

TAGORE INSTITUTE OF ENGINEERING AND TECHNOLOGY

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Department of Electronics and Communication Engineering

IV Year- VII Semester - Electronics and Communication Engineering

EC 8761 Advanced Communication Laboratory

LAB MANUAL

Academic Year 2020-2021

(2017 Regulation)

DEPARTMENT OF ELECTRONICS & COMMUNICATION
ENGINEERING VII SEM - E.C.E.
EC 8761 – ADVANCED COMMUNICATION LABORATORY

S.NO	NAME OF 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)
5.	Wireless Channel Simulation including fading and Doppler effects
6.	Simulation of Channel estimation, Synchronization& Equalization techniques
7.	Analyzing Impact of Pulse Shaping and Matched filtering using MATLAB.
8.	OFDM Signal Transmission and Reception using MATLAB
9.	VSWR and Impedance Measurement and Impedance Matching
10.	Characterization of Directional Couplers , Isolators , Circulators
11.	Gunn diode Characteristics

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VII SEM – E.C.E.

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CYCLE I

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. i) Fiber optic Analog Characterization- frequency response(analog)
ii) Fiber optic Digital Link Characterization -eye diagram and BER (digital)
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CYCLE II

6. Simulation of Channel estimation, Synchronization& Equalization techniques
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8. OFDM Signal Transmission and Reception using MATLAB.
9. VSWR and Impedance Measurement and Impedance Matching.
10. Characterization of Directional couplers, Isolators and Circulators.
11. Gunn diode Characteristics

EXP. NO: 1

DATE:

MEASUREMENT OF CONNECTOR, BENDING AND FIBER ATTENUATION LOSSES

AIM:

To measure the bending and connector and fiber attenuation losses of optical fibers.

APPARATUS REQUIRED:

Sl.No	Equipments	Quantity
1.	Power Supply	1
2.	Link B kit	1
3.	1 & 3 Meter Fiber cable	1

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 elections, 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 of 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 180 dB/Km. whenever the condition for angle of incidence of the incident light is violated the losses are introduced due to reflection of light. This occurs when fiber is subjected to bending. Lower the radius of curvature more is the loss. Another losses are due to the coupling of fiber at LED & photo detector ends with fibers.

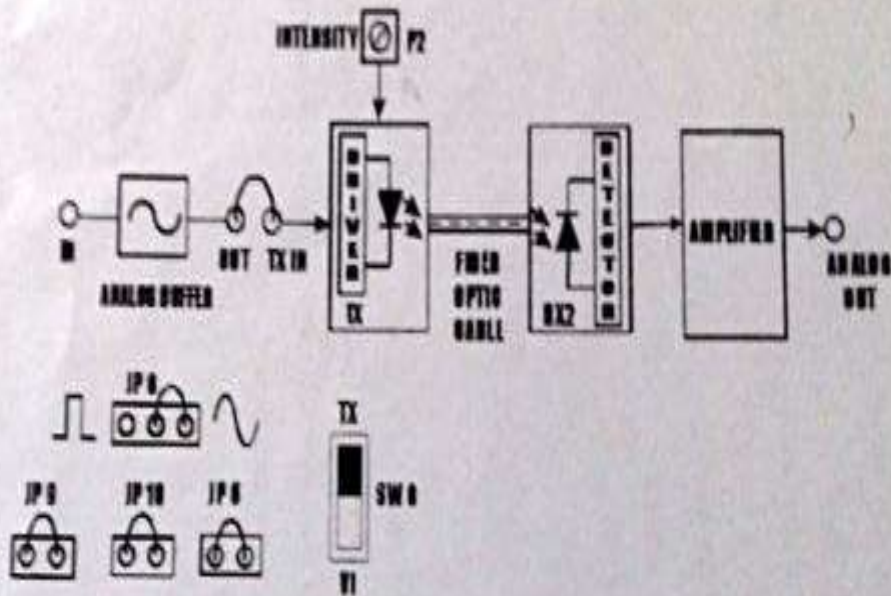
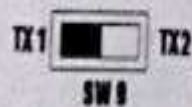
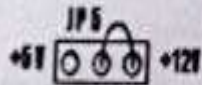


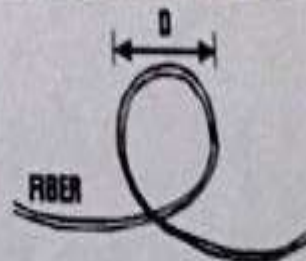
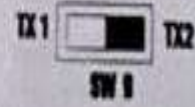
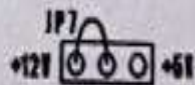
FIG. 3.1 BLOCKDIAGRAM FOR STUDY OF LOSSES IN OPTICAL FIBER.

JUMPER SETTING DIAGRAM

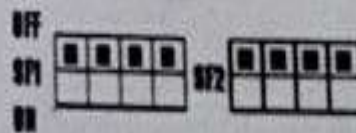
FOR TX 1 (SFH750V)



FOR TX 2 (SFH450V)



FIBER BENDING FOR LOSS MEASUREMENT



SWITCH FRACIES

MEASUREMENT OF CONNECTION LOSS

PROCEDURE:

1. Connections are made as per circuit diagram.
2. Slightly unscrew the cap of IR LED 450V (960nm) from kit1. 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 tighten the cap by screwing back.

3. Connect the power supply cables with proper polarity to Transmitter kit and lit 2. While connecting this, ensure that the power supply is OFF.
4. Connect the on board signal generator between the AMP I/P and GND posts in Transmitter kit to feed the analog to the amplifier.
5. Keep the signal generator in sine wave mode and select the frequency =1 KHz with amplitude =2V p-p.
6. Switch on the power supply.
7. Check the output signal of the amplifier at the post AMP O/P in Transmitter kit.
8. Now rotate the Optical Power Control Pot P1 located below power supply connector in kit1 in anticlock wise direction. This ensures minimum current flow through LED.
9. Short the following posts in kit1 with the links provided.

A. +9V and +9V – This ensures supply to the transmitter

B. AMP O/P and TRANSMITTER I/P.

10. Connect the other end of the fiber to detector SFH 250V (Analog Detector) in kit2 very carefully as per the instructions in step 1.
11. Ensure that the jumper located just above IC U1 I Receiver kit is shorted to pins 2 and 3. Shorting of the jumper allows connection of PIN photodiode to the transimpedance amplifier input.
12. Observe the output signal from the detector at AC OUTPUT post in kit2 on CRO. Adjust Optical Power Control pot P1 in kit1. You should get the reproduction of the original transmitted signal. Also adjust the amplitude of received signal as that of the transmitted one. Mark this amplitude level as V_1 .
13. Now move the position of connecting fibers for 1 cm length from the source.
14. Switch on the power supply and signal generator.
15. Observe the output signal from the detector at AC OUTPUT post in Receiver kit on CRO.
16. Now again move the connecting position of the fiber 2 cm away from fiber source . Measure the amplitude level at the receiver side again.
17. Plot the graph connecting distance versus output amplitude.

TABULATION

Connecting distance (mm)	Input Amplitude V	Output Amplitude V

MEASUREMENT OF BENDING LOSSES:

PROCEDURE:

1. Repeat all the steps from. 1 to 11 as above.
2. Bend the fiber in loop. Measure the amplitude of the received signal.
3. Keep reducing the diameter to about 1-2 cm & take corresponding output voltage readings. (Do not reduce loop diameter less than 2 cm.)
4. Plot a graph of the received signal amplitude versus the loop diameter.

TABULATION:

Bending Radius	Input Amplitude	Output Amplitude

RESULT:

Thus the Connector loss and bending loss are measured.

EXP. NO: 2A NUMERICAL APERATURE OF OPTICAL FIBER

DATE:

AIM:

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

APPARATUS REQUIRED:

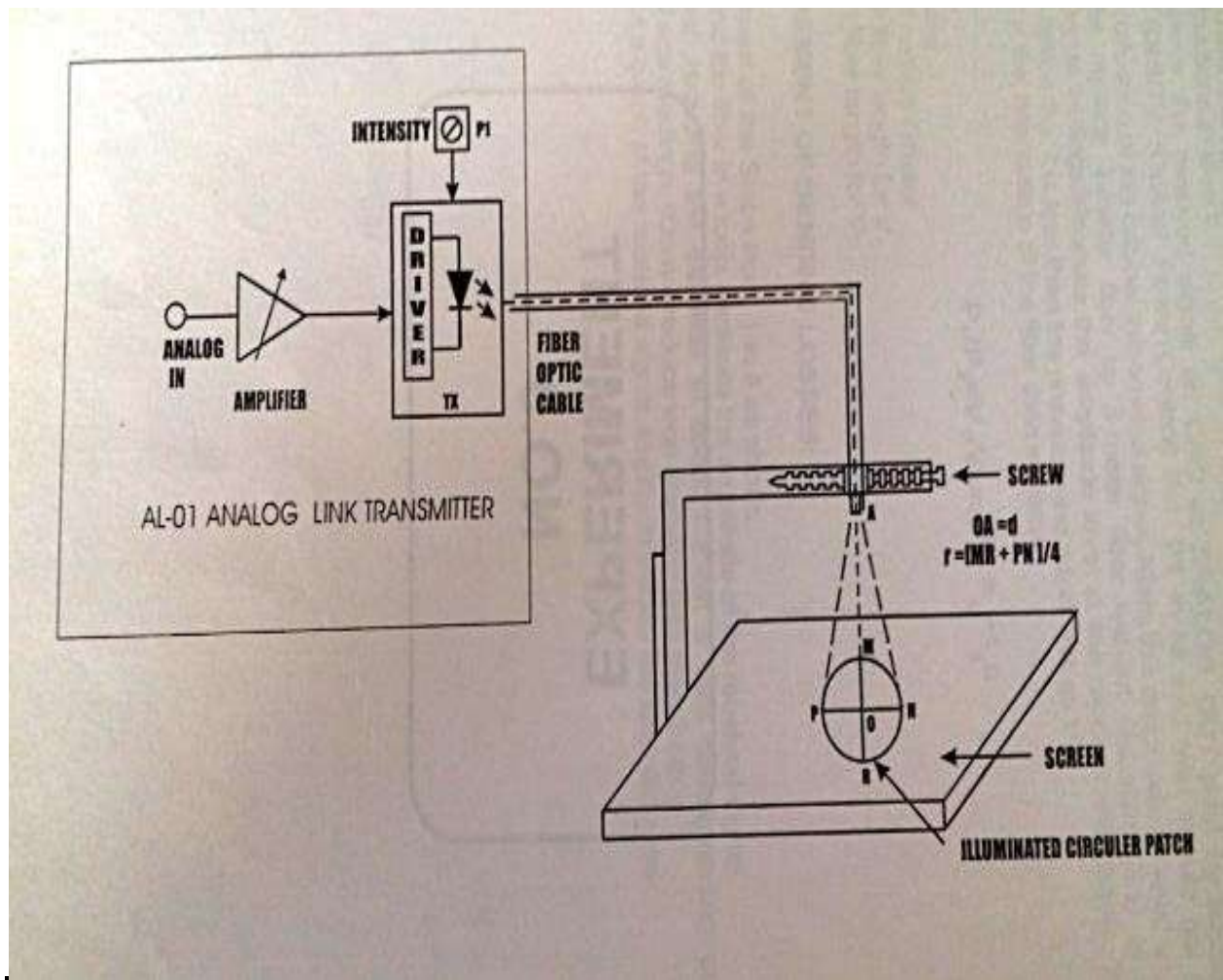
Sl.No	Equipments	Quantity
1.	Power Supply	1
2.	AL-01 KIT	1
3.	1-meter fiber cable	1
4.	NA JIG	1
5.	Ruler	1

THEORY:

Numerical aperture refers to the maximum angel 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 on the fiber. The light ray should strike the fiber end within its cone of acceptance; else it is refracted out of the fiber core.

Considerations in Measurement:

1. It is very important that the optical source should be properly aligned with the cable & the distance from the launched point & the cable the property 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.



Numerical aperture measurement in optical fiber

PROCEDURE:

1. Connections are made as per circuit diagram.
2. Slightly unscrew the cap of LED SFH756V (660nm). 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 show in the jumper diagram
4. Connect the power cord to the kit & 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 that the 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 thus 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 horizontal diameters MR and PN.

9. Mean radius is calculated using the following formula. $r = (\text{MR} + \text{PN}) / 4$.

10. Find the numerical aperture of the fiber using the formula.

$$\text{NA} = \sin \theta_{\max} = r / \sqrt{d^2 + r^2}$$

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

TABULATION:

Sl.No	Distance d(mm)	MR (mm)	NP (mm)	$r = (\text{MR} + \text{NP}) / 4$ (mm)	Numerical Aperture $= r / \sqrt{r^2 + d^2}$	$\theta_{\max} = \sin^{-1}(\text{NA})$

RESULT

Thus the numerical aperture of the given fiber optic is measured.

EXP.NO:2B

MODE CHARACTERISTICS OF OPTICAL FIBER

DATE:

AIM:

To study the mode characteristics of fiber optic cable and observe the lower order Linearly Polarized (LP) modes.

APPARATUS REQUIRED:

1. LASER Source (633 nm – 1mW)
2. Source to Fiber Coupler
3. Single Mode Fiber
4. Fiber Holding Stand
5. Opaque Screen

THEORY :

The central spot carries 95% of the intensity for laser beams with Gaussian profile. $I = I_0 e^{-2(r/w)^2}$ where $e = 2.718$ is the base of the natural logarithm. An accepted definition of a radius of a Gaussian beam is the distance at which the beam intensity has dropped to $1/e^2 = 0.135$ times its peak value I_0 . This radius is called spot size. The spot diameter is w .

Spot Diameter (d) micron = Focal length of the Lens (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.

$$NA_{\text{rays}} = \text{Laser Beam Diameter (B.D.)}$$

$$2 \times \text{Lens Focal Length (f)}$$

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 screw driver to alter the angular orientation of one base plate relative to the other can then adjust the screws.

The number of modes propagating through the fiber depends on V-number. If the fiber whose V-number is less than 2.045, it allows to propagate single mode through it, so it is called as Single Mode fiber. For a Multimode fiber, V-number is slightly greater than 2.045 but the number of allowed modes is small enough so that they may be individually identified when the output of the fiber is examined.

When $V < 2.045$, then only a single mode may propagate in the fiber waveguide. This mode is HE_{11} mode or LP_{01} – Linearly Polarized mode.

When $V > 2.045$, other modes may propagate, when V is slightly greater than 2.045 i.e. $V = 4.91$ then 4 Linearly Polarized modes will propagate through fiber.

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 bread board from the bottom side with the help of Allen screws provided with it. Confirm the rigid ness of the mount.
3. Fix the laser to the fiber coupler mount on to the bread board with base plate orientation of it towards He-Ne laser exit.
4. Turn on the He-Ne laser and locate the beam spot on 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 laser spot from the rod lens of the coupler. In case if you found the back spot, away from the exit of the 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.
6. 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 of center, adjust it to the center by slightly moving the screws of the laser mount.
7. 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.
8. Notice 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.
9. Observe the bright round shape circular spot with laser speckle pattern on to the screen. Multimode pattern can be refined by screws provided with laser-fiber coupler. Slightly adjusting or moving the screws on the laser mount, view the change in pattern of this multimode spot.
10. After observing the multimode pattern, change multimode fiber optic patch cord with single mode fiber patch cord.
11. For single mode patch cord, the blur pattern of the various single mode

patterns will appear on the screen. That is, single circular two lobes, three lobes and four lobes patterns can be very well observed by slightly adjusting the Allen screws of the laser-fiber coupler.

OBSERVATION & CALCULATION :

Parameter of given fiber are,

$$A = 4.5\mu\text{m (core radius), } N.A = 0.11, \lambda = 633\text{nm}$$

$$V = 2 \pi \times A \times N.A / \lambda = 4.91$$

From fig. shows only 4 LP modes propagates.

$$\text{Total number of modes} = V^2 / 2 = 4.91^2 / 2 = 12$$

RESULT

Thus the mode characteristics of fiber optic cable are studied and the lower order Linearly Polarized modes are observed

EXP. NO: 3 DC CHARACTERISTICS OF LED AND PIN PHOTODETECTOR

DATE:

AIM

To determine the characteristics of fiber optic LED and Photo detector.

APPARATUS REQUIRED:

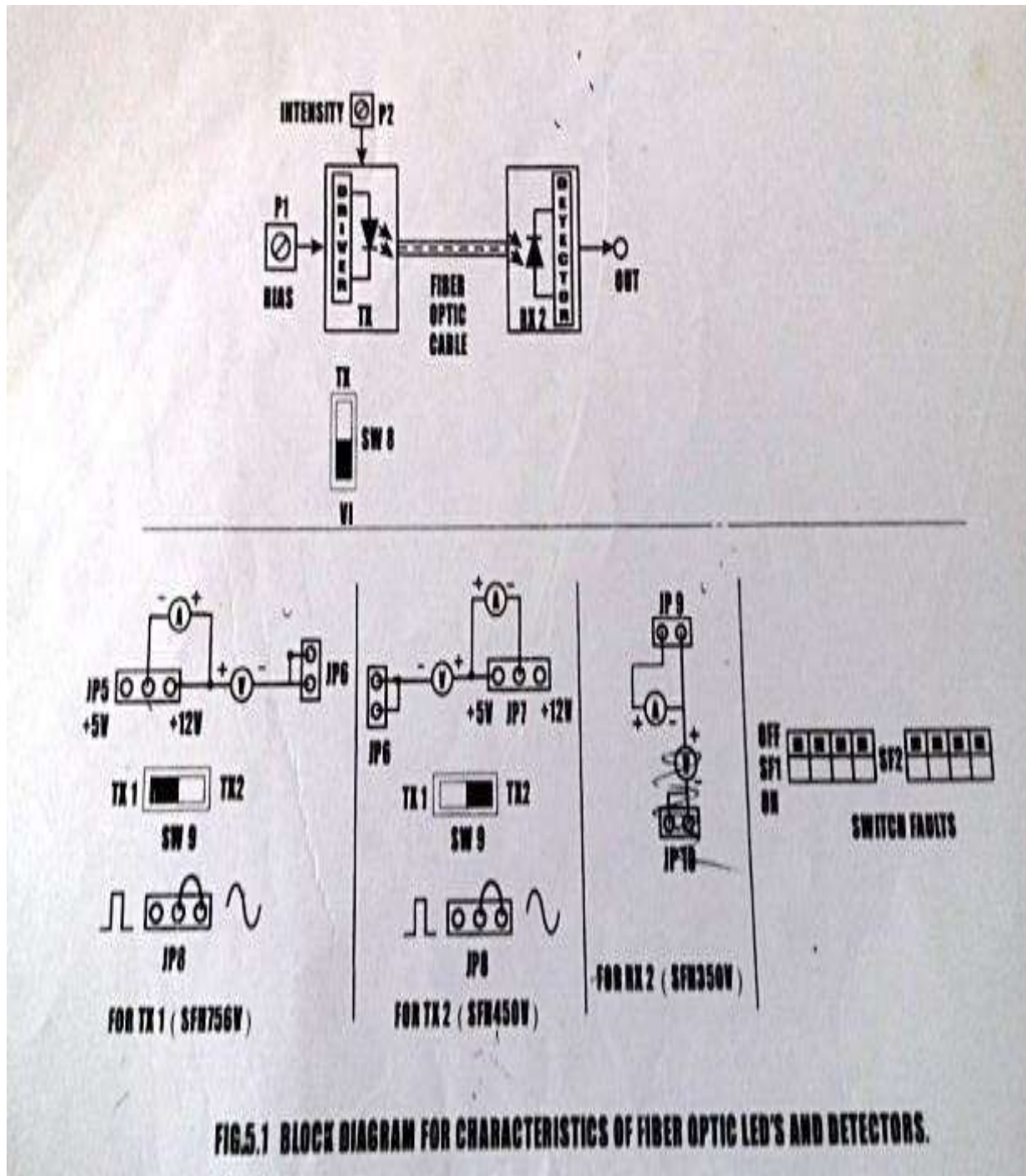
Sl.No	Equipments	Quantity
1.	Power Supply	1
2.	Link B Kit	1
3.	20 MHz Dual Trace Oscilloscope	1
4.	Volt Meter	1
5.	Ammeter	1
6.	Jumper to crocodile wires.	1

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 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 plastic fiber. Data sheets for LEDs usually specify electrical and optical characteristics, out of which are important peak wavelength of emission, conversion efficiency (usually specified in terms of power launched in optical fiber for specified forward current), optical rise and fall times which put the limitation on operating frequency, maximum forward current through LED and typical forward voltages across LED.

