



# **Sri Shanmugha College of Engineering and Technology**

**Approved by AICTE, New Delhi and Affiliated to Anna University,  
Chennai**

**Accredited by NAAC and NBA (ECE/CSE/MECH)**

**Pullipalayam, Sankari, Salem (Dt.)**



## **Department of Electronics and Communication Engineering**

### **LAB MANUAL**

**SUBJECT CODE/ NAME:**

**REGULATION :**

**YEAR /SEMESTER :**

**DEPARTMENT :**

**Prepared by**  
**(M.Dhivyaa, AP/ECE)**

## **Syllabus**

**EC8761**

**ADVANCED COMMUNICATION LABORATORY**

**L T P C 0 0 4 2**

### **OBJECTIVES:**

**The student should be made to:**

- ❖ Understand the working principle of optical sources, detector, fibers.
- ❖ Develop understanding of simple optical communication link.
- ❖ Understand the measurement of BER, Pulse broadening.
- ❖ Understand and capture an experimental approach to digital wireless communication.
- ❖ Understand actual communication waveforms that will be sent and received across wireless channel.

### **LIST OF OPTICAL EXPERIMENTS**

1. Measurement of connector, bending and fiber attenuation losses.
2. Numerical Aperture and Mode Characteristics of Fibers.
3. DC Characteristics of LED and PIN Photo diode.
4. Fiber optic Analog and Digital Link Characterization - frequency response (analog), eye diagram and BER (digital).

### **LIST OF WIRELESS COMMUNICATION EXPERIMENTS**

1. Wireless Channel Simulation including fading and Doppler effects.
2. Simulation of Channel Estimation, Synchronization & Equalization techniques.
3. Analysing Impact of Pulse Shaping and Matched Filtering using Software Defined Radios.
4. OFDM Signal Transmission and Reception using Software Defined Radios

### **LIST OF MICROWAVE EXPERIMENTS**

1. VSWR and Impedance Measurement and Impedance Matching.
2. Characterization of Directional Couplers, Isolators, Circulators.
3. Gunn Diode Characteristics.
4. Microwave IC – Filter Characteristics.

### **TOPIC BEYOND THE SYLLABUS EXPERIMENT**

1. Radiation Pattern Measurement of Parabolic Reflector Antenna.

**Total: 60 Periods**

## **OUTCOMES:**

**On completion of this lab course, the student would be able to**

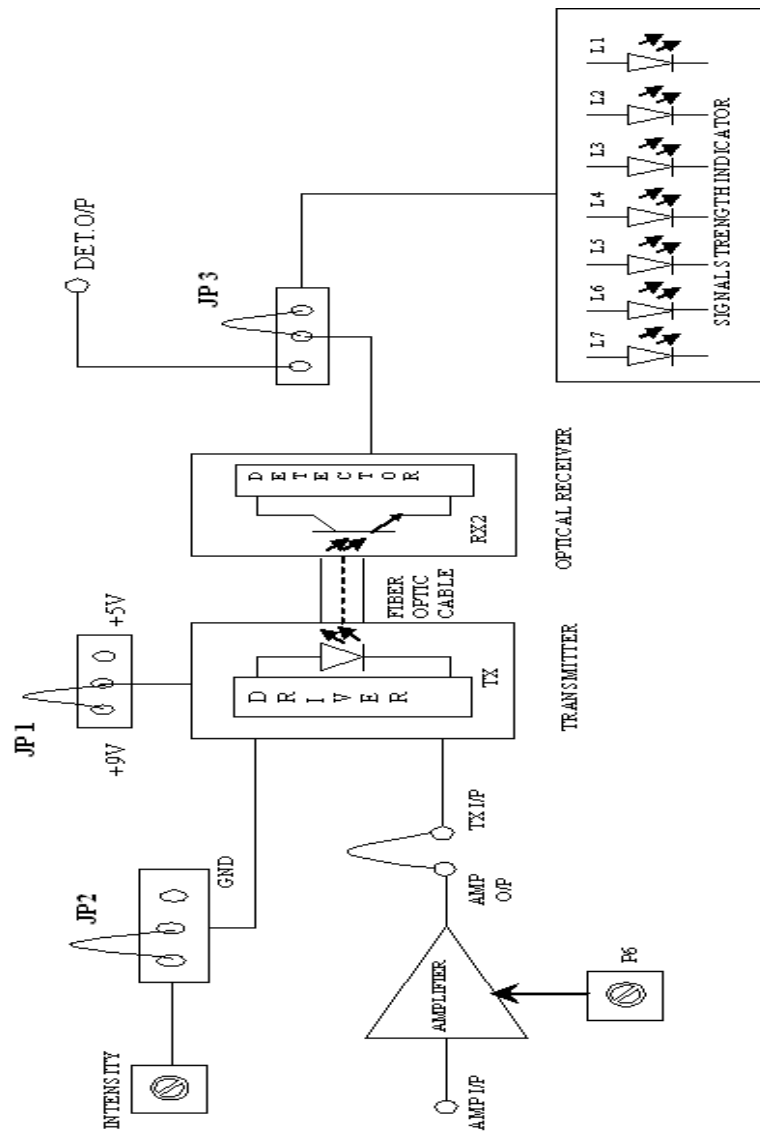
- ❖ Analyze the performance of simple optical link by measurement of losses and analyzing the mode characteristics of fiber.
- ❖ Analyze the Eye Pattern, Pulse broadening of optical fiber and the impact on BER.
- ❖ Estimate the Wireless Channel Characteristics and analyze the performance of Wireless Communication System.
- ❖ Understand the intricacies in Microwave System design.

## **List of Experiments**

1. Measurement of connector, bending and fiber attenuation losses.
2. (a) Numerical Aperture  
(b) Mode Characteristics of Fibers.
3. DC Characteristics of LED and PIN Photo diode.
4. (a) Fiber optic Analog and Digital Link Characterization - frequency response (analog).  
(b) Eye diagram  
(c) BER (digital).
5. Wireless Channel Simulation including fading and Doppler effects
6. Simulation of Channel Estimation, Synchronization & Equalization techniques
7. Analysing Impact of Pulse Shaping and Matched Filtering using Software Defined Radios
8. OFDM Signal Transmission and Reception using Software Defined Radios
9. VSWR and Impedance Measurement and Impedance Matching
10. (a) Characterization of Directional Couplers  
(b) Isolators  
(c) Circulators
11. Gunn Diode Characteristics
12. Microwave IC – Filter Characteristics.
13. Radiation Pattern Measurement of Parabolic Reflector Antenna.

# **OPTICAL EXPERIMENTS**

# BLOCK DIAGRAM FOR PROPAGATION LOSS:



## **EX.NO: 1 MEASUREMENT OF CONNECTOR, BENDING AND FIBER ATTENUATION LOSSES**

### **AIM:**

To measure the propagation loss, bending loss and fiber attenuation losses.

### **APPARATUS REQUIRED:**

<b>S.No.</b>	<b>Name of the Equipments</b>	<b>Quantity</b>
1	Link – D Fiber Optic Communication Trainer Kit	1
2	Power Supply	1
3	Fiber Optic Cable (Plastic)	1, 4 meter
4	Patch Chords	Required

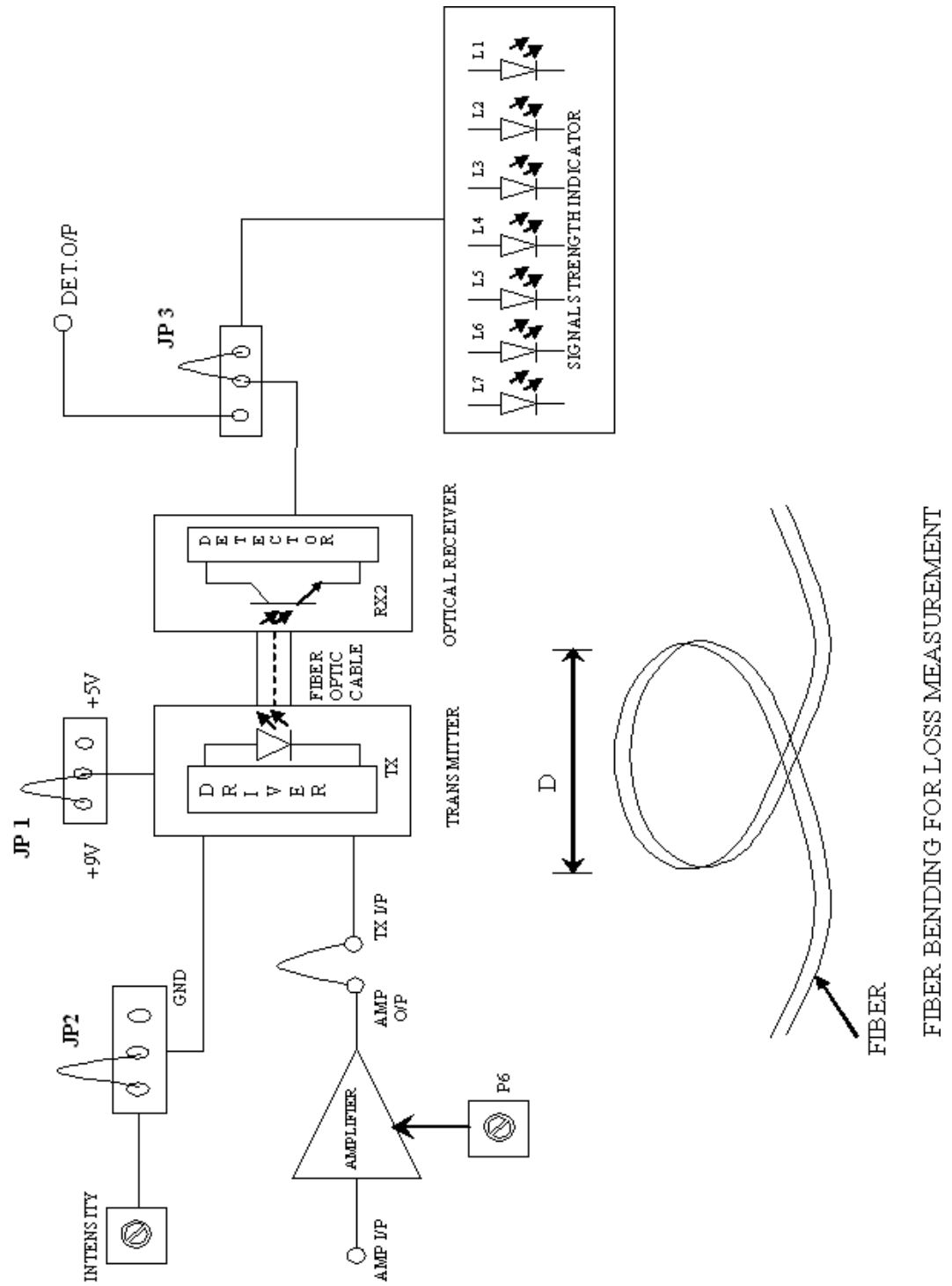
### **Pre lab questions:**

1. What are the types of fiber?
2. Draw the structure of a fiber.
3. How the light is transmitted through the fiber?
4. Define attenuation.
5. What are the basic attenuation mechanism in a fiber?

### **THEORY:**

Optical fibers are available in different variety of materials. These materials are usually selected by taking into account their absorption characteristics for different wavelengths of light. In case of optical fiber, since the signal is transmitted in the form of light, which is completely different in nature as that of electrons, one has to consider the interaction of matter with the radiation to study the losses in fiber. Losses are introduced in fiber due to various reasons. As light propagates from one end of fiber to another end, part of it is absorbed in the material exhibiting absorption loss. Also part of the light is reflected back or in some other directions from the impurity particles present in the material contributing to the loss of the signal at the other end of the fiber. In general terms it is known as propagation loss. Plastic fibers have higher loss of the order of 18 dB/Km. whenever the condition for the angle of incidence of the incident light is violated the losses are introduced due to refraction of light.

# **BLOCK DIAGRAM FOR BENDING LOSS:**





This occurs when fiber is subjected to bending. Lower the radius of curvature more is the loss. Another loss are due to the coupling of fiber at LED and photo detector ends.

## **PROCEDURE:**

### **FOR PROPAGATION LOSS:**

1. Make jumper connections as shown in jumper block diagram. Connect the power supply cables with proper polarity to Link – D Kit. While connecting this, ensure that the power supply is OFF.
2. Connect the **AMP O/P** as a constant signal to the **TX I/P** using a patch cord.
3. You will measure the light output using the SIGNAL STRENGTH section of the kit. The loss will be larger for a longer piece of fiber, so you will measure the loss of the long piece of fiber. In order to measure the loss in the fiber you first need a reference of how much light goes in to the piece of fiber from the LIGHT TRANSMITTER. You will use the short piece of fiber to measure this reference.
4. Switch on the power supply. Connect the short piece of fiber to between the transmitter TX and the receiver RX2 of the kit. Adjust the transmitter level until the signal strength reads 6. This will be your reference value. Now connect the long piece of fiber instead of the short piece. What reading do you get? Loss in optical fiber systems is usually measured in dBs. Loss of fiber itself is measured in dBs per meter.

Subtract the length of the short fiber from the length of the long fiber to get the difference in the fiber lengths (4m-1m).

### **FOR BENDING LOSS:**

1. Make jumper connections as shown in jumper block diagram. Connect the power supply cables with proper polarity to Link – D Kit. While connecting this, ensure that the power supply is OFF.
2. Connect the **AMP O/P** as a constant signal to the **TX I/P** using a patch cord. You will measure the light output using the SIGNAL STRENGTH section of the kit.
3. Switch ON the power supply. Connect the long piece of fiber to between the light transmitter **TX** and the photo detector receiver **RX2** so there are no sharp bends in the fiber between them.

**OBSERVATION FOR PROPAGATION LOSS:**

S.No	Length of the Fiber	Signal Strength/Optical Power (dBm)
1	1 m	
2	4 m	

**FORMULA:**

$$\text{POWER} = 10 \log (P_2/P_1) \text{ dB}$$

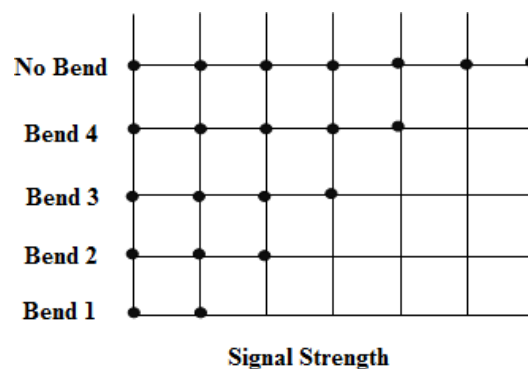
Where P<sub>2</sub> : Reference reading by 1 meter fiber

P<sub>1</sub> : Reading obtained after replacing the fiber.

$$\begin{aligned} \text{Fiber loss (dB/m)} &= \text{Power / Difference in fiber length} \\ &= \quad \quad \quad (\text{dB/m}) \end{aligned}$$

**OBSERVATION FOR BENDING LOSS:**

S.No:	Bending Diameter in cm	Signal Strength/Optical Power (dBm)
1.		
2.		
3.		
4.		
5.		

**BEND Vs SIGNAL STRENGTH**

4. Adjust the transmitter power so that the **SIGNAL STRENGTH** reading is 6. Now take the portion of the fiber and loop it to match the bends as shown in a diagram. As you match each bends write down the reading from SIGNAL STRENGTH indicator. What happens as bends the fibers? Don't bend the fiber too tightly or it may not come back to shape.
5. If you were designing the fiber optic communications system, you would need to known the relationship between the size of the bend and the light loss from the bend.

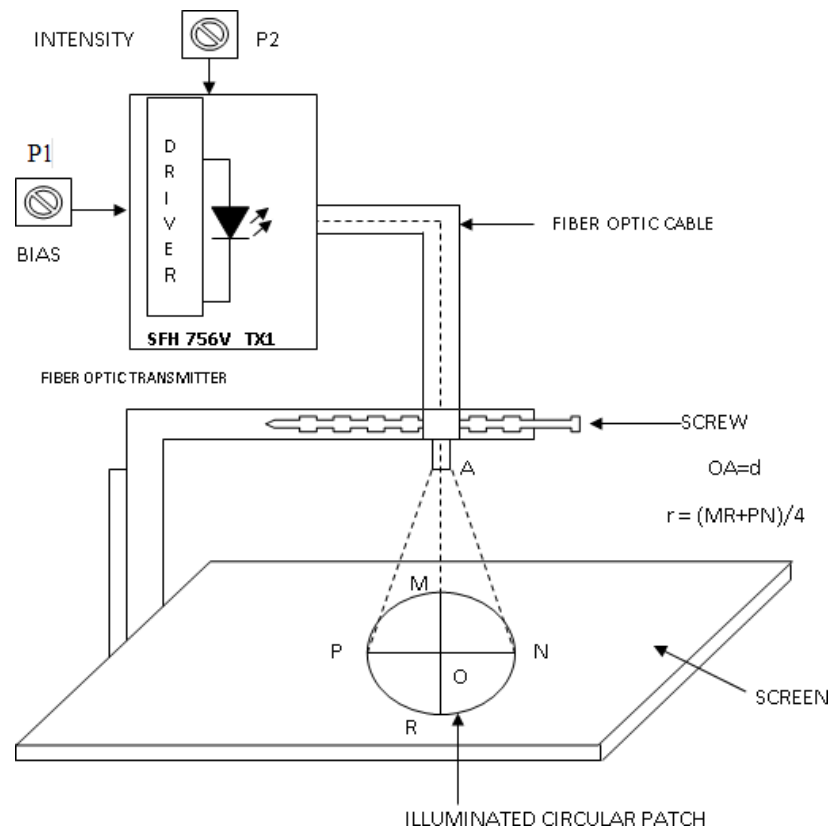
**Post lab questions:**

1. What is bending loss?
2. Mention the types of bending loss.
3. How the radius of curvature is calculated?
4. What are the steps taken to minimize the micro bending losses?
5. Write the standard formula for expressing the total power loss in an optical fiber.

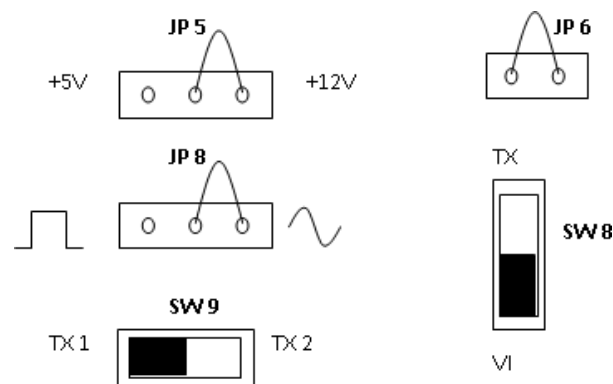
**RESULT:**

Thus the fiber propagation, bending and attenuation losses was measured.

**Experimental Setup Diagram for Numerical Aperture of a Fiber**



**Jumper Settings of the Fiber Optic Communication Trainer Kit**



## EX.NO:2 (a) NUMERICAL APERTURE OF FIBER

### AIM:

To measure the numerical aperture of the plastic fiber provided with kit using 660 nm wavelength LED.

### APPARATUS REQUIRED:

S.No.	Name of the Equipments	Quantity
1	Link – B Advance Fiber Optic Communication Trainer Kit	1
2	Power Supply	1
3	Fiber Optic Cable (Plastic)	1 meter
4	Numerical Aperture measurement Jig	1
5	Steel Ruler	1
6	Patch Chords	Required

### Pre lab questions:

1. Write down the ranges of optical frequency.
2. What are the advantages of optical fiber?
3. Define reflection, refraction.
4. Define Snell's law.
5. What is acceptance angle?

### THEORY:

Numerical aperture refers to the maximum angle at which the light incident on the fiber end is totally internally reflected and is transmitted properly along the fiber. The cone formed by the rotation of this angle along the axis of the fiber is the cone of acceptance of the fiber. The light ray should strike the fiber end within its cone of acceptance, else it is refracted out of the fiber core.

### Consideration in Measurement:

1. It is very important that the optical source should be properly aligned with the cable and the distance from the launched point and the cable be properly selected to ensure that the maximum amount of optical power is transferred to the cable.
2. This experiment is best performed in a less illuminated room.

