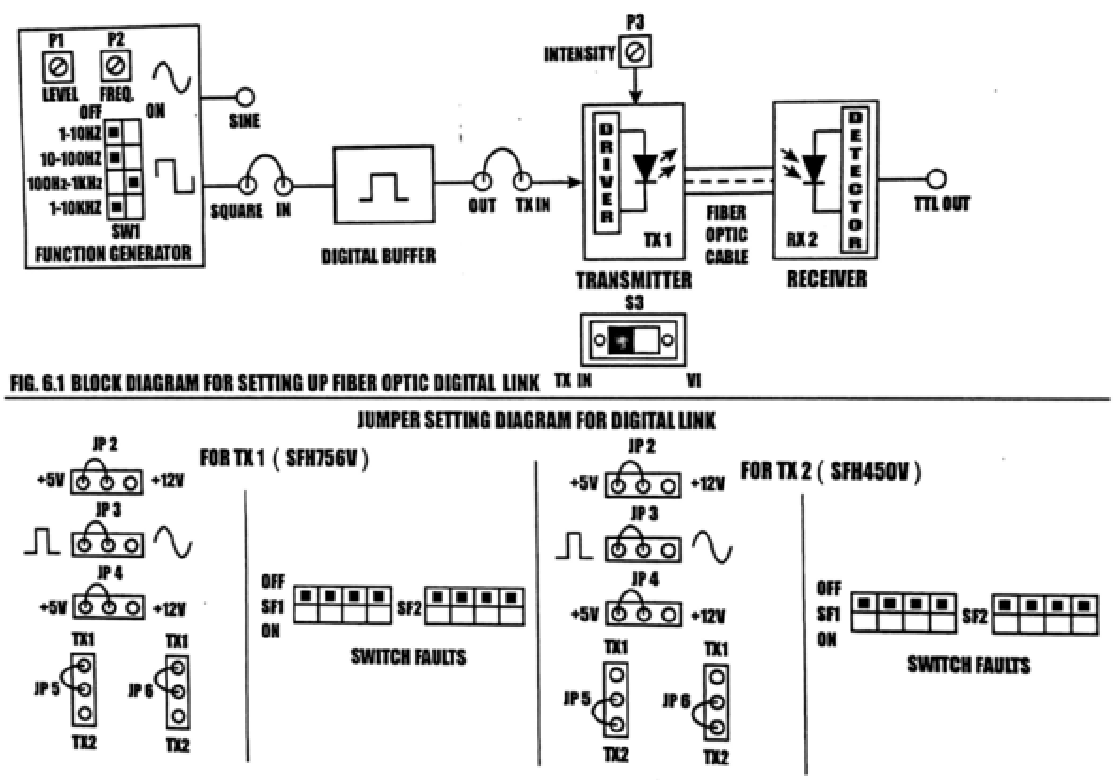
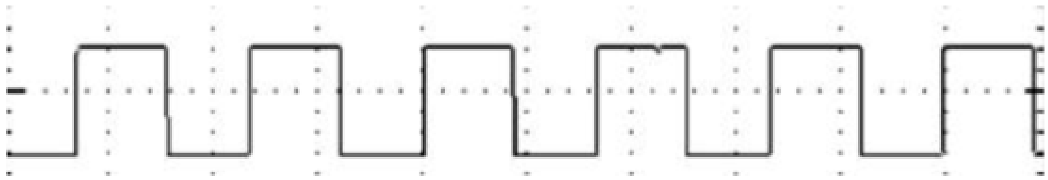
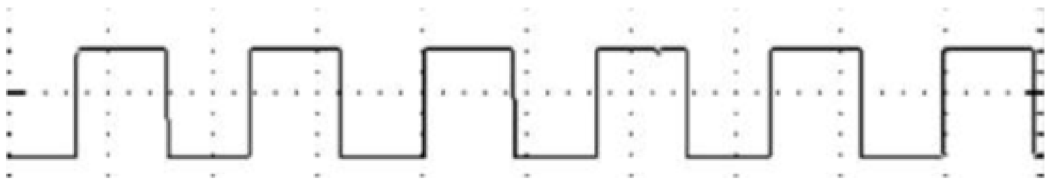


Fig.3.1 Experimental set up for Digital link

Model Graph:



Input Signal 1 KHz, 2Vpp



Output Signal 1 KHz, 2Vpp

Fig.3.2 Expected Digital input and Output waveforms

Procedure:

1. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF. Now switch on the power supply.
2. Keep all the switch faults in OFF position.
3. Keep Jumpers JP2 & JP4 towards +5V position, JP3 towards pulse position, JP5 & JP6 towards TX1 position.
4. Keep Switch SW1 at 100 Hz - 1 kHz.
5. Feed the Onboard Square (TTL) signal of about 1 KHz to IN post of Digital Buffer Section and observe the signal at its OUT post. It should be same as that of the input signal.
6. Connect OUT post of the Digital Buffer Section to TX IN post of TRANSMITTER. Slightly unscrew the cap of LED SFH 756V (660 nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.
7. Connect the other end of the fiber to detector SFH 551V RX2 (Digital Detector) very carefully.
8. Keep Switch S3 in TXIN position.

9. Observe the received signal on CRO at TTL OUT post. The transmitted signal & received signal are same. Vary the frequency of the input signal and observe the output response.
10. Keep Jumpers JP5 & JP6 towards TX2 position.
11. Remove fiber from TX 1 and connect to TX 2 (SFH 450V (950 nm).-
12. Observe the received signal on CRO at TTL OUT post.

Precautions:

1. Should not deform the optical fiber.
2. Do not apply more pressure while connecting fiber cable to TX and RX.
3. Connect the power supply connector carefully.
4. Connect the jumpers more carefully.

Result:

Model Viva Questions:

1. Which type of oscillator is used in the function generator used in this experiment?
2. Which type of amplifier is used in the function generator used in this experiment?
3. What is the buffer? Explain its significance in this experiment?
4. Which type of modulation is used in the given kit?
5. Give the range of radiation intensity in the given kit?
6. What is your observation in the used in this experiment?
7. List the various applications of fiber optic analog and digital link.
8. What is the effect of fiber joint on the transmission?
9. It is possible to join two fibers with different radius of core for transmission?
10. How cross section of optical fiber effects the transmission?

Experiment-4

MEASUREMENT OF NA

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

Equipment Required:

1. Link – A Fiber Optic Trainer kit.
2. 1 Meter Fiber cable.
3. NA JIG.
4. Steel Ruler.
5. Power supply.

Experimental set up:

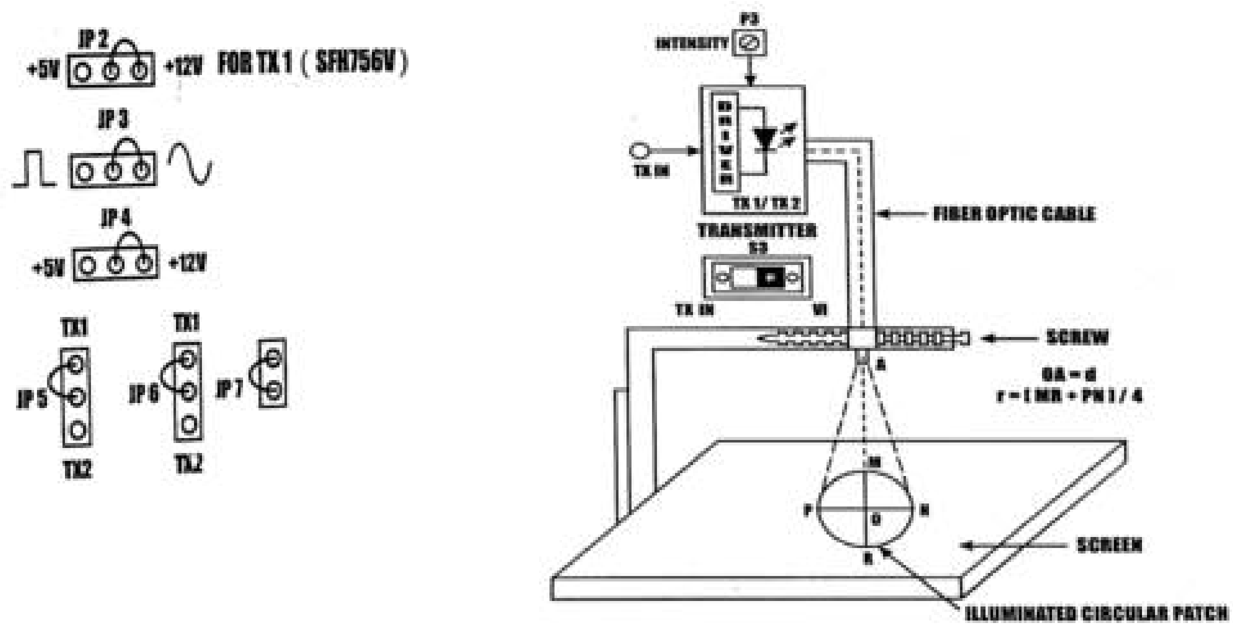


Fig.4.1: Experimental Setup for Numerical Aperture Measurement

Procedure:

1. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF. Do not apply any TTL signal from Function Generator. Make the connections as shown in block diagram.
2. Keep all the switch faults in OFF position.
3. Keep Pot P3 fully Clockwise Position and P4 fully anticlockwise position.

4. Slightly unscrew the cap of LED SFH756V (660 nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.
5. Keep Jumpers JP2 towards +5V position, JP3 towards sine position, JP5 & JP6 towards TX1 position.
6. Keep switch S3 towards VI position.
7. Insert the other end of the fiber into the numerical aperture measurement jig. Hold the white sheet facing the fiber. Adjust the fiber such that its cut face is perpendicular to the axis of the fiber.
8. Keep the distance of about 10 mm between the fiber tip and the screen. Gently tighten the screw and thus fix the fiber in the place.
9. Now adjust Pot P4 fully Clockwise Position and observe the illuminated circular patch of light on the screen.
10. Measure exactly the distance d and also the vertical and horizontal diameters MR and PN indicated in the block diagram.
11. Mean radius is calculated using the following formula. $r = \frac{MR+PN}{4}$
12. Find the numerical aperture of the fiber using the formula.

$$NA = \frac{r}{\sqrt{[r^2+d^2]}} = \sin\theta \max$$

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

Precautions:

1. Keep the intensity knob at minimum position before switching ON the kit.
2. Jumper connection should be done carefully.

Observations:

Vertical diameter, MR = ____cm

Horizontal diameter, MR = ____cm

Mean radius, $r = \frac{MR+PN}{4}$ = _____cm

d = _____cm

$NA = \frac{r}{\sqrt{[r^2+d^2]}}$ = ______

Sin θ_{max} = NA

$\theta_{max} = Sin^{-1}(NA) =$ ________

Result:

Model Viva Questions:

1. Define Numerical aperture of a step index fiber?
2. Define Mode-field diameter?
3. What is Snell's law?
4. What is the necessity of cladding for an optical fiber?
5. What are step index and graded index fibers?
6. Define acceptance angle?
7. Why do we prefer step index single mode fiber for long distance communication?
8. Define relative refractive index difference?
9. What are meridional rays?
10. What are skew rays?
11. What are the conditions for total internal reflection?
12. Give the relation between numerical aperture of skew rays and meridional rays.
13. Define cutoff wavelength of the fiber?
14. Mention the rule distinguishing 'mode' and 'order'?
15. Give the expression for numerical aperture in graded index fibers?

Experiment-5

MEASUREMENT OF LOSSES FOR ANALOG OPTICAL LINK

Objective: To measure propagation and bending losses in the fiber cable.

Equipment Required:

1. Link - A Fiber Optic Trainer kit.
2. 20 MHz Dual Trace Oscilloscope.
3. Fiber cables (1mtr & 3mtr).
4. Power supply.

Experimental set up:

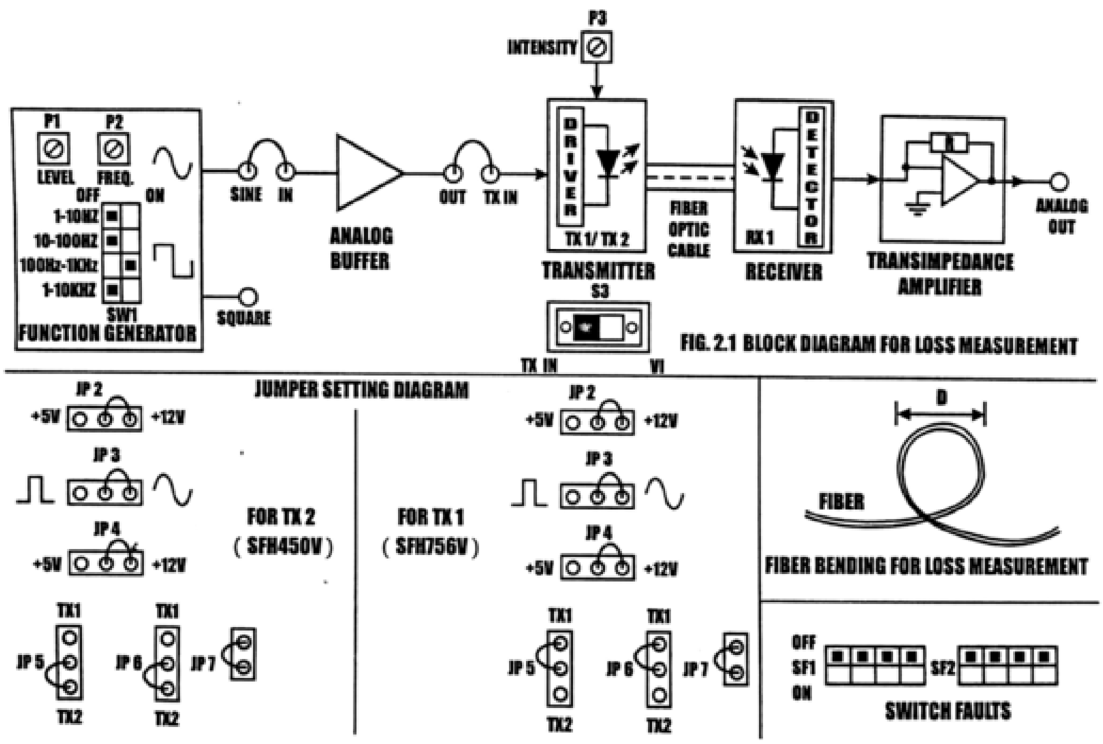
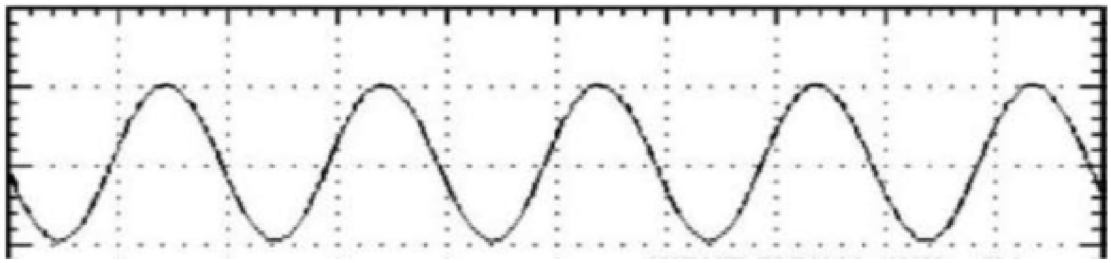
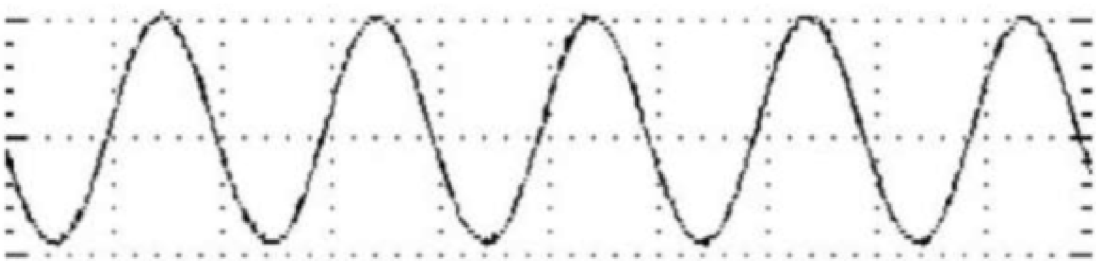


