Sri SAI RAM ENGINEERING COLLEGE

An Autonomous Institution | Affiliated to Anna University & Approved by AICTE, New Delhi

Accredited by NBA and NAAC "A+" | BIS/EOMS ISO 21001 : 2018 and BVQI 9001 : 2015 Certified and NIRF ranked institution

Sai Leo Nagar, West Tambaram, Chennai - 600 044. www.sairam.edu.in

PROSPERITY THROUGH TECHNOLOGY

LAB MANUAL

20ECPL701-ADVANCED COMMUNICATION LABORATORY

IV YEAR VII SEMESTER

Academic year: 2024-2025

Department

of

Electronics and Communication Engineering

INSTITUTION VISION

To emerge as a ”Centre of excellence“ offering Technical Education and Research opportunities of very high standards to students, develop the total personality of the individual and instill high levels of disciple and strive to set global standards, making our students technologically superior and ethically stronger, who in turn shall contribute to the advancement of society and humankind.

INSTITUTION MISSION

We dedicate and commit ourselves to achieve, sustain and foster unmatched excellence in Technical Education. To this end, we will pursue continuous development of infra-structure and enhance state- of-art equipment to provide our students a technologically up-to date and intellectually inspiring environment of learning, research, creativity, innovation and professional activity and inculcate in them ethical and moral values.

INSTITUTION POLICY

We at Sri Sai Ram Engineering College are committed to build a better Nation through Quality Education with team spirit. Our students are enabled to excel in all values of Lifeand become Good Citizens. We continually improve the System, Infrastructure and Serviceto satisfy the Students, Parents, Industry and Society.

DEPARTMENT VISION

To emerge as a “centre of excellence” in the field of Electronics and Communication Engineering and to mould our students to become technically and ethically strong to meet the global challenges. The Students in turn contribute to the advancement and welfare of the society.

DEPARTMENT MISSION

M1: To achieve, sustain and foster excellence in the field of Electronics andCommunication Engineering.

M2: To adopt proper pedagogical methods to maximize the knowledge transfer.

M3: To enhance the understanding of theoretical concepts through professional society activities

M4: To improve the infrastructure and provide conducive environment of learning and research following ethical and moral values

Program Educational Objectives (PEOs)

To prepare the graduates to:

PEO1: Graduates are prepared to analyze and solve Engineering problem with strong background in Scientific, Mathematical and Engineering fundamentals to develop solutions in various research areas of Electronics and Communication Engineering.

PEO2: Graduates are trained with good scientific and engineering breadth to design and create novel products and solutions for real world problems.

PEO3: Graduates are equipped with the qualities of Professional leadership for improving the technical and career growth in multidisciplinary domain that leads to societal benefits.

PEO4: Graduates are involved in Professional activities and industry-oriented training program which enhances their employability with good communication skills.

PEO5: Graduates are motivated to develop Professional Excellency which inculcates ethical and moral behavior through life-long learning.

PROGRAM OUTCOMES (POS)

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities withthe engineering community and with society at large, such as, being able to

comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, asa member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

1. An ability to recognize, adapt and to apply the knowledge of Electronics and Communication to optimize communication systems and to develop techno- economical real-world applications.
2. An ability to design and conduct the experiments, analyze and interpret the data using modern software tools with proper understanding of basic concepts of Electronics and Communication Engineering.

INDEX

NAME: **REG.NO:**

S.No	Date of Exp.	Name of the experiment	Date of sub.	Marks	Staff Sign

		L	T	P	C
20ECPL701 **SDG NO. 4,11,15**	**ADVANCED COMMUNICATION LABORATORY**	**0**	**0**	**3**	**1.5**

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 and 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, Impedance Measurement and Impedance Matching.
2. Characterization of Directional Couplers, Isolators, Circulators.
3. Gunn Diode Characteristics.
4. Microwave IC – Filter Characteristics.
5. S parameters Characterization of RF/ Microwave components using Vector Network Analyzer (VNA).
6. Analysis of RF Signals using Spectrum Analyzer.

TOTAL: 45 PERIODS

EXP NO: **DATE:**

GUNN OSCILLATOR CHARACTERISTICS

AIM:

To determine the various characteristics of the Gunn Diode:

APPARATUS REQUIRED:

Gunn power supply, Gunn oscillator, Pin modulator, Isolator, Frequency meter, Slotted section with probe, Detector mount, VSWR meter, Power Meter

THEORY:

The gunn oscillator is based on negative differential conductivity effect in bulk semiconductors which has two conduction bands separated by an energy gap. A disturbance at the cathode give rise to high field region which travels towards the anode. When this field domain reaches anode it disappears and another domain is formed at the cathode and starts moving towards anode and so on. The time required for domain to travel from cathode to anode (transit time) give oscillation frequency.

Although Gunn oscillator can be amplitude modulated with the bias voltage. The PIN modulator is used for square wave modulation of the signal coming from gunndiode . A measure of the square wave modulation capability is the modulation depth.The parameters can be observed are

1.Threshold Voltage: It is defined as the voltage at which the current starts decreasing.

2.Valley Voltage: It is the voltage at which the negative resistance region ends.

Peak current: It is the current corresponding to peak voltage.

3.Valley current: It is the current corresponding to the valley voltage.

4.Negative resistance: It is the reciprocal of the slope of the negative resistance region of the Gunn diode.

PROCEDURE:

For Determining the Parameters:

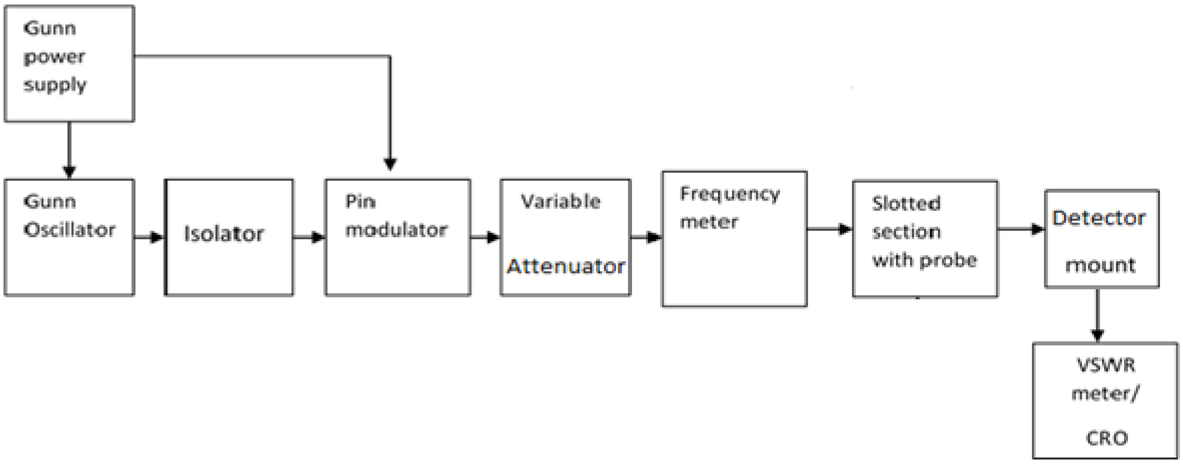
1. Set up the connections as shown in the block diagram. Switch on the Gunn power supply and Gunn bias voltage.
2. Increase the Gunn bias voltage in steps of 0.5V using bias voltage control knobs and Note down Gunn bias voltage.
3. Read the corresponding current in the panel meter of the power supply by switching the selector knob from voltage mode to current mode. Repeat this till the maximum allowable Gunn bias voltage (10V).

Note: Before switching the Gunn power supply make sure that the initial conditions are as explained in the general procedure. In any case the Gunn current should not exceed 450mA. The Gunn diode characteristics is obtained by drawing a graph between Gunn bias voltage in the X axis and Gunn current in the Y axis. From this characteristics curve the above parameters can be obtained.

For Determining the FREQUENCY VS VOLTAGE:

1. Switch ON the Gunn power supply and Gunn bias supply.
2. By slowly increasing the bias voltage select a voltage which is just above the Threshold voltage.
3. Note down the corresponding Gunn bias voltage.
4. Adjust the slotted section to obtain the maximum output from the oscillator.
5. Rotate the frequency meter and when a dip is obtained in CRO note down the corresponding frequency.
6. Increase the Gunn bias voltage in steps of 0.5V using the bias voltage control knob.
7. Repeat this to the maximum allowable Gunn bias voltage.

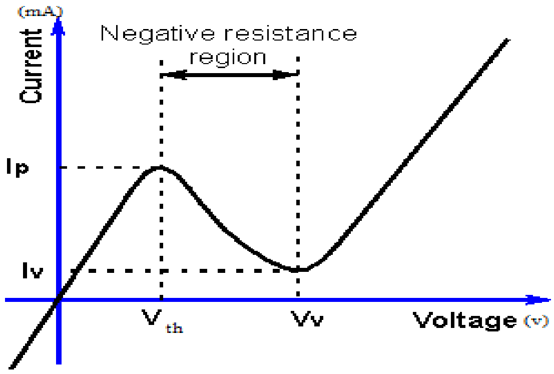
BLOCK DIAGRAM



TABULATION:
V - I Characteristics

S.NO	Gunn Bias Voltage in volts	Gunn bias current in mAmps	S.NO	Gunn Bias Voltage in volts	Gunn bias current in mAmps

MODEL GRAPHS



Freq (Ghz)

Voltage (V)

RESULT:

REVIEW QUESTIONS:

1. What is meant by TEDs?
2. What are the various materials used for Gunn diodes?
3. List difference between transistor and TEDs
4. Why are electrons very hot in TEDs?
5. What is the value of 'Saturated drift velocity' of electrons in a semiconductor?

EXP NO: **DATE:**

MEASUREMENT OF VSWR, IMPEDANCE MEASUREMENT AND IMPEDANCE MATCHING

AIM:

To measure the VSWR,Impedance Measurement and Impedance Matching of the given microwave source

APPARATUS REQUIRED:

Klystron power supply, Klystron mount with tube, Klystron mount, Isolator, Frequency meter, Slotted section with probe, Detector mount, VSWR meter, CRO

THEORY:

The gunn oscillator is based on negative differential conductivity effect in bulk semiconductors which has two conduction bands separated by an energy gap. A disturbance at the cathode gives rise to high field region which travels towards the anode. When this field domain reaches anode it disappears and another domain is formed at the cathode and starts moving towards anode and so on. The time required for domain to travel from cathode to anode (transit time) give oscillation frequency.

Although Gunn oscillator can be amplitude modulated with the bias voltage. We have used a PIN modulator for square wave modulation of the signal coming from gunndiode. A measure of the square wave modulation capability is the modulation depth.

PROCEDURE:

VSWR Measurement:

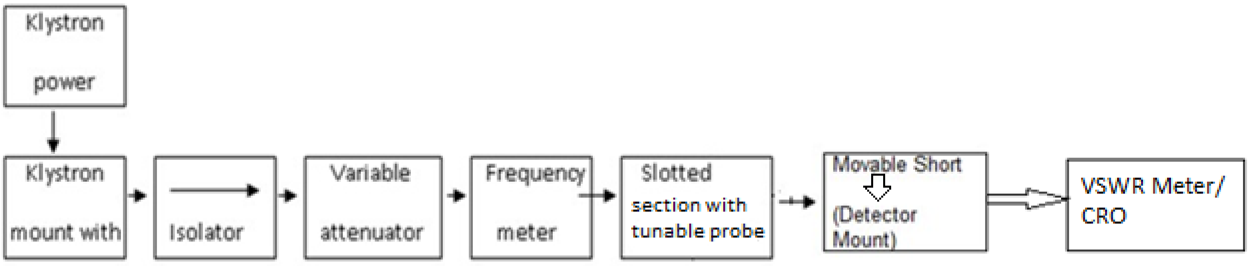
1. Obtain the oscillations using given microwave source.
2. Adjust the slotted section to get the maximum output power.
3. Connect the probe to the VSWR meter.
4. Keep the knob in the normal position, select the suitable dB range and take the third knob to the 200Ω
Point.
5. Keep the gain's coarse and fine control in minimum position.
6. Adjust the gain control knob and bring the needle to point to1 on the normal VSWR scale (top most scale). This is normalizing the meter.