**Observation:**

<b>d (mm)</b>	<b>MR(mm)</b>	<b>PN(mm)</b>	<b>r(mm)</b>	<b>NA</b>

$$r = \frac{(MR+PN)}{4} \qquad NA = \sin \theta_{\max} = \sqrt{d^2 + r^2}$$

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

### PROCEDURE:

1. Make connections as shown in figure. Connect the power supply cables with proper polarity to Link – B Kit. While connecting this, ensure that the power supply is OFF.
2. Keep Intensity control pot **P2** towards **minimum** position.
3. Keep Bias control pot **P1** fully clockwise position.
4. Switch ON the power supply.
5. Slightly unscrew the cap of SFH 756V (660) nm. Do not remove the cap from the connector. Once the cap is loosened, insert the 1 Meter Fiber into the cap. Now tighten the cap by screwing it back.
6. Insert the other end of the Fiber into the numerical aperture measurement jig. Adjust the fiber such that its cut face is perpendicular to the axis of the Fiber.
7. Keep the distance of about 5mm between the fiber tip and the screen. Gently tighten the screw and thus fix the fiber in the place.
8. Increase the intensity pot **P2** to get bright red light circular patch.
9. Now 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** as indicated in the Figure.
11. Mean radius is calculated using the following formula  $r = (\mathbf{MR} + \mathbf{PN}) / 4$
12. Find the numerical aperture of the fiber using the formula

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

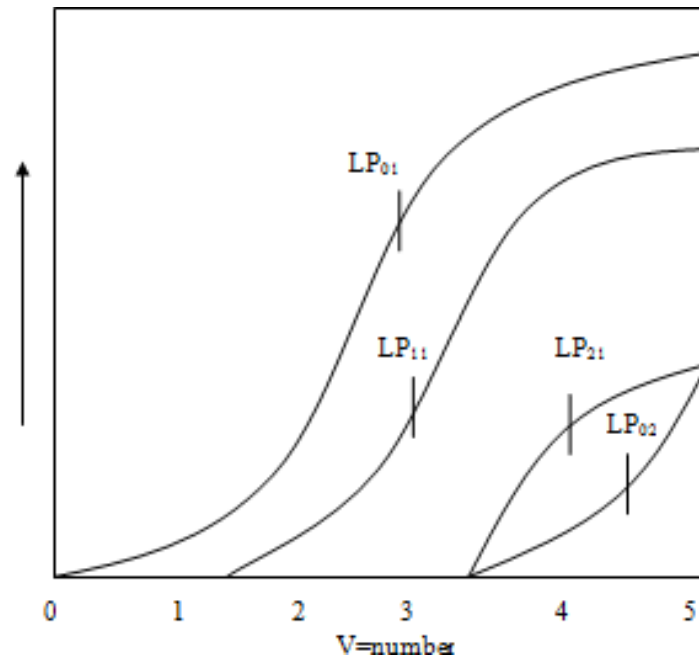
### Post lab questions:

1. Contrast glass and plastic fiber cables.
2. Define Numerical Aperture.
3. Mention the necessary conditions for TIR.
4. What are the limitations of fiber?
5. Define Critical angle.

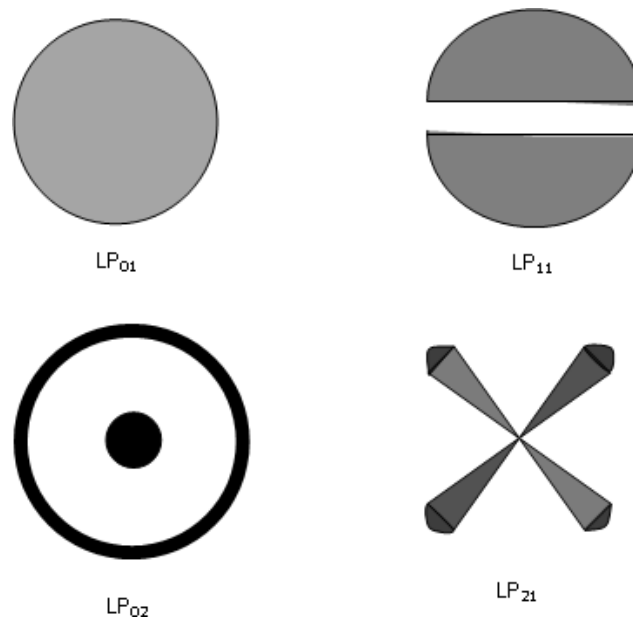
### RESULT :

Thus the Numerical aperture of the plastic fiber provided with kit using 660 nm wavelength LED was measured.

## Lower Order Linearly Polarised Modes of Optical Fiber



## Irradiance Pattern of Some Lower Order Linearly Polarized Mode





## EX.NO: 2 (b) MODE CHARACTERISTICS OF FIBER

### AIM:

To observe the mode characteristics of fiber.

### APPARATUS REQUIRED:

S.No.	Name of the Equipments	Specification	Quantity
1	Laser source (633nm-1mW)	2mW	1
2	Source to Fiber Coupler		1
3	Single Mode Fiber	SMF 9/125μm	1 meter
4	Fiber Holding Stand		1
5	Opaque Screen		1
6	Multimode Fiber	62.5/125μm	1meter

### Pre lab questions:

1. What are TE modes?
2. Define Hybrid mode.
3. Write Maxwell's equations.
4. Mention the different types of modes in a fiber.
5. Define weakly guiding approximation.

### THEORY:

The central spot carries 95% of the intensity for laser beams with Gaussian profile.  $I = I_0 e^{-z(t/w)^2}$

Where  $e=2.718$  beam of natural algorithm accepted definition of a radius of a Gaussian beam is the distance at which beam intensity has dropped to  $1/e^2=0.135$  times its peak value  $I_0$ . This radius called spot size. The spot diameter is  $W$ . Spot diameter (d) micron=focal length of the Lenses (f) mm X Laser Beam full divergence angle (DA) mrad.

In order to achieve maximum coupling efficiency, the fiber core diameter has to be bigger than the spot diameter.

$$NA_{\text{rays}} = \frac{\text{Laser Beam Diameter (B.D)}}{2 \times \text{Lens FocalLength (f)}}$$

If  $NA_{\text{rays}} \leq NA_{\text{fiber}}$  and spot diameter ( $w$ )  $\leq$  fiber core diameter ( $d$ ), then all of the laser light will be coupled into the fiber. 90% coupling efficiency into the single mode fiber from the Ne-Ne lasers is achievable. For beginners, coupling efficiency of 50% is considered to be a good result.

**OBSERVATION:**Single mode Fiber:

$$a = 4.5\mu\text{m (core radius)}$$

$$\text{NA} = 0.11$$

$$V = \frac{2 \times \pi \times 4.5 \times 10^{-6} \times 0.11}{633 \times 10^{-9}}$$

$$V = 4.91$$

From figure only 4 LP modes propagate.

$$\text{Total number of modes} = V^2/2$$

$$\text{No. of modes} = 12$$

Multimode Fiber:

$$a = 31.25\mu\text{m (core radius)}$$

$$\text{NA} = 0.11$$

$$V = \frac{2 \times \pi \times 31.25 \times 10^{-6} \times 0.11}{633 \times 10^{-9}}$$

$$V = 34.12$$

$$\text{Total number of modes} = V^2/2 = (34.12)^2/2$$

$$\text{No. of modes} = 582.11$$

When V-number is less than 2.405, then only a single mode may propagate in the fiber wave-guide. This mode is  $\text{HE}_{11}$  mode or  $\text{LP}_{01}$  – Linearly Polarized mode. When V-number > 2.405, other modes may propagate in the fiber. The first LP mode, which comes in at  $V=2.405$ , is the  $\text{LP}_{11}$  mode, the next lowest mode in the weakly guiding approximation.

When V is slightly greater than 2.405 i.e.  $V=4.91$  then 4 Linearly Polarized modes will propagate through fiber.

$\text{LP}_{02}$ : Degenerated twice: 2 modes,  $\text{LP}_{11}$ : 4 times degenerated: 4 modes

$\text{LP}_{02}$ : Degenerated twice: 2 modes,  $\text{LP}_{21}$ : 4 times degenerated: 4 modes

Total 12 modes can propagate through fiber. This number is identical to that given by formula:  $M_a = V^2/2 = 12$ . The electromagnetic field distributions of these modes are as shown figure. We have a fiber with the proper V-number; varying the position and angle at which a tightly focused beam of the proper wavelengths is projected onto the fiber core can selectively launch these modes.

### **Operation Principle of Laser to Fiber Source Coupler**

The source coupler is comprised of two base plates. One of the base plates contains a focusing lens and a female connector receptacle. The other base plate is attached onto the laser. An O-ring is sandwiched between the base plates. Threaded screws interconnect the two base plates. A screwdriver to alter the angular orientation of one base plate relative to the other can then adjust the screws.

For small tilt angles, the resolution of the coupler  $\Delta z$  is determined by  $\Delta z = f \Delta x / L$ , where  $\Delta x$  is the resolution of the screws and  $L$  is the lever arm. For 80TPI (threads per inch) screws, a lens with 1mm focal length, and 20mm lever arm  $\Delta z = 1\text{mm} \cdot 2\text{micron}/20\text{mm} = 0.1\text{micron}$ .

The number of modes propagating through the fiber depends on V-number. If the fiber whose V-number is less than 2.405, it allows to propagate single mode through it, so it is called as Single Mode Fiber. This time you will start with a fiber, which has V-number slightly greater than 2.405. Such a fiber is Multimode fiber, but the number of allowed modes is small enough so that they may be individually identified when the output of the fiber is examined.

#### **PROCEDURE:**

1. Keep Optical Bread board onto original and flat table surface, so that it will not toggle.
2. Fix the pre-fitted cylindrical head of the He-Ne laser source on to the surface of the breadboard from the bottom side with the help of Allen screws provided with it. Confirm the rigidity of the mount.
3. Fix the laser to the fiber coupler mount on to the breadboard with the base plate orientation of it towards He-Ne laser exit.
4. Turn on the He-Ne laser and locate the beam spot on to the central portion of the laser-fiber coupling lens assembly by adjusting the vertical and horizontal travel arrangement provided with the mount. Tighten the screws of the vertical and horizontal slots.
5. Now look for the back reflection of the He-Ne spot from the rod lens of the coupler.

#### **Irradiance Pattern of Some Lower Order Linearly Polarized Mode**

1. Cylindrical laser head of the laser, adjust the back-reflected spot going back in exit hole by slowly moving the four screws provided for the laser mount.
2. Confirm the central alignment of the laser beam at the exit of the laser fiber coupler by putting a white card sheet and zooming the spot on to it. In case the spot is found off-center, adjust it to the center by slightly moving the screws of the laser mount.

3. Put the multimode optical patch cord on to the laser-fiber coupler exit and fix the other end of the fiber in the fiber holding stand by moving the grub screws provided with the holder.
4. You will see the bright laser-beam spot coming out of the fiber. Adjust the height of exit tip of the fiber to about 50mm. Min. from the white sheet of the paper.
5. Now you will see a bright round shape circular spot with laser speckle pattern on to the screen. If multimode pattern can be refined screws provided with laser-fiber coupler. Slightly adjusting or moving the screws on the laser mount can also view the change in pattern of this multimode spot.

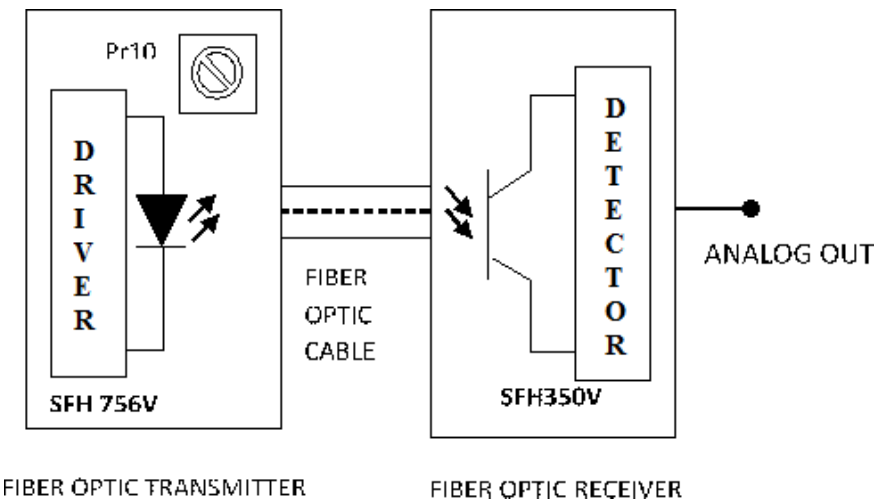
**Post lab questions:**

1. What are TM modes?
2. Write the expression for the total number of guided mode supported by the graded index fiber.
3. Define normalized frequency.
4. Why single mode fiber is widely used in telecommunications?
5. What is mode field diameter?

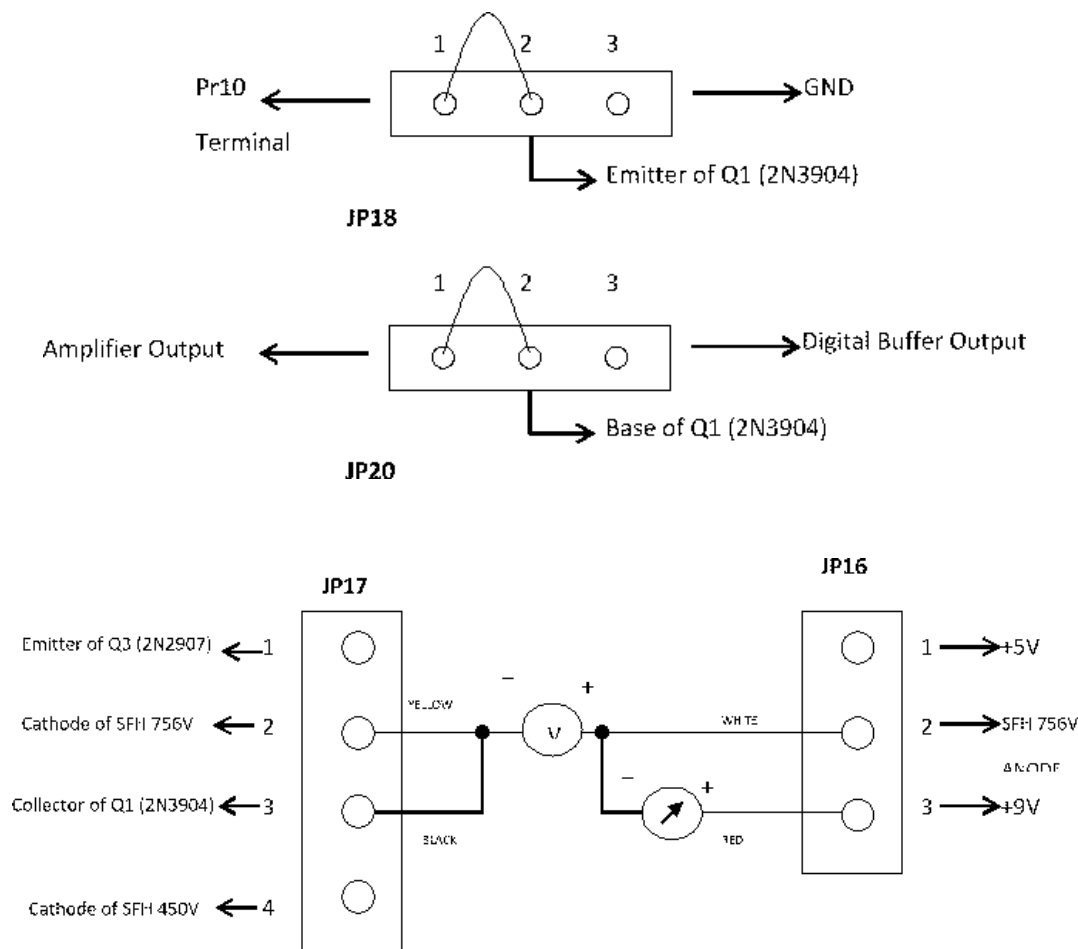
**RESULT:**

Thus the mode characteristics of fiber was observed.

**Block Diagram:**



**Jumper Setting Diagrams:**



### EX.NO: 3 DC CHARACTERISTICS OF LED & PIN PHOTO DIODE

#### AIM:

To obtain the characteristics of fiber optic LED and plot the graph of forward current Vs output optical energy, also study the photo detector response.

#### APPARATUS REQUIRED:

S.No.	Name of the Equipments	Range	Quantity
1	Link – B Fiber Optic Communication Trainer Kit	-	1
2	Power Supply	-	1
3	Fiber Optic Cable (Plastic)	-	1 meter
4	Voltmeter	(0-5)V, (0-10)V	Each 1
5	Ammeter	(0-50)mA	1
6	Connecting Wires, Patch Chords	-	Required

#### Pre Lab questions:

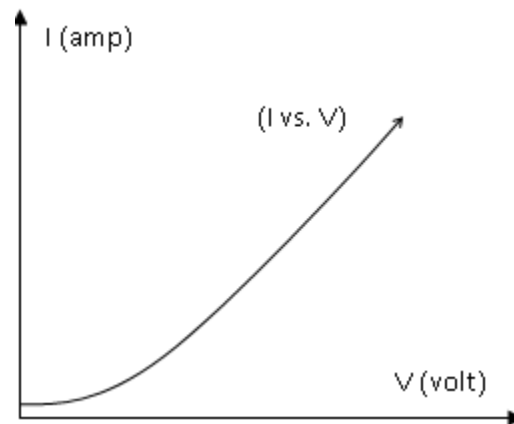
1. What are the major components used in optical transmitter?
2. Define transducer.
3. Draw the structure of PIN Photodiode.
4. Define the modulation bandwidth of LED.
5. Define responsivity.

#### 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 the various emitter diodes. All the emitters distinguish themselves in offering high output power coupled into the important peak wavelength of emission, conversion efficiency usually specified in terms of power launched in optical fiber peak wavelength of emission, optical rise and fall times which put the limitation on operating frequency, maximum forward current through LED and typical forward voltage across LED.

**Model Graph:**

**I Vs V Characteristics of SFH 756 V**



**Characteristics of Optical Power of Led Vs  $I_f$ :**

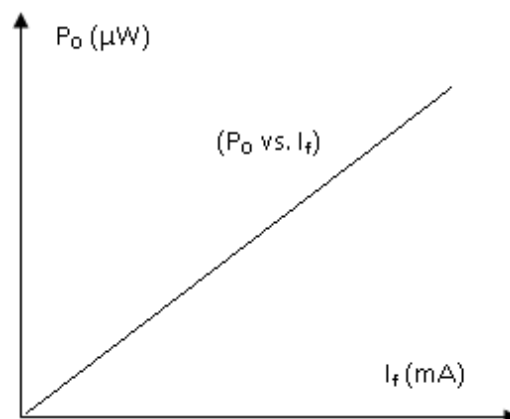


Photo detectors usually comes in variety of forms photoconductive, photovoltaic, transistor type output and diode type output. Here also characteristics to be taken into account are response time of the detector which puts the limitation on the operating frequency, wavelength sensitivity and responsivity.

#### **PROCEDURE:**

1. Confirm that the power switch is on **OFF** position.
2. Make the jumper settings as shown in the jumper diagram.
3. Insert the jumper connecting wires (provided along with the kit) in jumper **JP17** and **JP16** at positions shown in figure.
4. Connect the ammeter and volt-meter with the jumper wires connected to JP17 and JP16 as shown in figure.
5. Keep the potentiometer **Pr10** in its **maximum** position (anti-clockwise rotation) and **Pr9** in its **minimum** position (clockwise rotation). Pr10 is used to control current flowing through the LED and Pr9 is used to vary the amplitude of the received signal at phototransistor.
6. To get the VI characteristics of LED, rotate Pr10 slowly and measure forward current and corresponding forward voltage. Take number of such readings for various current values and plot VI characteristics graph for the LED.
7. For each reading taken above, find out the power which is product of I and V. This is the electrical power supplied to the LED.
8. With this efficiency assumed, find out optical power coupled into plastic Optical Fiber for each of the reading in step7. Plot the graph of forward current vs. output optical power of the LED.
9. In our experimental kit, when Pr9 is at its minimum position, 100 ohms of resistance is in series of emitter and ground of phototransistor.
10. Connect the 1m optical Fiber Cable supplied with the kit between LED SFH 756V (660nm) and phototransistor SFH 350V (Analog Detector).