Fig 5.1: Experimental setup for Fiber Optic loss measurement

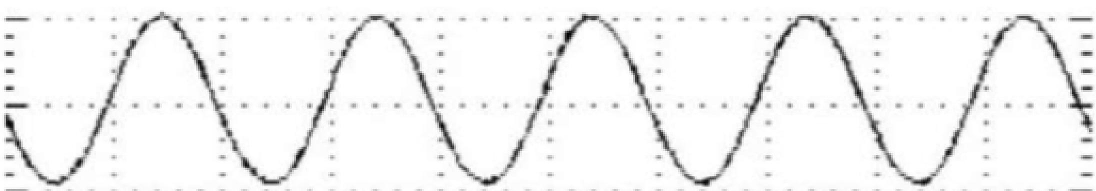
Model Graphs:-



Input Signal 1 KHz, 2Vpp



Detected signal (for 1mtfiber optic)



Detected signal (for 3mtfiber optic)

Fig 5.2 Expected Waveforms

Procedure:

Measurement of Propagation loss:

1. Make the connections and Jumper settings as shown in block diagram Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF.
2. Keep all the switch faults in OFF position.
3. Switch on the power supply.
4. Select the frequency range of Function Generator with the help of Range Selection Switch SW1, frequency can be varied with Pot P2. Adjust the voltage LEVEL of the

Sine Wave with Pot P1 as per following setting. FREQUENCY: 1 KHz, LEVEL: 2Vpp.

5. Connect SINE post of the Function Generator section to IN post of Analog Buffer Section.
6. Keep Jumpers JP2 & JP4 towards +12V position, JP3 towards sine position, JP5 towards TX1 position, JP6 towards TX1 position & JP7 shorted.
7. Keep switch S3 towards TX IN position.
8. Connect OUT post of the Analog Buffer Section to TX IN post of TRANSMITTER.
9. Slightly unscrew the cap of LED SFH 756V TX1 (660 nm) from kit. Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap and assure that the fiber is properly fixed. Now tight the cap by screwing it back. Keep INTENSITY pot P3 at minimum position i.e. fully anticlockwise.
10. Connect the other end of the fiber to detector SFH 250V (RX 1) in kit very carefully. Check the output signal of the Analog Buffer at its OUT post in Kit. It should be same as that of the applied input signal.
11. Now replace 1 meter fiber by 3 meter fiber without disturbing any of the previous settings.
12. Measure the amplitude level at the receiver side again. You will notice that it is less than the previous one, Mark this as V2.
13. If alpha is the attenuation of the fiber then we have,

$$\frac{P_1}{P_2} = \frac{V_1}{V_2} = \exp[-\alpha(L_1 - L_2)]$$

Where α is the loss given in nepers / meter

L_1 = fiber length for V_1

L_2 = fiber length for V_2

14. This alpha is for the wavelength of 660 nm /950 nm.

Measurement of bending losses:

15. Bend the fiber in a loop as shown in block diagram, Measure the diameter of the loop using a scale and the respective amplitude of the received signal.
16. Keep reducing the diameter to about 2 cm & take corresponding output voltage readings. (Do not reduce loop diameter less than 2 cm.)
17. Plot a graph of the received signal amplitude versus the loop diameter.

Table 5.1 Tabular column to observe the bending losses of given optical fiber:

S.NO	**Diameter of the bent cable (cm)**	**Output voltage (mV)**
1		
2		
3		
4		

Precautions:

1. Should not bend the optical fiber below 2cm.
2. Do not apply more pressure while connecting fiber cable to TX and RX.
3. Connect the power supply connector carefully.

Observations:

Output amplitude when L_1=1meter optical cable is used, V_1= _____V

Output amplitude when L_2=3meter optical cable is used, V_2= _____V

Loss in dB= $\left\{\frac{10}{L1-L2}\right\} Log\left(\frac{V2}{V1}\right)$= ____dB

Result:

Model Viva Questions:

1. What are various losses in optical fibers?
2. In which type of fiber bending losses are more?
3. In which type of fibers, bending losses are very poor?
4. In which situation optical fiber subject to bend?
5. Why bending losses is negligible in multi-mode fiber?
6. How radiation intensity decreases in an optical fiber when it is subjected to bend?
7. Which parameter undergo change when optical fiber is subjected to bend?
8. What are bending losses?
9. How attenuation depends in an optical fiber?
10. What are the limitations of optical fibers in long distance communications?

Experiment-6

RADIATION PATTERN MEASUREMENT OF HORN ANTENNA

Objective: To measure the radiation pattern of pyramidal horn antenna.

Equipment Required:

1. Klystron Power Supply (SKPS-610)
2. Klystron Tube (2K-25) with Klystron Mount (XM-25),
3. Isolator (XI -621), Frequency Meter (XF- 710),
4. Variable Attenuator (XA-520),
5. Detector Mount (XD-451),
6. Wave Guide Stand (XU-535),
7. VSWR Meter (SW-115),
8. Pyramidal Horn Antennas XH-541
9. Multi Meter
10. BNC -BNC Cable.

Theory:

The radiation pattern is a graphical representation of the strength of radiation of an antenna as a function of direction. The strength of radiation is usually measured in terms of field strength although sometimes radiation intensity (power radiated per unit solid angle) is also used. For the purpose of radiation pattern, one considers the given antenna to be located at the origin of a spherical polar coordinates systems (r,θ,φ) and the variation in the field strength at different points on an imaginary concentric spherical surface of radius r is noted. For sufficiently larger r, as explained later on, the field variation or the pattern is independent or r and also the fields are tangential to the hypothetical spherical surface. In general, separate patterns are plotted for θ and φ polarization.

Usually the radiation pattern is shown in principal planes of interest. Further, for linearly polarized antennas, patterns may be plotted in E – plane or H – plane E- plane is defined as the plane passing through the antenna in the direction of beam maximum and parallel to the far field E – vector. One defines the H – plane similarly. It is quite common to plot the pattern by normalizing the field values with respect to the field strength in the direction of maximum radiation.

The radiation pattern of typical microwave antennas consists of a main lobe and a few minor or side-lobes. Beam-width of an antenna is defined as the angular separation between 3 dB points with respect to the maximum field strength. Side lobes represent a loss and leakage of information in the transmit mode. In the receive mode, side lobes may cause an uncertainty in determining the angle of arrival of a signal. However, side lobes are very sensitive to the surroundings in which the radiation pattern is measured.

The wave fronts in the vicinity of an antenna have a small radius or curvature but after traveling some distance the radius of curvature increases to such an extent as to make the wave front practically a plane wave. A receiving antenna is considered to be in the far-field of the test antenna if the wave front across it is practically plane. Most measurements are carried out in the far field region since; otherwise, when the receiving antenna is kept in the region of curved waveform, there will be a phase difference across the receiving aperture. It can be shown that the phase variation over the receiving aperture is less than one sixteenth of a wavelength if it is at a distance R from the transmitting antenna, where

$$R = \frac{2D^2}{\lambda}$$

In which D = largest dimension of the receiver and transmitter antennas.

Experimental set up:

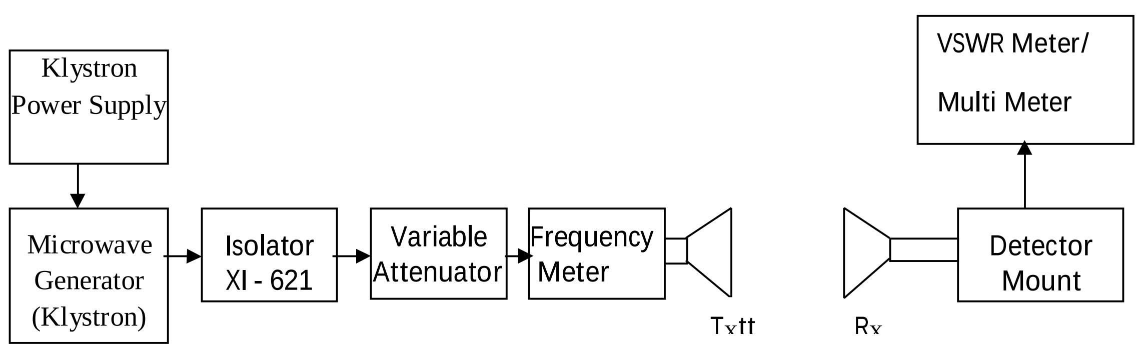


Fig.6.1 Experimental set up to obtain the antenna gain & radiation pattern

Model Graph:

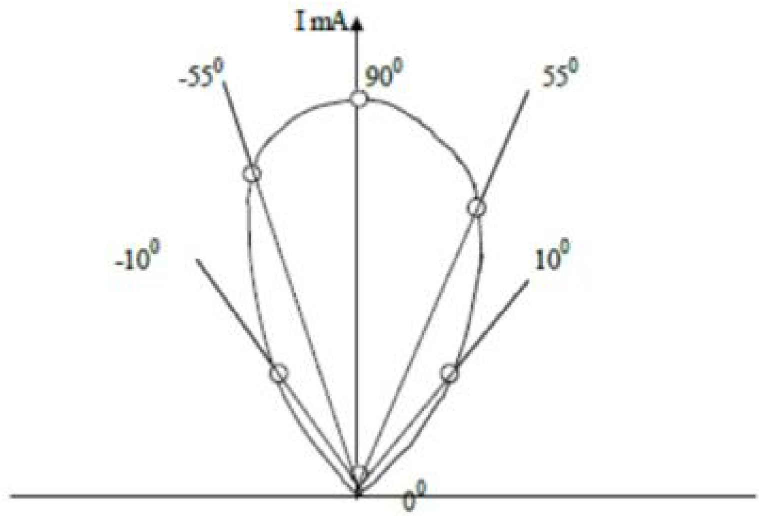


Fig.6.2 Radiation pattern of horn antenna

Procedure:

Antenna Radiation Pattern:

1. Set up the equipments as shown in Fig.6.1.
2. Keep variable attenuator at maximum position.
3. Keep the Control knobs of VSWR meter as below:
    a. Range dB ------ 40dB/50dB
    b. Input Switch ------ Impedance Low
    c. Meter Switch ------ Normal
    d. Gain (Coarse-Fine) ------ Mid position approximately
4. Keep the Control knobs of Klystron Power Supply as below:
    a. Meter Switch ------ OFF
    b. Mod Switch ------ ‘AM’
    c. Beam Voltage Knob ------ Fully Anti-Clockwise
    d. Reflector Voltage Knob ------ Fully Clockwise
    e. AM Frequency and Amplitude knob ------ Mid position approximately
5. ‘ON’ the Klystron Power Supply, VSWR Meter and Cooling Fan.
6. Turn the Meter Switch of Klystron Power Supply to beam voltage position and set the beam voltage between 240V to 300V.
7. Keep the axis of both antennas in same line and the receiving antenna at 0^0 in the scale of receiving antenna mount.

8. Obtain full scale deflection at any convenient range switch position of the VSWR meter by gain control knob of VSWR meter or by Variable attenuator.
9. Rotate the receiving antenna to 360^0 in steps of 5^o and note down the corresponding power reading in normal dB range. When necessary change range switch to next higher range.
10. Plot the relative power pattern vs. angle.
11. From the diagram determine 3 dB width (beam width) of the horn antenna.

Gain Measurement:

12. Set the various components and instruments as per the block diagram.[remove the Horn antennas & connect only Detector mount]
13. Switch on the Klystron Power Supply Unit and VSWR
14. Set the beam voltage between 240V to 300Vand adjust Repeller voltage for maximum deflection in VSWR meter. Measure the power reading (P_t)
15. Now disconnect the Detector mount and connect the antenna in place of Detector mount for which the gain to be measured. Keep the radial distance (S) between the antennas as 10cm.
16. Measure the received power (P_r) by aligning the antennas at 0^0
17. Find the frequency of oscillation in frequency meter and obtain value of λ_0

    We have, $\lambda_0 = \frac{C}{f}$; $C= 3*10^8$ m/s

18. Calculate the gain G using the formula $G = \frac{4\pi S}{\lambda_0}\sqrt{P_r/P_t}$

Observations:

For Half Power Beam Width:

Table 6.1 Tabular column to observe the Half Power Beam Width:

S.NO	Angle of rotation (90 + or 90-) Degrees	Output Power dB
1	0^0	
2	$+10^0$	
3	$+20^0$	
4	$+30^0$	
5	-10^0	
6	-20^0	
7	-30^0	

Half Power Beam Width (2θ) = ____degrees

For Gain Measurement:

Radial Distance between horns S = 10cm.

Frequency, f= ____G Hz

⟹ λ_0= C / f = ____cm [Where C=3*10^8 m/s]

P_t = ______ dB

P_r = ____ dB

Where P_r and P_t are receiving and transmitting powers in dB.

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

$G\ dB = 10\log(G)$ = ______ dB

Result:

Model Viva Questions:

1. List the applications of horn antenna.
2. Write the salient feature of horn antenna?
3. List the types of horn antenna.
4. Give the radiation resistance of short monopole horn antenna.
5. Write the relation for radiation resistance of short dipole.
6. What is power pattern?
7. What is field pattern?
8. What is the difference between polar plot and rectangular plot?
9. What is the difference between isotropic and Omni directional pattern?
10. The side lobe level of an antenna is 20dB down. Explain?
11. For a high directional antenna FBR must be……?
12. What antenna reciprocity?
13. Explain the terms bi-directional pattern and Uni-directional pattern?
14. In radiation pattern measurement experiment how you increase transmitted peak power using PIN diode?
15. What is the relation for patch area illuminated by an antenna in a scan?

