BACHELOR DEGREE
IN
ELECTRONICS AND COMMUNICATION

SUB. CODE: EC8761

SUB. NAME: ADVANCED COMMUNICATIONS LAB

MANUAL

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LIST OF EXPERIMENTS	
Sl.No.	**Name of Experiment**
	Optical Experiment
1	DC characteristics of LED and PIN Photo Diode.
2	Mode Characteristics of Fibers
3	Measurement of Connector and Bending Losses.
4	Fiber Optic Analog and Digital Link
5	Numerical Aperture Determination for Fibers
6	Attenuation Measurement in Fibers
	Microwave Experiments
1	Reflex Klystron – Mode characteristics
2	Gunn Diode – Characteristics
3	VSWR, Frequency and Wave Length Measurement
4	Directional Coupler – Directivity and Coupling Coefficient – S – parameter measurement
5	Isolator and Circulator – S - parameter measurement
6	Attenuation and Power measurement
7	S - matrix Characterization of E-Plane T, H-Plane T and Magic T.
8	Radiation Pattern of Antennas.
9	Antenna Gain Measuremen
	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

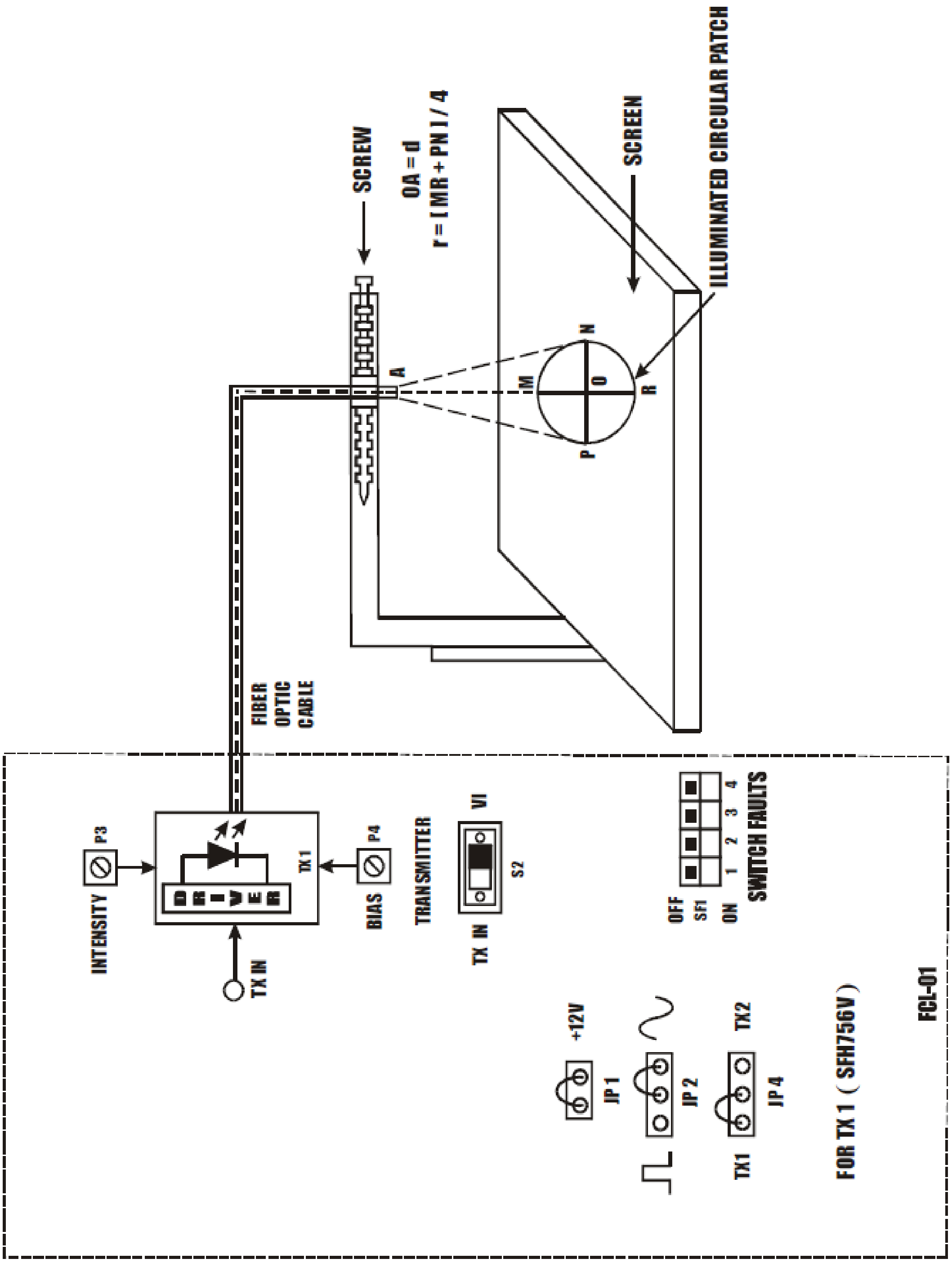


FIG. 5.1 BLOCK DIAGRAM FOR NUMERICAL APERTURE MEASUREMENT

Ex No.1 MEASUREMENT OF NUMERICAL APERTURE OF OPTICAL FIBER

AIM:

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

OBJECTIVES :

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

EITC (Equipment’s, Instruments, Tools, Consumables) REQUIRED

1.FCL-01
2.1-meter fiber cable
3.NA JIG (Precision Jig No.1)
4.Ruler
5.Power Supply (Use only one provided)

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.

PROCEDURE :

1. Make connections as shown in fig 1. Connect the power supply cables with proper polarity to FCL-01 Kit. While connecting this, ensure that the power supply is OFF.

2. Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector.

3. Once the cap is loosened, insert the fiber into the cap. Now tighten the cap by screwing it back.

4. Keep the jumpers JP1, JP2 & JP4 on FCL-01 as shown in fig.1.Keep switches S2 in VI position on FCL-01.

5. Switch on the power supply. 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. Keep the distance of about 10 mm between the fiber tip and the screen.

TABULATION:

Radius (r) cm	Height (d) cm	Numerical Aperture $r/\sqrt{r^2+d^2}$.
0.05	**0.1**	**0.44**

MODEL CALCULATION:

NA =0.05/$\sqrt{0.05^2+0.1^2}$ **=0.44**

6. Gently tighten the screw and thus fix the fiber in the place Observe the bright red light spot on the screen by varying Intensity pot P3 and Bias P4.
7. Measure exactly the distance d and also the vertical and horizontal diameters MR and PN as indicated in the fig. 1.
8. Mean radius is calculated using the following formula r = (MR + PN) / 4
9. Find the numerical aperture of the fiber using the formula.NA=sinθ$_{max}$

   NA=r/ $\sqrt{r^2} + d^2$.

RESULT :

The numerical aperture of the plastic fiber provided with the kit using 660 nm wavelengths LED is measured.

Ex No.2 MEASUREMENT OF LOSSES OF OPTICAL FIBER

AIM:

To measure the losses of optical fiber.

OBJECTIVES :

The objective of this experiment is to measure loss in the fiber.

A. Propagation Loss
B. Bending Loss
C. Connector Loss

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-01 & FCL-02
2.1 & 3 Meter Fiber cable
3.0.5-meter connectorized fibers
4.Patch chords
5.Power Supply (Use only one provided)
6.20 MHz Dual Channel Oscilloscope

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 direction 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 refraction of light. This occurs when fiber is subjected to bending. Lower the radius of curvature more is the loss. Other losses are due to the coupling of fiber at LED & photo detector ends.

When light travels down optical fibers, some of the light is absorbed by the glass or plastic. This means that the light coming out of the end of the fiber is not as strong as the light going into the fiber. While designing a fiber communication system, you need to know this loss, to calculate the maximum distance the signal will travel. In this experiment, you will try one way of measuring the loss in the fiber.

A.MEASUREMENT OF PROPAGATION L

MODEL CALCULATION :

Equation 1.0:

Power = 10 log (P_2 / P_1) dB

= 10 log (8 / 6) dB

= 1.25 dB

P_2 : Reference reading by 1 meter fiber.

P_1 : Reading obtained after replacing 3 meter fiber.

PROCEDURE :

1. Make connections as shown in fig.Connect the power supply cables with proper polarity to FCL-01 & FCL-02 Kits. While connecting this, ensure that the power supply is OFF.
2. Keep the jumpers **JP1**, **JP2**, **JP3** & **JP4** on FCL-01 as shown in fig.
3. Keep the jumpers **JP1** & **JP2** on FCL-02 as shown in fig.
4. Keep switches **S2** in **VI** position on FCL-01.
5. Switch on the power supply.
6. Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 1meter fiber into the cap. Now tighten the cap by screwing it back.
7. Now rotate the Optical Power Control pot **P3** in FCL-01 in anticlockwise direction. This ensures minimum current flow through LED. Slightly unscrew the cap of Photo Diode SFH250V. 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.
8. Keep Switch **SW1** to **SIGNAL STRENGTH** position in FCL-02.
9. Connect the output of Photo Diode detector post **OUT** to post **IN** of Signal Strength Indicator blocks.
10. Observe the signal strength LEDs, adjust the transmitter level using Intensity control pot **P3** until you get the reading of all LED glow.
11. Now remove the 1meter fiber and insert 3meter fiber.

B.MEASUREMENT OF BENDING LOSS

12. Keep the connections with 1-meter fiber as per the above procedure.
13. Adjust the transmitter power so that the Signal Stength reading is 8.
14. Now take the portion of the fiber and loop it to match the bends as shown in fig..
15. If you were designing the fiber optic communications system, you would need to know the relationship between the size of the bend and the light loss from the bend. In order to describe this relationship, you can measure the loss for a number of different bends and plot them on a graph.

C.MEASUREMENT OF CONNECTOR LOSS

16. Keep the connections with 1-meter fiber as per the above procedure.
17. Adjust the transmitter power so that the SIGNAL STENGTH reading is 8.

RESULT :

The losses of the optical fiber were measured.

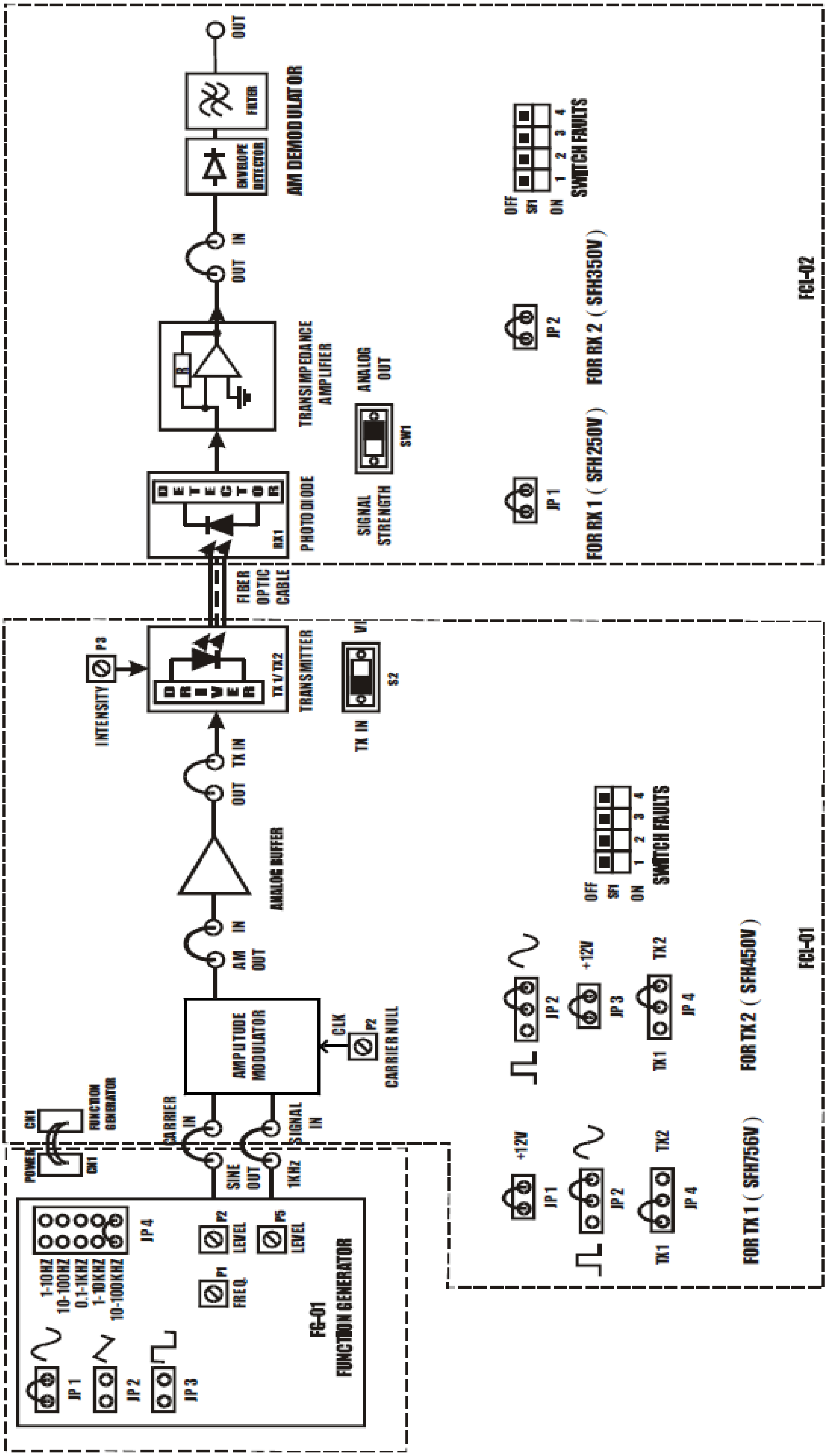


FIG. 11.3 BLOCK DIAGRAM FOR AMPLITUDE MODULATION AND DEMODULATION

Ex No.3 TRANSMISSION OF AMPLITUDE MODULATION

AIM:

To obtain Amplitude Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver.

OBJECTIVE:

The objective of this experiment is to obtain pulse Amplitude Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver end to get back the original signal.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-01 & FCL-02
2.FG-01 with power cable
3.20 MHz Dual Channel Oscilloscope
4.1 meter Fiber cable
5.Patch chords
6.Power supply (Use only one provided)

THEORY:

AMPLITUDE MODULATION:

In Amplitude Modulation the amplitude of high frequency sine wave (carrier) is varied in accordance with the instantaneous value of the modulating signal.

ENVELOPE DETECTOR:

The extraction of the modulating signal from an AM signal can be carried out using an envelope detector. Consider the AM signal shown in Fig., and note that the modulating signal constitutes the envelope of the waveform reported. The most common envelope detector consists of a diode followed by a RC filter. Its operation is analogous to the half-wave rectifier, as the output voltage follows the maximum values of the carrier. As the amplitude of the carrier is variable, by properly choosing R and C, the output of the detector can faithfully reproduce faithfully these variations.

PROCEDURE:

1. Refer to figure and make the following connections.
2. Connect the power supply with proper polarity to FCL-01 and FCL-02. While connecting this, ensure that the power supply if OFF.
3. Connect Function Generator FG-01 to FCL-01 using power cable.
4. Keep the jumpers **JP1** & **JP4** on FG-01 as shown in fig.
5. Keep the jumpers **JP1**, **JP2**, **JP3** & **JP4** on FCL-01 as shown in fig..

Tabulation:

	Amplitude(v)	Time period(ms)
Modulating signal		
Carrier Signal		
Modulated Signal		
Demodulated Signal		

Model Graph

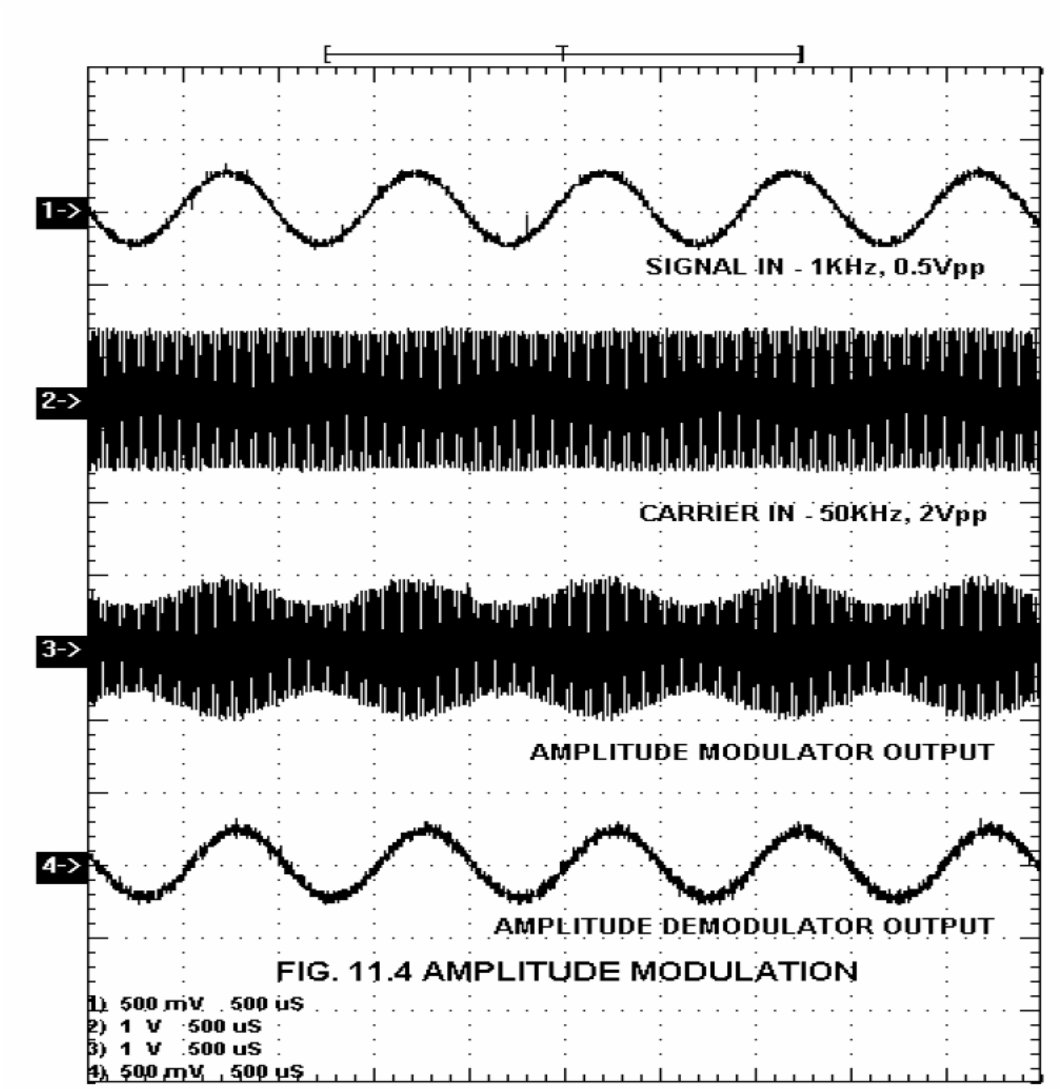


FIG. 11.4 AMPLITUDE MODULATION

6. Keep the jumpers **JP1** & **JP2** on FCL-02 as shown in fig.
7. Keep switches **S2** in **TX IN** position on FCL-01.
8. Switch on the power supply.
9. Connect the **1 KHz, 0.5Vpp** Signal from FG-01 as a constant signal to the **SIGNAL IN** post of Amplitude Modulator section on FCL-01.
10. Keep **SINEOUT** signal of about **50 KHz** with amplitude of **2Vpp**.
11. Connect the post **SINEOUT** of FG-01 to post **CARRIER IN** of Amplitude Modulator section on FCL-01.
12. Connect the output of Amplitude Modulator section post **AM OUT** to post **IN** of Analog Buffer on FCL-01. Keep pot **P2** fully clockwise position.
13. Connect the output of Analog Buffer post **OUT** to post **TX IN**.
14. Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 1-meter fiber into the cap. Now tighten the cap by screwing it back.
15. Slightly unscrew the cap of Photo Diode SFH250V. 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.

RESULT:

The Amplitude Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver end to get back the original signal was studied.