**OBSERVATION:****Characteristics of Led:**

LED voltage $V_d$ (V)	LED Current $I_d$ (mA)	Optical power Of LED $P_d$ (dBm)	Optical power Of LED $P_d$ (mW)

**To Convert dBm to mW****Characteristics of Detector:** **$R = 100 \Omega$** 

LED Current $I_d$ (mA)	Optical power Of LED $P_d$ (mW)	Detector voltage $V_p$ (V)	Detector Current $I_p$ (mA)

11. From the transfer characteristics obtained in step 8, launched known optical energy into plastic fiber and measure output voltage at **ANALOG OUTPUT TERMINAL**. Find out the current flowing through phototransistor with this voltage value and 100 ohms of resistance.
12. Repeat step 11 for various launched Optical energy values and plot the graph for the responsivity of phototransistor. Find out the portion where detector response is linear.

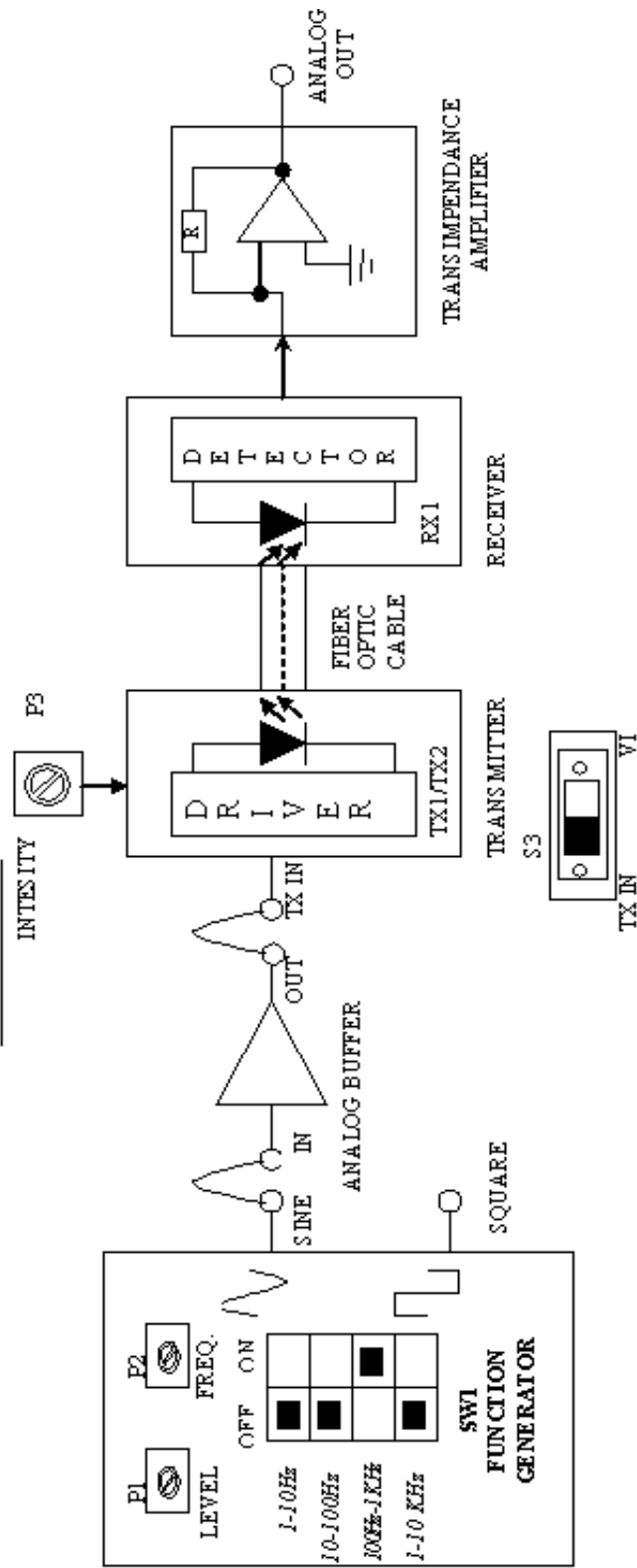
**Post Lab questions:**

1. Give the advantages of LED.
2. Define internal quantum efficiency for LED.
3. Why carrier confinement is used in LED ?
4. What is radiance or brightness ?
5. Define photodiode dark current

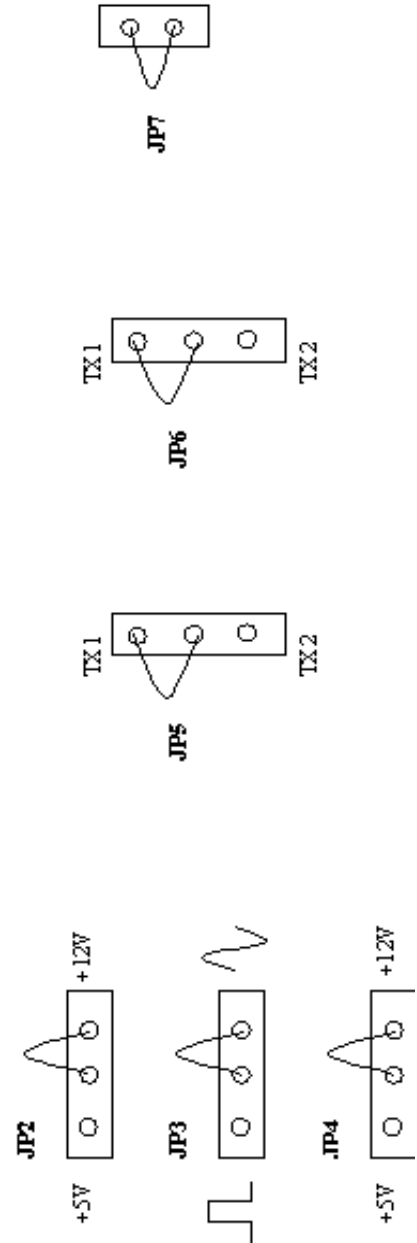
**RESULT :**

Thus the characteristics of fiber optic LED was observed and the graph was plotted for the forward current Vs output optical energy, also studied the photo detector response.

# **BLOCK DIAGRAM OF FOR SETTING UP ANALOG LINK**



## **JUNPER SETTING DIAGRAM FOR TX1 (SFH 756H):**



**EX.NO: 4 (a)      FIBER OPTIC ANALOG AND DIGITAL LINK**  
**CHARACTERISTICS - FREQUENCY RESPONSE (ANALOG)**

**AIM:**

To obtain the frequency response of a transmitted signal by using optical fiber in an analog and digital fiber optic link.

**APPARATUS REQUIRED:**

S.No.	Name of the Equipments	Quantity
1	Link – A Fiber Optic Trainer Kit	1
2	Fiber Optic Cable (Plastic)	1 meter
3	Power Supply	1
4	20 MHz Dual Channel Oscilloscope	1
5	Probe, Patch Chords	Required

**Pre Lab Questions:**

1. What is the function of an optical transmitter in an optical repeater?
2. Write the advantages of optical communication.
3. Write the functions of light sources.
4. What was the technique used in earlier communication?
5. Compare repeater and transponder.

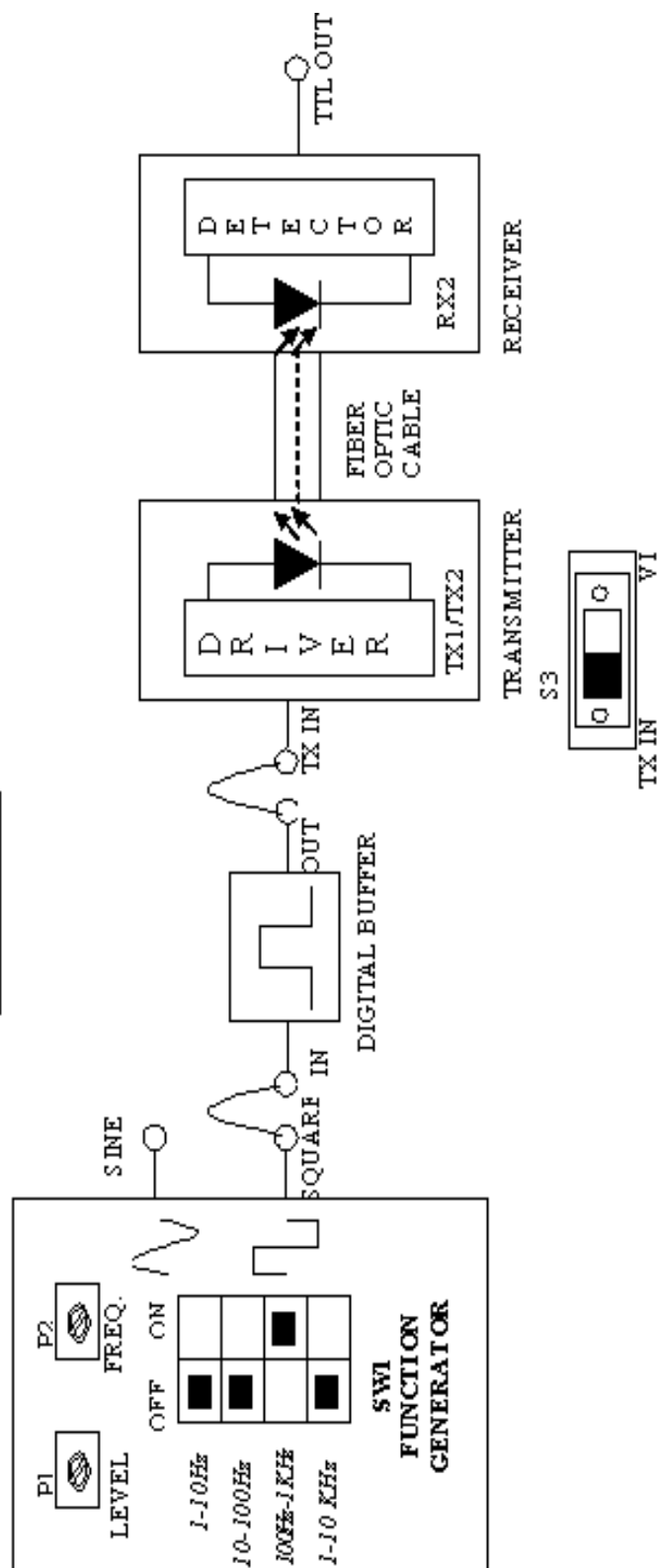
**THEORY:**

**ANALOG LINK:** Fiber Optic Links can be used for transmission for digital as well as analog signals. Basically a fiber optic link contains three main elements, a transmitter, an optical fiber & a receiver. The transmitter module takes the input signal in electrical form & then transforms it into optical (light) energy containing the same information. The optical fiber is the medium which carries this energy to the receiver. At the receiver, light is converted back into electrical form with the same pattern as originally fed to the transmitter.

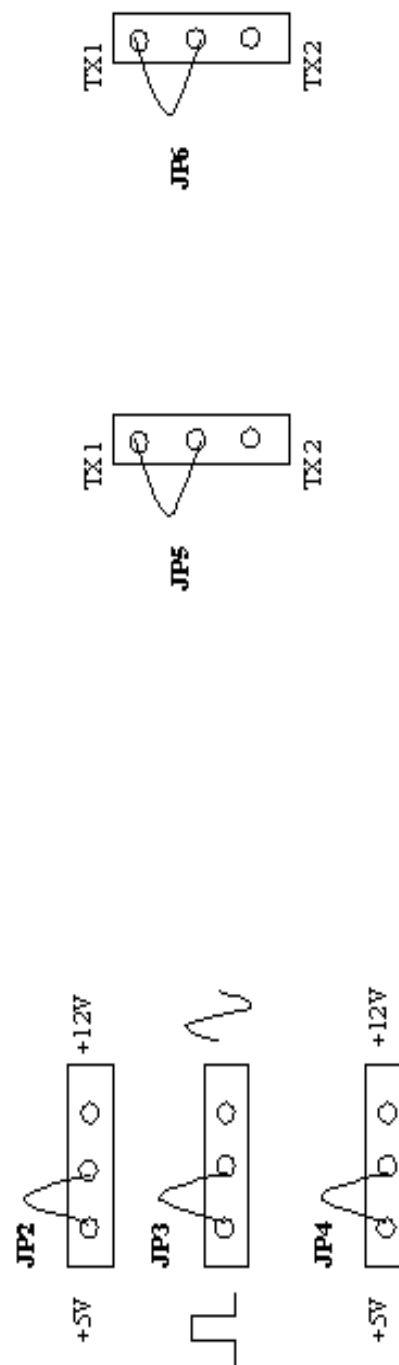
**TRANSMITTER:**

Fiber optic transmitters are typically composed of a buffer, driver & optical source. The buffer electronics provides both an electrical connection & isolation between the transmitter & the electrical system supplying the data. The driver electronics provides electrical power to the optical source in a fashion that duplicates the pattern of data being

# **BLOCK DIAGRAM OF FOR SETTING UP DIGITAL LINK**



## **JUMPER SETTING DIAGRAM FOR TX1 (SFH 750H):**



fed to the transmitter. Finally the optical source (LED) converts the electrical current to light energy with the same pattern. The LED SFH 756V supplied with the kit operates inside the visible light spectrum. It's optical output is centered at near visible wavelength of 660 nm. The emission spectrum is broad, so a dark red glow can usually be seen when the LED is on. The LED SFH 450V supplied with the kit operates outside the visible light spectrum. It's optical output is centered at near infrared wavelength of 950 nm.

#### **RECEIVER:**

The function is to convert the optical energy into electrical form which is then conditioned to reproduce the transmitted electrical signal in its original form. The detector SFH250V used in the kit has a diode type output. The parameters usually considered in the case of detector are it's responsivity at peak wavelength & response time. SFH250V has responsivity of about  $4\mu\text{A}$  per  $10\mu\text{W}$  of incident optical energy at 950 nm and it has rise & fall time of  $0.01\mu\text{sec}$ . PIN photodiode is normally reverse biased. When optical signal falls on the diode, reverse current start to flow, thus diode acts as closed switch and in the absence of light intensity, it acts as an open switch. Since PIN diode usually has low responsivity, a trans impedance amplifier is used to convert this reverse current into voltage. This voltage is then amplified with the help of another amplifier circuit. This voltage is the duplication of the transmitted electrical signal.

#### **DIGITAL LINK**

In the experiment no. 1, we have seen how analog signal can be transmitted and received using LED, fiber and detector. The same LED, fiber and detector can be configured for the digital applications to transmit binary data over fiber. Thus basic elements of the link remains same even for digital applications.

#### **TRANSMITTER:**

LED digital, DC coupled transmitters are one of the most popular variety due to their ease of fabrication. Standard TTL gate is used to drive a NPN transistor, which modulates the LED SFH450V OR SFH756V source (Turns it ON and OFF).

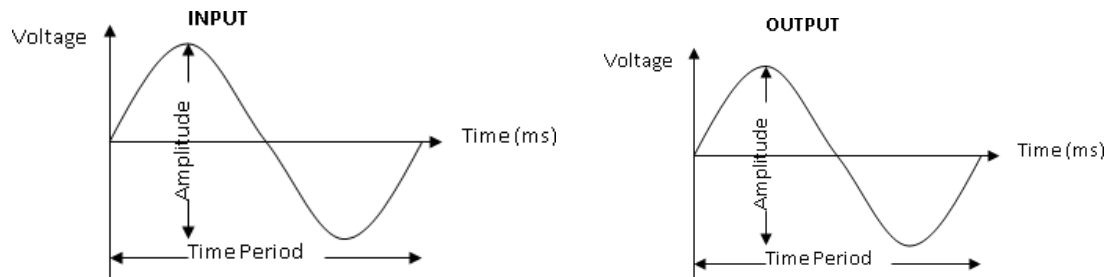
#### **RECEIVER:**

There are various methods of configure detectors to extract digital data.

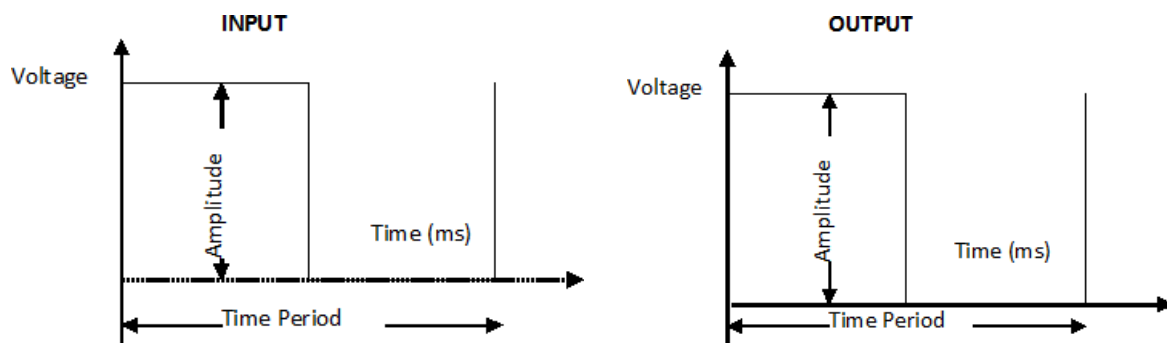
Usually detectors are of linear nature. Photo detector SFH551V has TTL type output. Usually it consist of PIN photo diode, trans impedance amplifier and level shifter.

## Model Graph:

### Fiber Optic Communication - Analog Link:



### Fiber Optic Communication – Digital Link:



## **PROCEDURE:**

### **FIBER OPTIC COMMUNICATION - ANALOG LINK:**

1. 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.
2. Make the connections and Jumper settings as shown in Figure. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF.
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:2Vp-p.
5. Connect **SINE** post of the Function Generator section to **IN** post of Analog Buffer Section.
6. Connect **OUT** post of the Analog Buffer Section to **TX IN** post of Analog Buffer Section.
7. Connect the other end of the fiber to detector SFH 250V (RX 1) in kit very carefully as per the instructions in step 1.
8. 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.
9. 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.



**Observation:**

**ANALOG LINK:**

<b>Mode</b>	<b>Amplitude (volts)</b>	<b>Time (seconds)</b>
<b>Input</b>		
<b>Output</b>		

**DIGITAL LINK:**

<b>Mode</b>	<b>Amplitude (volts)</b>	<b>Time (seconds)</b>
<b>Input</b>		
<b>Output</b>		

### **FIBER OPTIC COMMUNICATION – DIGITAL LINK:**

1. 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.
2. Make the connections and Jumper settings as shown in Figure. 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
3. Feed the Onboard Square (**TTL**) signal of about 1 KHz to **IN** post of Digital Buffer Section and observe the signal at OUT post. It should be same as that of the input signal.
4. Connect **OUT** post of the Digital Buffer section to **TX IN** post of TRANSMITTER.
5. Connect the other end of the fiber to detector **SFH 551V RX 2** (Digital Detector) in kit very carefully as per the instructions in step 1.
6. Observe the output signal from the detector at **TTL OUT** post on CRO. The Transmitted signal and received signal are same. Vary the frequency of the input signal and observe the output response.

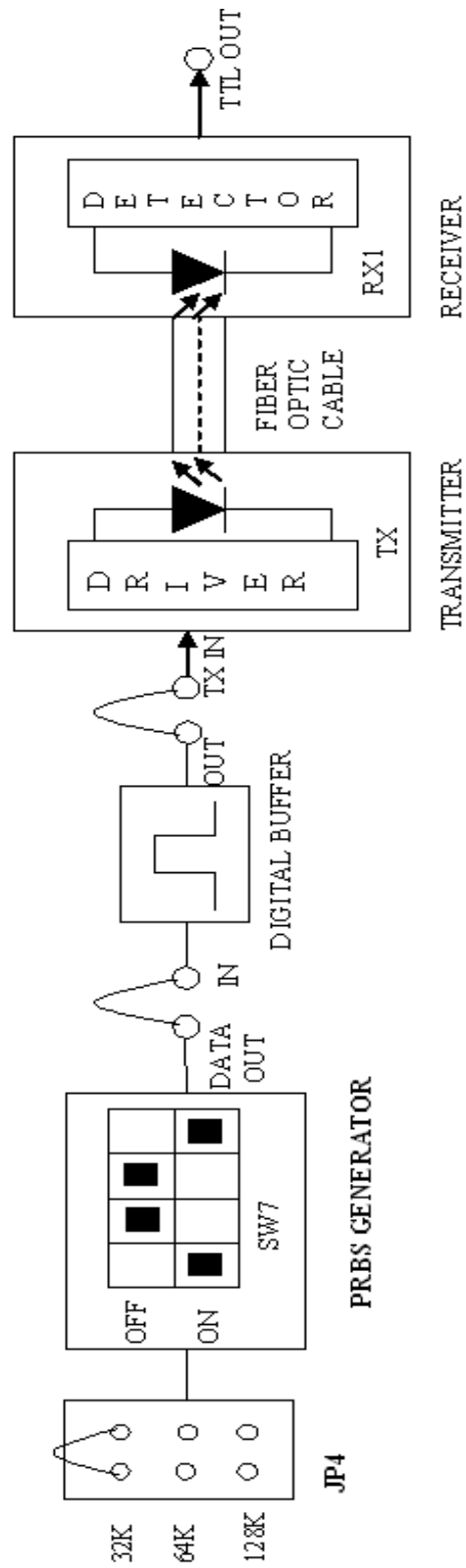
### **Post Lab Questions:**

1. What is link?
2. Define node.
3. Give the difference between analog link and digital link.
4. Differentiate wired and wireless communication.
5. What is the function of an optical receiver in an optical repeater?