Additional Experiments

Experiment-1(a)

SETTING UP A FIBER OPTIC ANALOG LINK

Objective: To study a 660 nm/ 950 nm Fiber Optic Analog Link. In this experiment you will study the relationship between the input signal & received signal.

Equipment Required:

1. Link - A fiber optic trainer kit.
2. 20 MHz Dual Trace Oscilloscope.
3. 1 Meter Fiber cables.
4. Power supply.

Experimental set up:

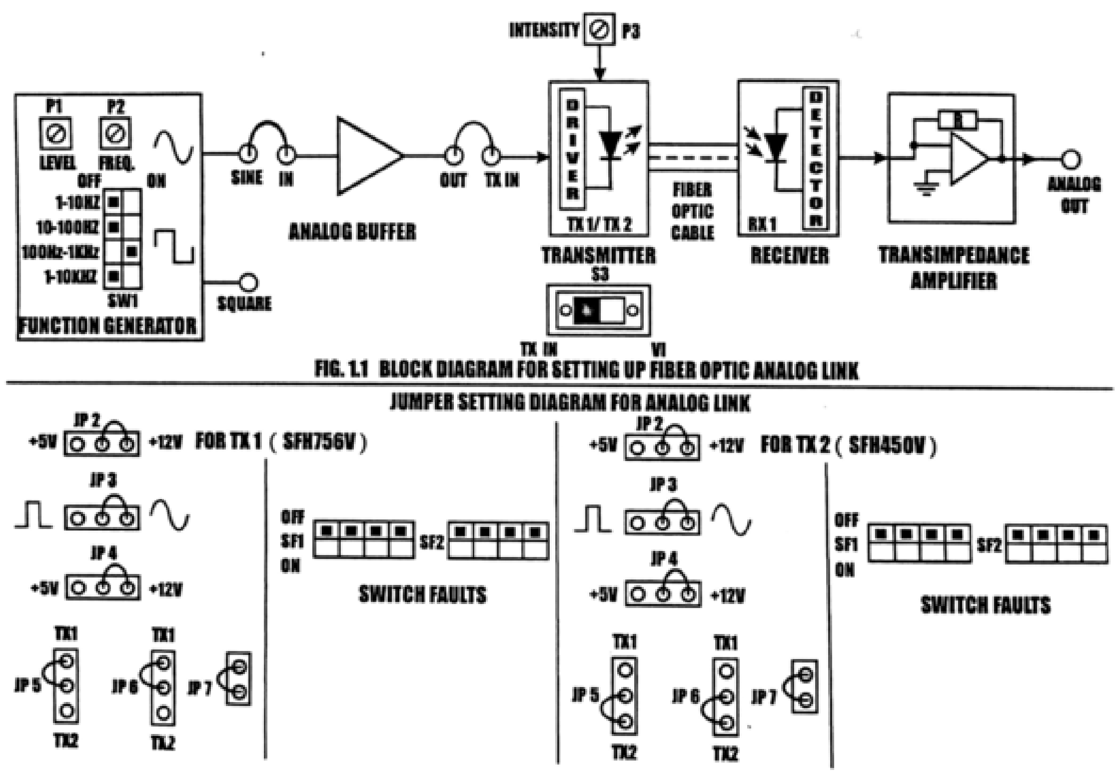
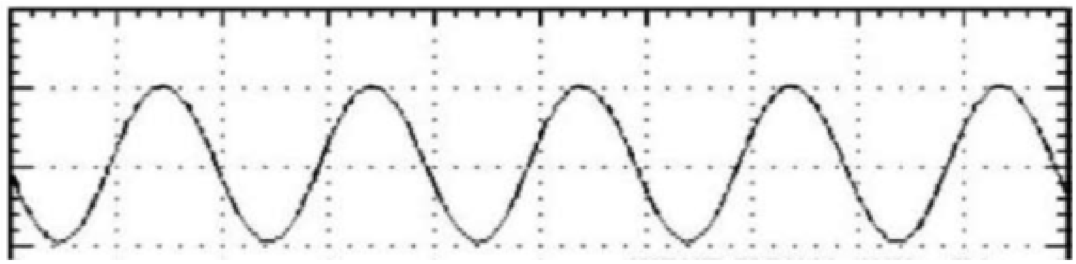
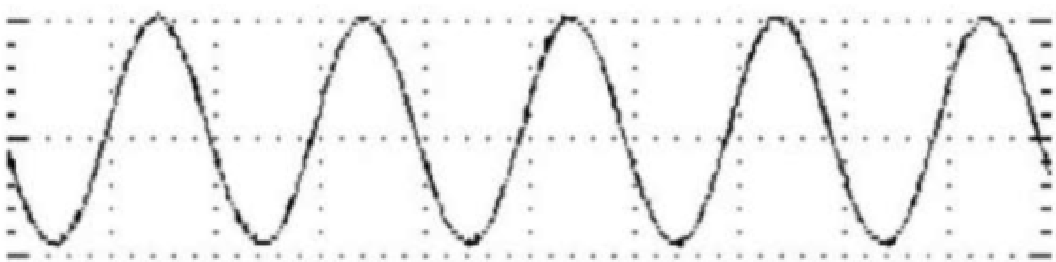


Fig 1.1 Experimental set up for Analog Link

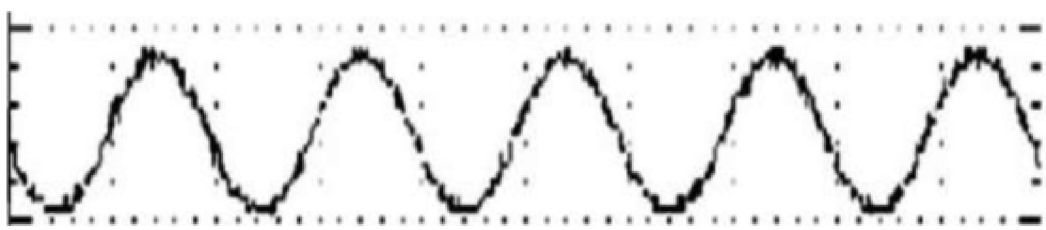
Model Graphs:



Input Signal 1 KHz, 2Vpp



Detected signal (for 660nm Source)



Detected signal (for 950nm Source)

Fig 1.2 Expected Analog input and Output waveforms

Procedure:

1. Make the connections and Jumper settings as shown in block diagram Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF.
2. Keep all the switch faults in OFF position.
3. Switch on the power supply.
4. Select the frequency range of Function Generator with the help of Range Selection Switch SW1, frequency can be varied with Pot P2. Adjust the voltage LEVEL of the

Sine Wave with Pot P1 as per following setting. FREQUENCY:1KHz, LEVEL: 2Vpp.

5. Connect SINE post of the Function Generator section to IN post of Analog Buffer Section.
6. Keep Jumpers JP2 & JP4 towards +12V position, JP3 towards sine position, JP5 towards TX1 position, JP6 towards TX1 position & JP7 shorted.
7. Keep switch S3 towards TX IN position.
8. Connect OUT post of the Analog Buffer Section to TX IN post of TRANSMITTER. Slightly unscrew the cap of LED SFH 756V TX1 (660 nm) from kit. Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap and assure that the fiber is properly fixed. Now tight the cap by screwing it back. Keep INTENSITY pot P3 at minimum position i.e. fully anticlockwise.
9. Connect the other end of the fiber to detector SFH 250V (RX 1) in kit very carefully.
10. Check the output signal of the Analog Buffer at its OUT post in Kit. It should be same as that of the applied input signal.
11. Observe the output signal from the detector at ANALOG OUT post on CRO by adjusting INTENSITY (Optical Power Control) Pot P3 in kit and you should get the reproduction of the original transmitted signal.
12. To measure the analog bandwidth of the link, connect the external Signal Generator with 2Vp-p sine wave to IN post of Analog Buffer Section and vary the frequency of the input signal from 100 Hz onwards. Measure the amplitude of the received signal for each frequency reading.
13. Plot a graph of gain / Frequency. Measure the frequency range for which the response is flat.
14. Keep Jumpers JP5 & JP6 towards TX2 position.
15. Remove Fiber from TX1. Slightly unscrew the cap of LED SFH 450V TX2 (950 nm) fromkit. Do not remove the cap from the connector. Once the cap is loosened, insert the fiber intothe cap and assure that the fiber is properly fixed. Now tight the cap by screwing it backs. KeepINTENSITY pot P3 at minimum position i.e. fully anti clockwise.
16. Check the output signal of the Analog Buffer at its OUT post in Kit. It should be same as that ofthe applied input signal.

17. Observe the output signal from the detector at ANALOG OUT post on CRO by adjustingINTENSITY (Optical Power Control) Pot P3 in kit and you should get the reproduction ofthe original transmitted signal.
18. To measure the analog bandwidth of the link, connect the external Signal Generator with 2Vp-psine wave to IN post of Analog Buffer Section and vary the frequency of the input signal from100Hz onwards. Measure the amplitude of the received signal for each frequencyreading.
19. Plot a graph of gain / Frequency. Measure the frequency range for which the response is flat.

Precautions:

1. Should not deform the optical fiber.
2. Do not apply more pressure while connecting fiber cable to TX and RX.
3. Connect the power supply connector carefully.

Result:

Experiment-1(b)

SETTING UP A FIBER OPTIC DIGITAL LINK

Objective: To study 950nm and 660 nm fiber optic digital link. Here you will study how digital signal can be transmitted over fiber cable and reproduced at the receiver end.

Equipment Required:

1. Link - A kit.
2. 20 MHz Dual Trace Oscilloscope.
3. 1 Meter Fiber cables.
4. Power supply.

Experimental set up:

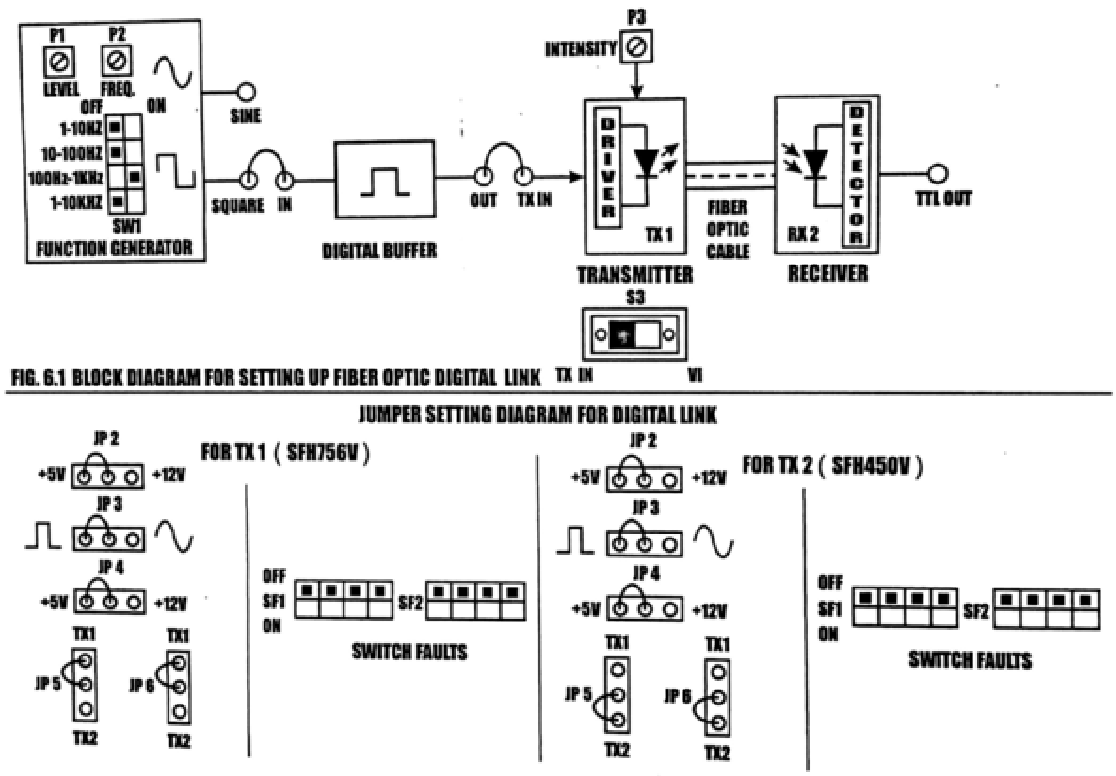
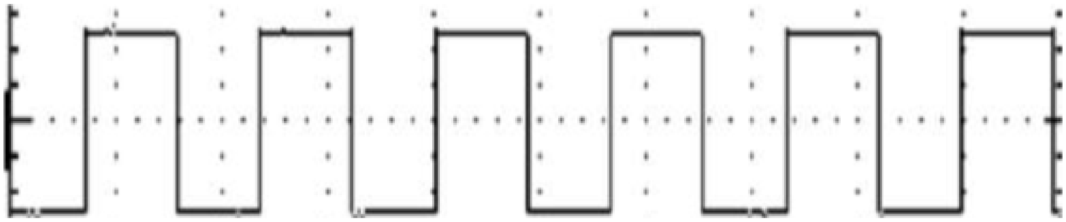
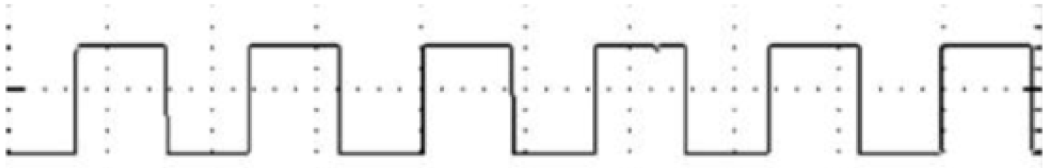


Fig 1.1 Experimental set up for Digital link

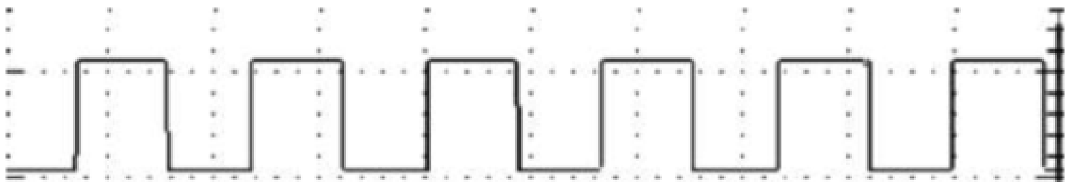
Model Graph:



Input Signal 1 KHz, 2Vpp



Detected signal for (660nm Source)



Detected signal for (660nm Source)

Fig 1.2 Expected Digital input and Output waveforms

Procedure:

13. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF. Now switch on the power supply.
14. Keep all the switch faults in OFF position.
15. Keep Jumpers JP2 & JP4 towards +5V position, JP3 towards pulse position, JP5 & JP6 towards TX1 position.
16. Keep Switch SW1 at 100 Hz - 1 kHz.
17. Feed the Onboard Square (TTL) signal of about 1 KHz to IN post of Digital Buffer Section and observe the signal at its OUT post. It should be same as that of the input signal.
18. Connect OUT post of the Digital Buffer Section to TX IN post of TRANSMITTER. Slightly unscrew the cap of LED SFH 756V (660 nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.