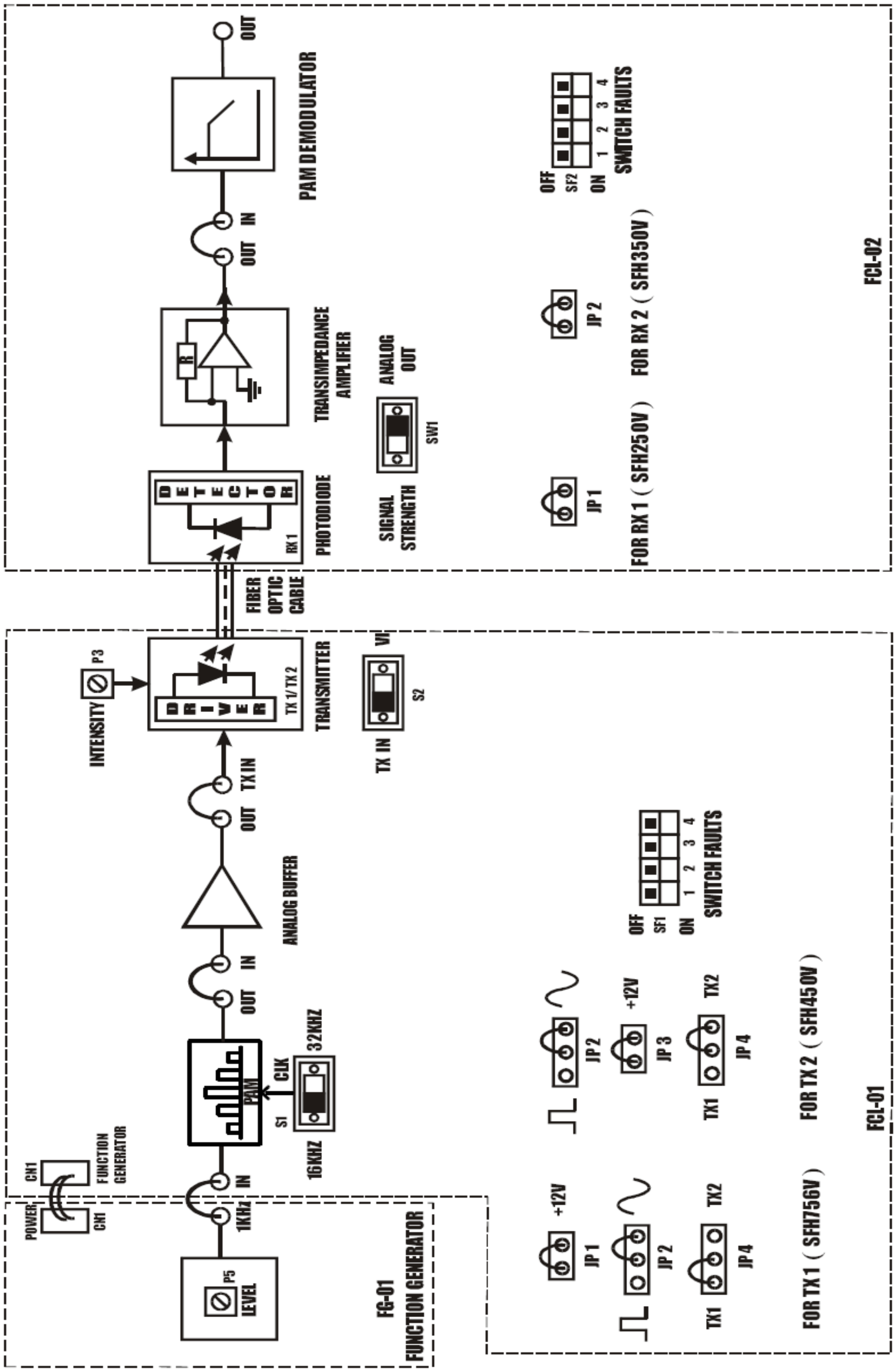


FIG. 9.1 BLOCK DIAGRAM FOR PULSE AMPLITUDE MODULATION

Ex No.4 TRANSMISSION OF PULSE AMPLITUDE MODULATION

AIM:

To obtain pulse Amplitude Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver.

OBJECTIVE:

The objective of this experiment is to obtain pulse Amplitude Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver end to get back the original signal.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-01 & FCL-02
2.FG-01 with power cable
3.20 MHz Dual Channel Oscilloscope
4.1 meter Fiber cable
5.Patch chords
6.Power supply (Use only one provided)

THEORY:

Pulse Amplitude Modulation is a technique of communication in which the high frequency square wave is modulated by the low frequency signal. The modulating signal is sampled by the pulses. The PAM signal is nothing but the high frequency square wave in which the amplitude of each pulse is equal to that of the information signal at the respective sampling instant.
The block diagram clearly indicates the pulse amplitude modulation and demodulation concept.

PROCEDURE:

1. Refer to fig and make the following connections.
2. Connect the power supply with proper polarity to FCL-01 and FCL-02. While connecting this, ensure that the power supply if OFF.
3. Connect Function Generator FG-01 to FCL-01 using power cable.
4. Keep the jumpers **JP1**, **JP2**, **JP3** & **JP4** on FCL-01 as shown in fig.9.1.
5. Keep the jumpers **JP1** & **JP2** on FCL-02 as shown in fig.9.1.
6. Keep switch **S1** at **16KHz** position on FCL-01.
7. Keep switch **S2** in **TX IN** position on FCL-01.
8. Switch on the power supply.
9. Connect the **1KHz, 2Vpp** Signal from FG-01 as a constant signal to the **IN** post of PAM section on FCL-01.
10. Connect the output of PAM section post **OUT** to post **IN** of Analog Buffer on FCL-01.
11. Connect the output of Analog Buffer post **OUT** to post **TX IN**.

Tabulation:

	Amplitude(v)	Time period(ms)
Modulating signal		
Carrier Signal		
Modulated Signal		
Demodulated Signal		

Model Graph

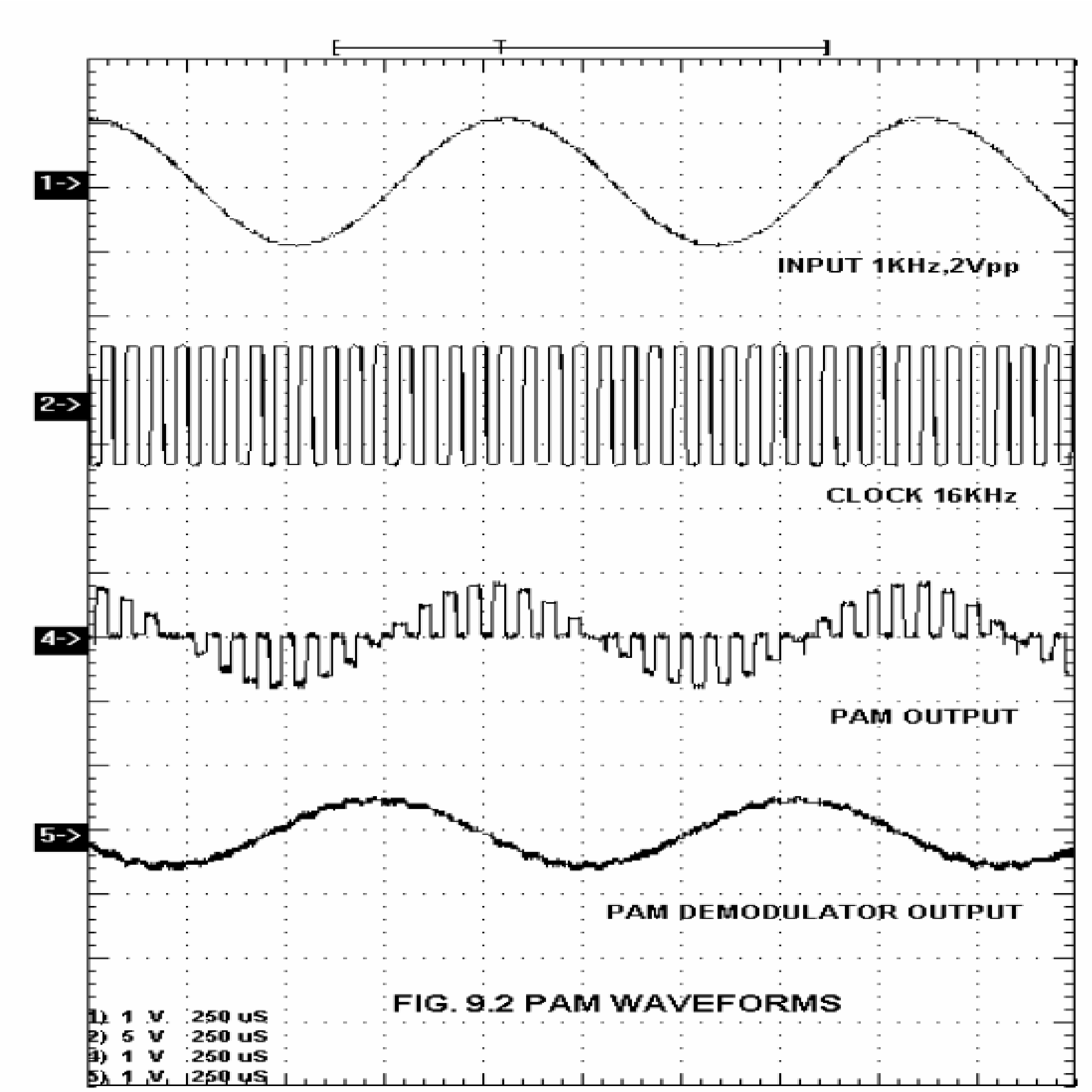
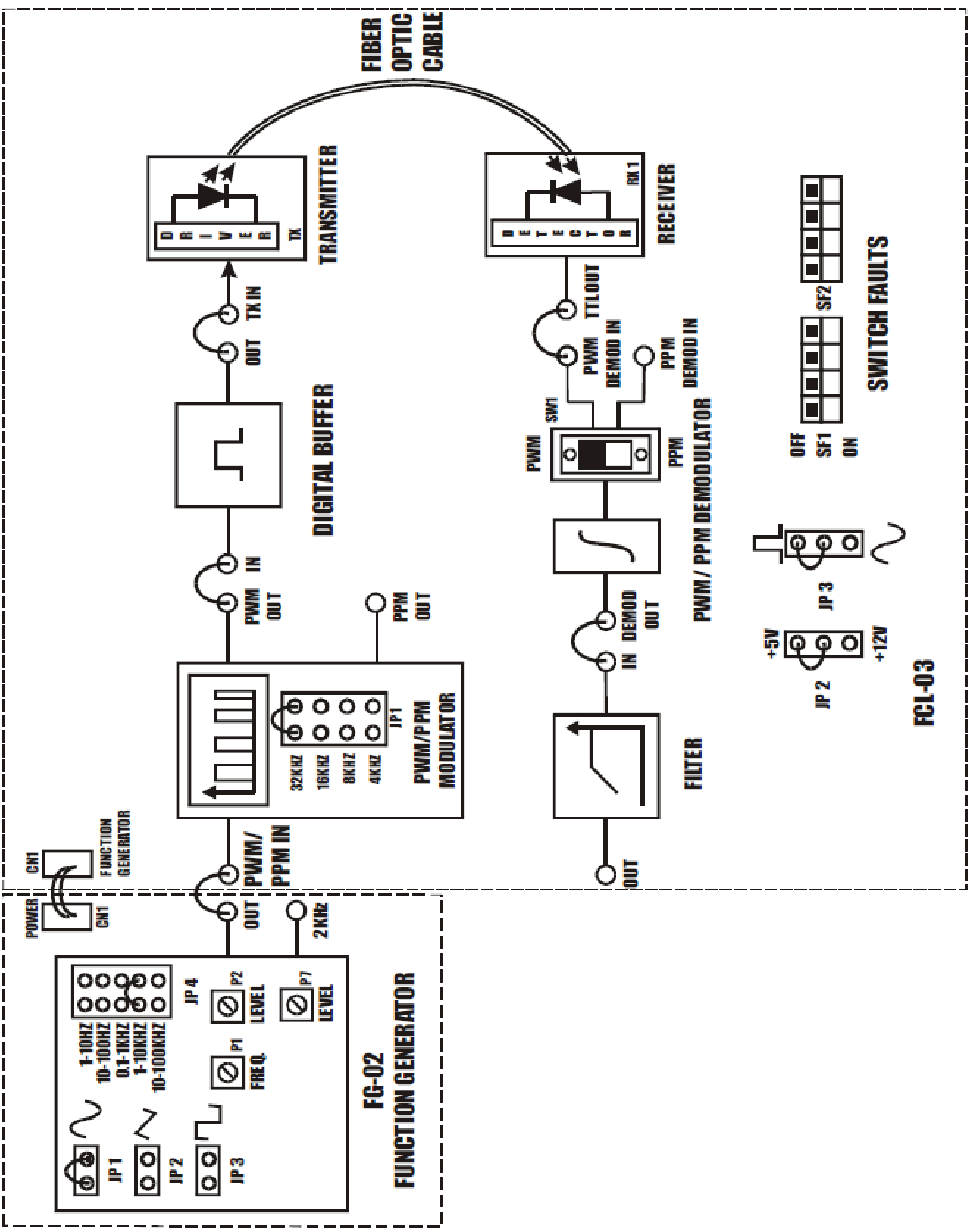


FIG. 9.2 PAM WAVEFORMS

12. Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 1-meter fiber into the cap. Now tighten the cap by screwing it back.
13. Slightly unscrew the cap of Photo Diode SFH250V. 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.
14. Keep switches **SW2** in **ANALOG OUT** position on FCL-02.
15. Connect the output of Photo Diode detector post **OUT** to post **IN** of PAM Demodulator Section.
16. Now observe the waveform at various test points. You will find fantastic pattern of square wave whose amplitude (i.e. Pulse height) is varying according to the sine wave input as shown in fig.
17. Observe the output in FCL-02, you will receiver the same sine wave at the output. In this way, the signal is pulse amplitude modulated, transmitted, received and again demodulated successfully as shown in fig.
18. Observe the effect of sampling rate by changing the sampling clock from 16 KHz to 32 KHz.
19. Observe the effect of varying signal frequency by applying different signals from FG-01 Function Generator or External signals.
20. Perform the above procedure again for all the combinations of Transmitter & Receiver.

RESULT:

The pulse Amplitude Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver end to get back the original signal was studied.


FIBER OPTIC CABLE
TRANSMITTER
DRIVER
TX
RECEIVER
DETECTOR
RX 1
TX IN
OUT
TTL OUT
DIGITAL BUFFER
IN
PWM OUT
PPM OUT
PWM/PPM MODULATOR
JP1
32KHZ
16KHZ
8KHZ
4KHZ
PWM/PPM IN
OUT
2KHz
POWER
CN1
FUNCTION GENERATOR
1-10HZ
10-100HZ
0.1-1KHZ
1-10KHZ
10-100KHZ
JP 4
JP 1
JP 2
JP 3
P1 FREQ.
P2 LEVEL
P7 LEVEL
FG-02
FUNCTION GENERATOR
PWM DEMOD IN
PPM DEMOD IN
SW1
PWM
PPM
PWM/ PPM DEMODULATOR
DEMOD OUT
IN
FILTER
OUT
OFF
SF1
ON
SF2
SWITCH FAULTS
JP 2
+5V
+12V
JP 3
FCL-03

Ex No.5 TRANSMISSION OF PULSE WIDTH MODULATION

AIM:

To obtain pulse width Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver.

OBJECTIVE:

The objective of this experiment is to obtain pulse width Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver end to get back the original signal.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-03
2.FG-02 with power cable
3.20 MHz Dual Channel Oscilloscope
4.1 meter Fiber cable
5.Patch chords
6.Power supply (Use only one provided)

THEORY:

PULSE WIDTH MODULATION:

This technique of modulation controls the variation of duty cycle of the square wave (With some fundamental frequency) according to the input modulating signal. Here the amplitude variation of the modulating signal is reflected in to ON period variation of square wave. Hence, it is also called as technique of V to T conversion.

PULSE WIDTH DEMODULATION:

The input signal is pulse width modulated, so the ON time of the signal is changing according to the modulating signal. In this demodulation technique, the ON time of PWM signal is changing according to the modulating signal. In this demodulation technique, the PWM signal is applied to an Integrator, whose output is then Filtered to obtain original signal. Thus at the output we get the original modulating signal extracted from PWM wave. Fiber optic transmitter (SFH756v) & receiver (SFH551v) are used to transmit and receive PWM signal respectively.

PROCEDURE:

1. Make connections as shown in fig.3.1. Connect the power supply cables with proper polarity to FCL-03 Kit. While connecting this, ensure that the power supply is OFF.
2. Connect Function Generator FG-02 to FCL-03 using power cable.
3. Switch on the power supply.

Tabulation:

	Amplitude(v)	Time period(ms)
Modulating signal		
Carrier Signal		
Modulated Signal		
Demodulated Signal		

Model Graph

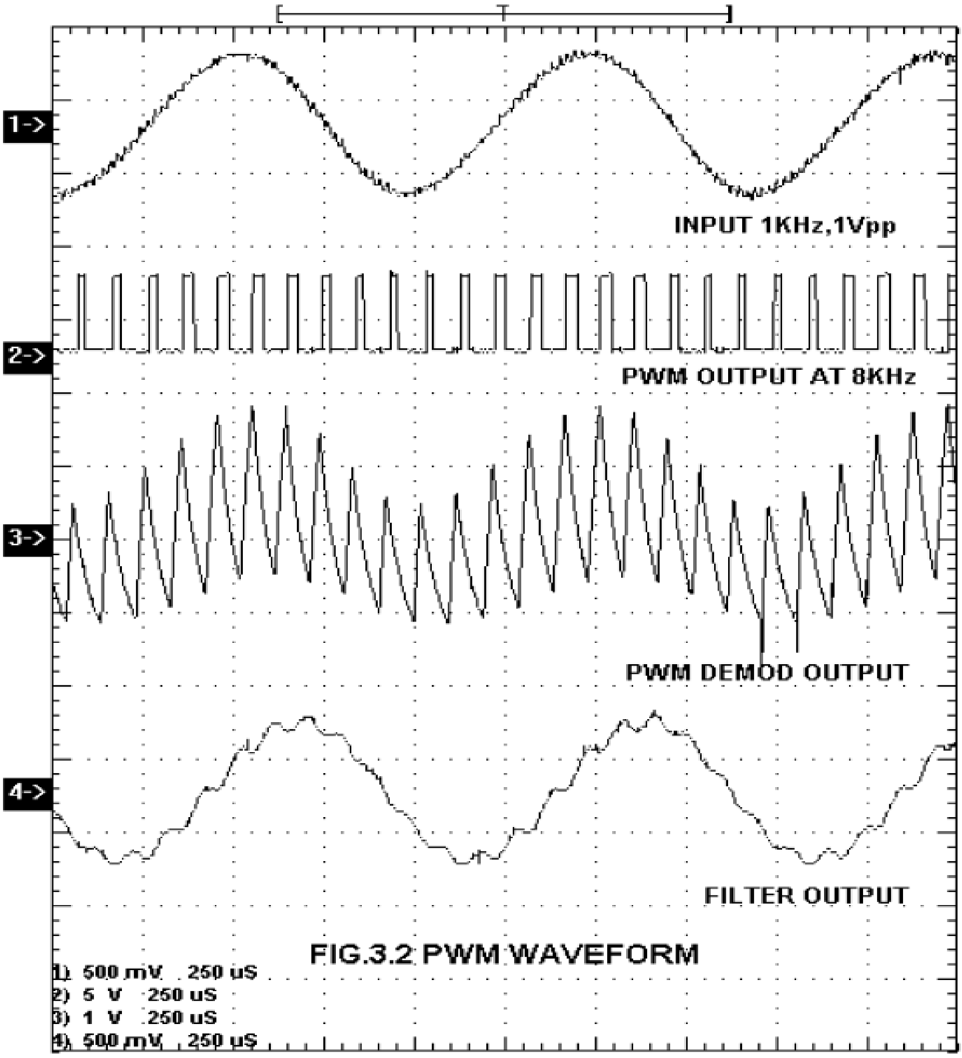
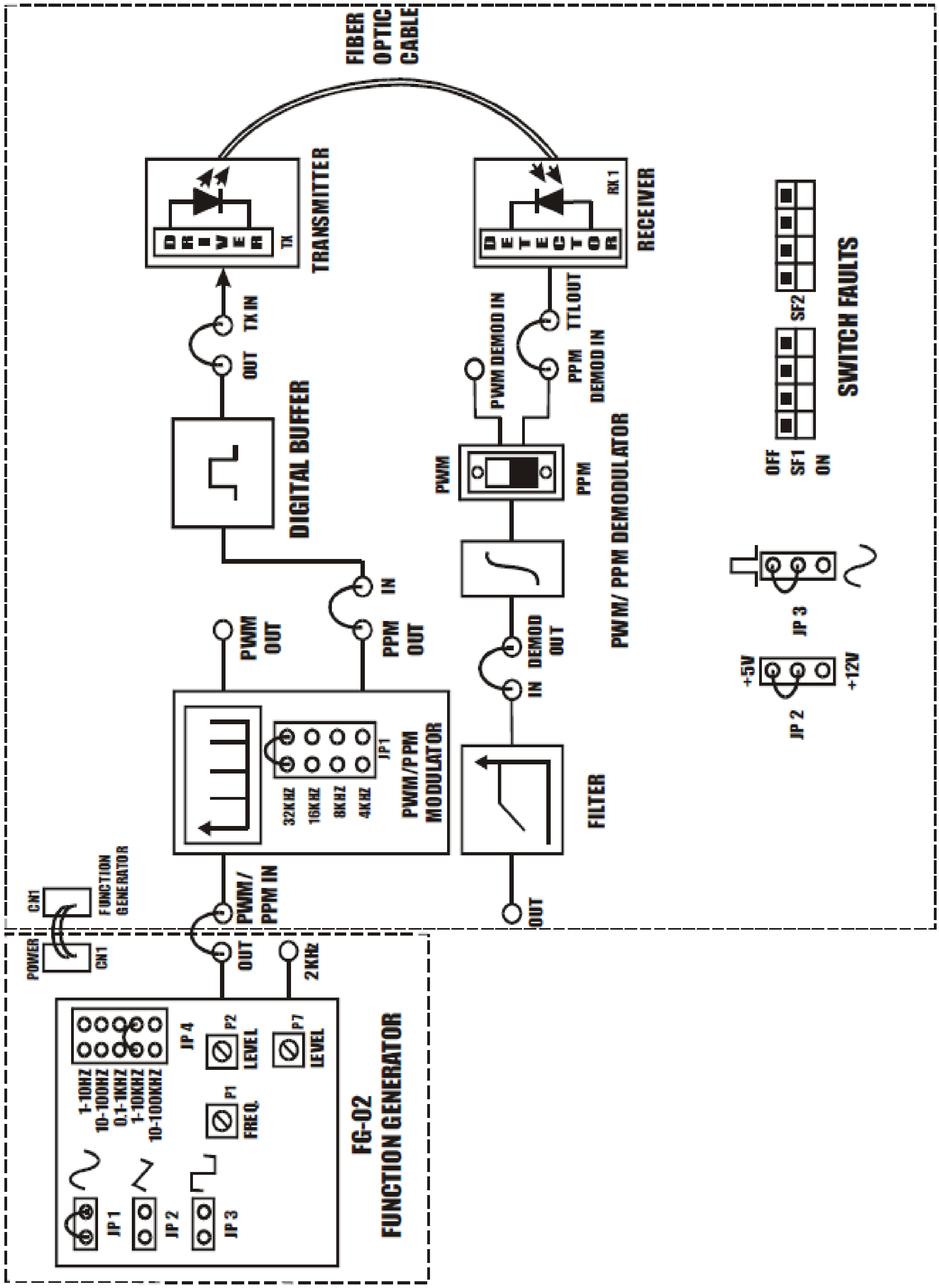