7. Move the slotted section in one direction, the needle moves into the scale and at one point a kickback occurs
8. The point of kick back is the VSWR reading.

Frequency and wavelength measurement:

1. Obtain the oscillations using given microwave source.
2. Adjust the slotted section to get the maximum output power.
3. With the help of the frequency meter find the dip in CRO and note down the corresponding frequency. This frequency is known as free space frequency.
4. Move the slotted section along the slot to find the first minimum power (measured with the voltagein the CRO).
5. Record the position as X_1, using the slotted section scales calibrated in centimeter.
6. Move the slotted section to obtain the second minimum power. Record its position as X_2.
7. The difference between X_1&X_2 will be λ_g /2. From this waveguide wavelength can be determined
8. Using the value of the broad dimension of the wave guide and the wavelength can be calculated theoretically using the equation
9. Find the free space wavelength and guided wavelength for different values of gunn oscillator by adjusting the micrometer fitted at one end of the gunn oscillator.

BLOCK DIAGRAM



TABULATION:

LOAD	Position of first minimum point X_1 (cm)	Position of second minimum point X_2 (cm)	λ_g (cm) = $2(X_1 \sim X_2)$	Vmax	Vmin	VSWR= Vmax/Vmin
DIODE DETECTOR						
MOVABLE SHORT						

Position of minimum with load P_L	Position of minimum with shortwise P_S	$X/\lambda_g = (P_L \sim P_S)/\lambda_g$	Using Smith chart

MODEL CALCULATION:
$\lambda_o = C / f_o$
$C = 3 \times 10^{10}$ cm
$\lambda_g = 2 (X_1 \sim X_2)$
$1/\lambda_g^2 = 1/\lambda_0^2 - 1/4a^2$
Where a=2.24 cm.
RESULT:

REVIEW QUESTION:
1. What sensors are used for power measurements?
2. What is free space wavelength?
3. What are the difference between guided wavelength and free space wavelength
4. What do you mean by standing wave ratio?
5. What is the relationship between specimen length and frequency?

EXP NO: **DATE:**

PERFORMANCE CHARACTERISTICS OF DIRECTIONAL COUPLERS

AIM:
To measure the coupling factor and directivity of the given direction couplers.

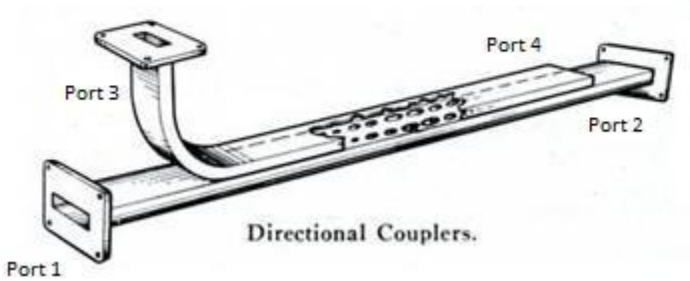
APPARATUS REQUIRED:
Klystron power supply, Klystron mount with tube, Klystron mount, Isolator, Detector mount, CRO, Power Meter, Directional Coupler , 3dB,10dB.

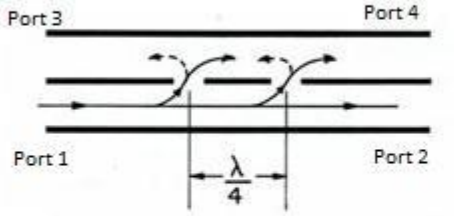
THEORY:
A directional coupler is a four port component in which two transmission lines are coupled in such a way that the output at a port of one transmission depends on the direction of propagation in the other. In a two hole directional coupler, the energy in the main guide flows from left to right. In the first hole a small portion of the energy is coupled to wave guide 2 and divides in to two equal parts a and b traveling in the two directions. After λ_o **/ 4,**main energy is again coupled into the second guide through hole 2 and divides in to two halves c and d. b and d add in phase. c is already delayed by $\pi/2$ and has to travel another $\pi/2$ to reach **a**. Total phase shift is π radian and so a and c cancel out, with the result the coupled energy in guide 2 will travel only from left to right.The main parameters of the directional coupler are coupling factor and directivity.

Coupling Factor
The coupling factor of a directional coupler is the ratio of the input power to the coupled power. Thus C= 10 $\log_{10} (P_1 / P_3)$ port 2 is terminated = 20 log (V_{in} / V_{14}),
Isolation =10 $\log_{10} (P_2 / P_3)$ P1 matched.
Therefore if the power out of arm d is 1/100 of the power output in to the arm A, the component is 20dB coupler .If the power out of the arm d is 10/100 of the power in to arm a the component is 10 dB coupler. Similarly if the power out of arm d is 50/100 of the power into arm a, the component is 3 dB coupler.

Directivity
A measure of the performance of a directional coupler is directivity. This is defined as the ratio, expressed in dB, of coupled backward power. Thus,

Directivity = 10 log $_{10}$ (P_2 / P_1)=20 log (V_{in} / V_{24})=Isolation - Coupling



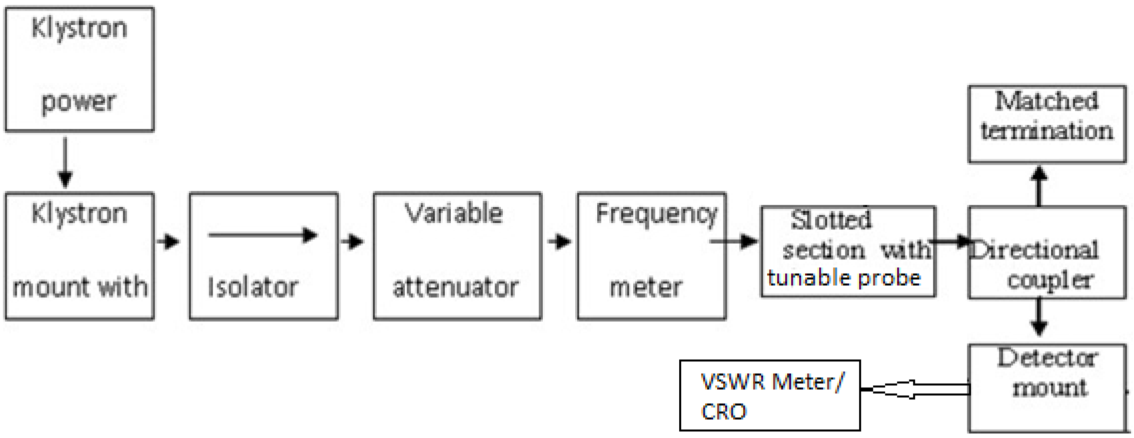


PROCEDURE:

1. Switch ON the powersupply.Obtain the oscillations as per the general procedure.
2. Keep the repeller voltage at some fixed level.
3. Without connecting directional coupler, measure the power output (P_A) at crystal detector (Input power is DC)
4. Repeat the same for various repeller voltages.
5. Now connect the directional coupler after the slotted section. Port A of the DC is connected to the slotted section.
6. The auxiliary arm B should be terminated with a matched load.
7. Since port D is closed permanently, power is measured at port C. The coupling factor is 10logP_1/P_3. The direction of the coupler is now reversed. The power at port C is measured for different values of repeller voltage (P_i)
8. Directivity is given by 10logP_2/P_1

NOTE: Measurement may take using Power meters and CRO.

BLOCK DIAGRAM



TABULATION:

Measurement using VSWR

Beam voltage = 275--v, Beam current = 3.14mA, Repeller Voltage = 41—v

DC	Coupling factor	Isolation	Directivity

RESULT:

REVIEW QUESTION:

1. List the different types of directional couplers.
2. Bring out the differences between a directional coupler and a magic Tee.
3. Define the two performance factors of directional couplers.
4. List out any two applications of Directional Coupler.
5. Give the formula for calculating directivity.

EXP NO: **DATE:**

PERFORMANCE MEASURES OF ISOLATOR AND CIRCULATOR

AIM:

To measure the isolation and coupling factors of the isolator and circulator.

APPARATUS REQUIRED:

Klystron power supply, Klystron mount with tube, Klystron mount, Isolator, Detector mount, CRO, Power Meter, Isolator, Circulator

THEORY:

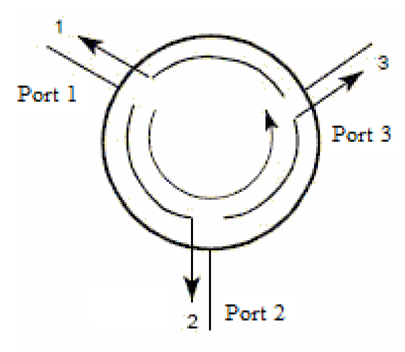
Circulator

It consists of a ferrite prism mounted inside a three port junction and is biased by a dc magnetic field, provided by a permanent magnet situated on the top and bottom of the junction. It works on the theory of Faraday rotation effect. The direction of an arrow indicates the direction in which the transmission will take place without much loss of power. The two parameter of the circulators are isolation and insertion loss. Isolation is defined as the ratio of power in dB at the input port to the isolated port. Insertion loss is defined as the ratio of the power in dB at the output port to the input port. A three port circulator may be converted into isolator by terminating the isolated port using a standard termination.

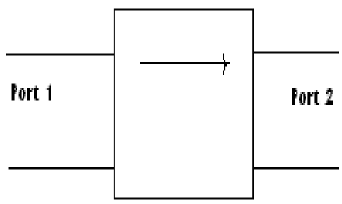
$$[S] = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad |\Gamma| = \left(\frac{S-1}{S+1}\right) \qquad [S] = \begin{bmatrix} s_{11} & s_{12} & s_{13} \\ s_{21} & s_{22} & s_{23} \\ s_{31} & s_{32} & s_{33} \end{bmatrix}$$

Insertion loss = -20log$|S_{21}|$ Isolation = -20log$|S_{31}|$

$$|S_{21}| = |S_{32}| = |S_{13}| \qquad |S_{31}| = |S_{23}| = |S_{12}|$$



Circulator



ISOLATOR

Isolator

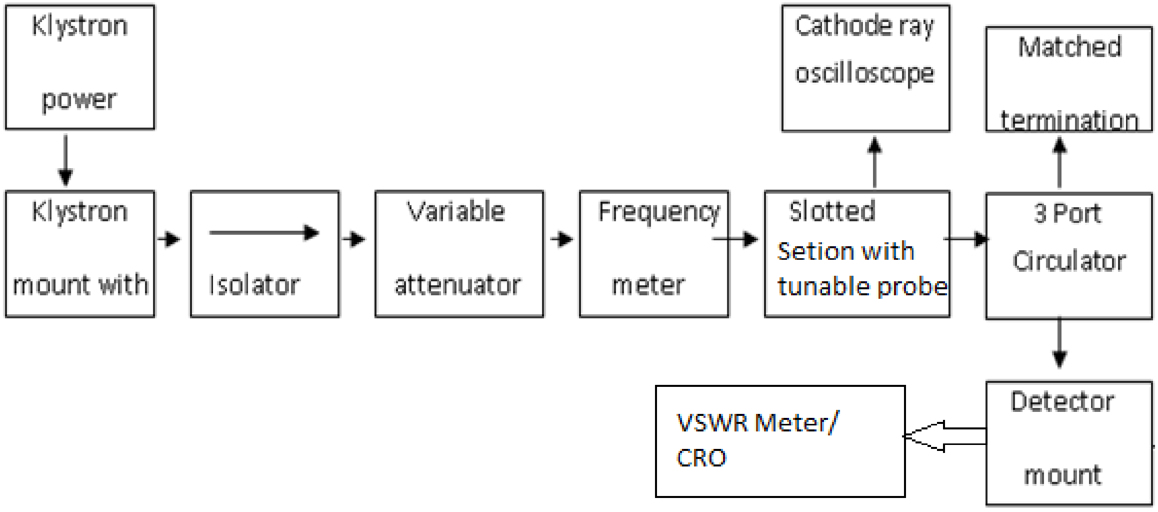
An ideal Isolator allows complete transmission between its two ports in one direction of propagation while no transmission occurs in the other direction. Thus isolators are one way transmission devices. Isolators or Uniliners as the name suggest, when used between the generators and Load network allow maximum, available power to be delivered to the load and yet reflections from the load do not get transmitted back to the generator output terminals.