19. Connect the other end of the fiber to detector SFH 551V RX2 (Digital Detector) very carefully.
20. Keep Switch S3 in TXIN position.
21. Observe the received signal on CRO at TTL OUT post. The transmitted signal & received signal are same. Vary the frequency of the input signal and observe the output response.
22. Keep Jumpers JP5 & JP6 towards TX2 position.
23. Remove fiber from TX 1 and connect to TX 2 (SFH 450V (950 nm).-
24. Observe the received signal on CRO at TTL OUT post.

Precautions:

1. Should not deform the optical fiber.
2. Do not apply more pressure while connecting fiber cable to TX and RX.
3. Connect the power supply connector carefully.
4. Connect the jumpers more carefully.

Result:

Model Viva Questions:

1. Which type of oscillator is used in the function generator used in this experiment?
2. Which type of amplifier is used in the function generator used in this experiment?
3. What is the buffer? Explain its significance in this experiment?
4. Which type of modulation is used in the given kit?
5. Give the range of radiation intensity in the given kit?
6. What is your observation in the used in this experiment?
7. List the various applications of fiber optic analog and digital link.
8. What is the effect of fiber joint on the transmission?
9. It is possible to join two fibers with different radius of core for transmission?
10. How cross section of optical fiber effects the transmission?

Experiment-2

STUDY OF FREQUENCY MODULATION & DEMODULATION USING FIBER OPTIC LINK

Objective: To study Frequency Modulation & Demodulation over Fiber Optic Link using 660 nm and 950 nm LED.

Equipment Required:

1. Link - A Fiber Optic trainer kit.
2. 20 MHz Dual Trace Oscilloscope.
3. 1 Meter Fiber cables.
4. Power supply.

Theory:

Frequency modulation (FM) is the standard technique for high-fidelity communications as is evident in the received signals of the FM band (88-108 MHz) vs. the AM band (450-1650 KHz). The main reason for the improved fidelity is that FM detectors, when properly designed, are not sensitive to random amplitude variations which are the dominant part of electrical noise (heard as static on the AM radio). Frequency modulation is not only used in commercial radio broadcasts, but also in police and hospital communications, emergency channels, TV sound, wireless (cellular) telephone systems, and radio amateur bands above 30 MHz.

The basic idea of an FM signal vs. an AM signal is shown in Fig. 1. In an FM signal, the frequency of the signal is changed by the modulation (baseband) signal while its amplitude remains the same. In an AM signal, we now know that it is the amplitude (or the envelope) of the signal that is changed by the modulation signal.

Experimental set up:

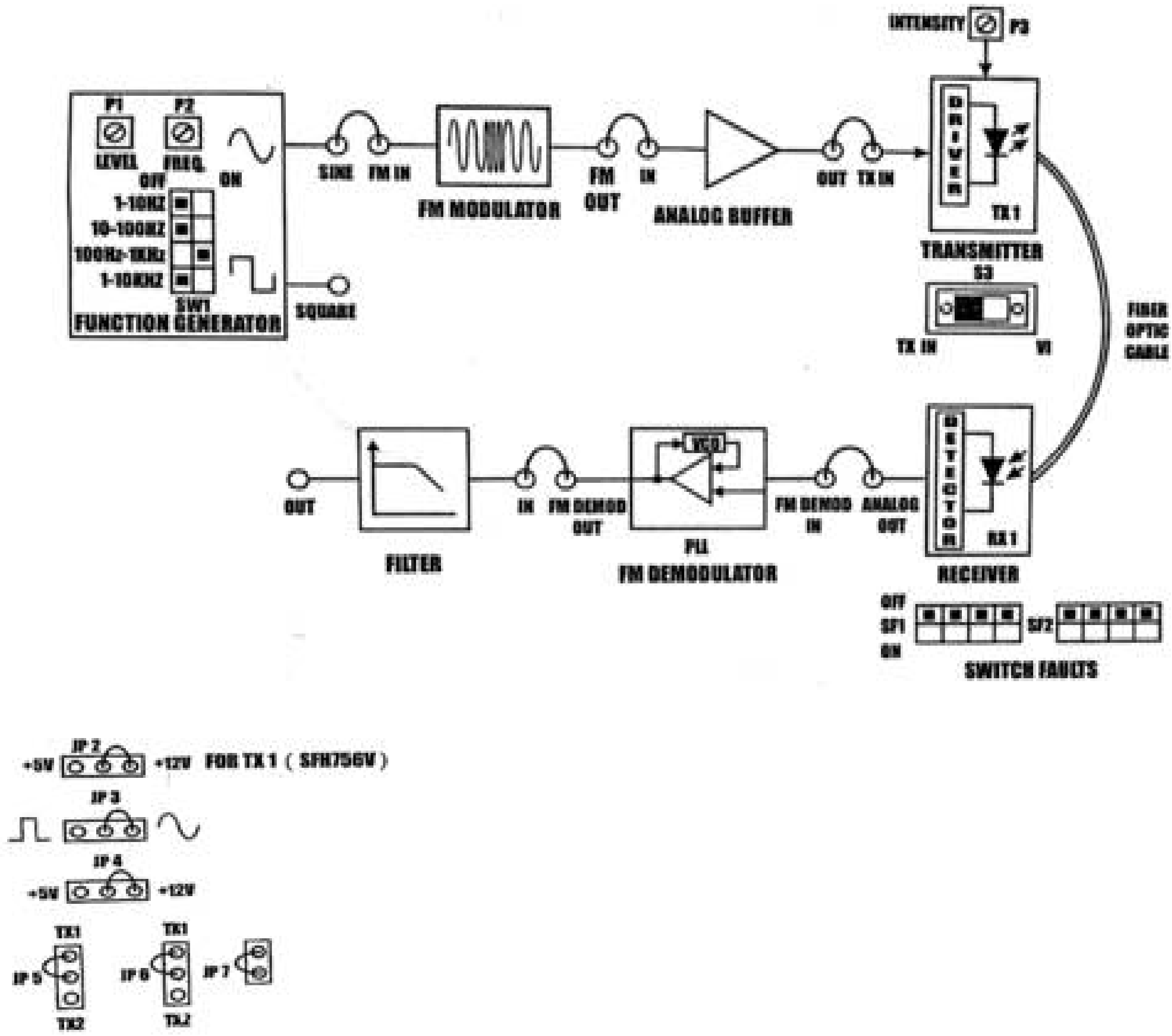
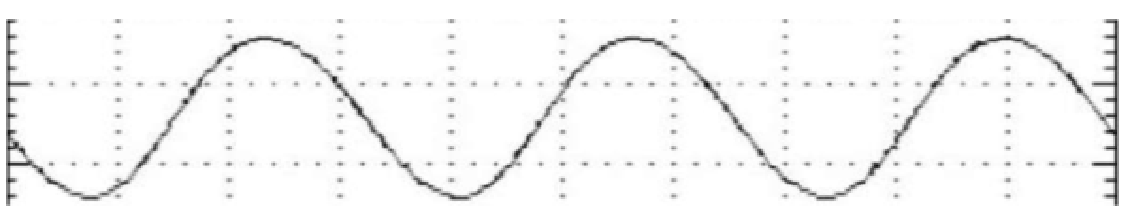
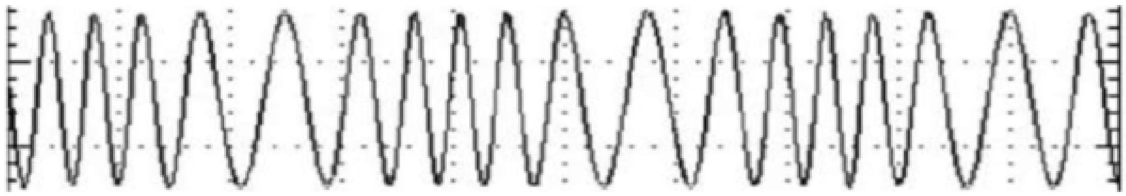


Fig 2.1 Experimental setup for Frequency Modulation and Demodulation Using fiber Optic Link

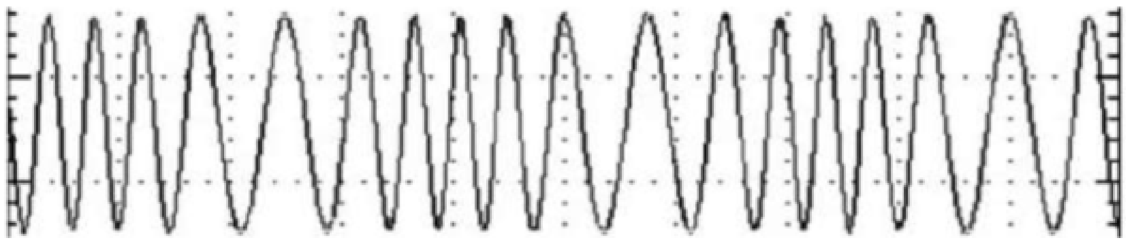
Model Graphs:



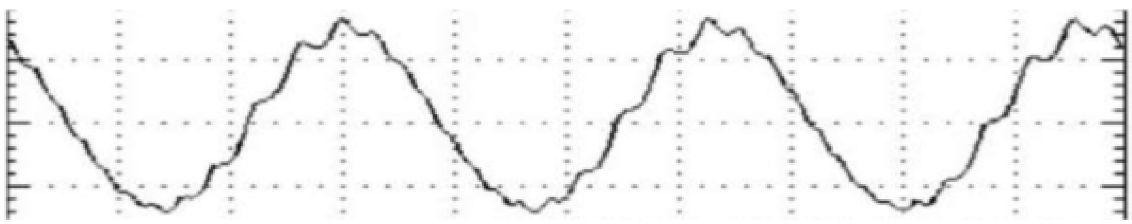
Input Signal 1 KHz, 2Vpp



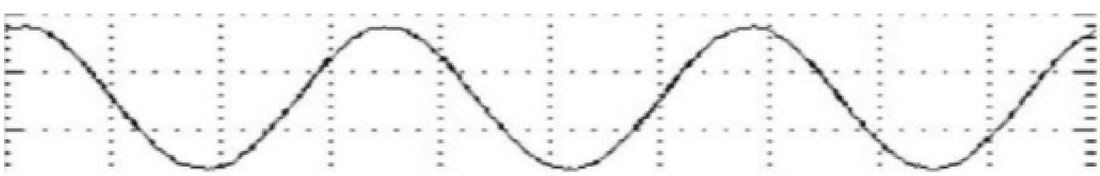
Frequency Modulated output



Detected analog output signal



Frequency Demodulated output



Filter output

Fig 2.2 Expected waveforms

Procedure:

1. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF.
2. Keep all the switch faults in OFF position.
3. Select the frequency range of about 1 KHz from Function Generator with the help of Range Selection Switch SW 1, frequency can be varied with Pot P2. Adjust the voltage LEVEL of the Sine Wave to 2Vp-p with Level Pot P1.

4. Keep Jumpers JP2 towards +12V position, JP3 towards sine position, JP5 & JP6 towards TX1 position & JP7 shorted.
5. Keep switch S3 towards TX IN position.
6. Connect SINE post of the Function Generator section to FM IN post of FM Modulator Section.
7. Connect FM OUT post section of FM Modulator section to IN post of Analog Buffer Section.
8. Connect OUT post of the Analog Buffer Section to TX IN post of TRANSMITTER. Slightly unscrew the cap of LED SFH 756V TX1 (660 nm) from kit. Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap and assure that the fiber is properly fixed. Now tight the cap by screwing it back. Keep INTENSITY pot P3 at minimum position i.e. fully anti clockwise.
9. Connect the other end of the fiber to detector SFH 250V (RX 1) in kit very carefully. Observe the output signal from the detector at ANALOG OUT post on CRO by adjusting INTENSITY pot P3 & you should get the reproduction of the original transmitted signal.
10. Connect ANALOG OUT in Receiver Transimpedance Amplifier Section to FM DEMOD IN post of FM Demodulator Section.
11. Connect FM DEMOD OUT post to IN post of Filter Section.
12. Observe demodulated signal at FM DEMOD OUT post and then observe output at Filter OUT post which is same as Input signal.

Precautions:

1. Should not deform the optical fiber.
2. Do not apply more pressure while connecting fiber cable to TX and RX.
3. Connect the power supply connector carefully.
4. Connect the jumpers more carefully.

Result:

Model Viva Questions:

1. Define Frequency modulation?
2. What is Frequency deviation?
3. What is carrier swing?
4. What is modulation index or factor in FM?
5. What is the range of band allotted for commercial FM broadcast?
6. What is main advantage of FM over AM?
7. What is main disadvantage of FM?
8. What method is used to compensate low frequency boost?
9. At what stage Pre-emphasis and de-emphasis circuits are used?
10. What is the bandwidth of commercial FM broadcast?
11. State Carson rule?
12. Why Armstrong method of FM is superior to reactance modulator?
13. Differentiate between narrow band FM and wideband FM.

Experiment-3

STUDY OF PULSE WIDTH MODULATION AND DEMODULATION

Objective: To study Pulse Width Modulation and Demodulation over Fiber Optic Digital Link.

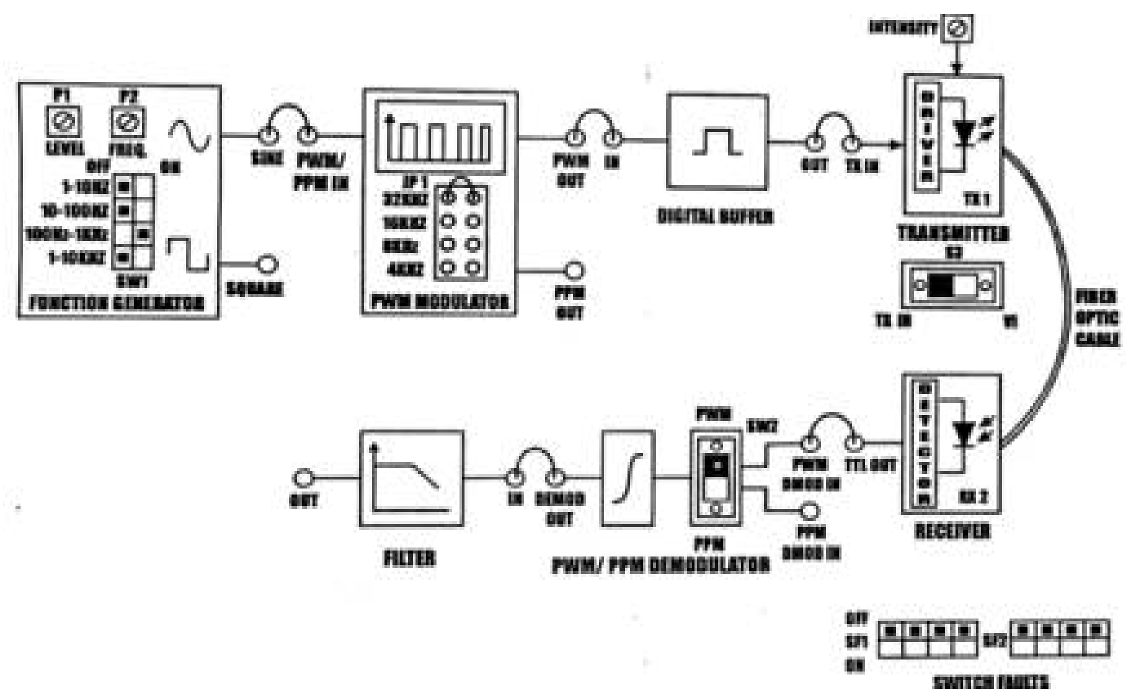
Equipment Required:

1. Link - A Fiber Optic trainer kit.
2. 20 MHz Dual Trace Oscilloscope.
3. 1 Meter Fiber cables.
4. Power supply.

Theory:

The PWM is also known as pulse duration modulation. It modulates the time parameter of the pulses. The width of PWM pulses varies. The amplitude is constant; width of the pulse is proportional to the amplitude of the modulating signal. Bandwidth on transmission channel depends on rise time of the pulse. The demodulation circuit used is a simple filter circuit that demodulator the PWM signal and gives the original message input.