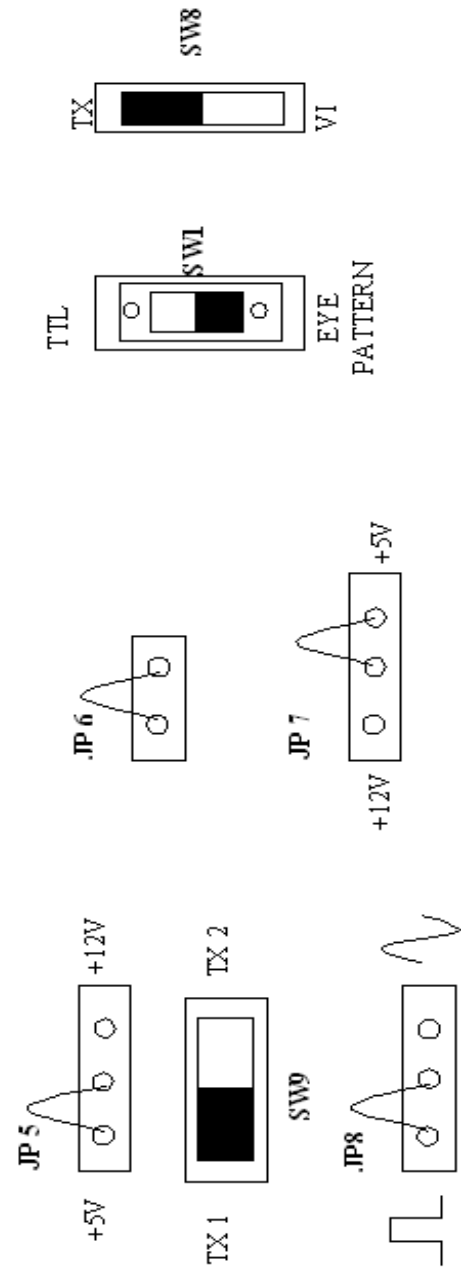
### **RESULT:**

Thus the frequency response was obtained for the transmitted signal by using optical fiber in an analog and digital fiber optic link.

## BLOCK DIAGRAM:



## JUMPER SETTING DIAGRAM:



## EX.NO: 4 (b) EYE DIAGRAM

### AIM:

To analyse the eye diagram using fiber optic link.

### APPARATUS REQUIRED:

S.No.	Name of the Equipments	Quantity
1	Link – B Advance Fiber Optic Communication Trainer Kit	1
2	Power Supply	1
3	Fiber Optic Cable (Plastic)	1 meter
4	20 MHz Dual channel Oscilloscope	1
5	Probes, Patch Chords	Required

### Pre Lab Questions:

1. Define time jitter.
2. Write the fundamental concepts of a coherent lightwave system.
3. What is mask testing?
4. Define eye contour.
5. Differentiate ASK, FSK and PSK.

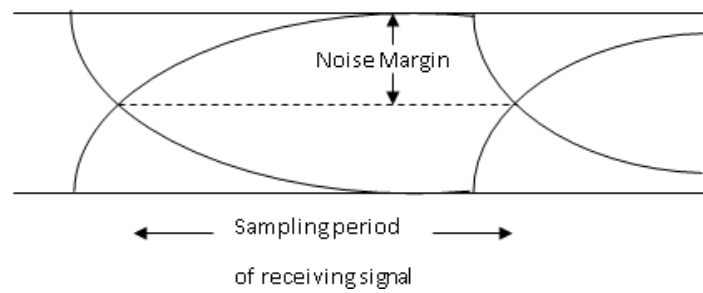
### THEORY:

The eye-pattern technique is a simple but powerful measurement method for assessing the data-handling ability of a digital transmission system. This method has been used extensively for evaluating the performance of wire systems and can also be applied to optical fiber data links. The eye-pattern measurements are made in the time domain and allow the effects of waveform distortion to be shown immediately on an oscilloscope.

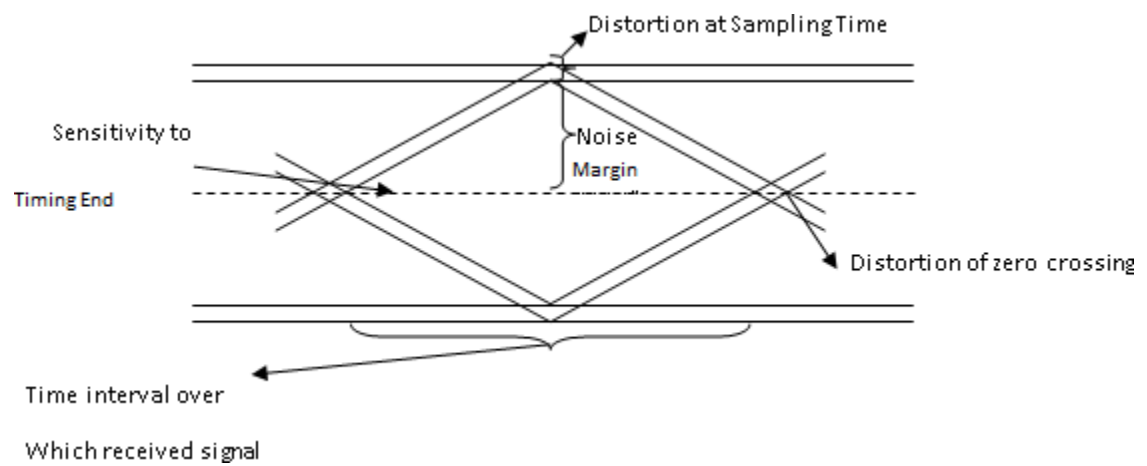
To measure system performance with the eye-pattern method, a variety of word patterns should be provided. A convenient approach is to generate a random data signal, because this is the characteristic of data streams found in practice. This type of signal generates ones and zeros at a uniform rate but in a random manner. A variety of pseudorandom pattern generators are available for this purpose. A pseudorandom bit sequence comprises four different 2-bit-long combinations, eight different 3-bit-long combinations, sixteen different 4-bit-long combinations, and so on (that is,

## MODEL GRAPH:

### Eye Pattern



### Interpretation of Eye Pattern



sequences of different N-bit-long combinations) up to a limit set by the instrument. After this limit has been generated, the data sequence will repeat.

#### **PROCEDURE:**

1. Make connections as shown in figure. Connect the power supply cables with proper polarity to Link – B Kit. While connecting this, ensure that the power supply is OFF.
2. Keep switch **SW7** as shown in figure to generate PRBS signal.
3. Keep switch **SW8** towards **TX** position.
4. Keep switch **SW9** towards **TX1** position.
5. Keep the switch **SW10** to **EYE PATTERN** position.
6. Select PRBS generator clock at 32 KHz by keeping jumper **JP4** at **32K** position.
7. Keep Jumper **JP5** towards **+5V** position.
8. Keep Jumper **JP6** shorted.
9. Keep Jumper **JP8** towards **TTL** position.
10. Switch ON the power supply.
11. Connect the post **DATA OUT** of PRBS Generator to the **IN** post of digital buffer.
12. Connect **OUT** post of digital buffer to **TX IN** post.
13. Slightly unscrew the cap of SFH 756V (660) nm. 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.
14. Slightly unscrew the cap of RX1 Photo Transistor with TTL logic output SFH 551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
15. Connect **CLK OUT** of PRBS Generator to **EXT.TRG.** Of Oscilloscope.
16. Connect detected signal **TTL OUT** to vertical channel **Y** input of oscilloscope. Then observe EYE PATTERN by selecting EXT.TRG. KNOB on oscilloscope as shown in figure. Observe the Eye Pattern for different clock frequencies. As clock frequency increases the EYE opening becomes smaller.

**OBSERVATION:**

<b>PRBS Generator Frequency</b>	<b>Noise Margin (V)</b>	<b>Sampling period of received Signal (sec)</b>
<b>32 KHz</b>		
<b>64 KHz</b>		
<b>128 KHz</b>		

**Post lab questions:**

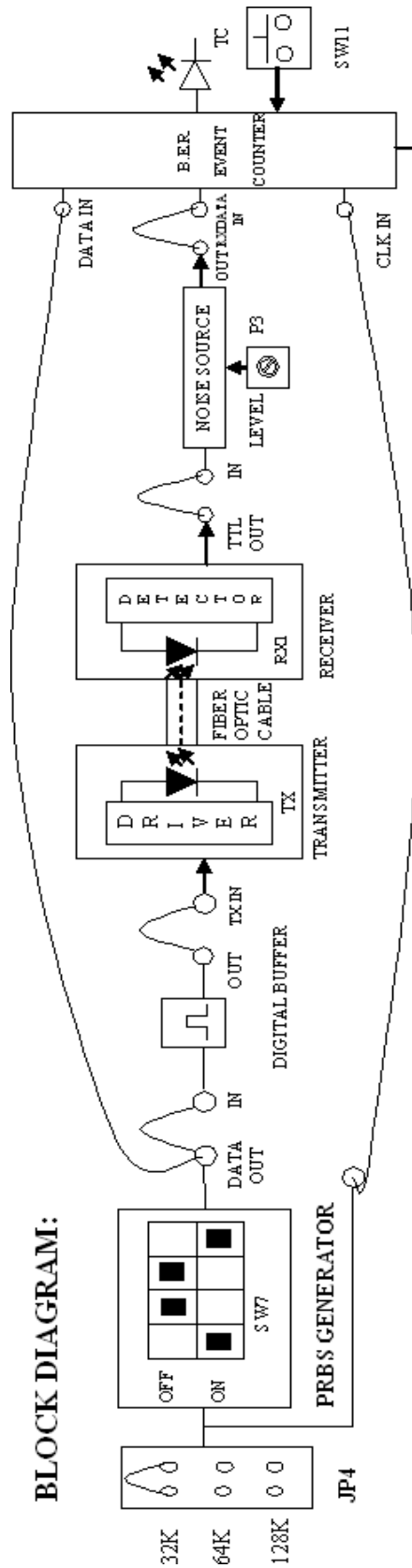
1. What is the significance of eye pattern?
2. What is intersymbol interference?
3. How the performance of analog receiver and digital receiver is measured?
4. What does pseudorandom means?
5. Define noise margin.

**RESULT :**

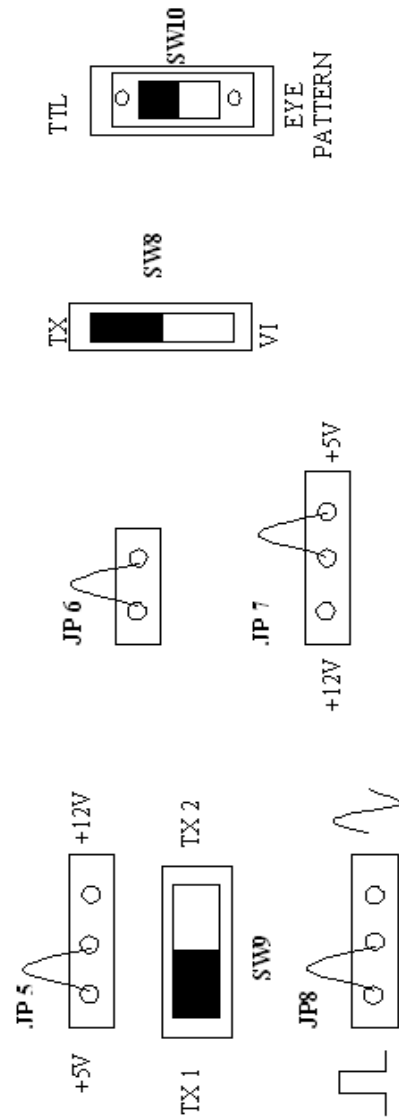
Thus the Eye Pattern was analyzed using Fiber optic Link.



# BLOCK DIAGRAM:



# JUMPER SETTING DIAGRAM:



### EX.NO.4 (c)BIT ERROR RATE

**AIM:**

To measure the bit error rate of a fiber.

**APPARATUS REQUIRED:**

S.No.	Name of the Equipments	Quantity
1	Link – B Advance Fiber Optic Communication Trainer Kit	1
2	Power Supply	1
3	Fiber Optic Cable (Plastic)	1 meter
4	20 MHz Dual channel Oscilloscope	1
5	Probes, Patch Chords	Required

**Pre lab questions:**

1. Explain the digital receiver performance.
2. Define Gaussian noise.
3. What is probability density function?
4. Define Quantum limit.
5. What is dark current?

**THEORY:****BIT ERROR RATE:**

In telecommunication transmission, the bit error rate (BER) is a Ratio of bits that have errors relative to the total number of bits received in a transmission. The BER is an indication of how often a packet of other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent.

**Measuring Bit Error Rate:**

A BERT (bit error rate tester) is a procedure or device that measures the BER for a given transmission. The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted.

$$\text{BER} = (\text{Bits in error}) / (\text{Total bits transmitted})$$

**Observation:**

$T_b = 320\text{Kbits}$

S.No:	Error Counter	Eb	BER
1.			
2.			
3.			
4.			
5.			

$$\text{BER} = \text{Eb}/T_b$$

Where Eb – Errored bits

$T_b$  – Total bits Transmitted in a period of time t seconds.

## PROCEDURE:

1. Make connections as shown in figure. Connect the power supply cables with proper polarity to Link – B Kit. While connecting this, ensure that the power supply is OFF.
2. Keep **PRBS** switch **SW7** as shown in figure to generate PRBS signal.
3. Keep switch **SW8** towards **TX** position.
4. Keep switch **SW9** towards **TX1** position.
5. Keep the switch **SW10** at fiber optic receiver output to **TTL** position.
6. Select PRBS generator clock at 32 KHz by keeping jumper **JP4** at **32K** position.
7. Keep Jumper **JP5** towards **+5V** position.
8. Keep Jumper **JP6** shorted.
9. Keep Jumper **JP8** towards **Pulse** position.
10. Switch ON the power supply.
11. Connect the post **DATA OUT** of PRBS Generator to the **IN** post of digital buffer.
12. Connect **OUT** post of digital buffer to **TX IN** post.
13. Slightly unscrew the cap of SFH 756V (660) nm. 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.
14. Slightly unscrew the cap of RX1 Photo Transistor with TTL logic output SFH 551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
15. Connect detected signal **TTL OUT** to Bit Error Rate event counter **DATA IN** post & post **IN** of Noise Source.
16. Connect post **OUT** of Noise Source to post **RXDATA IN** of Bit Error Rate event counter.
17. Connect post **CLK OUT** of PRBS Generator to post **CLK IN** of Bit Error Rate event counter.
18. Press Switch **SW 11** to start counter.
19. Vary pot **P3** for **Noise Level** to observe effect of noise level on the error count.
20. Observe the Error Count LED's for the error count in received signal in time 10 seconds as shown in figure.



**REVIEW QUESTIONS:**

1. Define bit error rate.
2. What is bit period?
3. What do you mean by excess noise factor?
4. Define threshold level.
5. Mention the stages available in an optical receiver.

**RESULT:**

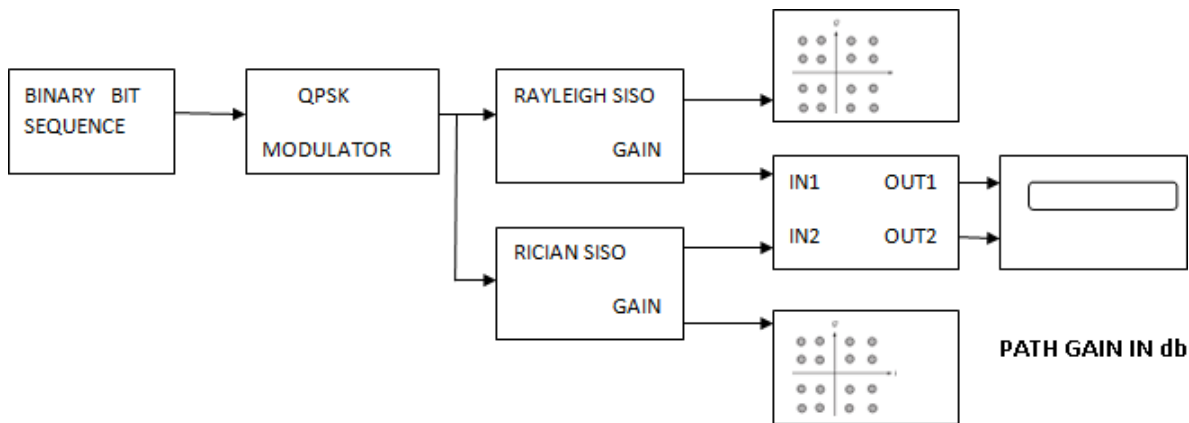
Thus the Bit error rate was measured for a fiber.



# **WIRELESS COMMUNICATION EXPERIMENTS**

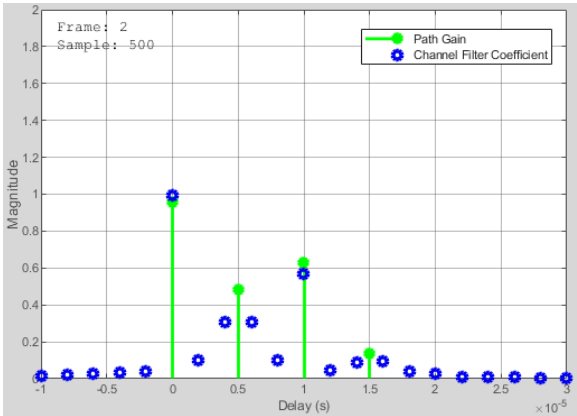


**Block Diagram:**

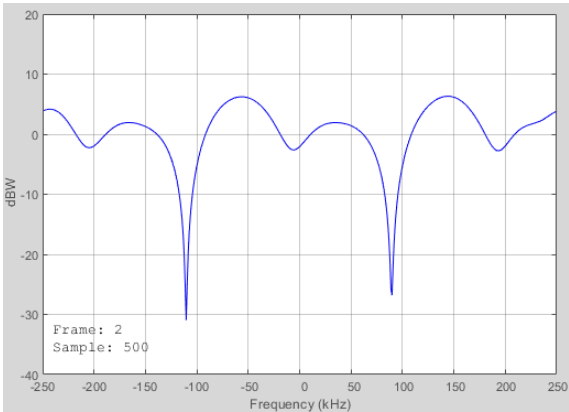


**Simulation Outputs:**

**Impulse Response**



**Frequency Response**



## **EX.NO: 1      WIRELESS CHANNEL SIMULATION INCLUDING FADING AND DOPPLER EFFECTS**

### **AIM:**

To simulate the wireless channel including Rayleigh and Rician multipath fading channel system objects and Doppler shifts.

### **COMPONENTS REQUIRED:**

- ❖ Personal computer
- ❖ MATLAB software

### **Pre Lab Questions:**

1. Define fading.
2. What is diffraction and scattering?
3. Define impulse response.
4. What is the need of MATLAB?
5. Define Brewster angle.