$[S]=\begin{bmatrix}0 & 0\\ 1 & 0\end{bmatrix}$ Insertion loss = -20log$|S_{21}|$ Isolation = -20log$|S_{12}|$ $[S]=\begin{bmatrix}0 & s_{12}\\ s_{21} & 0\end{bmatrix}$

PROCEDURE:

1. Obtain the oscillations from microwave source.
2. Without connecting the passive device find the input power using power meter.
3. Without disturbing the setup connect the given passive device.
4. Connect the passive device with one of the collinear arm towards source and another arms with detector mount.
5. Close the other collinear arms using matched termination
6. Note down the power output at collinear arms using power meter.

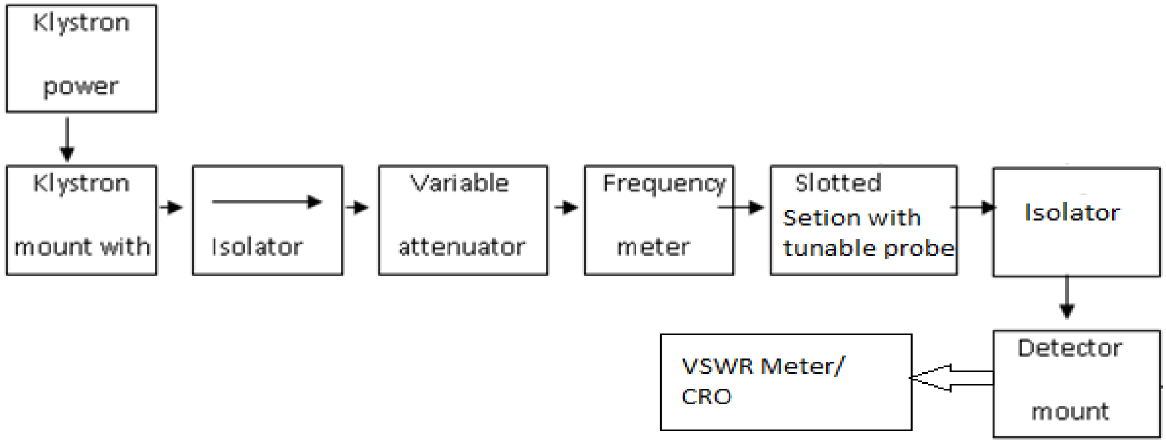
BLOCK DIAGRAM:



TABULATION:

Circulator Measurements

Port 1	Port 2	Port 3
Input		
	Input	
		Input



Isolator Measurements

Input	Output
Port 1	Port 2 ( )
Port 2	Port 1 ( )

Calculation of S Parameter:

RESULT:

REVIEW QUESTIONS:

1. What is meant by isolator?
2. Define insertion loss & isolation of a microwave isolator.
3. What is meant by circulator?
4. Why isolators and circulators are called as non-reciprocal devices?
5. Explain a typical application of a circulator.

Exp. No.: **Date:**

MICROWAVE IC – FILTER CHARACTERISTICS USING NETWORK ANALYZER

AIM:

To measure the return loss (S_{11}) and VSWR for various antenna using Network Analyzer.

Components Required:

- ❖ Network Analyzer (300 KHz – 3 GHz) with Cal-Kit
- ❖ Half-wave dipole antenna
- ❖ Yagi-Uda Antenna array

Procedure:

STEP 1: Determining Measurement Conditions

Step 1.1: Preset the E5062A.

• *Preset+ - OK

Step 1. 2: Set the S-parameter to S11.

• *Meas+ – S11;

Step 1. 3: Set the data format to the log magnitude format.

• *Format+ - Log Mag

STEP 2: Calibration

To turn the error correction ON, set the calibration type to the full 2-port calibrationand measure the calibration data.

Step 2.1: Select the calibration kit suitable for the measurement cable. In this measurement example, Calibration Kit 85032F is selected.

• *Cal+ - Cal Kit - 85032F

Step 2.2: Set the calibration type to the full 2-port calibration.

• *Cal+ - Calibration - 2-Port Cal

Step 2.3: Connect the OPEN standard (included in the calibration kit) to the other end of the measurement cable that is connected to the test port 1 as shownin Figure, and measure the open calibration data at the test port 1.

After measuring the open calibration data, symbol √ is displayed to the left of thePort1 Open button.

• *Cal+ - Calibration - 2-Port Cal - Reflection - Port1 Open

In the same way, measure the calibration data for the SHORT/LOAD standards at thetest port 1.

Step 2.4: In the same way as described above, measure the calibration data for theOPEN/SHORT/LOAD standards at the test port 2.

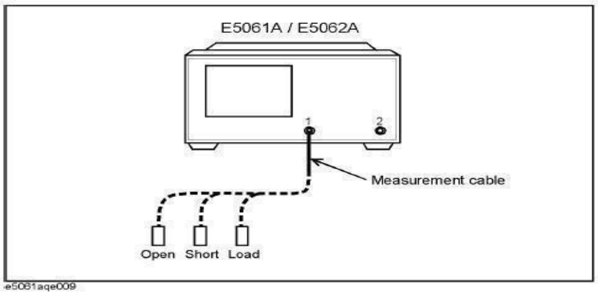


Figure: Connecting the Cal Kit

Step 2.5: Connect the THRU standard between the measurement cables as shown in Figure, and measure the thru calibration data. After measuring the thru calibration data, symbol √ is displayed to the left of the Port 1-2 THRU button.

- *Cal+ - Calibration - 2-Port Cal - Transmission - Port 1-2 Thru.

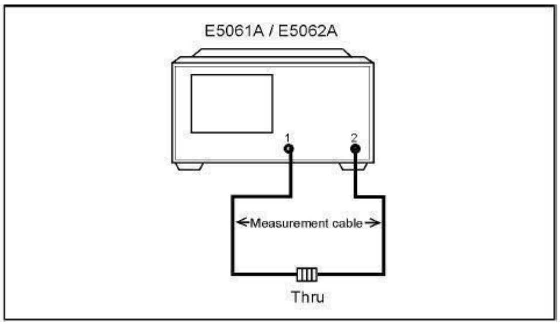


Figure: Connecting the THRU Cal Kit

Step 2.6: Make the full 2-port calibration measurement DONE. The calibration factor is calculated based on the calibration data acquired, and the error correction is turned ON.

- *Cal+ - Calibration - 2-Port Cal - Done

Step 2.7: Select the type in which the data is to be saved before saving the calibrationfactor (calculated based on the calibration data).

- *Save/Recall+ - Save Type - State & Cal

Step 2.8: Store the calibration file to the disk of the E5062A. The symbol ‚X‛ appearing in the operations below represent the assigned numbers to be used when the file is saved.

- *Save/Recall] - Save State - State 0X

STEP 3: Connecting the Device Under Test (DUT)

Step 3.1: Connect the DUT to the E5062A.

Step 3.2: Set the appropriate scale by executing the auto scale.

- *Scale+ - Auto Scale

You can also adjust the scale by entering arbitrary values in the Scale/Div button,Reference Position button, and Reference Value.

STEP 4: Analyzing Measurement Results

This section describes how to use the marker function to read out important parameters for the DUT. Measuring the Insertion Loss

Step 4.1: Display a marker

- *Marker+ - Marker 1

Step 4.2: Using one of the following methods, move the marker to the center frequency of the DUT, For Example, if the Centre frequency is 947.5 MHz

- On the entry bar, press *9+ *4+ *7+ *.+ *5+ *G/μ+.
- Turn the rotary knob on the front panel to set it to the center frequency(947.5 MHz)

Step 4.3: Read the marker value displayed as shown on the LCD display of thenetwork analyzer.

STEP 5: Outputting Measurement Results (Save)

You can save not only the internal data but also the measurement results such as trace data and display screens to the disk.

Saving the Trace Data (in CSV format)

You can save the trace data to the disk of the E5062A in CSV file format (extension: .csv). Since the CSV-formatted data to be saved is a text file, you can analyze the data using Microsoft Excel.

Step 1: Follow the operation method described below to save the trace data.

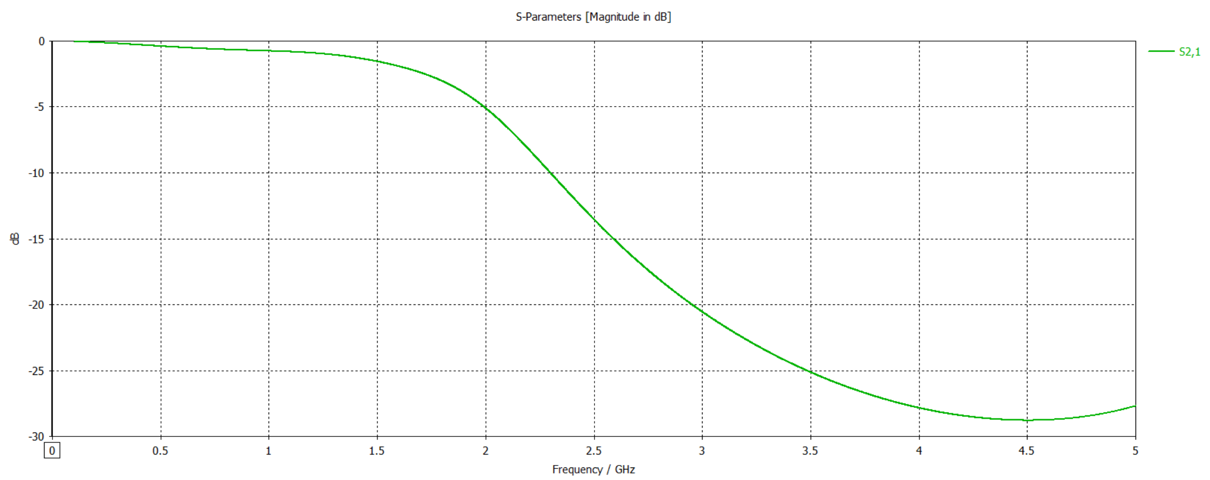
- *Save/Recall+ - Save Trace Data

Saving the Display Screen

You can save the screen displayed on the E5062A to the disk of the E5062A in Windows bitmap file format (extension: .bmp) or Portable Network Graphics format (extension: .png).

Step 1: Follow the operation method described below to save the display screen.

- *System+ - Dump Screen Image



Result:

OPTICAL COMMUNICATION

EXP NO: **DATE:**

MODE CHARACTERISTICS OF OPTICAL FIBER

AIM:

To study the mode characteristics of single mode and multimode optical fibers and to study the V numbers.