Experimental set up:



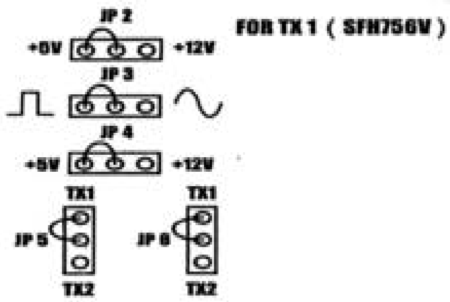
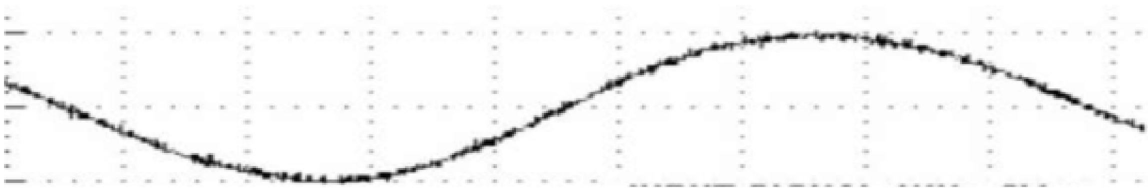


Fig 3.1 Experimental setup for Pulse Width Modulation and Demodulation Using fiber Optic Link

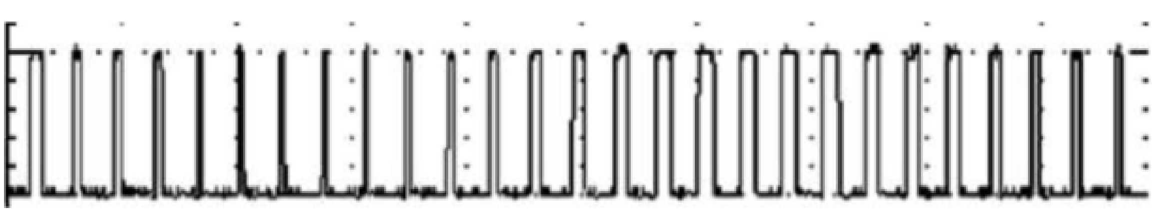
Model Graphs:



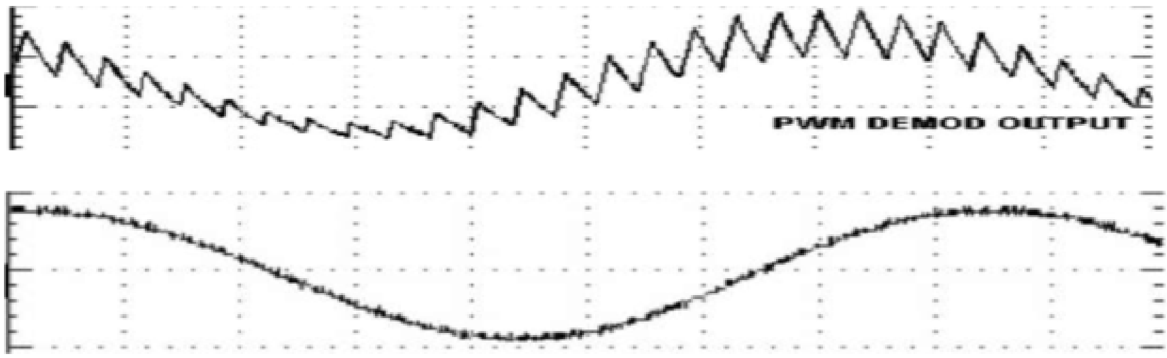
Input Signal 1 KHz, 2Vpp

Pulse Width Modulated Signal Output

Buffer Output



Detected Signal Output



Filter Output

Fig 3.2 Expected Waveforms

Procedure:-

1. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF. Now switch on the power supply.
2. Keep all the switch faults in OFF position.
3. Keep Jumpers JP2 & JP4 towards +5V position, JP3 towards pulse position, JP5 & JP6 towardsTX1 position.
4. Keep Switch SW1 at 100 Hz - 1 kHz.
5. Connect SINE post of the Function Generator section to PWM IN post of PWM/ PPM Modulator Section.
6. Keep sine frequency at 1 KHz & amplitude of 2Vp-p.
7. Keep Jumpers JP1 at 32 KHz position.
8. Observe PWM signal at PWM OUT Post.
9. Connect PWM OUT post of PWM/PPM Modulator Section to IN post of Digital Buffer Section.
10. Connect OUT post of the Digital Buffer Section to TX IN post of TRANSMITTER.
11. Slightly unscrew the cap of SFH756V (660 nm). Do not remove the cap from the connector.
12. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.
13. Keep Switch S3 in TXIN position.
14. Connect the other end of fiber to detector SFH551V (Digital Detector) very carefully.

15. Observe the received signal over fiber at TTL OUT post. It should be exactly similar to the signal available at PWM OUT post.
16. Slide the switch SW 2 to PWM position.
17. Connect this TTL OUT post to PWM DEMOD IN Post in PWM / PPM Demodulator Section.
18. Vary input freq. POT P2 and observe demodulated signal at DEMOD OUT post.
19. Connect PWM / PPM DEMOD OUT post to IN post of Filter Section and observe output at its OUT post which is same as Input signal.
20. For Different Sampling frequencies change the jumper cap of JP1 from 32 KHz to the desired value of frequency. You can observe the PWM output clearly at lower sampling frequency, demodulated PWM OUT is more distorted at lower sampling frequency.

Precautions:

1. Should not deform the optical fiber.
2. Do not apply more pressure while connecting fiber cable to TX and RX.
3. Connect the power supply connector carefully.
4. Connect the jumpers more carefully.

Result:

Model Viva Questions:

1. What is Pulse Width Modulation?
2. What are the other names for PWM?
3. Why is PWM used rarely in any sort of communication or broadcasting?
4. Where does PWM technology find its applicability?

Experiment-4

STUDY OF PULSE POSITION MODULATION AND DEMODULATION

Objective: to study Pulse Position Modulation and Demodulation over Fiber Optic Digital Link.

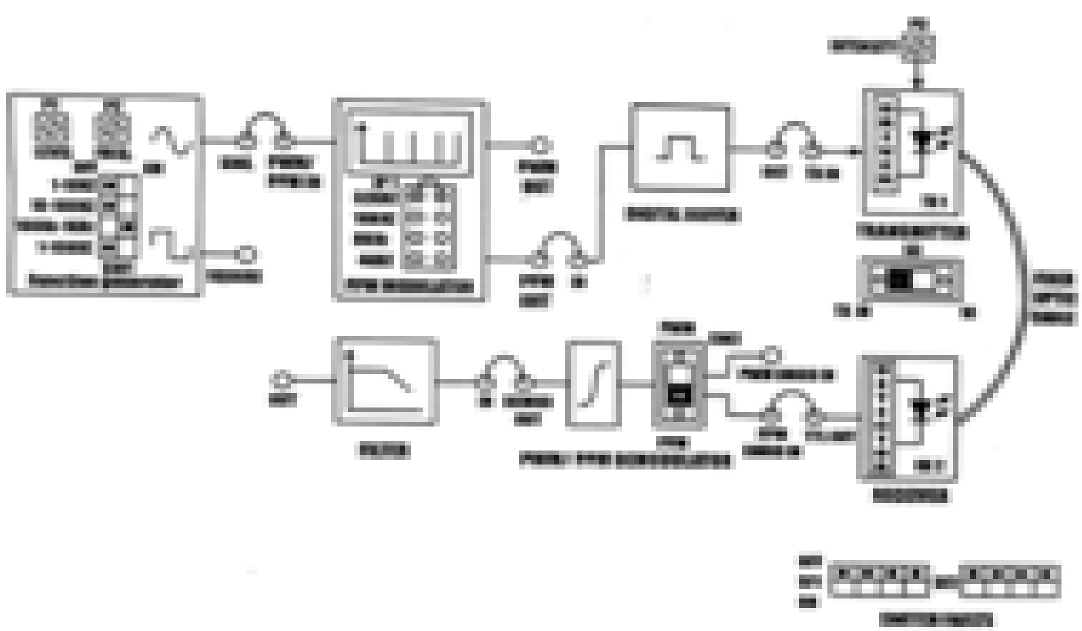
Equipment Required:

1. Link - A Fiber Optic trainer kit.
2. 20 MHz Dual Trace Oscilloscope.
3. 1 Meter Fiber cables.
4. Power supply.

Theory:

In Pulse Position Modulation, both the pulse amplitude and pulse duration are held constant but the position of the pulse is varied in proportional to the sampled values of the message signal. Pulse time modulation is a class of signaling techniques that encodes the sample values of an analog signal on to the time axis of a digital signal and it is analogous to angle modulation techniques. The two main types of PTM are PWM and PPM. In PPM the analog sample value determines the position of a narrow pulse relative to the clocking time. In PPM rise time of pulse decides the channel bandwidth. It has low noise interference.

Experimental set up:



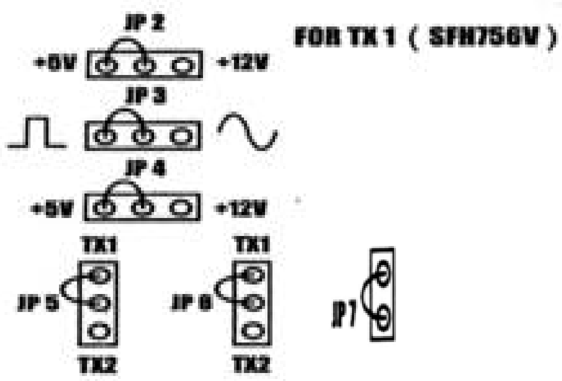
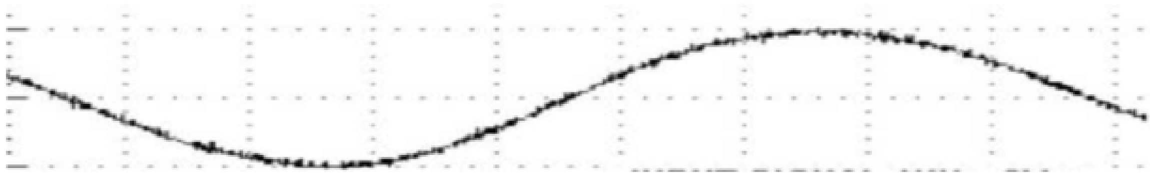
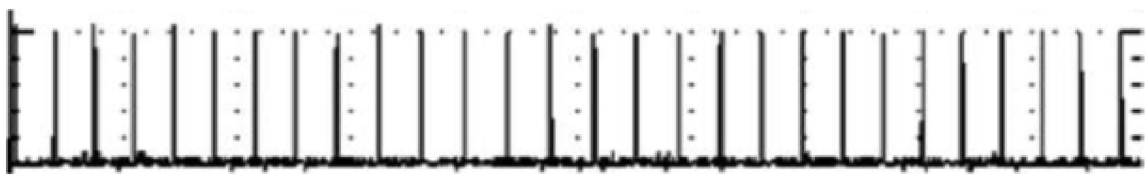


Fig 4.1 Experimental setup for Pulse Position Modulation and Demodulation Using fiber Optic Link

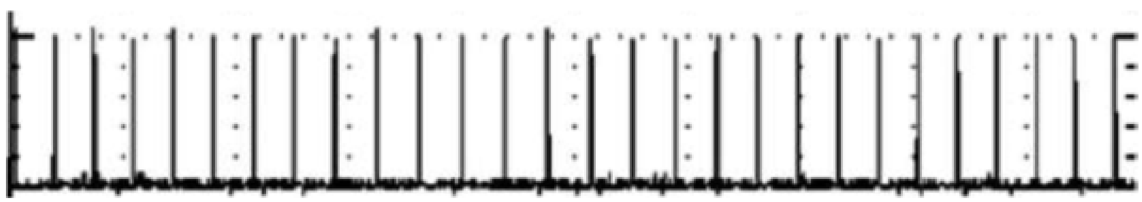
Model Graphs:



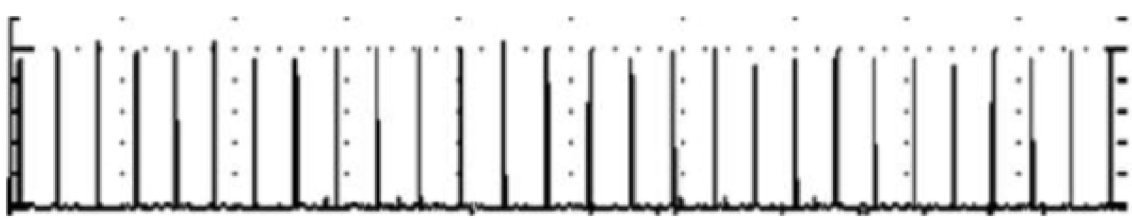
Input Signal 1 KHz, 2Vpp



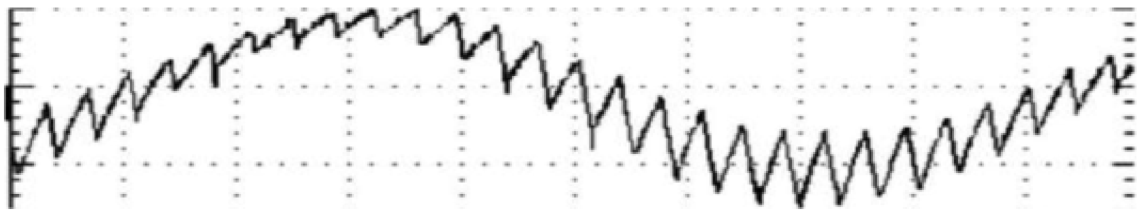
Pulse Position Modulated Signal Output



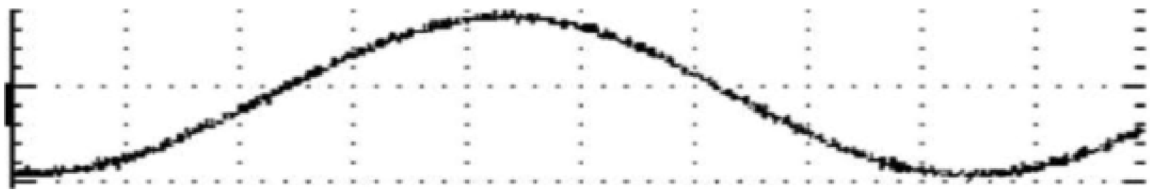
Buffer Output



PPM DMOD Output



Detected Signal Output



Filter Output

Fig 4.2 Expected Waveforms

Procedure:

1. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF.
2. Keep all the switch faults in OFF position.
3. Keep Jumpers JP2 & JP4 towards +5V position, JP3 towards pulse position, JP5 & JP6 towards TX1 position.
4. Keep Switch SW1 at 100 Hz - 1 kHz.
5. Connect SINE post of the Function Generator section to PPM IN post of PWM/ PPM Modulator Section.
6. Switch on the power supply.
7. Keep sine frequency at 1 KHz & amplitude of 2Vp-p.
8. Keep Jumpers JP1 at 32 KHz position.
9. Observe PPM signal at PPM OUT Post.
10. Connect PPM OUT post of PWM/PPM Modulator section to IN post of Digital Buffer Section.
11. Connect OUT post of the Digital Buffer Section to TX IN post of TRANSMITTER.
12. Slightly unscrew the cap of SFH756V (660 nm). Do not remove the cap from the connector.
13. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.