### **THEORY:**

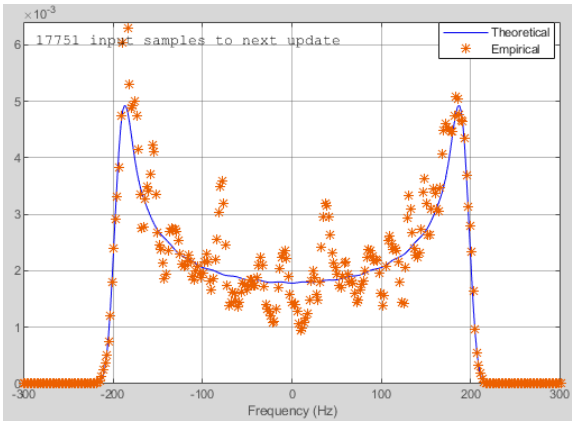
#### **Fading:**

Fading is used to describe the rapid fluctuations of the amplitudes, phases or multipath delays of a radio signal over a short period of time or travel distance, so that large-scale path loss effects may be ignored. Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. These waves called multipath waves, combine at the receiver antenna to give a resultant signal which can vary widely in amplitude and phase, depending on the distribution of the intensity and relative propagation time of the waves and the bandwidth of the transmitted signal.

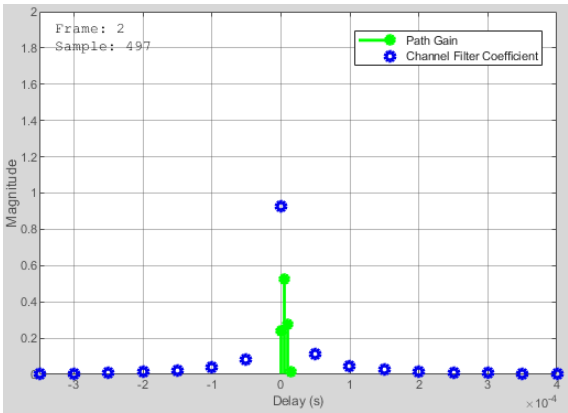
The three most important effects are

- ❖ Rapid changes in signal strength over a small travel distance or time interval.

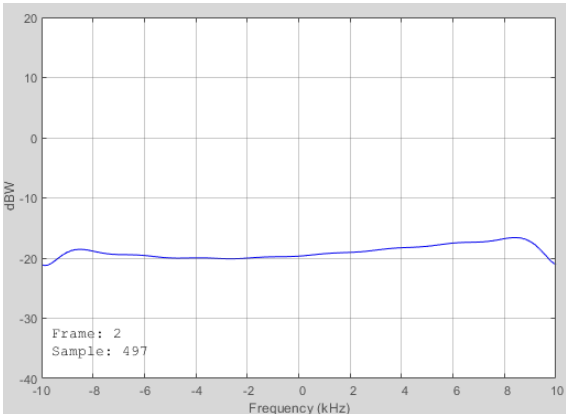
Doppler Spectrum



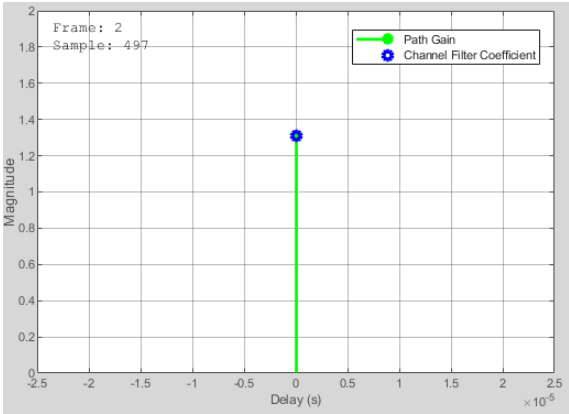
Impulse Response



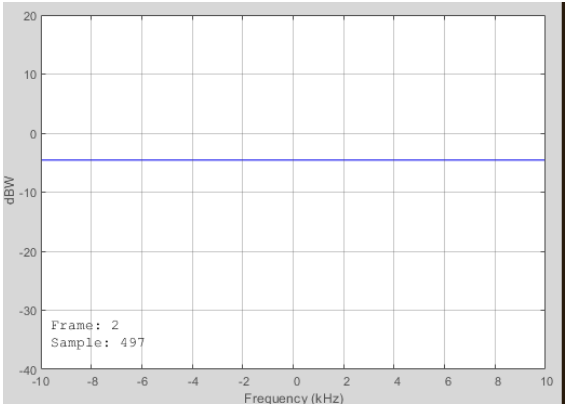
Frequency Response



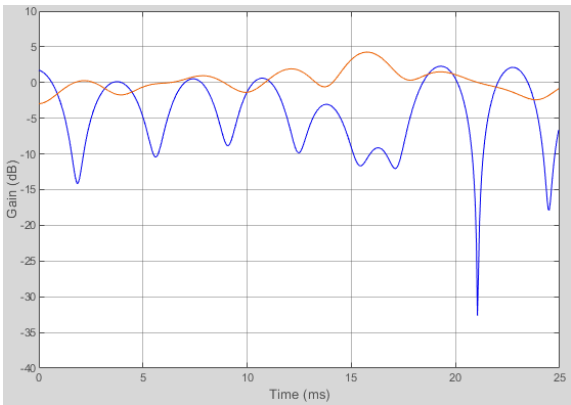
Impulse Response



Frequency Response



Multipath Gain



- ❖ Random frequency modulation due to varying Doppler shifts on different multipath signals.
- ❖ Time dispersion (echoes) caused by multipath propagation delays.

### **Doppler Effects:**

Due to the relative motion between the mobile and base station each multipath wave experiences an apparent shift in frequency. The shift in received signal frequency due to motion is called Doppler Effect, and it is directly proportional to the velocity and direction of motion of the mobile with respect to the direction of arrival of the received multipath wave.

### **PROCEDURE:**

*Processing a signal using a fading channel involves the following steps:*

1. Create a channel System object that describes the channel that you want to use. A channel object is a type of MATLAB variable that contains information about the channel, such as the maximum Doppler shift.
2. Adjust properties of the System object, if necessary, to tailor it to your needs. For example, you can change the path delays or average path gains.
3. Apply the channel System object to your signal using the step method, which generates random discrete path gains and filters the input signal. The characteristics of a channel can be shown with the built-in visualization support of the System object.

### **PROGRAM:**

```
sampleRate500kHz = 500e3; % Sample rate of 500K Hz
sampleRate20kHz = 20e3; % Sample rate of 20K Hz
maxDopplerShift = 200; % Maximum Doppler shift of diffuse components (Hz)
delayVector = (0:5:15)*1e-6; % Discrete delays of four-path channel (s)
gainVector = [0 -3 -6 -9]; % Average path gains (dB)

KFactor = 10; % Linear ratio of specular power to diffuse power
specDopplerShift = 100; % Doppler shift of specular component (Hz)

% Configure a Rayleigh channel object
```

```

rayChan = comm.RayleighChannel( ...
    'SampleRate',      sampleRate500kHz, ...
    'PathDelays',      delayVector, ...
    'AveragePathGains', gainVector, ...
    'MaximumDopplerShift', maxDopplerShift, ...
    'RandomStream',    'mt19937ar with seed', ...
    'Seed',            10, ...
    'PathGainsOutputPort', true);

```

% Configure a Rician channel object

```

ricChan = comm.RicianChannel( ...
    'SampleRate',      sampleRate500kHz, ...
    'PathDelays',      delayVector, ...
    'AveragePathGains', gainVector, ...
    'KFactor',         KFactor, ...
    'DirectPathDopplerShift', specDopplerShift, ...
    'MaximumDopplerShift', maxDopplerShift, ...
    'RandomStream',    'mt19937ar with seed', ...
    'Seed',            100, ...
    'PathGainsOutputPort', true);

```

```

qpskMod = comm.QPSKModulator( ...
    'BitInput', true, ...
    'PhaseOffset', pi/4);

```

% Number of bits transmitted per frame is set to be 1000. For QPSK

% modulation, this corresponds to 500 symbols per frame.

```
bitsPerFrame = 1000;
```

```
msg = randi([0 1],bitsPerFrame,1);
```

% Modulate data for transmission over channel

```
modSignal = qpskMod(msg);
```

```

% Apply Rayleigh or Rician channel object on the modulated data
rayChan(modSignal);
ricChan(modSignal);

release(rayChan);
release(ricChan);

rayChan.Visualization = 'Impulse and frequency responses';
rayChan.SamplesToDisplay = '100%';

numFrames = 2;

for i = 1:numFrames % Display impulse and frequency responses for 2 frames
    % Create random data
    msg = randi([0 1],bitsPerFrame,1);
    % Modulate data
    modSignal = qpskMod(msg);
    % Filter data through channel and show channel responses
    rayChan(modSignal);
end

release(rayChan);
rayChan.Visualization = 'Doppler spectrum';
numFrames = 5000;

for i = 1:numFrames % Display Doppler spectrum from 5000 frame transmission
    msg = randi([0 1],bitsPerFrame,1);
    modSignal = qpskMod(msg);
    rayChan(modSignal);
end

```

### ***Narrowband or Frequency-Flat Fading***

```
release(rayChan);  
rayChan.Visualization = 'Impulse and frequency responses';  
rayChan.SampleRate = sampleRate20kHz;  
rayChan.SamplesToDisplay = '25%'; % Display one of every four samples  
  
numFrames = 2;  
  
for i = 1:numFrames % Display impulse and frequency responses for 2 frames  
    msg = randi([0 1],bitsPerFrame,1);  
    modSignal = qpskMod(msg);  
    rayChan(modSignal);  
end
```

### ***release(rayChan);***

```
rayChan.PathDelays = 0; % Single fading path with zero delay  
rayChan.AveragePathGains = 0; % Average path gain of 1 (0 dB)  
  
for i = 1:numFrames % Display impulse and frequency responses for 2 frames  
    msg = randi([0 1],bitsPerFrame,1);  
    modSignal = qpskMod(msg);  
    rayChan(modSignal);  
end
```

### ***release(rayChan);***

```
rayChan.Visualization = 'Off'; % Turn off System object's visualization  
ricChan.Visualization = 'Off'; % Turn off System object's visualization  
  
% Same sample rate and delay profile for the Rayleigh and Rician objects  
ricChan.SampleRate = rayChan.SampleRate;  
ricChan.PathDelays = rayChan.PathDelays;
```

```

ricChan.AveragePathGains = rayChan.AveragePathGains;
% Configure a Time Scope System object to show path gain magnitude
gainScope = dsp.TimeScope( ...
    'SampleRate', rayChan.SampleRate, ...
    'TimeSpan', bitsPerFrame/2/rayChan.SampleRate, ... % One frame span
    'Name',      'Multipath Gain', ...
    'ShowGrid', true, ...
    'YLimits',   [-40 10], ...
    'YLabel',    'Gain (dB)');

% Compare the path gain outputs from both objects for one frame
msg = randi([0 1],bitsPerFrame,1);
modSignal = qpskMod(msg);
[~, rayPathGain] = rayChan(modSignal);
[~, ricPathGain] = ricChan(modSignal);
% Form the path gains as a two-channel input to the time scope
gainScope(10*log10(abs([rayPathGain, ricPathGain]).^2));

```

### **Post Lab Questions:**

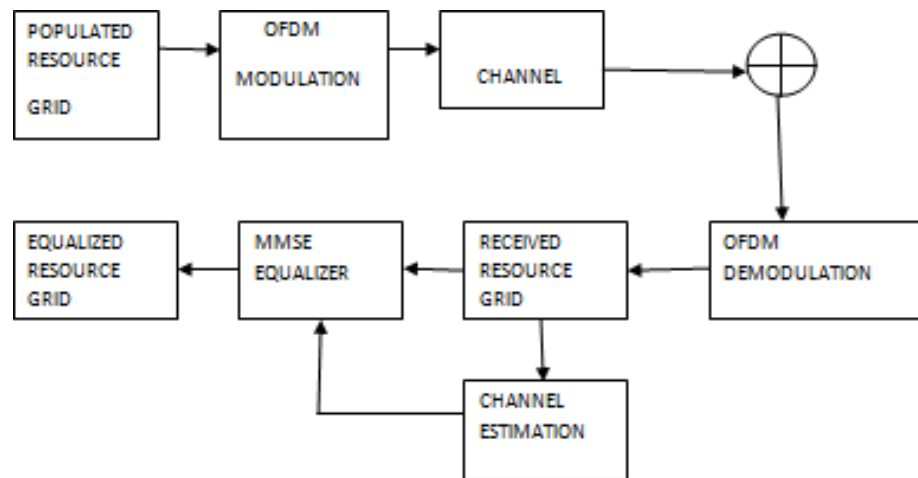
1. Differentiate slow fading and fast fading.
2. Define Doppler shift.
3. What are the factors influencing small scale fading?
4. What are the important parameters of mobile multipath channels?
5. Define frequency selective fading.

### **RESULT:**

Thus the wireless channel including Rayleigh and Rician multipath fading channel system objects and Doppler shifts were simulated and the graphs are noted.



### Block Diagram:



## **EX.NO: 2      SIMULATION OF CHANNEL ESTIMATION, SYNCHRONIZATION AND EQUALIZATION TECHNIQUES**

### **AIM:**

To Simulate the Channel Estimation, Synchronization & Equalization techniques using MATLAB.

### **COMPONENTS REQUIRED:**

- ❖ Personal computer
- ❖ MATLAB

### **Pre Lab Questions:**

1. Define simplex, duplex.
2. What is full duplex?
3. Give the advantages of wireless communication.
4. Define channel estimation.
5. What is channel assignment?

### **THEORY:**

#### **Channel Estimation:**

In digital wireless communication systems, information is transmitted through a radio channel. For conventional, coherent receivers, the effect of the channel on the transmitted signal must be estimated to recover the transmitted information. For example, with binary phase shift keying (BPSK), binary information is represented as +1 and -1 symbol values. The radio channel can apply a phase shift to the transmitted symbols, possibly inverting the symbol values. As long as the receiver can estimate what the channel did to the transmitted signal, it can accurately recover the information sent.

Channel estimation is a challenging problem in wireless communications. Transmitted signals are typically reflected and scattered, arriving at the receiver along multiple paths. When these paths have similar delays, they add either constructively or destructively, giving rise to fading. When these paths have very different delays, they appear as signal echoes. Due to the mobility of the transmitter, the receiver, or the scattering objects, the channel changes over time.

**Program:**

```
enb.NDLRB = 15;           % Number of resource blocks
enb.CellRefP = 1;         % One transmit antenna port
enb.NCellID = 10;         % Cell ID
enb.CyclicPrefix = 'Normal'; % Normal cyclic prefix
enb.DuplexMode = 'FDD';    % FDD
SNRdB = 22;               % Desired SNR in dB
SNR = 10^(SNRdB/20);      % Linear SNR
rng('default');           % Configure random number generators

cfg.Seed = 1;             % Channel seed
cfg.NRxAnts = 1;          % 1 receive antenna
cfg.DelayProfile = 'EVA';  % EVA delay spread
cfg.DopplerFreq = 120;     % 120Hz Doppler frequency
cfg.MIMOCorrelation = 'Low'; % Low (no) MIMO correlation
cfg.InitTime = 0;          % Initialize at time zero
cfg.NTerms = 16;           % Oscillators used in fading model
cfg.ModelType = 'GMEDS';   % Rayleigh fading model type
cfg.InitPhase = 'Random';  % Random initial phases
cfg.NormalizePathGains = 'On'; % Normalize delay profile power
cfg.NormalizeTxAnts = 'On'; % Normalize for transmit antennas

cec.PilotAverage = 'UserDefined'; % Pilot averaging method
cec.FreqWindow = 9;        % Frequency averaging window in REs
cec.TimeWindow = 9;        % Time averaging window in REs

gridsize = lteDLResourceGridSize(enb);
K = gridSize(1); % Number of subcarriers
L = gridSize(2); % Number of OFDM symbols in one subframe
P = gridSize(3); % Number of transmit antenna ports
```

```

txGrid = [];

% Number of bits needed is size of resource grid (K*L*P) * number of bits
% per symbol (2 for QPSK)
numberOfBits = K*L*P*2;

% Create random bit stream
inputBits = randi([0 1], numberOfBits, 1);

% Modulate input bits
inputSym = lteSymbolModulate(inputBits,'QPSK');

% For all subframes within the frame
for sf = 0:10

    % Set subframe number
    enb.NSubframe = mod(sf,10);

    % Generate empty subframe
    subframe = lteDLResourceGrid(enb);

    % Map input symbols to grid
    subframe(:) = inputSym;

    % Generate synchronizing signals
    pssSym = ltePSS(enb);
    sssSym = lteSSS(enb);
    pssInd = ltePSSIndices(enb);
    sssInd = lteSSSIndices(enb);

```

```

% Map synchronizing signals to the grid
subframe(pssInd) = pssSym;
subframe(sssInd) = sssSym;

% Generate cell specific reference signal symbols and indices
cellRsSym = lteCellRS(enb);
cellRsInd = lteCellRSIndices(enb);
% Map cell specific reference signal to grid
subframe(cellRsInd) = cellRsSym;

% Append subframe to grid to be transmitted
txGrid = [txGrid subframe]; %#ok

end

[txWaveform,info] = lteOFDMModulate(enb,txGrid);
txGrid = txGrid(:,1:140);

cfg.SamplingRate = info.SamplingRate;

% Pass data through the fading channel model
rxWaveform = lteFadingChannel(cfg,txWaveform);

% Calculate noise gain
N0 = 1/(sqrt(2.0*enb.CellRefP*double(info.Nfft))*SNR);

% Create additive white Gaussian noise
noise = N0*complex(randn(size(rxWaveform)),randn(size(rxWaveform)));

% Add noise to the received time domain waveform
rxWaveform = rxWaveform + noise;

```

```

offset = lteDLFrameOffset(enb,rxWaveform);
rxWaveform = rxWaveform(1+offset:end,:);

rxGrid = lteOFDMDemodulate(enb,rxWaveform);

enb.NSubframe = 0;
[estChannel, noiseEst] = lteDLChannelEstimate(enb,cec,rxGrid);
eqGrid = lteEqualizeMMSE(rxGrid, estChannel, noiseEst);
% Calculate error between transmitted and equalized grid
eqError = txGrid - eqGrid;
rxError = txGrid - rxGrid;

% Compute EVM across all input values
% EVM of pre-equalized receive signal
EVM = comm.EVM;
EVM.AveragingDimensions = [1 2];
preEqualisedEVM = EVM(txGrid,rxGrid);
fprintf('Percentage RMS EVM of Pre-Equalized signal: %0.3f%%\n', ...
    preEqualisedEVM);
% EVM of post-equalized receive signal
postEqualisedEVM = EVM(txGrid,eqGrid);
fprintf('Percentage RMS EVM of Post-Equalized signal: %0.3f%%\n', ...
    postEqualisedEVM);
% Plot the received and equalized resource grids
hDownlinkEstimationEqualizationResults(rxGrid, eqGrid);

```

**Synchronization:**

Synchronization is the process by which a receiver node determines the correct instants of time at which to sample the incoming signal. Carrier synchronization is the process by which a receiver adapts the frequency and phase of its local carrier oscillator with those of the received signal.

**Equalization:**

Equalization is the reversal of distortion incurred by a signal transmitted through a channel. Equalizers are used to render the frequency response—for instance of a telephone line— flat from end-to-end. When a channel has been equalized the frequency domain attributes of the signal at the input are faithfully reproduced at the output. Telephones, DSL lines and television cables use equalizers to prepare data signals for transmission.

Equalizers are critical to the successful operation of electronic systems such as analog broadcast television. In this application the actual waveform of the transmitted signal must be preserved, not just its frequency content. Equalizing filters must cancel out any group delay and phase delay between different frequency components.

**PROCEDURE:**

The example generates a frame worth of data on one antenna port. As no transport channel is created in this example the data is random bits, QPSK modulated and mapped to every symbol in a subframe. A cell specific reference signal and primary and secondary synchronization signals are created and mapped to the subframe. 10 subframes are individually generated to create a frame. The frame is OFDM modulated, passed through an Extended Vehicular A Model (EVA5) fading channel, additive white Gaussian noise added and demodulated. MMSE equalization using channel and noise estimation is applied and finally the received and equalized resource grids are plotted.