THEORY

CORE DIAMETER CALCULATION :

Calculation of SST-ST-PC-3-A Patchcord Core diameter

Manufacturers specify the mode field Diameter rather than core diameter for describing the single mode fiber .Single core diameter of single mode fiber is needed Vnumber calculation ,it can be calculation from the typical values of cutoff wavelength and NA of fiber which as given below

$$V = 2 * \pi * NA / \lambda$$

Where,

λ is LD lasing Wavelength
NA is the Numerical Aperture of the fiber
a is the core Radius of the fiber

Core Radius $a = V * \lambda / (2 * \pi * NA)$

For Single- Mode Operation V should be <= 2.405 .substituting the value of cutoff wavelength of the fiber λ = 1260nm and NA of the fiber = 0.12
the core radius becomes ,

$a = 2.405 * 1260 * 10^{-9} / (2 * \pi * 0.12) = 4.0190602$ µm.

Core Diameter = 2 *a. = 8.03812040µm.

Calculation of SST-ST-PC-3-C Patch cord Core diameter

Substituting cutoff Wavelength λ of the fiber as 600nm and the NA of the Fiber as 0.12 the core radius becomes,

$a = 2.405 * 600 * 10^{-9} / (2 * \pi * 0.12) = 1.91384$ µm.
Core Diameter = 3.82768µm.

VNumber Calculation

Calculation of V number of SST-ST-PC-3-A patchcord at source wavelength is 650nm

V= (2* π *a*NA)/wavelength of the source λ
where ,
λ is LD lasing wavelength 650nm or HeNe source wavelength
NA =0.12
a=4.0190602µm

Calculate Vnumber of the fiber and find out the number of LP modes supported by the fiber using relationship between the normalized frequency V and LP modes.

Calculation of V number of SST-ST-PC-3-C patchcord at source wavelength is 650nm

Use above mentioned formula for Vnumber calculation of SST-ST-PC-3-C .Substitute core radius 'a' as 1.91384 µm and NA as 0.12.Calculate Vnumber of the fiber and find out the number of LP modes supported by the fiber using relationship between the normalized frequency V and LP modes.

Calculation of V number of ST-PC-3 patchcord at source wavelength is 650nm

Use Vnumber formula and substitute core radius 'a' as 25 µm and NA as 0.20 Calculate Vnumber of the fiber.

The multimode fiber output with single –mode fiber, the multimode fiber output can be directly seen on white screen as shown in fig 1.

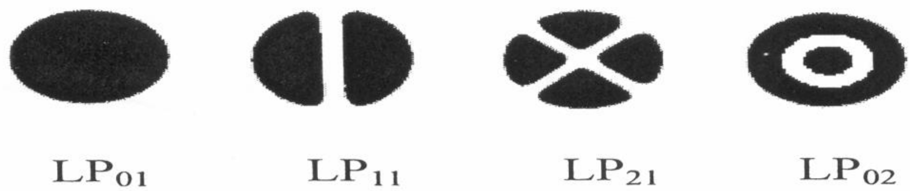


Figure 1 : Lower order modes

RESULT

REVIEW QUESTIONS:

1. What are V-Numbers in single mode fibers?
2. What are V-Numbers in multimode fibers?
3. Define the various modes in optical fiber.
4. What is a He-He Laser Source?
5. What is Normalized propagation constant?

EXP NO: **DATE**:

LOSSES IN OPTICAL FIBER

AIM:

To measure the bending loss in plastic fiber for different wavelengths of radiation as 850nm and 660nm.

APPARATUS REQUIRED:

Power supply, Optical Fiber Trainer (OFT) kit, 20 MHz Dual Trace Oscilloscope, 1 & 3 Meter Fiber Cable.

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. 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:

1. Identify the component on the OFT with the help of the layout diagram. The block diagram of the circuit used in this experiment is shown in fig.
2. Set the switch SW8 to the ANALOG position. Ensure that the shorting plot of the jumper JP2 is shorting plugs from coded data shorting links. S6 in the Manchester coder block and S26 in the Decoder & clock recovery block.
3. Take the 1m fibre and set up an analog link using LED 1 in the Optical Tx1 block and detector PD1 in the Optical Rx1 block [850 nm link]. Drive a 1V p-p 10 KHz sinusoidal signal with zero d.c at P11. Observe the signal at P31 n the oscilloscope. Use the BNC I/O for feeding in and observing signals as described in Experiment1. Adjust the GAIN such that the received signal is not saturated. Do not disturb the level of the signal at the function generator or the gain setting throughout the rest of the experiment.
4. Note the peak value of the signal received at P31 and designate it as V_1. Replace the 1m fibre by the 3m fibre between LED1 and PD1. Again, note the peak value of the received signal and designate it as V_3. If alpha is the attenuation in the fibre and I_1 and I_3 are the exact length of 1m and 3m fibres in meters respectively. We have

$$\frac{P_3}{P_1} = \frac{V_3}{V_1} = \exp[-\alpha(l_3 - l_1)]$$

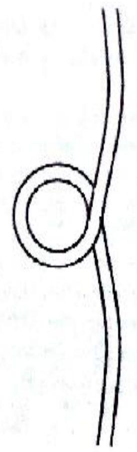
   Where α is in nepers/m, and P1 and P3 are the received optical power with 1m and 3m fibre respectively.
5. Set up the 850 nm analog link using the 1m fibre. Drive a 1V p-p sinusoidal signal of 10KHz with zero d.c. at P11 and observe the received signal at P31 on the oscilloscope. Now bend

the fibre in a loop as shown in fig. Reduce the diameter of the loop slowly and observe the reduction of the received signal at p31. Keep reducing the diameter of the loop to about 2 cm and plot the amplitude of the received signal versus the diameter of the loop. [Do not reduce the loop diameter to less than 1 cm].

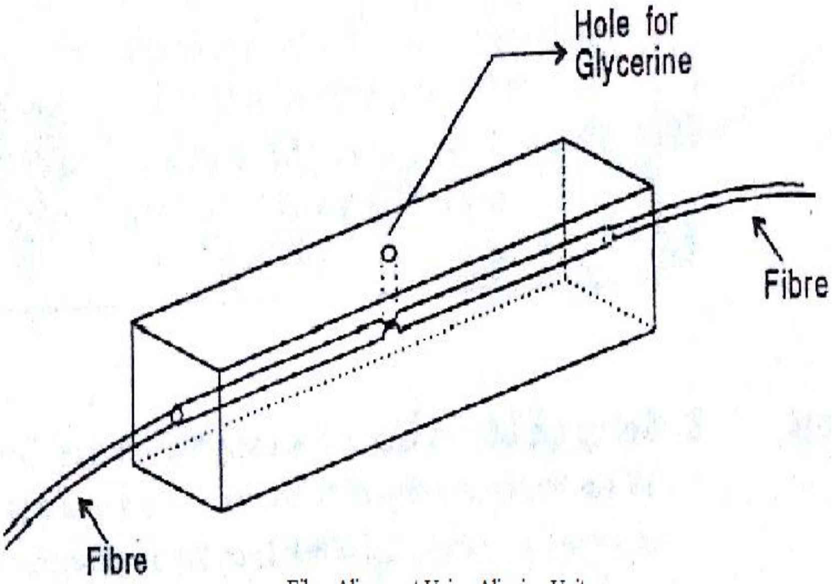
6. Connect one end of the 1m fibre to LED2 and the other and to the detector PD1. Drive the LED with a 10 KHz TTL signal at post B of S6. Note the peak signal received at P31 and designate it as V_1 [ensure that the GAIN is low to prevent saturation.] Now disconnect the fibre from the detector. Take the 3m fibre and connect one end to the detector PD1. The optical signal can be seen emerging from the other end of the 1m fibre. Bring the free ends of the two fibres as close as possible and align them as show in fig. using the fibre alignment unit. Observe that the received signal at P31 varies as the free ends of the fibres are brought closer and moved apart. Note the received signal level with the best possible alignment and designate it as V_4. Using the attenuation constant value obtained in step4. Compute the coupling loss associated with the above coupling of the two fibres using

   η = -10 $\log(\frac{V_4}{V_1})$-$\alpha(l_3+l_1)$

7. With the two ends of the fibre are aligned as close as possible, place a drop of glycerine/ isopropylene through the hole provided in the fibre alignment unit to cover the fibre ends. Note that the received signal now increases. Computer the coupling loss in the presence of a index matching fluid like glycerine. Why does the index matching fluid affect the coupling loss?
8. Now try aligning the two fibres without using the Fibre Alignment unit. How well are you able to align the fibres? Estimate the losses as the two fibres are offset laterally and also when the two fibres are offset laterally and also when the two fibres are at angle as shown in fig.



Bending the Optical Fibre



Fibre Alignment Using Aligning Unit

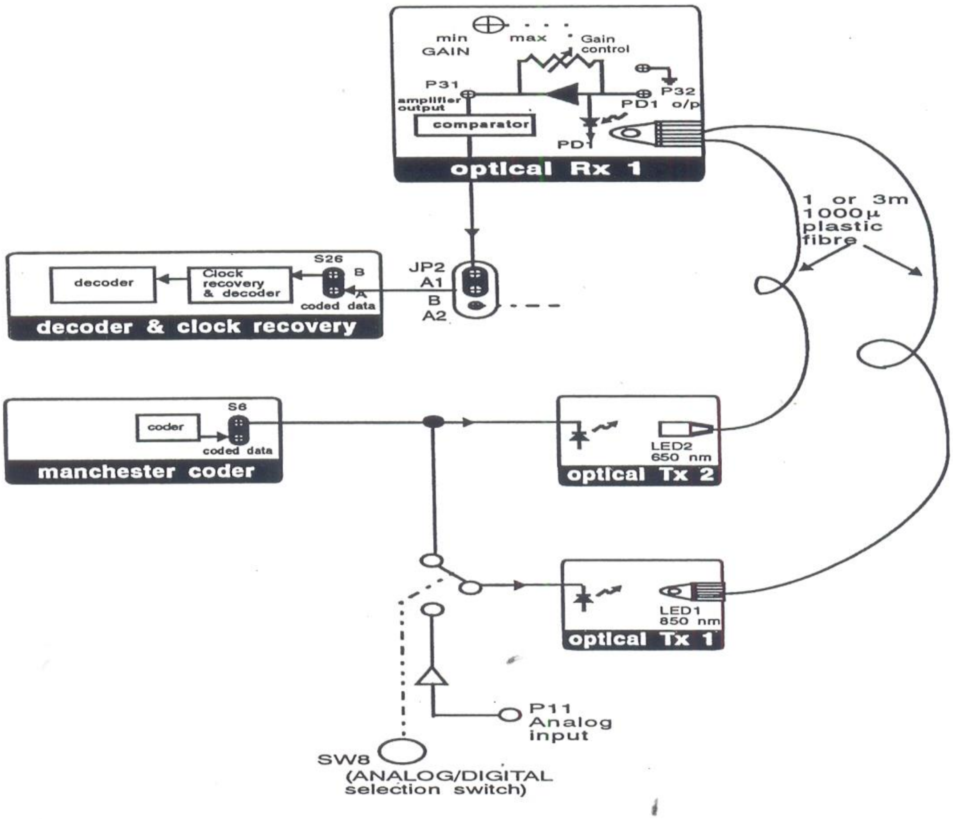


Fig.1

CALCULATION:
ATTENUATION LOSS:

$$\frac{P_3}{P_1} = \frac{V_3}{V_1} = \exp[-\alpha(l_3 - l_1)]$$

Compute α' in dB/Km =4.343α, where α is in nepers/m.

L_1=length of shorter fiber — V_1=Amplitude measure using shorter fiber

L_3= length of longer fiber — V_3=Amplitude measure using longer fiber

COUPLING LOSS:

$\eta = -10 \log(\frac{V_4}{V_1}) - \alpha(l_3+l_1)$ — V_4=Amplitude measure using 1m&3m fibers

BENDING LOSS:
TABULATION:

S.No.	BEND DIAMETER (cm)	OUTPUT POWER (dBm) / OUTPUT VOLTAGE (V)

RESULT:

REVIEW QUESTIONS:

1. What does signal attenuation determine?
2. What is the effect of distortion in an optical fiber?
3. Define signal attenuation
4. How is absorption caused in a fiber.
5. What are atomic defects?