14. Keep Switch S3 in TXIN position.
15. Connect the other end of fiber to detector SFH551V (Digital Detector) very carefully.
16. Observe the received signal over fiber at TTL OUT post. It should be exactly similar to the signal available at PPM OUT post.
17. Connect this TTL OUT post to PPM DEMOD IN Post in PWM / PPM Demodulator Section.
18. Slide the switch SW 2 to PPM position.
19. Vary input freq. (not more than 3 KHz) & observe demodulated signal at DEMOD OUT post.
20. Connect DEMOD OUT post to FILTER IN post & observe output at FILTER OUT post which is same as Input signal.
21. For Different Sampling frequencies change the jumper cap of JP1 from 32 KHz to the desired value of frequency.

Precautions:

1. Should not deform the optical fiber.
2. Do not apply more pressure while connecting fiber cable to TX and RX.
3. Connect the power supply connector carefully.
4. Connect the jumpers more carefully.

Result:

Model Viva Questions:

1. Define Pulse Position Modulation?
2. What are the applications of PPM?
3. What is the main advantage of PPM over PAM and PWM?
4. What are the disadvantages of PPM?

Experiment-5

DATA COMMUNICATION THROUGH FIBER OPTIC LINK USING RS 232.

Objective: The objective of this experiment is to connect the RS-232 ports of two computers using Optical Fiber Digital Link, transmit data from one computer over this link and receive the same data on the other computer.

Equipment Required:

1. Link-A Fiber Optic trainer kit with power supply.
2. Patch chords.
3. 1 Meter fiber cable.
4. 9 Pin D connector Cables – 2 Nos.
5. Computers – PC, PC/XT, 386 or 486–two Nos (Minimum Configuration).

Theory:

Microprocessor is a parallel device. It transfers the 8, 16 or 32 bit of data simultaneously over the data lines. The number of data lines depends upon the type of microprocessor used in the system. This is parallel I/O mode of the data transfer.

However in many situations the parallel data transfer is either impractical or impossible. This is very expensive and noisy especially when the distances are large. Also some devices such as CRT or CTD are not designed for parallel I/O. More over in many scientific and industrial process control applications, the devices under control are at the site or plant which may be long enough from control room. In these situations the serial I/O mode is used where in only one bit at a time is transferred over a single cable. This cable may be a normal cable or an optical fiber.

Very important advantage of serial mode of data transfer is that it is inexpensive. Also the data is accurately transferred and received in the link. It is daily practice to put checks for the data and framing it. Uninterrupted data transfer is greatest advantage of serial mode, and exactly this is the reason behind the fact that serial mode is preferred in many applications. This plays vital role in many applications like PC to PC data communication, Industrial Process controls, Robotics, CNC and DNC (Distributed numerical control) and many more. So it is necessary to have some system which will perform serial I/O operation between PC and outside device using optical fiber link. And exactly Link-A fulfills this need. It provides the simplest and powerful way for serial communication through optical fiber. It is very easy to install and use. Also one can enhance its flexibility through software.

FUNCTION OF MAX 232 (RS-232C TRANCEIVER):

The computer communicates from serial com port which is at RS232C levels i.e. at 12V. Transceiver MAX 232 performs the function of converting RS232C signals to TTL levels and vice versa.

HARDWARE SETTINGS:

Switch off the power supply of PC. To perform this expt. the com ports of PC are used. On board 9-pin D-type (female) connectors are provided for interfacing with the PC. Two 9-pin cables with one end clamped with 9-pin D-type female. Connector and the other end connected to 9-pin D-type male connector are provided with this kit. Connect D-type female connector end of one cable to one of the com ports of PC and the 9-pin D-type connector end to CN6 (9-pin D-type connector). Similarly connect other cable to other port and CN7.

Experimental set up:

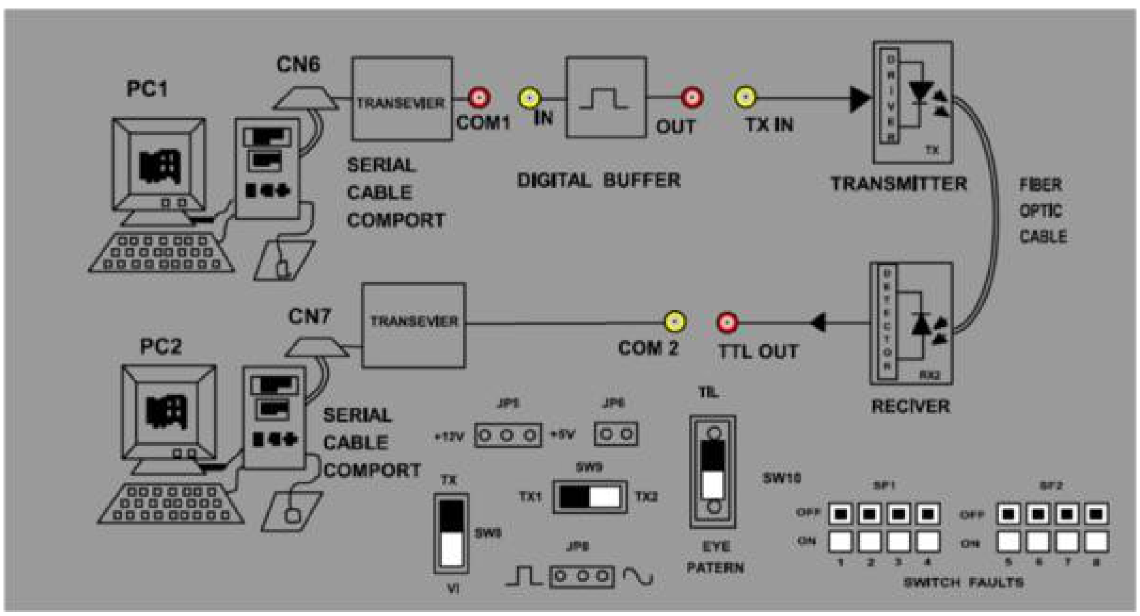


Fig 5.1 Block diagram for setting up pc to pc communication via fiber optic cable

Procedure:

1. Refer to the block diagram & carry out the following connections and settings.
2. Connect the power supply with proper polarity to the kit link-B and switch it on.
3. Keep all Switch Faults in OFF position.

4. Keep switch SW8 towards TX position.
5. Keep switch SW9 towards TX1 position.
6. Keep switch SW10 towards TTL position.
7. Keep Jumper JP5 towards +5V position.
8. Keep Jumpers JP6 shorted.
9. Keep Jumper JP8 towards Pulse position.
10. Connect one end of the 9 to 9 pin cable to PC COM1 port and other end to CN6 connector.
11. Connect second 9 to 9 pin cable one end to second PC COM2 port and other end to CN7 connector.
12. Connect COM1 post on the KIT (RS-232 section) to IN post of Digital Buffer Section.
13. Connect OUT post of digital buffer to TX IN post.
14. Slightly unscrew the cap of SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the one meter fiber into the cap. Now tighten the cap by screwing it back.
15. Connect the other end of the Fiber to detector SFH551V (Photo Transistor Detector) very carefully.
16. Connect detected signal TTL OUT to COM2 post on the KIT (RS-232 section).
17. Switch on the Computers.
18. After putting ON one of the PC, go to START MENU, PROGRAMS, ACCESSORIES, COMMUNICATION and then Click on HYPER TERMINAL.
19. A new Window will open, where you Double Click on HYPERTRM, Two Widows will open, one at the background and another (small window) with title Connection Description which will be Active.
20. Enter the name in the box by which you would like to store your connection, for e.g. (PC2PC) and click OK. Also you could select the Icon provided below. The background window title will change to the name provided by you.

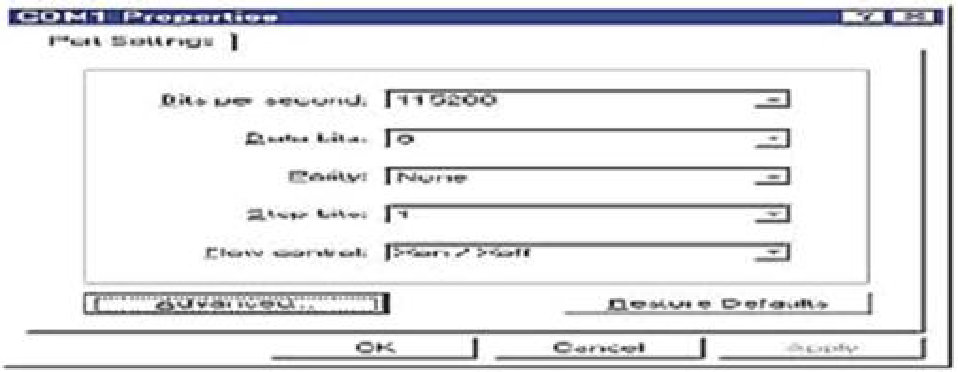
21. Then specify connect using: by selecting Direct to COM1 or port where your cable is connected and then click on OK. See Fig. Now Window with
22. Title COM 1 Properties will appear where Port Setting should be done as shown below and click on OK.

Bits Per Second	:-	Up to 115200
Data Bits	:-	8
Parity	:-	None
Stop Bits	:-	1
Flow Control	:-	Xon / Xoff

23. After the above settings you click OK. The Background window will become Active

24. Click on File, Save As and save it in the Directory, which you want.
25. Perform the same procedure on the computer with whom you want to communicate.
26. To start communication between the two PCs. click on the TRANSFER Menu and again click on Send File. A window will be prompted having title Send File with File

Name and Protocol.



27. Select Browse for the file, which you would like to send to the PC connected, select the file and Click on Open, the file name and address will be displayed in the small window.
28. Then select the Kermit Protocol, (optional use protocols are X modem, Y modem and 1K X modem.)
29. To receive the file on the PC click on the TRANSFER Menu and again click on Receive File. A window will be prompted having title Receive File with Location at which you want to store the Received file and Receiving Protocol.

30. Select Browse for the location where you would like to store the received file, select

the folder and click OK, the folder name and address will be displayed in the small window. Protocol to be selected should be Kermit and same as file transmitting PC.

31. On the PC from which the selected file to be transmitted, click on SEND. A window will open showing file transfer status. Immediately at the Receiving PC Click Receive (otherwise Time Out Error will be displayed and communication will fail) .You will see a window showing file is begin received in the form of packets.
32. After file is transferred, both the windows in the (transmitting & receiving PCs) will close. Check for the received file in the folder where the file is stored.
33. You can do this procedure vice-versa to transfer the file.

Result:

Experiment 6

MEASUREMENT OF ANTENNA CHARACTERISTICS USING XPO-ANT ANTENNA TRAINER

Objective: To understand the basic principles of a given antenna (here Half-Wave Simple Dipole antenna) and practically measure the following characteristics of this antenna:

1 The Radiation pattern (Azimuth XY-plane plot).
2 Antenna Beamwidth.
3 Antenna Front-to-Back ratio.
4 The Gain using standard reference antenna.

NOTE: For gain measurement of this antenna, use folded dipole antenna as reference antenna, the gain of which already measured at previous unit using absolute gain measurement method. The approach is same for all the antennas.

Equipment Required:

1 Two nos. of folded dipole antennas of same physical shape & mounting setup.
2 Half-wave simple dipole antenna.
3 Transmitting Mast with in-built stepper.
4 Receiving mast.
5 RF generator (Model: RF-6).
6 RF power meter (Model: RFM-5M).
7 2 nos. of BNC-to-BNC cable.
8 Antenna graph utility software hardware setup.

Theory:

This antenna contains one half-wave element, means the length of antenna element is one-half of wavelength & hence the name half-wave dipole. Mount this antenna as per your experiments using provided M8x45mm screw & wing nut.

On red-masked base-plate, the element is placed or mounted on its proper location (drills). Rotate this mounted antenna using transmitting mast assembly from 0^0 to 360^0 to get its Radiation pattern.

Gain measurement:

For gain measurement of this antenna, we used reference gain measurement method. In which three antennas are required; one is a reference antenna of known gain (i.e. folded dipole in our case), second is any type of antenna connected at receiving side, whose gain not necessarily to be known (i.e. another folded dipole, but at receiving side) and third is an antenna whose gain is to be measured (i.e. Antenna Under Test, AUT).

Use following equation for measurement of gain using reference antenna method:

$$G_{HWSD}(dBi) = G_{Ref(folded)}(dBi) + [P_{Meas(HWSD)}(dBm) – P_{Ref(folded)}(dBm)] \quad ……(1)$$

Where,

G_{HWSD} = Measured Gain of AUT antenna (in dBi).

$G_{Ref(folded)}$ = Gain of reference Folded dipole antenna

= **24 dBi** (this is measured in previous unit).

$P_{Meas(HWSD)}$ = Power meter reading when AUT is connected at transmitting side (in dBm).

$P_{Ref(folded)}$ = Power meter reading when reference folded dipole antenna is connected at transmitting side (in dBm).

Procedure:

A) Measurement of Radiation pattern:

1 Mount this antenna (used as AUT) on top of the transmitting mast by using holder box connected below the base-plate of antenna and tight with M8x45mm screw & wing nut.
2 Connect output of RF generator to this AUT using BNC-to-BNC cable at BNC input of bottom holder box, which contains balun internally connected between antenna & input BNC socket.
3 Mount a folded dipole Antenna (used as receiving antenna) on top of the receiving mast by using holder box connected below the base-plate of antenna and tight with M8x45mm screw & wing nut.
4 Connect input of RF power meter to receiving antenna using BNC-to-BNC cable.
5 Keep distance of 3m (approx. 10 feet) between transmitting & receiving antennas. And keep both antennas at line-of-sight & facing each-other by considering there sight as 0^0 position.
6 Switch ON both the RF power meter & the RF signal generator.
7 Adjust frequency on RF generator to 500 MHz and set amplitude knob at maximum clock-wise position i.e. maximum amplitude of electro-magnetic wave to be transmitted.