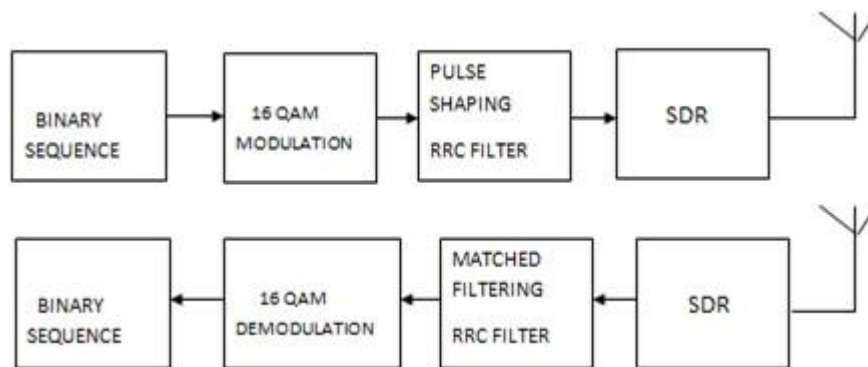
**Post Lab Questions:**

1. Define synchronization.
2. What is equalization?
3. What are the different types of channel models?
4. Give the main idea of equalization in the time domain and frequency domain.
5. What is linear equalizer and mention the types of linear equalizer.

**Result:**

Thus the Simulation of Channel Estimation, Synchronization & Equalization techniques was done using MATLAB and the output was verified.

**Block Diagram:**





## **EX:NO: 3     ANALYSING IMPACT OF PULSE SHAPING AND MATCHED FILTERING USING SOFTWARE DEFINED RADIOS**

### **AIM:**

To analyse the impact of pulse shaping and matched filtering by using SDR.

### **COMPONENTS REQUIRED:**

- ❖ Personal computer
- ❖ MATLAB software
- ❖ SDR hardware

### **Pre Lab Questions:**

1. Define pulse.
2. Mention the types of pulse code modulations.
3. What is filter?
4. List the types of filter.
5. Define SDR.

### **THEORY:**

#### **Pulse shaping:**

Pulse shaping is the process of changing the waveform of transmitted pulses. Its purpose is to make the transmitted signal better suited to its purpose or the communication channel, typically by limiting the effective bandwidth of the transmission. By filtering the transmitted pulses this way, the intersymbol interference caused by the channel can be kept in control. In RF communication, pulse shaping is essential for making the signal fit in its frequency band.

Typically pulse shaping occurs after line coding and modulation.

Examples of pulse shaping filters that are commonly found in communication systems are:

- ❖ Sinc shaped filter
- ❖ Raised-cosine filter
- ❖ Gaussian filter

**PROGRAM:**

```
M = 16; % Modulation order
k = log2(M); % Number of bits per symbol
numBits = 3e5; % Number of bits to process
sps = 4; % Number of samples per symbol (oversampling factor)
filtlen = 10; % Filter length in symbols
rolloff = 0.25; % Filter rolloff factor
rrcFilter = rcosdesign(rolloff,filtlen,sps);
fvtool(rrcFilter,'Analysis','Impulse')
rng default; % Use default random number generator
dataIn = randi([0 1],numBits,1); % Generate vector of binary data
dataInMatrix = reshape(dataIn,length(dataIn)/k,k); % Reshape data into binary 4-tuples
dataSymbolsIn = bi2de(dataInMatrix); % Convert to integers
dataMod = qammod(dataSymbolsIn,M);
txFiltSignal = upfirdn(dataMod,rrcFilter,sps,1);
EbNo = 10;
snr = EbNo + 10*log10(k) - 10*log10(sps);
rxSignal = awgn(txFiltSignal,snr,'measured');
rxFiltSignal = upfirdn(rxSignal,rrcFilter,1,sps); % Downsample and filter
rxFiltSignal = rxFiltSignal(filtlen + 1:end - filtlen); % Account for delay
dataSymbolsOut = qamdemod(rxFiltSignal,M);
dataOutMatrix = de2bi(dataSymbolsOut,k);
dataOut = dataOutMatrix(:); % Return data in column vector
[numErrors,ber] = biterr(dataIn,dataOut);
fprintf('\nFor an EbNo setting of %3.1f dB, the bit error rate is %5.2e, based on %d errors.\n', ...
    EbNo,ber,numErrors)
```

**Visualize Filter Effects**

```
EbNo = 20;
snr = EbNo + 10*log10(k) - 10*log10(sps);
rxSignal = awgn(txFiltSignal,snr,'measured');
```

```
rxFiltSignal = upfirdn(rxSignal,rrcFilter,1,sps); % Downsample and filter
rxFiltSignal = rxFiltSignal(filtlen + 1:end - filtlen); % Account for delay
```

```
eyediagram(txFiltSignal(1:2000),sps*2);
eyediagram(rxSignal(1:2000),sps*2);
eyediagram(rxFiltSignal(1:2000),2);
```

```
scatplot = scatterplot(sqrt(sps)*...
    rxSignal(1:sps*5e3),...
    sps,0,'g. ');
hold on;
scatterplot(rxFiltSignal(1:5e3),1,0,'kx',scatplot);
title('Received Signal, Before and After Filtering');
legend('Before Filtering','After Filtering');
axis([-5 5 -5 5]); % Set axis ranges
hold off;
```

### **Matched Filter:**

A matched filter is obtained by correlating a known delayed signal, or *template*, with an unknown signal to detect the presence of the template in the unknown signal. This is equivalent to convolving the unknown signal with a conjugated time-reversed version of the template. The matched filter is the optimal linear filter for maximizing the signal-to-noise ratio (SNR) in the presence of additive stochastic noise.

Matched filters are commonly used in radar, in which a known signal is sent out, and the reflected signal is examined for common elements of the out-going signal. Pulse compression is an example of matched filtering. It is so called because impulse response is matched to input pulse signals. Two-dimensional matched filters are commonly used in image processing, e.g., to improve SNR for X-ray. Matched filtering is a demodulation technique with LTI (linear time invariant) filters to maximize SNR. It was originally also known as a North filter.

**Software Defined Radio:**

Software-defined radio (SDR) is a radio communication system where components that have been traditionally implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system. While the concept of SDR is not new, the rapidly evolving capabilities of digital electronics render practical many processes which were once only theoretically possible.

A basic SDR system may consist of a personal computer equipped with a sound card, or other analog-to-digital converter, preceded by some form of RF front end. Significant amounts of signal processing are handed over to the general-purpose processor, rather than being done in special-purpose hardware (electronic circuits). Such a design produces a radio which can receive and transmit widely different radio protocols (sometimes referred to as waveforms) based solely on the software used. Software radios have significant utility for the military and cell phone services, both of which must serve a wide variety of changing radio protocols in real time.

In the long term, software-defined radios are expected by proponents like the SDR Forum (now The Wireless Innovation Forum) to become the dominant technology in radio communications. SDRs, along with software defined antennas are the enablers of the cognitive radio.

A software-defined radio can be flexible enough to avoid the "limited spectrum" assumptions of designers of previous kinds of radios, in one or more ways including.

- ❖ Spread spectrum and ultrawideband techniques allow several transmitters to transmit in the same place on the same frequency with very little interference, typically combined with one or more error detection and correction techniques to fix all the errors caused by that interference.
- ❖ Software defined antennas adaptively "lock onto" a directional signal, so that receivers can better reject interference from other directions, allowing it to detect fainter transmissions.
- ❖ Cognitive radio techniques: each radio measures the spectrum in use and communicates that information to other cooperating radios, so that transmitters can avoid mutual interference by selecting unused frequencies. Alternatively, each radio connects to a geolocation database to obtain information about the spectrum occupancy in its location and, flexibly, adjusts its operating frequency and/or transmit power not to cause interference to other wireless services.

- ❖ Dynamic transmitter power adjustment, based on information communicated from the receivers, lowering transmit power to the minimum necessary, reducing the near-far problem and reducing interference to others, and extending battery life in portable equipment.
- ❖ Wireless mesh network where every added radio increases total capacity and reduces the power required at any one node. Each node transmits using only enough power needed for the message to hop to the nearest node in that direction, reducing the near-far problem and reducing interference to others.

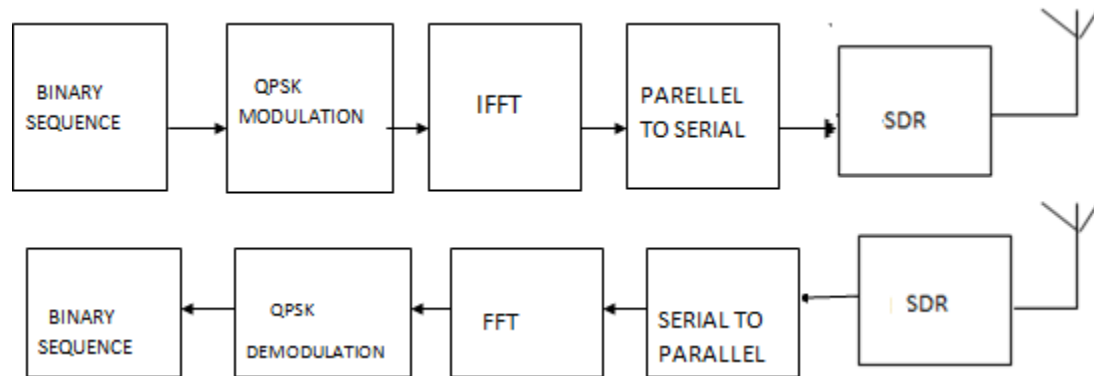
**Post Lab Questions:**

1. Is SDR is compatible for wireless communication? How?
2. What is the advantage of SDR?
3. What is ISI?
4. Define ICI.
5. Mention the advantages of PRBS.

**Result:**

Thus the impact of Pulse Shaping and Matched Filtering was analyzed using Software Defined Radios and its outputs were verified.

### Block Diagram:



## **EX.NO: 4      OFDM SIGNAL TRANSMISSION AND RECEPTION USING SDR**

### **AIM:**

To transmit and receive the OFDM signal using SDR.

### **COMPONENTS REQUIRED**

- ❖ Personal computer
- ❖ MATLAB software
- ❖ SDR

### **Pre Lab Questions:**

1. What are the main requirements of the modulation technique in a communication?
2. Why OFDM is preferred in a wireless communication?
3. State the advantages of OFDM.
4. What is PAPR in OFDM?
5. What are the steps involved in transmission in the wireless communication link?

### **THEORY:**

Implementation of OFDM in actual hardware using Software Defined Radio (SDR) concepts and verification of its performance with different channel estimation methods in various propagation environments have been almost unexplored. The great flexibility feature of SDR systems facilitates the implementation and experimentation of OFDM systems with less cost and effort, compared to the implementation of the whole system in hardware. In this paper, a customized SDR testbed has been developed based on the GNU radio software platform and version-2 Universal Software Radio Peripheral (USRP2) devices to evaluate the practical error performance of OFDM-based systems in both Gaussian and Rician propagation environments. Three different channel interpolation techniques, namely linear interpolation, second-ordered interpolation and cubic spline interpolation, and a blind SNR estimation algorithm have been implemented in our testbed. The performances show that, as opposed to our intuition, linear channel interpolation in some cases might not only be simpler, but also more accurate than the two other non-linear interpolation techniques, implying that channels might change linearly between neighboring subcarriers. The experimental OFDM system on the developed SDR testbed performs very close to the simulated OFDM system, thus the developed testbed can be used to verify advanced signal processing techniques in OFDM systems in various realistic channels by simply developing software, without the need for otherwise complicated hardware developments.

## PROGRAM

```
%=====
==

% The mfile investigates the generation, transmission and reception of
% the OFDM signal without channel noise or HPA effect
%=====
==

clear all
clc
close
% .....
% A: Setting Parameters
% .....
M = 4;           % QPSK signal constellation
no_of_data_points = 64;    % have 64 data points
block_size = 8;        % size of each ofdm block
cp_len = ceil(0.1*block_size); % length of cyclic prefix
no_of_ifft_points = block_size;    % 8 points for the FFT/IFFT
no_of_fft_points = block_size;
% .....
% B: %  +++++ TRANSMITTER  +++++
% .....
% 1. Generate 1 x 64 vector of data points phase representations
data_source = randsrc(1, no_of_data_points, 0:M-1);
figure(1)
stem(data_source); grid on; xlabel('data points'); ylabel('transmitted data phase representation')
title('Transmitted Data "O"')
% 2. Perform QPSK modulation
qpsk_modulated_data = pskmod(data_source, M);
scatterplot(qpsk_modulated_data);title('qpsk modulated transmitted data')
```



```

% 3. Do IFFT on each block
% Make the serial stream a matrix where each column represents a pre-OFDM
% block (w/o cyclic prefixing)
% First: Find out the number of columns that will exist after reshaping
num_cols=length(qpsk_modulated_data)/block_size;
data_matrix = reshape(qpsk_modulated_data, block_size, num_cols);
% Second: Create empty matrix to put the IFFT'd data
cp_start = block_size-cp_len;
cp_end = block_size;
% Third: Operate columnwise & do CP
for i=1:num_cols,
    ifft_data_matrix(:,i) = ifft((data_matrix(:,i)),no_of_ifft_points);
    % Compute and append Cyclic Prefix
    for j=1:cp_len,
        actual_cp(j,i) = ifft_data_matrix(j+cp_start,i);
    end
    % Append the CP to the existing block to create the actual OFDM block
    ifft_data(:,i) = vertcat(actual_cp(:,i),ifft_data_matrix(:,i));
end
% 4. Convert to serial stream for transmission
[rows_ifft_data cols_ifft_data]=size(ifft_data);
len_ofdm_data = rows_ifft_data*cols_ifft_data;
% Actual OFDM signal to be transmitted
ofdm_signal = reshape(ifft_data, 1, len_ofdm_data);
figure(3)
plot(real(ofdm_signal)); xlabel('Time'); ylabel('Amplitude');
title('OFDM Signal');grid on;
% .....
% E: % +++++ RECEIVER +++++
% .....
% 1. Pass the ofdm signal through the channel

```

```

recvd_signal = ofdm_signal;
% 4. Convert Data back to "parallel" form to perform FFT
recvd_signal_matrix = reshape(recvd_signal,rows_ifft_data, cols_ifft_data);
% 5. Remove CP
recvd_signal_matrix(1:cp_len,:)=[];
% 6. Perform FFT
for i=1:cols_ifft_data,
    % FFT
    fft_data_matrix(:,i) = fft(recvd_signal_matrix(:,i),no_of_fft_points);
end
% 7. Convert to serial stream
recvd_serial_data = reshape(fft_data_matrix, 1,(block_size*num_cols));
% 8. Demodulate the data
qpsk_demodulated_data = pskdemod(recvd_serial_data,M);
scatterplot(qpsk_modulated_data);title('qpsk modulated received data')
figure(5)
stem(qpsk_demodulated_data,'rx');
grid on;xlabel('data points');ylabel('received data phase representation');title('Received Data "X"')

```

**Post Lab Questions:**

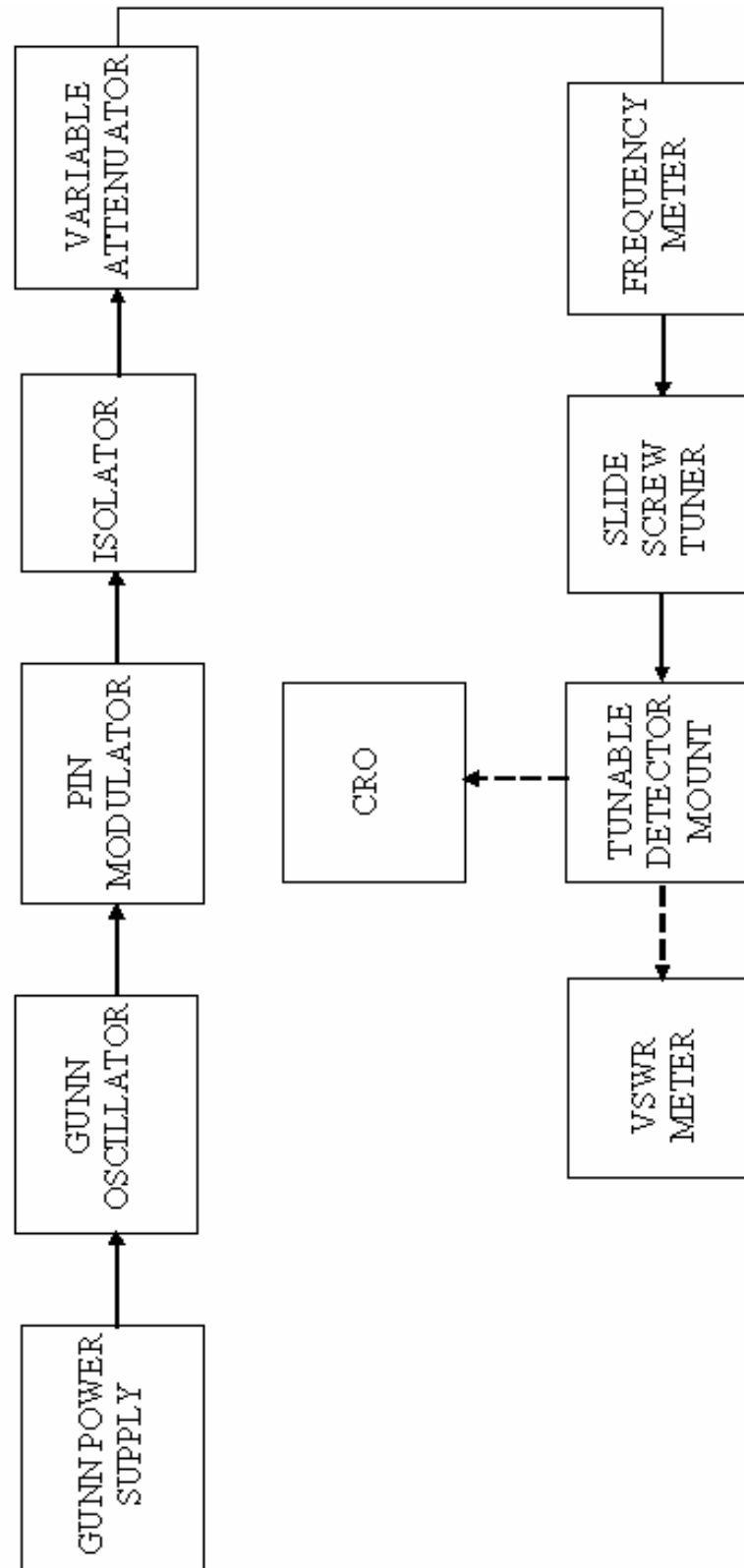
1. Mention the purpose of FFT and IFFT in OFDM.
2. Define Carson's rule.
3. Define Guard interval.
4. What is meant by data field in OFDM?
5. Brief about windowing in OFDM.

**Result:**

Thus the OFDM signal transmission and reception was done using SDR.

# **MICROWAVE EXPERIMENTS**

**BLOCK DIAGRAM:**



## **EX.NO.1      VSWR AND IMPEDANCE MEASUREMENT AND IMPEDANCE MATCHING**

### **AIM:**

To determine the VSWR, Impedance Measurement and Impedance Matching.

### **COMPONENTS REQUIRED:**

- i.     Gunn Power Supply
- ii.    Gunn Oscillator
- iii.   PIN Modulator
- iv.    Isolator
- v.     Variable Attenuator
- vi.    Frequency Meter
- vii.   Slide Screw Tuner
- viii.   Tunable Detector Mount
- ix.    VSWR Meter, CRO
- x.     Bayonet Neill Concelman(BNC) Connector
- xi.    Threaded Neill Concelman(TNC) Connector
- xii.   Cooling Fan
- xiii.   Waveguide Stand, Screw & Net

### **Pre Lab Questions:**

1. What are all the microwave frequencies?
2. Define VSWR.
3. What is the function of frequency meter?
4. Is the microwave frequency is harmful to human beings?
5. Is the characteristic impedance of the sampler line section important?

### **THEORY:**

The electromagnetic field at any point of transmission line, may be considered as the sum of two traveling waves the 'Incident Wave, which Propagates from the source to the load and the reflected wave which propagates towards the generator. The reflected wave is set up by reflection of incident wave from a discontinuity in the line or from the load impedance. The superposition of the two traveling waves, gives rise to a standing wave along the line. The maximum field strength is found where the waves are in phase and minimum where the two waves add in opposite phase. The distance

**OBSERVATION:**

Frequency of Oscillation = \_\_\_\_\_GHz.

No. of Threads	VSWR (S)	Reflection Co-efficient $K=(S-1)/(S+1)$

between two successive minimum (or maximum) is half the guide wavelength on the line. The ratio of electrical field strength of reflected and incident wave is called reflection coefficient.