EXP NO: DATE**:**

SETTING UP A FIBER OPTIC ANALOG AND DIGITAL LINK

AIM:

To set up an 850 nm fiber optic digital and analog link and to plot its frequency response.

APPARATUS REQUIRED:-

Power supply, Optical Fiber Trainer (OFT) kit, 20 MHz Dual Channel Oscilloscope, 1 Meter Fiber cable

THEORY:-

Fiber optic links can be used for transmission of digital as well as analog signals. Basically, a fiber optic link contains three main elements, a transmitter, an optical fiber and a receiver. The transmitter module takes the input signal in electrical form and 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.

PROCEDURE:-

SETTING UP FIBER OPTIC ANALOG LINK

1. Identify the component on the OFT with the help of the layout diagram. The block diagram of the circuit used in this experiment is shown in fig.
2. Set the switch SW8 to the ANALOG position. Switch power on. The power on switch is located at the top right-hand corner.
3. Feed a 1V p-p sinusoidal signal at 1KHz from function generator, to the Analog In P11 [using BNC socket I/O and patch cord].
4. Connect one end of the 1m fiber to the LED source LED1 in the optical transmitter block and the other end of the fiber to the detector PD1 in the receiver block.
5. The PIN detector output signal is available at P32 in the optical receiver block.
6. Vary the input signal level driving the LED and observe the received signal at the PIN detector. Plot the received signal with respect to input signal.

SETTING UP FIBER OPTIC DIGITAL LINK

1. Identify the component on the OFT with the help of the layout diagram. The block diagram of the circuit used in this experiment is shown in fig.
2. Set the switch SW8 to the DIGITAL position.
3. Connect a 1m optical fibre between LED1 and the PIN diode PD1.
4. Set the binary input data by using SPDT switches [sw0-sw7] and verify the output through output LEDs [L0-L7] at the receiver block.

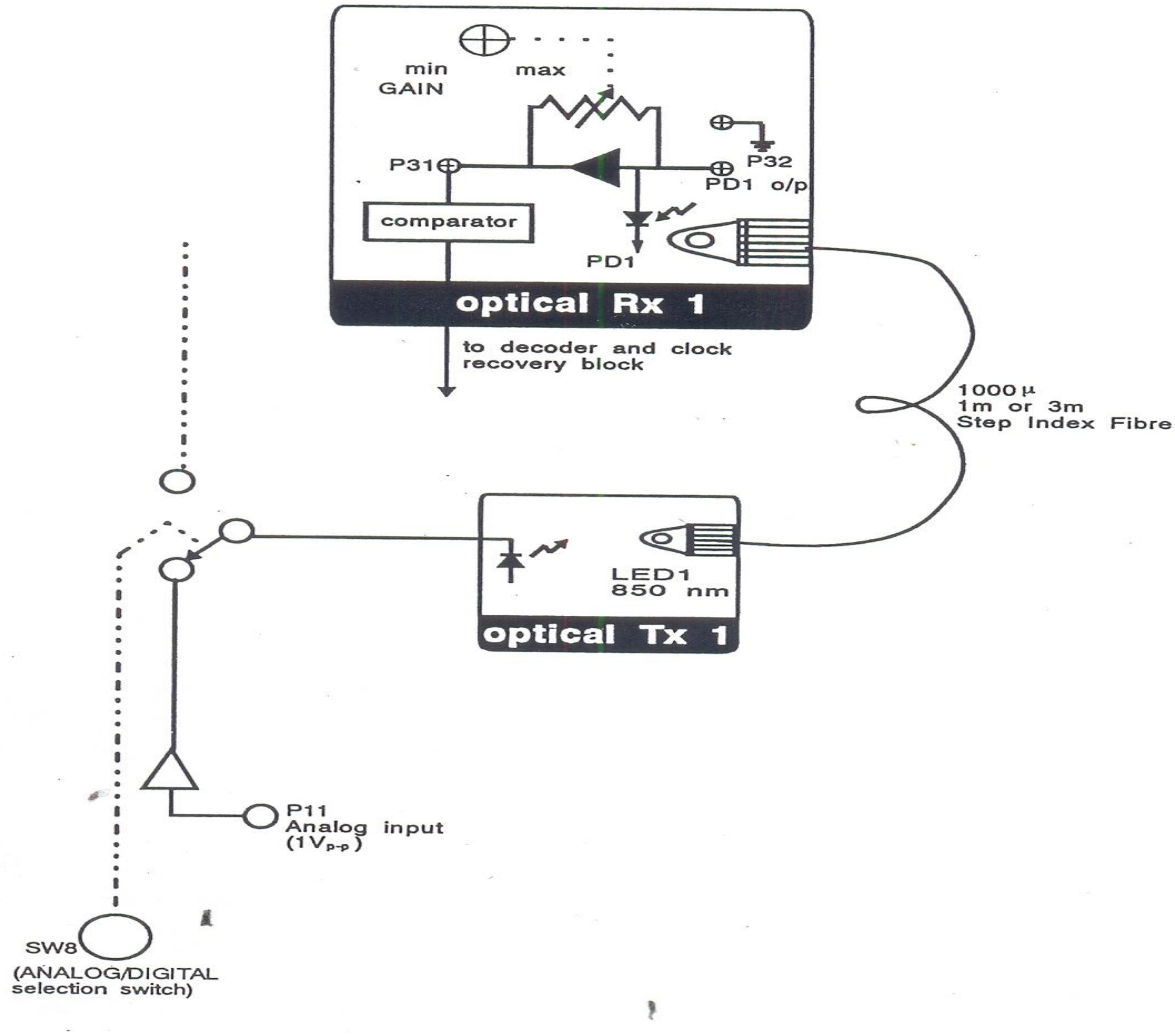


Fig.1

SETTING UP FIBER OPTIC DIGITAL LINK

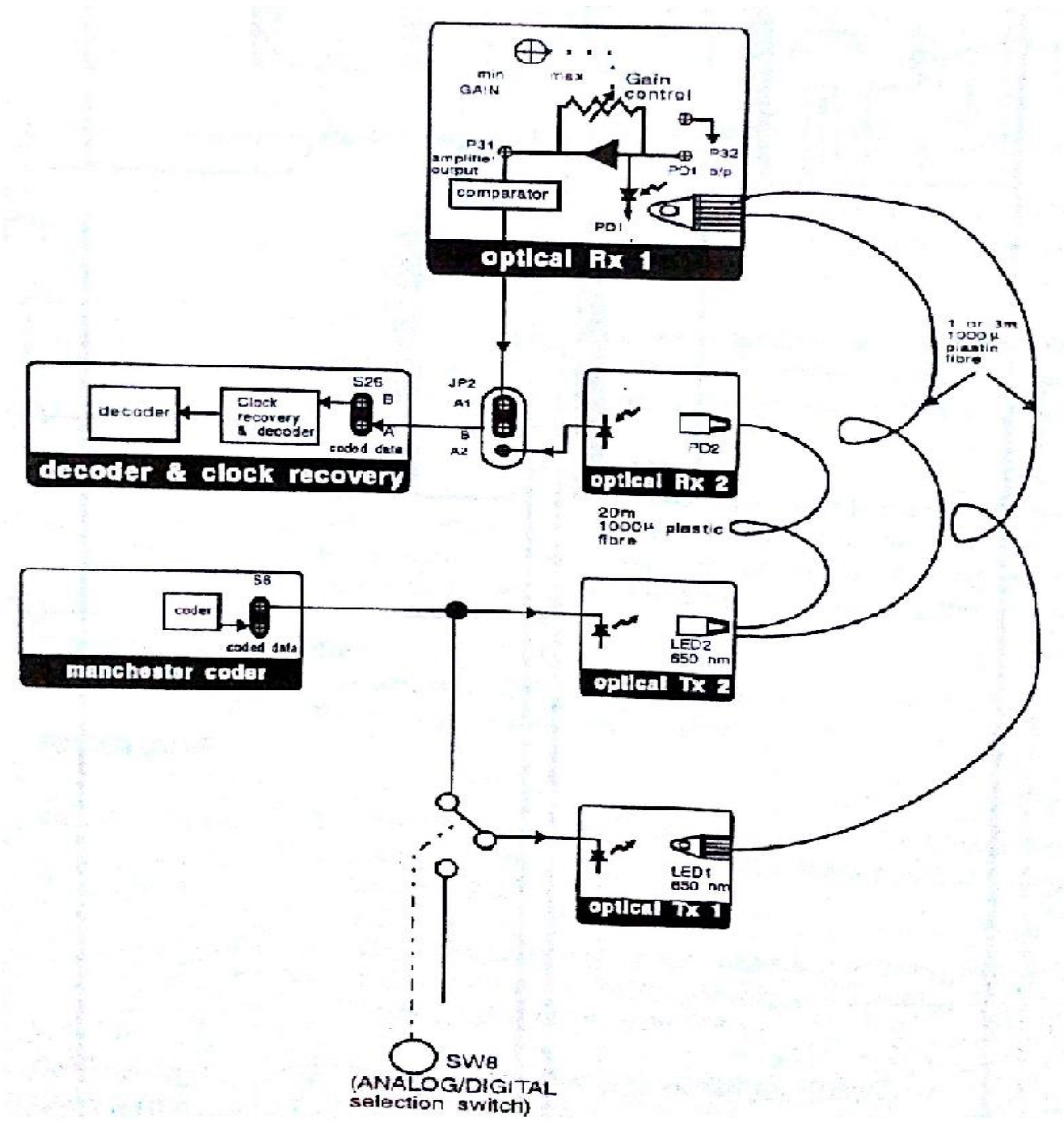


Fig.2

TABULATION: for digital link

Input Data	Output Signal

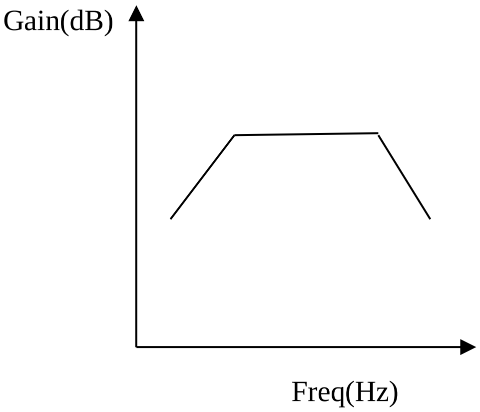
TABULATION: for analog link

Input Vi = Freq=

FREQUENCY (Hz)	OUTPUT VOLTAGE (V)	GAIN = 20 log (Vo/Vi) (dB)

MODEL GRAPH :

Analog Link:



RESULT:

REVIEW QUESTIONS:

1. Why do we prefer digital transmission rather than the analog transmission?
2. Define BER.
3. What are the requirements of an optical receiver?
4. What are the requirements for a preamplifier?
5. Why do we prefer Tran impedance preamplifier rather than high impedance preamplifier?

EYE DIAGRAM AND BER (DIGITAL)

AIM:

To analyze the Eye diagram and Bit Error Rate by using an optical receiver.