Photo detectors usually come in variety of forms like 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. Connections are made as per circuit diagram.
2. Confirm that the power switch is in OFF position.
3. Make the jumper settings as shown in the jumper diagram.
4. Insert the jumper connecting wires (Provided along with the kit) in jumpers JP 17 and JP 16 at positions shown in the diagram.

5. Connect the current-meter and volt-meter with the jumper wires connected to JP 17 and JP 16 as shown in the diagram.
6. Keep the potentiometer Pr10 in its maximum position (anti-clockwise rotation) and Pr9 in its minimum position (clockwise rotation). Pr 10 is used to control current flowing through the LED and Pr 9 is used to vary the amplitude of the received signal at phototransistor.
7. To get the IV characteristics of LED, rotate slowly and measure forward current and corresponding forward voltage. Take number of such readings for various current values and plot IV characteristics graph for the Led.
8. For each reading taken above, find out the power which is product of I and V. This is the electrical power coupled into plastic fiber when forward current was 10 mA as 200μW of optical energy. Hence the efficiency of the LED comes out to be approx. 1.15%.
9. With this efficiency assumed, find out optical power coupled into plastic optical fiber for each of the reading in step 7. Plot the graph of forward current v/s output optical power of the LED.
10. Data sheets for the phototransistor detector specified responsivity as 0.8 mA for 10 μW of incident optical energy. In our experimental kit, when Pr9 is at its minimum position, 100Ω of resistance is in series of emitter and ground of phototransistor.
11. Connect the 30 cm optical fiber cable supplied with kit between LED SFH576V (660nm) and phototransistor SFH350V (Analog Detector).
12. 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 100Ω of resistance.
13. 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.

V-I CHARACTERISTIC OF FIBER OPTIC LED & DETECTOR

V_f (V)	I_f (mA)	P_i (mW)	P_o (μW)	V (V)	I (mA)	R

V_f = Forward voltage of LED

I_f = Forward current of LED P_i = V * I (Electrical Power)

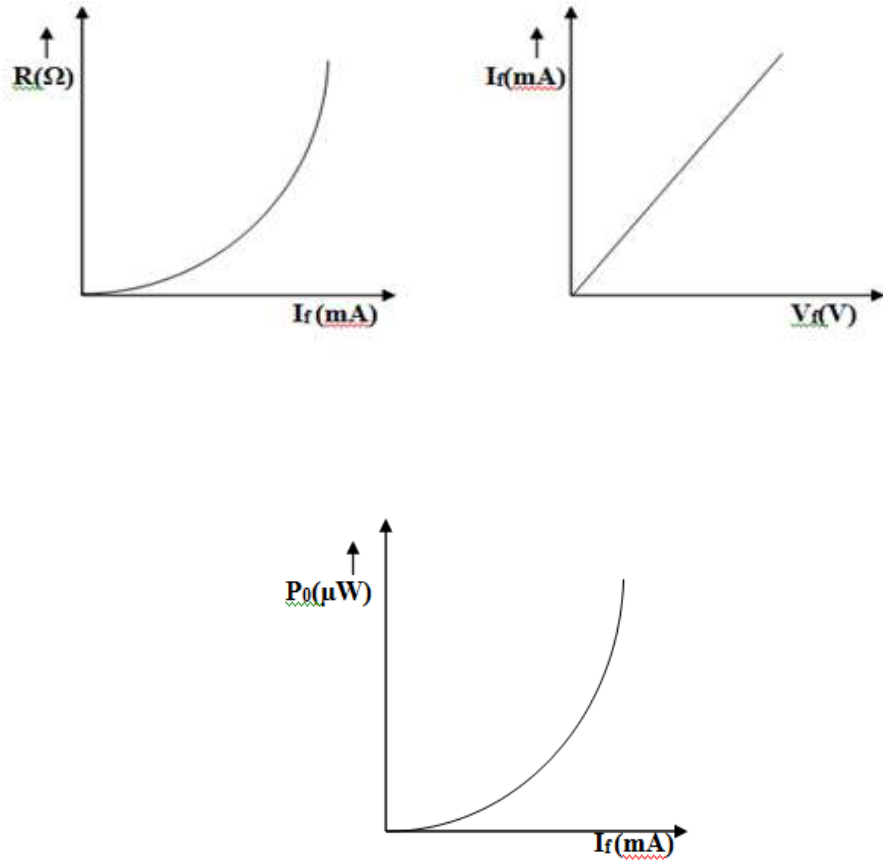
P_o = P_i * 1.615% (Optical power of LED 756)

V = Output voltage of SFH 350

I = V/R = V/100 ohm (O/P Current)

R = 0.8mA*P_O / 10μw (Responsivity)

MODEL GRAPH:



RESULT:

Thus the LED and photo diode characteristic has been verified and output is calculated and graph is plotted.

EXP.NO: 4A FIBER OPTIC ANALOG LINK CHARACTERIZATION
DATE:

AIM

To establish 950 nm Fiber Optic Analog Link and find its frequency response.

APPARATUS REQUIRED

Sl.No	Equipments	Quantity
1.	Power Supply	1
2.	Kit 4	1
3.	20 MKz Dual Trace Oscilloscope	1
4.	1 Meter Fiber Cable	1

THEORY:

Fiber Optic Analog 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 & 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.

PROCEDURE:

1. Connections are made as per circuit diagram.
2. Slightly unscrew the cap of IRLED SFH 450V (950nm) from Transmitter 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 tighten the cap by screwing it back.
3. Connect the power supply cables with proper polarity to Transmitter kit and Receiver kit. While connecting this, ensure that the power supply is OFF.
4. Connect the 1KHz sine wave to the AMP I/P posts in Transmitter kit to feed the analog signal to the amplifier.
5. Keep the signal generator in sine wave and select the frequency of 1 kHz with amplitude of 1V p-p.
6. Switch on the power supply
7. Check the output signal of the amplifier at the post AMP O/P in Transmitter kit.

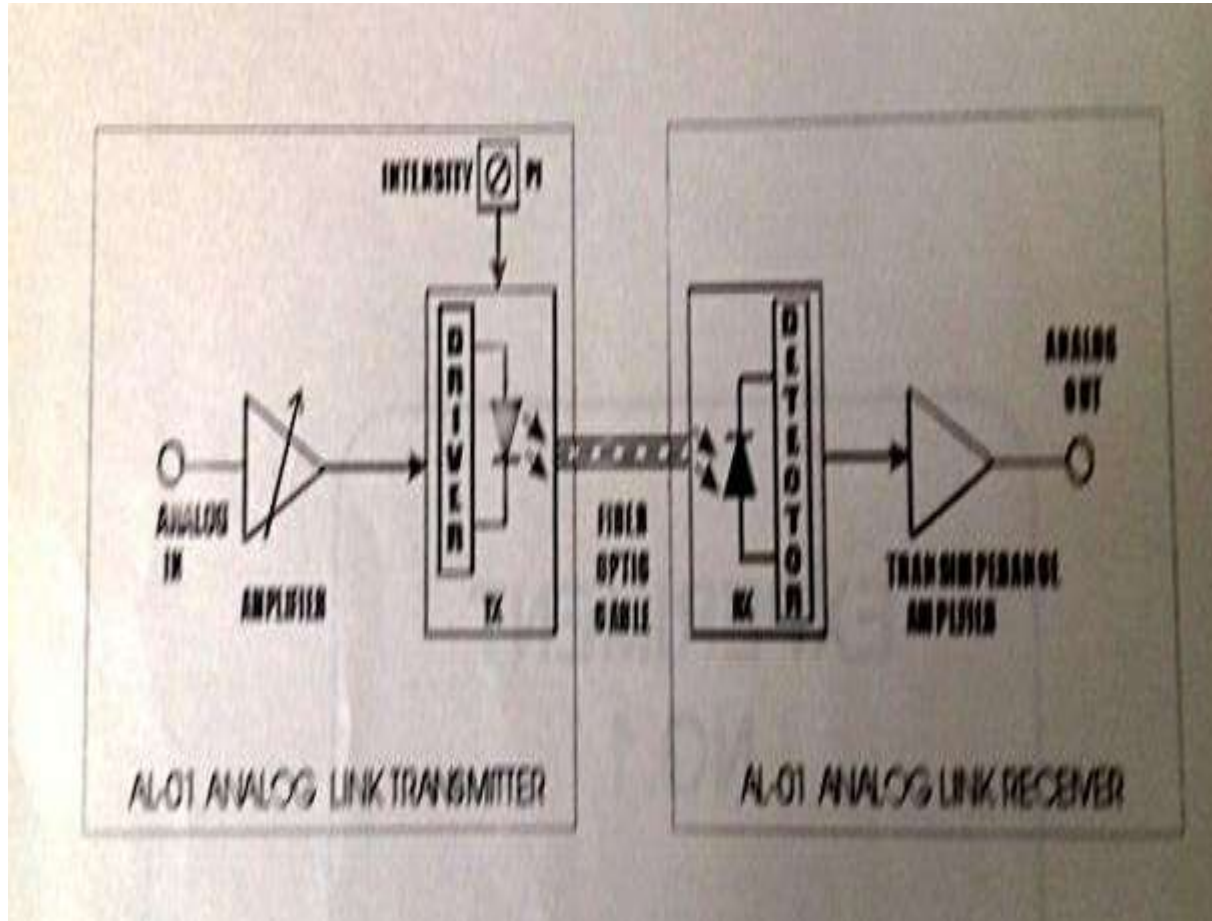
8. Now rotate the Optical Power Control pot P1 located below power supply connector in Transmitter kit in anticlockwise direction. This ensures minimum current flow through LED.
9. Short the following posts in kit1 with the links provided.

a. +9V and +9V – This ensures supply to the transmitter

b. AMP O/P and TRANSMITTER I/P.

Connect the other end of the fiber to detector SFH 250V (Analog Detector) in kit2 very carefully as per the instructions in step 1.

10. Ensure that the jumper located just above IC U1 in Receiver kit is shorted to pins 2 and 3. Shorting of the jumper allows connection of PIN photodiode to the trans impedance amplifier stage.
 11. Observe the output signal from the detector at DETECTOR O/P post on CRO by adjusting Optical Power Control pot P1 in kit1 and you should get the reproduction of the original transmitted signal.
- NOTE: Same output signal is available at post AC O/P in Receiver kit without any DC Component.
12. To measure the analog bandwidth of the link, keep the same connections and amplitude of the received signal for each frequency reading.
 13. Plot a graph of Gain/Frequency. Measure the frequency range for which the response is flat.



TABULATION:

Frequency	Input amplitude	Output amplitude

RESULT:

Thus the analog link has been established and the frequency response is determined.

EXP.NO: 4B

FIBER OPTIC DIGITAL LINK CHARACTERIZATION

DATE:

AIM:

To establish 950 nm fiber optic digital link and to transmit the digital signal through optical fiber and to study eye pattern using fiber optic link

APPARATUS REQUIRED:

Sl.No	Equipments	Quantity
1.	Power Supply	1
2.	Link-B kit	1
3.	20 MHz Dual Trace Oscilloscope	1
4.	1 MHz Function Generator	1
5.	1m Fiber Cable	1

THEORY

EYE PATTERN

The eye-pattern technique is a simple but powerful measurement method of 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.

A great deal of system performance information can be deduced from the eye-pattern display. To interpret the eye pattern, follow the procedure ahead

PROCEDURE:

1. Make the connections as shown in fig.12.1. 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 fig.12.1 to generate PRBS signal.
3. Keep switch SW8 towards TX position.
4. Keep switch SW9 towards TX1 position.
5. Keep 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 LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the one-meter fiber into the cap. Now tighten the cap by screwing it back.
14. Slightly unscrew the cap of RX1 photo transistor with TTL logic output SFH551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap by screwing it back.
15. Connect CLK OUT of PRBS Generator to EXT, TRIG of oscilloscope.
16. Connect detected signal TTL OUT to vertical channel Y input of oscilloscope. Then observe EYE PATTERN by selecting EXT. TRIG KNOB on oscilloscope as shown in Fig.12.2. Observe the Eye pattern for different clock frequencies. As clock frequency increases the EYE opening becomes smaller.

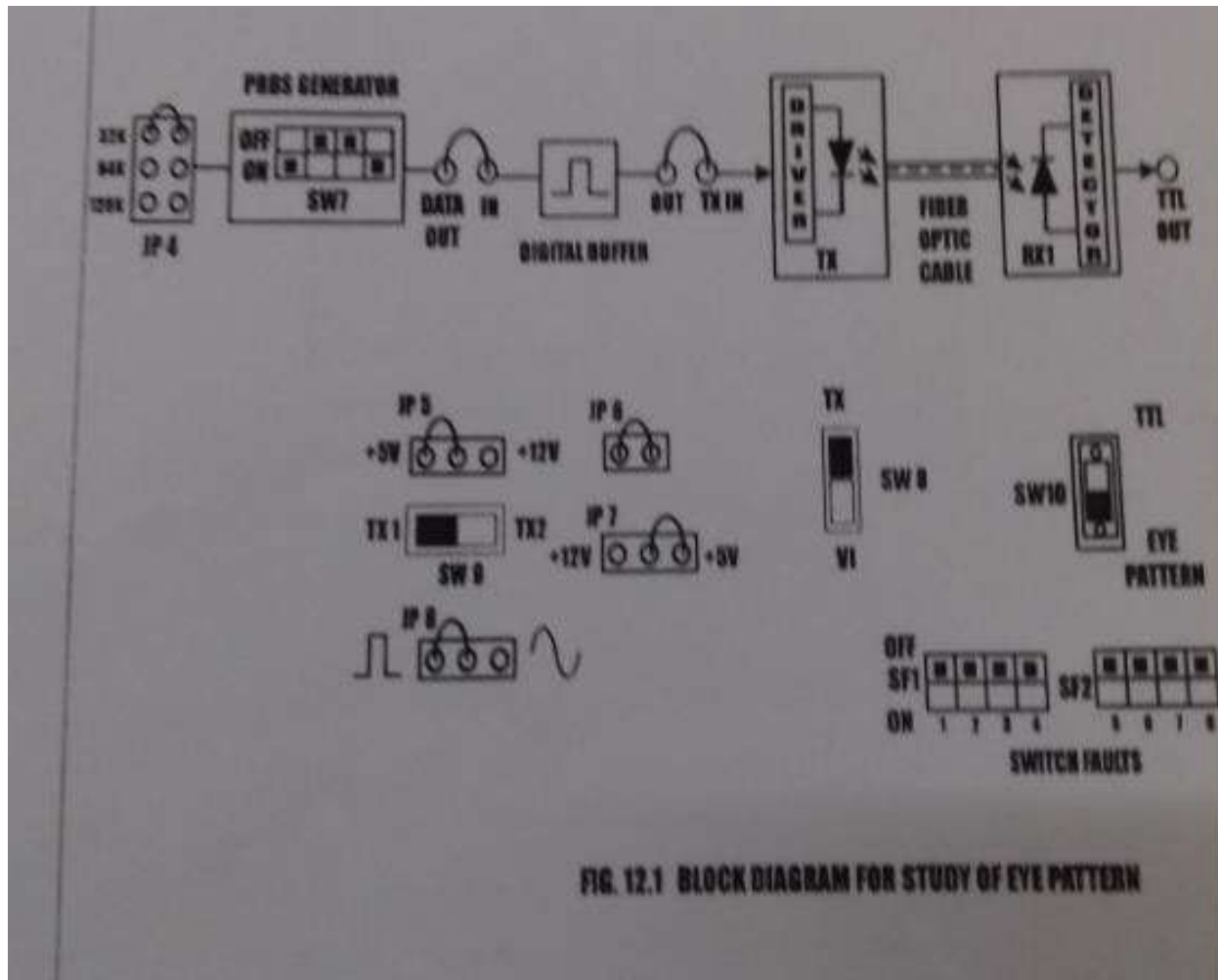
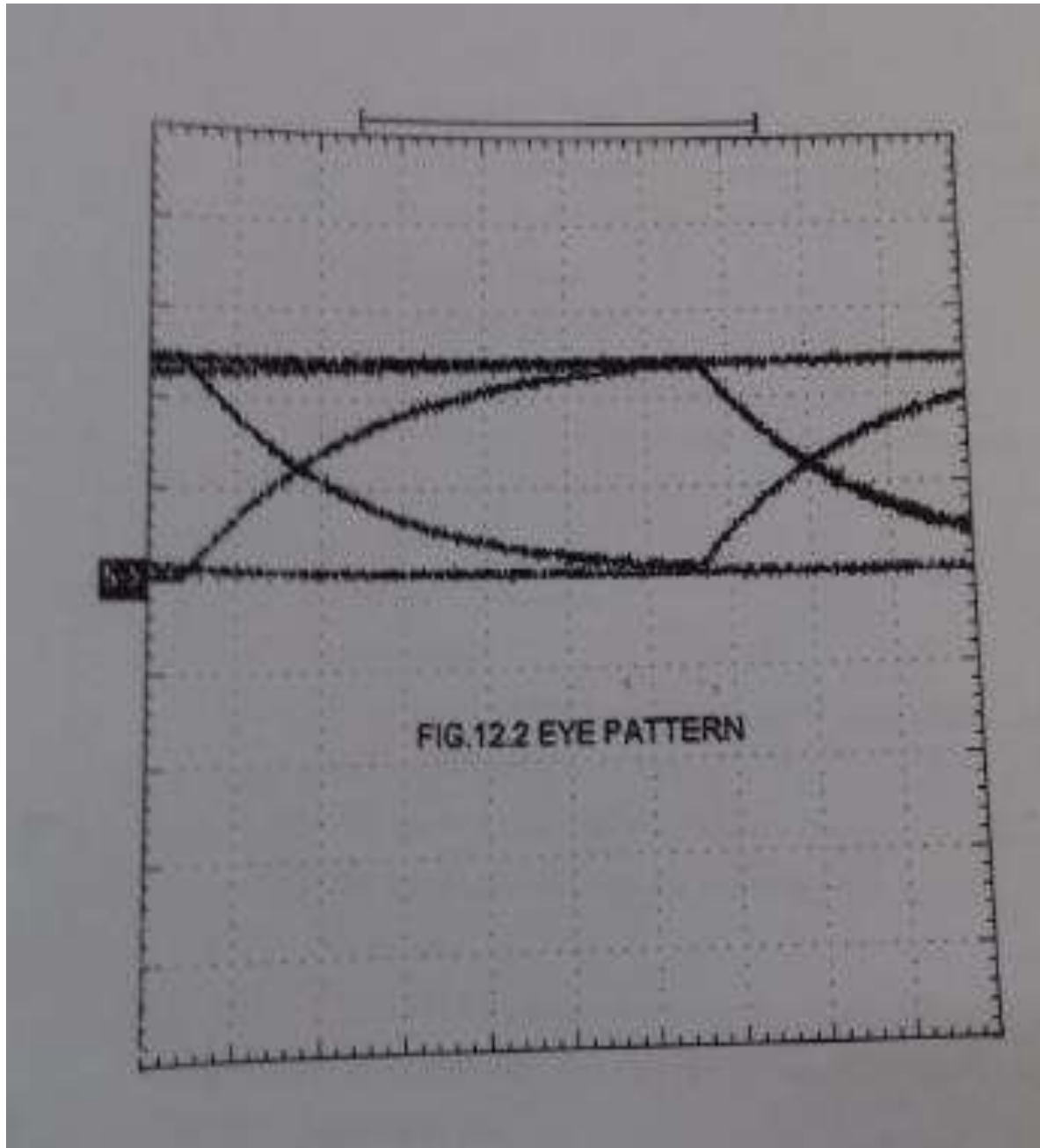


FIG. 12.1 BLOCK DIAGRAM FOR STUDY OF EYE PATTERN



RESULT:

Thus the fiber optic digital link has been established also the eye pattern is obtained.