FIG.3.2 PWM WAVEFORM

4. Keep the jumpers **JP1**, **JP2** & **JP3** on FCL-03 as shown in fig.3.1.
5. Keep the function generator **JP1** shorted & **JP2**, **JP3** open.
6. Keep the function generator **JP4** in **1-10 KHz** position.
7. Connect the **OUT** Signal from FG-02 to the **PWM/PPM IN** post of PWM/PPM Modulator on FCL-03 and keep the signal frequency at **1 KHz** & Amplitude at **1Vpp**.
8. Connect the **PWM OUT** Signal from PWM/PPM Modulator to the **IN** post of Digital Buffer on FCL-03.
9. Connect the output of Digital Buffer post **OUT** to post **TX IN**.
10. 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.
11. 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. Now tighten the cap by screwing it back.
12. Connect the output of detector post **TTL OUT** to post **PWM DEMOD IN** of PWM/PPM Demodulator.
13. Keep Switch **SW1** in PWM position.
14. Connect the output of PWM/PPM Demodulator post **DEMOD OUT** to post **IN** of Filter 1.
15. Observe PWM signal at PWM OUT Post. Variation in width of square wave is high because the frequency is high. Due to persistence of vision, only blurt band in the waveform will be observed. If the modulating frequency is kept low around 1-10Hz by keeping FG-02 jumper **JP4** in **1-10Hz** range, we can observe the variation in the width of square wave. If the signal generator is OFF, only square wave of fundamental frequency and fixed ON time will be observed and no width variations are present.
16. Observe the received signal at Filter O/P post **OUT** Demodulated signal represents original signal.

RESULT:

The pulse width Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver end to get back the original signal was studied.



FIBER OPTIC CABLE
DRIVER
TX
TRANSMITTER
DETECTOR
RX 1
RECEIVER
OUT
TX IN
DIGITAL BUFFER
PWM DEMOD IN
TTL OUT
PPM DEMOD IN
PWM
PPM
PWM/ PPM DEMODULATOR
OFF
SF1
ON
SF2
SWITCH FAULTS
JP 3
JP 2
+5V
+12V
PWM OUT
PPM OUT
IN
IN
DEMOD OUT
FILTER
OUT
32KHZ
16KHZ
8KHZ
4KHZ
JP1
PWM/PPM MODULATOR
PWM/ PPM IN
CN1
FUNCTION GENERATOR
POWER
CN1
OUT
2KHz
1-10HZ
10-100HZ
0.1-1KHZ
1-10KHZ
10-100KHZ
JP 4
P2
LEVEL
P7
LEVEL
P1
FREQ.
JP 1
JP 2
JP 3
FG-02
FUNCTION GENERATOR

Ex No.6 TRANSMISSION OF PULSE POSITION MODULATION

AIM:

To obtain pulse position Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver.

OBJECTIVE:

The objective of this experiment is to study the circuit action of Pulse Position Modulation and Demodulation over Fiber Optic Digital Link.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-03
2.FG-02 with power cable
3.20 MHz Dual Channel Oscilloscope
4.1 meter Fiber cable
5.Patch chords
6.Power supply (Use only one provided)

THEORY:

The position of the TTL pulse is changed on time scale according to the variation of input modulating signal amplitude. Pulse width modulated signal is fed as input to this circuit. Please note that input modulating signal must be converted into pulse width modulated form before applying to pulse position modulator. As the signal is PWM, naturally according to the input signal, the pulse duration is changing and this change in pulse duration causes for the delay in triggering. The input is given to trailing edge trigger input of monoshot. So finally we get the pulses at the output, which are shifted on the time slot. This is nothing but pulse position modulation. Thus Pulse Positions are directly proportional to the instantaneous values of modulating signal. This PPM signal is then transmitted through transmitter (SFH756v) and received at detector output (SFH551v).

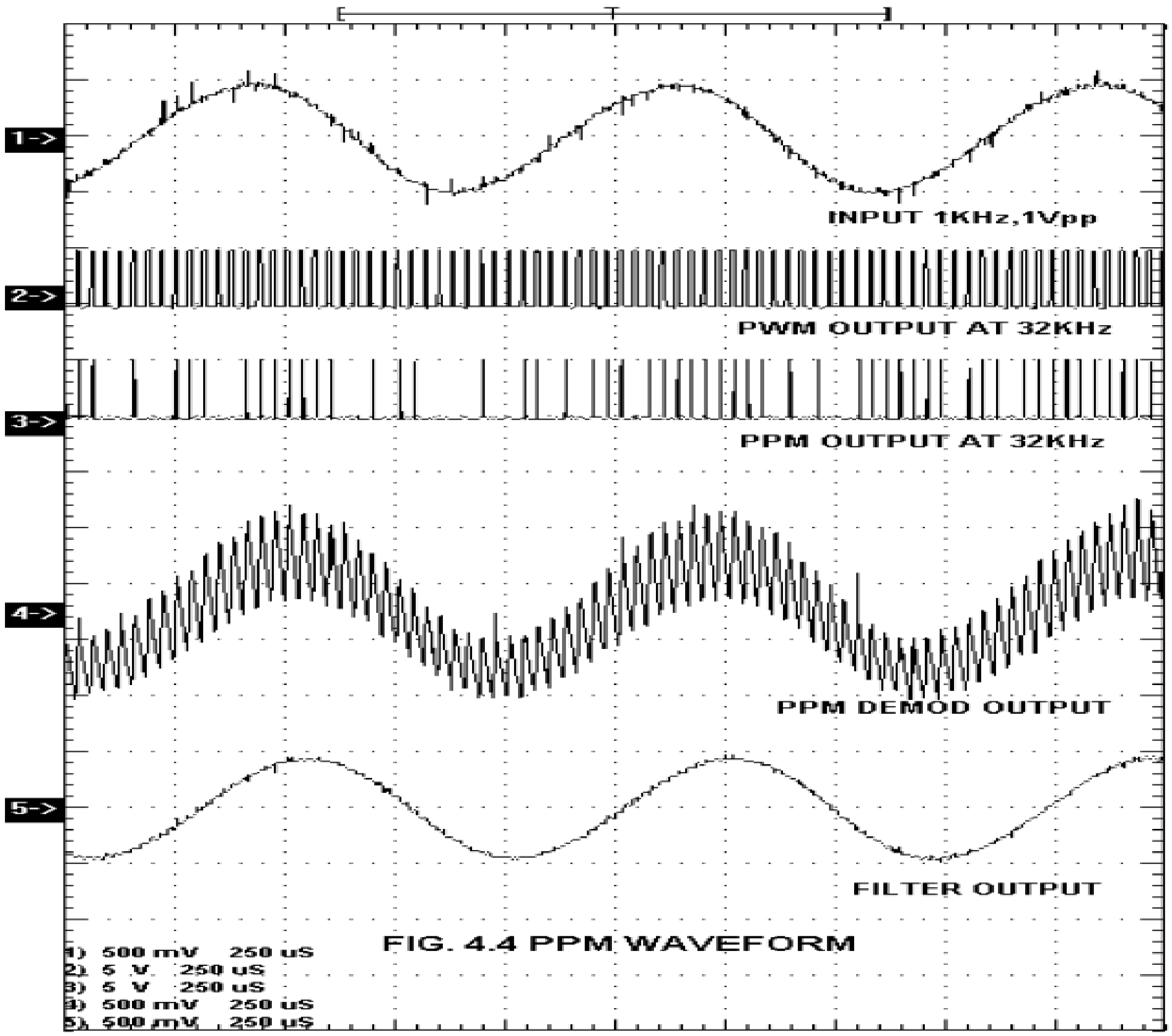
PROCEDURE:

1. Make connections as shown in fig.4.1. Connect the power supply cables with proper polarity to FCL-03 Kit. While connecting this, ensure that the power supply is OFF.
2. Connect Function Generator FG-02 to FCL-03 using power cable.
3. Switch on the power supply.
4. Keep the jumpers **JP1**, **JP2** & **JP3** on FCL-03 as shown in fig.4.1.
5. Keep the function generator **JP1** shorted & **JP2**, **JP3** open.
6. Keep the function generator **JP4** in **1-10KHz** position.
7. Connect the **OUT** Signal from FG-02 to the **PWM/PPM IN** post of PWM/PPM Modulator on FCL-03 and keep the signal frequency at **1KHz** & Amplitude at **1Vpp**.
8. Connect the **PPM OUT** Signal from PWM/PPM Modulator to the **IN** post of Digital Buffer on FCL-03.

Tabulation:

	Amplitude(v)	Time period(ms)
Modulating signal		
Carrier Signal		
Modulated Signal		
Demodulated Signal		

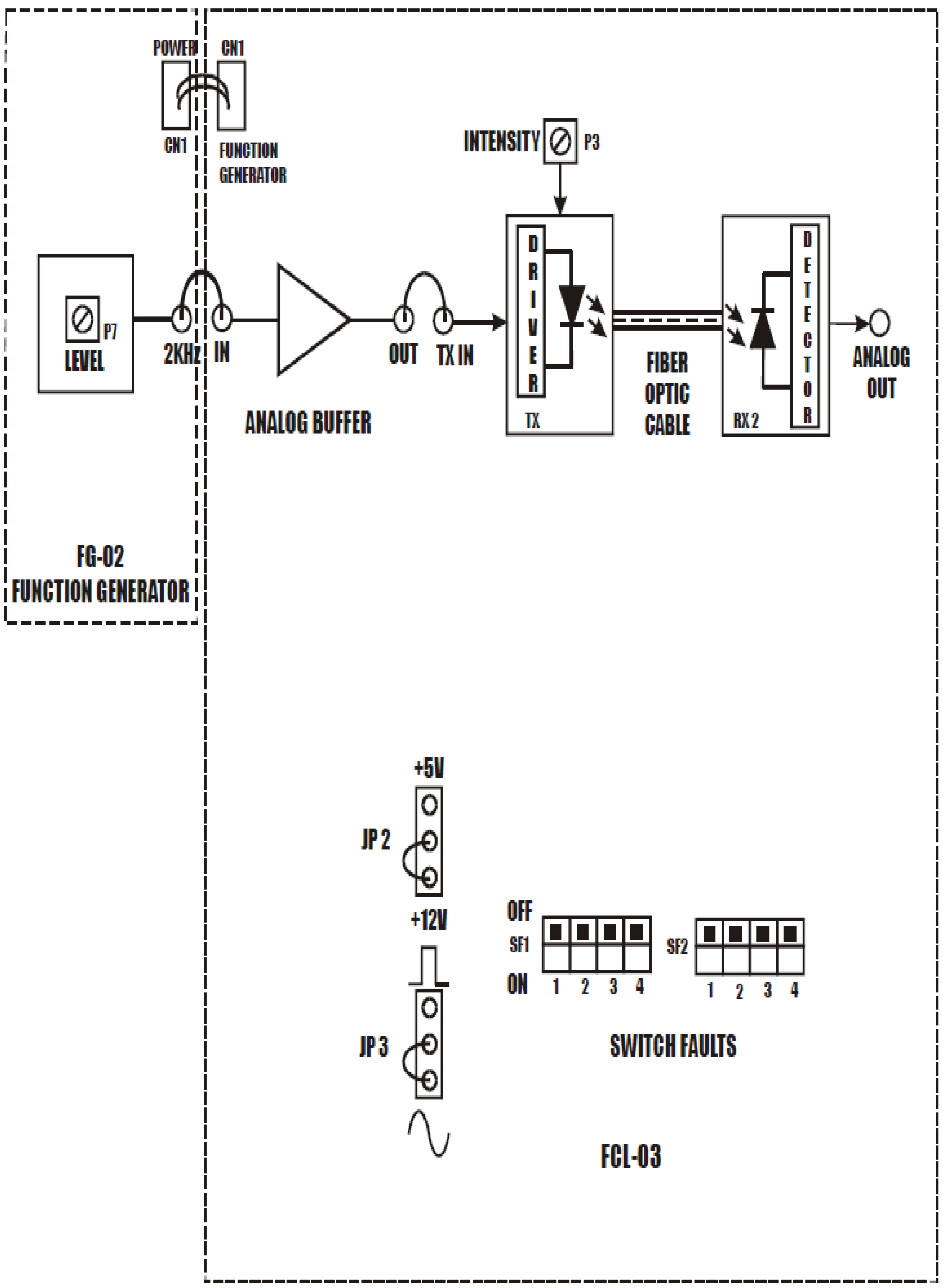
Model Graph



9. Connect the output of Digital Buffer post **OUT** to post **TX IN**.
10. 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.
11. 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. Now tighten the cap by screwing it back.
12. Connect the output of detector post **TTL OUT** to post **PPM DEMOD IN** of PWM/PPM Demodulator.
13. Keep Switch **SW1** in PPM position.
14. Connect the output of PWM/PPM Demodulator post **DEMOD OUT** to post **IN** of Filter 1.
15. Observe PPM signal at PPM OUT Post. Variation in position of square wave is high because the frequency is high. Due to persistence of vision, only blurt band in the waveform will be observed. If the modulating frequency is kept low around 1-10Hz by keeping FG-02 jumper **JP4** in **1-10Hz** range, we can observe the variation in the position of square wave. If the signal generator is OFF, only square wave of fundamental frequency and fixed position will be observed and no position variations are present.
16. Observe the received signal at Filter O/P post **OUT** Demodulated signal represents original signal.

RESULT:

The pulse position Modulation of the analog signal, transmit it over a fiber optic cable and demodulate the same at the receiver end to get back the original signal was studied.


POWER
CN1
CN1
FUNCTION GENERATOR
INTENSITY
P3
P7
LEVEL
2KHz
IN
OUT
TX IN
D R I V E R
TX
FIBER OPTIC CABLE
D E T E C T O R
RX 2
ANALOG OUT
ANALOG BUFFER
FG-02
FUNCTION GENERATOR
+5V
JP 2
+12V
JP 3
OFF
SF1
ON
1 2 3 4
SF2
1 2 3 4
SWITCH FAULTS
FCL-03

Ex No.7 SETTING UP A OPTICAL FIBER –(ANALOG LINK)

AIM:

To find out the relation between input and received signal through an optical fiber by setting an analog link**.**

OBJECTIVE:
The objective of this experiment is to study a 660 nm Fiber Optic Analog Link. In this experiment, student will study the relationship between the input signal & received signal.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-03
2.FG-02 with power cable
3.20 MHz Dual Channel Oscilloscope
4.1 meter Fiber cable
5.Patch chords
6.Power supply (Use only one provided)

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 & 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. Make connections as shown in fig.1.1. Connect the power supply cables with proper polarity to FCL-03 Kit. While connecting this, ensure that the power supply is OFF.
2. Connect Function Generator FG-02 to FCL-03 using power cable.
3. Switch on the power supply.
4. Keep the jumpers **JP2** & **JP3** on FCL-03 as shown in fig.1.1.
5. Connect the **2KHz, 2Vpp** Signal from FG-02 as a constant signal to the **IN** post of Analog Buffer on FCL-03.
6. Connect the output of Analog Buffer post **OUT** to post **TX IN**.
7. 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.
8. Now rotate the Optical Power Control pot **P3** in FCL-03 in anticlockwise direction. This ensures minimum current flow through LED.
9. Slightly unscrew the cap of **RX2** Photo Diode SFH250V. 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.

Tabulation:

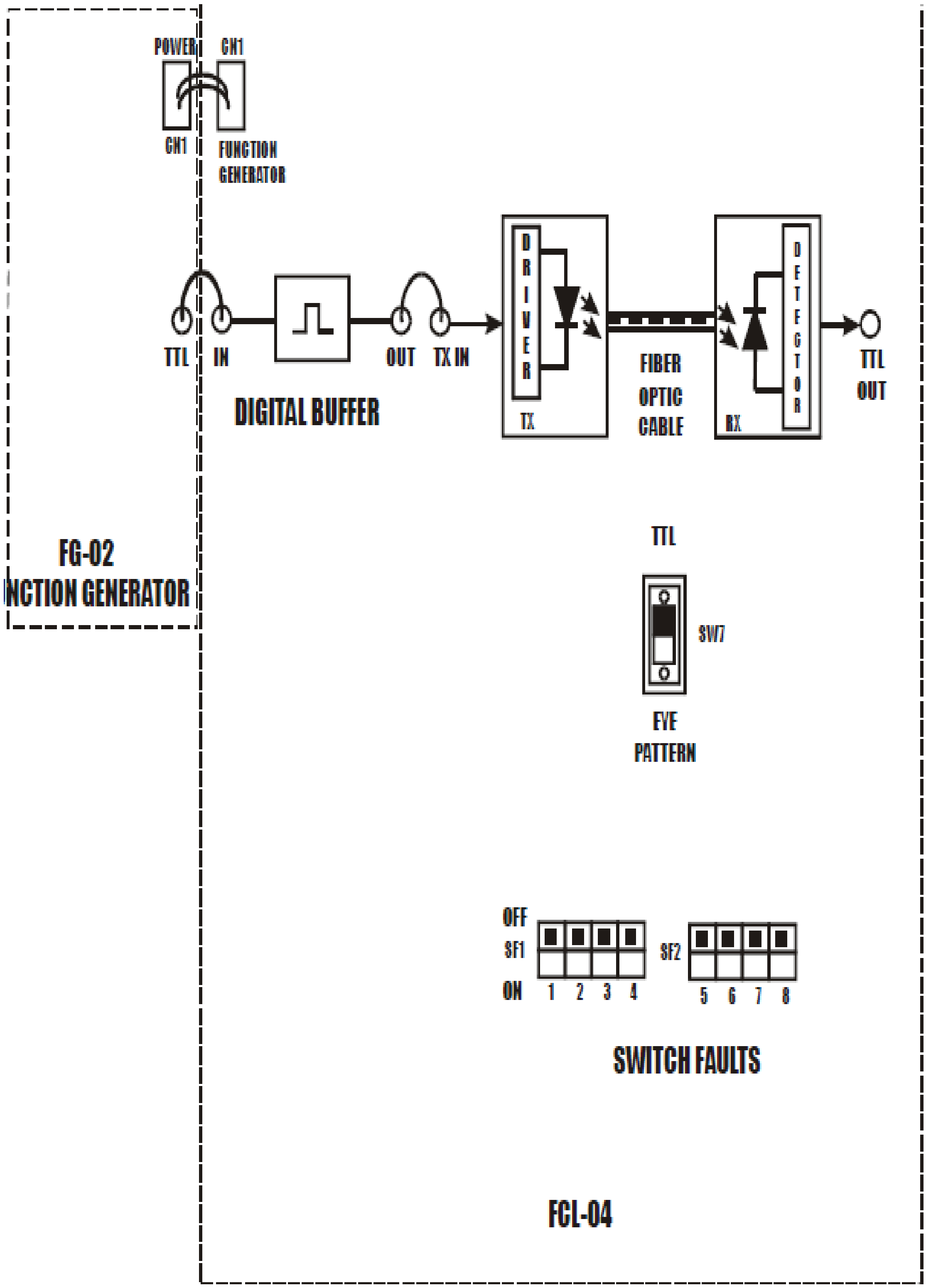
V_{in}=1v pp

s.no	Output (v_{out})	Output 20 log (v_{out}/v_{in})
1		

10. Observe the output signal from the detector at **ANALOG OUT** post on Oscilloscope by adjusting Optical Power Control Pot **P3** in clockwise direction and you should get the reproduction of the original transmitted signal.
11. To measure the analog bandwidth of the link, keep the same connections and vary the frequency of the input signal from 100 Hz onwards. Measure the amplitude of the received signal for each frequency reading.
12. Plot a graph of Gain/Frequency. Measure the frequency range for which the response if flat.