SOFTWARE USED:

Optisystem 14

MODULES REQUIRED:

- BER Analyzer
- Optical Fiber Cable
- Signal generator
- Pulse generator
- DFB laser
- Optical Receiver

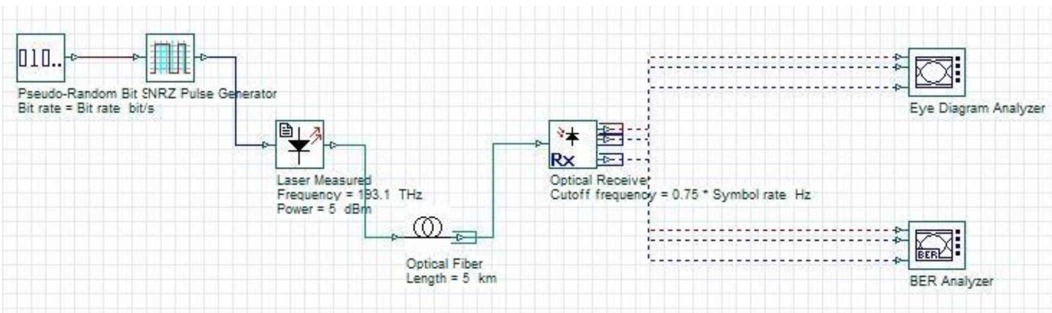
Pre-lab questions:

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

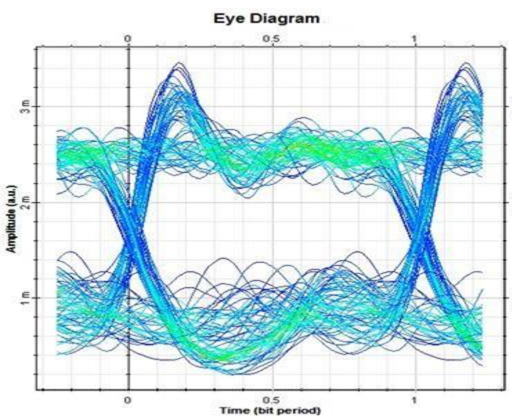
THEORY:

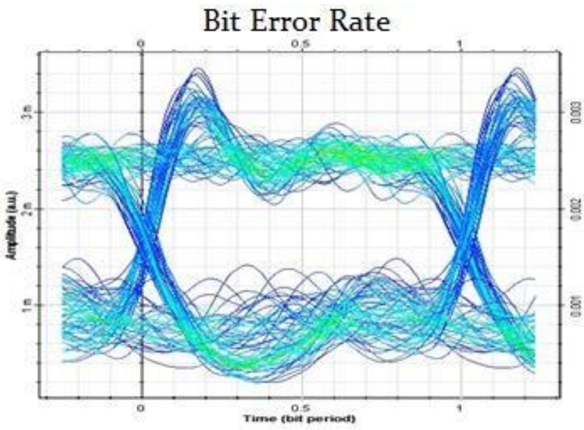
Eye diagrams are generated on a Bit Error Rate (BER) analyzer and are used to measure the reliability and performance of the communication system. It can be used to measure the quality of the transmission link. An eye diagram is a display showing overlapping of all the possible one-zero combination. Eye diagram is known as multi- valued displays, because each point in time axis has multiple voltage values. The width of the eye represents the pulse width or bit period. As the eye closes horizontally, it signifies that the bits are more closely together, increasing the possibility of ISI. The vertical aspect of the eye diagram shows how accurate the system can distinguish a bit 1 and 0. If the eye closes vertically, it signifies the system will not be able to distinguish 1's and 0's accurately.

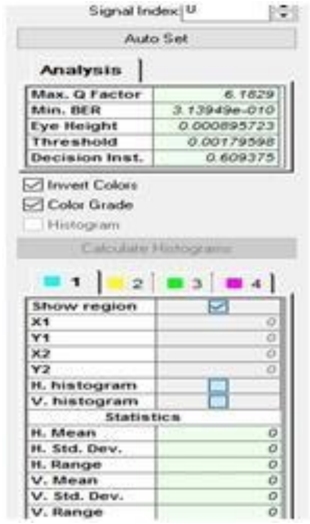
Optical Fiber Communication Link:



OUTPUT:

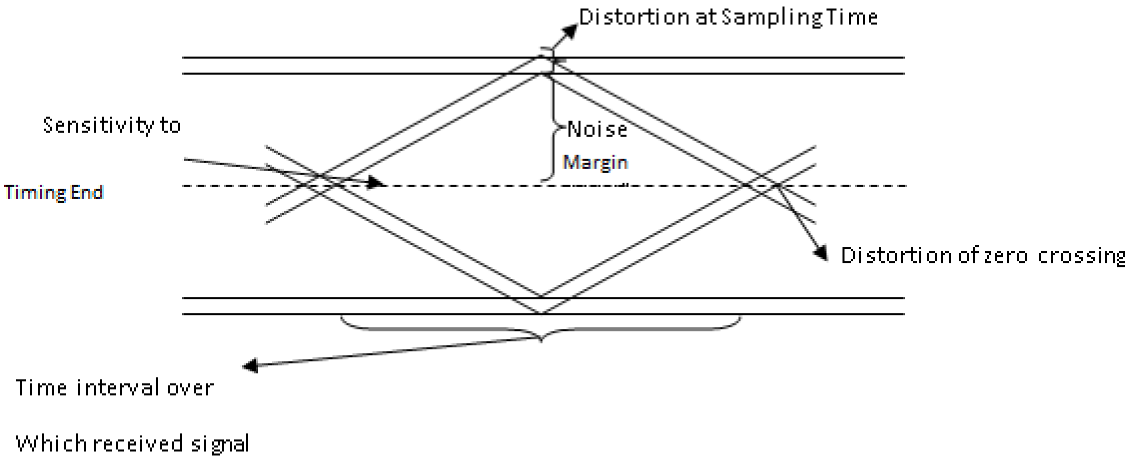






Interpretation of Eye Pattern

PROCEDURE:



1. Refer to Figure and make the following connections using Optisystem software.
2. Set the data rate of 2.5Gbps.
3. Simulate the optical communication link.
4. View the eye diagram and bit error rate value using either Eye diagram analyzer orBER analyzer.

RESULT:

Thus the Eye diagram and Bit Error Rate was analyzed by using an optical receiver.

EXP NO: **DATE:**

NUMERICAL APERTURE DETERMINATION FOR FIBERS

AIM:

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

APPARATUS REQUIRED:

Power supply, Numerical Aperture measurement Set up, 1 meter fiber cable, NA JIGRuler.

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.

PROCEDURE:

1. Refer to Fig.1 and make the following connections.
2. Slightly unscrew the cap of LED SFH756V (650nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tighten the cap by screwing it back.
3. Now short the jumpers as shown in the diagram.
4. Connect the power cord to the kit and switch on the power supply.
5. Insert the other end of the fiber into the numerical aperture measurement jig. Hold the white sheet facing the fiber. Adjust the fiber such that its cut face is perpendicular to the axis of the fiber.
6. Keep the distance of about 10mm between the fiber tip and the screen. Gently tighten the screw and this fix the fiber in the place.
7. Now observe the illuminated circular patch of light on the screen.
8. Measure exactly the distance d and also the vertical and horizontal diameters MR and PN as indicated in the Figure 2.
9. Mean radius is calculated using the following formula r =(MR + PN)/4
10. Findthe numerical aperture of the fiber.

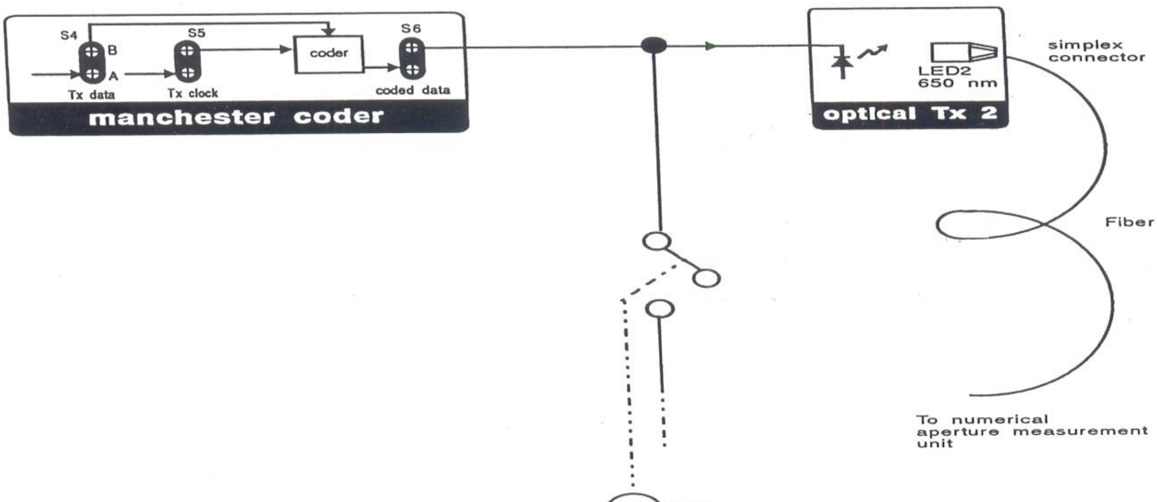
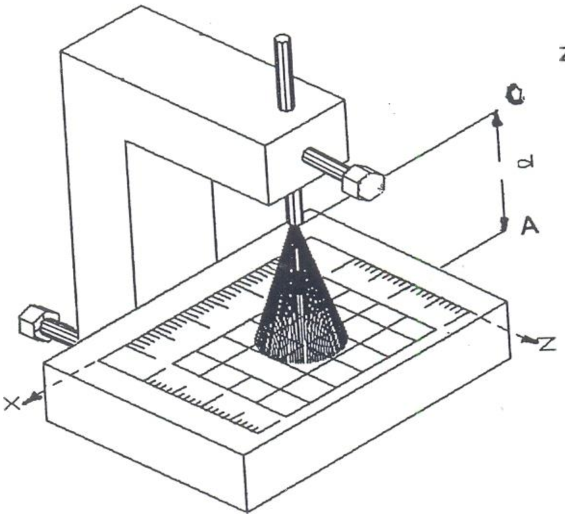


Fig 1: optical Numerical Aperture kit



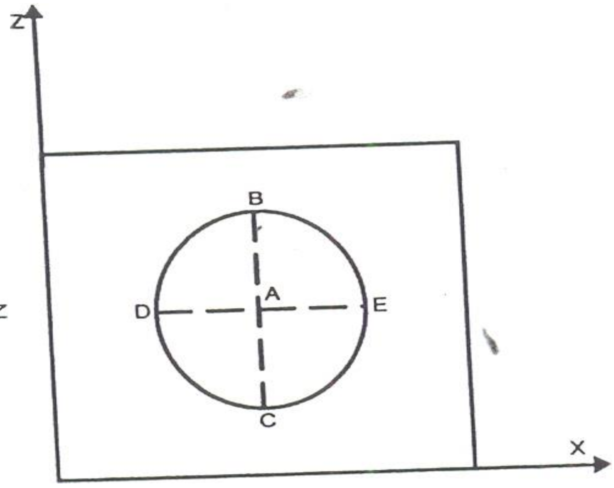


Fig 2 : optical illuminating stand

Fig 3 : illuminated surface

TABULATION:

S. NO.	Diameter (cm) D	Radius (cm) r	Height (cm) h	NA= $r/(h^2 + r^2)^{1/2}$	$\Theta = \sin^{-1}(NA)$

RESULT:

REVIEW QUESTIONS:

1. State Snell's Law.
2. Give the refractive index expression for step index fiber.
3. What is critical angle of incidence?
4. Give the refractive index expression of a graded index fiber.
5. Define Numerical Aperture of a step index fiber.

EXP NO: **DATE:**

DC CHARACTERISTICS OF LED AND PIN PHOTO DIODE

AIM

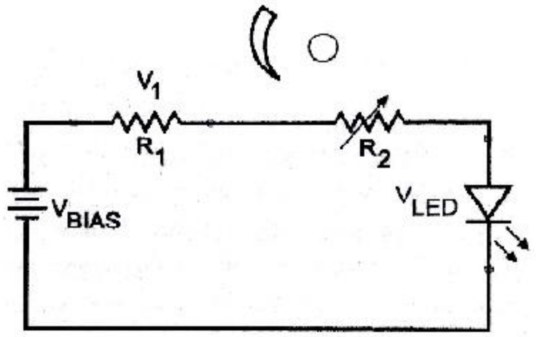
To determine the characteristic of an LED and PIN photo diode.