EXP. NO: 4C DETERMINATION OF BIT ERROR RATE USING DIGITAL LINK
DATE:

AIM:

To establish 950 nm fiber optic digital link and to transmit the digital signal through optical fiber to determine the bit error rate.

APPARATUS REQUIRED:

Sl.No	Equipments	Quantity
1.	Power Supply	1
2.	Link-B kit	1
3.	20 MHz Dual Trace Oscilloscope	1
4.	1 MHz Function Generator	1
5.	1m Fiber Cable	1

THEORY:

Bit Error rate

In telecommunication transmission, the bit error rate (BER) is a ratio of bits that have errors related to the total number of bits received in a transmission. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high 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 present.

Measuring bit error rate:

A BERT (bit error rate tester) is a procedure or device that measure 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.

$$BER = \frac{\text{Bits in Error}}{\text{Total bits transmitted}}$$

Using the bench setup, this is easily measured by means of a comparator in which the transmitted bits are matched in an XOR gate with the received bits. Figure shows the schematic of the device used for the following measurements.

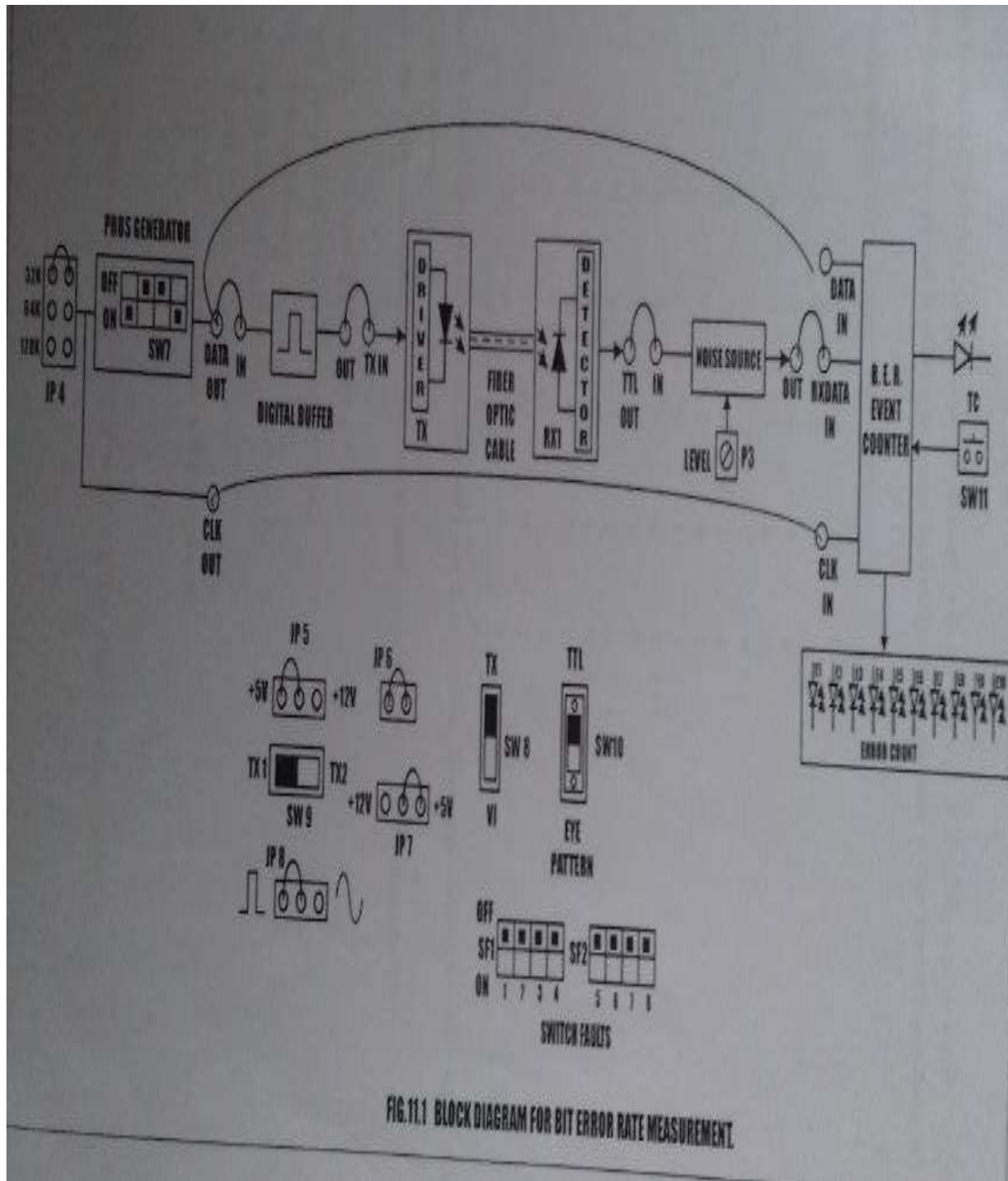


FIG.11.1 BLOCK DIAGRAM FOR BIT ERROR RATE MEASUREMENT.

If the bits are alike at the XOR gate input, when clocked in from the D flip flop, the output is low. If they are different, the XOR output goes high, causing an event count. The event counter can be set for various time periods. the more accurate is the count.

A random character generator and white noise source should be used for these measurements. The number of bit error is dependent upon the amount of noise entering the system. White noise or background noise has an average or RMS value that is exceeded periodically by peaks that rise many times that level. These peaks exist for a very short period of time.

When the peak equals or exceeds the signal level that is noise energy =bit energy , there is a

50/50 chance of error. The peak time periods can be calculated statically from the error function. In LinkB , PRBS sequence is generated by using a 4 bit right shift register whose feedback is completed by the XOR gate. Let initially 1001 be the 4 bit switch setting on the SW7.

Clock states	D1	D2	D3	D4	
			A	B	C
1	1	0	0	1	1
2	1	1	0	0	0
3	0	1	1	0	1
4	1	0	1	1	0
5	0	1	0	1	1
6	1	0	1	0	1
7	1	1	0	1	1
8	1	1	1	0	1
9	1	1	1	1	0
10	0	1	1	1	0
11	0	0	1	1	0
12	0	0	0	1	1
13	1	0	0	0	0
14	0	1	0	0	0
15	0	0	1	0	1
16	1	0	0	1	1

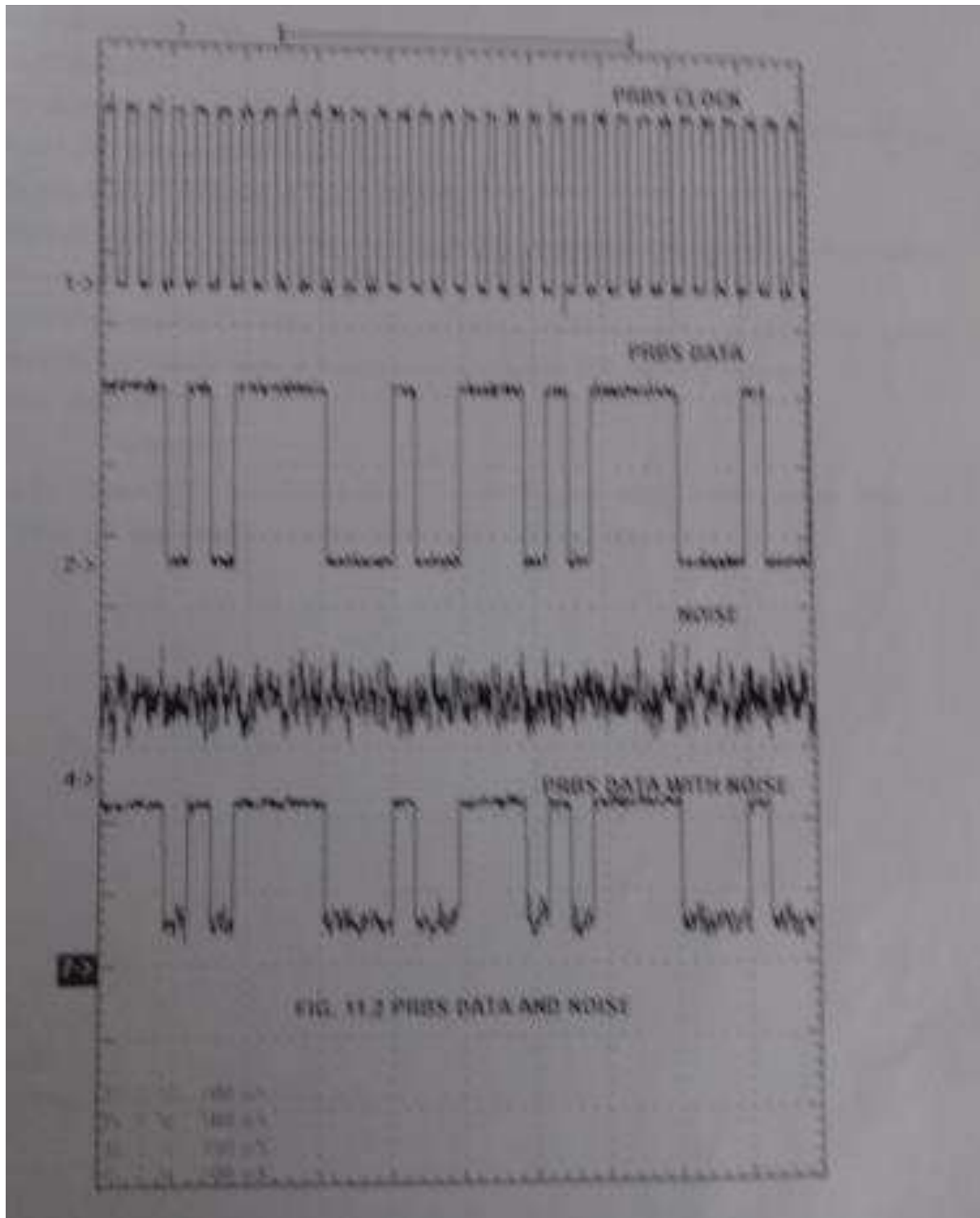
- Thus the sequences repeat constantly with a period corresponding to 16 clock states.
- Length of sequence = $2^4 = 16$
- Now the pseudorandom random sequence pattern is C=1010111100010011

NOTE:KEEP ALL SWITCH ES IN OFF POSITION

PROCEDURE:

- 1.Make connection as shown in figure.Connect the power supply cables with proper polarity to linkB kit.While connecting this,ensure that the ppower supply is OFF.
2. Keep PRBS switch 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 32KHz 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 DATAOUT PRBS generator to the IN post of Digital buffer and also to the DATA IN post of Bit error rate event counter.
12. Connect the OUT post Digital buffer TX IN post transmitter.
13. Slightly unscrew the cap of LEDSFH756v (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the one meter fiber into the cap. Now tighten the cap by screwing it back.
14. Slightly unscrew the gap of RX1 photo transistor with TTL logic output SFH551v. 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. Connected digital signal TTL OUT to post IN of noise source.
16. Connect post OUT of noise source to post RXDATAIN of bit error rate event counter.
17. Connect post CLKOUT of PRBS generator to post CLKIN of bit error rate event counter.
18. Press switch SW11 to start counter.
19. Vary POT P3 for noise level to observe the effect of noise level on the error count.
20. Observe the error count in received signal in time 10 seconds as shown in figure.



BER MEASUREMENT

As per the definition the BER is a ratio of Errored bits (E_b) to the total bits transmitted (T_b) in a period of time t seconds.

ie

$$BER = \frac{E_b}{T_b}$$

For example in this experiment if PRBS data is transmitted at 32K bits per second (jumper selection

at 32KHz) for a period of 10 seconds.so total bits transmitted in 10 seconds(Tb)
=320Kbits.

The TTL OUT data and data with noise is fed to BER counter which compares the the two data inputs at each clock input.

The counter displays the Error count(Eb) on LED in 10 bit binary form.(eg.0000001010) which has to be converted in decimal form. (it becomes 10) so the BER ratio then becomes

$$BER = \frac{10}{320 \times 10^3}$$

$$= 0.00003125$$

ie.the channel bit error ratio is 3.1×10^{-5} (3/100000) or in other words we can say that out of 100000 bits transmitted through the channel gives 3 bits in error.

RESULT

Thus the bit error rate was measured using digital link .

EXP. NO: 5

DATE:

WIRELESS CHANNEL SIMULATION INCLUDING FADING AND DOPPLER EFFECTS

AIM:

To simulate and verify output in wireless Channel including Doppler and fading effects.

APPARATUS REQUIRED:

Personal Computer

MATLAB Software

THEORY:

Rayleigh and Rician fading channels are useful models of real-world phenomena in wireless communication. These phenomena include multipath scattering effects, time dispersion, and Doppler shifts that arise from relative motion between the transmitter and receiver.

STEPS INVOLVED:

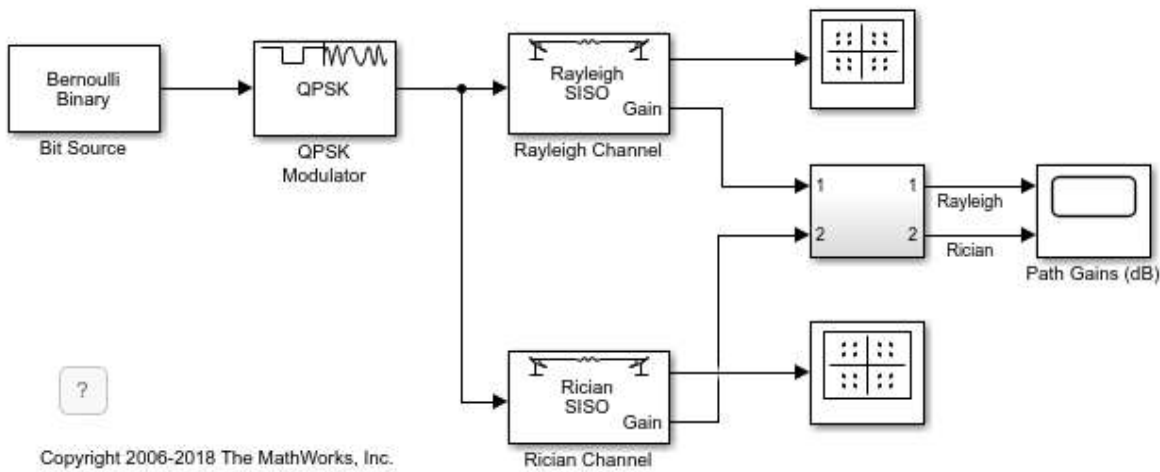
Processing a signal using a fading channel involves the following steps:

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.
4. The characteristics of a channel can be shown with the built-in visualization support of the System object.