8 Adjust transmitting antenna pointer to 0^0 and take reading on RF power meter (near receiving antenna). Now rotate transmitting antenna in clockwise or anti-clockwise **(use BS5-11 on stepper driver panel for stepper direction control)** with 10^0 angle increment & take corresponding reading on power meter.

9 Now take another reading with angle steps of 10^0, up to 360^0 of complete rotation & note-down the corresponding readings.

10 After taking all readings, fill the below table.

Table 6.1: Rad. pattern observation table of Half-wave simple dipole antenna

Sr. No.	**Angle (degrees)**	**Observed Power (dBm)**
1.	0	
2.	10	
3.	20	
4.	30	
5.	40	
6.	50	
7.	60	
8.	70	
9.	80	
10.	90	
11.	100	
12.	110	
13.	120	
14.	130	
15.	140	
16.	150	
17.	160	
18.	170	
19.	180	
20.	190	
21.	200	
22.	210	
23.	220	
24.	230	
25.	240	
26.	250	
27.	260	
28.	270	
29.	280	
30.	290	
31.	300	
32.	310	
33.	320	

34.	330	
35.	340	
36.	350	

10. Now, plot the polar graph between angle (in degree) versus observed power meter readings (in dBm) on your paper by drawing a polar circle of different radius from minimum to maximum (draw min. & max. radii as per your observations on graph). Means in your all 360^0 observations, you got -56.0dBm as minimum power output & -30.0 dBm as maximum power output, then on polar circle, take first radius as -56.0 (which in minimum) & last will be -30.0 and take radius step as suitable.

NOTE: You can also use “Antenna Graph Utility software” to plot antenna radiation pattern either in ONLINE mode or OFFLINE mode as given below:

i) In ONLINE mode: There are two sections in ONLINE mode, one is ONLINE-AUTO & other is ONLINE-MANUAL. In this ONLINE mode, you can directly interface hardware to antenna PC based software and acquire signal strength at different angular position of transmitting antenna by providing CLOCK signal from software to stepper driver panel to rotate transmitting antenna as per selection of buttons provided on the software, please refer unit-2 for complete hardware wiring & procedure for **“How to use antenna software”** in detail.

ii) In OFFLINE mode: Whatever the data observed as per above procedure for antenna radiation pattern measurement directly fill in the table of antenna software & click the “OK button” on software to plot the antenna radiation pattern.

B) Measurement of Beamwidth:

From the observed radiation pattern of this AUT antenna, find the -3dB power level on center line and draw an arc from center of pattern to -3dB level and then measure the either side angles. Note down that angle as beamwidth of antenna [from fig.6.1]

Beamwidth, θ = ____^{0} (at right side) + ____^{0} (at left side) = ______^{0}.

C) Measurement of Front-to-Back Ratio:

From the observed radiation pattern of this AUT antenna, find the power level of main-lobe (i.e. lobe having more strength) & write it as “Pmaj” and then find power level lobe, which is 180^0 off from main lobe, write it as “Pmin”, then calculate Front-to-Back Ratio using the below equation;

Front-to-Back Ratio = Pmaj – Pmin (in dBm)

= _________dBm.

D) Measurement of Gain:

Use RF Generator (Model: RF-6) for 500MHz RF signal output & RF Power meter (Model: RFM-5M) for measurement of power level in each step.

Follow the given steps to measure the gain of this antenna using folded-dipole antenna as reference:

1. Connect folded dipole antenna on receiving side using on provided receiving mast and connect other folded dipole antenna of known gain (use the same antenna whose gain calculated in previous unit, as reference antenna) on transmitting mast. Keep both antennas in line-of-sight & facing each-other at a distance of 1.5m as shown:

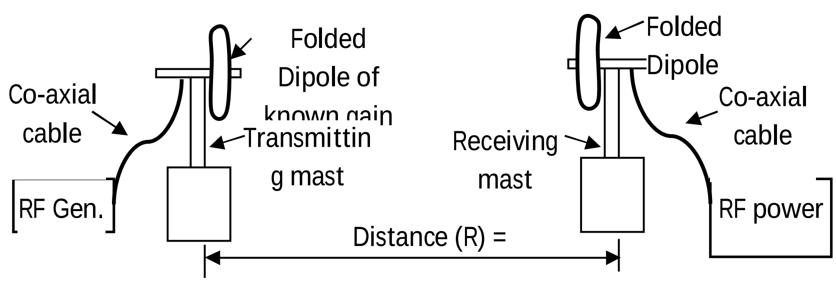


Fig. 6.2 Setup for Measurement of P_{Ref}

2. Set RF generator at 500MHz RF output & connect to transmitting antenna and connect RF power meter to receiving antenna. Do not disturb the setup & location of devices/panels until the completion of experiment. Keep the amplitude knob of signal generator at maximum position, so as to transfer maximum strength of RF signal through transmitting antenna.
3. Now switch ON both RF power meter & RF generator and measure the power meter reading, this is the power reading of reference folded dipole antenna,

i.e. $P_{Ref(folded)}$ = ---------------------- dBm.

4. Without disturbing the above setup, switch OFF both the RF power meter & generator. Now replace the reference folded dipole antenna of transmitting side with AUT antenna facing to folded dipole antenna of receiving side as shown;

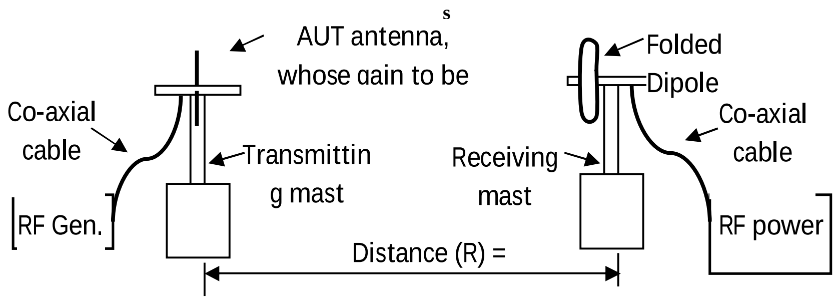


Fig. 6.3 Setup for Measurement of P_{Meas}

5. Now switch ON both the RF power meter & generator. And note down the power meter reading, this is the measured power level of AUT antenna,

i.e. $P_{Meas(HWSD)}$ = ---------------------- dBm.

6. Substitute the measured values in above equation-1;

= G_{HWSD} (in dBi) = 24 (in dBi) + [$P_{Meas(HWSD)}$ (in dBm) – $P_{Ref(folded)}$ (in dBm)]

= ---------------------- dBi.

Result:

Model Viva questions

1. What is an Isotropic radiator?
2. Isotropic radiator is also called as………
3. Define Field strength pattern and Power radiation patterns
4. What is the formula to measure P_{avg}?
5. Define Radian and Steradian
6. Define Radiation intensity
7. Define Directive Gain and Directivity
8. Define Power gain and Radiation Efficiency (Antenna Efficiency)
9. Define Effective aperture
10. Define Beamwidth & Front to Back Ratio
11. Define Antenna Beam Efficiency
12. Define Antenna Bandwidth

Appendix-A

Experiment A.1

STUDY OF HALF-WAVE FOLDED DIPOLE ANTENNA

Objective: To understand the basic principles related to folded dipole antenna and practically measure the following characteristics of folded dipole antenna:

1. The Radiation pattern (Azimuth XY-plane plot).
2. Antenna Beamwidth.
3. Antenna Front-to-Back ratio.
4. The absolute Gain using FRIIS transmission equation.

NOTE: For gain measurement of other antennas provided in this trainer set, a reference gain measurement method is used (you will study this method in next unit) & for this a folded dipole antenna is used as reference. Here in this unit, the gain of folded dipole antenna is measured using absolute gain measurement method to make this antenna as reference for gain measurement of other antenna.

Equipment Required:

1. Two nos. of folded dipole antennas of same physical shape & mounting setup.
2. Transmitting Mast with in-built stepper.
3. Receiving mast.
4. RF generator (Model: RF-6).
5. RF power meter (Model: RFM-5M).
6. 2 nos. of BNC-to-BNC cable.
7. Antenna graph utility software hardware setup.

Theory:

A folded dipole antenna is a half-wavelength ($\lambda/2$) dipole. Means the physical antenna is constructed of conductive elements whose combined length is about half of a wavelength at its intended frequency of operation. This is a simple antenna that radiates its energy out toward the horizon (perpendicular to the antenna).

For gain measurement of folded-dipole, we used the absolute gain measurement method. For this, a FRIIS transmission equation is used as given below:

$$P_R/P_T = G_T * G_R * \left[\frac{\lambda}{4\pi R}\right]^2 \quad \text{......(1)}$$

Where,

P_R = Received power at receiver antenna side (in Watts),

P_T = Transmitted power from transmitter antenna side (in Watts),

G_R = Receiver antenna gain (unit less),

G_T = Transmitter antenna gain i.e. AUT (unit less),

λ= Wavelength of transmitted signal = 60 cm (for 500MHz),

R = Distance between both antennas (in meter).

Then,

$$G_T * G_R = \frac{P_R}{P_T} * \left[\frac{4\pi R}{\lambda}\right]^2 \quad \text{......(2)}$$

Procedure

A) Measurement of Radiation pattern:

1. Mount a folded dipole (λ/2) Antenna (used as AUT) on top of the transmitting mast by using holder box connected below the base-plate of antenna and tight with M8x45mm screw & wing nut.
2. Connect output of RF generator to folded dipole using BNC-to-BNC cable at BNC input of bottom holder box, which contains balun internally connected between antenna & input BNC socket.
3. Mount another folded dipole Antenna (used as receiving antenna) on top of the receiving mast by using holder box connected below the base-plate of antenna and tight with M8x45mm screw & wing nut.
4. Connect input of RF power meter to receiving antenna using BNC-to-BNC cable.
5. Keep distance of 3m (approx. 10 feet) between transmitting & receiving antennas. And keep both antennas at line-of-sight & facing each-other by considering there sight as 0^0 position.
6. Switch ON both the RF power meter & the RF signal generator.

7. Adjust frequency on RF generator to 500 MHz and set amplitude knob at maximum clock-wise position i.e. maximum amplitude of electro-magnetic wave to be transmitted.
8. Adjust transmitting antenna pointer to 0^0 and take reading on RF power meter (near receiving antenna). Now rotate transmitting antenna in clockwise or anti-clockwise **(use BS5-11 on stepper driver panel for stepper direction control)** with 10^0 angle increment & take corresponding reading on power meter.
9. Now take another reading with angle step of 10^0 up to 360^0 of complete rotation & note-down the corresponding readings.

After taking all readings, fill the below table.

Table 3.1 Radiation pattern observation table of Folded dipole antenna

Sr. No	**Angle (degrees)**	**Observed power (dB)**
1.	0	
2.	10	
3.	20	
4.	30	
5.	40	
6.	50	
7.	60	
8.	70	
9.	80	
10.	90	
11.	100	
12.	110	
13.	120	
14.	130	
15.	140	
16.	150	
17.	160	
18.	170	
19.	180	
20.	190	
21.	200	
22.	210	
23.	220	
24.	230	
25.	240	
26.	250	
27.	260	
28.	270	
29.	280	
30.	290	

31.	300	
32.	310	
33.	320	
34.	330	
35.	340	
36.	350	

10. Now, plot the polar graph between angle (in degree) versus observed power meter readings (in dBm) on your paper by drawing a polar circle of different radius from minimum to maximum (draw min. & max. radii as per your observations on graph). Means in your all 360^0 observations, you got -56.0dBm as minimum power output & -30.0 dBm as maximum power output, then on polar circle, take first radius as -56.0 (which in minimum) & last will be -30.0 and take radius step as suitable.

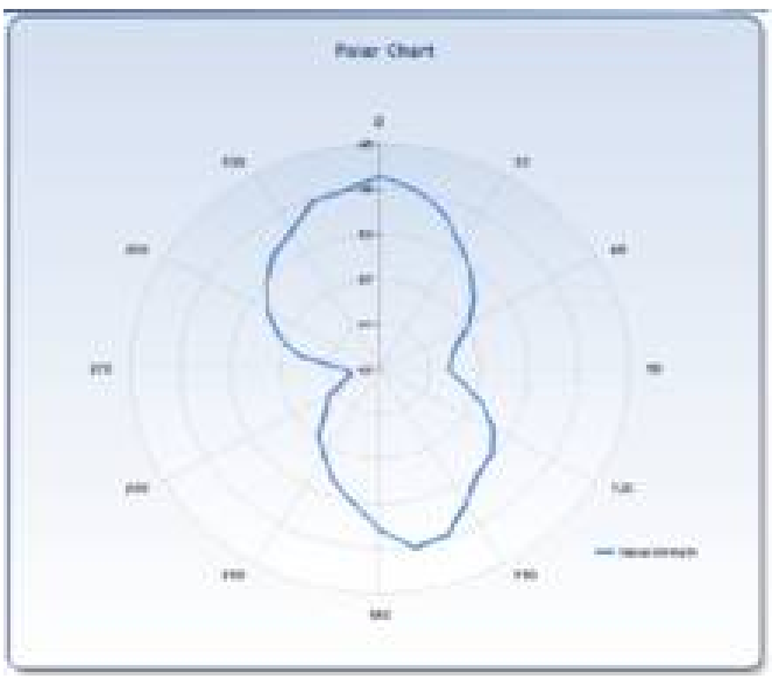


Fig.A.1.1 Radiation pattern of Folded dipole antenna

NOTE: You can also use "Antenna Graph Utility software" to plot antenna radiation pattern either in ONLINE mode or OFFLINE mode as given below:

i) **In ONLINE mode:** There are two sections in ONLINE mode, one is ONLINE-AUTO & other is ONLINE-MANUAL. In this ONLINE mode, you can directly interface hardware to antenna PC based software and acquire signal strength at different angular position of transmitting antenna by providing CLOCK signal from software to stepper driver panel to rotate transmitting antenna as per selection of buttons provided on the software, please refer unit-1 & 2 for complete hardware wiring & procedure for **“How to use antenna software”** in detail.

ii) **In OFFLINE mode:** Whatever the data observed as per above procedure for antenna radiation pattern measurement directly fill in the table of antenna software & click the “PLOT button” on software to plot the antenna radiation pattern.

B) Measurement of Beamwidth:

Follow the given procedure to calculate beamwidth from radiation pattern;

1. From the observed radiation pattern of folded dipole antenna, find the angle at which the signal strength of observed RF signal is maximum.
2. Then from that level, mark -3dB level (towards the center of graph) on center line and draw an arc from center of polar graph to -3dB level.
3. The arc will cut the graph at either side. Then from here, draw straight lines from the arc cut-out on graph to center of graph as shown below.
4. Now measure the either side angles from center line of graph. Note down that angles & add them, this will be the Beamwidth of antenna under test;

Hence, **Beamwidth = θ =** ---------------------- Degree.