The voltage standing wave Ratio (VSWR) is defined as ratio between maximum and minimum field strength along the line

Hence VSWR denoted by S is as follows

$$S = \frac{E_{\max}}{E_{\min}} = \frac{\{|E_i| + |E_r|\}}{\{|E_i| - |E_r|\}}$$

Where  $E_i$  = Incident Voltage

$E_r$  = Reflected Voltage

Reflection Coefficient,  $\rho$  is

$$\rho = \frac{E_r}{E_i} = \frac{(Z_L - Z_0)}{(Z_L + Z_0)}$$

Where  $Z_L$  is the load impedance,  $Z_0$  is characteristics impedance.

The above equation gives following equation

$$(\rho) = \frac{(S-1)}{(S+1)}$$

#### **INITIAL SETUP IN VSWR METER:**

1. Set input selector switch in 200 Ohms.
2. Keep meter selector in Normal.
3. Select the range as 50db or 40db or 30db and then vary the gain knob (fine and coarse) to get minimum attenuation. (VSWR = 1).



**PROCEDURE:**

1. Setup the equipment as shown in block diagram.
2. Keep the control knobs of Gunn power supply (GPS) as below.

Meter Switch	– off
Gunn bias knob	– Fully anticlockwise
PIN Mod. Amp knob	– Mid position
PIN Mod. Freq.knob	– Mid position
3. Switch ON the Gunn power supply, VSWR meter and Cooling fan. Set Gunn bias Voltage at 7.5V.
4. Tune the frequency meter to get a ‘dip’ on the CRO. Measure the operating frequency using frequency meter and detune the frequency meter.
5. Then remove the CRO and connect the VSWR meter to Tunable Detector mount.
6. If necessary change the range dB-switch, Variable attenuator position and gain control knob to get deflection in the scale of VSWR meter.
7. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates 1.0 on normal VSWR Scale.
8. Set the depth of S.S Tuner to around 3-4 mm. Read the VSWR on scale and record it.
9. Repeat the above step for change of S.S. Tuner probe depth and record the corresponding SWR.
10. If the reading at the minimum is lower than 3 on the top scale, set RANGE Switch to next higher range and read the indication on the second SWR or (3 to 10) scale of SWR.
11. If the range switch is changed by two steps used top SWR scale, however all indication on this scale must be multiplied by 10.
12. Using the formula,  $K = S - 1/S + 1$ , find the reflection co-efficient.

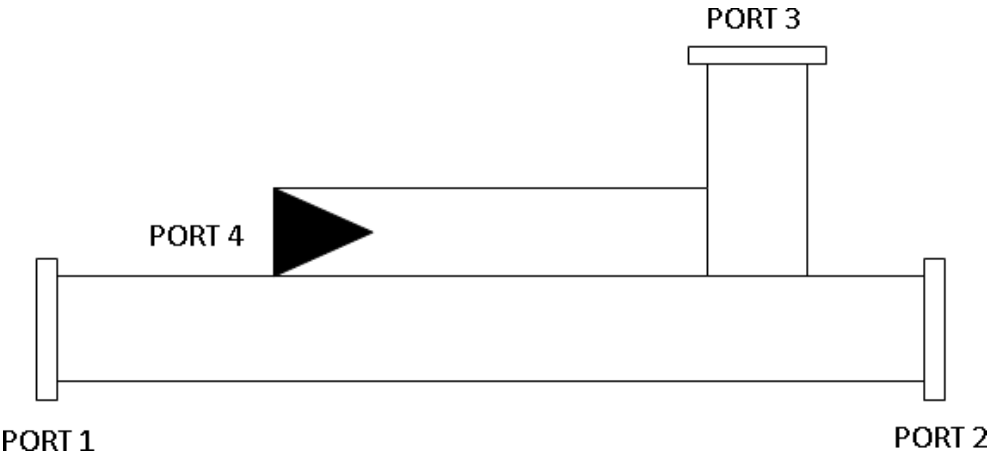
**Post Lab Questions:**

1. Does VSWR vary with line length?
2. Can the magnitude of the reflection coefficient ( $\rho$ ) be greater than 1?
3. Can VSWR be negative?
4. Is there a minimum length of transmission line required on either side of the VSWR meter for valid readings?
5. What is an acceptable VSWR?

**RESULT:**

Thus the VSWR, Impedance Measurement and Impedance Matching were determined.

**DIRECTIONAL COUPLER:**



## **EX.NO.2 (a) CHARACTERIZATION OF DIRECTIONAL COUPLERS**

### **AIM:**

To characterise the directional coupler.

### **COMPONENTS REQUIRED:**

- i. Gunn Power Supply
- ii. Gunn Oscillator
- iii. PIN Modulator
- iv. Isolator
- v. Variable Attenuator
- vi. Frequency Meter
- vii. Multihole Directional Coupler
- viii. Tunable Detector Mount
- ix. Matched Termination
- x. VSWR Meter, CRO
- xi. Bayonet Neill Concelman(BNC) Connector
- xii. Threaded Neill Concelman(TNC) Connector
- xiii. Cooling Fan
- xiv. Waveguide Stand, Screw & Net

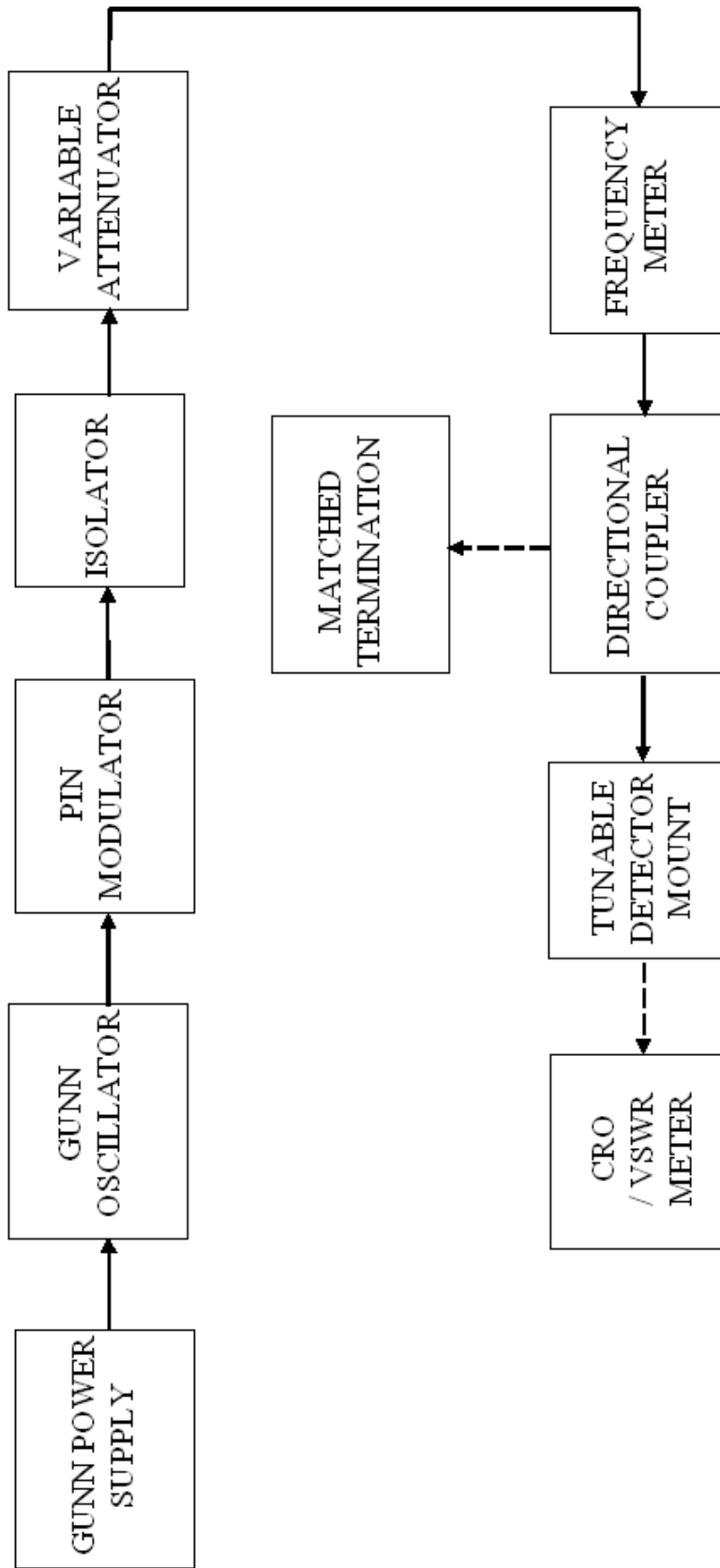
### **Pre Lab Questions:**

1. Why Gunn oscillator is chosen?
2. Explain impedance matching.
3. What is meant by directional coupler?
4. Define waveguide.
5. What is insertion loss?

### **THEORY:**

A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consist of two transmission lines the main arm and auxiliary arm, electromagnetically coupled to each

**BLOCK DIAGRAM:**



other. The power entering, in the main-arm gets divided between port 2 and 3, and almost no power comes out in port (4) Power entering at port (2) is divided between port (1) and (4)

The coupling factor is defined as

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

Isolation (dB) =  $10 \log_{10} [P_2/P_3]$  where  $P_1$  is matched.

With built-in termination and power entering at Port 1, the directivity of the coupler is a measure of separation between incident wave and the reflected wave. Directivity is measured indirectly as follows:

Hence Directivity D (dB) = Isolation – Coupling

$$= 10 \log_{10} [P_2/P_1]$$

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

#### **INITIAL SETUP IN VSWR METER:**

1. Set input selector switch in 200 Ohms.
2. Keep meter selector in Normal.
3. Select the range as 50db or 40db or 30db and then vary the gain knob (fine and coarse) to get minimum attenuation. (VSWR = 1).

#### **PROCEDURE:**

1. Setup the equipments as shown in block diagram.
2. Keep the control knobs of Gunn power supply (GPS) as below.  
Meter Switch – off  
Gunn bias knob – Fully anticlockwise  
PIN Mod. Amp knob – Mid position  
PIN Mod. Freq. knob – Mid position
3. SwitchON the Gunn power supply, VSWR meter and Cooling fan. Set Gunn bias Voltage at 7.5V.
4. Tune the frequency meter to get a ‘dip’ on the CRO. Measure the operating frequency using frequency meter and detune the frequency meter.
5. Then remove the CRO and connect the VSWR meter to Tunable Detector mount.
6. Remove the multihole directional coupler and connect the detector mount of the frequency meter.

7. Set any reference level of power on VSWR meter with the help of variable attenuator, gain control knob of VSWR meter, and note down the reading (reference level let X)
8. Insert the directional coupler as shown in block diagram with detector to the auxiliary port 3 and matched termination to port 2. (Without changing the position of variable attenuator and gain control knob of VSWR meter).
9. Note down the reading on VSWR meter on the scale with the help of range-dB switch if required. (Let it be Y).
10. Calculate coupling factor which will be  $X - Y = C(\text{dB})$
11. Now carefully disconnect the detector from the auxiliary port 3 and match termination from port 2 without disturbing the set-up.
12. Connect the matched termination to the auxiliary port 3 and detector to port 2 and measure the reading on VSWR meter. Suppose it is Z.
13. Compute insertion loss  $X - Z$  in dB.
14. Connect the directional coupler in the reverse direction. i.e. port 2 to frequency meter side. Matched termination to port 1 and detector mount to port 3. (Without disturbing the position of variable attenuator and gain control knob of VSWR meter.)
15. Measure and note down the reading on VSWR meter. Let it be  $Y_d$ .  $X - Y_d$  gives Isolation I (dB).
16. Compute the directivity as  $Y - Y_d = I - C$

### OBSERVATION:

Frequency of Oscillation	=	GHz.
X	=	dB (Without Directional Coupler)
Z	=	dB (I/p at port 1, o/p at port 2, Terminate at port 3)
Y	=	dB (I/p at port 1, o/p at port 3, Terminate at port 2)
$Y_d$	=	dB (I/p at port 2, o/p at port 3, Terminate at port 1)
Coupling Factor,	$C = X - Y$	= dB
Insertion loss,	$= X - Z$	= dB
Isolation	$I = X - Y_d$	= dB
Directivity	$D = Y - Y_d$	= dB

**Post Lab Questions:**

1. What is the primary purpose of a directional coupler?
2. How far apart are the two holes in a simple directional coupler?
3. What is the purpose of the absorbent material in a directional coupler?
4. In a directional coupler that is designed to sample the incident energy, what happens to the two portions of the wavefront when they arrive at the pickup probe?
5. What happens to reflected energy that enters a directional coupler that is designed to sample incident energy?

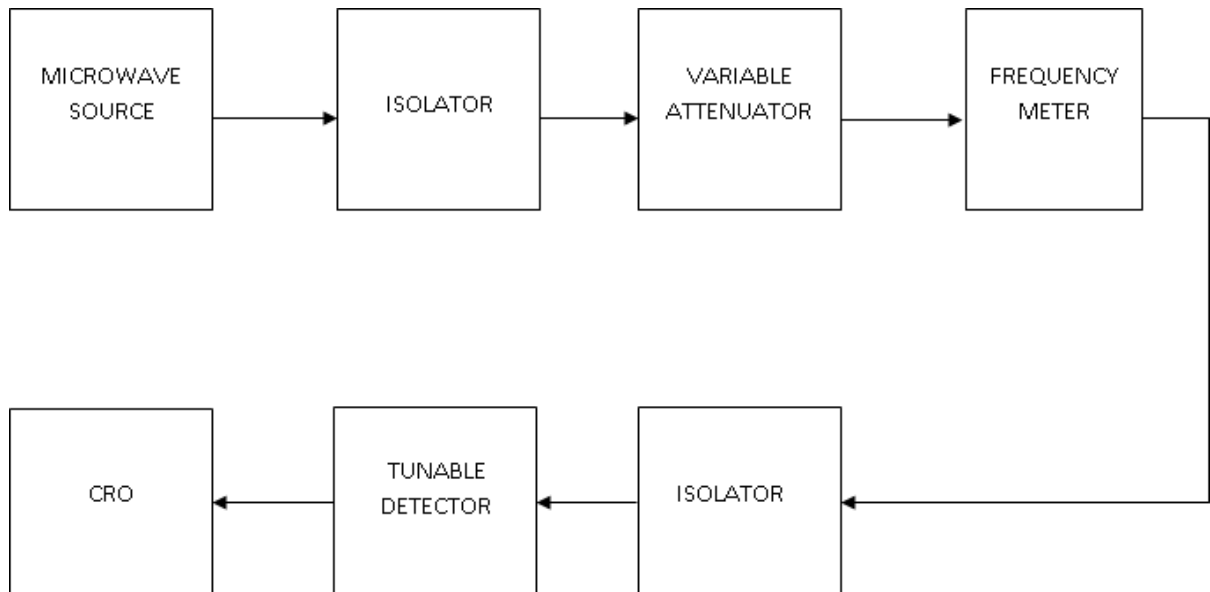
**RESULT:**

Thus the Directional coupler was characterized and the following measurement was done.

Coupling Factor,	C =	dB
Insertion loss,	=	dB
Isolation	I =	dB
Directivity	D =	dB



**BLOCK DIAGRAM:**



## **EX.NO. 2 (b) ISOLATORS**

### **AIM:**

To measure the S-parameter of isolators.

### **COMPONENTS REQUIRED:**

1. Microwave source (Gunn, Klystron)
2. Isolator
3. Frequency Meter
4. Variable Attenuator
5. Detector Mount
6. CRO / VSWR
7. Bayonet Neill Concelman(BNC) Connector
8. Cooling Fan
9. Waveguide Stand, Screw & Nut

### **Pre Lab Questions:**

1. Mention the different types of parameters which is used to analyse the microwave devices.
2. Define Isolator.
3. State Klystron working principle.
4. Define input VSWR.
5. What is the use of S-parameter?

### **THEORY:**

#### **ISOLATOR:**

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

The isolator can be derived from a three-port circulator by simply placing a matched load (reflection less termination) on one port.

The important isolator parameters are:

#### **A. Insertion loss:**

Insertion loss is the ratio of power detected at the output port to the power supplied by source to the input port, measured with other ports terminated in the matched load. It is expressed in dB.

**READINGS:**

PORT 1 (Volts)	PORT 2 (Volts)	S-PARAMETER

**The S matrix of Isolator**

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

**B. Isolation:**

Isolation is the ratio of power applied to the output to that measured at the input. This ratio is expressed in dB. The isolation of a circulator is measured with the third port terminated in a matched load.

**C. Input VSWR:**

The input VSWR of an isolator or circulator is the ratio of voltage maximum to voltage minimum of the standing wave existing in the line with all parts except the test port are matched

**PROCEDURE:**

1. Set the components as shown in the block diagram,
2. Keep the control knob of microwave power supply as mentioned in the basic setup.
3. Switch on the power supply and energize the microwave source. Get the maximum output in CRO without connecting the Isolator. Measure the voltage using CRO.
4. Tune the frequency meter knob to get a dip in CRO and note down the frequency of oscillation directly. Detune the frequency meter.
5. Connect the Isolator in forward direction i.e. port 1 at input side(Frequency meter) and port 2 at output side (Tunable Detector) measure the input and output voltage using CRO.
6. Now connect the isolator in reverse direction i.e. Port 1 at output side and port 2 at input side and measure the output voltage using CRO.

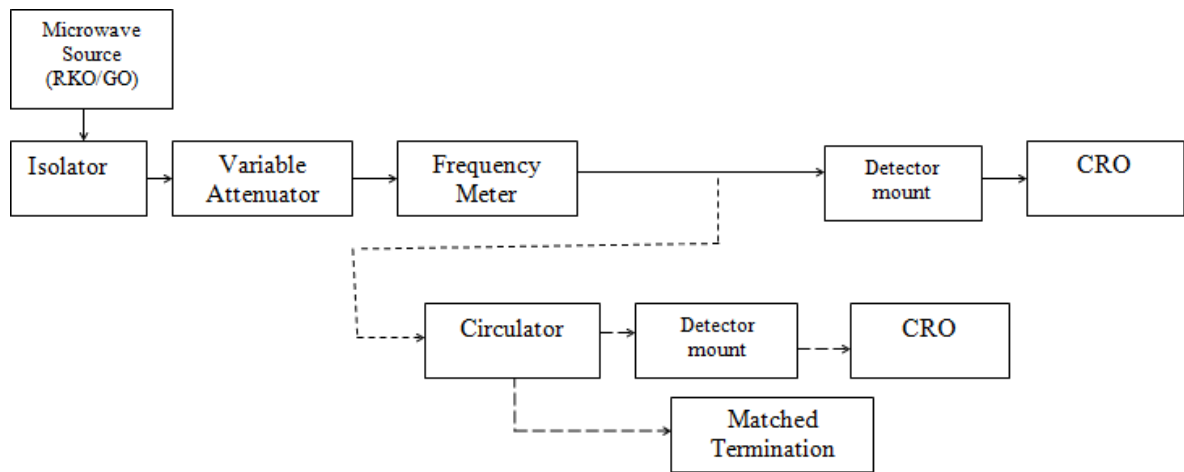
**Post Lab Questions:**

1. What are the reasons that low frequency parameters cannot be measured in microwaves?
2. What is S matrix and write the S matrix of N port network?
3. What is meant by hybrid coupler?
4. Compare z parameters and ABCD parameters with S-parameters.
5. State the properties of S matrix.

**RESULT:**

Thus the S-parameters of isolators were measured.

### Block Diagram:



## EX.NO.4 (c) CIRCULATOR

### AIM :

To find the S-parameters of Circulator.

### COMPONENT REQUIRED:

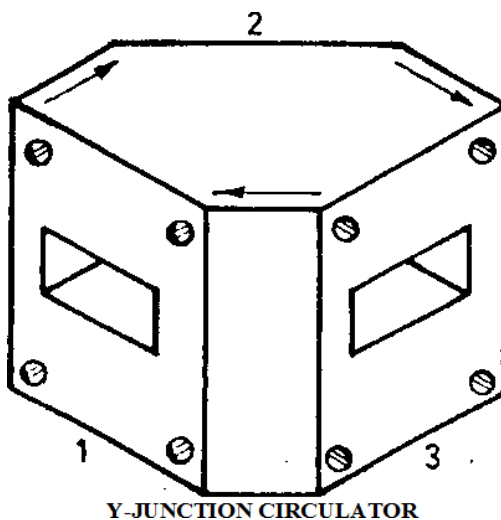
- i. Microwave Source (RKO/GO)
- ii. Isolator
- iii. Variable Attenuator
- iv. Frequency meter
- v. detector mount
- vi. VSWR meter
- vii. Circulator and
- viii. Matched Terminations-2.