Model and Parameters

```
modelName = 'commmultipathfading';  
rayleighBlock = [modelName '/Rayleigh Channel'];  
ricianBlock = [modelName '/Rician Channel'];  
rayleighCD = [modelName '/Rayleigh Constellation Diagram'];  
pathGainBlock = [modelName '/Path Gains (dB)'];  
open_system(modelname);
```

Multipath Rayleigh and Rician Fading Channels



bitRate % Transmission rate (b/s)

bitsPerFrame % Number of bits per frame

bitRate = 10000000

bitsPerFrame = 2000

delayVector % Discrete path delays (s)

gainVector % Average path gains (dB)

delayVector =

1.0e-06 *

0 0.2000 0.4000 0.8000

gainVector = 0 -3 -6 -9

maxDopplerShift % Maximum Doppler shift of diffuse components (Hz)

maxDopplerShift = 200

LOSDopplerShift % Doppler shift of line-of-sight component (Hz)

KFactor % Ratio of specular power to diffuse power (linear)

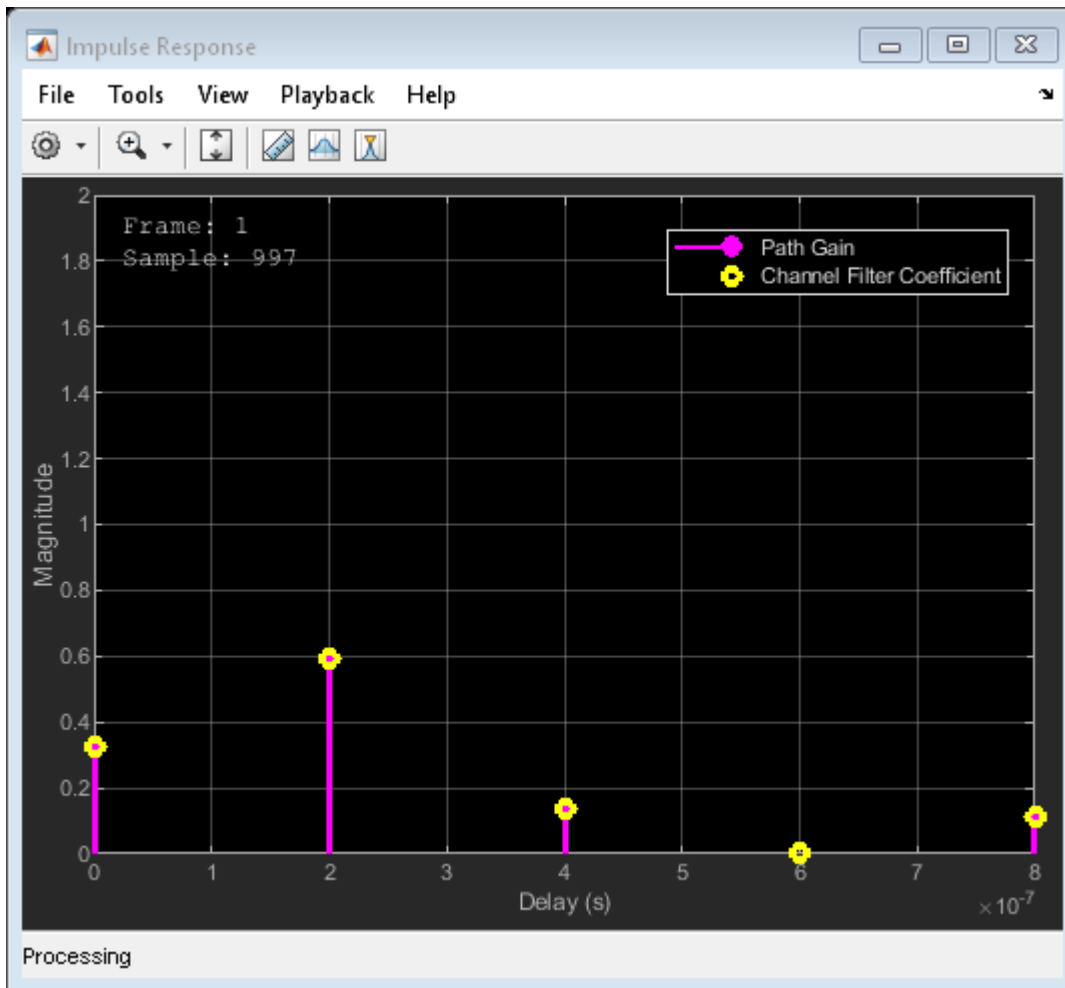
LOSDopplerShift = 100

KFactor =

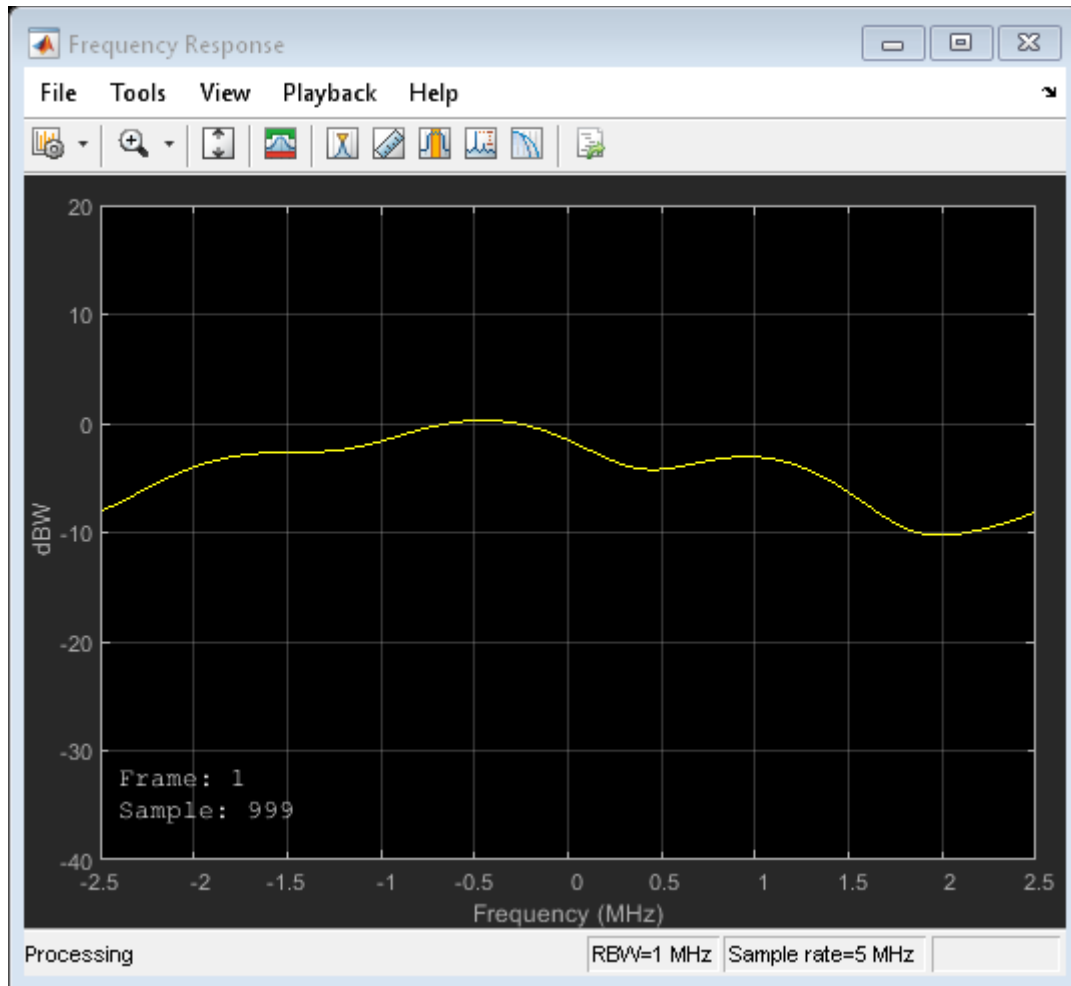
10

Wideband or Frequency-Selective Fading

```
set_param(rayleighBlock, 'Visualization', 'Impulse response');  
set_param(modelname, 'SimulationCommand', 'start');  
set_param(modelname, 'SimulationCommand', 'pause');
```



```
set_param(modelname, 'SimulationCommand', 'stop');  
set_param(rayleighBlock, 'Visualization', 'Frequency response');  
set_param(rayleighBlock, 'SamplesToDisplay', '50%');  
set_param(modelname, 'SimulationCommand', 'start');  
set_param(modelname, 'SimulationCommand', 'pause');
```



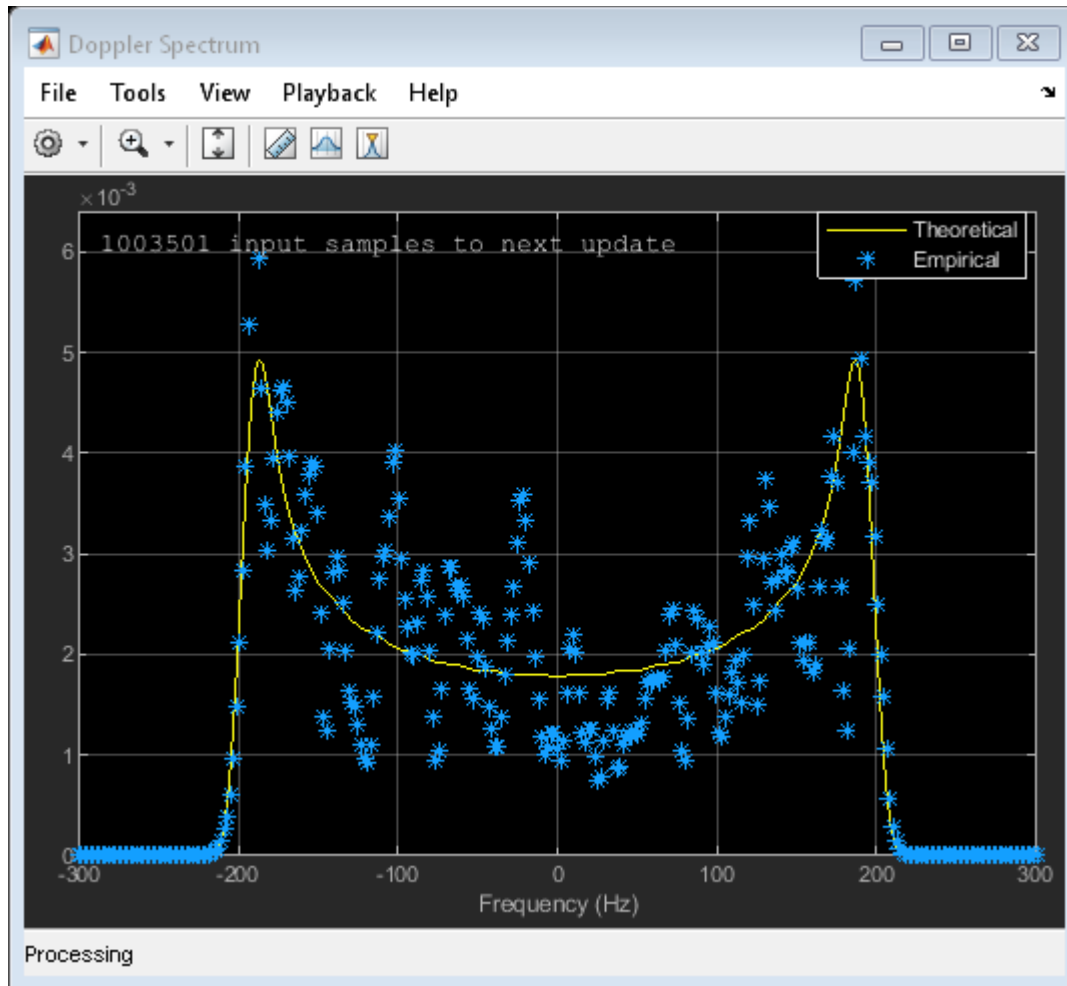
Multipath Fading Channel Simulink

```

set_param(modelname,'SimulationCommand','stop');
set_param(rayleighBlock,'Visualization','Doppler spectrum');
set_param(modelname,'StopTime','3');
set_param(modelname,'SimulationCommand','start');
set_param(modelname,'SimulationCommand','pause');

while get_param(modelname,'SimulationTime') < 2
    set_param(modelname,'SimulationCommand','continue');
    pause(1);
    set_param(modelname,'SimulationCommand','pause');
end

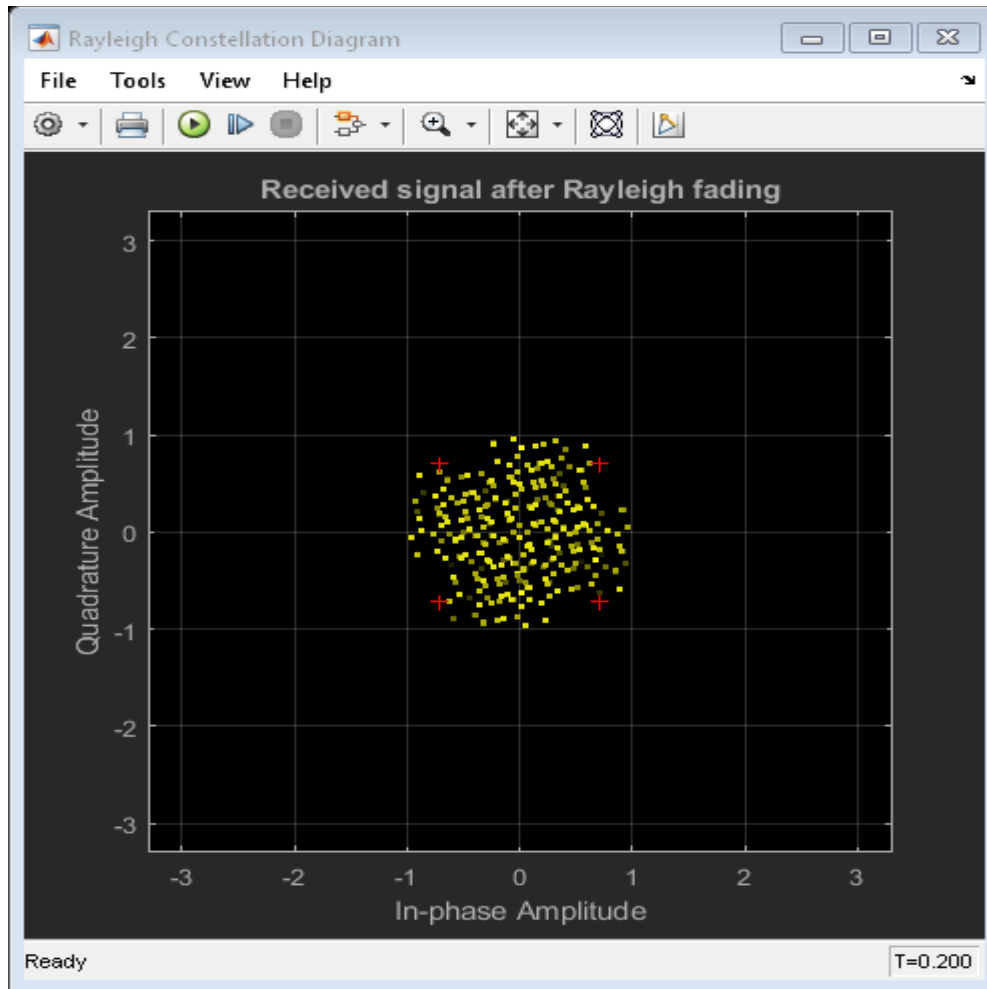
```



```

set_param(modelname,'SimulationCommand','stop');
maxDopplerShift = 5;
set_param(rayleighBlock,'Visualization','Off');
set_param(rayleighCD,'openScopeAtSimStart','on')
sim(modelname,0.2);

```



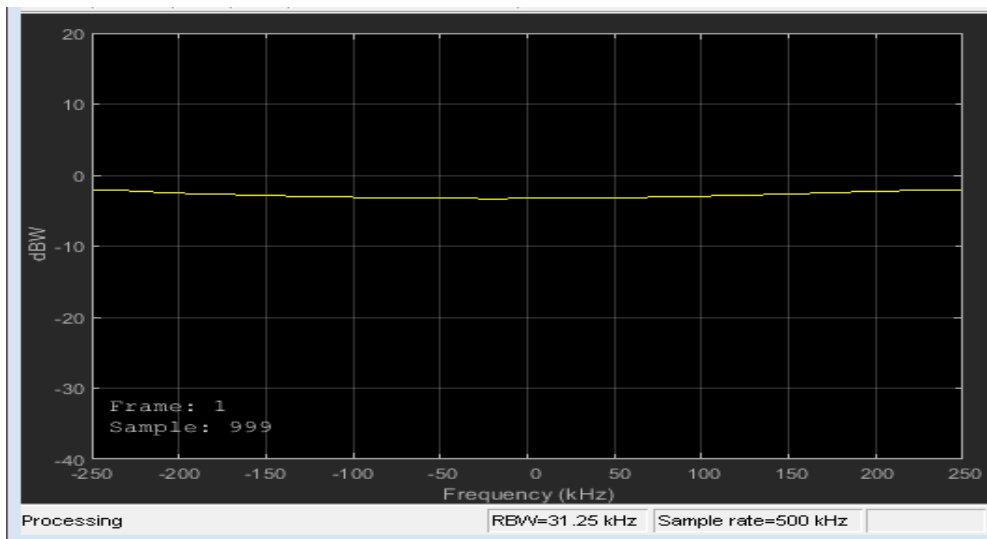
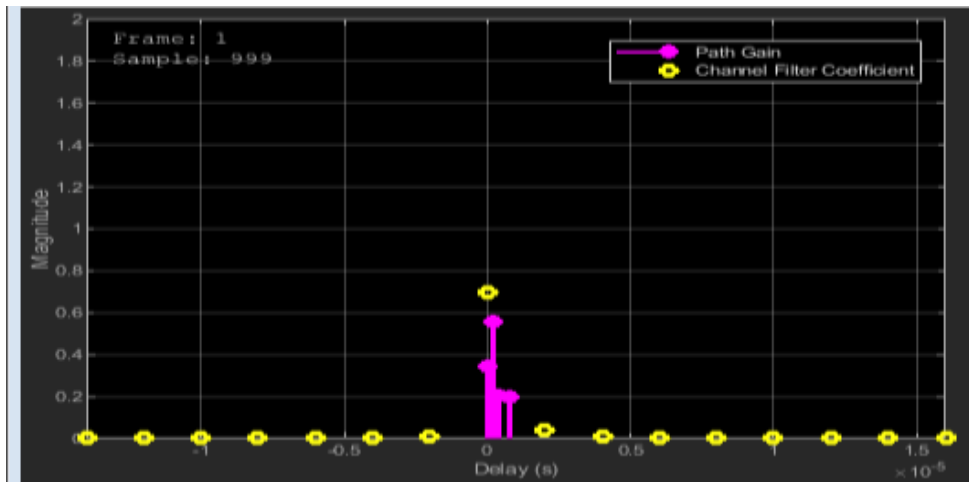
Narrowband or Frequency-Flat Fading

bitRate = 1e6 % 50 kb/s transmission

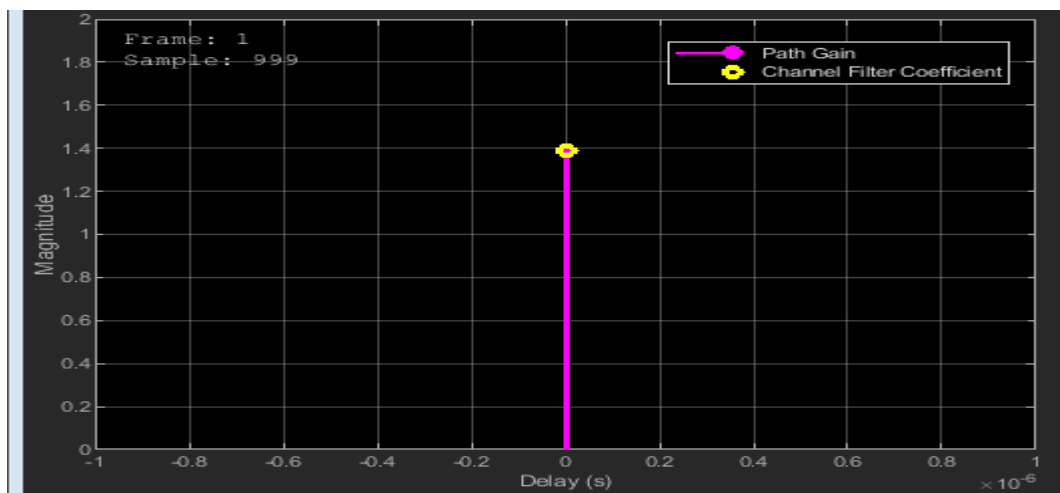
bitRate =

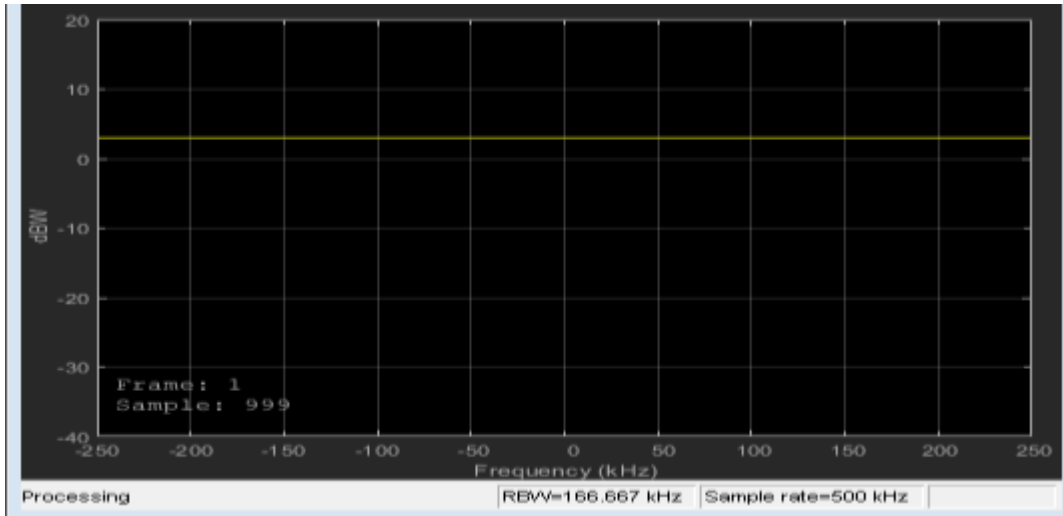
1000000

```
close_system(rayleighCD);
set_param(rayleighCD,'openScopeAtSimStart','off')
maxDopplerShift = 200; % Change back to the original value
set_param(rayleighBlock,'Visualization','Impulse and frequency responses');
set_param(modelname,'SimulationCommand','start');
set_param(modelname,'SimulationCommand','pause');
```



```
set_param(modelname, 'SimulationCommand', 'stop');
delayVector = 0; % Single fading path with zero delay
gainVector = 0; % Average path gain of 0 dB
set_param(modelname, 'SimulationCommand', 'start');
set_param(modelname, 'SimulationCommand', 'pause');
```