RESULT:

The relation between input and received signal through an optical fiber by setting an analog link was studied.


POWER
CN1
CN1
FUNCTION
GENERATOR
TTL
IN
OUT
TX IN
DIGITAL BUFFER
DRIVER
TX
FIBER
OPTIC
CABLE
RX
DETECTOR
TTL
OUT
FG-02
NCTION GENERATOR
TTL
SW7
EYE
PATTERN
OFF
SF1
ON
1 2 3 4
SF2
5 6 7 8
SWITCH FAULTS
FCL-04

Ex No.8 SETTING UP A OPTICAL FIBER –(DIGITAL LINK)

AIM:

To find out the relation between input and received signal through an optical fiber by setting a digital link**.**

OBJECTIVE:
The objective of this experiment is to study a 660 nm Fiber Optic digital Link. In this experiment, student will study the relationship between the input signal & received signal.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-04
2.FG-02 with power cable
3.20 MHz Dual Channel Oscilloscope
4.1 meter Fiber cable
5.Patch chords
6.Power supply (Use only one provided)

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 & a receiver. The transmitter module takes the input signal in electrical form & then transforms it into optical (light) energy containing the same information. The optical fiber is the medium, which carries this energy to the receiver. At the receiver, light is converted back into electrical form with the same pattern as originally fed to the transmitter.

TRANSMITTER:
LED, digital, DC coupled transmitters are one of the most popular variety due to their ease of fabrication. We have used a standard TTL gate to drive a NPN transistor, which modulates the LED SFH450V (950nm) source (Turns it ON and OFF).

RECEIVER:
There are various methods to configure detectors to extract digital data. Usually detectors are of linear nature. We have used a photo detector having TTL type output. Usually it consists of PIN photodiode, trans impedance amplifier and level shifter.

PROCEDURE:

1. Make connections as shown in fig.1.1. Connect the power supply cables with proper polarity to FCL-04 Kit. While connecting this, ensure that the power supply is OFF.
2. Connect Function Generator FG-02 to FCL-04 using power cable.
   the power supply.

Tabulation:

V_{in}=1v pp

s.no	Output (v_{out})	Output 20 log (v_{out}/v_{in})
1		

Model Graph:

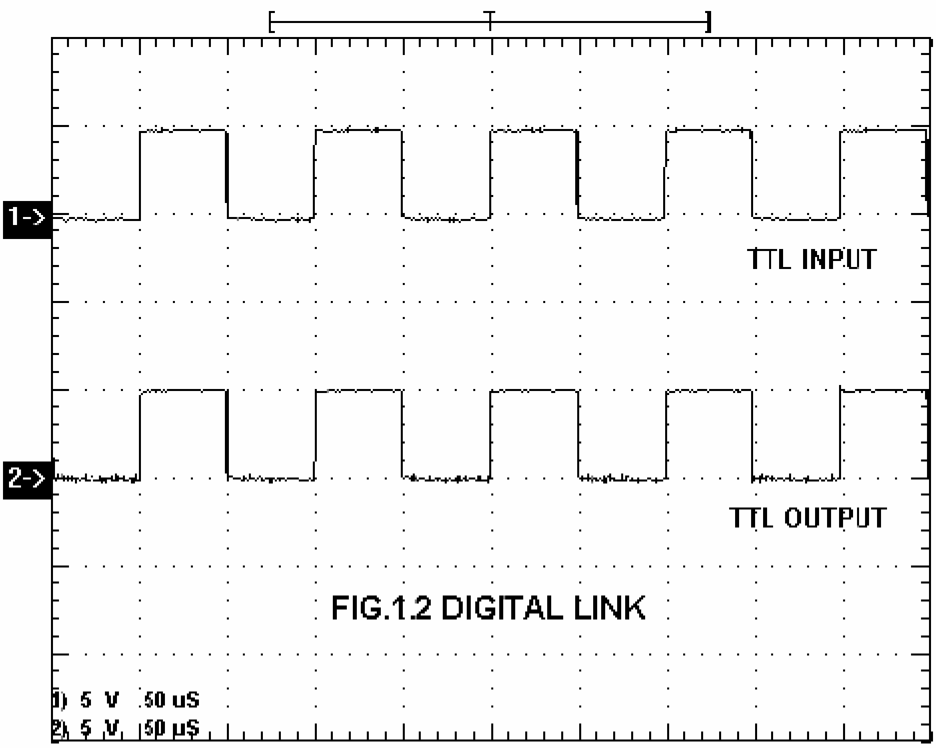


FIG.1.2 DIGITAL LINK

4. Keep the switch **SW7** to **TTL** position on FCL-04 as shown in fig.
5. Connect the **TTL** Signal from FG-02 as a constant signal to the **IN** post of Digital Buffer on FCL-04.
6. Connect the output of Digital Buffer post **OUT** to post **TX IN**.
7. Slightly unscrew the cap of LED SFH450V (950nm). 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.
8. Slightly unscrew the cap of 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.
9. Observe the output signal from the detector at **TTL OUT** post on Oscilloscope you should get the reproduction of the original transmitted signal.
10. To measure the digital bandwidth of the link, keep the same connections and vary the frequency of the input signal from 100Hz – 1.5MHz onwards. Observe the variation in duty cycle of the received signal for each frequency reading and determine the maximum bit rate that can be transmitted on the digital link.

RESULT:

The relation between input and received signal through an optical fiber by setting an digital link was studied.

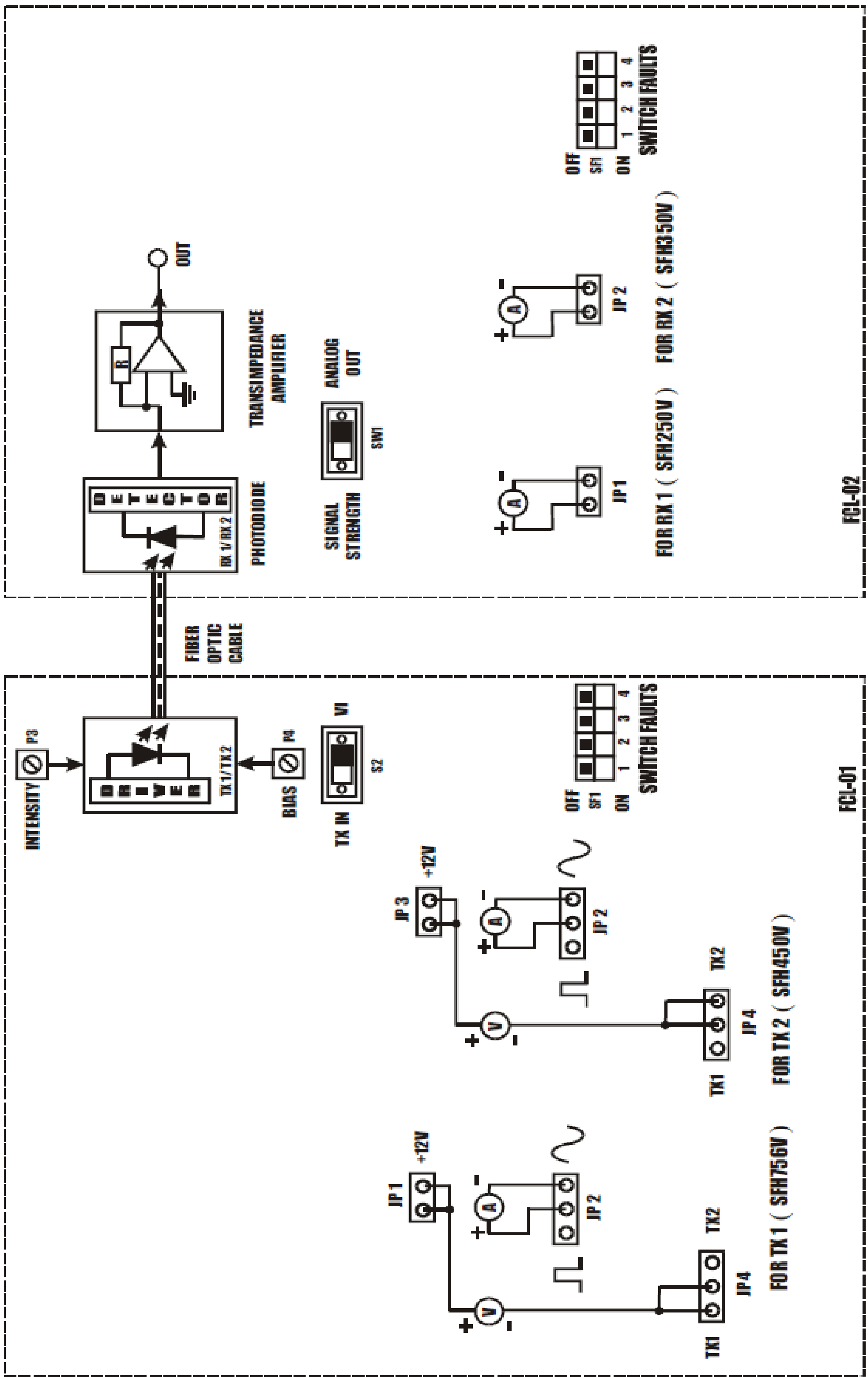


FIG. 14.1 BLOCK DIAGRAM FOR CHARACTERISTICS OF FIBER OPTIC LED'S AND DETECTORS

Ex No.9 CHARACTERISTICS OF LED AND PHOTO DETECTOR

AIM:

To determine the characteristics of LED and photo detector

OBJECTIVE:
To study the IV characteristics of fiber optic LED and plot the graph of forward current v/s output optical energy and also to study the photo detector response

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1.FCL-01 & FCL-02
2.1 meter Fiber cable
3.Patch chords
4.Jumper to crocodile wires
5.Power supply (Use only one provided)
6.20 MHz Dual Channel Oscilloscope
7.Volt meter
8.Ammeter

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. Datasheets for LEDs usually specify electrical and optical characteristics, out of which the important ones are peak wavelength of emission, conversion efficiency (usually specified in terms of power launched in optical fiber for specified forward current), optical rise and fall ties which put the limitation on operating frequency, maximum forward current through LED and typical forward voltage across LED. Photodetectors usually comes 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:

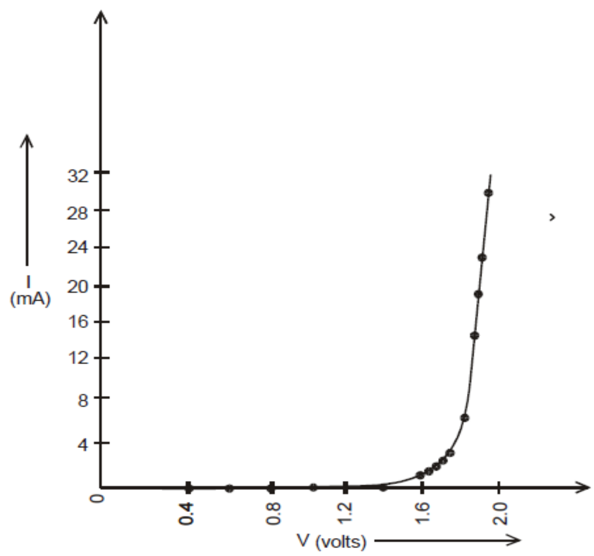
1. Make connections as shown in fig.14.1. Connect the power supply with proper polarity to FCL-01 & FCL-02 Kits. While connecting this, ensure that the power supply is OFF.
2. Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 1-meter fiber into the cap. Now tighten the cap by screwing it back.
3. Slightly unscrew the cap of Photo Diode SFH250V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber

VI CHARACTERISTICS OF FIBER OPTIC LED & DETECTOR

LED CHARACTERISTICS			
Vf (V)	If (mA)	Pi (mW)	Po (uW)
1.559	0.248	0.386	4.4
1.6	0.882	1.4	16.0
1.62	1.461	2.36	27.0
1.64	2.5	4.1	47.0
1.66	3.8	6.3	72.0
1.68	5.8	9.7	111.5
1.70	8.0	13.6	156.4
1.72	10.6	18.2	210.0
1.74	13.6	23.6	271.4
1.76	17.3	30.4	350.0
1.78	21.8	38.8	446.2
1.81	27.5	49.7	571.5

DETECTOR CHARACTERISTICS		
V (V)	Ip (uA)	R (mA)
0.07	1.0	0.22
0.124	5.3	0.33
0.240	9.9	0.36
0.260	17.8	0.37
0.445	29.7	0.41
0.750	47.1	0.42
1.15	68.2	0.43
1.76	92.3	0.43
2.81	121.0	0.44
3.54	152.5	0.43
4.16	186.1	0.41
4.58	247.0	0.43

Vf = Forward voltage of LED SFH756
If = Forward current of LED SHF 756
Pi = V * I (Electrical power)
Po = Pi*1.15% (Optical Power of LED 756.)
V = Out put Voltage of SFH350
I_p = Out put Current of SFH350
R = I_p / P_o (Responsivity)



into the cap. Now tighten the cap by screwing it back.

4. Keep the jumpers **JP1**, **JP2**, **JP3** & **JP4** on FCL-01 as shown in fig.14.1.
5. Keep the jumpers **JP1** & **JP2** on FCL-02 as shown in fig.14.1.
6. Keep switch **S2** in **VI** position on FCL-01.
7. Connect voltmeter and current meter as per the polarities shown in fig.14.1.
8. Switch on the power supply.
9. Keep the potentiometer **P3** in its maximum position (anti-clockwise rotation). **P3** is used to control current flowing through the LED.
10. Keep the potentiometer **P4** in its fully clockwise rotation. **P4** is used to control bias voltage of the LED.
11. To get the IV characteristics of LED, rotate **P3** 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.
12. For each reading taken above, find out the power, which is product of V and I. This is the electrical power supplied to the LED. Data sheets for the LED specify optical power coupled into plastic fiber when forward current was 10 mA as 200 μW. This means that the electrical power at 10 mA current is converted into 200 μW of optical energy. Hence the efficiency of the LED comes out to be approx. 1.15%.
13. With this efficiency assumed, find out optical power coupled into plastic optical fiber for each of the reading. Plot the graph of forward current v/s output optical power of the LED.
14. Similarly measure the current at the detector.
15. Plot the graph of receiver current v/s output optical power of the LED.
16. Perform the above procedure again for all the combinations of Transmitter & Receiver.
17. Calculate the responsivity of the detector

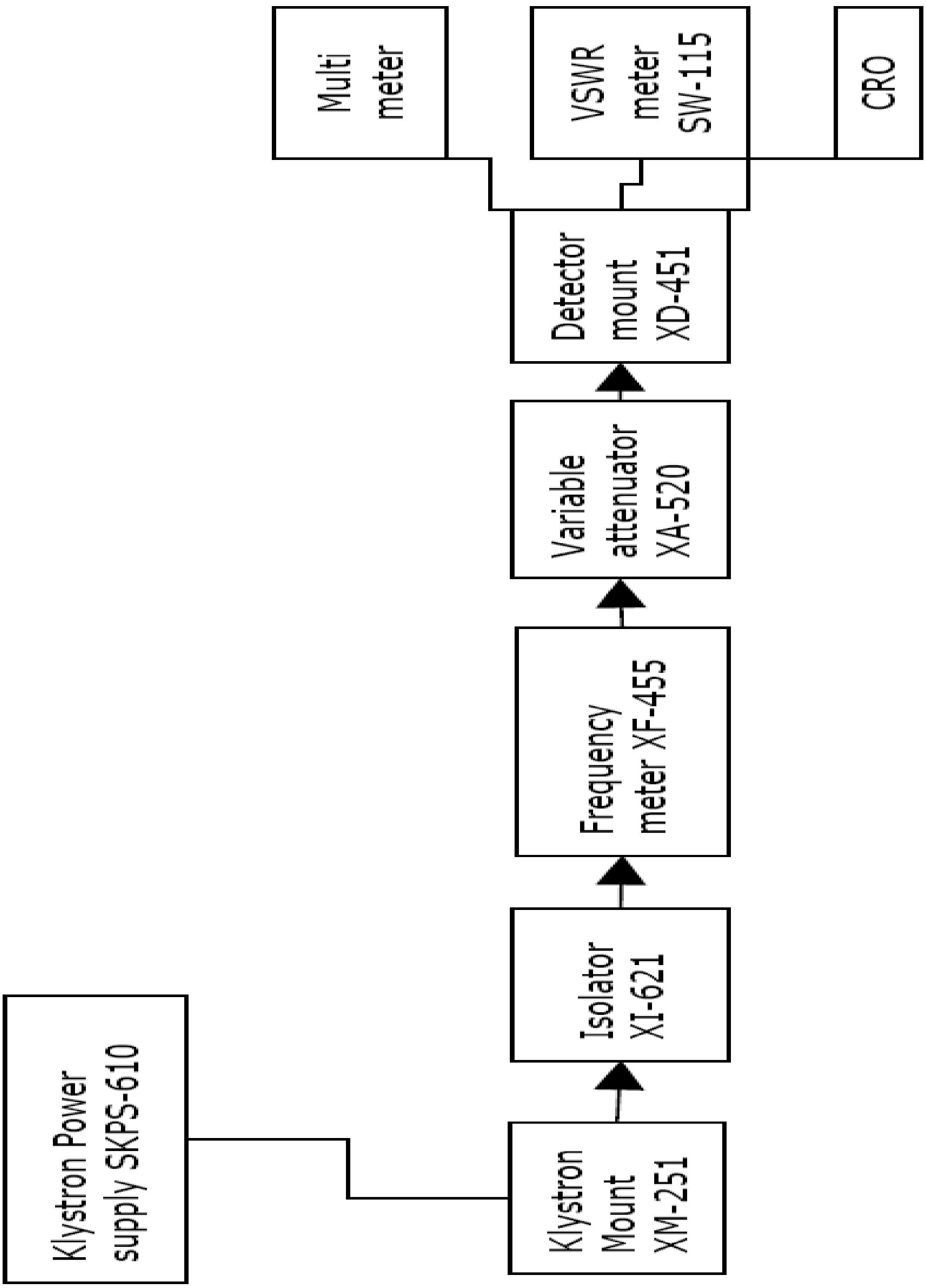
    R = Ip / Po (A/W) = Photocurrent in μA / Optical power in μW

    Quantum efficiency (η) = (Ip / q)/ (Po / hf)

    q = 1.60218 × 10-19 C

RESULT:

The characteristics of LED and photo detector was determined.


Multi
meter
VSWR
meter
SW-115
CRO
Detector
mount
XD-451
Variable
attenuator
XA-520
Frequency
meter XF-455
Isolator
XI-621
Klystron Power
supply SKPS-610
Klystron
Mount
XM-251

Ex No.1 MODE CHARACTERISTICS OF REFLEX KLYSTRON

AIM:
To study the mode characteristics of the reflex klystron tube and to determine its Electronic tuning range.

OBJECTIVE:
The objective of this experiment is
(i) To study the mode characteristics of the reflex klystron tube and
(ii) To determine its Electronic tuning range.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1. Klystron power supply – {SKPS – 610 }
2. Klystron tube 2k-25 with klystron mount – {XM-251}
3. Isolator {X1-625}
4. Frequency meter {XF-710}
5. Detector mount {XD-451}
6. Variable Attenuator {XA-520}
7. Wave guide stand {XU-535}
8. VSWR meter {SW-215}
9. Oscilloscope
10. BNC Cable

THEORY:
The reflex klystron is a single cavity variable frequency microwave generator of low power and low efficiency. This is most widely used in applications where variable frequency is desired as

1. In radar receivers
2. Local oscillator in µw receivers
3. Signal source in micro wave generator of variable frequency
4. Portable micro wave links.
5. Pump oscillator in parametric amplifier

Voltage Characteristics:

Oscillations can be obtained only for specific combinations of anode and repeller voltages that gives farable transit time.

Power Output Characteristics:

The mode curves and frequency characteristics. The frequency of resonance of the cavity decides the frequency of oscillation. A variation in repeller voltages slightly changes the frequency.

TABULATION

Beam Voltage :…………V (Constant)

Beam Current :………….mA

Repeller Voltage (V)	Current (mA)	Power (mW)	Dip frequenct(GHz)

PROCEDURE:

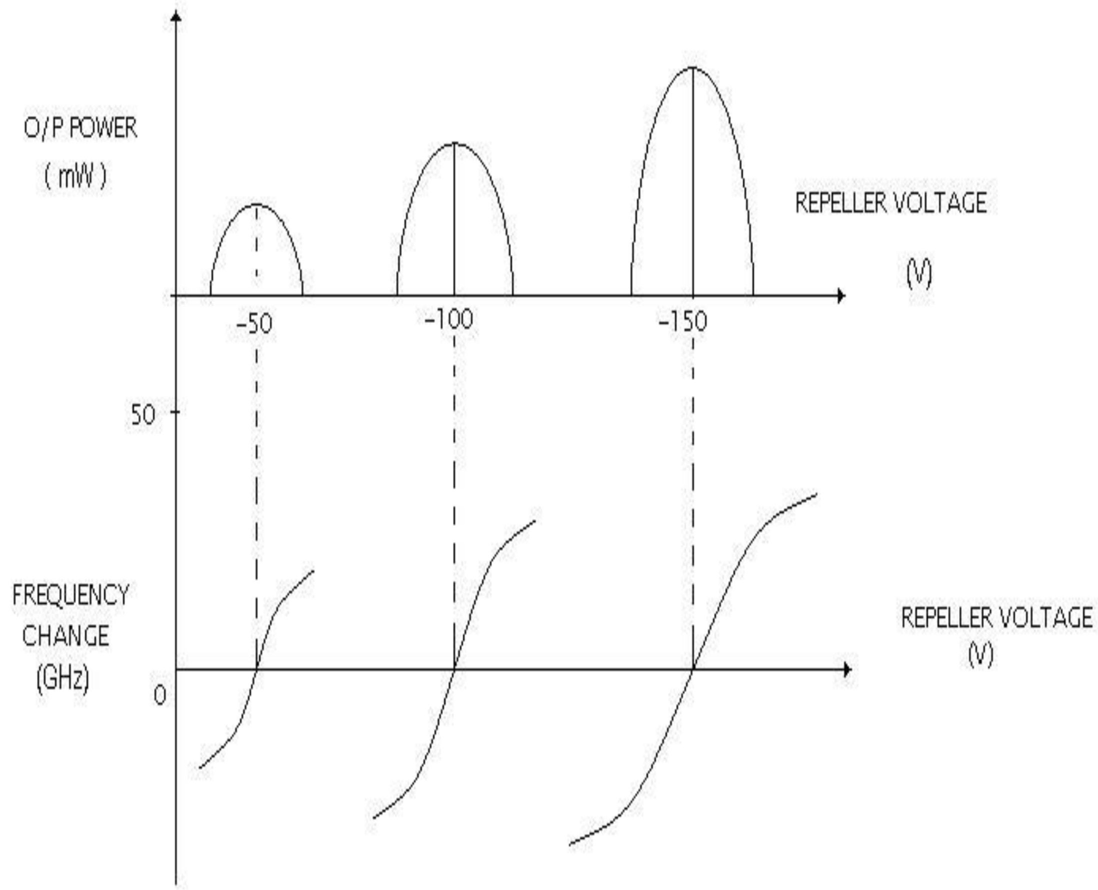
A.CARRIER WAVE OPERATION:

1. Connect the equipments and components as shown in the figure.
2. Set the variable attenuator at maximum Position.
3. Set the MOD switch of Klystron Power Supply at CW position, beam voltage
4. control knob to fully anti clock wise and repeller voltage control knob to fully clock wise and meter switch to 'OFF' position.
4. Rotate the Knob of frequency meter at one side fully.
5. Connect the DC microampere meter at detector.
6. Switch "ON" the Klystron power supply, CRO and cooling fan for the Klystron tube..
7. Put the meter switch to beam voltage position and rotate the beam voltage knob clockwise slowly up to 300 Volts and observe the beam current on the meter by changing meter switch to beam current position. The beam current should not increase more than 30 mA.
8.Change the repeller voltage slowly and watch the current meter, set the maximum voltage on CRO.
9.Tune the plunger of klystron mount for the maximum output.
10.Rotate the knob of frequency meter slowly and stop at that position, where there is less output current on multimeter. Read directly the frequency meter between two horizontal line and vertical marker. If micrometer type frequency meter is used read the micrometer reading and find the frequency from its frequency calibration chart.
11.Change the repeller voltage and read the current and frequency for each repeller voltage. .

B. SQUARE WAVE OPERATION:

1. Connect the equipments and components as shown in figure
2. Set Micrometer of variable attenuator around some Position**.**
3. Set the range switch of VSWR meter at 40 db position, input selector switch to crystal impedance position, meter switch to narrow position.
4. Set Mod-selector switch to AM-MOD position .beam voltage control knob to fully anti clockwise position.
5. Switch "ON" the klystron power Supply, VSWR meter, CRO and cooling fan.
6. Switch "ON" the beam voltage. Switch and rotate the beam voltage knob clockwise up to 300V in meter.
7. Keep the AM – MOD amplitude knob and AM – FREQ knob at the mid position.
8. Rotate the reflector voltage knob to get deflection in VSWR meter or square wave on CRO.
9. Rotate the AM – MOD amplitude knob to get the maximum output in VSWR meter or CRO.
10. Maximize the deflection with frequency knob to get the maximum output in VSWR meter or CRO.
11. If necessary, change the range switch of VSWR meter 30dB to 50dB if the deflection in VSWR meter is out of scale or less than normal scale respectively. Further the output can be also reduced by variable attenuator for setting the output for any particular position.

MODEL GRAPH:

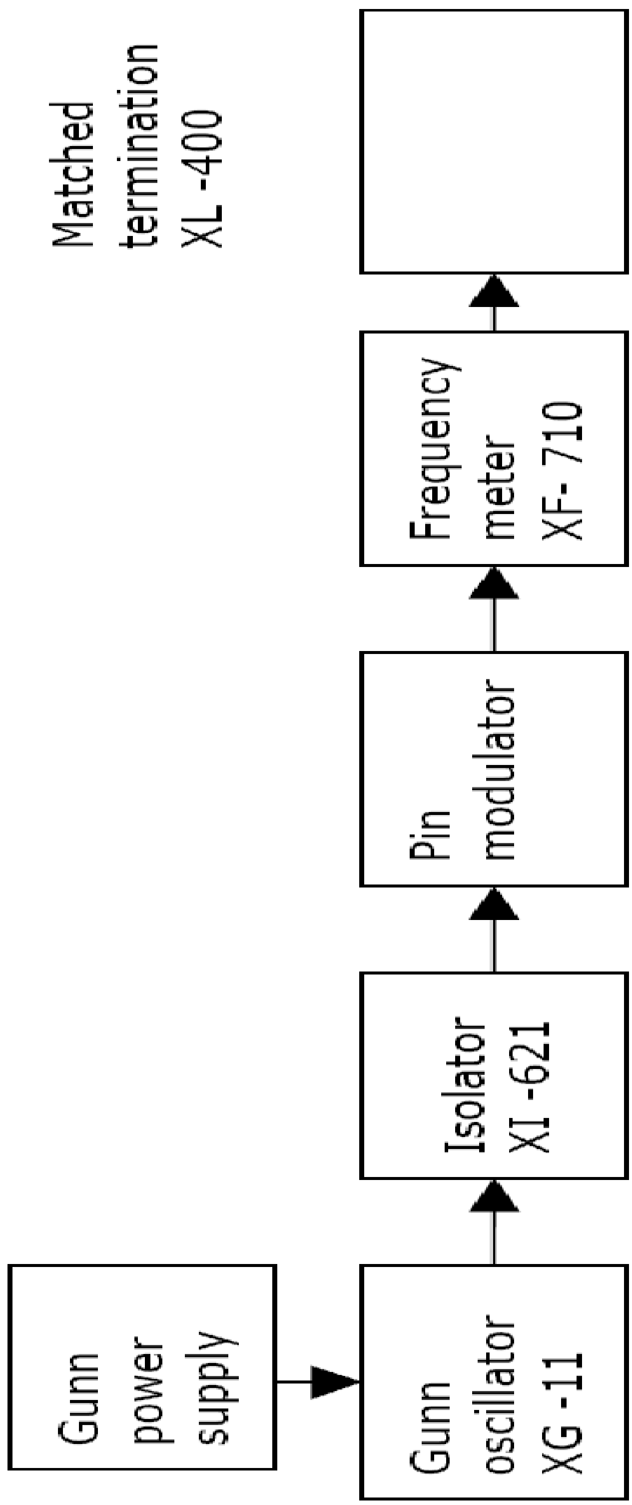

O/P POWER
(mW)
REPELLER VOLTAGE
(V)
-50
-100
-150
50
FREQUENCY
CHANGE
(GHz)
0
REPELLER VOLTAGE
(V)

C. **MODE STUDY ON OSCILLOSCOPE**:

1.Set up the components and equipments as shown in Fig.
2. Keep position of variable attenuator at min attenuation position.
3.Set mode selector switch to FM-MOD position FM amplitude and FM frequency knob at mid position keep beam voltage knob to fully anti clock wise and reflector voltage knob to fully clockwise position and beam switch to ‘OFF’ position.
4. Keep the time/division scale of oscilloscope around 100 HZ frequency measurement and volt/div. to lower scale.
5. Switch ‘ON’ the klystron power supply and oscilloscope.
6. Change the meter switch of klystron power supply to Beam voltage position and set beam voltage to 300V by beam voltage control knob.
7. Keep amplitude knob of FM modulator to max. Position and rotate the reflector voltage anti clock wise to get the modes as shown in figure on the oscilloscope. The horizontal axis represents reflector voltage axis and vertical represents o/p power.
8.By changing the reflector voltage and amplitude of FM modulation in any mode of klystron tube can be seen on oscilloscope.

RESULT:

The mode characteristics of the reflex klystron tube was studied.


Gunn power supply
Gunn oscillator XG -11
Isolator XI -621
Pin modulator
Frequency meter XF- 710
Matched termination XL -400

Ex No.2 I-V CHARACTERISTICS OF A GUNN DIODE

AIM:
To study the I-V characteristics of Gunn diode.

OBJECTIVE:
The objective of this experiment is

(i) To study the IV characteristics of a Gunn diode.
(ii) To calculate the negative resistance

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1. Gunn power supply
2. Gunn oscillator
3. PIN Modulator
4. Isolator
5. Frequency Meter
6. Variable attenuator
7. Matched termination
8. CRO.

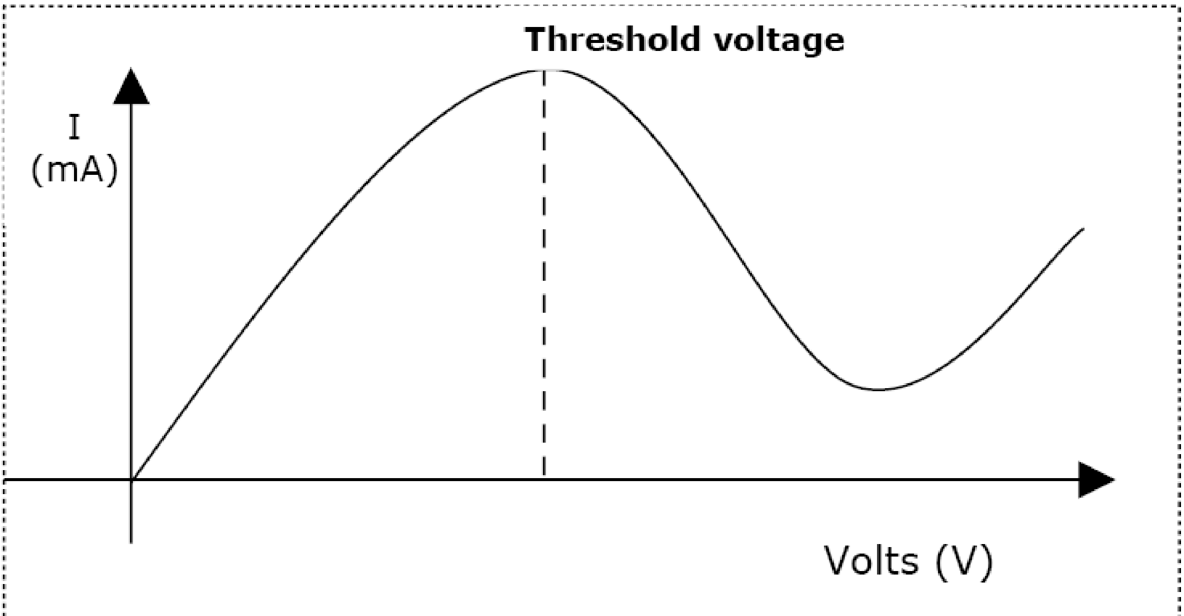
THEORY:

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 capacitively 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.

TABULATION:

MODEL GRAPH:



I-V CHARACTERISTICS OF GUNN OSCILLATOR

PROCEDURE:

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.

Note: Do not keep Gunn bias knob position at threshold position for more than 10-15 sec. readings should be obtained as fast as possible. Otherwise due to excessive heating Gunn diode may burn

RESULT:

The I-V characteristics of Gunn diode was studied and negative resistance was calculated.

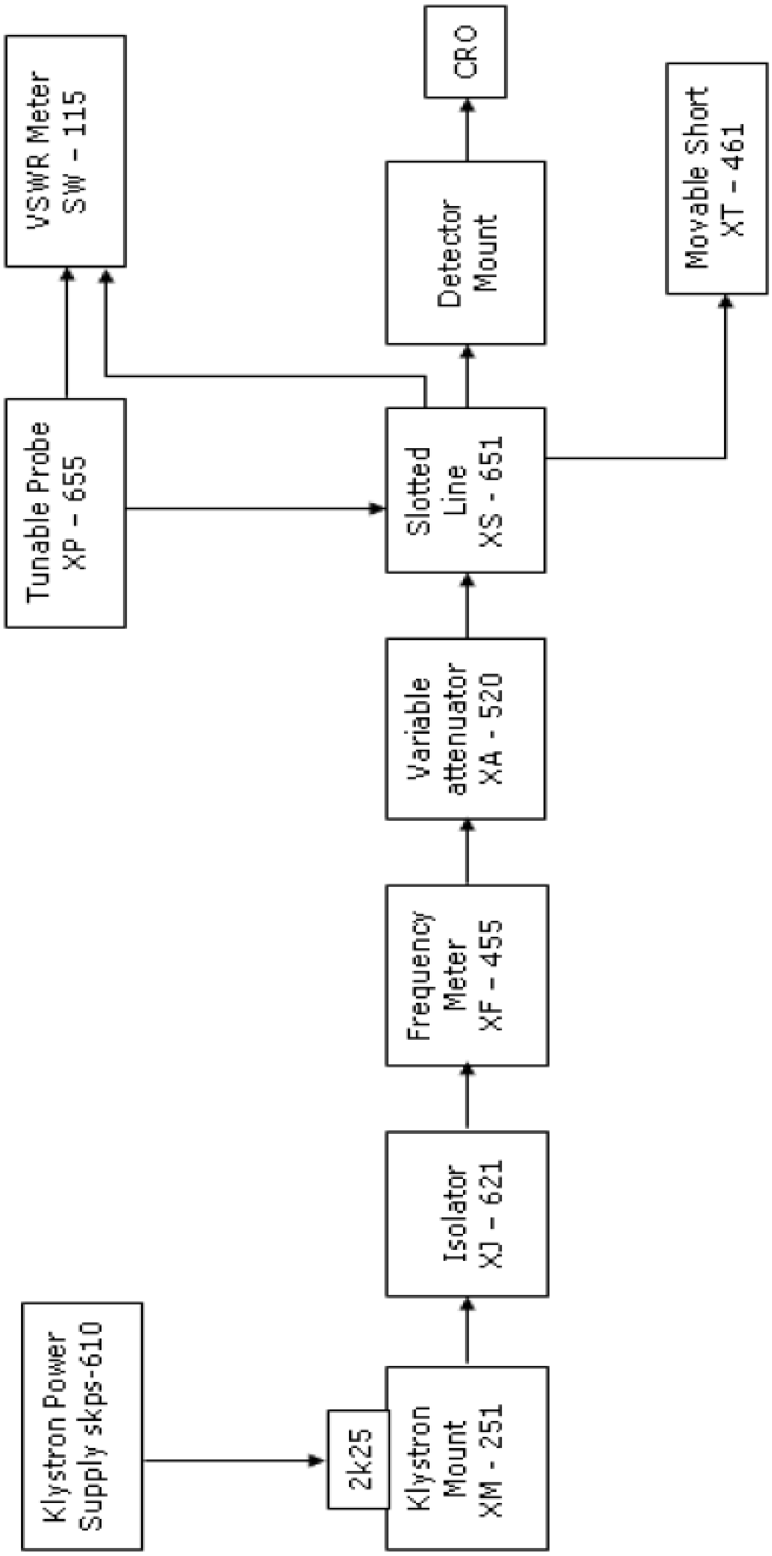


FIG: SET UP FOR FREQUENCY AND WAVELENGTH MEASUREMENT

Ex No.3 MEASUREMENT OF FREQUENCY AND WAVELENGTH

AIM:

To determine the frequency and wavelength in a rectangular waveguide working on TE10 model.

OBJECTIVE:

The objective of the experiment is to determine the frequency and wavelength in a rectangular waveguide working on TE10 model and verify the same.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1. Klystron power supply,
2. Reflex klystron oscillator
3. Frequency meter,
4. Variable attenuator,
5. Slotted section,
6. VSWR meter,
7. Detector mount
8. CRO.

THEORY:

For dominant TE_{10} mode in rectangular waveguide λ_0, λ_g , λ_c are related as below.

$$1/ \lambda_0^2 = 1/ \lambda_g^2 + 1/ \lambda_c^2$$

λ_0 = Free space wavelength
λ_g = guide wavelength
λ_c = cut off wavelength

For TE10 mode λ_c = 2a where a is the broad dimension of waveguide. The following relationship can be proved.

$$c = f \lambda$$

c = velocity of light f = frequency

PROCEDURE:

1. Set up the components and equipments as shown in figure.

2 Set up variable attenuator at minimum attenuation position.

3 Keep the control knobs of klystron power supply as below:
Beam voltage – OFF
Mod-switch – AM
Beam voltage knob – Fully anti clock wise
Repeller voltage – Fully clock wise
AM – Amplitude knob – Around fully clock wise
AM – Frequency knob – Around mid position

TABULATION:

d1 cm	d2 cm	d1-d2	F(in GHz)

CALCULATION

$$1/\lambda_0^2 = 1/\lambda_g^2 + 1/\lambda_c^2$$

λ_0 = Free space wavelength
λ_g = guide wavelength
λ_c = cut off wavelength

4. Switch ‘ON’ the klystron power supply, CRO and cooling fan switch.

5.Switch ’ON’ the beam voltage switch and set beam voltage at 300V with help of beam voltage knob.

6.Adjust the repeller voltage to get the maximum amplitude in CRO

7.Maximize the amplitude with AM amplitude and frequency control knob of power supply.

8.Tune the plunger of klystron mount for maximum Amplitude.

9.Tune the repeller voltage knob for maximum Amplitude.

10.Tune the frequency meter knob to get a ‘dip’ on the CRO and note down the frequency from frequency meter.

11.Replace the termination with movable short, and detune the frequency meter.

12.Move the probe along with slotted line. The amplitude in CRO will vary .Note and record the probe position , Let it be d1.

13.Move the probe to next minimum position and record the probe position again, Let it be d2.

14.Calculate the guide wave length as twice the distance between two successive minimum position obtained as above.

15..Measure the wave guide inner board dimension ‘a’ which will be around 22.86mm for x- band.

RESULT:

The frequency and wavelength in a rectangular waveguide working on TE10 model was calculated.

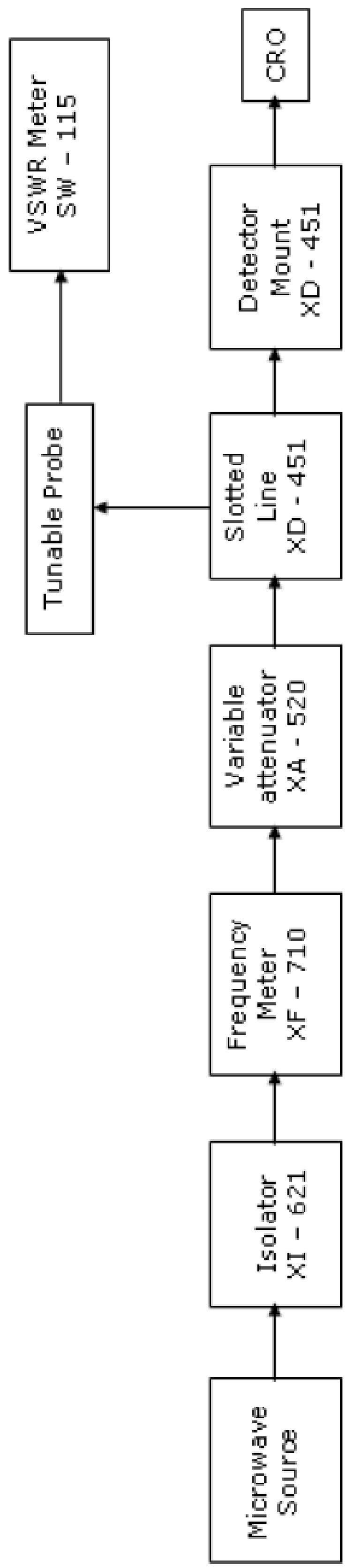


FIG: SET UP FOR LOW VSWR MEASUREMENT

Ex No.4 MEASUREMENT OF VOLTAGE STANDING WAVE RATIO (VSWR)

AIM:
To determine the standing-wave ratio and reflection coefficient.

OBJECTIVE:

The objective of the experiment is to determine the
(i)Low voltage standing wave ratio
(ii)High standing wave ratio

EITC (Equipment's, Instruments, Tools, Consumables) 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 t 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

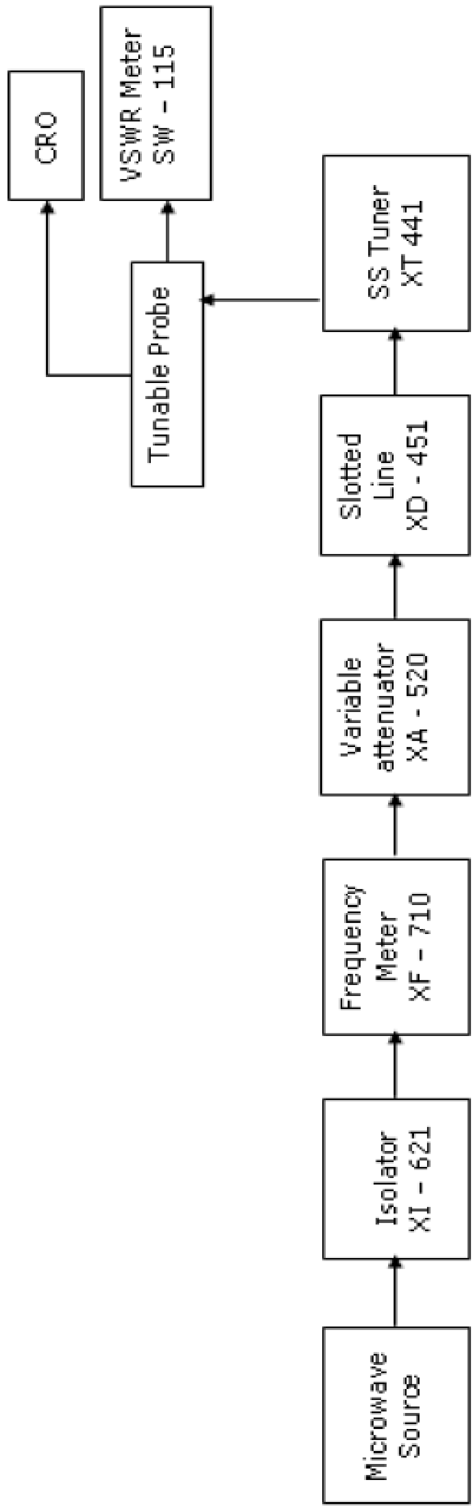


FIG: SET UP FOR HIGH VSWR MEASUREMENT

greater than 10. In this method, the probe is inserted to a depth where the minimum can be read without difficulty. 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.

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. If required, change the range db-switch variable attenuator position and (given) gain control knob to get deflection in the scale of VSWR meter.

10. As your move probe along the slotted line, the deflection will change.

TABULATION

LOW VSWR

VSWR = ________

HIGH VSWR

Beam Voltage (v)	x1 (cm)	x2 (cm)	x1 (cm)	x2 (cm)	Avg (x1-x2) = x (cm)	λg=2x (cm)

Guide wavelength =6 cm

d1 (cm)	d2 (cm)	d1-d2 (cm)	VSWR = λg / □ (d1-d2)

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 n 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 λg.
8. Compute SWR from following equation

$$SWR = \frac{\lambda_g}{\pi \,(d_1 - d_2)}$$

RESULT:

The low and medium voltage standing wave ratio was measured.

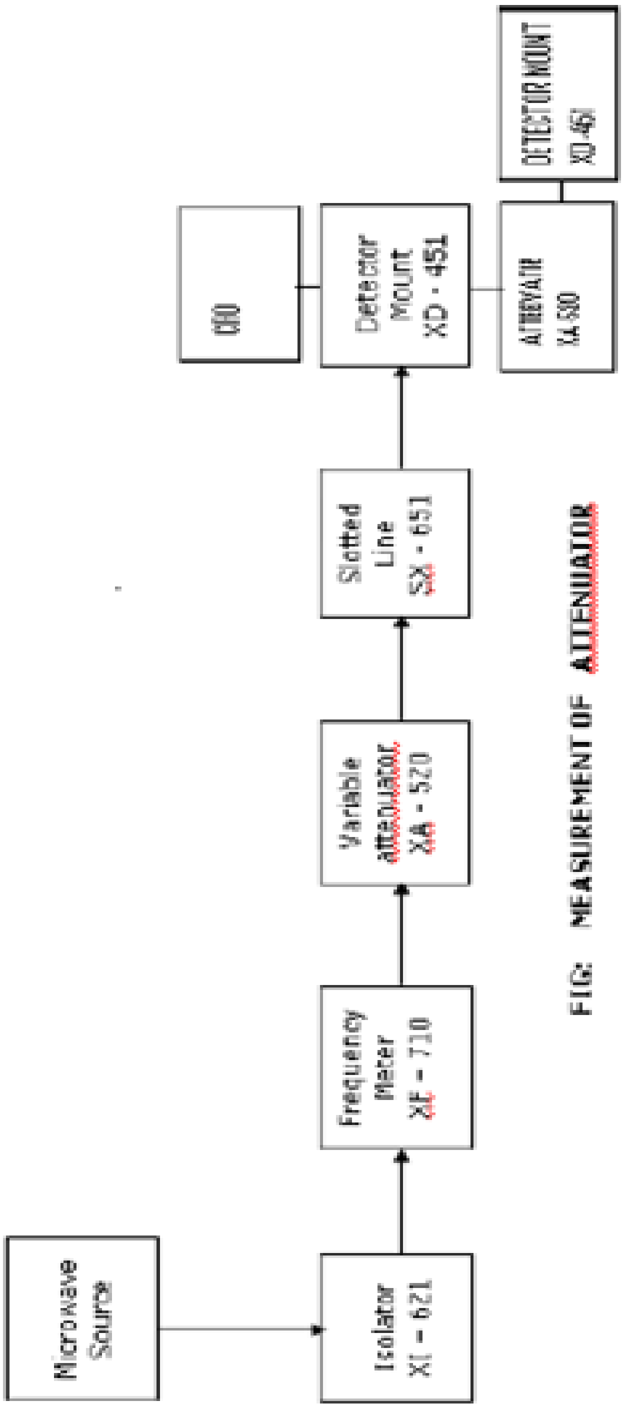


FIG: MEASUREMENT OF ATTENUATOR

Ex No.5 MEASUREMENT OF ATTENUATION AND POWER

AIM:
To study insertion loss and attenuation measurement of attenuator.

OBJECTIVE:
The objective of the experiment is to determine the
(i)Attenuation of the fixed and variable attenuators

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED

1. Microwave source Klystron tube (2k25)
2. Isolator (xI-621)
3. Frequency meter (xF-710)
4. Variable attenuator (XA-520)
5. Slotted line (XS-651)
6. Tunable probe (XP-655)
7. Detector mount (XD-451)
8. Matched termination (XL-400)
9. Test attenuator
   a) Fixed
   b) Variable
10. Klystron power supply & Klystron mount
11. Cooling fan
12. BNC-BNC cable
13. Power Meter

THEORY:

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

Attenuation A (dB) = 10 log (P1/P2)

Where P1 = Power detected by the load without the attenuator in the line

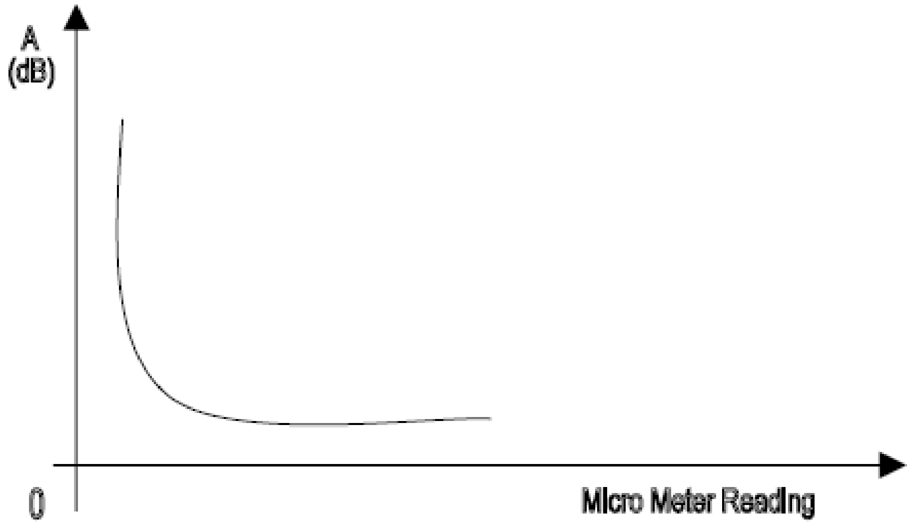
P2 = Power detected by the load with the attenuator in the line.

PROCEDURE:
1. Connect the equipments as shown in the above figure.

TABULATION:

Micrometer reading	P1 (dB)	P2 (dB)	Attenuation = P1-P2 (dB)

MODEL GRAPH:



2. Energize the microwave source for maximum power at any frequency of operation
3. Connect the detector mount to the slotted line and tune the detector mount also for max deflection on VSWR or on CRO
4. Set any reference level on the VSWR meter or on CRO with the help of variable attenuator. Let it be P1.
5. Carefully disconnect the detector mount from the slotted line without disturbing any position on the setup place the test variable attenuator to the slotted line and detector mount to O/P port of test variable attenuator. Keep the micrometer reading of text variable attenuator to zero and record the readings of VSWR meter or on CRO. Let it to be P2. Then the insertion loss of test attenuator will be P1-P2 db.
6. For measurement of attenuation of fixed and variable attenuator. Place the test attenuator to the slotted line and detector mount at the other port of test attenuator. Record the reading of VSWR meter or on CRO. Let it be P3 then the attenuation value of variable attenuator for particular position of micrometer reading of will be P1-P3 db.
7. In case the variable attenuator change the micro meter reading and record the VSWR meter or CRO reading. Find out attenuation value for different position of micrometer reading and plot a graph.
8. Now change the operating frequency and all steps should be repeated for finding frequency sensitivity of fixed and variable attenuator.

Note: For measuring frequency sensitivity of variable attenuator the position of micrometer reading of the variable attenuator should be same for all frequencies of operation.

RESULT:

The insertion loss and attenuation measurement of attenuator was studied.

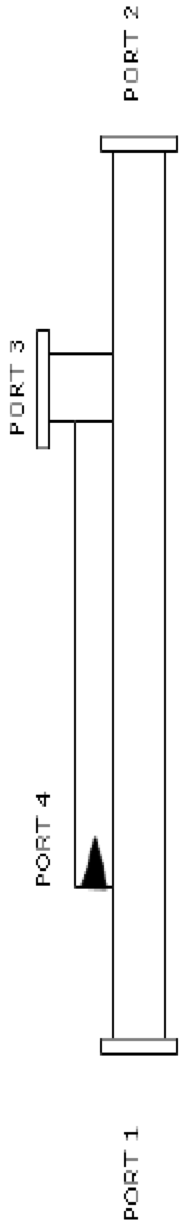


FIG. **DIRECTIONAL COUPLER**

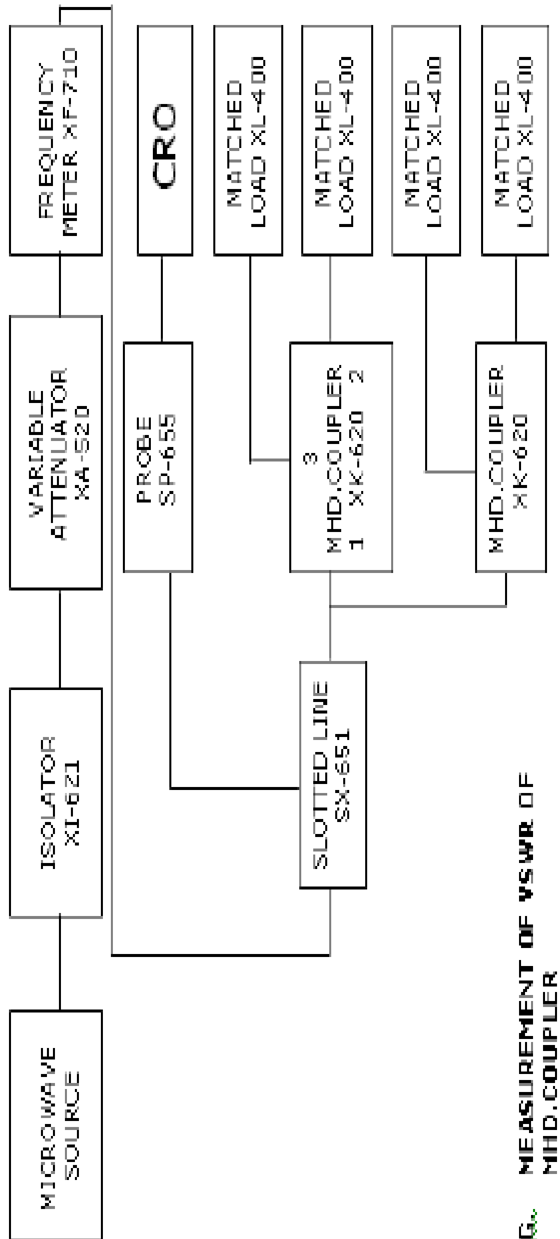


FIG. **MEASUREMENT OF VSWR OF MHD.COUPLER**

Ex No.6 STUDY OF DIRECTIONAL COUPLER

AIM:

To study the function of multi-hole directional coupler.

OBJECTIVE:

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

(i)The Coupling factor,

(ii)Insertion Loss

(iii)Directivity of the Directional coupler

EITC (Equipment's, Instruments, Tools, Consumables) 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 consist 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. 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 log10 [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 live VSWR is SWR measured

The coupling factor is defined as

Coupling (db) = 10 log10 [P1/P3]

where port 2 is terminated,

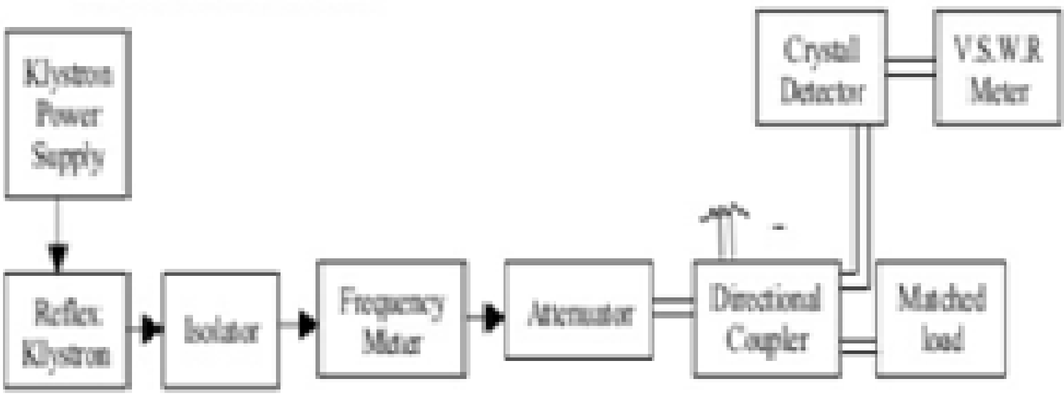
Isolation (dB) = 10 log10 [P2/P3]

where P1 is matched.

Directivity D (db) = I-C = 10 log10 [P2/P1]

Insertion Loss (dB) = 10 log10 [P1/P2]

EXPERIMENTAL SETUP:



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:

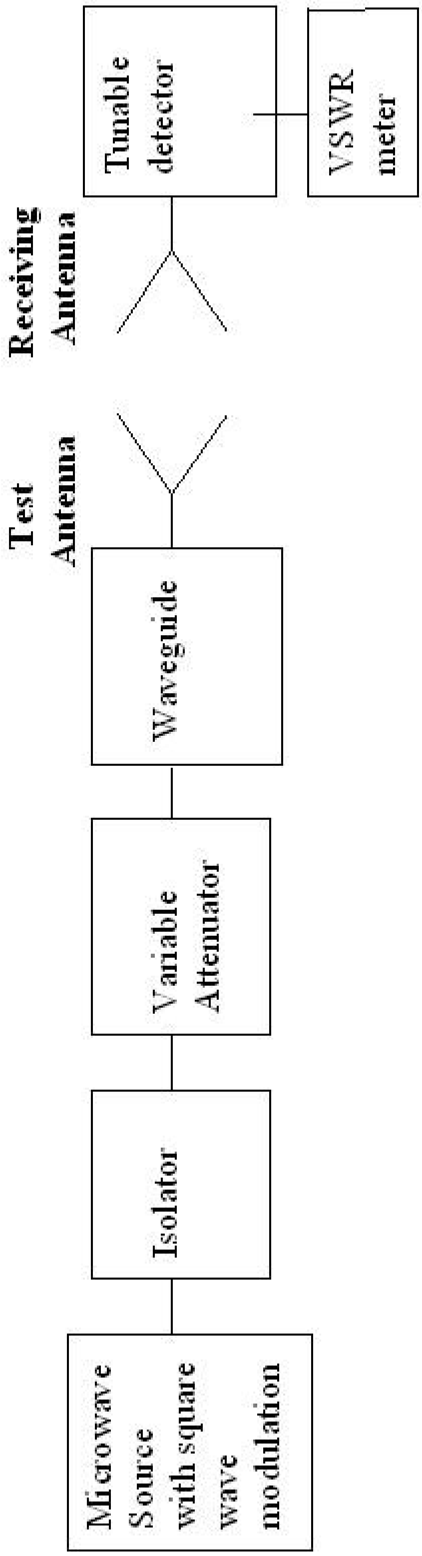
Insertion Loss (dB) = 10 log10 [P1/P2]

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 Y0.
14. Compute the Directivity as Y-Y0 in dB.

RESULT:

The functions of multi-hole directional coupler was studied.


Microwave Source with square wave modulation
Isolator
Variable Attenuator
Waveguide
Test Antenna
Receiving Antenna
Tunable detector
VSWR meter

Ex No.7 GAIN AND RADIATION PATTERN OF HORN ANTENNA

AIM:

To measure the gain and radiation pattern of microwave antennas.

OBJECTIVE:

To study the horn antenna ,measure the following parameters:

(i)Radiation Pattern,

(ii)Gain

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED:

1. Microwave source and power supply
2. X-band waveguide components
3. Calibrated attenuator
4. Detector and VSWR meter
5. Microwave antennas

THEORY:

The radiation pattern is a graphical representation of the strength of radiation of an antenna as a function of direction. The strength of radiation is usually measured in terms of field strength although sometimes radiation intensity (power radiated per unit solid angle) is also used.

PROCEDURE:

1. Use the RF substitution method to measure the radiation pattern of at least three different types of antennas.
2. Set the test antenna to the 0°position and place it to receive maximum power (maximum deflection on VSWR meter).

3. Adjust the calibrated attenuator to the 30 dB setting (call this A1). Set the position of the needle on the VSWR meter to a convenient value (reference level).

3. Turn the antenna to the 5°position.

5. Adjust the calibrated attenuator until the needle of the VSWR meter reaches the reference level (the attenuator setting is called A2).

GAIN MEASUREMENT:

$$G = \frac{4\pi S}{\lambda_0}\sqrt{P_R / P_T}$$

6. By subtracting A2 from A1 one obtains the amount the gain has decreased.

7. While using the same reference level on the attenuator (A1) and the same

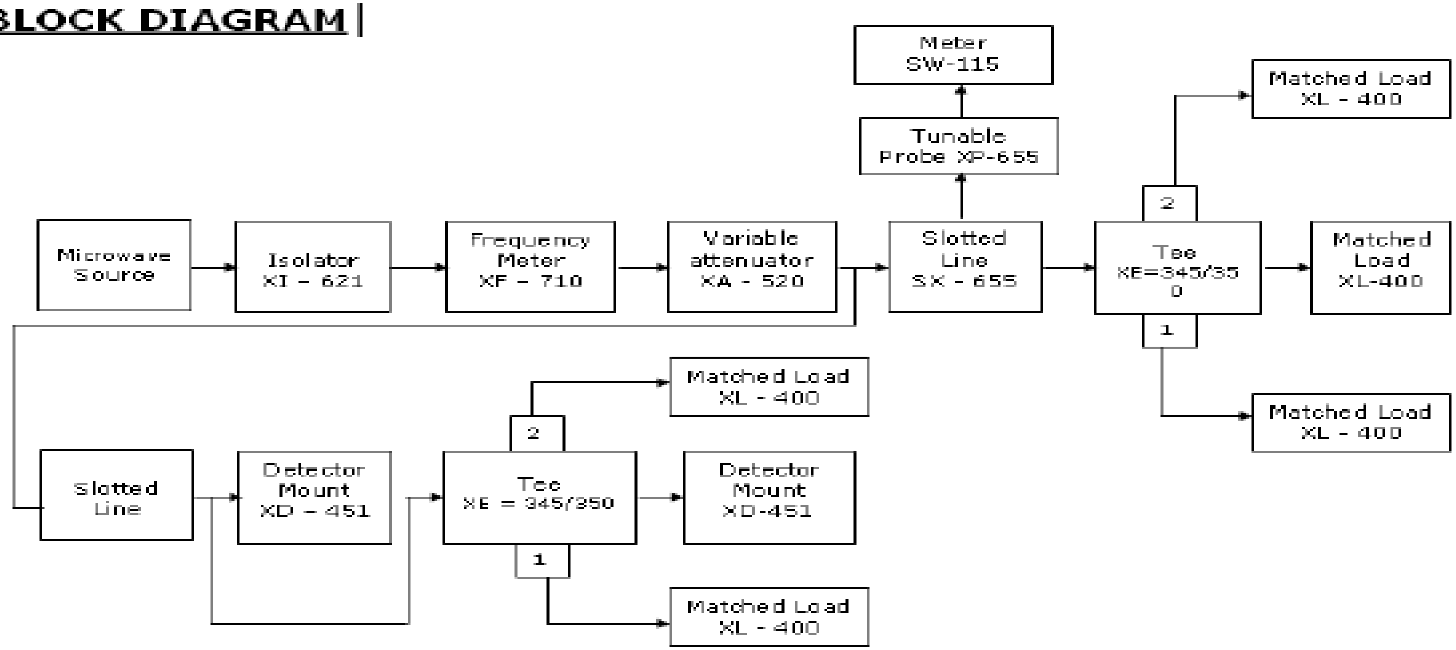
8. Reference level on the VSWR meter, repeat steps 4 and 5 rotating the antenna to 90°in 5°steps

9. Plot the above data using polar coordinates.

RESULT:

The gain and radiation pattern of horn antenna was studied.

BLOCK DIAGRAM



Ex No.8 STUDY OF MAGIC TEE

AIM:
To Study the operation of Magic Tee and calculate Coupling Co-efficient and Isolation.

OBJECTIVE:
The objective of this experiment is to study the operation of
(i) Magic Tee /E TEE/H TEE
(ii) Calculate Coupling Co-efficient and Isolation.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED:

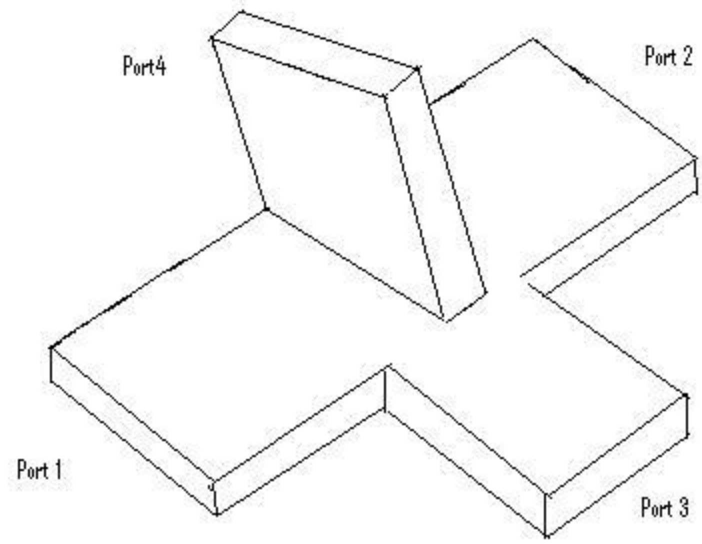
1. Microwave source : Klystron tube (2k25)
2. Isolator (XI-621)
3. Frequency meter (XF-710)
4. Variable Attenuator (XA-520)
5. Slotted line (SX-651)
6. Tunable probe (XP-655)
7. Detector Mount (XD-451)
8. Matched Termination (XL-400)
9. Magic Tee
10. Klystron Power Supply + Klystron Mount
11. Wave guide stands and accessories

THEORY:

The device Magic Tee is a combination of E and H plane Tee. Arm 3 is the H-arm and arm 4 is the E-arm. If the power is fed, into arm 3 (H-arm) the electric field divides equally between arm1 and 2 with the same phase and no electric field exists in the arm 4. If power is fed in arm 4 (E-arm) it divides equally into arm 1 and 2 but out of phase with no power to arm 3, further, if the power is fed in arm 1 and 2 simultaneously it is added in arm 3 (H-arm) and it is subtracted in E-arm i.e., arm 4.

A. Isolation:

The Isolation between E and H arm is defined as the ratio of the power supplied by the generator connected to the E-arm (port 4) to the power detected at H-arm (port 3) when side arm 1 and 2 terminated in matched load. Isolation (dB) = 10 log10 [P4/P3]



TABULATION:

Ports	Power (W)

CALCULATION:

Coupling Co Efficient

$$\alpha = 10 \log \frac{V_i}{V_f}$$

$$\text{Therefore } C = 10^{-\alpha/20}$$

Similarly, Isolation between other ports may be defined.

B. Coupling Factor:

It is defined as Cij = 10 – ∞/20

Where '∞' is attenuation / isolation in dB when 'i' is input arm and 'j' is output

arm. Thus, ∞= 10 log10 [P4/P3]

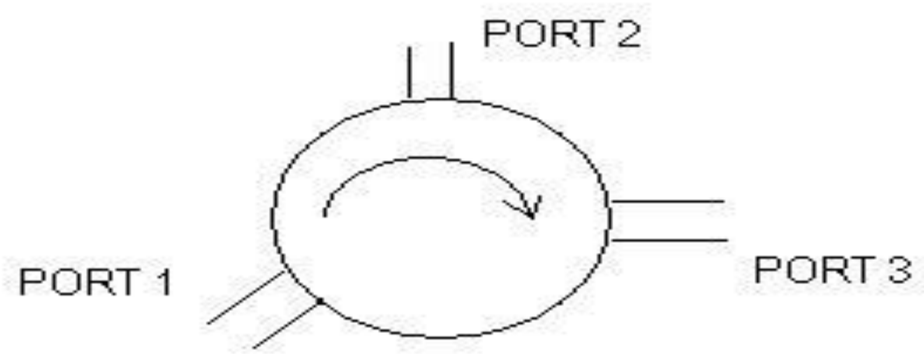
12\. Where P3 is the power delivered to arm 'i' and P4 is power detected at 'j' arm.

PROCEDURE:

1. Setup the components and equipments as shown in figure.
2. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
3. With the help of variable frequency of operation and tune the detector mount for maximum output attenuator, set any reference in the CRO let it be V3.
4. Without disturbing the position of the variable attenuator, carefully place the Magic Tee after the slotted line, keeping H-arm to slotted line, detector mount to E-arm and matched termination to Port-1 and Port-2.
5. Note down the amplitude using CRO, Let it be V4.
6. Determine the Isolation between Port-3 and Port-4 as V3-V4.
7. Determine the coupling co-efficient from the equation given in theory part.
8. The same experiment may be repeated for other Ports also.

RESULT:

The operation of Magic Tee and Coupling Co-efficient and Isolation was calculated.


PORT 2
PORT 1
PORT 3

Ex No.9 STUDY OF CIRCULATOR

AIM:

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

OBJECTIVE:

The objective of this experiment is to study the operation of

(i) Circulator
(ii) Calculate insertion loss and Isolation.

EITC (Equipment's, Instruments, Tools, Consumables) 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.

THEORY:

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.

The important circulator 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 orts 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.

PROCEDURE:

Measurement of insertion

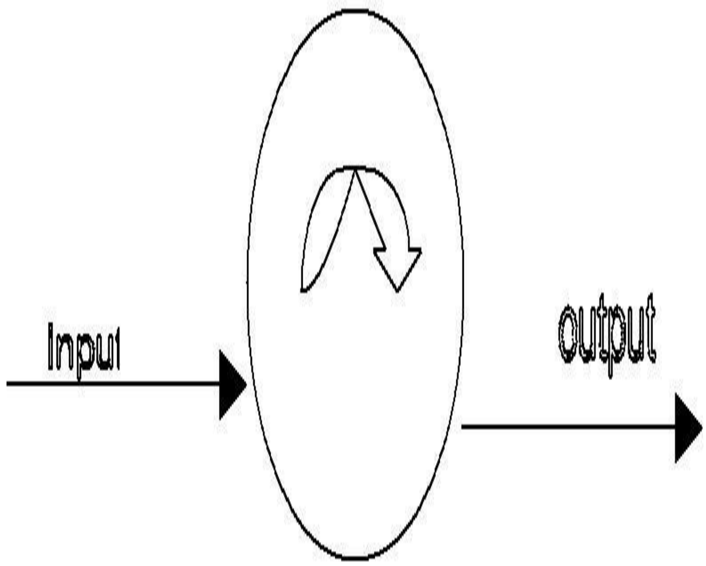
1. Remove the circulator from slotted line and connect the detector mount to the slotted section. The output of the detector mount should be connected with CRO.
2. Energize the microwave source for maximum output for a particular frequency of operation. Tune the detector mount for maximum output in the CRO.
3. Set any reference level of output in CRO with the help of variable attenuator, Let it be V1.
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. Record the output in CRO, Let it be V2
6. Compute Insertion loss given as V1-V2 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 V3.
9. Compute Isolation as V1-V3 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:

The measurement of the Insertion Loss and Isolation of Circulators were studied.


Input
output

Ex No.10 STUDY OF ISOLATOR

AIM:

To study the isolators and measure the Insertion Loss and Isolation of isolator.

OBJECTIVE:

The objective of this experiment is to study the operation of
(i) Isolator
(ii) Calculate insertion loss and Isolation.

EITC (Equipment's, Instruments, Tools, Consumables) 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.

THEORY:

ISOLATOR:

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

PROCEDURE:

Measurement of insertion

5. Remove the isolator from slotted line and connect the detector mount to the slotted section. The output of the detector mount should be connected with CRO.
6. Energize the microwave source for maximum output for a particular frequency of operation. Tune the detector mount for maximum output in the CRO.
7. Set any reference level of output in CRO with the help of variable attenuator, Let it be V1.
8. 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. Record the output in CRO, Let it be V2
12. Compute Insertion loss given as V1-V2 in db.

Measurement of Isolation:

13. 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).
14. Record the output of CRO and let it be V3.
15. Compute Isolation as V1-V3 in db.
16. The same experiment can be done for other ports of circulator.
17. Repeat the above experiment for other frequency if needed.

RESULT:

The measurement of the Insertion Loss and Isolation of isolators were studied.

Ex No.11 STUDY OF E PLANE TEE

AIM:
To Study the operation of E-TEE and calculate Coupling Co-efficient and Isolation.

OBJECTIVE:
The objective of this experiment is to study the operation of
(i) E TEE
(ii) Calculate Coupling Co-efficient and Isolation.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED:

1. Microwave source : Klystron tube (2k25)
2. Isolator (XI-621)
3. Frequency meter (XF-710)
4. Variable Attenuator (XA-520)
5. Slotted line (SX-651)
6. Tunable probe (XP-655)
7. Detector Mount (XD-451)
8. Matched Termination (XL-400)
9. Magic Tee
10. Klystron Power Supply + Klystron Mount
11. Wave guide stands and accessories

THEORY:
The device E TEE, If the power is fed, (E-arm) it divides equally into arm 1 and 2 but out of phase with no power to arm 3, further, if the power is fed in arm 1 and 2

ISOLATION:

The Isolation between E and H arm is defined as the ratio of the power supplied by the generator connected to the E-arm (port 4) to the power detected at H-arm (port 3) when side arm 1 and 2 terminated in matched load. Isolation (dB) = 10 log10 [P4/P3]

TABULATION:

Ports	Power (W)

Similarly, Isolation between other ports may be defined.

B. Coupling Factor:

It is defined as Cij = 10 – ∞/20

Where '∞' is attenuation / isolation in dB when 'i' is input arm and 'j' is output

arm. Thus, ∞= 10 log10 [P4/P3]

13. Where P3 is the power delivered to arm 'i' and P4 is power detected at 'j' arm.

PROCEDURE:

9. Setup the components and equipments as shown in figure.
10. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
11. With the help of variable frequency of operation and tune the detector mount for maximum output attenuator, set any reference in the CRO let it be V3.
12. Without disturbing the position of the variable attenuator, carefully place the Magic Tee after the slotted line, keeping H-arm to slotted line, detector mount to E-arm and matched termination to Port-1 and Port-2.
13. Note down the amplitude using CRO, Let it be V4.
14. Determine the Isolation between Port-3 and Port-4 as V3-V4.
15. Determine the coupling co-efficient from the equation given in theory part.
16. The same experiment may be repeated for other Ports also.

RESULT:
The operation of E Tee was studied.

Ex No.12 STUDY OF H PLANE TEE

AIM:
To Study the operation of H-TEE and calculate Coupling Co-efficient and Isolation.

OBJECTIVE:
The objective of this experiment is to study the operation of
(i) H TEE
(ii) Calculate Coupling Co-efficient and Isolation.

EITC (Equipment's, Instruments, Tools, Consumables) REQUIRED:

1. Microwave source : Klystron tube (2k25)
2. Isolator (XI-621)
3. Frequency meter (XF-710)
4. Variable Attenuator (XA-520)
5. Slotted line (SX-651)
6. Tunable probe (XP-655)
7. Detector Mount (XD-451)
8. Matched Termination (XL-400)
9. Magic Tee
10. Klystron Power Supply + Klystron Mount
11. Wave guide stands and accessories

THEORY:
The device Magic H plane Tee. Arm 3 is the H-arm. If the power is fed, into arm 3 (H-arm) the electric field divides equally between arm1. Further, if the power is fed in arm 1 and 2 simultaneously it is added in arm 3 (H-arm) and it is subtracted in E-arm i.e., arm 4.

B. Isolation:

The Isolation between E and H arm is defined as the ratio of the power supplied by the generator connected to the E-arm to the power detected at H-arm when side arm 1 and 2 terminated in matched load. Isolation (dB) = 10 log10 [P4/P3]

TABULATION:

Ports	Power (W)

Similarly, Isolation between other ports may be defined.

B. Coupling Factor:

It is defined as Cij = 10 – ∞/20

Where '∞' is attenuation / isolation in dB when 'i' is input arm and 'j' is output arm. Thus, ∞= 10 log10 [P4/P3]

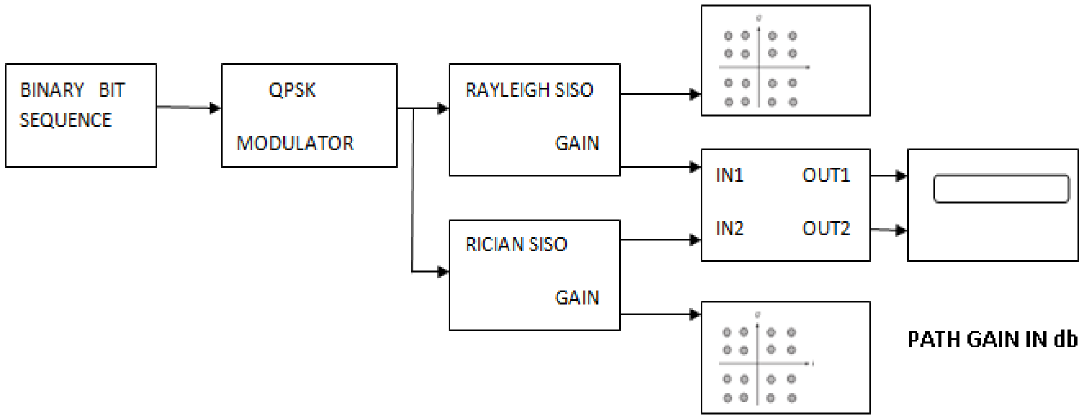
14. Where P3 is the power delivered to arm 'i' and P4 is power detected at 'j' arm.

PROCEDURE:

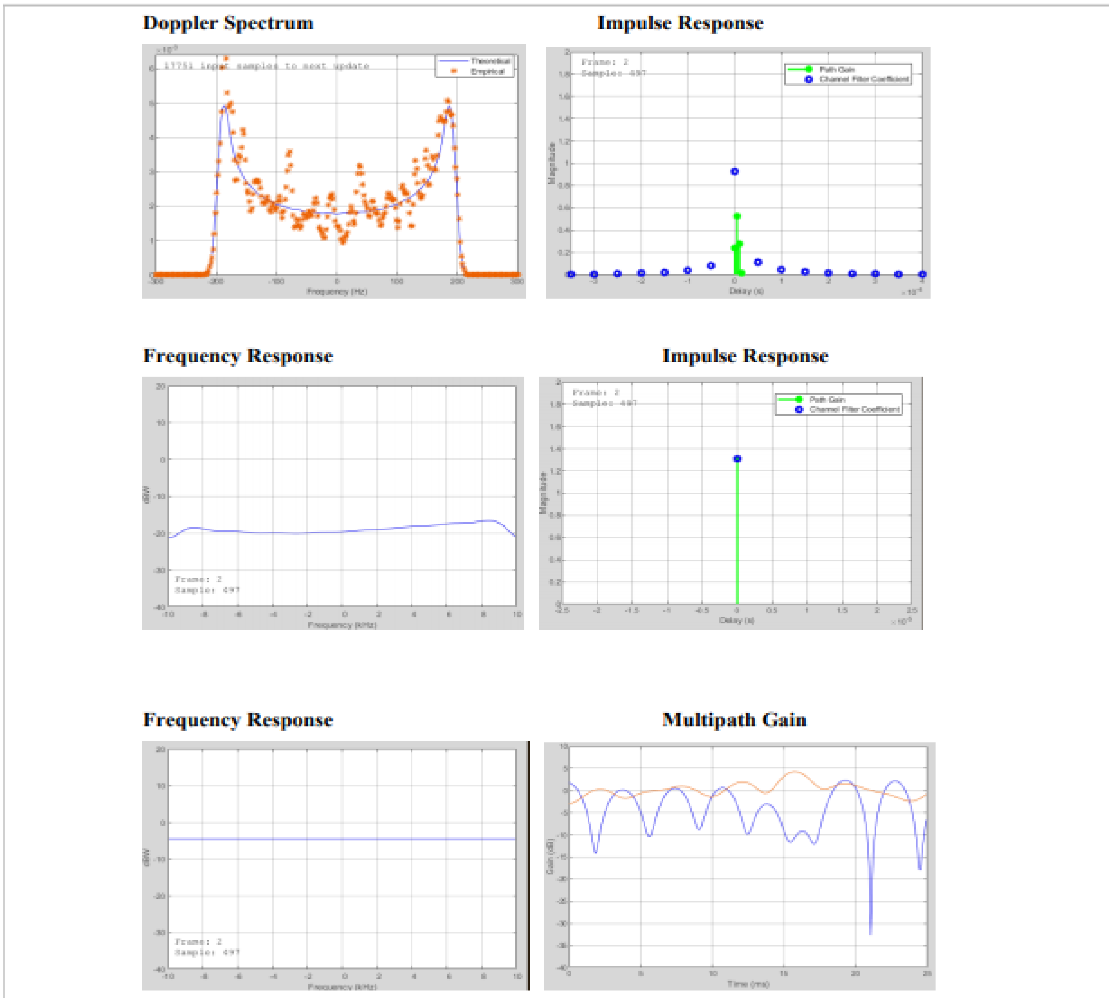
1. Setup the components and equipments as shown in figure. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
2. With the help of variable frequency of operation and tune the detector mount for maximum output attenuator, set any reference in the CRO let it be V3.
3. Without disturbing the position of the variable attenuator, carefully place the Magic Tee after the slotted line, keeping H-arm to slotted line, detector mount to E-arm and matched termination to Port-1 and Port-2.
4. Note down the amplitude using CRO, Let it be V4.
5. Determine the Isolation between Port-3 and Port-4 as V3-V4.
6. Determine the coupling co-efficient from the equation given in theory part.
7. The same experiment may be repeated for other Ports also.

RESULT:
The operation of H TEE was studied.

Block Diagram:



Simulation output



EX.NO:1 WIRELESS CHANNEL SIMULATION INCLUSING 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

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.
- 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:

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.

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.

Apply the channel System object to your signal using the step method, which generates random discrete path gains and filters the input signal. The characteristics of a channel can be shown with the built-in visualization support of the System object.

Program

```
sampleRate500kHz = 500e3; % Sample rate of 500K Hz
sampleRate20kHz = 20e3; % Sample rate of 20K Hz
maxDopplerShift = 200; % Maximum Doppler shift of diffuse components (Hz)
delayVector = (0:5:15)*1e-6; % Discrete delays of four-path channel (s)
gainVector = [0 -3 -6 -9]; % Average path gains (dB)
KFactor = 10; % Linear ratio of specular power to diffuse power
specDopplerShift = 100; % Doppler shift of specular component (Hz)
% Configure a Rayleigh channel object
rayChan = comm.RayleighChannel( ...
 'SampleRate', sampleRate500kHz, ...
 'PathDelays', delayVector, ...
 'AveragePathGains', gainVector, ...
 'MaximumDopplerShift', maxDopplerShift, ...
 'RandomStream', 'mt19937ar with seed', ...
 'Seed', 10, ...
 'PathGainsOutputPort', true);
% Configure a Rician channel object
ricChan = comm.RicianChannel( ...
 'SampleRate', sampleRate500kHz, ...
 'PathDelays', delayVector, ...
 'AveragePathGains', gainVector, ...
 'KFactor', KFactor, ...
 'DirectPathDopplerShift', specDopplerShift, ...
 'MaximumDopplerShift', maxDopplerShift, ...
 'RandomStream', 'mt19937ar with seed', ...
 'Seed', 100, ...
 'PathGainsOutputPort', true);
qpskMod = comm.QPSKModulator( ...
 'BitInput', true, ...
 'PhaseOffset', pi/4);
% Number of bits transmitted per frame is set to be 1000. For QPSK
% modulation, this corresponds to 500 symbols per frame.
bitsPerFrame = 1000;
msg = randi([0 1],bitsPerFrame,1);
```

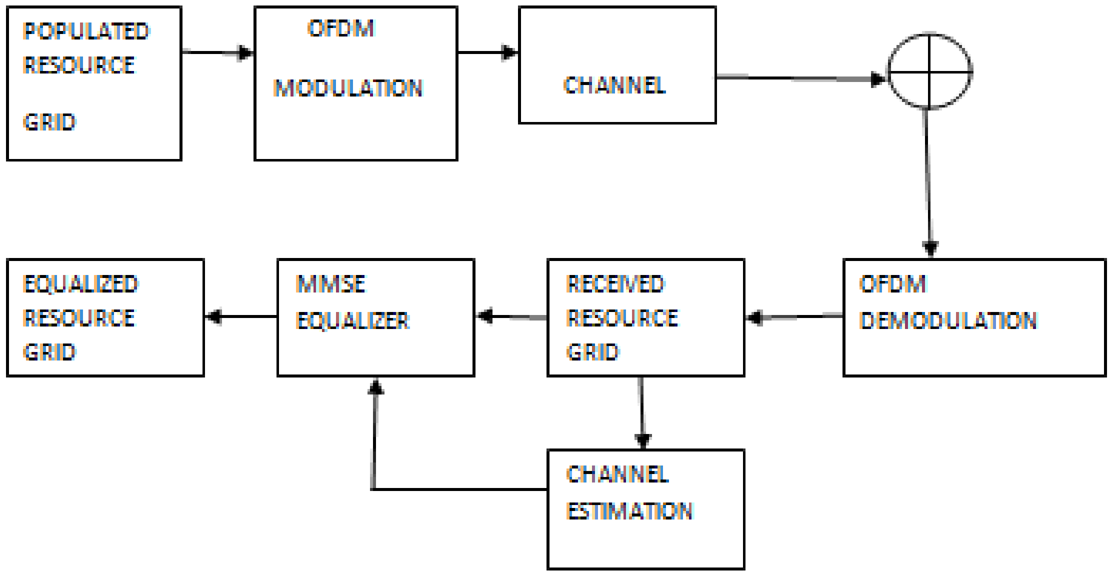
```
% Modulate data for transmission over channel
modSignal = qpskMod(msg);
% Apply Rayleigh or Rician channel object on the modulated data
rayChan(modSignal);
ricChan(modSignal);
release(rayChan);
release(ricChan);
rayChan.Visualization = 'Impulse and frequency responses';
rayChan.SamplesToDisplay = '100%';
numFrames = 2;
for i = 1:numFrames % Display impulse and frequency responses for 2 frames
 % Create random data
 msg = randi([0 1],bitsPerFrame,1);
 % Modulate data
 modSignal = qpskMod(msg);
 % Filter data through channel and show channel responses
 rayChan(modSignal);
end
release(rayChan);
rayChan.Visualization = 'Doppler spectrum';
numFrames = 5000;
for i = 1:numFrames % Display Doppler spectrum from 5000 frame transmission
 msg = randi([0 1],bitsPerFrame,1);
 modSignal = qpskMod(msg);
 rayChan(modSignal);
end
%Narrowband or Frequency-Flat Fading
release(rayChan);
rayChan.Visualization = 'Impulse and frequency responses';
rayChan.SampleRate = sampleRate20kHz;
rayChan.SamplesToDisplay = '25%'; % Display one of every four samples
numFrames = 2;
for i = 1:numFrames % Display impulse and frequency responses for 2 frames
 msg = randi([0 1],bitsPerFrame,1);
 modSignal = qpskMod(msg);
 rayChan(modSignal);
end
release(rayChan);
rayChan.PathDelays = 0; % Single fading path with zero delay
rayChan.AveragePathGains = 0; % Average path gain of 1 (0 dB)
for i = 1:numFrames % Display impulse and frequency responses for 2 frames
 msg = randi([0 1],bitsPerFrame,1);
 modSignal = qpskMod(msg);
 rayChan(modSignal);
end
release(rayChan);
rayChan.Visualization = 'Off'; % Turn off System object's visualization
ricChan.Visualization = 'Off'; % Turn off System object's visualization
% Same sample rate and delay profile for the Rayleigh and Rician objects
```

```
ricChan.SampleRate = rayChan.SampleRate;
ricChan.PathDelays = rayChan.PathDelays;
ricChan.AveragePathGains = rayChan.AveragePathGains;
% Configure a Time Scope System object to show path gain magnitude
gainScope = dsp.TimeScope( ...
 'SampleRate', rayChan.SampleRate, ...
 'TimeSpan', bitsPerFrame/2/rayChan.SampleRate, ... % One frame span
 'Name', 'Multipath Gain', ...
 'ShowGrid', true, ...
 'YLimits', [-40 10], ...
 'YLabel', 'Gain (dB)');
% Compare the path gain outputs from both objects for one frame
msg = randi([0 1],bitsPerFrame,1);
modSignal = qpskMod(msg);
[~, rayPathGain] = rayChan(modSignal);
[~, ricPathGain] = ricChan(modSignal);
% Form the path gains as a two-channel input to the time scope
gainScope(10*log10(abs([rayPathGain, ricPathGain]).^2));
```

RESULT:

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

BLOCK DIAGRAM



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

AIM:

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

COMPONENTS REQUIRED:

Personal computer
MATLAB

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.

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.

Program:

```
enb.CellRefP = 1; % One transmit antenna port
enb.NCellID = 10; % Cell ID
enb.CyclicPrefix = 'Normal'; % Normal cyclic prefix
enb.DuplexMode = 'FDD'; % FDD
SNRdB = 22; % Desired SNR in dB
SNR = 10^(SNRdB/20); % Linear SNR
rng('default'); % Configure random number generators
cfg.Seed = 1; % Channel seed
cfg.NRxAnts = 1; % 1 receive antenna
cfg.DelayProfile = 'EVA'; % EVA delay spread
cfg.DopplerFreq = 120; % 120Hz Doppler frequency
cfg.MIMOCorrelation = 'Low'; % Low (no) MIMO correlation
cfg.InitTime = 0; % Initialize at time zero
cfg.NTerms = 16; % Oscillators used in fading model
cfg.ModelType = 'GMEDS'; % Rayleigh fading model type
cfg.InitPhase = 'Random'; % Random initial phases
cfg.NormalizePathGains = 'On'; % Normalize delay profile power
cfg.NormalizeTxAnts = 'On'; % Normalize for transmit antennas
cec.PilotAverage = 'UserDefined'; % Pilot averaging method
cec.FreqWindow = 9; % Frequency averaging window in REs
cec.TimeWindow = 9; % Time averaging window in REs
gridsize = lteDLResourceGridSize(enb);
K = gridsize(1); % Number of subcarriers
L = gridsize(2); % Number of OFDM symbols in one subframe
P = gridsize(3); % Number of transmit antenna ports
txGrid = [];
% Number of bits needed is size of resource grid (K*L*P) * number of bits
% per symbol (2 for QPSK)
numberOfBits = K*L*P*2;
% Create random bit stream
inputBits = randi([0 1], numberOfBits, 1);
% Modulate input bits
inputSym = lteSymbolModulate(inputBits,'QPSK');
% For all subframes within the frame
for sf = 0:10
```

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

 % Generate empty subframe
 subframe = lteDLResourceGrid(enb);

 % Map input symbols to grid
 subframe(:) = inputSym;
 % Generate synchronizing signals
 pssSym = ltePSS(enb);
 sssSym = lteSSS(enb);
 pssInd = ltePSSIndices(enb);
 sssInd = lteSSSIndices(enb);
 % Map synchronizing signals to the grid
 subframe(pssInd) = pssSym;
 subframe(sssInd) = sssSym;
 % Generate cell specific reference signal symbols and indices
 cellRsSym = lteCellRS(enb);
 cellRsInd = lteCellRSIndices(enb);
 % Map cell specific reference signal to grid
 subframe(cellRsInd) = cellRsSym;

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

end
[txWaveform,info] = lteOFDMModulate(enb,txGrid);
txGrid = txGrid(:,1:140);
cfg.SamplingRate = info.SamplingRate;
% Pass data through the fading channel model
rxWaveform = lteFadingChannel(cfg,txWaveform);
% Calculate noise gain
N0 = 1/(sqrt(2.0*enb.CellRefP*double(info.Nfft))*SNR);
% Create additive white Gaussian noise
noise = N0*complex(randn(size(rxWaveform)),randn(size(rxWaveform)));
% Add noise to the received time domain waveform
rxWaveform = rxWaveform + noise;
offset = lteDLFrameOffset(enb,rxWaveform);
rxWaveform = rxWaveform(1+offset:end,:);
rxGrid = lteOFDMDemodulate(enb,rxWaveform);
enb.NSubframe = 0;
[estChannel, noiseEst] = lteDLChannelEstimate(enb,rxGrid);
size(estChannel);
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)
```

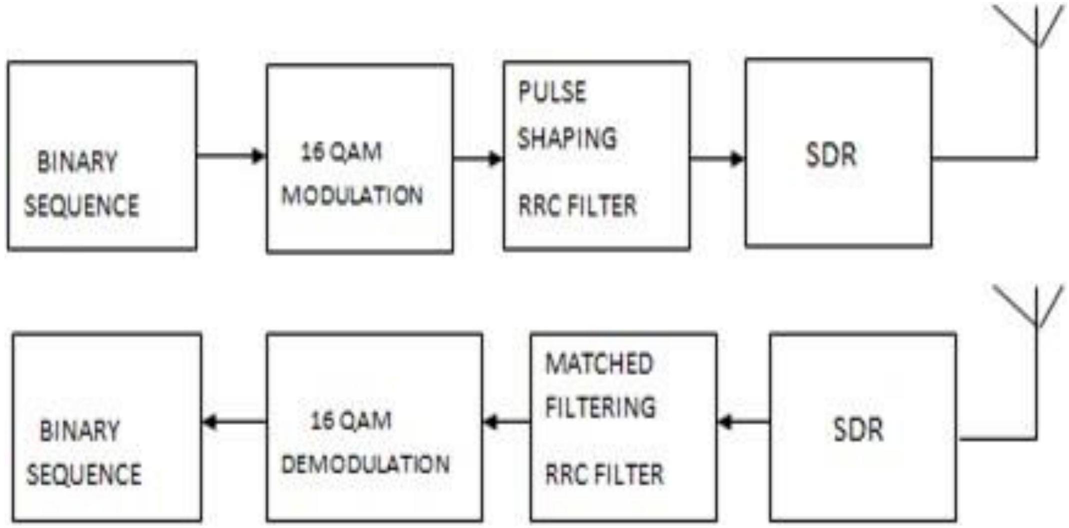
PROCEDURE:

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

Result:

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

BLOCK DIAGRAM



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

AIM:

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

COMPONENT REQUIRED

- Personal computer
- MATLAB software
- SDR hardware

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 inter symbol 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

Matched Filter:

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

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

Software Defined Radio:

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

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

Software radios have significant utility for the military and cell phone services, both of which must serve a wide variety of changing radio protocols in real time.

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

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

Spread spectrum and 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 geo location 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.

program

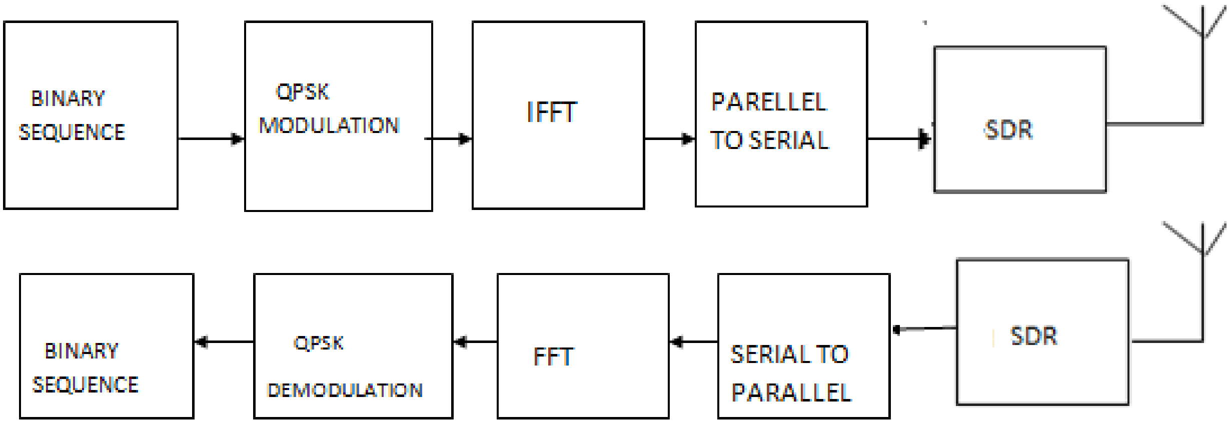
```
M = 16; % Modulation order
k = log2(M); % Number of bits per symbol
numBits = 3e5; % Number of bits to process
sps = 4; % Number of samples per symbol (oversampling factor)
filtlen = 10; % Filter length in symbols
rolloff = 0.25; % Filter rolloff factor
rrcFilter = rcosdesign(rolloff,filtlen,sps);
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');
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
eyediagram(txFiltSignal(1:2000),sps*2);
```

Result

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

Block Diagram



Ex.No: 4 OFDM SIGNAL TRANSMISSION AND RECEPTION USING SDR

AIM:

To transmit and receive the OFDM signal using SDR.

COMPONENTS REQUIRED

Personal computer
MATLAB software
SDR

THEORY:

Implementation of OFDM in actual hardware using Software Defined Radio (SDR) concepts and verification of its performance with different channel estimation methods in various propagation environments have been almost unexplored. The great flexibility feature of SDR systems facilitates the implementation and experimentation of OFDM systems with less cost and effort, compared to the implementation of the whole system in hardware. In this paper, a customized SDR testbed has been developed based on the GNU radio software platform and version-2 Universal Software Radio Peripheral (USRP2) devices to evaluate the practical error performance of OFDM-based systems in both Gaussian and Rician propagation environments.

Three different channel interpolation techniques, namely linear interpolation, second-ordered interpolation and cubic spline interpolation, and a blind SNR estimation algorithm have been implemented in our test bed. 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

```
clear all
clc
close
% ---------------
% A: Setting Parameters
% ---------------
M = 4; % QPSK signal constellation
no_of_data_points = 64; % have 64 data points
block_size = 8; % size of each ofdm block
cp_len = ceil(0.1*block_size); % length of cyclic prefix
no_of_ifft_points = block_size; % 8 points for the FFT/IFFT
no_of_fft_points = block_size;
% ---------------------------------------------
% B: % +++++ TRANSMITTER +++++
% ---------------------------------------------
% 1. Generate 1 x 64 vector of data points phase representations
data_source = randsrc(1, no_of_data_points, 0:M-1);
figure(1)
stem(data_source); grid on; xlabel('data points'); ylabel('transmitted data phase
representation')
title('Transmitted Data "O"')
% 2. Perform QPSK modulation
qpsk_modulated_data = pskmod(data_source, M);
scatterplot(qpsk_modulated_data);title('qpsk modulated transmitted data')
% 3. Do IFFT on each block
% Make the serial stream a matrix where each column represents a pre-OFDM
% block (w/o cyclic prefixing)
% First: Find out the number of 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 data
cp_start = block_size-cp_len;
cp_end = block_size;
% Third: Operate columnwise & do CP
for i=1:num_cols,
 ifft_data_matrix(:,i) = ifft((data_matrix(:,i)),no_of_ifft_points);
 % Compute and append Cyclic Prefix
 for j=1:cp_len,
 actual_cp(j,i) = ifft_data_matrix(j+cp_start,i);
 end
 % Append the CP to the existing block to create the actual OFDM block
 ifft_data(:,i) = vertcat(actual_cp(:,i),ifft_data_matrix(:,i));
end
% 4. Convert to serial stream for transmission
[rows_ifft_data cols_ifft_data]=size(ifft_data);
len_ofdm_data = rows_ifft_data*cols_ifft_data;
% Actual OFDM signal to be transmitted
ofdm_signal = reshape(ifft_data, 1, len_ofdm_data);
```

```
figure(3)
plot(real(ofdm_signal)); xlabel('Time'); ylabel('Amplitude');
title('OFDM Signal');grid on;
% -----------------------------------------
% E: % +++++ RECEIVER +++++
% -----------------------------------------
% 1. Pass the ofdm signal through the channel
recvd_signal = ofdm_signal;
% 4. Convert Data back to "parallel" form to perform FFT
recvd_signal_matrix = reshape(recvd_signal,rows_ifft_data, cols_ifft_data);
% 5. Remove CP
recvd_signal_matrix(1:cp_len,:)=[];
% 6. Perform FFT
for i=1:cols_ifft_data,
 % FFT
 fft_data_matrix(:,i) = fft(recvd_signal_matrix(:,i),no_of_fft_points);
end
% 7. Convert to serial stream
recvd_serial_data = reshape(fft_data_matrix, 1,(block_size*num_cols));
% 8. Demodulate the data
qpsk_demodulated_data = pskdemod(recvd_serial_data,M);
scatterplot(qpsk_modulated_data);title('qpsk modulated received data')
figure(5)
stem(qpsk_demodulated_data,'rx');
grid on;xlabel('data points');ylabel('received data phase representation');title('Received
Data "X"')
```

Result:

Thus the OFDM signal transmission and reception was done using SDR