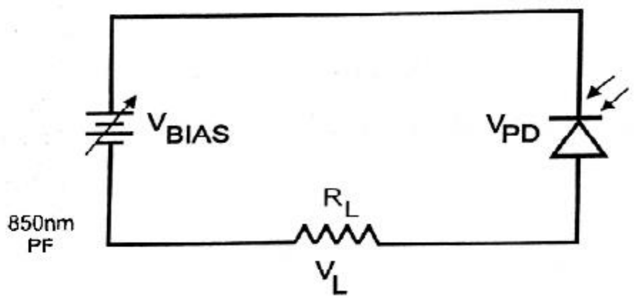
APPARATUS REQUIRED:

a. OFT power supply
b. A digital multimeter
c. LED module -850nm (or) 1300nm.
d. Fibre optic power supply.
e. Fibre adapter-plastic (850nm).
f. ST adapter for meter (for 1300nm GF).
g. 1.25m plastic fibre(for 850nm PF).

h. 1m ST-ST patch cord.
i. PD MODULE

KIT DIAGRAM LED MODULE - 850 nm Photo Diode Module





THEORY

LED is the vital part in a fiber optic communication link .It forms the Electrical-Optical section of the transmitter in any link .In LED module the injection current through an 850nm/1300nm fiber optic LED is varied and there by its characteristics are studied .The injection current through the LED is controlled using a multi-turn potentiometer ,which enables the user to have a control it .the module needs an external DC power supply to operate .The LED module is provided with appropriate monitoring posts for taking the necessary measurements.

LED Module Setup: The LED module mainly consist of a fiber optic LED for which the characteristics will be studied, a multi-turn potentiometer for varying the current through LED, a high precision resistor for calculating the current.

CALCULATION:

Conversion Efficiency, $\eta = Po / I_F$

Where

P_{o}- Output Power and

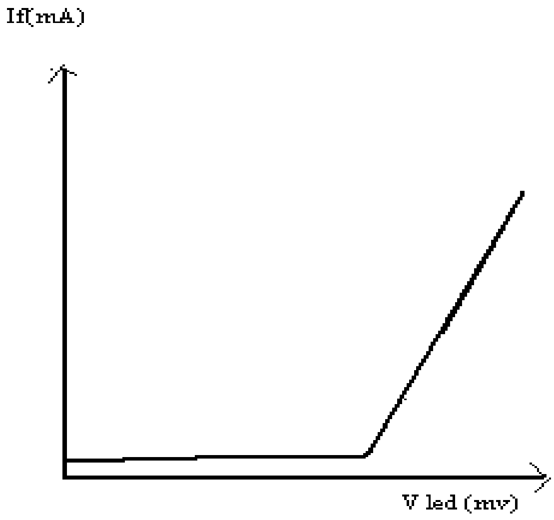
I_F- Forward current

PROCEDURE:

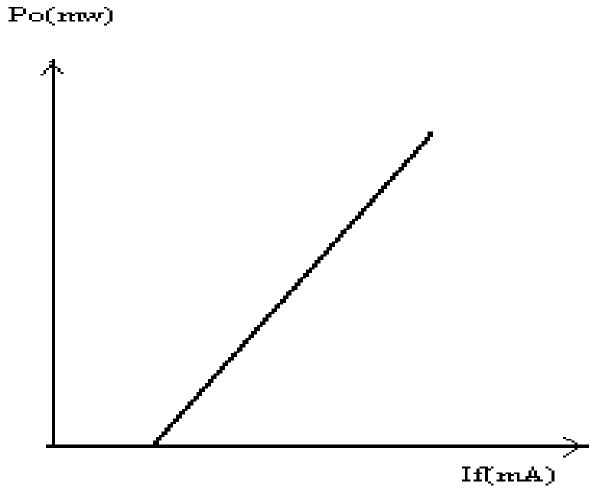
1. Connect the Optical Fibre Trainer power supply properly to the module using the DIN-DIN cable provided with the power supply .Turn the multi-turn pot to its minimum position and switch ON the module .
2. Measure the voltage V_1 across the resistor R_1 (180ohms for 850nm PF or 150ohms for 1300nm GF-mm)and calculate the current through the LED I_F which is given as $I_F = V_1 /180$ for 850nm PF. Now measure the voltage V_{LED} across the LED and note down.
3. Remove the dummy adaptor cap from the power meter PD exposing the larger area photo detector. Mount the bare fiber adaptor-plastic over the PD .Carefully hold the LED source very close to the photo-detector window perpendicular to it to couple all the optical power from the LED to the power meter .Now without changing any voltage or the potentiometer, measure the optical power output P of the LED.
   Calculate the power in mW and note it down which is given as $Po = 10^{P/10}$. Turn the potentiometer clockwise direction slightly towards the maximum till you get a convenient reading V_1 and repeat the step 1 to 3 and tabulate them as shown.
4. Repeat step 4 and note down several readings till the potentiometer reaches it maximum position and plot the graph for V_{LED} Vs I_F and I_F Vs P_o.
   Calculate the E-O conversion efficiency 'η' of the LED from the plotted graph I_F Vs P_o. which is given as
   $\eta = P_o / I_F$
5. Put 10K resistor across V_L in the PD module and adjust the potentiometer & fix the bias voltage at 10V.
6. Connect the ST connector end of the patch cord and vary the optical power & tabulate the readings. Plot the graph P_o vs I_R. and $I_R = V_L/10x10^3$.

MODEL GRAPH

V-I Characteristics of LED



P-I Characteristics of PD



TABULATION:

S.No	V_1 (mv)	I_F (mA)	V_{LED} (mv)	P (dBm)	P_o (mw)	V_L (V)	I_R (mA)

RESULT:

REVIEW QUESTIONS:

1. Give some application of LED.
2. What is used to control the LED current ?
3. What are the two optical wavelength?
4. Define responsivity.
5. What are the desired features of photo detector?

Ex.No.: 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. How impulse response.is mentioned for the free space signal.
4. Mention the advantage of MATLAB in computation of wireless channel parameters.
5. Define Brewster angle.

THEORY:

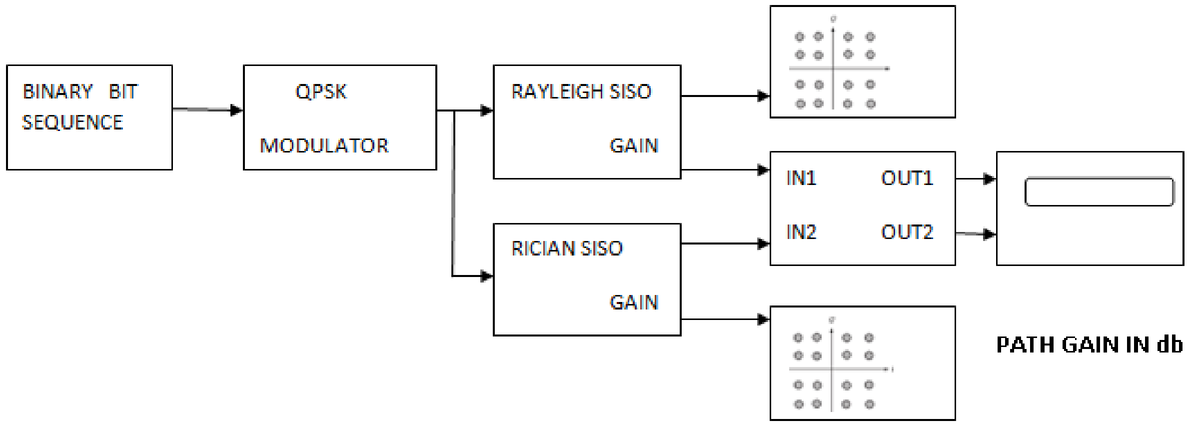
Fading:

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

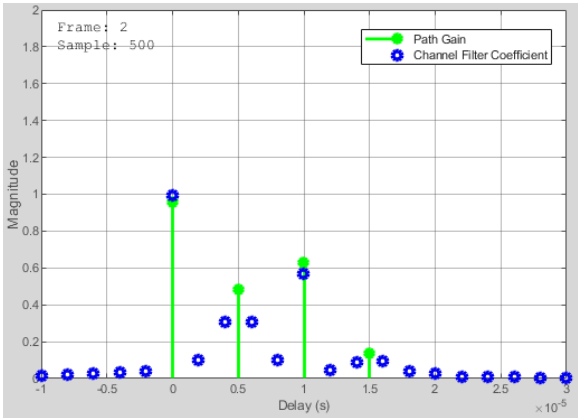
- Rapid changes in signal strength over a small travel distance or time interval.

Block Diagram:

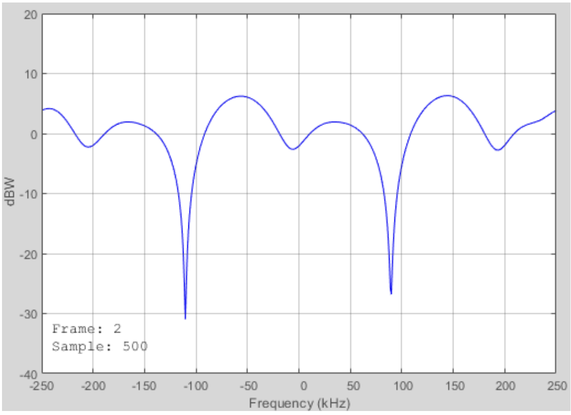


Simulation Outputs:

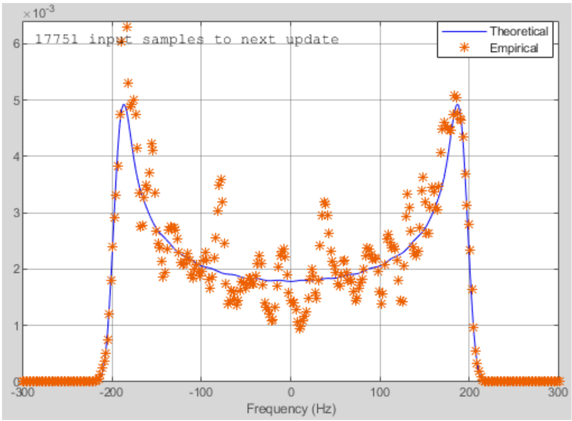
Impulse Response



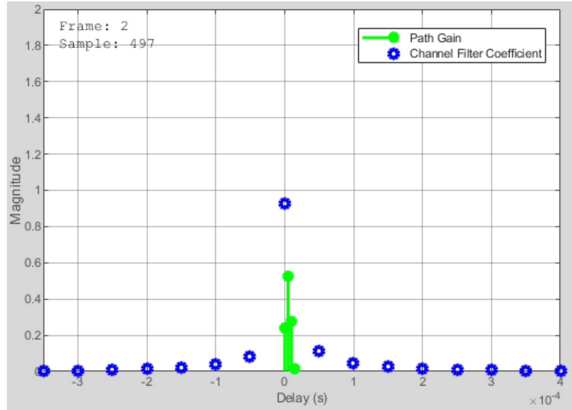
Frequency Response



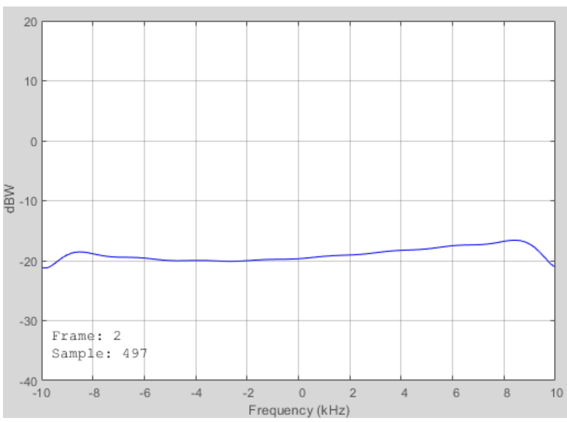
Doppler Spectrum



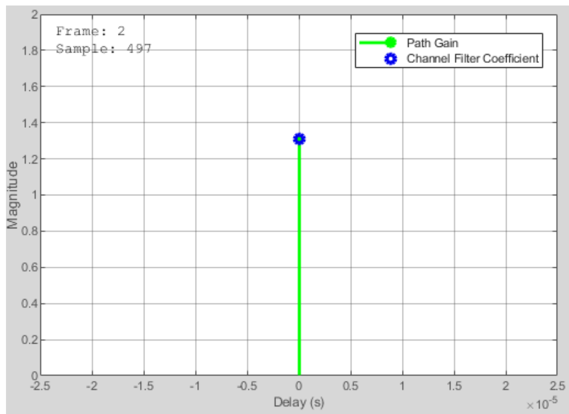
Impulse Response



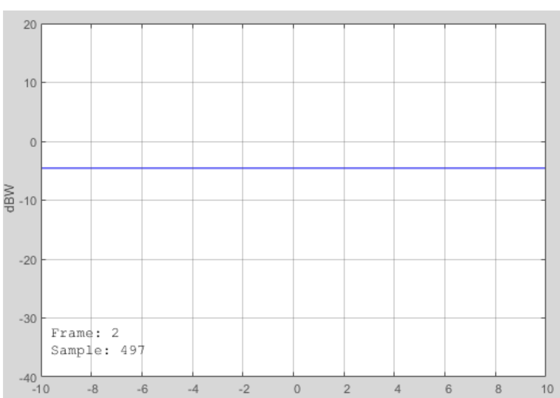
Frequency Response



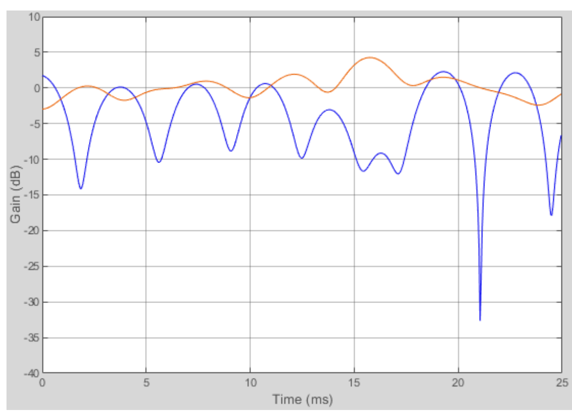
Impulse Response



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 transmissionmsg =
    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 framesmsg =
    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 framesmsg =
    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 magnitudegainScope
= 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. List the factors influencing small scale fading.
4. What are the important parameters of mobile multipath channels?
5. How frequency selective fading differs from flat fading ?

RESULT:

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

Ex.No.: **SIMULATION OF CHANNEL ESTIMATION, SYNCHRONIZATION AND EQUALIZATION TECHNIQUES**

AIM:

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

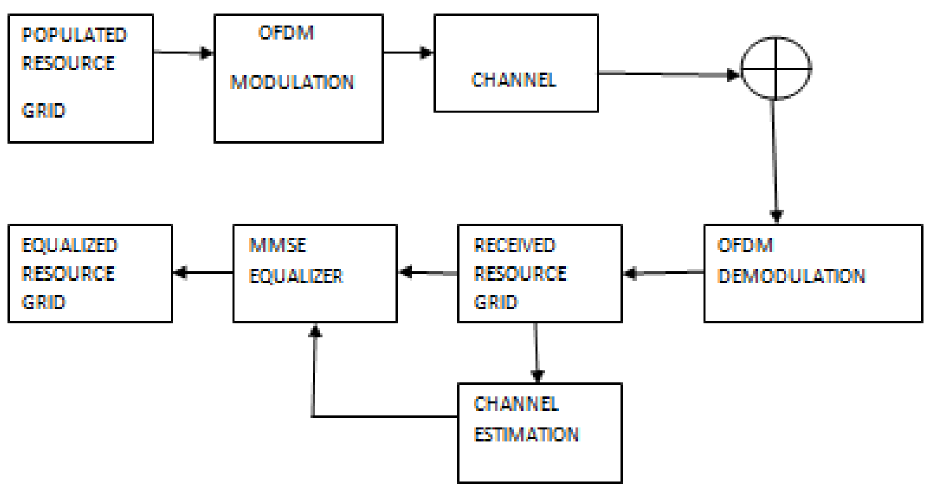
COMPONENTS REQUIRED:

- Personal computer
- MATLAB

Pre Lab Questions:

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

Block Diagram:



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 subframeP =
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 framefor
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. Outline the features of equalization.
3. List 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 wasdone using MATLAB and the output was verified.

Ex. No. 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.

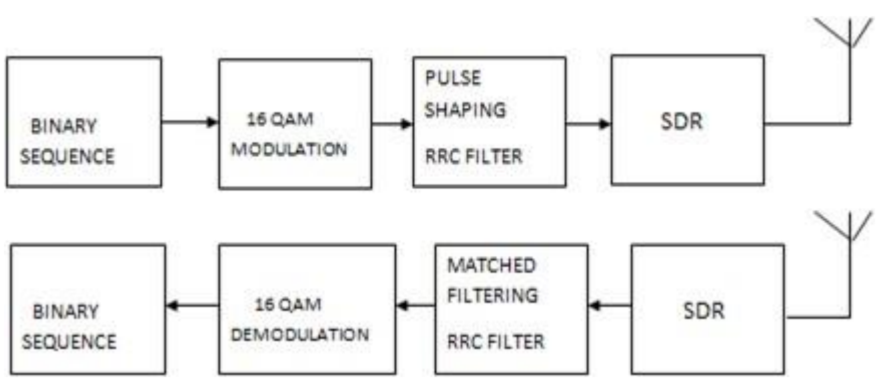
COMPONENTS REQUIRED:

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

Pre Lab Questions:

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

Block Diagram:



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 such as mixers , filters, amplifiers, modulators, demodulators, 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 ultra wideband 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:

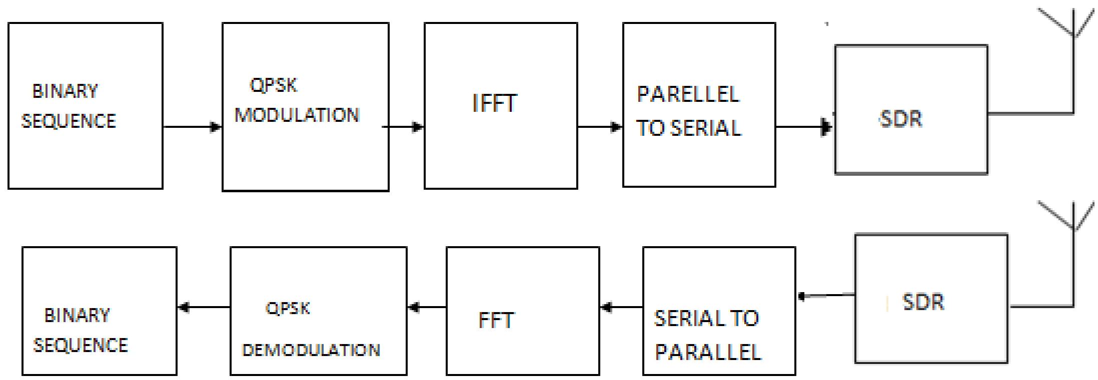
1. Is SDR compatible with standards in wireless communication?
2. What is the advantage of SDR?
3. Outline the significance of ISI in wireless communication.
4. Define ICI.
5. Mention the advantages of PRBS.

Result:

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

Ex.No.: **OFDM SIGNAL TRANSMISSION AND RECEPTION USINGSOFTWARE DEFINED RADIO**

Block Diagram:



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 inboth 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 representationsdata_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 colums 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 matix to put the IFFT'd datacp_start =
block_size-cp_len;
cp_end = block_size;
% Third: Operate columnwise & do CPfor
i=1:num_cols,
    ifft_data_matrix(:,i) = ifft((data_matrix(:,i)),no_of_ifft_points);
    %  Compute and append Cyclic Prefixfor
    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.

Ex. No.: ANALYSIS OF RF SIGNAL USING SPECTRUM ANALYZER

Aim: To measure the spectrum of the given RF source

Apparatus Required:

1) Spectrum Analyzer
2) Signal source
3) BNC – BNC cable

Theory:

The analysis of electrical signals is a fundamental problem for many engineers and scientists. Even if the immediate problem is not electrical, the basic parameters of interest are often changed into electrical signals by means of transducers. The rewards for transforming physical parameters to electrical signals are great, as many instruments are available for the analysis of electrical signals in the time and frequency domains.

The traditional way of observing electrical signals is to view them in the time domain using an oscilloscope. The time domain is used to recover relative timing and phase information which is needed to characterize electric circuit behavior. However, not all circuits can be uniquely characterized from just time domain information. Circuit elements such as amplifiers, oscillators, mixers, modulators, detectors and filters are best characterized by their frequency response information. This frequency information is best obtained by viewing electrical signals in the frequency domain. To display the frequency domain requires a device that can discriminate between frequencies while measuring the power level at each. One instrument which displays the frequency domain is the spectrum analyzer. It graphically displays voltage or power as a function of frequency on a CRT (cathode ray tube).

In the time domain, all frequency components of a signal are seen summed together. In the frequency domain, complex signals (i.e. signals composed of more than one frequency) are separated into their frequency components, and the power level at each frequency is displayed. The frequency domain is a graphical representation of signal amplitude as a function of frequency. The frequency domain contains information not found in the time domain and therefore, the spectrum analyzer has certain advantages compared with an oscilloscope.

The analyzer is more sensitive to low level distortion than a scope. Sine waves may look good in the time domain, but in the frequency domain, harmonic distortion can be seen. The sensitivity and wide dynamic range of the spectrum analyzer is useful for measuring low-level modulation. It can be used to measure AM, FM and pulsed RF. The analyzer can be used to measure carrier frequency, modulation frequency, modulation level, and modulation distortion. Frequency conversion devices can be easily characterized. Such parameters as conversion loss, isolation, and distortion are readily determined from the display.

The spectrum analyzer can be used to measure long and short term stability. Parameters such as noise sidebands on an oscillator, residual FM of a source and frequency drift during warm-up can be measured using the spectrum analyzer's calibrated scans. The swept frequency responses of a filter or amplifier are examples of swept frequency measurements possible with a spectrum analyzer. These measurements are simplified by using a tracking generator.

Procedure:

1. Switch on the signal source and the spectrum analyser.
2. Set the frequency of signal source to, say f MHz.
3. Check the Spectrum analyzer if it calibrated. (The RED LED of UCAL will blink, if not calibrated). Change the SCANWIDTH and BANDWIDTH settings for calibration.
4. Connect the source and the spectrum analyzer using a BNC – BNC connector.
5. Set the centre frequency to f MHz.
6. Note the display in the Spectrum analyzer. Spectrum Analyzer will display power Vs frequency.
7. Select MARKER. Marker will be displayed in the screen as a vertical line.
8. Align the marker to the center frequency and note the frequency of the source. Also note the level of the signal and tabulate it.
9. Move the marker to the adjacent spectral line and tabulate the level.
10. Repeat step 8 and 9 and note the readings.

Sl. No.	Frequency	Level in dB

Result: Thus the spectrum of the given RF source is measured and plotted