### Pre Lab Questions:

1. How does a microwave circulator work?
2. What is the purpose of a circulator?
3. What is the difference between isolator and circulator?
4. What is the use of isolator in microwave?
5. Define reflection amplifier.

### THEORY:

The circulator is a multi port junction that permits transmission in certain ways. The wave incident at  $n$ th port can be coupled to  $(n+1)^{\text{th}}$  port only.



**READINGS:**

PORT 1 (Volts)	PORT 2 (Volts)	PORT 3 (Volts)	S-PARAMETER
			$S_{12}=$
			$S_{13}=$
			$S_{21}=$
			$S_{23}=$
			$S_{31}=$
			$S_{32}=$

**The S matrix of circulator**

$$S = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}$$

**PROCEDURE:**

1. Set the components as shown in the block diagram,
2. Keep the control knob of microwave power supply as mentioned in the basic setup.
3. Switch on the power supply and energize the microwave source. Get the maximum output in CRO without connecting the circulator. Measure the voltage using CRO.
4. Tune the frequency meter knob to get a dip in CRO and note down the frequency of oscillation directly. Detune the frequency meter.
5. Connect the port 1 of circulator at input side (Frequency meter) and port 2 at output side (Tunable Detector) and port 3 is at matched termination. Measure the output voltage using CRO.
6. Similarly measure the output voltage by interchanging the ports.

**Post Lab Questions:**

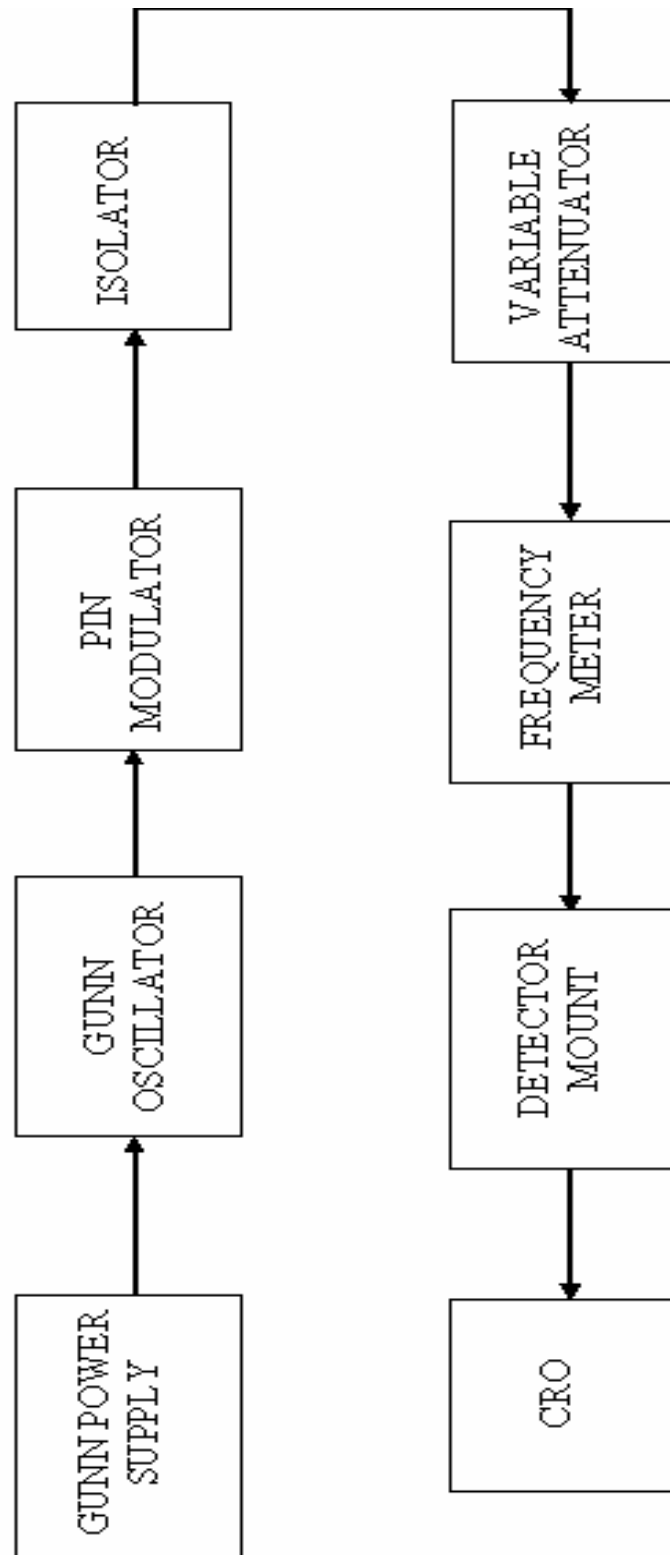
1. Define nonferrite circulators.
2. How are microwave measurements different from low frequency measurements?
3. Define ferrite circulators.
4. Write the scattering matrix for an ideal three-port circulator.
5. How ports are available in the circulator and mention its uses.

**RESULT:**

Thus the S-parameters of circulator were found and its values are noted.



**BLOCK DIAGRAM:**



### **EX.NO: 3 GUNN DIODE CHARACTERISTICS**

#### **AIM :**

To determine the characteristics of Gunn Diode.

#### **COMPONENTS REQUIRED:**

- i. Gunn power Supply
- ii. Gunn oscillator
- iii. PIN modulator
- iv. Isolator
- v. Frequency Meter
- vi. Variable Attenuator
- vii. Detector Mount
- viii. CRO
- ix. Bayonet Neill Concelman(BNC) Connector
- x. Threaded Neill Concelman(TNC) Connector
- xi. Cooling Fan
- xii. Waveguide Stand, Screw & Net

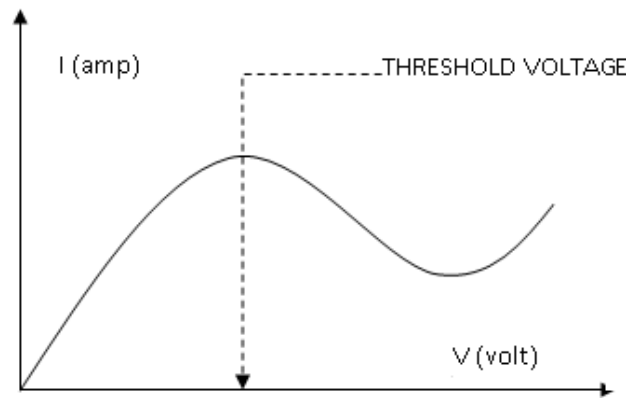
#### **Pre Lab Questions:**

1. Define Gunn Effect.
2. What is the necessary condition for an IMPATT to produce oscillations?
3. List the differences between microwave transistor and TED devices.
4. What are the advantages and disadvantages of parametric amplifier?
5. What is meant by avalanche transit time device?

#### **THEORY:**

Gunn diodes are negative resistance device which are normally used as low power oscillator at microwave frequencies in transmitter and as local oscillator in receiver front end. J.B. Gunn in 1963 discovered microwave oscillation. At low electric field in the material most of the electron will be located in the lower central valley. At high electric field most of the electron will be transferred in to the higher frequency satellite L and X valleys.

### MODEL GRAPH:



**OBSERVATION:**

S.No	Voltage (V)	Current (mA)

**PROCEDURE:**

1. Set the components as shown in block diagram.
2. Keep the control knobs of Gunn power supply (GPS) as below.  
Meter Switch – off  
Gunn bias knob – Fully anticlockwise  
PIN Mod. Amp knob – Mid position  
PIN Mod. Freq.knob – Mid position
3. SwitchON the Gunn power supply, VSWR meter and Cooling fan. Set Gunn bias Voltage at 7.5V.
4. Set the micrometer of Gunn oscillator for required frequency of operation.
5. Measure the operating frequency using frequency meter.
6. Measure the Gunn Diode Current corresponding to the various Gunn bias voltage. Do not exceed the bias voltage above 10 volts.
7. Plot the voltage Vs Current and measure the threshold voltage which corresponds to maximum current.

**NOTE:**

**Do not** keep gun bias knob position at **threshold position** for more than **10-15 seconds** reading should be obtained as fast as possible. Otherwise due to excessive heating, **Gunn diode** may **burn**

**Post Lab Questions:**

1. Define Attenuation.
2. What are the types of attenuator?
3. What is negative resistance in Gunn diode?
4. Name the semiconductor used in Gunn diode.
5. What is transferred electron effect?

**RESULT:**

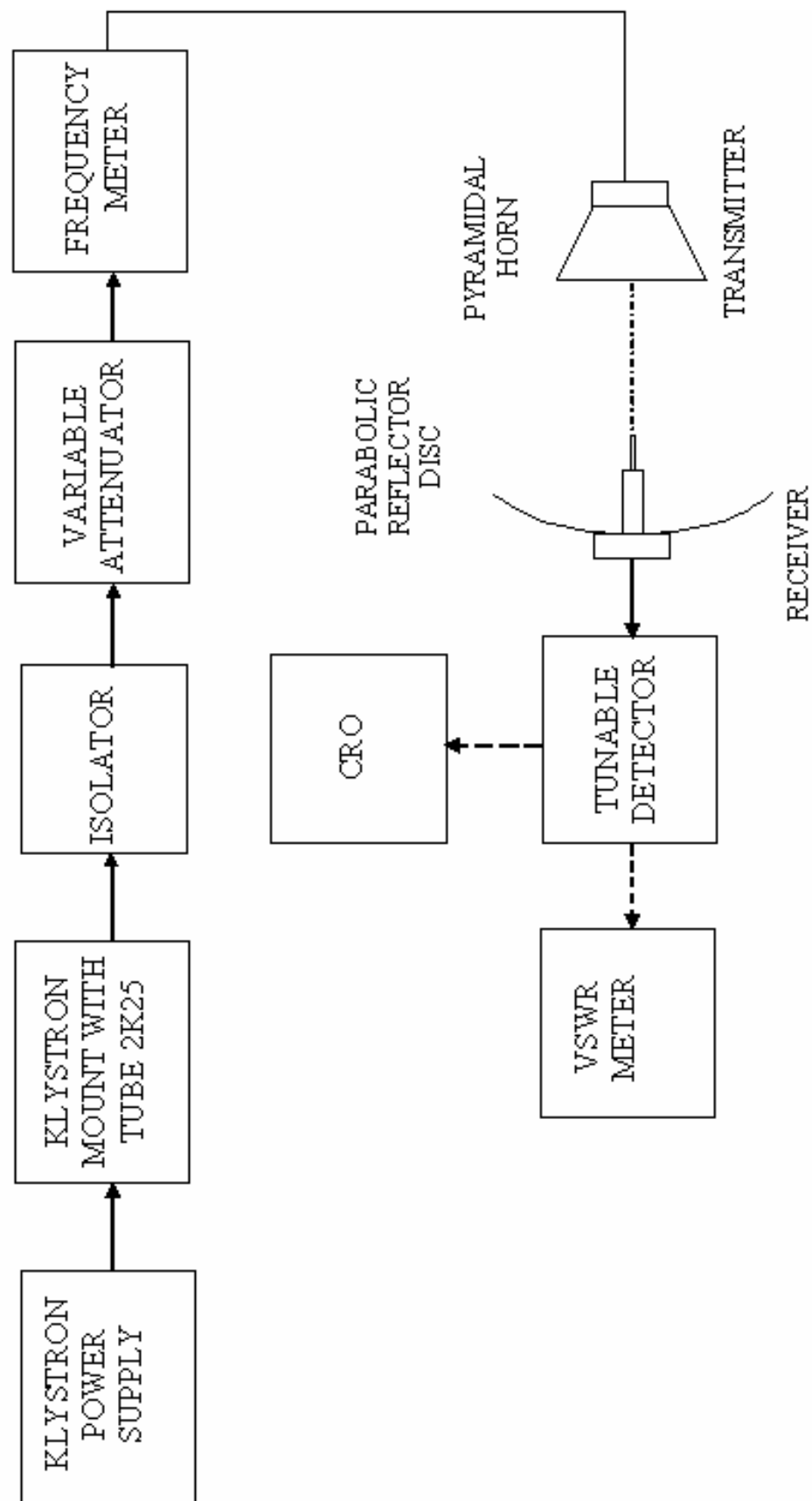
Thus the characteristics of Gunn Diode was determined.

Threshold voltage,  $V_{th}$  =      Volts



# **TOPIC BEYOND THE SYLLABUS EXPERIMENT**

**BLOCK DIAGRAM:**



## **EX.NO. 1 RADIATION PATTERN MEASUREMENT OF PARABOLIC REFLECTOR ANTENNA**

### **AIM:**

To measure the radiation pattern of a Parabolic Reflector antenna.

### **COMPONENTS REQUIRED:**

- i. Klystron Power Supply
- ii. Klystron Mount with Tube 2K25
- iii. Isolator
- iv. Variable Attenuator
- v. Frequency Meter
- vi. One Horn Antenna
- vii. Parabolic Reflector
- viii. Tunable Detector Mount
- ix. VSWR Meter, CRO
- x. Bayonet Neill Concelman (BNC) Connector
- xi. Cooling Fan
- xii. Radiation pattern Twin Table
- xiii. Waveguide Stand, Screw & Net

### **Pre Lab Questions:**

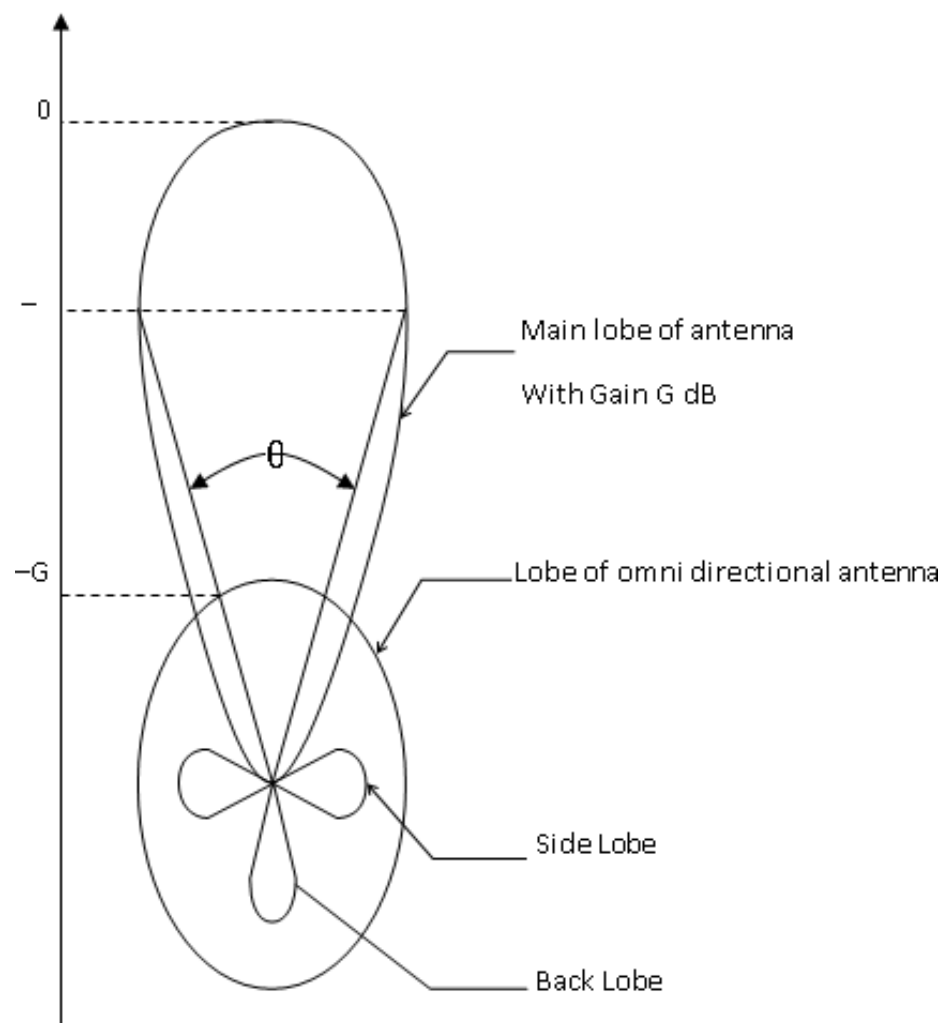
1. Define antenna.
2. What is dipole antenna?
3. Mention the importance of radiation pattern.
4. What is parabolic reflector?
5. Why antenna is needed in wireless communication?

### **THEORY:**

To improve the overall radiation characteristic of the reflector antenna, the parabolic structure is frequently used. Basically a parabola is a locus of a point which moves in such a way that the distance of the point from fixed point called focus plus the distance from the straight line called directrix is constant. When the beam of parallel rays is incident on a Parabolic reflector, then the radiations focus at a focal point. This principle is used in the receiving antenna.



### MODEL GRAPH: (Polar port)



**INITIAL SETUP IN VSWR METER:**

1. Set input selector switch in 200 Ohms.
2. Keep meter selector in Normal.
3. Select the range as 50db or 40db or 30db and then vary the gain knob (fine and coarse) to get minimum attenuation. (VSWR = 1).

**INITIAL ADJUSTMENTS IN KLYSTRON POWER SUPPLY:**

1. Keep the variable attenuator in the minimum attenuation position.
2. Keep the control knob of klystron power supply as below, before switching ON the device.

Beam voltage	=	OFF
Mod-switch	=	AM
Beam voltage knob	=	Fully anticlockwise
Repeller voltage knob	=	Fully clockwise
AM freq. & Amp. Knob	=	Around mid position
FM freq. & Amp. Knob	=	minimum position

**PROCEDURE:**

1. Set the components as shown in Block diagram.
2. Keep the control Knobs of klystron Power supply as mentioned in the basic set up.
3. Replace the transmitting horn by detector mount or keep the transmitting and receiving antenna at close position.
4. Switch ON the VSWR meter, CRO, cooling fan & Klystron power supply and set the beam voltage at 250 volts.
5. Adjust the repeller Voltage (120V) to get maximum output in CRO.
6. Tune the frequency meter knob to get a 'dip' on CRO and note down the frequency of oscillation directly. Detune the frequency meter.
7. Using the formula  $r = 2D^2/\lambda_0$ , Calculate the distance between antennas and keeping the axis of antennas in same line.
8. Then remove the CRO and connect the VSWR meter to Tunable Detector mount.
9. Obtain full scale deflection (0dB) on normal dB scale (0-10dB) and change the appropriate range dB position to get the deflection on scale (do not touch the gain control knob)
10. Note the range dB position and deflection of VSWR meter.

**OBSERVATION:**

Operating Frequency =            GHz.

Right			Left		
Angle $\theta$ (Degree)	Power (dB)	Relative Power (dB)	Angle $\theta$ (Degree)	Power (dB)	Relative Power (dB)

**CALCULATION:**

$$\lambda_o = C/f =$$

$$r = 2D^2/\lambda_o = \quad \text{cm}$$

**FORMULA:**

$$r \geq 2D^2/\lambda_o, \lambda_o = C/f \text{ ( for rectangular horn antenna)}$$

Where

r– Distance between transmitter and receiver horn antenna.

D– Size of the broad wall of horn antenna.(10.1 cm)

$\lambda_o$ – Free space wavelength.  $C = 3 \times 10^8$  m/s. (Velocity of light)

f – Frequency of oscillation in GHz.

11. Tune the receiving parabolic reflector to the left in  $10^\circ$  steps up to  $40^\circ$  and note down the corresponding VSWR dB reading in the normal dB range. (When necessary, change the range switch to next higher range and add 10dB to observed value.)
12. Repeat the above step but this time turn the receiving parabolic reflector to the right and note down the readings.  
Plot a relative power pattern i.e. Output vs. angle.
13. From the diagram determine 3dB-width (beam width) of the Parabolic Reflector.

**Post Lab Questions:**

1. Define front to back Ratio.
2. Give the relation between gain & directivity.
3. Name the types of parabolic reflectors.
4. Define radiation resistance.
5. Write the applications of parabolic reflectors.

**RESULT:**

Thus the radiation pattern of the parabolic reflector antenna was measured.

HPBW=