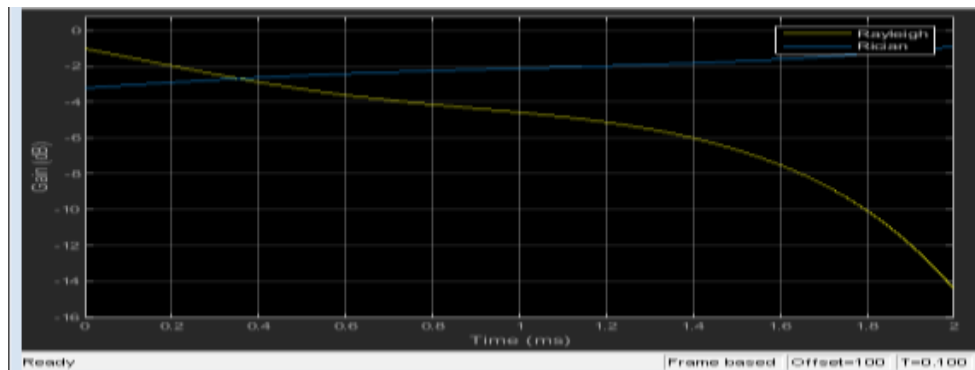




```
set_param(modelname,'SimulationCommand','stop');
delayVector = [0 2 4 8]*1e-7; % Change back to original value
gainVector = (0:-3:-9); % Change back to original value
maxDopplerShift = 5; % Reduce to slow down channel dynamics
set_param(rayleighBlock,'Visualization','Off');
set_param(rayleighCD,'openScopeAtSimStart','on')
sim(modelname,0.15);
```

Rician Fading

```
delayVector = 0; % Single fading path with zero delay
gainVector = 0; % Average path gain of 0 dB
maxDopplerShift = 200; % Change back to the original value
close_system(rayleighCD);
set_param(rayleighCD,'openScopeAtSimStart','off')
set_param(pathGainBlock,'OpenAtSimulationStart','on');
sim(modelname,0.1);
```



RESULT:

The simulation of wireless channel using fading effect and Doppler effects were verified.

EXP.NO:6 SIMULATION OF CHANNEL ESTIMATION, SYNCHRONIZATION & EQUALIZATION TECHNIQUES

DATE:

AIM:

To simulate and verify output in -wireless Channel for channel estimation, synchronization and Equalization Techniques.

APPARATUS REQUIRED:

Personal Computer

MATLAB Software

THEORY:

Channel Estimation OFDM communication system consists of channel model through which data symbols are transmitted to the receiver. This channel model produces line of sight communication and also various reflections due to which multipath effect come to picture. To minimize the multipath effect and noise introduced by the channel, we go for channel estimation.

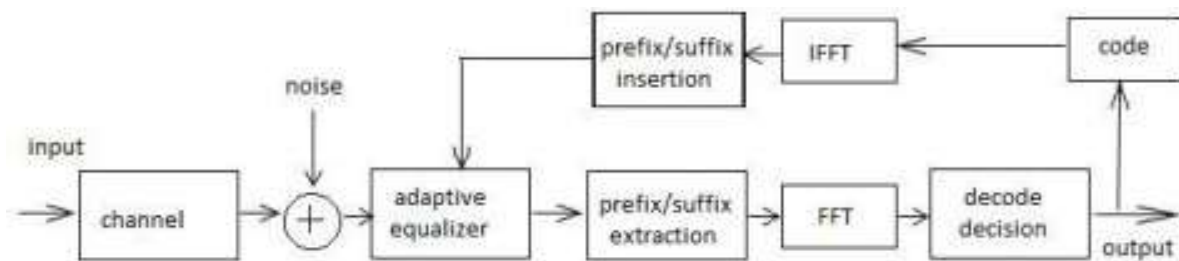


Fig. Channel Equalization

Synchronization and Channel Equalization In OFDM communication systems, at the transmitter digital to analog conversion and at the receiver, analog to digital conversion is carried out. DAC and ADC never have exactly the same sampling period. Due to this, intercarrier interference and the slow shift of the symbol timing point occurs and so orthogonality is lost. This results in need of Synchronization and Channel Equalization.

Cell-Wide Settings

```
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
```

SNR Configuration

```
SNRdB = 22;               % Desired SNR in dB
SNR = 10^(SNRdB/20);      % Linear SNR
```

```
rng('default'); % Configure random number generators
```

Channel Model Configuration

```
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
```

Channel Estimator Configuration

```
cec.PilotAverage = 'UserDefined'; % Pilot averaging method
cec.FreqWindow = 9; % Frequency averaging window in REs
cec.TimeWindow = 9; % Time averaging window in REs
cec.InterpType = 'Cubic'; % Cubic interpolation
cec.InterpWinSize = 3; % Interpolate up to 3 subframes
% simultaneously
cec.InterpWindow = 'Centred'; % Interpolation windowing method
```

Subframe Resource Grid Size

```
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
```

Transmit Resource Grid

```
txGrid = [];
```

Payload Data Generation

```
% 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');
```

Frame Generation

```
% 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

```

OFDM Modulation

```

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

```

Fading Channel

```

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,:);
```

OFDM Demodulation

```
rxGrid = lteOFDMDemodulate(enb,rxWaveform);
```

Channel Estimation

```
enb.NSubframe = 0;
[estChannel, noiseEst] = lteDLChannelEstimate(enb,cec,rxGrid);
```

MMSE Equalization

```
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);
```

```
Percentage RMS EVM of Pre-Equalized signal: 124.133%
```

```
% EVM of post-equalized receive signal
```

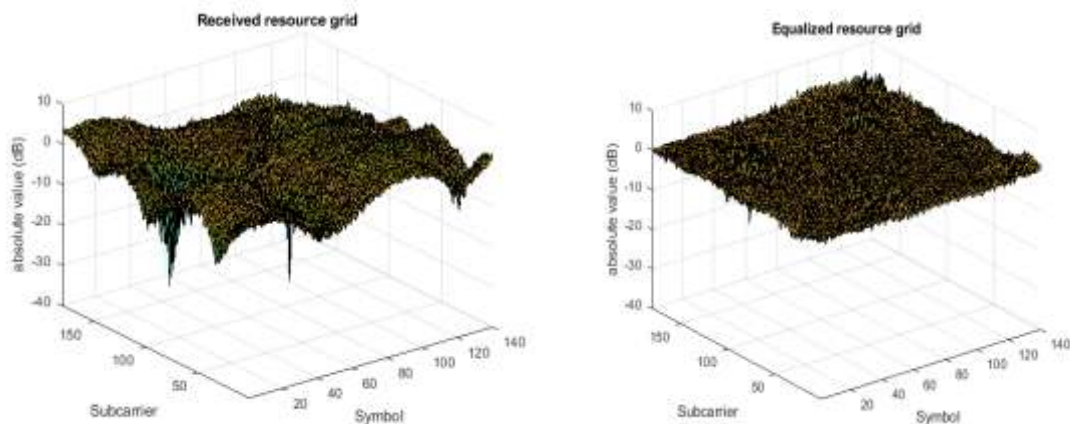
```
postEqualisedEVM = EVM(txGrid,eqGrid);
```

```
fprintf('Percentage RMS EVM of Post-Equalized signal: %0.3f%%\n', ...
    postEqualisedEVM);
```

```
Percentage RMS EVM of Post-Equalized signal: 15.598%
```

```
% Plot the received and equalized resource grids
```

```
hDownlinkEstimationEqualizationResults(rxGrid, eqGrid);
```



SYNCHRONIZATION

```
message = 'Live long and prosper, from the Communications Toolbox Team at MathWorks!';  
numFrames = 1e2;
```

```
% Adjustable channel parameters  
EbN0dB = 12; % Channel noise level (dB)  
frequencyOffset = 1e4; % Frequency offset (Hz)  
phaseOffset = 15; % Phase offset (Degrees)  
delay = 80; % Initial sample offset for entire data stream (samples)
```

```
% Display recovered messages  
displayRecoveredMsg = false;
```

```
% Enable scope visualizations  
useScopes = true;
```

```
% Check for MATLAB Coder license  
useCodegen = checkCodegenLicense;  
if useCodegen  
    fprintf(['--MATLAB Coder license found. ',...  
            'Transmitter and receiver functions will be compiled for ',...  
            'additional simulation acceleration.--\n']);  
end
```

```
% By default the transmitter and receiver functions will be recompiled  
% between every run, which is not always necessary. To disable receiver  
% compilation, change "compileIt" to false.  
compileIt = useCodegen;
```

```
% Compile transmitter with MATLAB Coder  
if compileIt  
    codegen generateOFDMSignal -args {coder.Constant(message),  
    coder.Constant(numFrames)}  
end
```

```
% Generate transmission signal  
if useCodegen  
    [txSig, frameLen] = generateOFDMSignal_mex(message, numFrames);  
else  
    [txSig, frameLen] = generateOFDMSignal(message, numFrames);  
end
```

```
% Pass signal through channel  
rxSig = applyOFDMChannel(txSig, EbN0dB, delay, frequencyOffset, phaseOffset);
```

```
% Compile receiver with MATLAB Coder
```

```

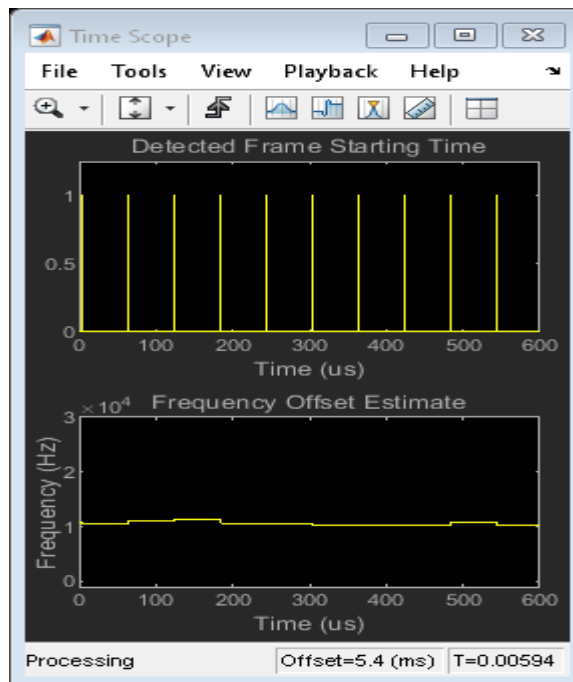
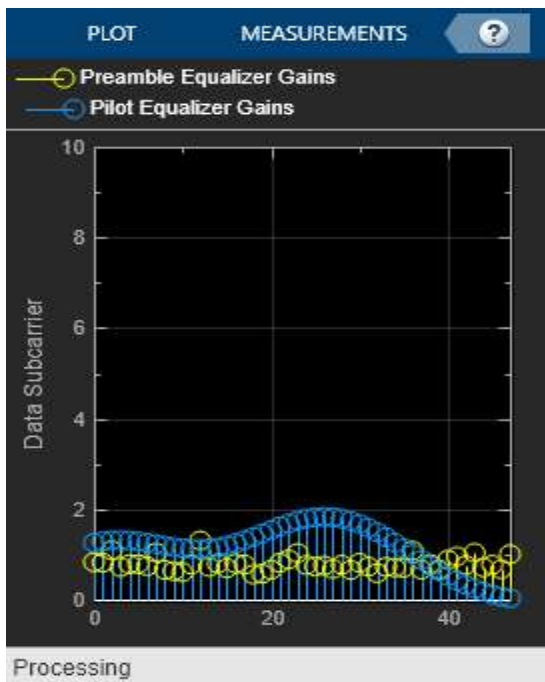
if compileIt
    codegen receiveOFDMSignal -args {rxSig, coder.Constant(frameLen),
coder.Constant(displayRecoveredMsg), coder.Constant(useScopes)}
end

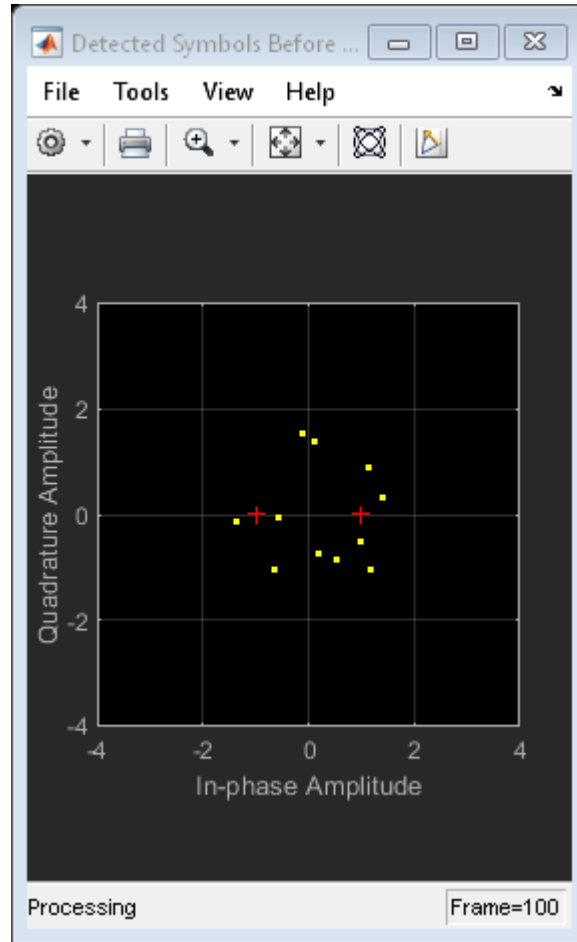
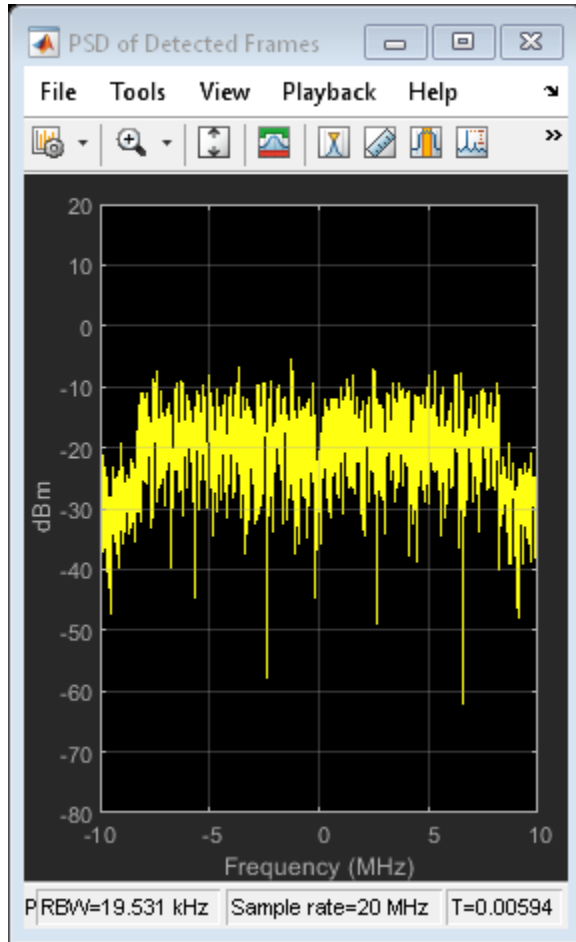
% Recover signal
if useCodegen
    [decMsgInBits, numFramesDetected] = receiveOFDMSignal_mex(rxSig, frameLen,
displayRecoveredMsg, useScopes);
else
    [decMsgInBits, numFramesDetected] = receiveOFDMSignal(rxSig, frameLen,
displayRecoveredMsg, useScopes);
end

% Calculate average BER
[FER, BER] = calculateOFDMBER(message, decMsgInBits, numFramesDetected);
fprintf('\nAt EbNo = %5.2fdB, %d frames detected among the %d transmitted frames with
FER = %f and BER = %f\n', ...
EbN0dB, numFramesDetected, numFrames, FER, BER);

```

At EbNo = 12.00dB, 100 frames detected among the 100 transmitted frames with FER = 0.010000 and BER = 0.000098





RESULT:

Thus the Wireless Channel Simulation of channel estimation, synchronization and Equalization Techniques were implemented by using MATLAB.

EXP. NO: 7 ANALYSIS THE IMPACT OF PULSE SHAPING AND MATCHED FILTERING

DATE:

AIM:

To analyze the impact of pulse shaping and matched filter using MatLab.

TOOLS REQUIRED:

- PC
- MATLAB

THEORY

At the transmitter, we focus on pulse shaping; while at the receiver, we focus on matched filtering. Pulse shaping is the process of shaping pulses to be transmitted based on the symbols generated via modulation. The goal is to make the signal suitable to be transmitted through the communication channel mainly by limiting its effective bandwidth

PROGRAM

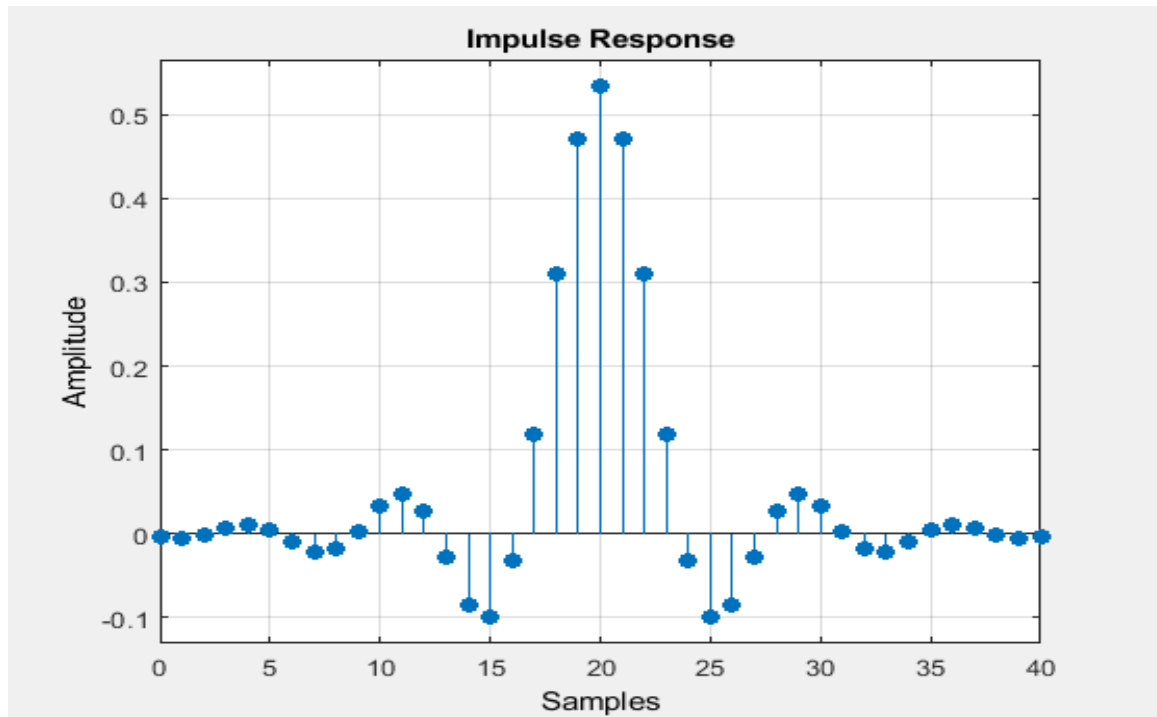
Establish Simulation Framework

```
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
Use the rcosdesign function to create an RRC filter.

rrcFilter = rcosdesign(rolloff,filtlen,sps);

fvtool(rrcFilter,'Analysis','Impulse')
```



Compute System BER

```

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)

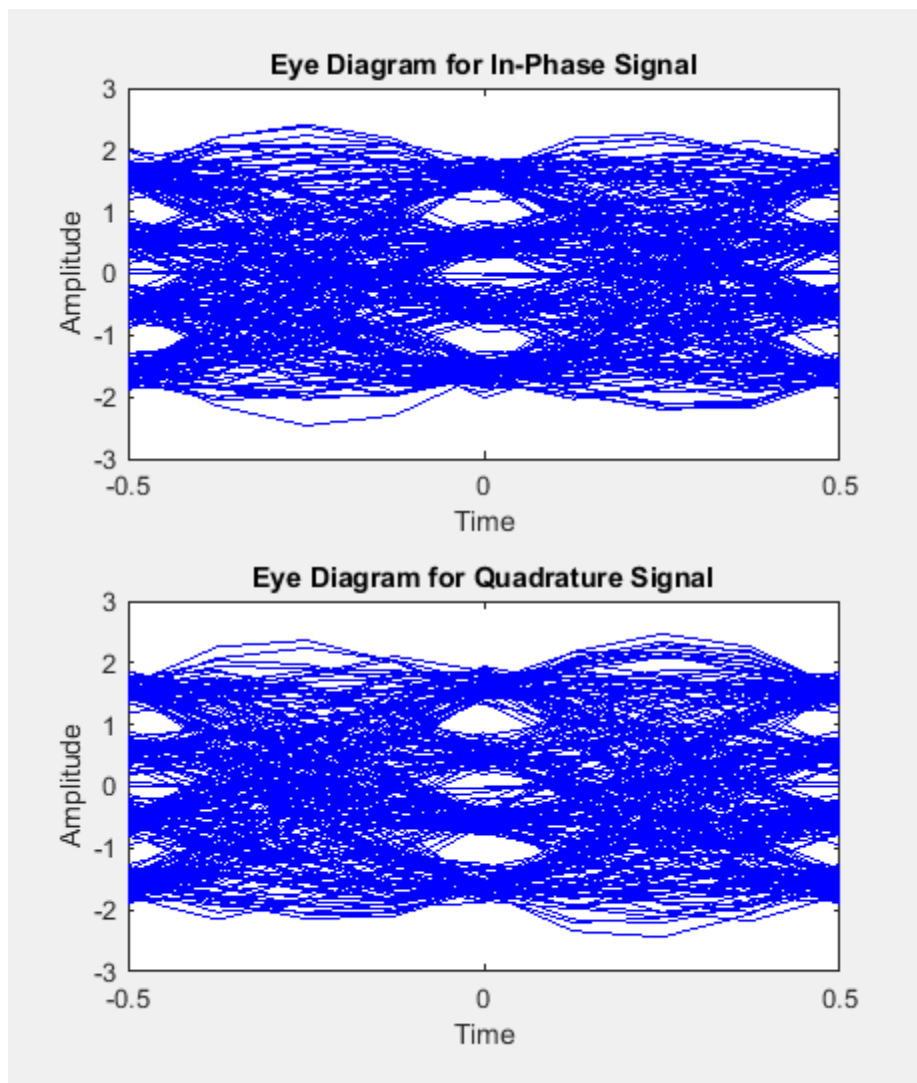
```

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);

```

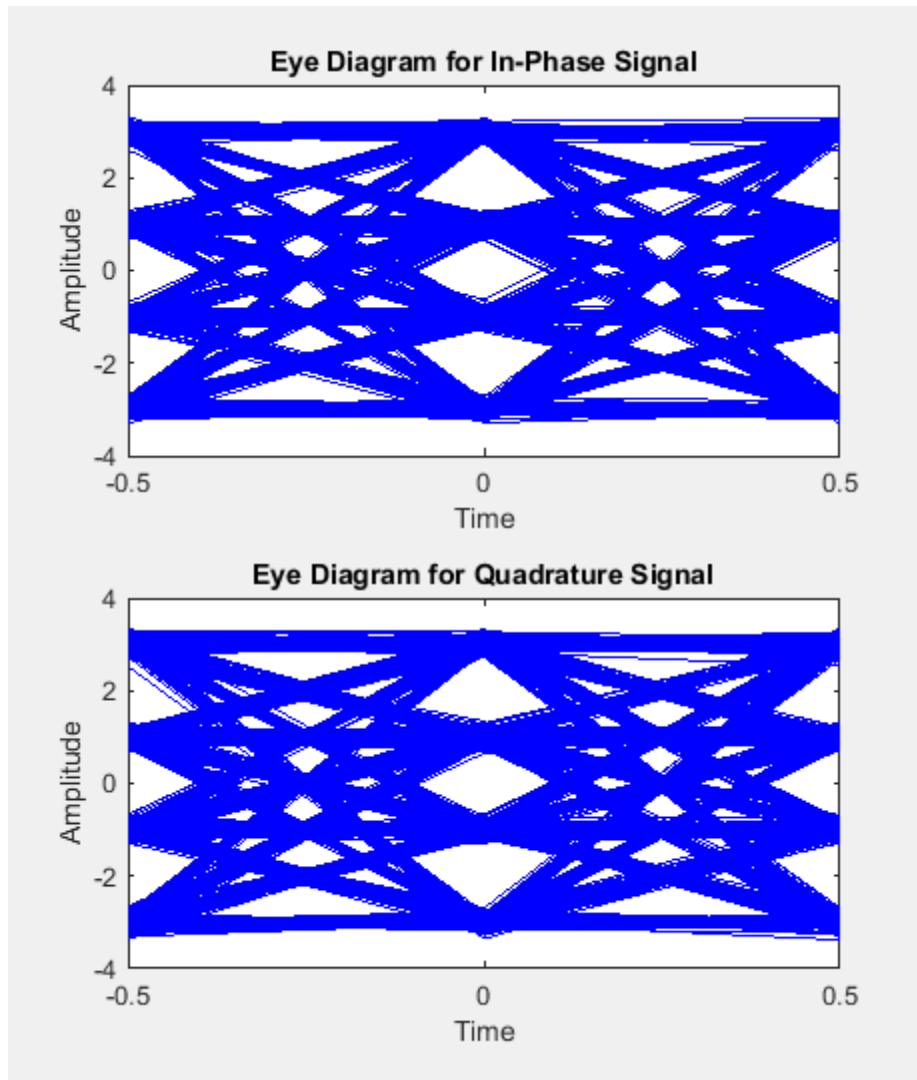


Displaying the eye diagram of the signal after the channel noise shows the signal with RRC filtering and noise. The noise level causes further narrowing of the eye diagram eye-opening.

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

Displaying the eye diagram of the signal after the matched receive filtering is applied shows the signal with raised cosine filtering. The wider eye diagram eye-openings, the signal has less ISI with raised cosine filtering as compared to the signal with RRC filtering.

```
eyediagram(rxFiltSignal(1:2000),2);
```

```

scatplot = scatterplot(sqrt(sps)*...
    rxSignal(1:sps*5e3),...
    sps,0,'g.');
```

hold on;

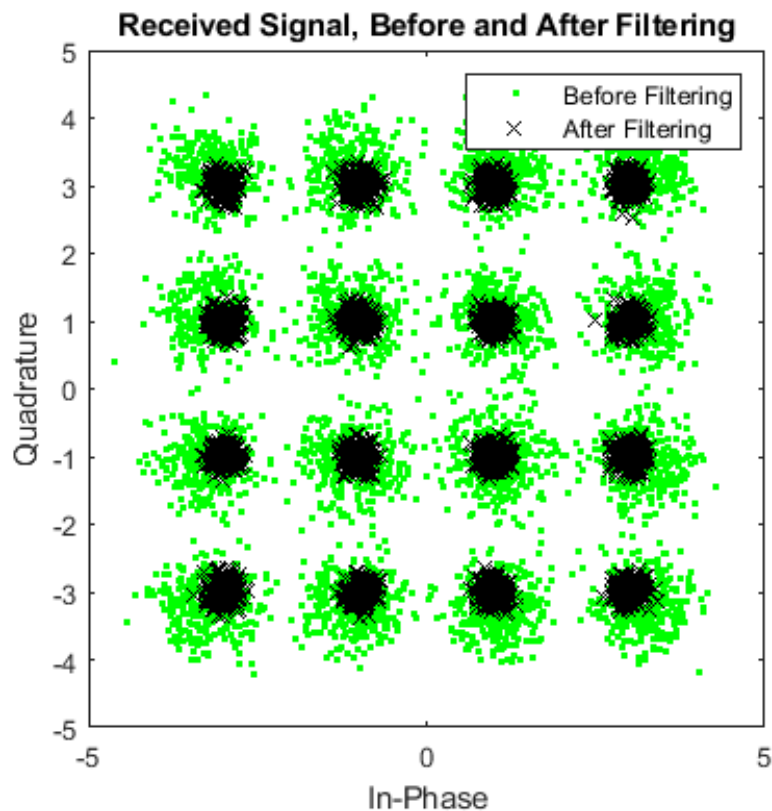
```

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 Filtering of Linear FM Waveform

```

waveform = phased.LinearFMWaveform('PulseWidth',1e-4,'PRF',5e3,...
    'SampleRate',1e6,'OutputFormat','Pulses','NumPulses',1,...
    'SweepBandwidth',1e5);

```

```

wav = getMatchedFilter(waveform);

```

Create a matched filter with no spectrum weighting, and a matched filter that uses a Taylor window for spectrum weighting.

```

filter = phased.MatchedFilter('Coefficients',wav);
taylorfilter = phased.MatchedFilter('Coefficients',wav,...
    'SpectrumWindow','Taylor');

```

Create the signal and add noise.

```

sig = waveform();
rng(17)
x = sig + 0.5*(randn(length(sig),1) + 1j*randn(length(sig),1));

```

Filter the noisy signal separately with each of the filters.

```

y = filter(x);
y_taylor = taylorfilter(x);

```

Plot the real parts of the waveform and noisy signal.

```

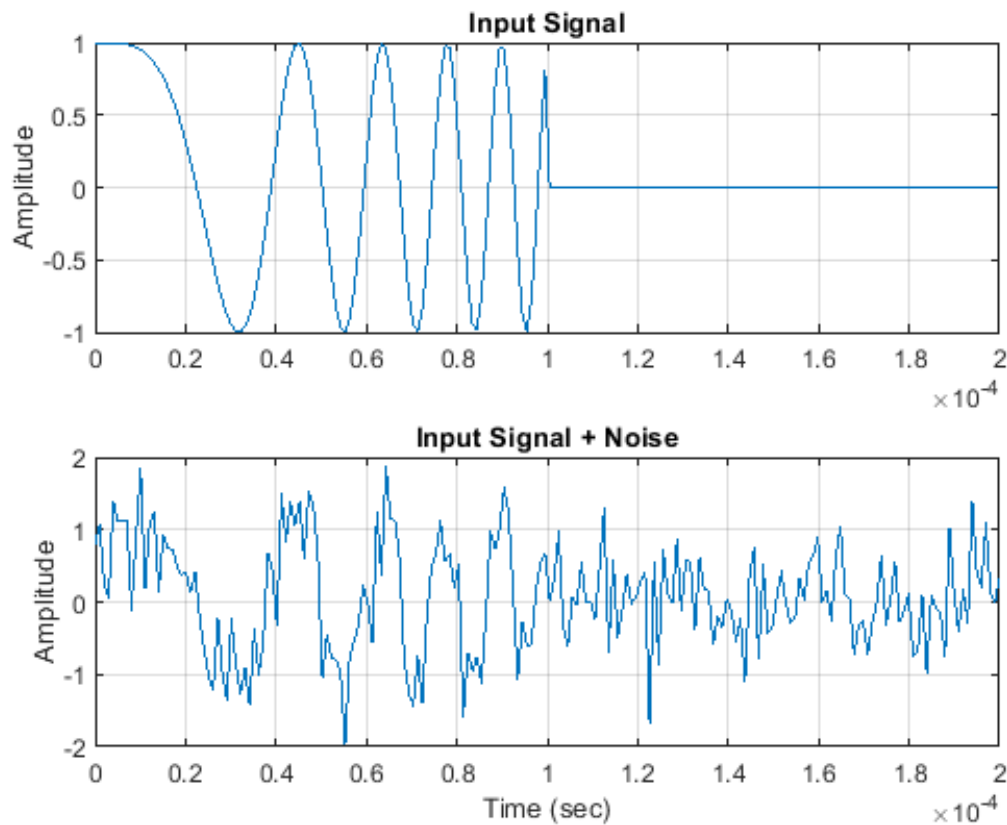
t = linspace(0,numel(sig)/waveform.SampleRate,...
    waveform.SampleRate/waveform.PRF);
subplot(2,1,1)
plot(t,real(sig))

```

```

title('Input Signal')
xlim([0 max(t)])
grid on
ylabel('Amplitude')
subplot(2,1,2)
plot(t,real(x))
title('Input Signal + Noise')
xlim([0 max(t)])
grid on
xlabel('Time (sec)')
ylabel('Amplitude')

```

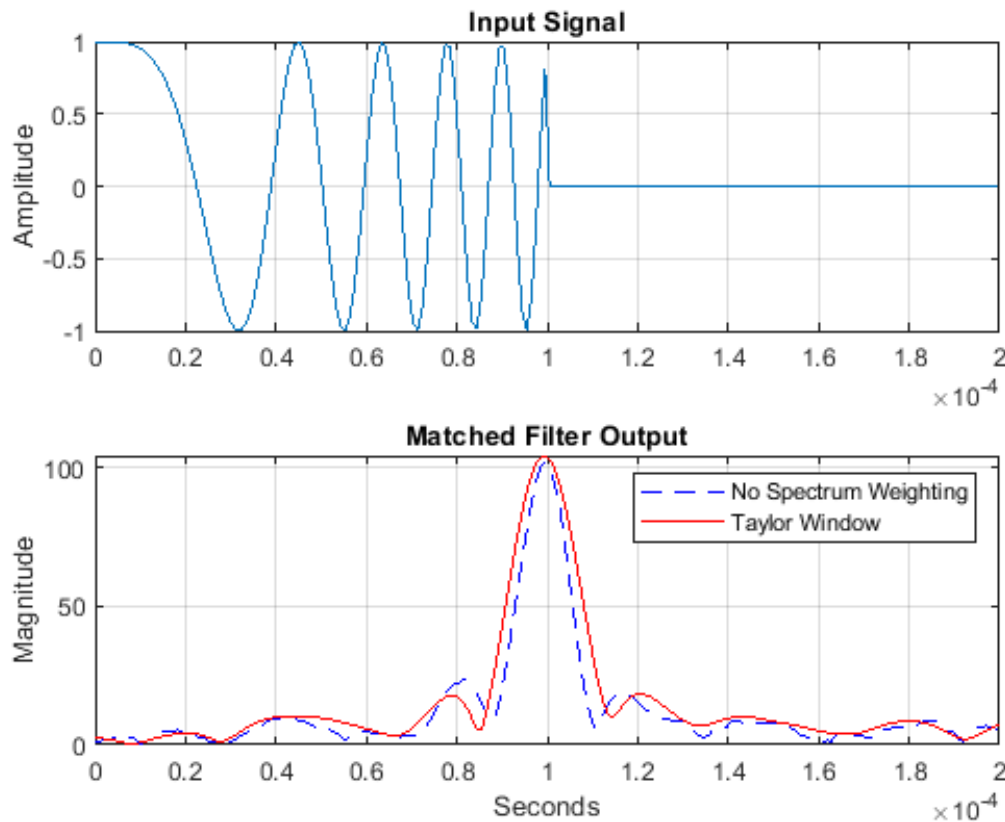


Plot the magnitudes of the two matched filter outputs.

```

plot(t,abs(y),'b--')
title('Matched Filter Output')
xlim([0 max(t)])
grid on
hold on
plot(t,abs(y_taylor),'r-')
ylabel('Magnitude')
xlabel('Seconds')
legend('No Spectrum Weighting','Taylor Window')
hold off

```



Matched Filtering to Improve SNR for Target Detection

```

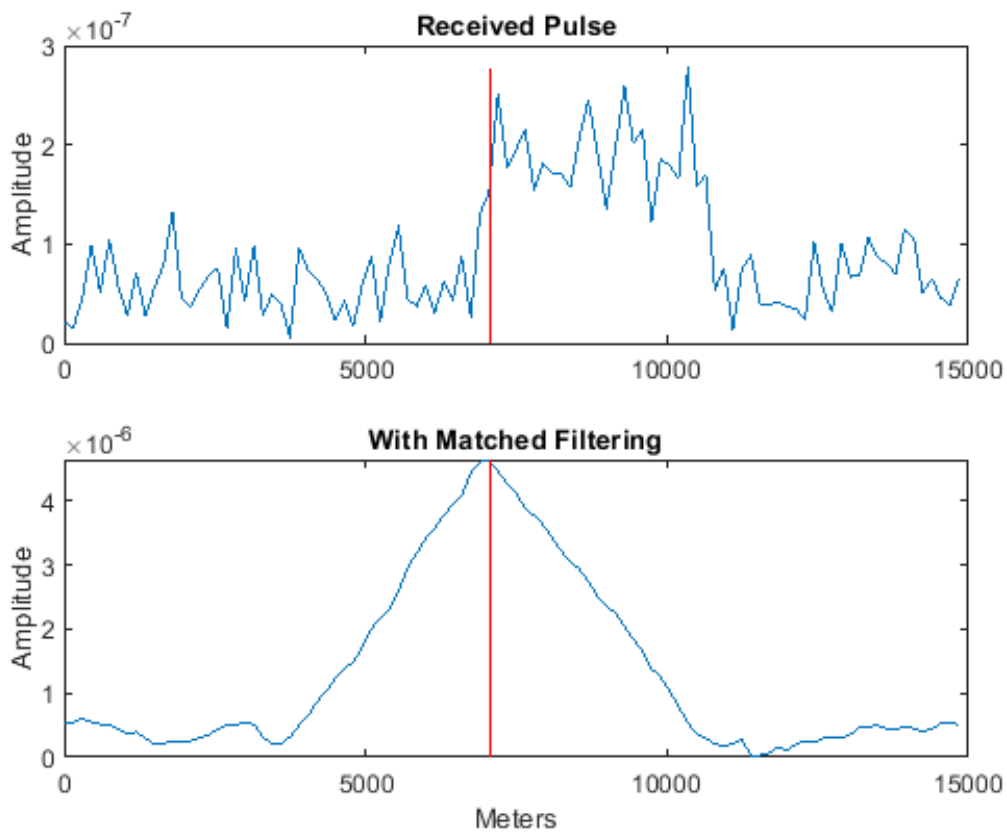
antenna = phased.IsotropicAntennaElement('FrequencyRange',[5e9 15e9]);
transmitter = phased.Transmitter('Gain',20,'InUseOutputPort',true);
fc = 10e9;
target = phased.RadarTarget('Model','Nonfluctuating',...
    'MeanRCS',1,'OperatingFrequency',fc);
txloc = [0;0;0];
tgtloc = [5000;5000;10];
transmitterplatform = phased.Platform('InitialPosition',txloc);
targetplatform = phased.Platform('InitialPosition',tgtloc);
[tgtrng,tgtang] = rangeangle(targetplatform.InitialPosition,...
    transmitterplatform.InitialPosition);
waveform = phased.RectangularWaveform('PulseWidth',25e-6,...
    'OutputFormat','Pulses','PRF',10e3,'NumPulses',1);
c = physconst('LightSpeed');
maxrange = c/(2*waveform.PRF);
SNR = npwgnthresh(1e-6,1,'noncoherent');
Pt = radareqpow(c/fc,maxrange,SNR,...
    waveform.PulseWidth,'RCS',target.MeanRCS,'Gain',transmitter.Gain);
transmitter.PeakPower = Pt;
radiator = phased.Radiator('PropagationSpeed',c,...
    'OperatingFrequency',fc,'Sensor',antenna);
channel = phased.FreeSpace('PropagationSpeed',c,...
    'OperatingFrequency',fc,'TwoWayPropagation',false);
collector = phased.Collector('PropagationSpeed',c,...
    'OperatingFrequency',fc,'Sensor',antenna);

```

```

receiver = phased.ReceiverPreampl('NoiseFigure',0,...
    'EnableInputPort',true,'SeedSource','Property','Seed',2e3);
filter = phased.MatchedFilter(...
    'Coefficients',getMatchedFilter(waveform),...
    'GainOutputPort',true);
wf = waveform();
[wf,txstatus] = transmitter(wf);
wf = radiator(wf,tgtang);
wf = channel(wf,txloc,tgtloc,[0;0;0],[0;0;0]);
wf = target(wf);
wf = channel(wf,tgtloc,txloc,[0;0;0],[0;0;0]);
wf = collector(wf,tgtang);Receive target echo.
rx_puls = receiver(wf,~txstatus);
[mf_puls,mfgain] = filter(rx_puls);
Gd = length(filter.Coefficients)-1;
mf_puls=[mf_puls(Gd+1:end); mf_puls(1:Gd)];
subplot(2,1,1)
t = unigrid(0,1e-6,1e-4,['']);
rangegates = c.*t;
rangegates = rangegates/2;
plot(rangegates,abs(rx_puls))
title('Received Pulse')
ylabel('Amplitude')
hold on
plot([tgtrng, tgtrng], [0 max(abs(rx_puls))], 'r')
subplot(2,1,2)
plot(rangegates,abs(mf_puls))
title('With Matched Filtering')
xlabel('Meters')
ylabel('Amplitude')
hold on
plot([tgtrng, tgtrng], [0 max(abs(mf_puls))], 'r')
hold off

```



RESULT

The Pulse shaping and Matched filtering are analyzed using MATLAB.

EXP. NO: 8 SIMULATION OF OFDM SIGNAL TRANSMISSION AND RECEPTION

DATE:

AIM:

To simulate the OFDM signal transmission and reception.

TOOLS REQUIRED:

- PC
- MATLAB

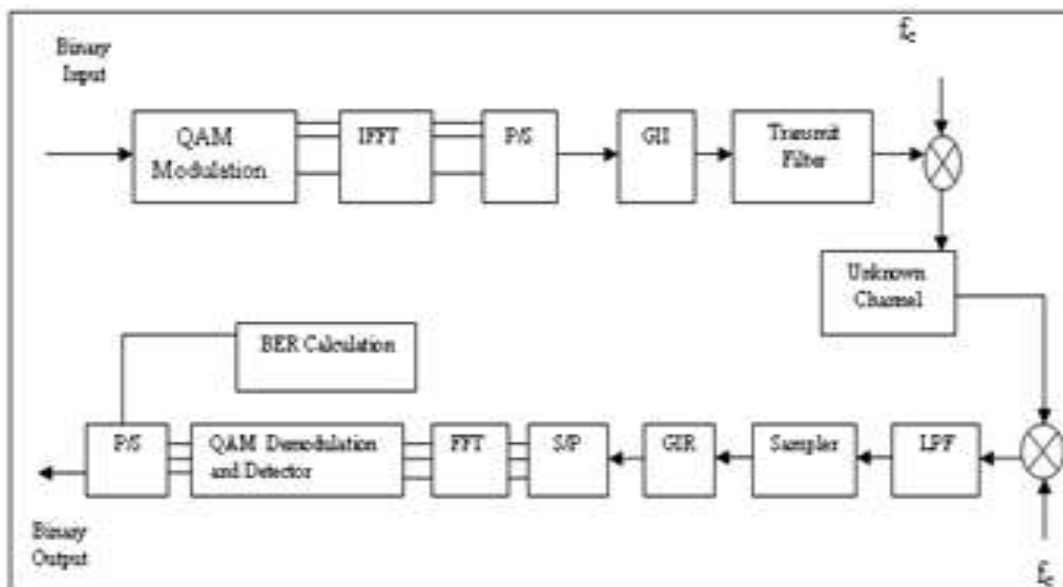
THEORY

OFDM is a form of multicarrier modulation. An OFDM signal consists of a number of closely spaced modulated carriers. When modulation of any form - voice, data, etc. is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to successfully demodulate the data. As a result when signals are transmitted close to one another they must be spaced so that the receiver can separate them using a filter and there must be a guard band between them. This is not the case with OFDM. Although the sidebands from each carrier overlap, they can still be received without the interference that might be expected because they are orthogonal to each other. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period.

The OFDM scheme differs from traditional FDM in the following interrelated ways:

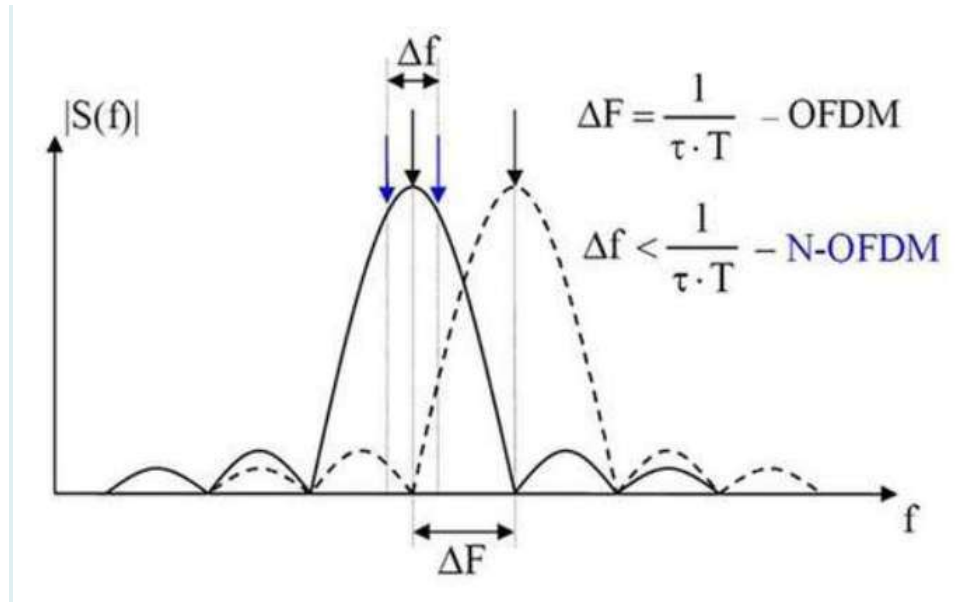
- Multiple carriers (called subcarriers) carry the information stream
- The subcarriers are orthogonal to each other.
- A guard interval is added to each symbol to minimize the channel delay spread and intersymbol interference.

BLOCK DIAGRAM



%code for OFDM signal transmission and reception in AWGN channel

```
n = 256; % Number of bits to process
x = randint(n,1); % Random binary data stream
M = 16; % Size of signal constellation
k = log2(M); % Number of bits per symbol
xsym = bi2de(reshape(x,k,length(x)/k).', 'left-msb');
% Convert the bits in x into k-bit symbols.
y = modulate(modem.qammod(M),xsym); % Modulate using QAM
tu=3.2e-6;%useful symbol period
tg=0.8e-6;%guard interval length
ts=tu+tg;%total symbol duration
nmin=0;
nmax=64;%total number of subcarriers
scb=312.5e3;%sub carrier spacing
fc=3.6e9;%carrier frequency
Rs=fc;
tt=0: 6.2500e-008:ts-6.2500e-008;
c=ifft(y,nmax);%IFFT
s=real(c'.*(exp(1j*2*pi*fc*tt)));%bandpass modulation
figure;
plot(real(s),'b');
title('OFDM signal transmitted');figure;
plot(10*log10(abs(fft(s,nmax))));title('OFDM spectrum');
xlabel(' frequency')
ylabel('power spectral density')
title('Transmit spectrum OFDM');
snr=10;%signal to noise ratio
ynois = awgn(s,snr,'measured');%awgn channel figure;
plot(real(ynois),'b');title('received OFDM signal with noise');
z=ynois.*exp(j*2*pi*fc*tt);%Bandpass demodulation
z=fft(z,nmax);%FFT
zsym=demodulate(modem.qamdemod(M),z);%demodulation of bandpass data.
z = de2bi(zsym,'left-msb'); %Convert integers to bits.
z = reshape(z.',prod(size(z)),1);%matrix to vector conversion
[noe,ber] = biterr(x,z) ;%BER calculation figure;
subplot(211);stem(x(1:256));
title('Original Message');
subplot(212);stem(z(1:256));
title('recovered Message');
```

RESULT:

The simulation of OFDM Signal was verified.

EXP. NO: 9A

VSWR MEASUREMENT

DATE:

AIM:

To determine the standing-wave ratio and reflection coefficient.

EQUIPMENTS REQUIRED:

1. Klystron tube (2k25)
2. Klystron power supply (skps - 610)
3. VSWR meter (SW 115)
4. Klystron mount (XM – 251)
5. Isolator (XF 621)
6. Frequency meter (XF 710)
7. Variable attenuator (XA – 520)
8. Slotted line (X 565)
9. Wave guide stand (XU 535)
10. Movable short/termination XL 400
11. BNC CableS-S Tuner (XT – 441)

THEORY:

Any mismatched load leads to reflected waves resulting in standing waves along the length of the line. The ratio of maximum to minimum voltage gives the VSWR. Hence minimum value of S is unity. If $S < 10$ then VSWR is called low VSWR. If $S > 10$ then VSWR is called high VSWR. The VSWR values more than 10 are very easily measured with this setup. It can be read off directly on the VSWR meter calibrated. The measurement involves simply adjusting the attenuator to give an adequate reading on the meter which is a D.C. mill volt meter. The probe on the slotted wave guide is moved to get maximum reading on the meter. The attenuation is now adjusted to get full scale reading. Next the probe on the slotted line is adjusted to get minimum, reading on the meter. The ratio of first reading to the second gives the VSWR. The meter itself can be calibrated in terms of VSWR. Double minimum method is used to measure VSWR greater than 10. In this method, the probe is inserted to a depth where the minimum can be read without difficulty. The probe is then moved to a point where the power is twice the minimum.

BLOCK DIAGRAM

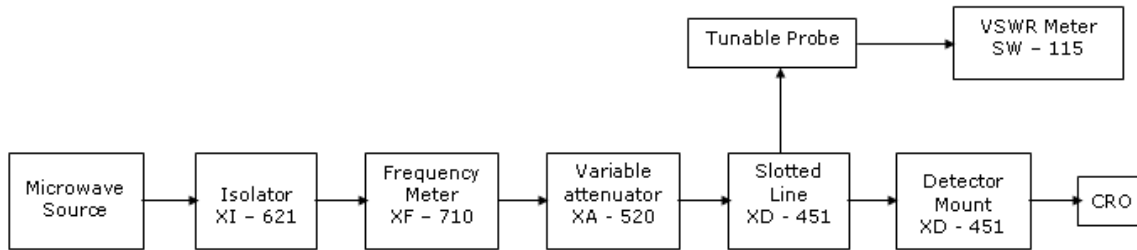


FIG: SET UP FOR LOW VSWR MEASUREMENT

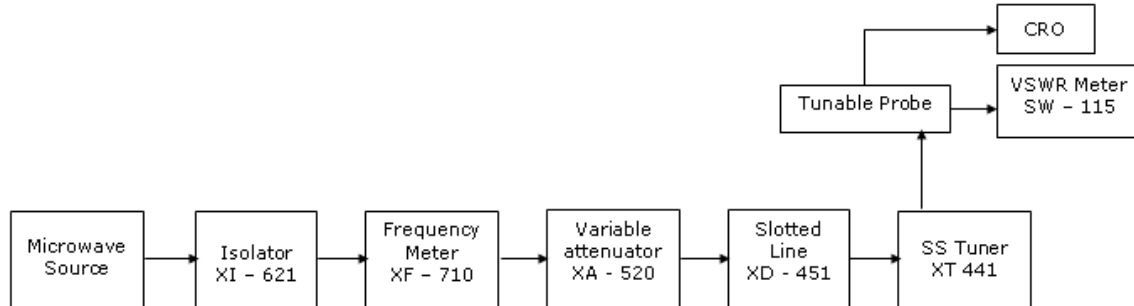


FIG: SET UP FOR HIGH VSWR MEASUREMENT

PROCEDURE:

1. Set up equipment as shown in figure.
2. Keep variable attenuator in minimum attenuation position.
3. Keep control knobs of VSWR meter as below
Range dB = 40db / 50db Input
switch = low impedance Meter
switch = Normal
Gain (coarse fine) = Mid position approximately
4. Keep control knobs of klystron power supply as below. Beam
Voltage = OFF
Mod-Switch = AM
Beam Voltage Knob = fully anti clock wise Reflection
voltage knob = fully clock wise
AM-Amplitude knob = around fully clock wise AM
frequency and amplitude knob = mid position
5. Switch 'ON' the klystron power supply, VSWR meter and cooling fan.
6. Switch 'ON' the beam voltage switch position and set (down) beam voltage at 300V.
7. Rotate the reflector voltage knob to get deflection in VSWR meter.
8. Tune the O/P by turning the reflector voltage, amplitude and frequency of AM modulation.
9. Tune plunges of klystron mount and probe for maximum deflection in VSWR meter.
10. If required, change the range db-switch variable attenuator position and (given) gain control knob to

get deflection in the scale of VSWR meter.

11. As you move probe along the slotted line, the deflection will change.

A. Measurement of low and medium VSWR:

1. Move the probe along the slotted line to get maximum deflection in VSWR meter.
2. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates 1.0 on normal VSWR scale.
3. Keep all the control knob as it is move the probe to next minimum position. Read the VSWR on scale.
4. Repeat the above step for change of S-S tuner probe depth and record the corresponding SWR.
5. If the VSWR is between 3.2 and 10, change the range 0dB switch to next higher position and read the VSWR on second VSWR scale of 3 to 10.

B. Measurement of High VSWR: (double minimum method)

1. Set the depth of S-S tuner slightly more for maximum VSWR.
2. Move the probe along with slotted line until a minimum is indicated.
3. Adjust the VSWR meter gain control knob and variable attenuator to obtain a reading of 3db in the normal dB scale (0 to 10db) of VSWR meter.
4. Move the probe to the left on slotted line until full scale deflection is obtained on 0-10 db scale. Note and record the probe position on slotted line. Let it be d1.
5. Repeat the step 3 and then move the probe right along the slotted line until full scale deflection is obtained on 0-10db normal db scale. Let it be d2.
6. Replace S-S tuner and termination by movable short.
7. Measure distance between 2 successive minima positions of probe. Twice this distance is guide wave length λ_g .
8. Compute SWR from following equation

$$SWR = \frac{\lambda_g}{\pi (d1 - d2)}$$

OBSERVATION TABLE:

LOW VSWR

VSWR = _____

HIGH VSWR

Beam Voltage (v)	x ₁ (cm)	x ₂ (cm)	x ₁ (cm)	x ₂ (cm)	Avg (x ₁ -x ₂) = x (cm)	λ _g =2x (cm)

$$\lambda_g = 6\text{cm}$$

d1 (cm)	d2 (cm)	d1-d2 (cm)	VSWR = $\lambda_g / \pi(d1-d2)$

RESULT: .

Thus the VSWR meter has been used to measure standing wave ratio.

EXP. NO: 9B

IMPEDANCE MEASUREMENT

DATE:

AIM

To measure an unknown impedance using the Reflex klystron.

EQUIPMENT REQUIRED:

1. Klystron tube 2k25
2. Klystron power supply Skps-610
3. Klystron mount XM-251
4. Isolator XF 62
5. Frequency meter XF 710
6. Variable attenuator XA – 520
7. Slotted line XS 565
8. Tunable probe XP 655
9. VSWR meter
10. Wave guide stand SU 535
11. S-S tuner (XT 441)
12. Movable short/termination

THEORY

The impedance at any point on a transmission line can be written in the form $R+jx$. For comparison SWR can be calculated as

$$S = \frac{1 + |R|}{1 - |R|} \quad \text{where reflection coefficient 'R'}$$

Given as

$$R = \frac{Z - Z_0}{Z + Z_0}$$

Z_0 = characteristics impedance of wave guide at operating frequency. Z is the load impedance

The measurement is performed in the following way.

The unknown device is connected to the slotted line and the position of one minima is determined. The unknown device is replaced by movable short to the slotted line. Two successive minima positions are noted. The twice of the difference between minima position will be guide wave length. One of the minima is used as reference for impedance measurement. Find the difference of reference minima and minima position obtained from unknown load. Let it be 'd'. Take a smith chart, taking '1' as centre, draw a circle of radius equal to S. Mark a point on circumference of smith chart towards load side at a distance equal to d/λ_g .

Join the center with this point. Find the point where it cut the drawn circle. The co-ordinates of this point will show the normalized impedance of load.

PROCEDURE:

1. Calculate a set of V_{min} values for short or movable short as load.
2. Calculate a set of V_{min} values for S-S Tuner + Matched termination as a load.

Note: Move more steps on S-S Tuner

3. From the above 2 steps calculate $d = d_1 - d_2$
4. With the same setup as in step 2 but with few numbers of turns (2 or 3). Calculate low VSWR.

Note: High VSWR can also be calculated but it results in a complex procedure.

5. Draw a VSWR circle on a smith chart.
6. Draw a line from center of circle to impedance value (d/λ_g) from which calculate admittance and Reactance ($Z = R + jX$)

BLOCK DIAGRAM

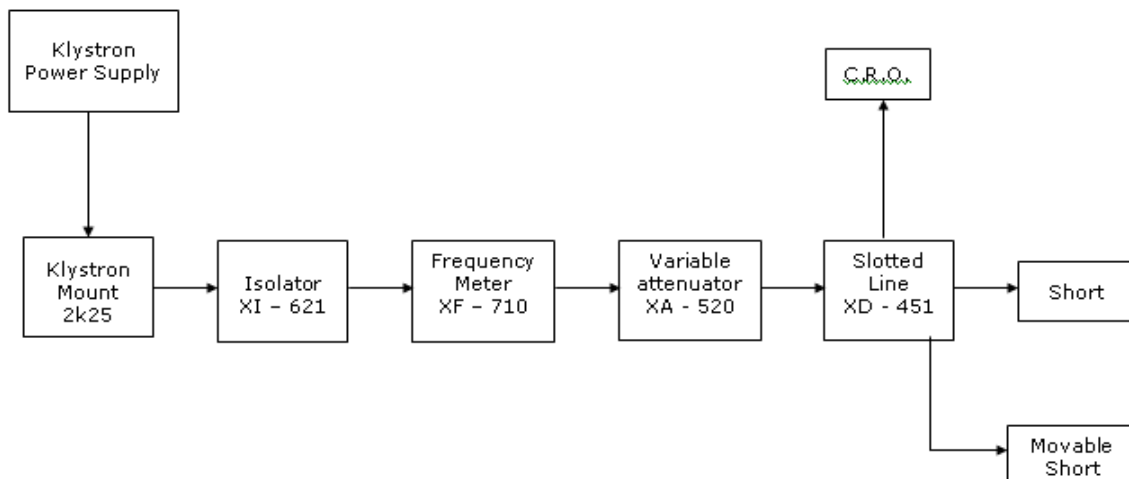


FIG: SET UP FOR IMPEDANCE MEASUREMENT

OBSERVATION TABLE:

Load (short or movable short)					
X ₁ (cm)	X ₂ (cm)	X ₁ (cm)	X ₂ (cm)	X ₁ (cm)	X ₂ (cm)

x = _____ λ_g =

Load (S.S. Tuner + Matched Termination)

S.S Tuner + Matched Termination	Short or Movable Short

d₁= , d₂ =
d = d₁ ~ d₂ =Z =
d/λ_g =

RESULT

Thus the unknown impedance has been measured by using Reflex klystron.

EXP.NO:10A

DIRECTIONAL COUPLER CHARACTERISTICS

DATE:

AIM:

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

1. The Coupling factor, Insertion Loss and Directivity of the Directional coupler

EQUIPMENT REQUIRED:

1. Microwave Source (Klystron or Gunn-Diode)
2. Isolator, Frequency Meter
3. Variable Attenuator
4. Slotted Line
5. Tunable Probe
6. Detector Mount Matched Termination
7. MHD Coupler
8. Waveguide Stand
9. Cables and Accessories
10. CRO.

THEORY:

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

The coupling factor is defined as

Coupling (db) = $10 \log_{10} [P1/P3]$ where port 2 is terminated, Isolation (dB) = $10 \log_{10} [P2/P3]$ where P1 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) = I-C = $10 \log_{10} [P2/P1]$

Main line VSWR is SWR measured, looking into the main-line input terminal when the matched loads are placed at all other ports.

Auxiliary line VSWR is SWR measured in the auxiliary line looking into the output terminal when the matched loads are placed on other terminals.

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

$$\text{Insertion Loss (dB)} = 10 \log_{10} [P1/P2]$$

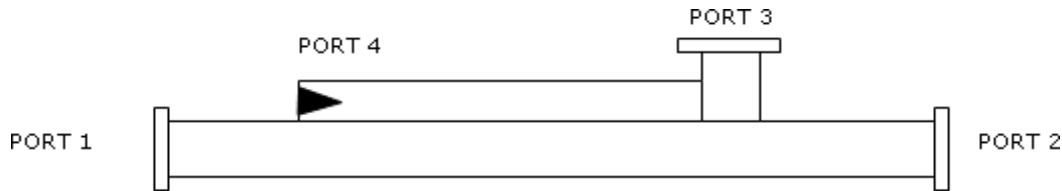


FIG. DIRECTIONAL COUPLER

BLOCKDIAGRAM:

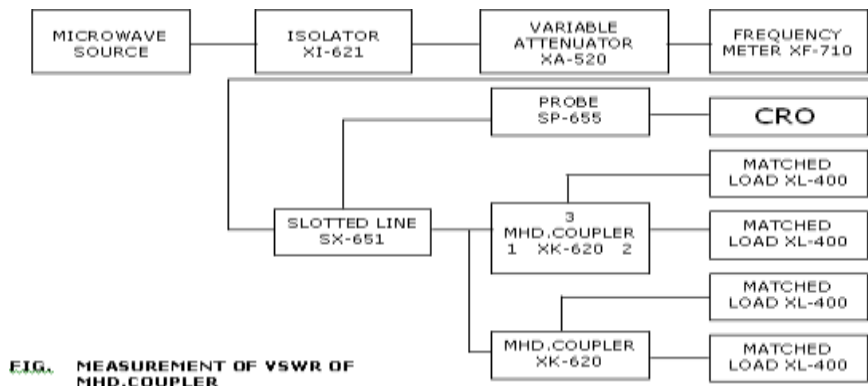


FIG. MEASUREMENT OF VSWR OF MHD, COUPLER

EXPERIMENTAL PROCEDURE:

1. Set up the equipments as shown in the Figure.
2. Energize the microwave source for particular operation of frequency .
3. Remove the multi hole directional coupler and connect the detector mount to the slotted section.
4. Set maximum amplitude in CRO with the help of variable attenuator, Let it be X.
5. Insert the directional coupler between the slotted line and detector mount. Keeping port 1 to slotted line, detector mount to the auxiliary port 3 and matched termination to port 2 without changing the position of variable attenuator.
6. Note down the amplitude using CRO, Let it be Y.
7. Calculate the Coupling factor X-Y in dB.
8. Now carefully disconnect the detector mount from the auxiliary port 3 and matched termination from port 2 , without disturbing the setup.
9. Connect the matched termination to the auxiliary port 3 and detector mount to port 2 and measure

the amplitude on CRO, Let it be Z.

10. Compute Insertion Loss= $X - Z$ in dB.

11. Repeat the steps from 1 to 4.

12. Connect the directional coupler in the reverse direction i.e., port 2 to slotted section, matched termination to port 1 and detector mount to port 3, without disturbing the position of the variable attenuator.

13. Measure and note down the amplitude using CRO, Let it be Y_0 .

Compute the Directivity as $Y - Y_0$ in dB.

RESULT:

Thus the Characteristics of Directional coupler were measured.

EXP.NO:10B SCATTERING PARAMETERS OF CIRCULATOR

DATE:

AIM:

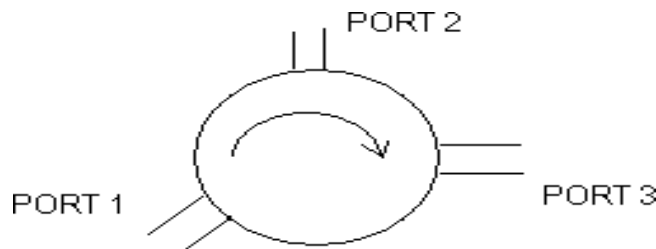
To study the Isolator and circulators and measure the Insertion Loss and Isolation of Circulator.

EQUIPMENT REQUIRED:

1. Microwave Source (Klystron or Gunn-Diode)
2. Isolator, Frequency Meter
3. Variable Attenuator
4. Slotted Line
5. Tunable Probe
6. Detector Mount Matched Termination
7. Circulator
8. Waveguide Stand
9. Cables and Accessories
10. VSWR Meter.

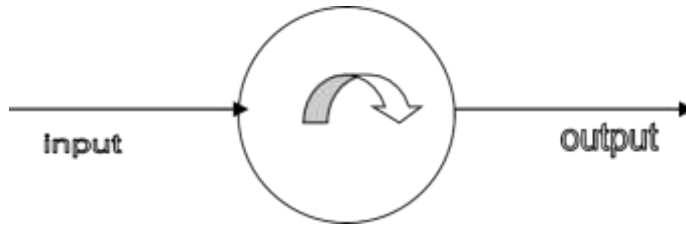
CIRCULATOR:

Circulator is defined as device with ports arranged such that energy entering a port is coupled to an adjacent port but not coupled to the other ports. This is depicted in figure circulator can have any number of ports.



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, shown in Fig. can be derived from a three-port circulator by simply placing a matched load (reflection less termination) on one port.

The important circulator and isolator parameters are:

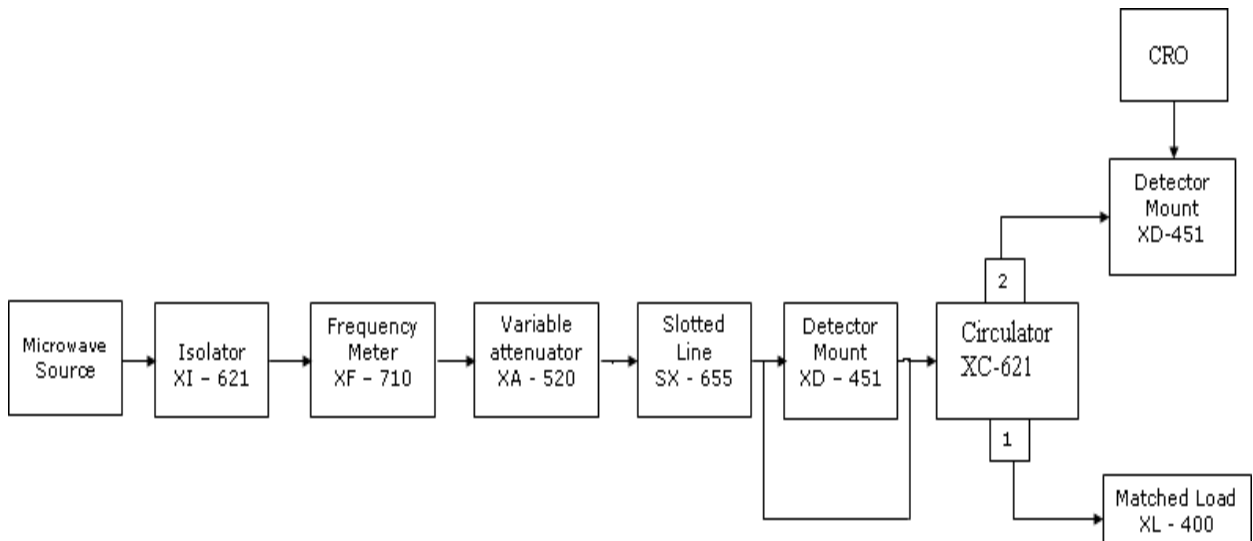
A. Insertion Loss

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.

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.

BLOCK DIAGRAM:



EXPERIMENTAL PROCEDURE:

Measurement of insertion

1. Remove the isolator or circulator from slotted line and connect the detector mount to the slotted section. The output of the detector mount should be connected with CRO.
2. Energize the microwave source for maximum output for a particular frequency of operation. Tune the detector mount for maximum output in the CRO.
3. Set any reference level of output in CRO with the help of variable attenuator, Let it be V_1 .
4. Carefully remove the detector mount from slotted line without disturbing the position of the set up. Insert the isolator/circulator between slotted line and detector mount. Keep input port to slotted line and detector its output port. A matched termination should be placed at third port in case of Circulator.
5. Record the output in CRO, Let it be V_2 .
6. Compute Insertion loss given as $V_1 - V_2$ in db.

Measurement of Isolation:

7. For measurement of isolation, the isolator or circulator has to be connected in reverse i.e. output port to slotted line and detector to input port with other port terminated by matched termination (for circulator).
8. Record the output of CRO and let it be V_3 .
9. Compute Isolation as $V_1 - V_3$ in db.
10. The same experiment can be done for other ports of circulator.
11. Repeat the above experiment for other frequency if needed.

RESULT:

Thus the Characteristics of Circulator and Isolator were measured.

EXP.NO:11

GUNN DIODE CHARACTERISTICS

DATE:

AIM:

To measure the V-I characteristics of Gunn diode.

EQUIPMENT REQUIRED:

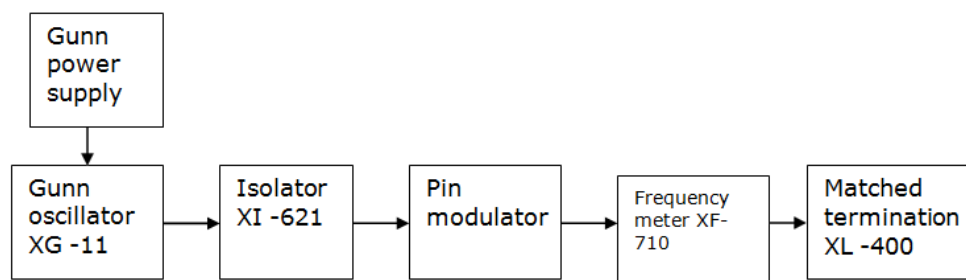
1. Gunn power supply
2. Gunn oscillator
3. PIN Modulator
4. Isolator
5. Frequency Meter
6. Variable attenuator
7. Slotted line
8. Detector mount and CRO.

THEORY:

Gunn diode oscillator normally consist of a resonant cavity, an arrangement for coupling diode to the cavity a circuit for biasing the diode and a mechanism to couple the RF power from cavity to external circuit load. A co-axial cavity or a rectangular wave guide cavity is commonly used.

The circuit using co-axial cavity has the Gunn diode at one end at one end of cavity along with the central conductor of the co-axial line. The O/P is taken using a inductively or capacitive coupled probe. The length of the cavity determines the frequency of oscillation. The location of the coupling loop or probe within the resonator determines the load impedance presented to the Gunn diode. Heat sink conducts away the heat due to power dissipation of the device.

BLOCK DIAGRAM

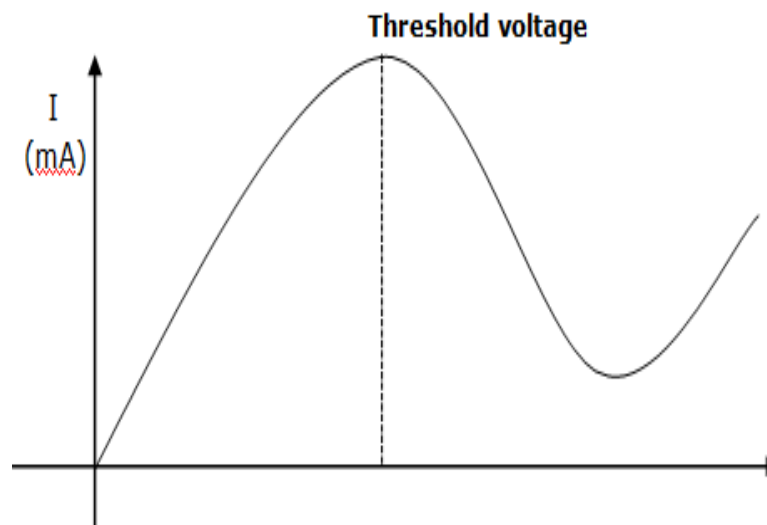


EXPERIMENTAL PROCEDURE:

Voltage-Current Characteristics:

1. Set the components and equipments as shown in Figure.
2. Initially set the variable attenuator for minimum attenuation.
3. Keep the control knobs of Gunn power supply as below
Meter switch – “OFF”
Gunn bias knob – Fully anti clock wise PIN
bias knob – Fully anti clock wise PIN mode
frequency – any position
4. Set the micrometer of Gunn oscillator for required frequency of operation.
5. Switch “ON” the Gunn power supply.
6. Measure the Gunn diode current to corresponding to the various Gunn bias voltage through the digital panel meter and meter switch. Do not exceed the bias voltage above 10 volts.
7. Plot the voltage and current readings on the graph.
8. Measure the threshold voltage which corresponding to max current.

MODEL GRAPH



OBSERVATION TABLE

Gunn bias voltage (v)	Gunn diode current (mA)

RESULT

Thus the V-I Characteristics of Gunn diode has been measured.