= _____degrees (at right side) + _____degrees (at left side)

NOTE: Follow the same procedure as illustrated above for calculation of Antenna Beamwidth for all Antennas Under Test (AUT) provided with the trainer set.

B) Measurement of Front-to-Back Ratio:

The front-to-back ratio is the ratio of the peak gain in the forward direction to the gain 180-degrees behind the peak, while considering the linear scale. But in a dB scale, the front-to-back ratio is just the difference between the peak gain in the forward direction (i.e. maximum gain of main lobe) and the gain 180-degrees behind the peak. **It can be calculated from the observed “Radiation pattern of the antenna under test”.**

Hence, Front-to-back ratio = (Pmaj - Pmin) dBm.

= _________ dBm

Where,

Pmaj = Maximum power level of main-lobe in dBm.

Pmin = Power of minor-lobe or power level at 180^0 behind the main-lobe in dBm.

NOTE: Follow the same procedure as illustrated above for calculation of Antenna Front-to-Back ratio for all Antennas Under Test (AUT) provided with the trainer set.

D) Measurement of Gain:

1. In this absolute measurement of antenna gain, two identical folded dipole antennas are required by considering the gain of each is same as provided with XPO-ANT complete experimental set

   Hence, $G_T = G_R = G$.

2. Use RF Generator (Model: RF-6) for 500MHz RF signal output & RF Power meter (Model: RFM5M) for measurement of power level in each step.
3. Connect dipoles on the provided masts, one as transmitting antenna (Antenna Under Test) & other as receiving or measuring antenna. And keep both antennas at a distance of 5 feet (or 1.5m).

   Hence, R = 1.5m.

4. The value of λ can be calculated for f = 500MHz RF signal as;

   Hence, $\lambda = c / f = (3*10^8) / (5*10^8) = 0.6$m.

Follow the given steps to measure the absolute gain of Folded-dipole antenna using FRIIS equation;

1. Connect the RF power meter directly to the RF generator as shown below & do not ON the RF generator, measure the power meter reading, this is the reference power reading of RF generator without RF input,

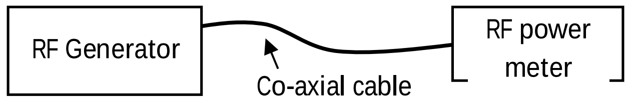


Fig. 3.3 Setup for Measurement of P_T

i.e. $P_{Ref(RF0)}$ = ---------------------- dBm.

Without disturbing the above setup, switch ON the RF generator and set it to 500MHz & set the power meter reading to +2 dBm using amplitude knob of signal generator (means set it to maximum position).

Then the transmitted power can be calculated as,

i.e. $P_T = [+2] - [P_{Ref(RF0)}]$ dBm.

2. Now switch OFF the RF power meter & generator. And connect RF generator to transmitting antenna **(keep it at OFF mode)** & connect power meter to receiving antenna. And keep both antennas in line-of-sight & facing each-other at a distance of 1.5m (approx. 5 feet) as shown below & do not disturb the setup until the completion of experiment.

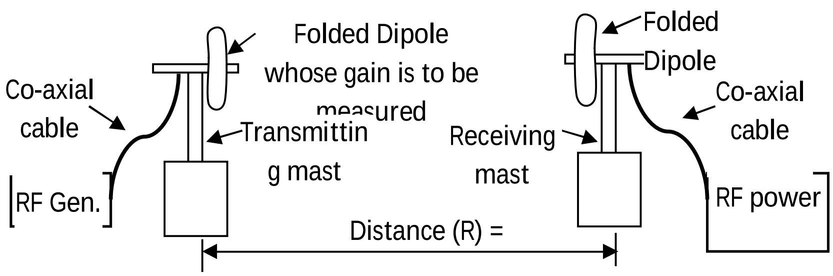


Fig A.1.4 Setup for Measurement of P_R

3. Now switch ON the power meter (when connected with receiving antenna, as in the above setup) & keep RF generator in OFF mode, note down the power meter reading, this is the reference power reading when connected to receiving antenna without RF input,

i.e. P_{Ref} = ----------------------- dBm.

4. At the same setup switch ON the RF generator without disturbing the frequency & amplitude knobs, calculate the measured power (P_{Meas}),

i.e. P_{Meas} = ----------------------- dBm.

Then the received power can be calculated as,

i.e. $P_R = [P_{Meas}] – [P_{Ref}]$ dBm.

= ________dBm

5. Substitute the above measured values in above equation-2 ;

$$G_T * G_R = \frac{P_R}{P_T}\left[\frac{4\pi R}{\lambda}\right]^2$$

As, $G_T = G_R = G$, $R = 1.5$m and $\lambda = 0.6$m

Then,

$$G*G = G^2 = \frac{P_R}{P_T}\left[\frac{(4)*(3.14)*(1.5)}{(0.6)}\right]^2$$

$$\Rightarrow G^2 = \frac{P_R}{P_T}(986.0)$$

$\Rightarrow$ G = -------------------- (Unit-less) = Gain (Measured)

For calculation of Gain in dBi, use equation-1 as,

$$\text{Gain (dBi)} = 10*\text{Log}\left[\frac{Gain\ (Measured)}{Gain\ (Isotropic)}\right]$$

= 10 * Log (G / 1) = 10 * Log (G) = ------------------- dBi.

Result:

Experiment A.2

STUDY OF YAGI UDA ANTENNAS

Objective: To understand the basic principles related to Yagi Uda antenna and practically measure the following characteristics of Yagi-Uda antenna (for 3-elements, 5-elements and 7-elements):

1. The Radiation pattern (Azimuth XY-plane plot).
2. Antenna Beam width.
3. Antenna Front-to-Back ration
4. The Gain using standard reference antenna.

Equipment Required:

1. Two nos. of folded dipole antennas of same physical shape & mounting setup.
2. Yagi Uda antenna (3-elements, 5-elements & 7-elements).
3. Transmitting mast with in-built stepper.
4. Receiving mast
5. 2nos.of BNC-to-BNC cable.
6. RF generator (Model: RF-6).
7. RF power meter (Model: RFM-5M).
8. Antenna graph utility software hardware setup.

Theory:

Yagi Uda antennas contain one folded-dipole antenna, one reflector and no. of the directors as per selection either 3-element or 5-element or 7-element.Mount antennas as per your experiments using provided M8*45mm screw &wing nut.

On red-masked base-plate, the elements of Yagi-uda antenna will be placed or mounted on their proper location (drills) as per below mentioned nomenclatures;

Reflector – YU1, Folded dipole – YU2, Director1 – YU3, Director2 – YU4, Director3 – YU5, Director4-YU6 and Director5-YU7.

Gain Measurement:

For gain measurement of this antenna, we used reference gain measurement method (as in case of Half-wave simple dipole antenna) and calculated the Gain using the following equation;

Use following equation for measurement of gain using reference antenna method;

$$G_{yagi}(dBi)=G_{Ref(folded)}(dBi)+[P_{Meas(yagi)}(dBm)-P_{Ref(folded)}(dBm)] \quad .....(1)$$

Where,

G_{yagi}=Measured Gain of AUT antenna (in dBi).

$G_{Ref(folded)}$=Gain of reference Folded dipole antenna

=24 dBi (this is measured in previous unit).

$P_{Meas(yagi)}$=Power meter reading when AUT is connected at transmitting side.

$P_{Ref(folded)}$=Meter reading when reference antenna at transmitting side (in dBm).

Procedure:

A) Measurement of Radiation pattern:

1. Mount Yagi-Uda antennas one-by-one from 3E to 7E (used AS AUT) on top of the transmitting mast by using holder box connected below the base plate antennas and tight with M8*45mm &wing nut each time.
2. Connect output of RF generator to this AUT using BNC-to-BNC cable.
3. Mount a receiving folded dipole Antenna on top of the receiving mast.
4. Connect input of RF power meter to receiving antenna using BNC-to-BNC cable.
5. Keep distance of 3m (approx.10 feet) between them and keep both antennas at line-of-sight & facing each –other by considering there sight as 0 0 position.
6. Switch on both RF power meter and RF signal generator.
7. Adjust frequency on RF generator to 500 MHz and set amplitude knob at maximum clock-wise position.
8. Adjust transmitting antenna pointer to 0^0 and take reading on RF power meter (near receiving antenna). Now rotate transmitting antenna & take corresponding reading on power meter. Now take another reading with angles of 10^0, up to $360^0$of complete rotation & note down the corresponding readings.
9. After taking all readings, fill the below table.

Table A.2.1: Radiation pattern observation table of Yagi-Uda antennas

Sr.N0.	Angle (in degree)	Observed power (in dBm)		
		3E	5E	7E
1	0			
2	10			
3	20			
4	30			
5	40			
6	50			

7	60			
8	70			
9	80			
10	90			
11	100			
12	110			
13	120			
14	130			
15	140			
16	150			
17	160			
18	170			
19	180			
20	190			
21	200			
22	210			
23	220			
24	230			
25	240			
26	250			
27	260			
28	270			
29	280			
30	290			
31	300			
32	310			
33	320			
34	330			
35	340			
36	350			

10. Now, plot the polar graph between angles (in degree) verses observed power meter readings (in dBm) on your paper or use Graph utility software (in OFFLINE-mode).

Note: Follow the procedures given in unit-1 & 2 for using Graph utility software.

B) Measurement of Beam width:

From the observed radiation pattern of this AUT antenna, find the -3dB power level on centerline and draw an arc from center of pattern to -3dB level and then measure the either side angles. Note down that angle as beam width of antenna;

Beam width=-------------------Degree.

For Yagi-Uda 3E: Beamwidth = θ =___^{0} (at right side) + ___^{0} (at left side) =94^0

For Yagi-Uda 5E: Beamwidth = θ =___^{0} (at right side) + ___^{0} (at left side) =60^0

For Yagi-Uda 7E: Beamwidth = θ =___^{0} (at right side) + ___^{0} (at left side) =39^0

C) Measurement of Front-to-Back Ratio:

From the observed radiation pattern of this AUT antenna, find the power level of main-lobe (i.e. lobe having more strength) & write it as "P_{maj}" and then find power level lobe, which is 1800 off from main lobe, write it a "P_{min}", then calculate Front –to-Back Ratio using the below equation;

Front –to-Back Ratio= P_{maj} - P_{min} (in dBm)---------------dBm.

For Yagi-Uda 3E: Front-to-back ratio = (_____)-(_____) = _____dBm

For Yagi-Uda 5E: Front-to-back ratio = (_____)-(_____) = ____dBm

For Yagi-Uda 7E: Front-to-back ratio = (_____)-(_____) = _____ dBm

D) Measurement of Gain:

Use RF Generator (Model: RF-6) for 500MHz RF signal output & RFPower meter (Model:RFM-5M) for measurement of power level in each step.

Follow the given steps to measure the gain of this antenna using folded-dipole antenna as reference;

Note:Follow same procedure as in case of Half-wave simple-dipole antenna done in previous unit,only some brief procedures are given below;

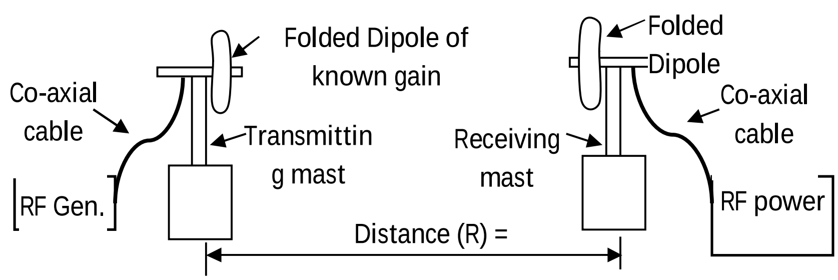


Fig A.2.4 Setup for Measurement of P_{ref}

1. Connect folded dipole antenna on receiving side and connect other folded dipole antenna of known gain on transmitting mast.

2. Set RF generator at 500MHz RF output & keep the amplitude knob of signal generator at maximum position and connect to transmitting antenna and connect RF power meter to receiving antenna.
3. Now switch ON both RF power meter & RF generator and measure the power meter reading, this is the power reading of reference folded dipole antenna,

i.e.$P_{Ref(folded)}$=------------------dBm.

4. Without disturbing the above setup, switch OFF both the RF power meter & generator. Now replace the reference folded dipole antenna of transmitting side with Yagi Uda antenna (3E to 7E one-by-one) facing dipole antenna of receiving side as shown;

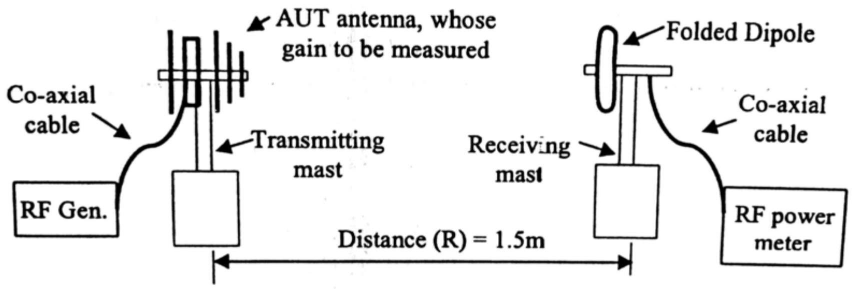


Fig A.2.5 Setup for Measurement of P_{Meas}

5. Now switch ON both the Rf power meter & generator.And notedown the power meter reading(s),this is measured power level of :Yagi Uda antenna,

i.e. $P_{Meas(yagi-3E)}$=---------------dBm

i.e. $P_{Meas(yagi-5E)}$=---------------dBm

i.e. $P_{Meas(yagi-7E)}$=---------------dBm

6. Substitute the measured values in above equation-1 for different elements Yagi-Uda antenna;

i.e. G_{yagi}(in dBi)=$G_{Ref(folded)}$(in dBi)+[$P_{Meas(yagi)}$(in dBm)-$P_{Ref(folded)}$(in dBm)]

= G_{yagi}(in dBi) = 24(in dBi)+[$P_{Meas(yagi)}$(in dBm)-$P_{Ref(folded)}$(in dBm)]

For Yagi-Uda antennas of different elements, the Gain will be;

$G_{yagi(3E)}$(in dBi)=24(in dBi)+[$P_{Meas(yagi-3E)}$(in dBm)-$P_{Ref(folded)}$(in dBm)]

$G_{yagi(5E)}$(in dBi)=24(in dBi)+[$P_{Meas(yagi-5E)}$(in dBm)-$P_{Ref(folded)}$(in dBm)]

$G_{yagi(7E)}$(in dBi)=24(in dBi)+[$P_{Meas(yagi-7E)}$(in dBm)-$P_{Ref(folded)}$(in dBm)]

Result: